

ROBERT M. ZINK, *Museum of Natural Science, Louisiana State Univ., Baton Rouge, Louisiana 70803*; AND JOHN T. KLIČKA, *Caesar Kleberg Wildlife Research Institute, Texas A&I Univ., Kingsville, Texas 78363*. (Present address JTK: *J. F. Bell Museum of Natural History, Univ. Minnesota, Minneapolis, Minnesota 55455*.) Received 8 Aug. 1989, accepted 21 Jan. 1990.

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Growth of Monk Parakeets.—Growth characteristics of nestlings vary considerably among bird species. These may result from the diverse selective pressures these species experience. For example, species with open nests are more prone to predation and may have evolved comparatively high growth rates in order to reduce the time in the nest (Lack 1968). Also intra-specific variations in growth parameters among years or in relation to hatching order indicate that the ability of growth processes to respond to different conditions may have adaptive value (Ricklefs 1968, 1976).

Parrots offer interesting material for analysis in this respect, due to their extreme altriciality, slow growth, and completely asynchronous hatching. Unfortunately, data for the group are scarce. Growth curves are known for only seven species, and for most the data come from captive birds (Caccamise and Alexandro 1976; Caccamise 1980; Saunders 1982, 1986; Bucher 1983; Stamps et al. 1985). Unique among the Psittaciformes, the Monk Parakeet (*Myiopsitta monachus*) is not a true cavity-nester since it builds large enclosed communal nests made of sticks where several pairs breed independently (Forshaw 1973; Martella 1985).

In this work, we present the parameters that describe the growth curve of nestlings of *Myiopsitta monachus catita* in a wild population and examine their variation among years and in relation to the hatching order within a brood.

Study area and methods.—The study was carried out in an area of 600 ha, situated near Jesús María, Córdoba, Argentina (31°05'S, 64°11'W).

From the pre-laying period to fledging time (November to March) in 1985–1986, 1986–1987 and 1987–1988, all the parakeet nests situated below 7 m height were checked. In order to minimize disturbance caused by the observers, visits were spaced nine days on average (range 7–12).

The eggs were measured to the nearest 0.1 mm (length and breadth), weighed to the nearest 0.1 g, and individually marked with indelible ink. After hatching, the nestlings were initially identified by toenail clipping. Later they were banded with numbered aluminum bands. On each visit, the nestlings were weighed to the nearest 0.1 and 1 g, for the weights under and over 10 g, respectively.

All the nestlings found dead in the nest, as well as those that disappeared before the minimum fledging age (estimated as 35 days), were excluded in our calculations. Seven successful nestlings that showed signs of malnutrition or weight recession at an early age were not included. Also, and due to the fact that in this species there is a recession of weight at fledging, we truncated the data of each successful nestling at the maximum mass value observed up to 36 days after the first visit.

Logistic curves were fitted by following the trial-and-error least-squares method proposed by Brown (1979), which is based on testing the goodness of fit of a series of logistic growth curves generated by varying stepwise the parameters A, K, and W_0 (see definitions below) in all combinations over a reasonable range for each one of them. This method adapts better

to our data than that used by Ricklefs (1967), since the precise age of each nestling was known only in a few cases, and there were not enough points per chick to fit individual curves properly. However, by means of Ricklefs' method we obtained a rough estimate of each parameter in order to determine the intervals in which to iterate. The ranges used here to generate the trial curves included the 99.9% confidence interval for the mean of each parameter, previously calculated by Ricklefs' method in eleven birds from eleven broods whose ages were exactly known because they were found during hatching. Their initial weight was roughly determined by subtracting from the weight of the pipped egg the weight of the shell (estimated as 0.7 g). This probably slightly overestimates hatchling mass (because there is an additional loss of water at hatching), but as stated below, the accuracy of this parameter does not influence the results of the curve fitting process.

