Growth of White Stork *Ciconia ciconia* nestlings

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The growth of White Stork *Ciconia ciconia* nestlings was studied during the breeding season of 1997 in Serres Prefecture, northern Greece. Body mass and bill length of 29 nestlings were measured at irregular time intervals, a total of 192 measurements for each growth variable. Nestling growth was best described by a logistic equation for body mass and by a simple linear equation for bill length. Body mass growth (K = 0.149 days^{-1}) levelled off at about 45 days and reached an asymptotic value of 3 436 g; it took some 30 days to increase from 10 to 90% of the asymptotic value. Bill length showed a linear mode of increase within the first 51 days of nestling life. Relative growth rates showed that both variables grew fastest when nestlings were 0 – 10 days old.

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The White Stork *Ciconia ciconia* is a large waterbird closely associated with human settlements. Its breeding population has declined rapidly during much of the 20th century (Boettcher-Streim & Schüz 1989), mostly following destruction of suitable feeding habitat through agricultural intensification in the breeding areas and long-lasting droughts in the western African wintering range (Schulz 1999). This decline has been reversed since the mid-1980s and breeding numbers increased by more than 20% by the mid-1990s due mainly to changes in land use policies in Spain and eastern European countries, and fewer droughts in West-Africa (Schulz 1999). The breeding numbers in Greece followed a trend similar to that described above (Martens 1966, Boettcher-Streim & Schüz 1989, Tsachalidis & Papageorgiou 1996).

Although the White Stork has drawn the interest of researchers throughout its range, growth and development of nestlings have received little attention. Only two studies on White Stork growth were found in the literature, and these concerned birds reared in captivity (Heinroth & Heinroth 1926, Gangloff *et al.* 1989). Therefore, the aim of this study is to describe the growth of White Stork nestlings in the wild, as nestling growth provides valuable information on the behaviour and ecology of individuals and populations (Ricklefs 1968, Starck & Ricklefs 1998a).

The study was conducted during April-June 1997 at the villages of Mitrousi (41°04'N, 23°28'E) and Koumaria (41°11'N, 23°26'E) in the Serres Prefecture, northern Greece. These villages are situated along the river Strymon, and are surrounded by riparian habitat and farmland with crops of rice, corn and alfalfa. Nests are built on the roofs of large old barns. Each nest was first examined using a mirror adjusted to the top of a pole to reduce disturbance, and reached only for the marking of a new nestling by means of a 4 m-long aluminium ladder. Nests were visited daily during the late incubation period to determine the hatching date of each nestling (defined as day 0). Nestlings were individually marked with indelible ink on one of their legs during their first days of life; when about one week old, elastic colour bands were placed on the tarso-metatarsus, replaced by plastic colour rings at an age of about 20 days.

Measurements of body mass and bill length of 29 nestlings were obtained at irregular time intervals during the growth period between 0 and 51 days (a total of n = 192 measurements for each growth variable). Nestlings were weighed using Pesola spring balances of 100, 500, 1 000, 2 500, and 5 000 g to the nearest 1, 5, 10, 25, and 50 g respectively. The upper mandible of the bill (from tip to first feathers) was measured with digital calipers to the nearest 0.01 mm. Mean body mass of White Stork nestlings at day 0 was 85.3 ± 13.1 g (n = 7), mean bill length 19.4 ± 1.5 mm (n = 7). Mean values are presented ± 1 SD.

Avian growth is usually described by one of three equations of sigmoid form, i.e. logistic, Gompertz, and von Bertalanffy (Starck & Ricklefs 1998b). We used the Non Linear Regression routine of Statistica 5.5 software to determine which one described the growth variables best (StatSoft, Inc. 1999). The t_{10-90} index, the time interval (in days) needed for growth from 10% to 90% of the equation's asymptotic value, was calculated according to Ricklefs (1967). Relative growth rates (R) were calculated, at five-day time intervals, using the equation of Brody (1945):

$$R = (\ln g_2 - \ln g_1) \,/\, (t_2 - t_1) \qquad (1),$$

where g_1 and g_2 are the values of the growth variable at age t_1 and t_2 (in days), respectively. The mean values for each growth variable at a given age were used.

