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ASPECTS OF THE BREEDING BIOLOGY AND PRODUCTIVITY OF BACHMAN'S SPARROW IN CENTRAL ARKANSAS

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ABSTRACT.—Breeding Bachman's Sparrows (*Aimophila aestivalis*) were studied in central Arkansas from 1983–85. Although one case of polygyny was observed, Bachman's Sparrows were primarily double-brooded and monogamous, breeding from 17 April–26 August. All nests were built on the ground. Clutches (mode = 4) laid during the first half of the breeding season were significantly larger than those laid during the second half. Females incubated eggs for 13–14 days, and both synchronous and asynchronous hatching were observed. The average nestling and fledgling periods were 9.0 ± 0.3 [SE] and 25.0 ± 1.2 days, respectively. Both parents cared for nestlings and fledglings. Females started second broods 12.3 ± 2.3 days after first-brood nestlings fledged, while males continued to care for first-brood fledglings. When nests failed, renesting attempts were made, and some pairs attempted 5 nests in one season. The average number of nests per season was 3.1 ± 0.2, and the average time interval between failed nests and repeat layings was 9.7 ± 1.6 days. The probability that an egg would produce a fledgling was 0.25. Predation was the major cause of nest failure. Nest success was not influenced by year, time of season, degree of nest concealment, habitat, or clutch size. On average, Bachman's Sparrow pairs produced 3.0 fledglings per year.
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Although the breeding range of Bachman's Sparrow (*Aimophila aestivalis*) extends throughout much of southeastern United States (AOU 1983), recent literature indicates that the species is now very local and declining in many parts of its former breeding range (Tate 1986). The Nature Conservancy (Drilling 1985) has ranked Bachman's Sparrow as endangered in five states (Illinois, Tennessee, Virginia, Texas, and Missouri) and rare in three (Kentucky, North Carolina, and Oklahoma). To discover why breeding populations of Bachman's Sparrow have declined and to recommend appropriate conservation efforts, more should be known about the Bachman's Sparrow breeding biology. Although reports exist on various aspects of its nesting biology (e.g., Lloyd 1931, Brooks 1938, Nolan 1953, Meanley 1959, Weston 1968, Nicholson 1976, Hardin 1977, Hardin et al. 1982), sample sizes were small, individual birds were not marked, and estimates of reproductive success and productivity were lacking.

This study was part of a larger investigation (Haggerty 1986), and its objectives were to: (1) obtain basic life history data from a marked population, (2) examine effects of various ecological factors on nest success

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and clutch size, (3) determine major causes of nest failure, and (4) estimate annual productivity.

STUDY AREA AND METHODS

The research was conducted from April through September in 1983, 1984, and 1985 in Hot Spring County, Arkansas, approximately 19 km south of Malvern. Daily observations began during the second week of May and continued through the second week of August. Observations before and after that period were made weekly. Seven shortleaf (*Pinus echinata*) and loblolly (*P. taeda*) pine plantations were the principal study areas. Plantations were divided into two classes: (1) those that did not have a canopy, "old field tracts" (N = 5) and (2) those with a canopy dominated by pine trees, "pine forest tracts" (N = 2). Old field tracts had been clearcut and were between 0–4 years old, depending upon age of planted pines. Pine forest tracts were approximately 45 and 70 years old and had been thinned and control burned. Angle of slope of the study tracts ranged from 0 to 20 degrees, and the average size of the tracts was 35.0 ± 8.6 [SE] ha.

