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AGE ESTIMATION AND GROWTH OF BLACK AND TURKEY VULTURES

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Abstract.—Relationships of growth to age are useful in studies of avian breeding behavior, mortality, and environmental adaptation. Accurate ages are difficult to obtain from repeated nest visits and can disrupt nesting. To develop predictive equations for estimating nestling age, we measured the weight, length of the flattened wing, and length of the fourth primary of known age nestlings. Growth rates of Black Vultures (*Coragyps atratus*) were less than growth rates of Turkey Vultures (*Cathartes aura*) and both species had low growth rates for semi-altricial raptors. Nestling age was best predicted by wing length. Eighteen wing measurements, not used in forming the equations, predicted age to within ±1.8 d. Black and Turkey vultures' sexual monomorphism and the priority given to wing growth over weight gain make these species well suited to aging from wing measurements.

ESTIMATIVOS DE LA EDAD Y EL CRECIMIENTO DE *CORAGYPS ATRATUS* Y *CATHARTES AURA*

Resumen.—El conocimiento de la relación entre el crecimiento y la edad en aves es util en estudios sobre su comportamiento reproductivo, mortalidad y adaptaciones ambientales. Determinación precisa de la edad es dificil de obtener mediante visitas periódicas a los nidos y además puede causar perturbaciones. Con el fin de desarrollar ecuaciones que permitan estimar la edad de los pichones, tomamos el peso de estos y medimos el largo del ala aplanada y de la cuarta primaria. La tasa de crecimiento de *Coragyps atratus* es menor que la de *Cathartes aura,* pero ambas tasas son bajas en comparación con las de otras aves rapaces seminidícolas. El mejor estimativo de la edad se logra a partir del largo del ala. Dieciocho medidas tomadas en las alas, las cuales no fueron consideradas en la formación de las ecuaciones, permitieron estimar la edad con una exactitud de 1.8 días. El monomorfismo sexual de estas dos especies estudiadas y la prioridad que estas dan al crecimiento del ala sobre el aumento del peso, son razones por las cuales a estas especies se les puede estimar la edad en base a medidas tomadas en el ala.

Quantitative data on growth is useful in studies of evolutionary adaptation and avian physiology (O'Connor 1977, Ricklefs 1984). Age-growth relationships are needed in behavior, mortality, and nesting phenology studies (Newton et al. 1983), and growth rates can be related to predation pressure, clutch size, and food supply (Lack 1968). Black Vultures (*Coragyps atratus*) and Turkey Vultures (*Cathartes aura*) are some of North America's largest avian scavengers, yet we know little about their growth.

Although nestling age or hatch date is an important variable, it is often difficult or undesirable to visit nest sites during hatching to determine exact times of hatch. Nest visits by researchers do not adversely affect all raptors (Gargett 1977, Luttich et al. 1971, Newton 1986), but adults of some species are sensitive to disturbance and will abandon their nests.

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Nestlings of other species are unable to withstand the stress of repeated human disturbance (Newton 1979). Additionally, frequent nest visits to determine exact hatch dates are time consuming. These problems can be avoided if nestling age is estimated from measurements taken at later stages of nestling development. Formulation of equations for age estimation requires initial intensive monitoring of nests and possible disturbance of birds during the late incubation and early nestling stages. Nevertheless, such equations can ultimately minimize effort and disturbance.

Age estimation equations have been developed for other raptors (Bortolotti 1984, Lyons and Mosher 1983, Petersen and Thompson 1977, Scharf and Balfour 1971) yet, as with most aspects of their biology, vulture growth-age relationships have been little studied. Our goal is to quantitatively describe the relationship between nestling age and changes in morphological parameters.

