Wilson Bull., 92(1), 1980, pp. 103–107

GENERAL NOTES

The determination of runt eggs in birds.—Abnormally small eggs occur uniformly rarely in a wide variety of birds (Koenig, in press). However, in at least 1 species, the Acorn Woodpecker (*Melanerpes formicivorus*), the frequency of runt eggs (4.3%) is significantly higher than in other species for which an adequate sample is available (Koenig, op. cit.). Although the reason for this high incidence is unknown, it indicates that significant differences in the frequency of egg dwarfism do exist. Such differences may provide clues about the ecology of the species involved. It is therefore desirable to have an objective set of criteria defining "runt" eggs.

Runt eggs frequently lack a yolk or the normal complement of embryonic membranes (Pearl and Curtis, J. Agric. Res. 6:977–1042, 1916). Nonetheless, internal distinctions between normal and runt eggs are not consistent (Pearl and Curtis 1916), nor do there appear to be electrophoretic differences in the albumins of runt eggs (Baker, Br. Egg Marketing Board Symp. 4:67–108, 1968). Thus, runts must be operationally defined as eggs which are "abnormally" small and which do not hatch because of some internal abnormality. To consistently identify runt eggs, cutoff values based on egg size must be determined.

To test possible criteria I measured maximum length and width of 756 Acorn Woodpecker eggs from 158 sets. Forty-three of these sets were measured in the field at Hastings Reservation, Monterey Co., California. The remainder were from museum collections. In addition, 311 Red-headed Woodpecker (*Melanerpes erythrocephalus*) and 286 Lewis' Woodpecker (*M. lewis*) eggs were measured to provide comparisons with the *M. formicivorus* data.

I compared 2 sets of criteria. The first was based on absolute size. The volume (length × width^2 × $\pi/6$) for each of the 756 Acorn Woodpecker eggs was calculated; these data are combined into 0.33-cc intervals in Fig. 1a. Analogous data for 311 Red-headed Woodpecker eggs, which average slightly smaller than Acorn Woodpecker eggs, are presented in Fig. 1b. A comparison of these 2 histograms clearly shows the relatively large number of unusually small eggs in the Acorn Woodpecker sample; these eggs also result in a significant skewness

TABLE 1

MEASUREMENTS OF ACORN WOODPECKER EGGS

	Mean	SD	Skewness[1]	Kurtosis[1]	K-S D[2]
A. All eggs (N = 756)					
Length (mm)	25.2	±2.00	−1.56[3]	5.26[3]	0.186[3]
Width (mm)	19.2	±1.16	−1.87[3]	6.70[3]	0.245[3]
Volume (cc)	4.91	±0.82	−1.29[3]	3.25[3]	0.089[3]
B. Excluding runts (N = 718)					
Length (mm)	25.5	±1.42	0.04	−0.15	0.159[3]
Width (mm)	19.4	±0.82	−0.21[4]	0.00	0.233[3]
Volume (cc)	5.04	±0.60	0.02	0.14	0.020

[1] Tested for significant departure from 0 (Sokal and Rohlf, Biometry, W. H. Freeman, ed., San Francisco, California 1969).

[2] Kolmogorov-Smirnov test for normality (Siegel, Nonparametric Statistics for the Behavioral Sciences, McGraw-Hill, New York 1956).

[3] $P < 0.001$.

[4] $P < 0.05$.