Adult sparrows were captured in mist nets, sexed by absence or presence of a cloacal protuberance and brood patch, and marked with an aluminum U.S. Fish and Wildlife Service band and a unique combination of colored leg bands. Nests were located by watching the behavior of adult birds. I visited nests with eggs every third day or until the yolk was no longer visible through the shell (usually around the seventh or eighth day of incubation), at which time daily visits were made. Egg width and length were measured with dial calipers to the nearest mm. Egg volume was calculated using the methods of Hoyt (Hoyt 1979). Once eggs hatched, nests were checked daily, and on day 5 (hatching day = day 0) of the nestling period, the young were color banded. For those nests that were located during the incubation or nestling periods, laying and hatching dates were approximated by aging nestlings and eggs. The degree of nest concealment was estimated by observing how much of the nest was exposed from the front (i.e., nest entrance), back, and right and left sides of the nest at three angular positions (10, 45, and 80 degrees) at a distance of 1 m. The following ratings were used at each position: 1 = ≤25% of the nest visible, 2 = 26–50% of the nest visible, 3 = 51–75% of the nest visible, and 4 = 76–100% of the nest visible. From those 12 points, an average nest concealment rating was obtained for each nest.

Since most nests were found after the laying period, the Mayfield method (Mayfield 1961, 1975) was used to determine egg success. The Johnson's statistic (Johnson 1979) was used to test for differences between daily success rates of the incubation and nestling periods. The number of "equally good months" for breeding was calculated using the formula:

$$\text{Months} = \exp(-\sum p_i \log_e p_i)$$

where p_i is the proportion of nests initiated each month (MacArthur 1964).

Statistical analyses were performed using the SAS computer software system (SAS 1985). Means are presented as $\bar{x} \pm$ SE. Statistical significance was set at $P < 0.05$.

RESULTS AND DISCUSSION

Site fidelity.—Of 34 adults (18 males and 16 females) banded over a 2-year period, 6 (18%) returned to the tract where they nested or defended a territory during a previous year. A greater percentage of males (22%) returned than females (13%), but sample size was too small to test for significance. Return rates between years also differed, with 29% (5 of 17) of the adults banded in 1983 returning in 1984 and 0% (0 of 17) of the birds banded in 1984 returning in 1985, but again small sample size made testing for significance impractical. One male, banded in 1983 but not seen in 1984, returned in 1985. Of the 60 nestlings banded and known to have fledged, none was captured in subsequent years.

Mating system.—Bachman's Sparrows have been reported to have a monogamous mating system (Verner and Willson 1969). Of the 31 territories that I studied, 28 contained monogamous pairs, one had a bigamous male, and two contained bachelors. Pairbonds were formed before I arrived on my study area in early May, so actual time of pairing was not known. Pairs usually remained together on the same territory throughout the breeding season. In one case, a pair was found together on the same pine plantation for two consecutive breeding seasons. In winter, Bachman's Sparrows occur singly and in pairs (Lowery 1960), which may indicate that some pairbonds are permanent (Wolf 1977).

Breeding season and number of nesting attempts.—The nesting activities of 18 pairs and one polygynous male were monitored closely during the three field seasons. Most nesting attempts were thought to have been found, but unsuccessful nesting cycles that lasted only a few days may have been missed. Additional data were collected from 10 pairs not observed as closely.

Egg laying occurred between 17 April–26 August, a period of 132 days, but 85% of the clutches were started in May, June, and July (Fig. 1). A recent examination of Bachman's Sparrow egg data slips (McNair 1987) found that clutch initiation occurred between 21 March–23 July ($\bar{x}$ = 13 May, SD = 24 days, N = 190). I found an average breeding season for

