J. Field Ornithol., 55(1):48–53

GROWTH OF NESTLING SCRUB JAYS IN CALIFORNIA

By Lyman V. Ritter

Although growth of nestling Florida Scrub Jays (*Aphelocoma coerulescens coerulescens*) has been described (Woolfenden 1978), no report on the growth of any other race exists. This paper describes the growth of nestling Scrub Jays of the race *A. c. superciliosa* based on work in a valley oak woodland near Chico, Butte County, California. The nesting biology of the Florida race differs from that of the other races in that many nestlings receive care from offspring of earlier year classes in addition to that provided by their parents (Woolfenden 1975, 1978, Stallcup and Woolfenden 1978). Such helpers have not been observed in other races including *A. c. superciliosa* (Ritter 1972, Verbeek 1973, Atwood 1978).

METHODS

I located nests by searching vegetation or by observing nest-building. Active nests were visited between 0600 and 0900 at 3- to 5-day intervals during April and May from 1971 through 1974. Nest visits were brief, to minimize altering the normal nesting duties or nest predation. Nestlings of known age (±1 day) were weighed to the nearest gram with spring scales. I determined age of nestlings by observing hatching or by estimating the time of hatching. Time of hatching was estimated from the number of eggs in a nest (assuming that one egg is laid per day), eventual clutch size, and length of the incubation period—18 days from the last egg laid until hatching of the last young (Ritter 1983). Hatching of eggs in a clutch usually spanned more than 1 day. Because the precise hatching period was not determined for any nest, all young in a brood were assigned the same hatching date (hatching of last young = day 0). Some of the newly-hatched nestlings, therefore, may have been a day old when weighed.

The graphical method (Ricklefs 1967) was used to estimate the growth rates directly from the daily increments in nestling weights. Growth rate was determined by fitting growth curve data to a logistic equation:

$$W = \frac{A}{1 + e^{-K(t_w - t_0)}},$$

in which W is the weight of the bird in grams at age t_w (days from hatching), A is the approximate asymptote of the growth curve, K is the growth rate constant, e is the base of natural logarithms, and t_0 is the age (days) at the inflection point of the growth curve—the point of maximum growth rate, which occurs at one-half the asymptotic weight on a logistic curve (Ricklefs 1967, 1968). Because of nestling mortality, and because all young were not weighed every day, growth curve estimates for each year are based on unequal sample sizes.

Adult and juvenile jays were captured with ground traps during autumn and winter in 1970–1972. Each jay was weighed, aged (Pitelka 1945), banded, and marked (patagial tags).

TABLE 1. Weights (g) of nestling Scrub Jays near Chico, Butte County, California, 1971 to 1974.

Age (days)	No. of broods	No. of nestlings	x̄	SD	Range	Asymptote (%)
0	9	31	5.4	0.49	5–6	7.2
1	3	14	7.6	0.85	6–9	10.0
2	9	42	10.2	3.30	5–16	13.4
3	5	20	15.2	3.56	8–23	20.5
4	4	15	21.1	7.05	13–28	28.4
5	6	23	26.4	5.68	18–38	35.5
6	10	38	28.2	6.37	16–41	37.9
7	9	35	32.5	6.03	22–50	43.8
8	5	22	38.0	7.30	26–54	51.1
9	5	21	41.8	7.21	33–54	56.6
10	6	24	48.3	4.81	32–55	64.5
11	6	23	54.6	6.43	41–66	73.5
12	3	14	55.9	5.39	48–67	75.1
13	9	35	59.0	6.08	46–69	79.4
14	6	22	62.8	9.04	45–76	84.4
15	6	23	71.7	4.05	62–78	96.4
16	4	12	78.7	5.44	64–82	99.1
17	1	3	74.3	6.65	70–82	100.0
18	1	5	71.6	3.57	67–76	96.3
19	2	5	73.2	2.77	72–77	98.5
20	1	1	80.0	0.00	80	107.6

RESULTS AND DISCUSSION

Data were obtained from 180 young from 41 nests (Table 1). The nestling period in undisturbed nests ranged from 16 to 26 days (Ritter 1983). However, most nestlings left the nest and were able to avoid capture when approached at 16 or 17 days of age. Premature departure from the nest in response to nest visits by humans has been reported for numerous species, including the Florida Scrub Jay (Woolfenden 1978) and the Pinyon Jay (*Gymnorhinus cyanocephalus*) (Bateman and Balda 1973). The mean weight of nestlings less than 24 h old was 5.4 g (SD = .49, n = 31). General changes in weight (Fig. 1) followed the sigmoid growth form common to other passerines (Ricklefs 1968). Growth rate varied among individuals, broods, and years. Part of the year-to-year variation in growth may have been caused by the small number of broods in a particular age class for a given year. Intraspecific variation in growth has been attributed to: sibling competition, brood size, parental age or experience or both, season, quality and quantity of food supply, environmental factors, inherent variability (Ricklefs 1968), and hatching sequence (Best 1977).

