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NESTLING GROWTH AND DEVELOPMENT IN BACHMAN'S SPARROWS

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Abstract.—Nestling growth and development of Bachman's Sparrows (*Aimophila aestivalis*) were studied in central Arkansas from 1983 to 1985. All feather tracts had feathers that had clearly emerged through the skin by day 4 (96–118 h) and had ruptured their sheaths by day 7 or 8. Mass and tarsus growth rate constants of logistic curves were 0.50 and 0.40, respectively. Nestlings fledged with a mass that was 72% of adult mean mass, a tarsus that was 99% of adult length, and a wing that was 70% of adult length. These growth patterns are consistent with those reported for other emberizines. Brood size, time of season, and habitat had no effect on mass or tarsus growth. Mass growth, but not tarsus growth, differed among years.

DESARROLLO Y CRECIMIENTO DE LOS PICHONES DE *AIMOPHILA AESTIVALIS*

Sinopsis.—De 1983 a 1985 se estudió el desarrollo y crecimiento de los pichones de *Aimophila aestivalis* en una localidad de la parte central de Arkansas. Para el cuarto día (96–118 h) todas las plumas han emergido de las pterilas, y para el séptimo a octavo día las mismas han roto su envoltura. La tasa de incremento en peso y crecimiento del tarso para curvas logísticas constantes resultó ser de 0.50 y 0.40, respectivamente. Los pichones abandonaron el nido con una masa corporal que resultó ser el 72% del promedio de la masa corporal de los adultos. La longitud del tarso y el ala resultó ser el 99% y 70%, respectivamente del tamaño en los adultos. El patrón de crecimiento en esta ave es consistente para el informado en otros emberizinos. El tamaño de la camada, época del año y el tipo de habitat no influyó en la masa corporal o crecimiento del tarso en las aves. Se encontraron diferencias en la masa corporal, pero no en el crecimiento del tarso, en los diferentes años de estudio.

Bachman's Sparrow (*Aimophila aestivalis*) is a ground foraging and nesting species of open pine forests and overgrown fields in south and central portions of the eastern United States (American Ornithologists' Union 1983, Dunning and Watts 1990). It is presently considered threatened or endangered in several states throughout its range and is listed as a species of uncertain status (i.e., Category 2) by the U.S. Fish and Wildlife Service (Dunning and Watts 1990, Haggerty 1988).

As part of a larger effort (Haggerty 1986, 1988, 1992), this study describes morphological and behavioral changes of Bachman's Sparrows during the nestling period. Documentation of external changes in nestlings over time may be especially helpful in future studies where nestling age estimates are required. In addition, because intraspecific variation in postnatal growth in some species has been attributed to differences in habitat (Murphy 1985, Rogers 1985, Ross 1980), season (Best 1977, Dyrcz 1974, Petersen et al. 1986, Ricklefs and Peters 1979), year (Pe-

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tersen et al. 1986, Ricklefs and Peters 1979, Ritter 1984) and brood size (Best 1977, Crossner 1977, Petersen et al. 1986, Ross 1980), I examined effects of those extrinsic factors on nestling growth in the Bachman's Sparrow.

STUDY AREA AND METHODS

Research was conducted during spring, summer and fall of 1983–1985 in Hot Spring Co., Arkansas, about 19 km south of Malvern (34°15'N, 92°47'W). The study was conducted on seven shortleaf (*Pinus echinata*) and loblolly (*P. taeda*) pine plantations. Five plantations had been clearcut and were 0–4 yr old, depending upon age of planted pines. The other two tracts were approximately 45 and 70 yr old, and had been thinned and control burned.

Five measurements were made daily on nestlings that had been uniquely marked with permanent ink: (1) body mass (g), determined to the nearest 0.1 g for 0–2-d-old nestlings and 0.25 g for individuals >2 d of age; (2) wing length (mm), distance from bend of wrist to tip of manus or to tip of longest primary, depending on age of the nestling; (3) bill length (mm), distance from anterior nares to tip; (4) tail length (mm), distance from tail base to tip of longest rectrix; and (5) tarsus length (mm), distance from intertarsal joint to fleshy protuberance just anterior to the hallux. Most nestlings were measured at the same time each day between 1000 and 1400 h. Lengths were measured with dial calipers and masses with Pesola scales that were regularly checked for accuracy. The nestling period lasted 9.0 ± 0.2 d ($n = 16$). Measurements and appearance of 75 nestlings of known age were used to age nestlings whose hatching dates were unknown. Feather tract terminology was similar to that used by Wetherbee (1957) and Pettingill (1970).