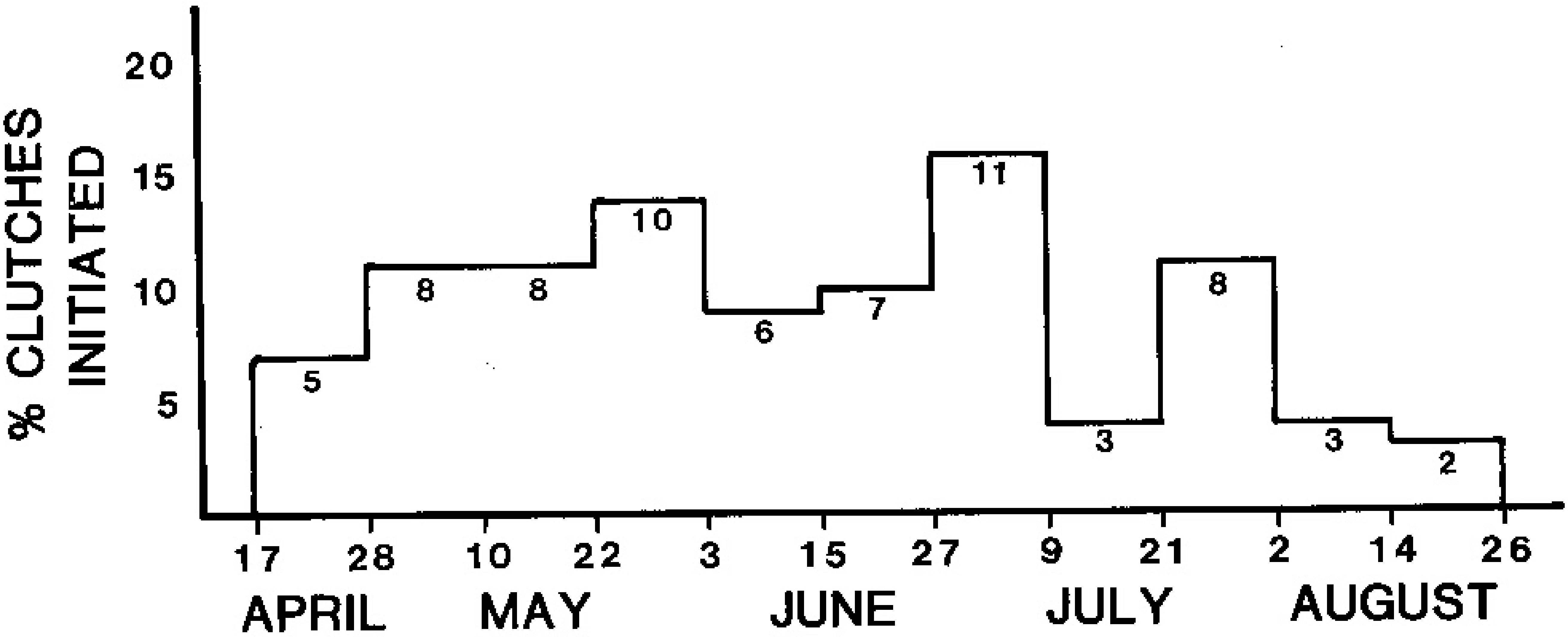

FIG. 1. Seasonal distribution of clutch initiation of Bachman's Sparrows, Hot Spring County, Arkansas, 1983–1985. Numbers in the bars are sample sizes.

individual pairs of 69.1 ± 5.1 days (N = 19, range = 33–126), and the number of equally good months for breeding was 4.2 (127 days: see Methods). Female breeding season length was positively correlated with the number of nesting failures she experienced (Spearman's rho = 0.83, $P < 0.01$, N = 19). Breeding season length is probably shorter in the northern portion of the species' range (Hardin 1977, Wolf 1977).

Number of nesting attempts per season per female ranged from 1 to 5 ($\bar{x} = 3.05 \pm 0.23$, N = 20). Females usually laid second clutches before young of a previous brood became independent. Average number of eggs laid per female per season was 11.6 ± 1.0 (N = 20). Pairs raised at most two broods per season even though time for a third brood often existed. Although three broods per season has been reported (Burleigh 1958, Sprunt and Chamberlain 1949, Potter et al. 1980), it is unclear if individual birds were marked.

Nest placement.—Bachman's Sparrows are ground nesters that build their nest at the base of grass clumps or other low vegetation (Weston 1968, Wolf 1977). In my study, all nests (N = 71) were built on the ground, and 50 (70%) were built at the base of *Andropogon spp.* grass clumps. Blades from these clumps were often woven into the nests and helped conceal them. The other 21 nests were located at the bases of various hardwood saplings, pine seedlings, forbs, and other grass species.