MATERIALS AND METHODS

The study area, described earlier (Coleman and Fraser 1987), is in southcentral Pennsylvania. During the spring of 1984, we visited Black and Turkey vulture nests three times a week to determine hatch dates. Nest visits were as brief as possible to minimize disturbance. After hatch we measured the developing young weekly. Although nestlings often regurgitated food during our visits, we observed them to reconsume the food; therefore, our effect on growth rates was probably minimal. We recorded weight (g), flattened wing length (mm), and fourth primary length (mm) for each of 10 Black Vulture and 4 Turkey Vulture nestlings (0–80 d old) from six Black Vulture and two Turkey Vulture nests (maximum of two young/nest). Prior to feather emergence we measured the wing from the wrist to the distal end of the phalanges; after feather emergence, at approximately 18 d of age, we measured from the wrist to the end of the longest primary. In analysis, we only used measurements from nestlings whose ages were known to the day and were apparently healthy. Because both species are sexually monomorphic (Fry 1983) and we were unable to distinguish the sexes, the sexes were not analyzed separately. Because age has little measurement error and ages sampled were non-random we regressed the morphological measurements on nestling age as recommended by Dapson (1980).

We used the Modified Gauss-Newton method (Hartley 1961, SAS 1979) to solve for t, K, and $asym.Y$ in order to fit the following logistic equation (Ricklefs 1967) to wing length and weight of known age nestlings.

$$Y = asym.Y/(1 + \exp(-K(AGE - \mathrm{t})))$$

where Y = wing length or weight at time of measurement; $asym.Y$ = theoretical asymptotic wing length or weight; K = a constant proportional to growth rate; AGE = the nestling's age at time of measurement; and t = age at the curve's inflection point (Ricklefs 1967). For comparison of growth rates (K) derived from the above logistic equation to growth rates derived by others from the Gompertz equation, we used a conversion factor of 0.68 (Ricklefs 1973). We found that the relationship between age and fourth primary length was best described by a linear as opposed to a logistic equation, based on comparisons of Coefficients of Simple Determination (r^2).

After equations were developed for each species with the morphological measurements as the dependent variable, we algebraically transformed the wing length and weight equations to predict age:

$$AGE = t - 1/K \times \ln((asym.Y/Y) - 1)$$

We similarly transformed the equation based on fourth primary length:

$$AGE = (Y - B0)/B1$$

where Y = fourth primary length; $B0$ = intercept of the line; and $B1$ = the slope of the line.

To determine the usefulness of the predictive equations based on the 3 morphological measurements we compared r^2 values, the width of the 95% Confidence Intervals around the predictive lines, and the accuracy of each equation's predictions. The 95% Confidence Intervals are most likely too narrow because successive measurements on individuals are not independent (White and Brisbin 1980). They are, however, still useful for comparisons between the three equations. Although our variance estimates for the equation's parameters may be too low, the curve fitting method used produces unbiased estimates of the parameters (White and Brisbin 1980).

Previously we had randomly selected and withheld 10 Black Vulture and 8 Turkey Vulture measurements when developing the predictive equations (Appendix 1). We used these measurements to test the accuracy of the equations.

RESULTS AND DISCUSSION

Nestling growth.—The growth curves (Table 1) all fit the morphological measurements well (all $r^2 > 0.82$; Table 2). Growth rates (K) of Black Vultures were less than those of Turkey Vultures (Table 2; Figs. 1, 2). Black and Turkey vultures had growth rates (K), based on the logistic equation fitted to weight, of 0.093 and 0.120, respectively. Ritter (1983) found similar rates ($K = 0.132$) for 3 Turkey Vulture nestlings in California. These rates are lower than those of other raptors of similar weight (Ricklefs 1973). They are, however, similar to those of storks (Ciconiidae) and also to altricial and semi-altricial sea-birds that raise only one young (Ricklefs 1973). Ricklefs (1968) suggested that for these birds, slow growth rates result from severe energy limitation. It may be, as has been suggested by McHargue (1981), that vultures, and in particular Black Vultures, limit growth because of unpredictable food resources. In a study of vulture foraging (Coleman and Fraser 1987) we found, as did Hatch (1970) and Yahner et al. (1986), that while vultures usually forage regularly, bad