Increasing nestling weights and tarsal lengths were analyzed by fitting logistic growth curves (Ricklefs 1967) to points obtained by averaging nestling measurements for each age group (i.e., mean for day 0, day 1, etc.). The logistic curve has the form:

$$M(t) = A/\{1 + \exp[-k(t - t_i)]\},$$

where M(t) is mass (g) or length (mm) at age t (days), A is the asymptote (g or mm), k is the growth rate constant (days), and t_i is the age at the inflection point. The curves were fitted using a least-squares regression procedure (PROC NLIN, SAS Institute 1985). Mass and tarsus measurements between days 2 and 5 were used to examine effects of brood size, season, year and habitat on nestling growth because some nests were not discovered on hatching day and measurements taken after day 5 would often induce premature fledging. As mass increase and tarsal growth are linear during this period (mass $r^2 = 0.97 \pm 0.06$ (SD), $n = 75$ nestlings; tarsus $r^2 = 0.99 \pm 0.02$, $n = 79$, Figs. 1A, B), the regression coefficient obtained from linear regression was used as a measure of growth rate. As nestling measurements within the same brood lacked independence, an average measurement per brood, rather than each individual nestling,

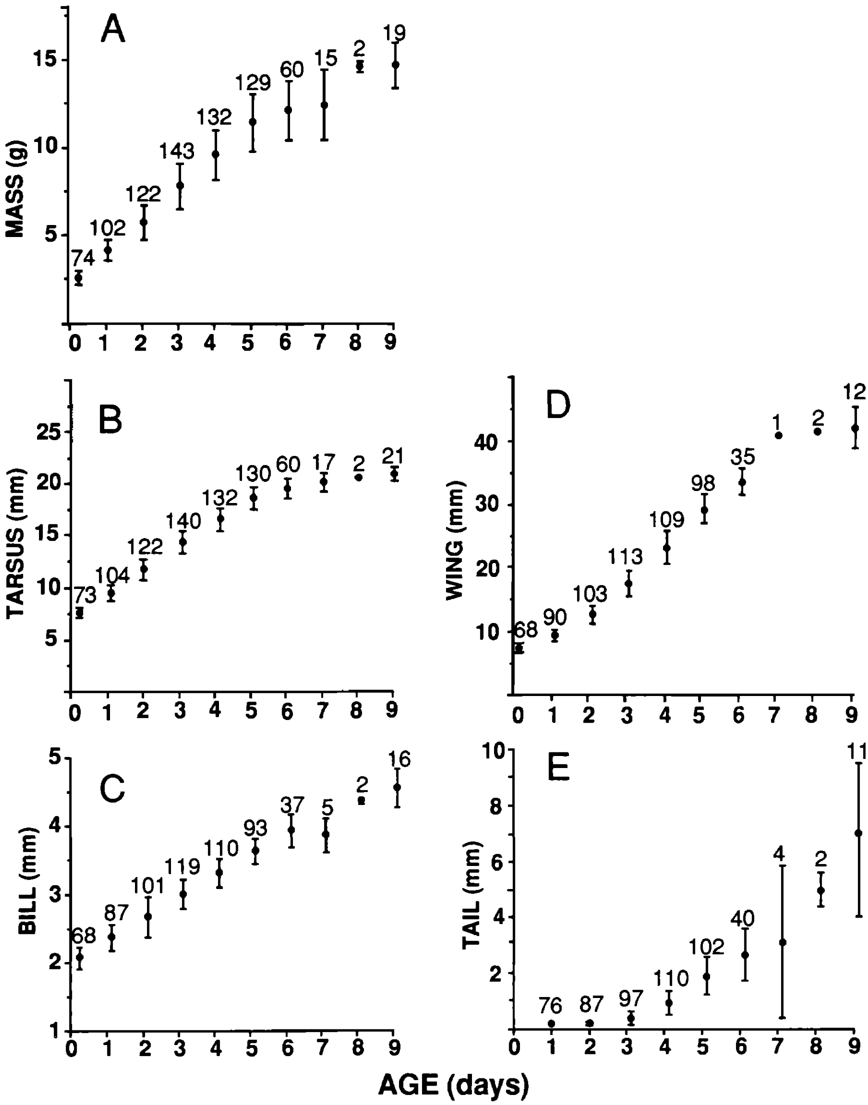

FIGURE 1. Bachman's Sparrow nestling growth curves for (A) mass, (B) tarsus, (C) bill, (D) wing and (E) tail. Dots and vertical bars represent $\bar{x} \pm 1$ SD. Values above bars are number of nestlings measured.

was used as the sample unit for statistical analyses. Broods were considered "small" if they contained 2–3 nestlings and "large" if 4–5 nestlings were present. Nestlings measured before or on June 30 were classified as "early" season nestlings and those after that date were considered "late" season nestlings. The five younger, clearcut tracts were classified as "old

TABLE 1. Approximate feather development in Bachman's Sparrow nestlings. Numbers in parentheses are numbers of nestlings examined for each day.