Clutch size.—McNair (1987) reported an average clutch size of 4.06 (SD = 0.62, range = 3–5, N = 196) for Bachman's Sparrow. In my study the modal clutch size was 4, and the mean was 3.9 ± 0.1 (range = 2–5, N = 71). Clutches laid during the first half of the breeding season ($\bar{x}$ = 4.1 ± 0.1, N = 42) were significantly larger than those laid during the second half ($\bar{x}$ = 3.7 ± 0.1, N = 29) (t = 2.6, P = 0.01, df = 69). Clutch size did not vary significantly among the three field seasons (F = 0.05, df = 2,70, P = 0.95) or between old field and pine forest tracts (t = 1.03, df = 69, P = 0.31).

Egg characteristics.—All eggs were white and had a short oval shape (Preston 1953). Of 50 eggs that were measured from 29 nests, the mean length, width, and volume were 19.82 ± 0.92 mm, 15.63 ± 0.40 mm, and 2471.78 ± 191.40 mm^3, respectively (see also Weston 1968). The average egg weight was 2.48 ± 0.04 g (N = 47).

Laying, incubation, and hatching.—Two females were monitored throughout the laying period. Each laid an egg a day, probably at dawn, and each began incubating the day the penultimate egg was laid (both laid 4 eggs). Only one nest was observed from the laying of the first egg through the hatching of the last egg. The fourth and final egg was laid on 7 July, and it hatched between 17:00–17:30 on 19 July, indicating an incubation period of 13 days. In another clutch that was discovered after the final egg was laid, the incubation period was at least 14 days. Meanley (1959) also reports an incubation period of 14 days, but in South Carolina a 12-day incubation period has been noted (Sprunt and Chamberlain 1949). Although males were seen and heard singing near the nest site during the incubation period, I never saw them at the nest (but see Gainer 1921) or carrying food to their mate. I marked no eggs to follow the hatching sequence in relation to laying time, but of 58 nests in which nestling measurements were made, 16 showed possible evidence of asynchronous hatching (i.e., had a runt in the brood) (see also Nolan 1953, Meanley 1959, Nicholson 1976). Two of the 23 nests observed throughout the hatching period had hatching intervals (i.e., time between the first and last hatching of eggs of the same clutch) that were between 24 and 48 h.

Nestling and fledgling periods.—The average nestling period was 9.0 ± 0.2 days (N = 16), and both parents cared for the young (see also Brooks 1938). The average fledgling period (i.e., time between when young fledged and when they became independent) was approximately 25.0 ± 1.5 days (N = 9 broods, range 21–30 days). Both parents were seen feeding fledged young, but males were seen more frequently with young, especially after the clutches of repeat layings were completed. All food deliveries took place on the ground, and during the latter half of the fledgling period, young often hopped behind their foraging parents. The length of a successful nesting cycle (i.e., period between laying of the first egg to fledging the last young) was approximately 51 d.

Internesting intervals.—The average interval between nests that fledged young and repeat layings was 12.3 ± 2.3 days (N = 11). The average interval between failed nests and repeat layings was 9.7 ± 1.6 days (N =

27). No significant difference was found between these two internesting intervals ($t = -0.86$, $P = 0.39$). The length of the internesting interval was significantly shorter during the second half of the breeding season than during the first ($t = -2.95$, $P = 0.01$). No significant relationship was found between the internesting interval length and clutch size (rho = -0.07, $P = 0.64$, N = 38), brood size (rho = -0.08, $P = 0.64$, N = 34), or nesting cycle length (rho = 0.19, $P = 0.26$, N = 38).