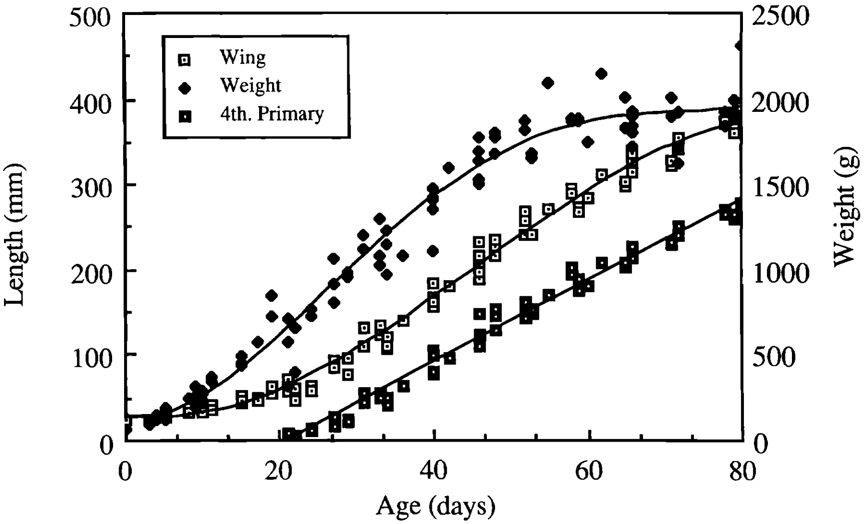

FIGURE 1. Growth curves based on wing length, fourth primary length, and weight of 10 Black Vulture nestlings. The data shown were used to calculate the curves.

weather can prevent daily feeding. Alternatively, slow growth could be due to a more precocial mode of development than would be expected of raptors. Nestlings hatch covered with thick down and brooding by adults stops within 5–7 d (Coles 1938, Davis 1983), suggesting early develop-

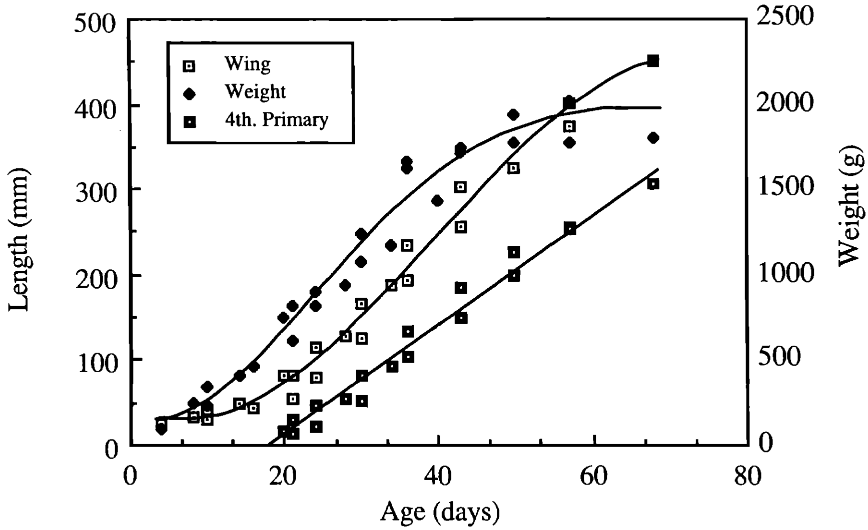

FIGURE 2. Growth curves based on wing length, fourth primary length, and weight of 4 Turkey Vulture nestlings. The data shown were used to calculate the curves.

TABLE 1. Growth equations used to estimate nestling age (d) from wing length (mm), fourth primary length (mm), and weight (g). Equations are based on measurements of 10 Black Vultures and 4 Turkey Vultures near Gettysburg, Pennsylvania, 1984.

	Equation
Black Vultures	
Wing length	Age = 45.84 − 14.74•ln((406.58/wing length) − 1)
Fourth primary length	Age = 21.89 + 0.20•(fourth primary length)
Weight	Age = 29.18 − 10.76•ln((1968.14/weight) − 1)
Turkey Vultures	
Wing length	Age = 38.96 − 11.43•ln((473.99/wing length) − 1)
Fourth primary length	Age = 18.56 + 0.15•(fourth primary length)
Weight	Age = 25.50 − 8.33•ln((1952.80/weight) − 1)

ment of homeothermy. The similarity of Black and Turkey vulture growth rates to those of the Ciconiidae is particularly interesting because of other strong evidence that the New World vultures are more closely related to this family than to any families in the order Falconiformes (Rea 1983).