The age corresponding to the first observed mass for each nestling was estimated by solving the logistic equation: $W_d = A/(1 + e^{-K(d-T)})$, in which W_d = mass (g) at d days of age, d = age of nestling in days, A = asymptotic mass (g), at which growth levels off just before fledging, K = growth rate constant (per day), e = base of natural logarithms, and $T = \ln(A/W_0 - 1)/K$, time, or age (specified in days) at inflection point of the curve, one half of the asymptotic weight.

The number of days between weighings was added to this value to obtain the estimated age at each visit. These ages were used in the logistic equation to calculate the respective predicted masses. The sum of squared deviations between observed and predicted masses of all nestlings was calculated for each trial curve.

To obtain the confidence intervals of the growth parameters we employed the Jackknife method, according to the criterion proposed by Bradley et al. (1984) and Brisbin et al. (1987). Ninety-five percent confidence intervals were calculated as suggested by Bradley et al. (1984): $I.C. = P \pm Et_{0.05, N-1}$, where P = parameter estimator of the curve calculated by means of the least-squares method; E = standard error of the pseudo values; t = critical value of the t distribution; and N = number of independent pseudo values (cases).

Pseudo values were computed for three parameters of the growth curve (A , K , T). The complete set of data for each individual was considered as a simple case when taking the sub-samples. Thus, the pseudo values were obtained for each case rather than each separate point. In this way, we made sure that the calculated pseudo values were independent and overstating the degrees of freedom was avoided (Bradley et al. 1984). We consider that this method is reasonably accurate bearing in mind the large sample size employed (447 data points, representing a total of 128 nestlings with three to five weights available for each of them).

Results and comments. — Table 1 shows the set of parameters that give the lowest sum of squares by Brown's method when the pooled data of all the nestlings that fledged successfully in all years were analyzed. As Brown (1979) points out, the variation of the hatchling mass W_0 within its range (4.07–5.45 g) produced a negligible effect on the total sum of squares. Thus, the average W_0 calculated for the 11 nestlings of known age was taken as a constant during the iterations in order to reduce substantially the computing time.

The differences in asymptotic weight (A) between years are less than 1.1%, while in the growth constant (K) there is a maximum difference of 11.6%. The growth rates corresponding to the first two years were significantly higher ($P < 0.05$) when compared to that of the last by using the method proposed by Gabriel (1978). The relative constancy of A compared with the variations detected in K suggests that growth rate change responds to environmental conditions, extending the time needed to achieve the asymptotic mass.

The derived curve can be compared with the mass data points which were aged by using the curve, as well as with the masses of eleven birds of known age (Fig. 1). The fit of the curve to the data appears visually adequate in both cases. Notice that in many cases the

TABLE 1
PARAMETERS OF THE LOGISTIC GROWTH CURVE CALCULATED BY A LEAST SQUARES
TRIAL-AND-ERROR METHOD^a

| Parameter | 1985/1986 | 1986/1987 | 1987/1988 | Pool | 95% C.I. ^b |
|-------------------------------------------|-----------|-----------|-----------|--------|-----------------------|
| Asymptote (A), in g | 103.2 | 103.9 | 104.3 | 103.9 | 102.5–105.3 |
| Growth rate (K), per day | 0.2598 | 0.2478 | 0.2327 | 0.2437 | 0.2498–0.2376 |
| Inflection point (T), in days | 11.40 | 11.98 | 13.07 | 12.46 | 12.11–12.81 |
| Initial weight (W ₀), in g | 4.76 | 4.76 | 4.76 | 4.76 | |
| T _{10–90} , in days | 16.9 | 17.7 | 18.9 | 18.0 | |
| No. nestlings | 16 | 61 | 51 | 128 | |
| No. broods | 7 | 15 | 17 | 39 | |

^a Increments during the iterations were 0.1 in A and 0.0001 in K.

^b Obtained using jackknife method.

last weights were registered fairly after the fledging age because fledglings were taken by surprise inside the nest.

When the approximate time of fledging (35 to 40 days) is measured by using an index expressed in growth units (as defined by Ricklefs 1967), this age is equivalent to 2.50–3.06 growth units. These growth index values fall within the range of 2.5–3.5 growth units given by Ricklefs (1973) for most altricial land-birds.