Growth of body mass was best described by the logistic equation:

$$BM = A \,/\, [1 + e^{-K(t-T)}] \qquad (2),$$

where BM is the body mass, A its asymptotic value, t the nestling's age in days, K the logistic growth rate constant in days^{-1}, which is proportional to the overall growth rate (Ricklefs 1968), and T is the age in days of the inflection point. The estimated values of the logistic growth parameters A, K, and T are given in Table 1.
Data for bill length were best described by the simple linear equation:

Table 1. Values of the equation parameters calculated for (1) body mass (logistic) and (2) bill length (linear) of nestling White Storks measured during the growth period. A is the asymptotic value of the body mass, K is the logistic growth constant (days^{-1}), and T is the age (days) of the inflection point. C and D are the linear equation parameters. Parameters are given with their standard errors (SE). R^2 values of the regressions and the t_{10-90} time (days) required to complete logistic growth from 10 to 90% of the asymptote are also given.

Growth variable Body mass (g)	A	SE	K	SE	T	SE	R^2	t_{10-90}
	3 436.2	51.68	0.149	0.005	20.6	0.32	0.97	29.50
Bill length (mm)	C	SE	D	SE	R^2			
	2.41	0.015	19.36	0.382	0.99			

$$BL = C \times t + D \quad (3),$$

where *BL* is the bill length, *t* the nestling's age in days, and *C* and *D* the linear growth parameters. The estimated values of the linear growth parameters *C* and *D* are given in Table 1. The high R^2 values show the good fit of the logistic and linear equations to the body mass and bill length data respectively (Fig. 1).

Body mass growth levelled off at about 45 days and reached an asymptotic value (*A*). Bill length did not level off, but grew linearly until the 51st day of nestling age. Relative growth rates (*R*) indicate that growth is faster during the first 10 days of the nestling's life, and especially between 0 and 5 days, for both variables (Table 2). Relative growth decreased with age, and for body mass it became negative after the age of 35 days.

White Stork nestlings, captive-bred in Strasbourg Zoo, weighed between 55 and 85 g (Gangloff *et al*. 1989) in their first day of life, less than the nestlings from the wild in northern Greece. Starck & Ricklefs (1998b) fitted the logistic equation to the average growth curve for body mass of three siblings bred in captivity, published by Heinroth & Heinroth (1926). They estimated an asymptote of 2 950 g and a logistic growth rate constant of 0.170 $days^{-1}$. The somewhat higher growth rate in comparison with the Greek population may suggest differences in growth between captive-bred and wild nestlings, probably related to differences in food provisioning rates and parental care. Such differences have been observed previously (Ricklefs 1973). Other factors like geographic and sex-specific variation may also explain intraspecific growth variability, but final conclusions cannot be drawn until these factors are assessed.

Marked differences were found in the growth patterns between body mass and bill length of the Greek nestlings. Body mass grew logistically, needed 30 days to complete from 10% to 90% of its growth and levelled off at about 45 days, a trend similar to that observed by Gangloff *et al*. (1989). They also observed that after levelling-off body mass even decreased after a nestling had fledged.