Growth rates for our Black Vultures were approximately 15% less than, and our estimated asymptotic weight of 1968 g was approximately 15% more than, those of 2 Panamanian Black Vultures (McHargue 1981). This is curious in light of the general tendency of tropical species to have reduced growth rates (Ricklefs 1976). Turkey Vultures grew more rapidly than did Black Vultures for all of the characteristics measured. In our study area Black Vulture nestlings hatch approximately 4 wk before

TABLE 2. Fit of nestling morphometric data to growth curves. Wing length and weight were fit best by logistic curves. Fourth primary length was best described by a straight line. Data from 10 Black Vulture and 4 Turkey Vulture nestlings, southcentral Pennsylvania, 1984.

		Age range over which curve	Width of 95% CI			Difference between estimate and known age[a]		
	N	was fit	Min.	Max.	r^2	*N*	x̄ (SE)	K^b
Black Vultures								
Wing length	74	0–80	1.4	3.8	0.98	10	1.8 (0.3)	0.068
Fourth primary length	54	21–80	1.2	2.5	0.98	8	1.4 (0.5)	
Weight	83	0–80	2.7	5.8	0.93	9	5.4 (1.6)	0.093
Turkey Vultures								
Wing length	26	4–68	1.9	5.0	0.98	8	1.8 (0.6)	0.088
Fourth primary length	18	20–68	2.1	4.8	0.98	7	1.9 (0.5)	
Weight	26	4–68	5.8	16.9	0.82	7	4.3 (1.0)	0.120

[a] Data withheld from original calculations of growth curves.
[b] Growth rate (Ricklefs 1967) based on a fit to a logistic equation.

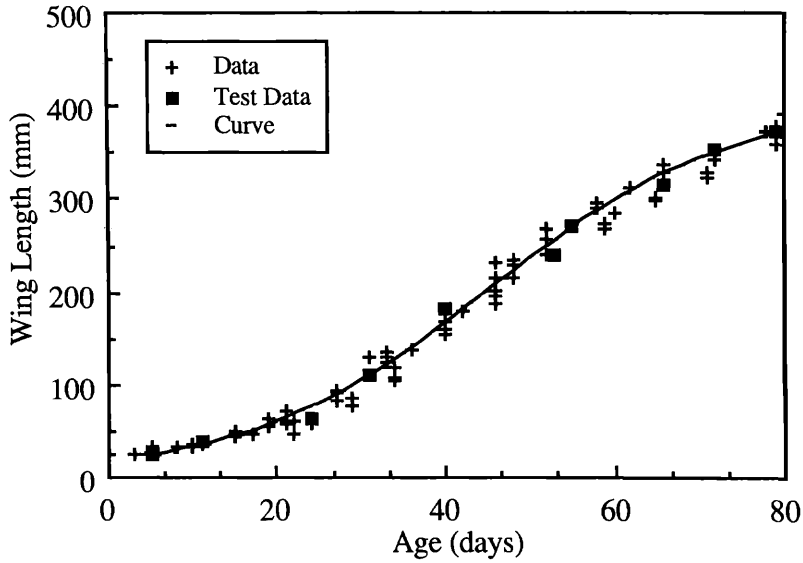

FIGURE 3. Curve generated by the predictive equation for estimating Black Vulture age from wing length, data used to form the equations, and 10 data points used to test the accuracy of the equation.

Turkey Vultures, while spring fogs are still common. Perhaps these hinder foraging and the low Black Vulture growth rates are in response to low early spring food availability. This is, however, just one of several possible explanations for the different growth rates.

Because Black and Turkey vulture primaries continue to grow after fledging, the estimated asymptotic wing lengths (406.58 and 473.99 mm, respectively) are low compared to known adult values (approximately 440 and 540 mm, respectively; Coleman 1985, Sweeney 1984). Estimated weight asymptotes (1968.14 and 1952.80 g, respectively) are also lower than known adult weights (approximately 2200 and 2100 g, respectively; Coleman 1985, Sweeney 1984).