Average adult weight at the end of the reproductive season (March) is 92.9 g (Navarro and Bucher unpubl. data). Thus, the ratio (R) between the asymptotic weight of nestlings and adult weight is 1.12. This value (over 1.10) does not correspond to a species such as the Monk Parakeet which has arboreal and ground feeding habits, but to a species which spend a large proportion of its foraging time in flight (Ricklefs 1968). However, this high R value coincides with what would be expected considering its long nestling period (Ricklefs 1976).

Nestling weight decreases by the time of fledging (Fig. 1), so the asymptote does not show the real mass at that moment. Based on the last weight registered for each successful nestling, we can estimate an average mass at fledging in 97.1 ± 8.38 g (SD) (N = 135).

The growth constant (K) obtained here is considerably below (25%) than the estimated by the allometric relationship for temperate altricial land-birds with an equivalent asymptote (Ricklefs 1968). However, it is 10% higher than the predicted value for tropical land-birds (Ricklefs 1976).

Our K value is higher than that for the cavity-nesting Psittaciformes studied by Bucher (1983). Given that K is inversely correlated with body size (Ricklefs 1968) and considering that three of those species have lower asymptotes than the Monk Parakeet, it is reasonable to attribute the discrepancies in K to the particular nesting habit exhibited by this parrot, bearing in mind that natural selection could favor a shorter nestling period in less protected nests (Lack 1968). The nest built by the Monk Parakeet, although safer than an open nest, is less secure than tree or cliff cavities. Falling of the nests due to strong winds is relatively frequent (pers. obs.), and important losses from vertebrate predators are common (Martella and Bucher 1984, Martella et al. 1985).

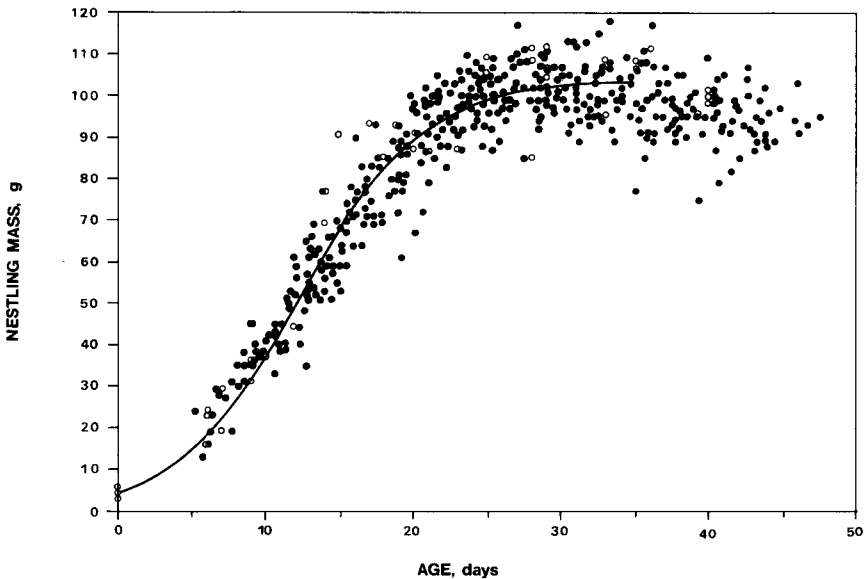


FIG. 1. Mass as a function of age in Monk Parakeets. The logistic curve was plotted using the parameters corresponding to the pooled data from three years. Solid circles show the observed successive masses of the birds whose age at first weighing was calculated by using the curve equation. Open circles represent the weights of eleven nestlings of known age.