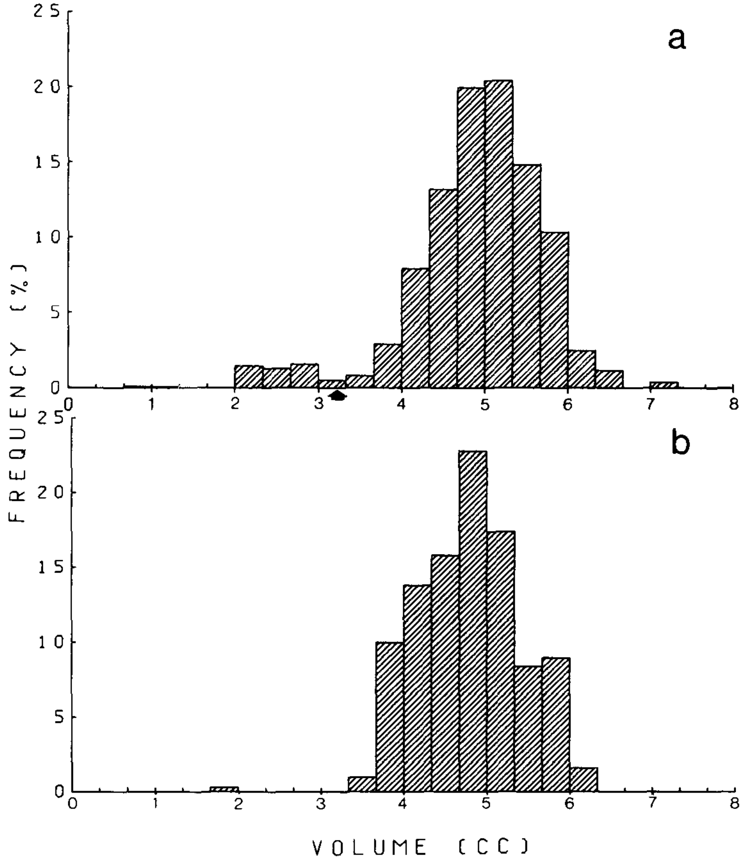

FIG. 1. Frequency distribution of the volume of Acorn Woodpecker eggs (a, N = 756) and Red-headed Woodpecker eggs (b, N = 311). The arrow in a. at 3.20 cc indicates an arbitrary cutoff between normal and runt eggs (see text).

and leptokurtosis in the distribution of egg volumes (Table 1). Comparison also suggests that a cutoff between normal and abnormally small eggs for these species might reasonably be made near the upper end of the 3.00- to 3.33-cc interval, below which only 1 clearly runt Red-headed Woodpecker egg was found. I arbitrarily chose 3.20 cc as the dividing line between the 2 parts of the histogram in Fig. 1a.

A graph of length vs width of Acorn Woodpecker eggs is presented in Fig. 2. The solid line is the isocline separating eggs with volumes greater and smaller than 3.20 cc. Also indicated are 5 eggs whose sizes are near this line and whose subsequent fates are known. Of the 3 above the line, 2 hatched; the volumes of these eggs were 3.87 and 3.56 cc. The 3 eggs which did not hatch had volumes of 3.56, 3.12 and 3.07 cc. Given that runt eggs do not hatch, a cutoff size should be smaller than 3.56 cc and probably near 3.12 cc. The value 3.20 cc provides a cutoff consistent with the division in Fig. 1a, above. A comparable cutoff