Weight of nestlings leveled off during the last week of the nestling period. The apparent reduced weight gain, and even weight loss near fledging in 1974 (Fig. 1), probably reflected increased nestling activities, such as exercising wings at the nest and making short excursions from

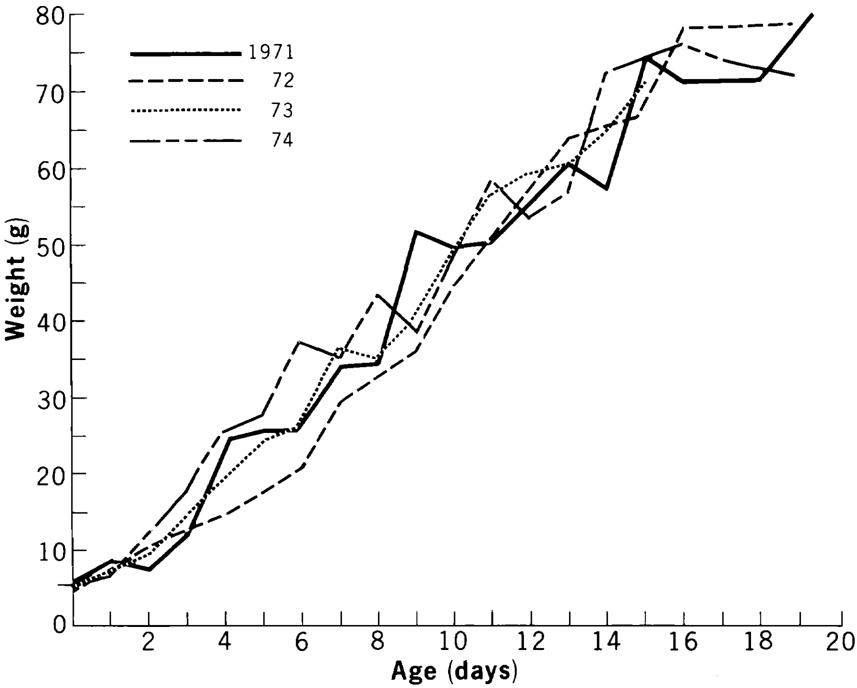

FIGURE 1. Weight increases of nestling Scrub Jays, by year, near Chico, Butte County, California.

the nest, rather than inadequate feeding by parents or increased energy demands for feather growth or thermoregulation (Banks 1959). The number of feedings increased during the last week of the nestling period, and the adults continued to feed fledglings another 5 weeks (Ritter 1972). Food deliveries to nestlings increased with age for the Australian Raven (*Corvus coronoides*) (Rowley 1973), and Florida Scrub Jay (Stallcup and Woolfenden 1978).

The data fit logistic and linear equations equally well. The logistic equation (Ricklefs 1967) best approximated the growth of Florida Scrub Jays (Woolfenden 1978) and Pinyon Jays (Bateman and Balda 1973). Ricklefs' (1967) procedure, which was used to fit nestling growth data to a logistic equation, transforms the growth curve into a straight line, the slope of which can be measured graphically. The slope is then directly proportional to the growth rate constant (K) and can be used for both intra- and interspecific comparisons where growth curves are fitted to the same equation.