Our K (0.2437) is higher by about 50% than that observed by Caccamise and Alexandro (1976) and Caccamise (1980) in captive bred Monk Parakeets. Consequently, the time required to grow between 10 and 90% of the asymptote (T_{10-90}) is in our case 9 days shorter than the 26.98 days determined by these authors. The difference between their K and ours is much greater than the maximum value of 30% observed in other species of birds for populations of the same subspecies in different localities (Ricklefs 1968). Unfortunately, we cannot assert if we are dealing with a different subspecies, since Caccamise and Alexandro (1976) and Caccamise (1980) do not mention the subspecies which they studied. On the other hand, there seem to be close similarities between their parakeets and ours since there are no significant differences in the dimensions of the eggs or in the average mass at laying (6.3 ± 0.56 g, $N = 419$), and there is also a great coincidence in the fledging age. However, adults in our case are 11.8% heavier than those used by Weathers and Caccamise (1978), and the same difference exists in the peak weight of nestlings. This is a noteworthy fact since our subspecies *M. m. catita* is not the largest within the species (Forshaw 1973), and our adult weight values correspond to the lightest period in the year (Navarro and Bucher in prep.).

We suspect that these discrepancies are not related to subspecific variations, being instead due to differences in diet quality resulting from captive breeding. However, as stated by Bucher (1983) the existence of dietary limits to growth is unestablished and virtually impossible to ascertain. This is one of the reasons why studies carried out under natural conditions are so important (see also Ricklefs 1968).

Given that the hatching of the eggs is asynchronous and considering that the average clutch size is 5.3 ± 1.70 eggs ($N = 156$), and initial brood size is 4.0 ± 1.71 nestlings ($N = 63$), the difference in age between the first and the last nestling in an average brood could be around 10 days. This leads to appreciable discrepancies in the sizes of nestlings. To test for differences in the growth pattern among siblings, logistic curves were fitted (iterative method) for two separate groups formed by the first and last hatched nestling from each one of the 23 broods in which both fledged. The oldest nestlings have a higher asymptote and growth rate than the youngest (0.9 and 4.4% higher, respectively). However, *t*-test analyses using standard deviations of jackknife pseudo values for each group revealed no significant differences according to order of hatch (A: $t = 0.474$, $df = 44$, $P > 0.50$; K: $t = 1.027$, $df = 44$, $P > 0.20$). In order to detect differences during the early stages of development, we carried out a further test that consisted in making paired comparisons between the percentage of the predicted mass that was achieved in the second weighing opportunity by the two extreme sibs in the brood. The relation $(O - E)100/E$ (where O is the observed second mass and E the predicted second mass from the logistic curve for the respective year) was lower in the youngest nestling in the brood compared to that of its eldest sibling in 14 cases out of a total of 23 (Wilcoxon sign test, $t = 68$, $P < 0.05$).

The lower growth rate of the youngest nestling at an early age is probably due to sibling competition for food that parents bring to the nest. Differences in size decrease in advanced stages of development, thus the young chick achieves a better competitive condition that permits it to increase its growth rate close to that of the first-hatched sib, or even to surpass it when the older members of the brood begin to leave the nest. This has been demonstrated by Stamps et al. (1985) in the Budgerigar (*Melopsittacus undulatus*). Another possibility is that parents in the Monk Parakeet might have feeding behavior strategies which allow control of brood reduction by eventually producing selective starvation of the younger nestlings only when food is scarce (see O'Connor 1978), as reported in the Budgerigar (Stamps et al. 1985).

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JOAQUIN L. NAVARRO AND ENRIQUE H. BUCHER, *Centro de Zoología Aplicada, Univ. Nac. de Córdoba, casilla de correo 122, 5000 Córdoba, Argentina. Received 15 May 1989, accepted 1 Dec. 1989.*

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Monitoring Galapagos Penguins and Flightless Cormorants in the Galapagos Islands.— Estimating bird population sizes has received much attention and many quantitative methods for analyzing population data have been developed (Ralph and Scott 1981, Seber 1986). However, assumptions implicit in these methods make censuses of some species difficult (Burnham et al. 1980), and replicated censuses which allow statistical testing of abundance patterns may be costly. Increasing the efficiency of census techniques would make replicated censuses more feasible, and if population estimates cannot be acquired due to financial limitations, identification of methods whereby populations could be monitored for major changes in size would be important. For species with restricted ranges, monitoring would be facilitated by identifying areas from which counts could be used to predict the total number that would be counted from a census of the species' entire range. Seber (1986)