Age prediction.—Of the variables measured, wing length was the best predictor of age. It could be measured at an earlier age than fourth primary length and it was less variable than weight (Table 2, Figs. 1, 2). The equations based on wing length and fourth primary length both had narrow 95% Confidence Intervals around mean estimates of age and gave good predictions of age but, unlike fourth primary length, wing length could be measured during the whole nestling period. As with other raptors (Bortolotti 1984, Newton 1979), weight fluctuated because of variation in the time since the last meal and was therefore a poor predictor of age. Weight estimates of crop contents can be made, but they tend to be subjective and were not used.

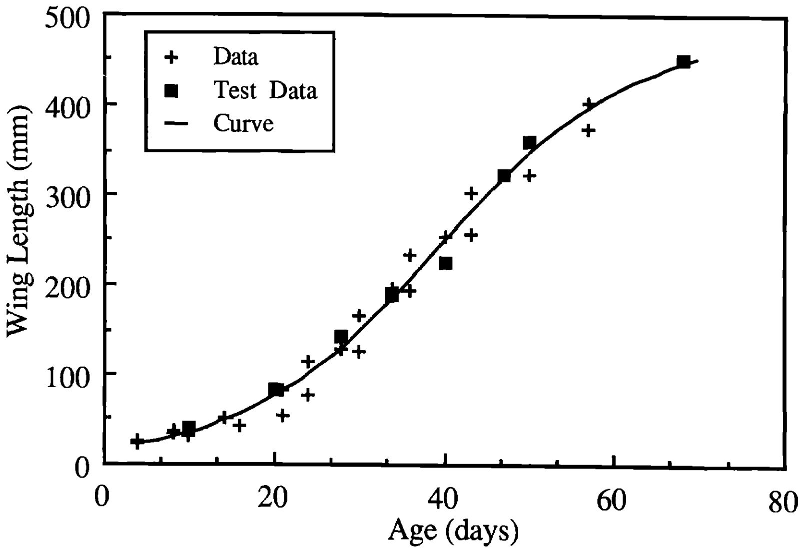

FIGURE 4. Curve generated by the predictive equation for estimating Turkey Vulture age from wing length, data used to form the equations, and 8 data points used to test the accuracy of the equation.

Unlike weight, wing length growth was apparently resistant to changes in food supply, and short term fluctuations were small. When one nestling was deprived of food for 2 wk due to temporary nest abandonment, its weight dropped to two thirds its previous level, yet wing and feather growth continued at apparently normal rates (Coleman 1985). Similarly, Newton (1986) and Houston (1976) found that in the Eurasian Sparrowhawk (*Accipiter nisus*) and several African vultures, feather growth took precedence over weight gain. In a study of Broad-winged Hawks (*Buteo platypterus*), Lyons and Mosher (1983) also found wing length to be the best predictor of nestling age.

The Black and Turkey vulture predictive equations based on wing length (Table 1), when tested using wing length measurements previously withheld, gave estimates within a mean of ±1.81 d and ±1.79 d of the known ages, respectively (Table 2; Figs. 3, 4). Age estimation with this degree of accuracy is probably sufficient for most uses.

Testing of the equations with additional data from birds not used in formulation of the equations is needed to confirm their rigor and suitability for Black and Turkey vultures in other regions. Data collected by others would be useful for strengthening the predictive accuracy of the equations presented here. Because of their sexual monomorphism and feather growth rate resistance to fluctuating food supply, vultures are well suited to this technique of age estimation.

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APPENDIX 1. Data used to form growth equations of nestling Black and Turkey vultures.