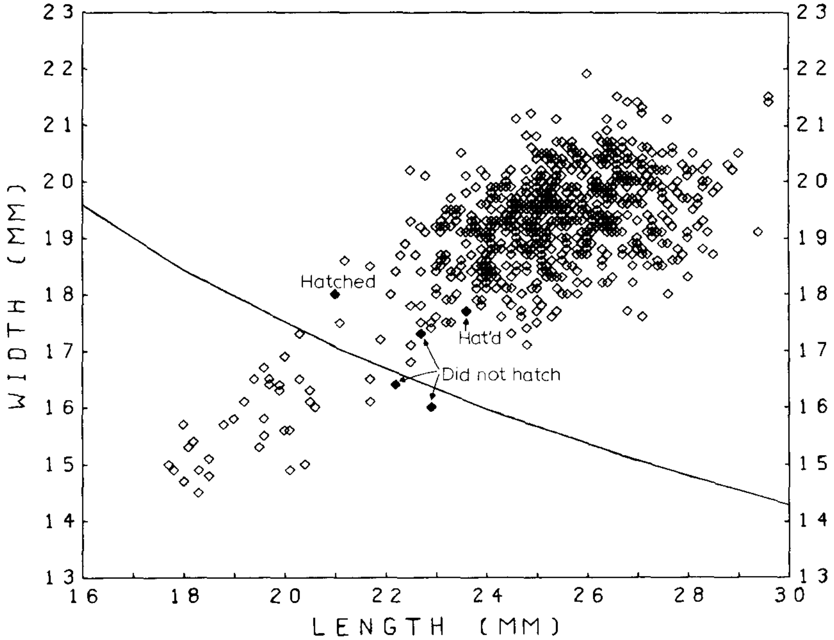

FIG. 2. Scattergram of length vs width of Acorn Woodpecker eggs. The solid line divides eggs whose volumes are smaller than 3.20 cc from those whose volumes are larger. Five eggs with volumes near 3.20 cc whose fates are known are indicated.

value based on absolute size could be determined for any particular species given enough data and a similar series of time consuming analyses.

A second possible set of criteria is based on the relative volume of possible runt eggs compared to others in the same clutch. The method has the advantage of focusing on eggs laid by a small number (usually 1) of females rather than the entire population. To test its viability, the volume of the smallest egg in each of 158 sets of Acorn Woodpecker eggs was divided by the average volume of all remaining eggs in the set to arrive at the relative volume of the smallest egg in each set. The distribution of the resulting values is strikingly bimodal (Fig. 3). (The secondary peak is much larger here than in Fig. 1a because the proportion of sets with a runt is much higher than the percent of runt eggs.)

The division between the 2 principal peaks of the histogram in Fig. 3 lies at about 75%. Two independent lines of evidence suggest that this value may provide a useful criterion for defining runt eggs. First, eggs considered to be runts which are illustrated, or for which weights are given in the literature, vary between 10% and 71.4% of the average volume of the other eggs in their clutch (Ingersoll, Condor 12:15–17, 1910; Kendeigh et al., Auk 73:42–65, 1956; Manning and Carter, Wilson Bull. 89:469, 1977). Second, the relative volumes of the smallest egg in 47 Lewis' Woodpecker and 65 Red-headed Woodpecker sets ranged between 99.2% and 77.2%, except for a 40.3% value for the 1 Red-headed Woodpecker runt egg measured.

By excluding eggs smaller than the 75% relative volume cutoff, the average volume of all

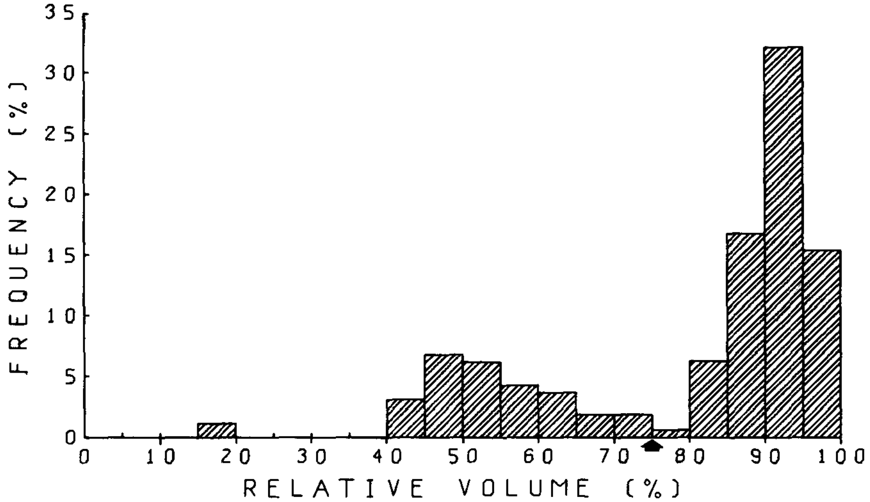

FIG. 3. Frequency distribution of the relative volume of the smallest egg compared to the average of the remaining eggs in 158 Acorn Woodpecker sets. The arrow at 75% indicates an arbitrary cutoff between normal and possibly runt eggs (see text).

