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GROWTH RATE OF THE BROWN NODDY ON THE DRY TORTUGAS

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INTRODUCTION

Growth rates within seabird species can vary with locality, season, and year (Nelson, 1970; Ricklefs, 1973). In studies of seabird biology, growth data can be used to lead to testable hypotheses concerning the relationship of development rate to genetics, physiology, and environmental conditions. For example, some studies suggest that growth rates are related to local food supply or to the distance adults travel to feeding areas (Ashmole and Ashmole, 1967; Lack, 1968; Nelson, 1970; Ashmole, 1971).

These matters are still poorly understood because the inaccessibility of most nesting seabirds and their long development periods have limited the number of growth studies. The logistical difficulties of determining seabird growth rates can be alleviated by constructing a composite growth curve for a population of young from measurements obtained in a few days (Ricklefs and White, 1975). A worker may then survey several colonies rapidly, or, because the composite curve portrays growth during a limited period, compare responses of one age class to different conditions within a breeding season.

Here, we apply the technique to Brown Noddy (*Anous stolidus*) data from Bush Key, Dry Tortugas, Florida in June 1972. The Brown Noddy has a pantropical distribution, making it a good subject for spatial as well as temporal comparisons. The colony on Bush Key consists of up to about 2,000 noddies nesting in bushes at the periphery of a larger colony of Sooty Terns (*Sterna fuscata*). Indeed our measurements of Brown Noddy nestlings were incidental to a study of the energetics of growth in the Sooty Terns (Ricklefs and White, Ms). The Bush Key terns have been described by Robertson (1964). The breeding biology of the Brown Noddy on Ascension Island has been described by Dorward and Ashmole (1962) and that of the smaller Black Noddy (*Anous tenuirostris*) by Ashmole (1962) and Cullen and Ashmole (1963). Watson (1908) and Bent (1921) give photographs of nests, eggs, nestlings, and adult noddies on the Dry Tortugas.

METHODS

On 5 June 1972, we banded, weighed, and measured 44 Brown Noddy nestlings. We measured 33 of the banded nestlings on 14 June, but the strong winds of approaching hurricane "Agnes" prevented our weighing them (White et al., 1976). On 30 June, William B. Robertson weighed 12 of the banded young. He also weighed and measured wing lengths of 3 more banded and 102 unbanded large chicks and fledglings on 1 to 5 July. Our measurements included wing length (wrist to wingtip flattened against a millimeter ruler), outer primary, longest scapular feather, and culmen. We also obtained body temperatures of 54 nestlings and 7 adults by inserting a thermistor probe (Yellow Springs Instruments) into the proventriculus.

RESULTS

The Composite Growth Curve

The composite growth curve is based on growth increments of appendages that are relatively insensitive to short-term nutritional deficiencies, making them reliable indices to age within a population. Wing and culmen lengths are most useful for this purpose.