Nest	Sibling	Weight (g)	Wing length (mm)	Fourth pri. length (mm)	Age
Black Vultures					
22	A	75	25	—	0
22	A	195	32	—	5
22	A	375	40	—	11*
22	A	490	51	—	15
22	A	715	72	8	21
22	A	1065	94	28	27
22	A	1300	135	55	33
22	A	1470	182	98	40
22	A	1770	232	123	46
22	A	1815	258	160	52
22	A	1880	290	201	58
22	A	1930	337	227	66
22	A	1900	—	—	66
22	A	1920	354	245	72*
22	A	1925	374	264	78
22	B	170	28	—	5
22	B	335	36	—	11
22	B	450	45	—	15
22	B	612	62	5	21
22	B	910	90	26	27
22	B	1025	130	52	33
22	B	1105	182	103	40*
22	B	1700	216	147	46
22	B	1865	267	151	52
22	B	1872	295	194	58
22	B	1850	—	—	66
22	B	1805	329	222	66
22	B	1725	354	250	72
22	B	1850	372	270	78
27	A	125	24	—	3
27	A	240	34	—	8
30	A	125	—	—	5
30	A	215	—	—	9
30	A	290	34	—	10
30	A	575	47	—	17
30	A	725	57	11	24
30	A	950	77	21	29
30	A	1145	108	42	34
30	A	1405	156	77	40
30	A	1507	188	114	46
30	A	1650	240	147	53*
30	A	1875	268	176	59
30	A	2010	302	208	65
30	A	2015	328	233	71
30	A	1995	360	260	79
30	B	125	—	—	5
30	B	190	—	—	9
30	B	270	32	—	10
30	B	575	48	—	17
30	B	760	64	14	24*
30	B	980	86	25	29

APPENDIX 1. Continued.

Nest	Sibling	Weight (g)	Wing length (mm)	Fourth pri. length (mm)	Age
30	B	1235	106	47	34
30	B	1420	168	80	40
30	B	1635	202	121	46
30	B	1685	241	152	53
30	B	1880	274	189	59
30	B	1825	298	202	65
30	B	1905	322	230	71
30	B	1930	372	259	79*
31	A	100	25	—	3
31	A	140	26	—	5*
31	A	235	37	—	10
31	A	435	46	—	15
31	A	577	58	7	21
31	A	802	84	17	27
31	A	970	120	48	34
31	A	1350	160	79	40
31	A	1525	197	110	46
31	A	—	241	142	52
31	A	1745	285	180	60
31	A	1725	314	212	66*
31	A	1630	342	240	72
31	A	1880	378	266	79
40	A	230	33	—	10
40	A	651	60	6	22
40	A	1080	124	49	33
40	A	1080	139	64	36
40	A	1595	179	96	42
40	A	1780	215	128	48
40	A	2090	271	170	55*
40	A	2140	312	208	62
40	A	2305	392	278	80
40	B	217	34	—	10
40	B	402	47	—	22
41	A	145	—	—	4
41	A	310	—	—	9
41	A	850	63	—	19
41	A	1205	130	54	31
41	A	1800	234	152	48
41	B	120	—	—	4
41	B	257	—	—	9
41	B	720	55	—	19
41	B	1125	110	45	31*
41	B	1680	228	144	48
Turkey Vultures					
07	A	98	24	—	4
07	A	240	36	—	8
07	A	450	50	—	14
07	A	922	82	18	20*
07	A	1150	142	64	28*
07	A	1425	196	106	34
07	A	1735	255	148	40

APPENDIX 1. Continued.

Nest	Sibling	Weight (g)	Wing length (mm)	Fourth pri. length (mm)	Age
07	A	1645	324	199	47*
07	B	97	25	—	4
07	B	240	34	—	8
07	B	409	50	—	14
07	B	752	83	16	20
07	B	945	129	55	28
07	B	1170	188	92	34*
07	B	1440	227	131	40*
56	A	345	40	—	10*
56	A	825	83	29	21
56	A	903	114	46	24
56	A	1240	167	81	30
56	A	1625	235	133	36
56	A	1755	304	187	43
56	A	1775	360	226	50*
56	A	1770	402	264	57
56	A	1810	451	307	68*
56	B	233	31	—	10
56	B	464	44	—	16
56	B	610	55	13	21
56	B	820	78	23	24
56	B	1080	126	51	30
56	B	1665	195	103	36
56	B	1715	258	151	43
56	B	1945	324	200	50
56	B	2020	374	254	57
56	B	2250	452	300	68

* Measurements used to test the equations.