Feather tract	Day of nestling period when first feathers of tract emerged through skin	Day first feathers of tract ruptured sheaths
Alar	0 (75), 1 (68)	5 (57)
Spinal	2 (66)	5, 6 (15)
Humeral	2	5, 6
Ventral	2	4 (60)
Capital	3 (62)	7 (2), 8 (2)
Femoral	3	5, 6
Crural	3	5, 6
Caudal	3	6

field" habitat and the two older tracts were classified as "pine forest" habitat. Weather data, measured at Malvern, were obtained from National Oceanic and Atmospheric Administration Climatological Data. Variation in growth rates and weather data were examined with one-way analysis of variance and two-tailed *t*-tests. Probability values ≤ 0.05 were considered significant.

RESULTS

Morphological and behavioral changes in nestlings.—Table 1 summarizes the approximate sequence of feather development. On day 0 (0–24 h), only the outermost primaries had emerged through the skin and they were difficult to see. Pale grayish down was present along the coronal and occipital regions of the capital tract; the interscapular, dorsal and pelvic regions of the spinal tract; the abdominal region of the ventral tract; and the alar, humeral, femoral and crural tracts. Small, faint, pigmented feather papillae were visible below the skin surface along the humeral, alar and spinal tracts. The skin was orange-pinkish.

The skin was more pinkish on day 1 than on day 0. Small, faint pigmented feather papillae were visible through the skin along capital, crural, and femoral tracts and the cervical region of the ventral tract. The emerged primary feathers were clearly visible. By day 2, the eyes were sometimes opened and feathers of humeral, ventral, and spinal feather tracts emerged, but were difficult to see. Pigmented feather papillae of crural, femoral and capital tracts were clearly visible through the skin. On day 3, feathers along spinal, ventral and humeral tracts had clearly emerged through the skin. Feathers of femoral, crural, caudal and capital tracts had emerged but were difficult to see. By day 4, feather sheaths of the axillar region of the ventral tract had ruptured and tips of feather sheaths along the alar and spinal tracts looked pale and ready to break. Nestlings continued to beg for food, even when handled.

On day 5, feather sheaths of the alar tracts ruptured. Spinal, humeral, crural and femoral tracts sometimes had sheaths that ruptured. Nestlings preened, stretched, emitted chitter calls and usually cowered when the nest was approached. By day 6, all pterylae except the capital tract had feathers that had clearly erupted from their sheaths. Sheath tissue around feathers of the alar tract was still present on more than half the proximal end of feather lengths. Nestlings remained motionless when the nest was approached and would often fledge prematurely if handled.

On days 7 and 8, the sheath tissue on feathers of most tracts was less than 50% of the feather length. By day 9, only feathers of the auricular and ocular regions of the capital tract remained in their sheaths. The body was well feathered, but the ventral apterium was still visible. The proximal thirds of primary and secondary feathers were still surrounded by sheath, but were covered from above by covert feathers.

Growth of mass, tarsus, wing, bill and tail.—Mean mass (±SD) of unfed, newly-hatched young was 1.9 g ± 0.12 (n = 4), about 77% of the mean egg mass ($\bar{x}$ = 2.48 g ± 0.24, n = 47 eggs). Hatching-day mass was 12% of the mean breeding adult mass ($\bar{x}$ = 20.8 g ± 5.2, n = 49) and 17% of the fledging-day mass. Greatest mass gains occurred during the first half of the nestling period (Fig. 1A). By day 5, nestlings had obtained 77% of the fledgling mass and on fledging day, nestlings were 72% of the adult mass. Growth rate constant, inflection point and asymptote of a logistic curve were 0.50 (95% confidence interval ±0.12), 3.1 (±0.57) days after hatching and 14.9 g (±1.41), respectively. Ratio of nestling mass asymptote to adult mass (R-value; Ricklefs 1968) was 0.74.

On hatching day, mean tarsus length was 36% of the mean adult length ($\bar{x}$ = 20.8 mm ± 0.7, n = 44). Greatest increases in length occurred between days 0–5 (Fig. 1B). Eighty-seven percent of the adult length had been attained by day 5 and 99% on fledging day. Growth rate constant, inflection point and asymptote of a logistic curve was 0.40 (95% Cl ± 0.07), 1.7 (±0.30) days after hatching and 21.8 mm (±1.04). Tarsus R-value was 1.04.