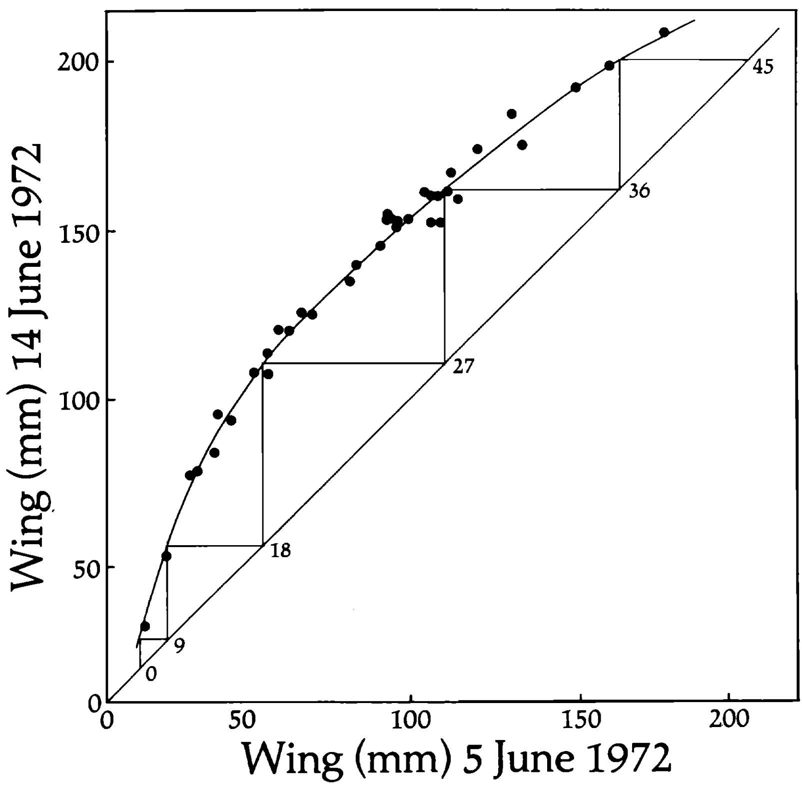

FIGURE 1. Relationship of wing lengths on 5 June and 14 June 1972 of 33 Brown Noddy nestlings on the Dry Tortugas, Florida. Three additional points comprising the greatest wing lengths were obtained at a later date (see text). Vertical and horizontal lines are used to derive an age-length relationship (see text).

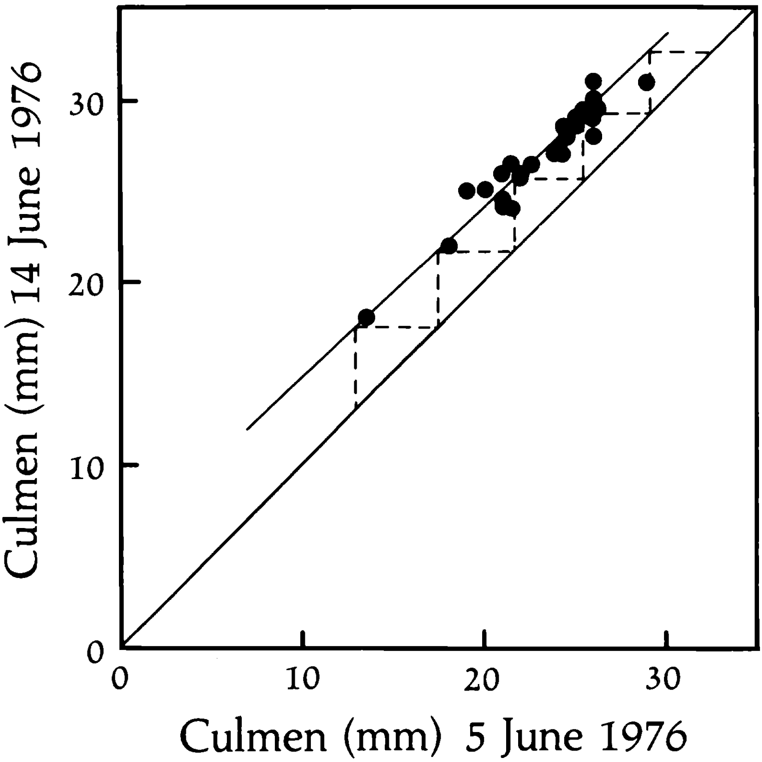

FIGURE 2. Relationship between Brown Noddy culmen lengths on 5 June and 14 June 1972. Data are treated as in Figure 1.

To construct the curve for noddy growth data, we first plotted each individual's wing and culmen lengths on 14 June as functions of their lengths on 5 June (Figs. 1 and 2). In addition to these 9-day increments, we estimated 3 increments for larger birds measured on 14 June and again in early July. The wing length of one was 102 mm on 14 June and 194 mm 17 days later on 1 July. From Figure 1, we would have expected the wing to increase to 159 mm in 9 days; therefore, we estimated the increase during the last 8 days of the 17-day interval to be 194 − 159 = 35 mm. Because this increment is equivalent to one of 39 mm (35 × 9/8) during a 9-day interval, we plotted 159 mm and 198 mm (159 + 39 mm). Similar calculations for two other chicks, remeasured on 1 July and 5 July, indicated increments of 149 to 192 mm and 175 to 208 mm for 9-day intervals.