Acorn Woodpecker eggs is changed from 4.91 ± 0.82 cc to 5.05 ± 0.60 cc (Table 1). The absolute size cutoff of 3.20 cc arrived at above is then slightly over 3.10 SD below the mean (this is a convenient value because in a normal curve, 0.1% of the values fall $\geq$ 3.10 SD below the mean).

A comparison between these 2 criteria for defining runt eggs suggests that the first, based on absolute size, is more conservative. In 37 of the 158 sets, the volume of the smallest egg was less than 3.20 cc. All 37 of these eggs had relative volumes less than 75% of the larger eggs in their clutch. Conversely, the smallest egg in 44 sets had a relative volume less than 75%, of which 37 (84%) were smaller than 3.20 cc. Four of the 6 cases meeting the relative volume criterion, but not the absolute size cutoff, resulted from the occurrence of a large egg (>1.3 SD above the mean of all eggs) in the set, depressing the relative volumes of otherwise normal eggs.

Thus, the method based on absolute size is preferable, but requires extensive data and effort to be used effectively. Fortunately, these 2 methods can be combined to minimize their respective disadvantages and provide a compromise between accuracy and ease of application. First, each egg in a set is weighed or its volume calculated. The relative volume of the second largest egg in the set is then compared to the largest. If the resulting value is more than 75%, the relative volume of the third largest egg is calculated compared to the average of the 2 larger eggs, and so on, to the smallest egg in the set. In practice, usually only the smallest egg in a set need be tested, and then only when it is obviously smaller to the naked eye than other eggs.

Finally, all suspected runt eggs are checked to be smaller than 3.10 SD below the mean volume of eggs not meeting the 75% relative volume cutoff. Eggs larger than this should be considered "normal" even if they meet the first criterion. Unless there are quite a few possible runts with volumes near a cutoff value, measurements of relatively few eggs (25–

50), from as many different sets as possible, should be adequate to determine an upper size limit for runts. An efficient procedure is to measure 1 egg chosen randomly from each available set. Clutches containing only runt eggs, such as have been recorded in several species, must be picked out by eye and tested, using the absolute size criterion alone.

By eliminating the 38 eggs defined as runts by these criteria from the total sample of Acorn Woodpecker eggs, the distributions of length, width and volume change markedly (Table 1). The striking skewness and leptokurtosis of all 3 variables are lost, and the distribution of volume is normalized ($P > 0.50$, Kolmogorov-Smirnov test for normality).

Given the low frequency of runt eggs in most natural populations, samples containing more than, at most, a very few runts are difficult to obtain, and thus differences from species to species are difficult to test using standard statistical methods such as the χ^2 test. The Fisher exact test (Bailey, Statistical Methods in Biology, English Universities Press, London, England, 1959), though usually employed when the total sample size is quite small, can be modified for this problem. This statistic can readily be calculated, regardless of the total sample size, by use of Forsyth's formula for ln n!:

$$\ln n! = \ln \sqrt{2\pi} + \left[(n + \tfrac{1}{2}) \times \ln\left(\frac{\sqrt{n^2 + n + \frac{1}{6}}}{e} \right) \right]$$

Even with the aid of this statistic, however, statistically significant differences in runt egg frequency between species will be testable only on the grossest scale without large sample sizes.

Care must also be taken to insure that samples are comparable. In particular, the bias of museum collectors toward anomalies may result in a higher frequency of runt eggs in collections than in the wild. Furthermore, this bias probably differs among species with different types of nesting habits and of differing degrees of rarity.

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Breeding biology of Eastern Phoebes in northern Wisconsin.— The Eastern Phoebe (*Sayornis phoebe*) breeds widely throughout North America (Bent, U.S. Natl. Mus. Bull. 179, 1942). Despite this, relatively few studies of its breeding biology have been done. Furthermore, only 2 studies (Middleton and Johnston, Jack Pine Warbler 34:63–66, 1956; Cuthbert, Jack Pine Warbler 40:68–83, 1962) have been conducted in the Great Lakes states where the species is fairly common.

During the 1974–76 nesting seasons, I studied several aspects of Eastern Phoebe breeding