Egg specific gravity and incubation in the Sooty Tern and Brown Noddy.—Flotation characteristics of birds' eggs are commonly used to estimate their age. Schreiber (1970) and Hays and LeCroy (1971) have recently attempted to quantify the relationship between the appearance (degree of emergence and position) of larid eggs placed in water and the age of the eggs. Westerskov (1950) has claimed that these flotation characteristics more precisely estimate the age of eggs than specific gravity. Changes in how eggs float in water depend upon changes in the specific gravity of the eggs, however, and the latter is more simple and general than an index based upon these flotation characteristics. Flotation characteristics are preferable only if they more accurately indicate changes in egg specific gravity than direct measurement of specific gravity under field conditions, or if information on the relative densities of different parts of an egg is needed to estimate age accurately. Statistical comparisons of the methods of aging eggs are necessary to resolve these problems. This paper presents data relating specific gravity and the incubation stage of the eggs of two tropical terns, including the parametric statistics of variation.

This study was conducted on Manana or Rabbit Island, off Oahu, Hawaii. Approximately 100,000 Sooty Terns, *Sterna fuscata*, and 30,000 Brown Noddies, *Anous stolidus*, nest on the island, females of each species laying a single egg per clutch (Brown 1973). In 1972, I delimited a 12 × 12 foot quadrat within the Sooty Tern colony and two 20 × 20 foot quadrats within the Brown Noddy colony. I checked each quadrat daily from before the first egg was laid until the last chick had fledged. I numbered new eggs and marked the nests either by placing a numbered rock next to the eggs or by painting a number directly upon the substrate. I measured the length and width of the eggs using vernier calipers accurate to 0.1 mm. Next I weighed the eggs in air, then in water, using a home-made Jolly balance. The Jolly balance is commonly used by geologists to determine the specific gravity of minerals, and was used by Carr (1939) to measure the freshness of hens' eggs. The difference between the weight of an egg in the air and the weight in the

TABLE 1

EGG DIMENSIONS OF SOOTY TERNS AND BROWN NODDIES ON MANANA ISLAND[1]

		Mean	Sample size	SD	Range
Length (cm)	Sooty	5.10	175	2.3	4.4–5.9
	Noddy	5.28	129	2.2	4.9–5.9
Width (cm)	Sooty	3.59	175	1.1	3.2–4.0
	Noddy	3.60	129	0.97	3.5–3.8
Weight (g)	Sooty	34.2	33	2.6	28.5–39.0
	Noddy	36.3	68	2.5	30.5–41.5
Volume (ml)	Sooty	32.1	33	2.2	27.5–36.5
	Noddy	34.1	69	0.58	26.5–39.0
K	Sooty	0.509	31	0.013	0.48–0.53
	Noddy	0.504	68	0.013	0.48–0.55

[1] Comparable data are available for the Sooty Tern and Brown Noddy on Ascension Island in the South Atlantic (Stonehouse 1963), although the volumes were calculated from length and width, and weighings were not made of fresh eggs exclusively.

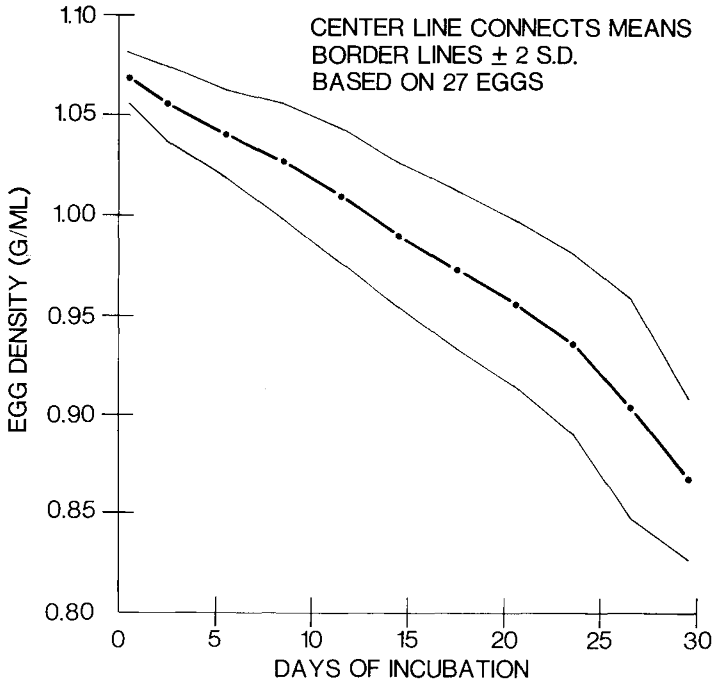

Fig. 1. Egg density or specific gravity, and the number of days of incubation of Sooty Tern eggs. The density of each of 27 eggs was determined at each age through 23.5 days. At 26.5 days 26 eggs remained unhatched and were weighed, whereas only 4 eggs remained unhatched to be weighed at 29.5 days.

water is equal to the weight of the water displaced by the egg (Archimedes' principle). The weight of the water displaced in grams is equal to the volume of the egg in milliliters. Barth (1953), Evans (1969), and others have used this principle to determine the specific gravity of birds' eggs.

Every third day I weighed each egg in the quadrats. Length, width, weight, and volume of the freshly laid Sooty Tern and Brown Noddy eggs are given in Table 1. The value K was calculated for each egg, where $K = \text{volume}/(\text{length})\ (\text{width})^2$.