To determine appendage lengths at successive 9-day intervals, we drew a curve through the plotted measurements, and alternated vertical and horizontal lines between this curve and the diagonal representing zero growth (Figs. 1 and 2). Because the wing grows slowly at first, we

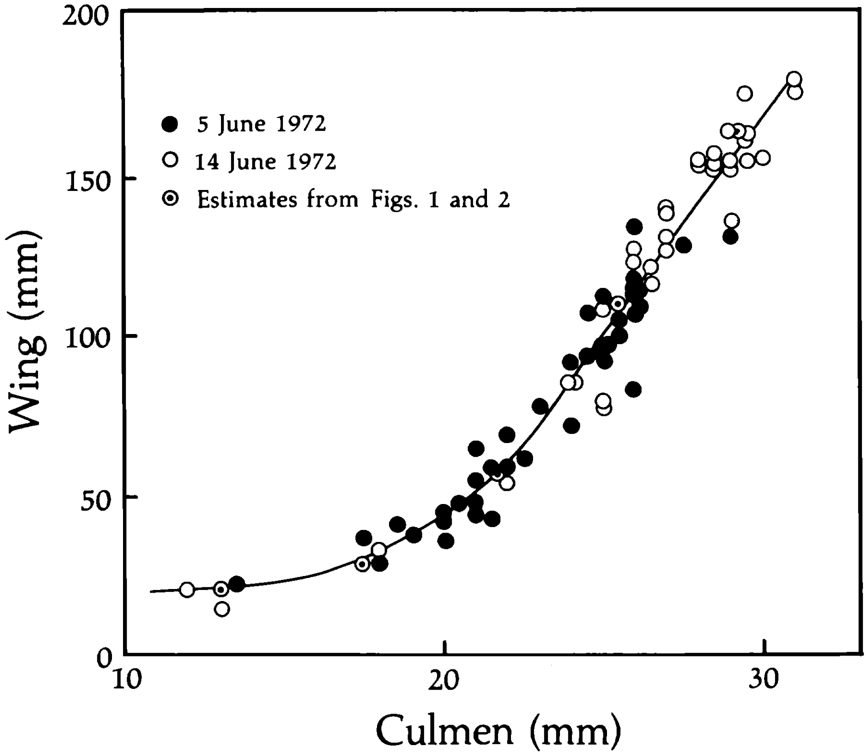

FIGURE 3. Relationship between wing and culmen lengths in Brown Noddy nestlings. The circled dots are transcribed from Figures 1 and 2 for ages 0, 9, 18, 27, 36, and 45 days. The solid line was fitted by eye.

based the early part of the age scale on increments of culmen length (Fig. 2). The three smallest nestlings we found, one of which was newly hatched, had culmens 12, 13, and 13.5 mm in length. Therefore, we chose 13 mm to represent the culmen length of a newly hatched nestling. From that point, culmen lengths at successive 9-day intervals were 17.5 mm (9 days), 21.5 (18), 25.5 (27), 29 (36), and 32.5 (45). From the relationship between culmen and wing length (Fig. 3), we estimated the wing length at 27 days to be 56 mm. Starting the step curve from this point (Fig. 1), wing lengths were 20 mm at hatching (0 days), 28 (9), 56 (28), 109 (27), 162 (36), and 200 (45). Drawing a smoothed curve through these points (Fig. 4), we obtained the age-wing length relationship given in Table 1.

Growth in Body Weight

From the relationship in Table 1, we converted the relationship between weight and wing length (Fig. 5) to a growth curve of body weight

TABLE 1.
Relationship between age and the lengths (in mm) of the culmen and wing used as aging criteria for the Brown Noddy.

	Age (days)									
	0	1	2	3	4	5	6	7	8	9
Culmen										
0–9 days	13	13.5	14	14.5	15	15.5	16	16.5	17	17.5
Wing										
0–9 days	20	20	21	21	22	23	23	24	26	28
10–19 days	30	32	34	37	40	43	47	51	55	59
20–29 days	63	70	76	82	89	95	102	108	114	120
30–39 days	126	132	138	144	150	156	162	167	171	176
40–45 days	180	184	188	192	196	200	—	—	—	—