To compare curves fitted to different growth equations (i.e., Gompertz or von Bertalanffy), other growth indices are available, including the time interval for growth from 10 to 90% of the asymptote (t_{10-90})

TABLE 2. Weight and growth rates of western Scrub Jays, Florida Scrub Jays,[a] and Pinyon Jays.[b]

Species and date	Nestlings	Asymptote A (g)[c]	Adult weight (g)	Ratio	Growth rate[d] K	Expected t_{10-90}	Observed	t_{50}
Western Scrub Jay								
1971	126	74.0	92.9	0.79	0.310	13.0	14.2	7.8
1972	66	78.0	92.9	0.84	0.285	13.2	14.6	8.8
1973	127	75.0	92.9	0.80	0.317	13.1	13.5	7.9
1974	109	76.5	92.9	0.82	0.250	13.1	13.0	7.5
Combined (average)	428	74.3	92.9	0.80	0.298	13.0	13.6	7.8
Broods ≤4	256	77.2	92.9	0.83	0.280	13.2	13.8	8.1
Broods >4	164	76.2	92.9	0.82	0.282	13.1	14.3	8.1
Florida Scrub Jay	674	60.0	79.2	0.76	0.335	12.3	13.1	8.2
Pinyon Jay	236	78.9	103.3	0.79	0.328	13.2	13.4	7.6

[a] Woolfenden 1978.
[b] Bateman and Balda 1973.
[c] Approximate asymptote of growth curve.
[d] K = Growth rate constant; t_{10-90} = Time interval for growth from 10 to 90% of the asymptote; Expected t_{10-90} = Calculated from regression equation of t_{10-90} to body size (Ricklefs 1968); t_{50} = The time needed to attain 50% of the asymptote.

and the time needed to attain 50% of the asymptote (t_{50}). Both t_{10-90} and t_{50} are inversely related to K, because as the rate of growth increases, the time required to achieve a certain level of growth decreases. These inverse measures of growth rate are calculated from the growth equation (Ricklefs 1967).

The BMDP program PAR was also used to fit the logistic equation to the data (Dixon and Brown 1977). The approximate final nestling weight, or asymptote (A), of Scrub Jays varied from 74.0 to 78.0 g (Table 2). Part of this variability probably was caused by insufficient data for older age classes. The asymptotic weight was lower for the Florida Scrub Jay (60.0 g)—a smaller race (Woolfenden 1978)—and slightly higher for the Pinyon Jay (78.9 g) (Bateman and Balda 1973).

The growth rate constant (K) averaged .298 (range .250–.317), a value below that for the Florida Scrub Jay (.335) and Pinyon Jay (.328). I conducted a confidence interval test, which was developed from a family of Bonferroni tests (Gallant 1975), for differences of K and t_{50} among years and brood sizes. Only between 1973 and 1974 was K significantly different ($P < .05$), indicating a faster growth rate in 1973 than in 1974. Little interspecific variation is seen in the overall growth rate for jays, although Best (1977) found wide variation in the Field Sparrow (*Spizella pusilla*; K = .444–.712), between early and late broods and between years.

The age at which half of the asymptote (t_{50}) was attained varied little among years, except in 1972, when the growth rate was significantly slower than in other years ($P < .05$). This probably resulted from earlier laying dates in 1972 than other years (Ritter 1983). Age t_{50} for this western Scrub Jay is similar to that for other jay species (Table 2).

The observed inverse measure of the growth rate, t_{10-90}, was lowest in 1974 (13.0) and highest in 1972 (14.6) (Table 2), although no test for significance was done. On the basis of Ricklefs' (1968) regression equation of t_{10-90} to body size ($t_{10-90} = 3.94\ A^{.278}$, in which A is the asymptote), the nestlings grew slower than expected in 1971, 1972, and 1973, and essentially as expected in 1974. Growth rate as a function of body size was lower than expected in the Florida Scrub Jay (Woolfenden 1978), but Pinyon Jay nestlings grew as expected (Bateman and Balda 1973).

On the basis of specific growth factors, broods of 3 or 4 of these western Scrub Jays appeared to grow no faster than broods of 5 or 6 ($P > .05$). Ricklefs (1973) argued against the hypothesis that growth rates in birds are adjusted to brood size. Mean weight of nestling Ipswich Sparrows (*Passerculus sandwichensis princeps*) at 7 days of age, however, declined significantly with increasing brood size (Ross 1980).

The ratio of adult weights to nestling asymptotes (A) provided an index of development at fledging. The ratio varied little between years (.79–.82) and was similar to that for other jays (Table 2). Because nestling jays were not sexed, average weight of all jays with adult plumage ($\bar{x}$ = 92.9 g, SD = 7.02, range 82–109, n = 53) was used in the analysis of the ratio (Pitelka 1945). Scrub Jays are sexually dimorphic in weight (Pitelka 1951, Woolfenden 1978, Atwood 1979). In my study, the mean weight of adult males (97.2 g, SD = 5.86, range 89–109, n = 24) differed significantly ($P < .001$) from that of adult females (87.7 g, SD = 3.25, range 80–93, n = 21).