The Brown Noddy eggs on Manana were about 2 g heavier than the Sooty Tern eggs ($t = 3.87$, $P < 0.001$), and 0.19 cm longer ($t = 2.21$, $P < 0.05$), although there was no significant difference in the widths of the two kinds of eggs.

I was able to calculate the specific gravities of the eggs when they were first laid, and to recalculate the specific gravities for subsequent weighings. All the eggs were approximately 0.5 days old when first weighed. Some were 1.5, some 2.5, and some 3.5 days old on the second weighing, and these were combined into a 2.5 day age class. Age classes of 5.5 days, 8.5 days, etc., were formed similarly. The egg densities in g/ml (specific gravities) of these Sooty Tern and Brown Noddy eggs are plotted against age in Figs. 1 and 2 respectively. The specific gravities of both kinds of eggs decreased at constant rates until the eggs were first cracked by the chicks, this resulting in a greater rate of weight loss. Barth (1953) obtained similar results for

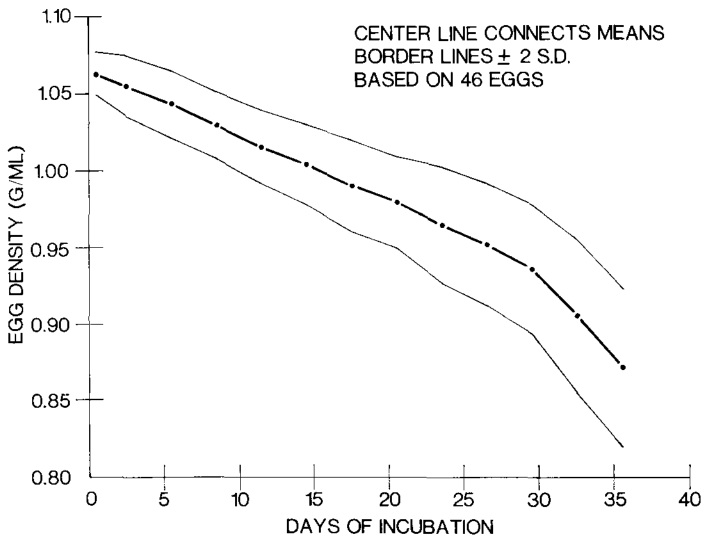

Fig. 2. Egg density or specific gravity, and the number of days of incubation of Brown Noddy eggs. The density of each of 46 eggs was determined at each age except 35.5 days, when 21 eggs remained unhatched and were weighed.

eggs of the Mew Gull, *Larus canus.* The Sooty Tern eggs lost an average of 0.19 g/day before cracking, whereas the Brown Noddy eggs lost 0.15 g/day ($t = 6.13$, $P < 0.01$). The Sooty Tern and Brown Noddy incubation periods on Manana are 28.6 and 36.0 days respectively (Brown 1973). Multiplying these figures by those for daily weight loss before cracking gives 5.4 g weight loss over incubation for each species. This is a weight loss during incubation of approximately 16% for the Sooty Tern eggs and 15% for the Brown Noddy eggs. If the higher rate of weight loss after cracking were incorporated into these calculations, then the percentages would be slightly higher. This, however, would reflect primarily an increased rate of evaporative water loss.

Figs. 1 and 2 should be useful both for estimating the age of any particular Sooty Tern or Brown Noddy egg and for studying the temporal distribution of laying within hard-to-reach colonies of each species. Measurements of length and width may be used to estimate egg volume according to the formula volume = K (length) $(\text{width})^2$. Use of the Jolly balance is preferable where time and circumstance permit, but one standard deviation of K for each species is only about 2.6% of the mean, therefore the formula accurately estimates egg volume in these species when the values of K given in Table 1 are used. Indeed, studies by Stonehouse (1963) and McNicholl (1973) indicate that a K of 0.51 may be accurate for eggs of many species of birds.

This paper is based upon a dissertation the author submitted to the University of Hawaii in partial fulfillment of the requirements for the Ph.D. degree in zoology.

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Body-bobbing woodcocks.—On 20 November 1974 a solitary American Woodcock (*Philohela minor*) spent the day on the lawn outside my dining room window in Eldora, Cape May County, New Jersey. It fed much of the time. When resting it remained perfectly still, but while walking or probing it constantly rocked its body in a pumping manner. This movement was confined to the antero-posterior plane, with no lateral displacement, and consisted of an oscillation between an elevated rear extreme and a depressed forward one when the bird's body nearly grazed the ground. The rate was 90 cycles per min. A striking part of the antic was that only the body took part—through binoculars I could see that the head and feet acted as if they were divorced from the large intermediate undulating mass. Thus the bird's stance as well as its field of vision remained fixed while the swaying continued.

The woodcock looked somewhat like one of the large dead leaves that had fallen from a nearby catalpa tree (*Catalpa bignonioides*), especially when an occasional breeze caused them to stir. But when the breeze was not blowing, the woodcock's movements made it conspicuous. Conversely, when the bird rested in immobility during the passage of a breeze, it stood out as a rock among adjacent shifting objects.

Pettingill (1936, Mem. Boston Soc. Nat. Hist. 9) describes bobbing in the woodcock exactly as I saw it (pp. 268–269), though he does not mention bobbing while feeding. He reviews reports in the literature that ascribe bobbing, accompanied by foot-stamping and other strenuous physical acts, to attempts to lure earthworms out of their burrows. But he comments that such tactics are (1) unnecessary, as the bird's bill is an efficient extractor, and (2) unlikely, as they imply too much sagacity and foreknowledge of earthworm behavior. He concludes: "I believe that bobbing is a nervous reaction resulting from fear or suspicion. I have observed it particularly