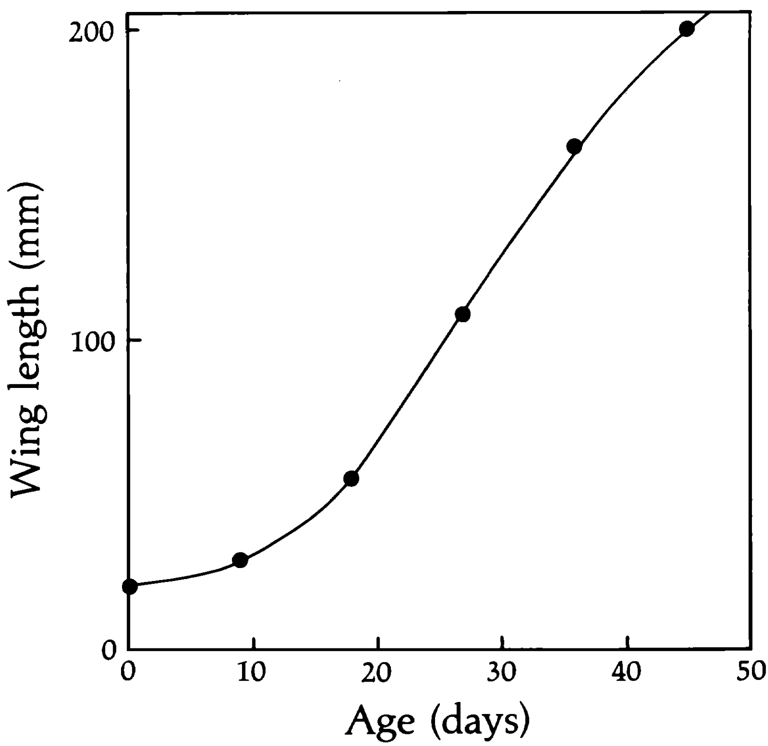

FIGURE 4. Relationship between wing length and age derived from Figure 1. The curve, drawn by eye through six points representing intervals of 9 days, was used as the aging criterion for Brown Noddy young.

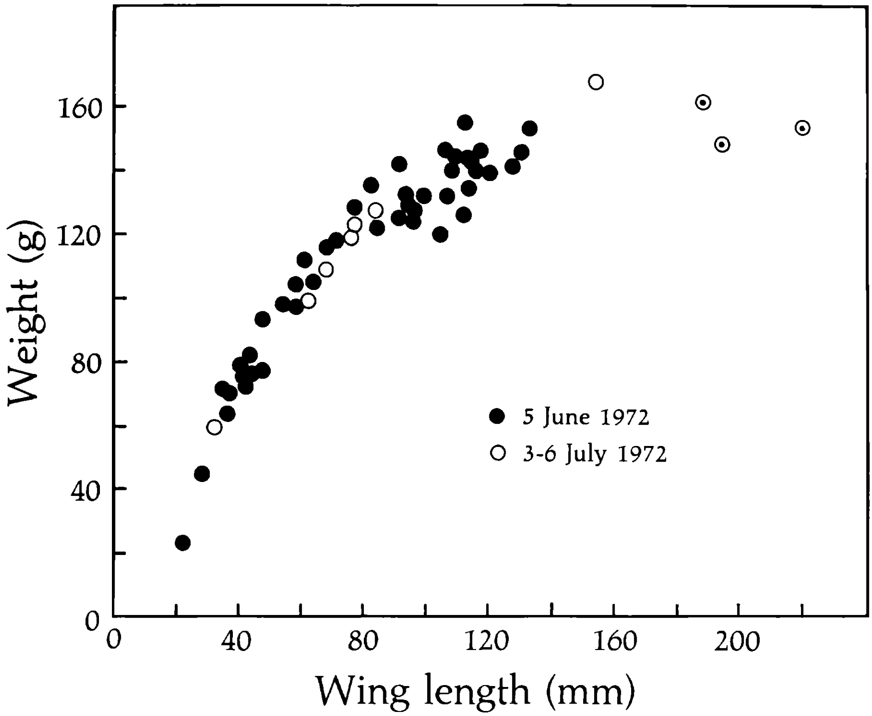

FIGURE 5. Relationship between weight and wing length of Brown Noddy nestlings on the Dry Tortugas, 5 June and 3–6 July 1972. Open circles with dots indicate young banded on 5 June, and reweighed 3–6 July.

TABLE 2.
Weights of Brown Noddy chicks and fledglings, 3–6 July 1976.[1]

	Wing length class (mm)						
Weights (g)	200–209	210–219	220–229	230–239	240–249	250–259	260–269
Nestlings							
n	3	4	9	11	8	1	
mean	160	157	160	162	164	176	
range	154–167	146–165	153–173	153–173	155–176	—	
Flying young							
n		2	4	22	21	4	1
mean		167	152	167	165	167	181
range		166–167	142–162	134–179	149–193	155–177	—

[1] Data supplied by W. B. Robertson, Jr.