Nesting failure and success.—Reported causes of nest failure in Bachman's Sparrows include snakes (Brooks 1938, Weston 1968), Brown-headed Cowbirds (*Molothrus ater*) (Blincoe 1921, Brooks 1938, Mengel 1965, Weston 1968) and American Crows (*Corvus brachyrhynchos*) (Weston 1968). In my study, failure of 38 nests was due to predation (95%) and Brown-headed Cowbird parasitism (5%) (Table 1). Predation was actually observed at only two nests, and of 36 nests that were depredated, all but one showed no signs of disturbance other than the absence of eggs or young. Of the 35 eggs that were lost (Table 1), 7 (20%) were removed by cowbirds and 28 (80%) were depredated. Of the 115 nestlings that were lost (Table 1), 90 (78%) were killed by unknown predators, 13 (11%) were assumed to have starved or died of unknown causes, 7 (6%) were seen being preyed upon by snakes, 4 (4%) were killed and partially consumed by an unknown mammal, and 1 probably died due to the presence of cowbird nestlings.

Nesting success, which is defined here as a nest that fledges at least one young, did not differ significantly among the three field seasons ($\chi^2 = 1.17$, df = 2, $P = 0.56$), between the first and second halves of the breeding season ($\chi^2 = 0.05$, df = 1, $P = 0.82$), between old field tracts and pine forest tracts ($\chi^2 = 0.04$, df = 1, $P = 0.84$), or between large-brood nests (4 or 5 nestlings) and small-brood nests (2 or 3 nestlings) ($\chi^2 = 0.8$, df = 1, $P = 0.77$). No significant difference in nest concealment was found between successful and failed nests ($t = 0.53$, df = 65, $P = 0.60$).

Using the Mayfield method, the probability that a Bachman's Sparrow egg would produce a nestling that fledged was 0.25. Although the daily success rate was greater for the incubation period (0.965) than the nestling period (0.919), the difference was not significant (Johnson's statistic = 1.16, $P > 0.20$) (Johnson 1979).

Annual productivity.—The average number of fledglings per nest attempt was 0.25 (probability an egg would fledge) $\times$ 3.91 (average clutch size) = 0.98. Since the average number of nests per season was 3.05, the yearly production was approximately 2.99 (0.98×3.05) fledglings per pair. If we assume an adult mortality close to 50% (Ricklefs 1973), then the estimate of first-year survival needed to maintain a stable population would be 34% ($0.50/1.49 \times 100$). If, however, the adult mortality rate is

TABLE 1
OUTCOME OF BACHMAN'S SPARROW EGGS AND NESTLINGS IN CENTRAL ARKANSAS, 1983–1985

	1983		1984		1985		Total	
Nests	15		26		25		66	
Eggs laid	58		100		97		255	
Eggs/nest	3.9		3.9		3.9		3.9	
Eggs hatched	51	(88)	77	(77)	78	(80)	206	(81)
Eggs hatched/nest	3.4		3.0		3.1		3.2	
Eggs failed to hatch	2	(3)	8	(8)	4	(4)	14	(5)
Eggs lost	5	(9)	15	(15)	15	(15)	35	(14)
Nestlings lost	24	(41)	44	(44)	47	(48)	115	(45)
Young fledged of eggs laid	27	(47)	33	(33)	31	(32)	91	(36)
Young fledged of eggs hatched	27	(53)	33	(43)	31	(40)	91	(44)
Young fledged/nest	1.8		1.3		1.2		1.4	
Successful nests[a]	8	(53)	11	(42)	9	(36)	28	(42)

[a] Nests that fledged at least one young.
Values in parentheses are percentages.

82%, as indicated by site-fidelity data (see above), then 55% of the young would have to survive the first year to maintain a stable population. Post-fledging data were difficult to collect, and I have no accurate estimate of the fledgling period survival rate. All nests that fledged young were successful in producing at least one juvenile.

Declining populations.—Although this study gives no clear answers as to why Bachman's Sparrows are declining in various regions of its range, it does indicate that in central Arkansas the annual fecundity and probability of egg success do not appear to be abnormally low. If other Bachman's Sparrow populations have similar productivity rates, then the cause of population declines may be due to other factors such as a shortage of breeding habitat and/or a high adult mortality rate possibly caused by a shortage of wintering habitat.

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