On hatching day, mean bill length was 24% of the mean adult bill length ($\bar{x}$ = 8.4 mm ± 0.4, n = 37) and 46% of the average fledging-day length (Fig. 1C). Nestlings fledged with bills that were 53% of the adult length.

On hatching day, mean wing length was 11% of the mean adult ($\bar{x}$ = 59.1 mm ± 2.4, n = 37) and 16% of the mean fledging-day length (Fig. 1D). Similar to mass and tarsal lengths, the greatest wing growth occurred during the first half of the nestling period, but growth did not taper off until after day 7. On fledging day, wings were 70% of adult length and were used for short flights (1–3 m) from the nest site.

Tail growth did not usually begin until day 3 (Fig. 1E). Unlike the other morphological features measured, greatest increases occurred during the second half of the nestling period. Nestlings fledged with tails that were 11% of the adult length ($\bar{x}$ = 60.7 mm ± 3.6, n = 31).

Brood size and time of season had no effect on nestling mass (brood size: t = 0.8, df = 24, P = 0.4; time of season: t = 1.3, df = 24, P = 0.2) or tarsus growth (brood size: t = 0.7, df = 24, P = 0.5; time of season: t

= 0.5, df = 24, P = 0.6). Year affected mass gain because nestlings in 1984 gained mass at a faster rate between days 2 and 5 than nestlings of 1983 (F = 3.3, df = 2, P = 0.05; Duncan multiple range test, $P < 0.5$). Year had no effect on tarsus growth (F = 1.6, df = 2, P = 0.2) and habitat had no effect on mass (t = 1.1, df = 24, P = 0.3) or tarsus growth (t = 1.7, df = 24, P = 0.1).

DISCUSSION

The overall development of Bachman's Sparrow nestlings varied little from the congeneric Rufous-winged Sparrow (*A. carpalis*; Austin and Ricklefs 1977). Rufous-winged Sparrow nestlings fledged, however, at a greater percentage of adult mass (77% vs. 69%) and had a greater mass growth rate constant (0.57 vs. 0.50). When compared to other emberizines, mass and tarsus growth constants and tarsus R-values were similar (Petersen et al. 1986, Rogers 1985, Smith and Andersen 1982). Yet, mass R-values tended to be lower for Bachman's Sparrows (0.74) than those reported for Sage Sparrows (*Amphispiza belli*, 0.85; Petersen et al. 1986) and Brewer's Sparrows (*Spizella breweri*, 0.97; Petersen et al. 1986). Obligate ground nesting species such as Bachman's Sparrows may have lower R-values because less development is required of fledglings that remain on the ground compared to those species that will sometimes nest and often seek refuge off the ground, or that forage aerially (Ricklefs 1968, Petersen et al. 1986). Absence of variation values for percentages of adult mass when fledging, growth constants and R-values inhibited statistical comparisons, however, so interspecific differences should be interpreted with caution.

Of the parameters measured, wings and tarsi grew at the fastest rates, but varied least (Fig. 1). Therefore, measurements of these parameters, appearance of feather tracts (Table 1), and the behavior of nestlings, should provide the best estimates of nestling age in the Bachman's Sparrow.

As nestlings of large and small broods received similar amounts of food per nestling (Haggerty 1992), similarity of mass gain and tarsus growth between the two sizes is not surprising. Although some investigators also found no growth differences among brood sizes (Biermann and Sealy 1982, Ritter 1984), others have (Best 1977, Ross 1980). This difference suggests that adults of some species may have more difficulty finding food for nestlings than others. Although habitat (Ross 1980) and season (Herlugson 1983, Ricklefs and Peters 1979) affected nestling growth in some species, I found no significant differences in mass or tarsus growth between broods raised in old field and pine forest habitats or between early and late broods. This result shows that Bachman's Sparrow adults were finding enough food for adequate nestling growth throughout the nesting season in both habitats.

The greater mass gain of the nestlings of 1984 compared to those of 1983 is difficult to explain. Weather has been linked to growth variation by some investigators (Murphy 1985, Petersen et al. 1986, Price 1985), but in my study neither average monthly temperature ($F = 0.08$, df $= 2$, $P = 0.9$) nor precipitation ($F = 0.3$, df $= 2$, $P = 0.7$) between April and August differed significantly among years.

In conclusion, my results show that in central Arkansas, forest management practices (e.g., clearcutting, chopping, selective cutting and burning) provide some suitable habitat for adequate nestling growth and development for Bachman's Sparrows (but see, Dunning and Watts 1990, Haggerty 1986). Few nestlings died of starvation (Haggerty 1988) and no evidence was found to show that population declines are due to parents being unable to find adequate nourishment for their young during the breeding season.

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