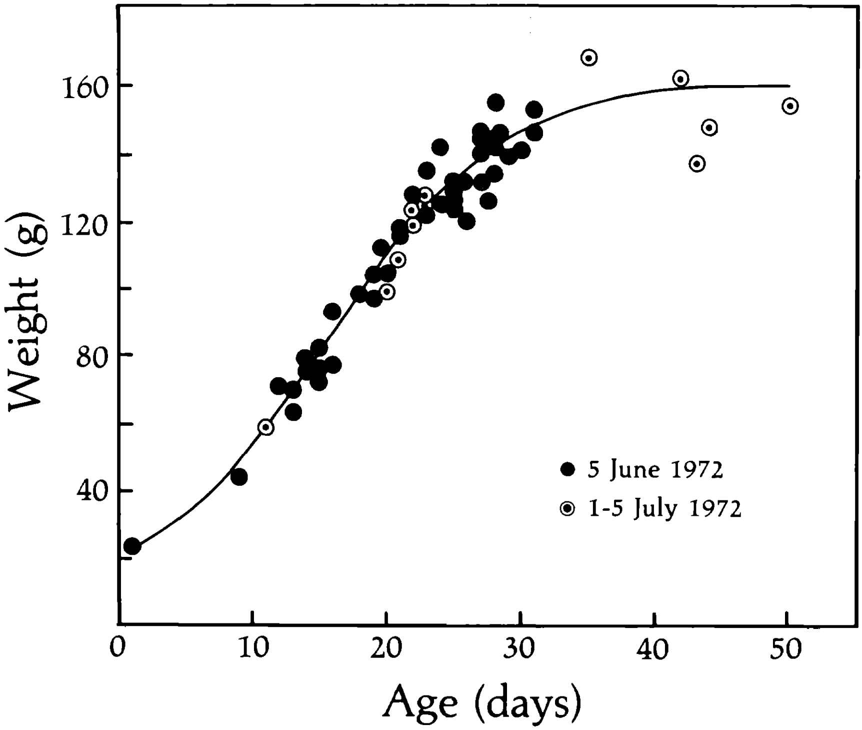

FIGURE 6. Relationship between weight and estimated age for Brown Noddy nestlings on the Dry Tortugas, 5 June and 3–6 July 1972. The curve was drawn by eye.

(Fig. 6). Although we have few data for nestlings aged less than 10 and more than 30 days, the growth curve appears sigmoid (as found in other tern species) and levels off between 150 and 170 grams. The average weight of 5 adult noddies weighed on 3 to 6 July was 159.2 g (153–170 g) and their average wing length was 266.4 mm (256–275 mm). Weights of large nestlings and recently fledged noddies also suggest a weight plateau of about 160 g (Table 2).

We used the graphical method described by Ricklefs (1967) to fit a growth equation to the smoothed growth curve (Fig. 6). In this case, the best fit was obtained with the logistic equation,

$$W(t) = \frac{A}{1 + \exp[-K(t - t_i)]}$$

where $W(t)$ is the weight at age t, A is the asymptote, K is a growth rate constant, and t_i is the age at the inflection point ($A/2$) of the growth curve. Values for the fitted equation were $A = 160$ g, $t_i = 14.0$ days, and $K = 0.153$. Growth constants for Brown Noddies on Kure Atoll, the westernmost of the Hawaiian chain (R. R. Fleet, unpubl.), were $A =$