Ricklefs (1968) hypothesized that among passerines the ratio of adult weight to fledging weight is correlated to a species' foraging behavior: ratios less than .9 are most common in ground-feeding species and ratios greater than 1.0 are most common in species that spend a large proportion of their foraging time in flight. The difference in the ratio between birds with different foraging behaviors emphasizes the greater relative importance of the development of flight compared with pedal locomotion, that is, anatomical adaptations accompanying the development of pedal locomotion preclude weight gain but those accompanying flight do not. At fledging (16+ days) Scrub Jays were unable to fly, but were adept at clambering about the vegetation near the nest. Therefore, the ratios I obtained for Scrub Jays agree with Ricklefs' hypothesis.

Juveniles slowly attained adult weight during the summer. Their weights between September and January ($\bar{x}$ = 91.6 g, SD = 6.05, n = 66) were statistically indistinguishable ($P > .05$) from those of adults taken between September and February ($\bar{x}$ = 92.9 g, SD = 7.02, n = 53). Juvenile Florida Scrub Jays did not attain adult weight until sometime after their first year (Woolfenden 1978).

ACKNOWLEDGMENTS

I thank Michael Erpino for his encouragement and guidance throughout this study. The help of Chuck Evans with statistical matters and programming is gratefully acknowledged. Michael Erpino, Jerome Jackson, John Kie, Jared Verner, Glen Woolfenden, and an anonymous reviewer gave useful comments on the manuscript. The field work was done in partial fulfillment of requirements for a Master of Arts degree in Biological Sciences at California State University, Chico. This work was supported in part by a National Science Foundation grant.

LITERATURE CITED

ATWOOD, J. L. 1978. The breeding biology of the Santa Cruz Island Scrub Jay, *Aphelocoma coerulescens insularis.* M.A. thesis, California State University, Long Beach.

———. 1979. Body weights of the Santa Cruz Island Scrub Jay. North Am. Bird-Bander 4:148–153.

BANKS, R. C. 1959. Development of nestling White-crowned Sparrows in central coastal California. Condor 61:96–109.

BATEMAN, G. C., AND R. P. BALDA. 1973. Growth, development, and food habits of young Pinyon Jays. Auk 90:39–61.

BEST, L. B. 1977. Nestling biology of the Field Sparrow. Auk 94:308–319.

DIXON, W. J., AND M. B. BROWN. 1977. Biomedical computer program series P, University of Calif., Berkeley.

GALLANT, A. R. 1975. Nonlinear regression. Am. Stat. 29:73–81.

PITELKA, F. A. 1945. Pterylography, molt and age determination of American jays of the genus *Aphelocoma.* Condor 47:229–260.

———. 1951. Speciation and ecologic distribution in American jays of the genus *Aphelocoma.* Univ. Calif. Publ. Zool. 50:195–464.

RICKLEFS, R. E. 1967. A graphical method of fitting equations to growth curves. Ecology 48:978–983.

———. 1968. Patterns of growth in birds. Ibis 110:419–451.

———. 1973. Patterns of growth in birds. II. Growth rate and mode of development. Ibis 115:177–201.

RITTER, L. V. 1972. The breeding biology of Scrub Jays. M.A. thesis, California State University, Chico.

———. 1983. Nesting ecology of Scrub Jays in Chico, California. Western Birds 14:147–158.

ROSS, H. A. 1980. Growth of nestling Ipswich Sparrows in relation to season, habitat, brood size and parental age. Auk 97:721–732.

ROWLEY, I. 1973. The comparative ecology of Australian Corvids. IV. Nesting and the rearing of young to independence. CSIRO Wildl. Res. 18:91–129.

STALLCUP, J. A., AND G. E. WOOLFENDEN. 1978. Family status and contributions to breeding by Florida Scrub Jays. Anim. Behav. 26:1144–1156.

VERBEEK, N. A. M. 1973. The exploitation system of the Yellow-billed Magpie. Univ. Calif. Publ. Zool. 99:1–58.

WOOLFENDEN, G. E. 1975. Florida Scrub Jay helpers at the nest. Auk 92:1–15.

———. 1978. Growth and survival of young Florida Scrub Jays. Wilson Bull. 90:1–18.

Pacific Southwest Forest and Range Experiment Station, Forest Service, USDA, 2081 East Sierra Avenue, Fresno, California 93710. Received 4 May 1982; accepted 10 Sept. 1983.