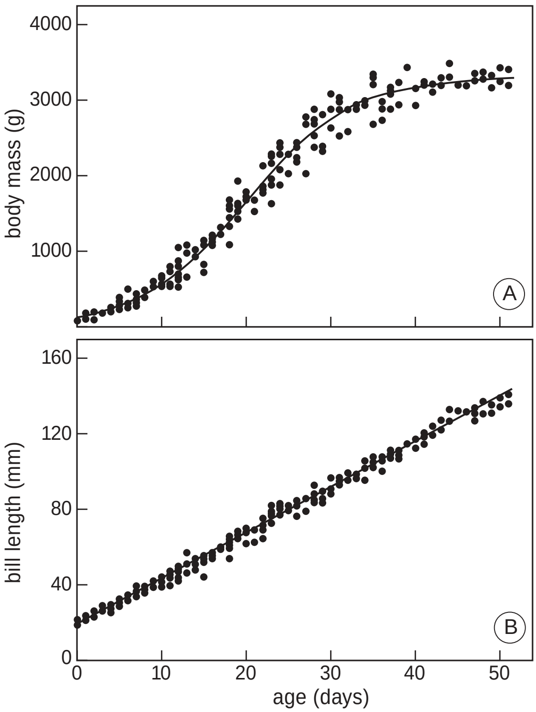

Figure 1. Growth of (A) body mass and (B) bill length of White Stork nestlings with age. Measurements (n = 192) from 29 different nestlings were used.

Table 2. Relative growth rates (*R*) calculated at five-day intervals during the growth period of White Stork nestlings.

Age (days)	Body mass (g^{-1} d^{-1})	Bill length (mm^{-1} d^{-1})
0 – 5	0.218	0.087
5 – 10	0.191	0.074
10 – 15	0.080	0.038
15 – 20	0.113	0.049
20 – 25	0.044	0.038
25 – 30	0.057	0.024
30 – 35	0.017	0.028
35 – 40	–0.012	0.017
40 – 45	0.030	0.015
45 – 50	–0.001	0.008

Many altricial and semialtricial birds, like the White Stork (Starck 1993), usually achieve higher body mass than adults before fledging (Ricklefs 1973). That trend was not revealed in this study because data were limited to the period before fledging. In contrast, bill length showed a different growth pattern. It did not level off within the 51 days of nestling age, but increased in a linear fashion. According to Kania (1988) and Gangloff *et al*. (1989), who fitted sigmoid curves to their data, bill growth does not reach an asymptote even after 70 days of life, the age at which nestlings are able to fly (Hancock *et al*. 1992). Our data are limited to the first 51 days of nestling life and could not demonstrate this trend. However, a linear growth, which fitted the data for the recorded period best, suggested further increase. Competition for nutrients between various growing tissues has been proposed as an explanation for differences in growth patterns of various body components (O'Connor 1977).

This was a first attempt to describe the growth of body components of wild White Stork nestlings. The results indicate differences in growth patterns between captive-bred and wild birds. They also revealed differences in growth patterns between body mass and bill length of Greek nestlings. We did not investigate the biological significance of these findings, nor did we differentiate between the sexes. Future research should concentrate on individual-specific logistic growth curves, allowing effects of nestling sex, parent size, brood size, hatching date and hatching order to be explored.

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SAMENVATTING

De groei van jonge Ooievaars *Ciconia ciconia* is tot nu toe alleen onderzocht aan de hand van vogels in gevangenschap. Deze studie in Noord-Griekenland gebruikte 192 metingen van 29 wilde kuikens om een logistische groeicurve van het gewicht en een lineaire groeicurve van de snavellengte te verkrijgen. De jongen bereikten hun maximale gewicht van gemiddeld 3 436 g na 45 dagen. De snavel bleef doorgroeien met een snelheid van 2.4 mm d^{-1} tot op de dag dat de waarnemingen werden gestopt (de jongen waren toen 51 dagen oud). In vergelijking met vogels in gevangenschap was het asymptotische gewicht van de wilde vogels iets hoger en lag de groeisnelheid wat lager, vermoedelijk als gevolg van verschillen in voedselaanbod en ouderzorg. Verschillen in groeisnelheid zijn onderhevig aan tal van factoren, zoals geslacht, ouderlijke kwaliteit, broedselgrootte, uitkomstdatum of volgorde binnen het nest. Deze factoren zijn echter niet bekeken. (RGB)

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