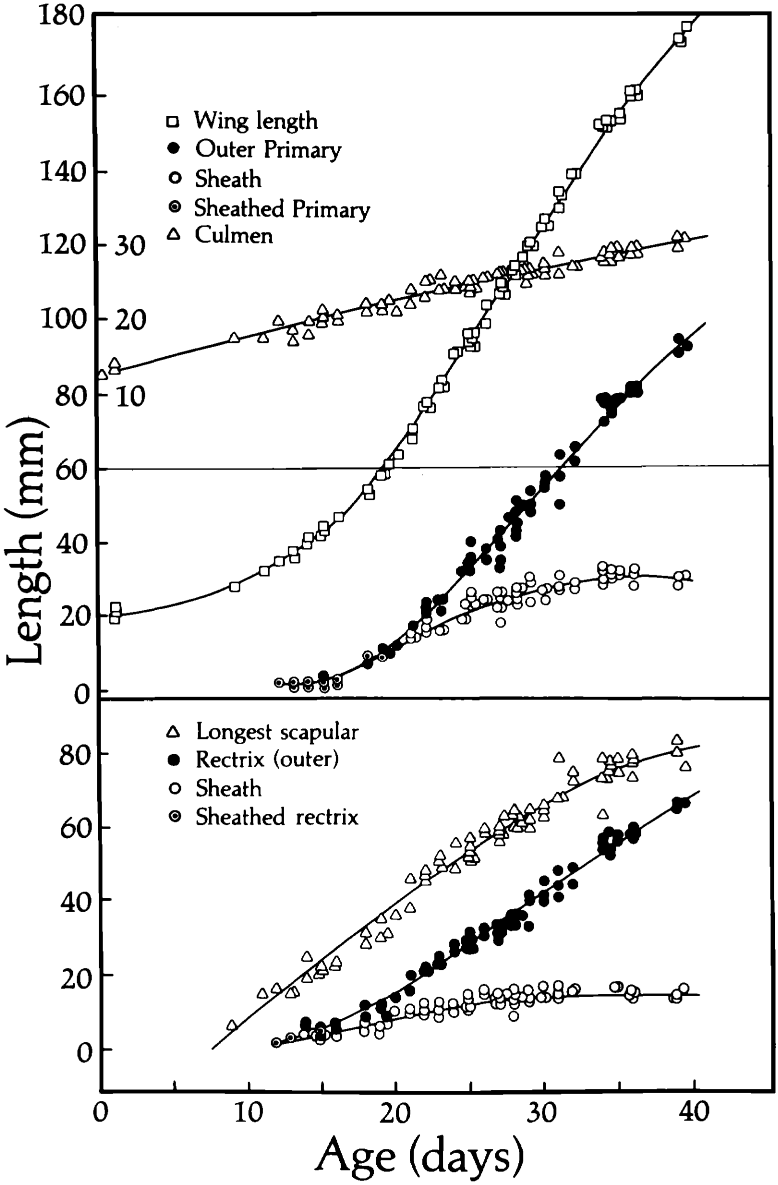

FIGURE 7. Brown Noddy wing, culmen, outer primary (and sheath), outer rectrix (and sheath), and longest scapular feather lengths as functions of age.

190 g, $t_i = 12.0$ days, and $K = 0.151$. On Manana Island, Hawaii (Brown, 1976), they were $A = 175$ g, $t_i = 13.8$ days, and $K = 0.134$.

Linear Measurements

Most linear measurements were still increasing at fledging (Fig. 7). The culmen grew continuously, but at a decreasing rate, through the nestling period (also see Fig. 2) and attained a length of about 30 mm at 40 days. This is considerably less than the adult culmen lengths given by Ridgway (1919), and of five museum specimens at the University of South Florida (USF) (range 40–45 mm). The scapular feathers were among the first to appear, at about 8 days, increasing to 80 mm by 40 days. They are well placed to help shield the body from sun and rain. The outer primary and outer rectrix emerged from the skin at about 15 and 12 days, respectively, and erupted from their sheaths within a few days. The outer primary grew more rapidly than the rectrix (4.0 mm and 2.7 mm per day, respectively). The sheathed portion of the feather shaft did not exceed an average of 15 mm of the rectrix and 30 mm of the outer primary. In both, the sheathed portion of the feather was protected by down or by developing coverts. The average lengths of outer primaries and outer rectrices of the USF adult specimens were 185 mm and 101 mm, respectively.

Body Temperature

On the warm, sunny afternoon of 5 June, between 1400 and 1640, body temperatures increased with age from 39 to 40°C for 10-day-old nestlings to 41 to 42°C for 20 to 30 day-old nestlings (Fig. 8). Body temperatures at 1600 on the cooler, overcast afternoon of 12 June were about 1°C lower. Only two nestlings, with body temperatures of 41.7 and 42.3°C, were observed to pant. Noddy nestlings apparently are seldom heat stressed. Nests are above the ground and often are shaded by vegetation.

Nestlings had lower body temperatures at night. Most measurements, after 2230 on 5 June, were 30 to 40°C. At the same time, body temperatures of four adults, some incubating or brooding small nestlings, were 37 to 41°C. Two incubating individuals had temperatures of 39.8 and 40.0°C. Another adult, with a temperature of 38.3°C, fell to the ground and did not fly when released. This behavior and the mild hypothermia we observed suggest a reduced state of arousal, and possibly of metabolism, at night, in contrast to the nocturnally active Sooty Tern.

DISCUSSION

Our estimate of the growth rate (K) of the Brown Noddy in Florida is nearly identical to that of noddies on Kure Atoll, and about 10 percent more rapid than on Manana Island. The Florida birds were lighter at fledging than at the other localities, but this may vary from one year to another. Our estimated age at fledging (about 40 days) was close to that

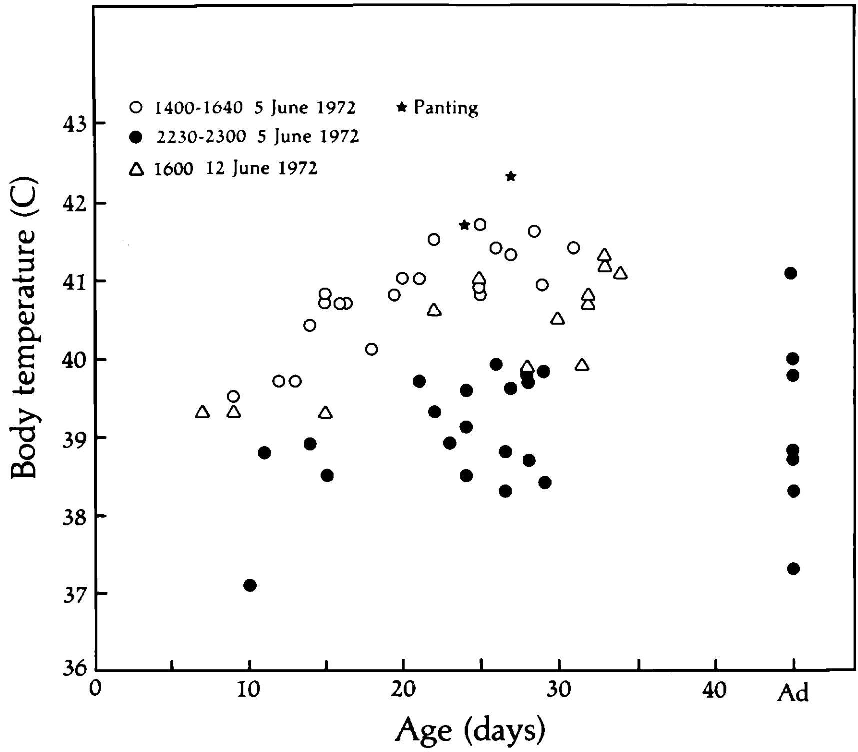

FIGURE 8. Relationship of body temperature to age in Brown Noddy nestlings during the day (open symbols) and night (solid symbols). Body temperatures of adults are shown at the right-hand side of the graph.

reported by Brown (1976) (42.5 days) and by Dorward and Ashmole (1963) (42 days).

Because we constructed the age scale from increments of growth in wing and culmen lengths, and because variations among individuals in measured characters tend to be correlated, the technique obliterates most variation and tends to smooth the growth curve. Comparisons of population variability between locations or seasons could be made from the increments themselves, however.

The growth curve we calculated was based primarily on three hours of field work on two days separated by eight days, yet our results were comparable to those of other studies. For best success, our method requires that the study be timed when young from hatching to fledging are evenly represented. In this study, we found young noddies with wing lengths of 21.5 to 133 mm (1 to 31 days old), or ¾ of the total nestling period, on the first visit to the colony. The older young were nearly ready to fly by the second visit. Had our study been a week earlier, we would have been unable to comment on the latter part of the growth curve. On 5 July, one month after our initial visit, the smallest noddy that Robertson measured had a wing length of 32 mm (11 days). Thus a full range of nestlings was present only between 16 and 26 June in 1972 and our study was fortuitously timed.

SUMMARY

We weighed and measured Noddy Tern chicks on Bush Key, Dry Tortugas, Florida, on 5 June and 14 June 1972. We used growth increments to calculate a composite wing length growth curve from which we estimated the ages of chicks. We then fitted a logistic curve to describe the relationship between weight and age. Growth constants of the fitted equation (growth rate $K = 0.153$, asymptote $A = 160$ grams, and age at inflection $t_i = 14.0$ days) were similar to values reported for the Brown Noddy on Kure Island and Manana Island, Hawaii. Also reported are outer primary and rectrix lengths and body temperatures of nestlings and adults.

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