# Egg Volumes from Linear Dimensions

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Egg volumes cannot readily be measured with accuracy in the field, and are derivable from weights only if length of incubation and other factors are known. Coulson (1963), Stonehouse (1963) and others have recently investigated ways of determining volume (V) from length (l) and greatest diameter (d)—the two dimensions most easily taken from field and museum specimens; for a summary of earlier studies and an ingenious alternative method of volume calculation see Barth (1953).

Coulson used a formula derived from the equation for the volume of an ellipsoid:

$$V = \frac{4}{3}\pi\left(\frac{d}{2}\right)^2\frac{l}{2} \qquad \ldots\ldots\ldots\ldots\ldots(1)$$

reduced by a factor of .9294 which he determined empirically from the volume of liquid required to fill the empty shell. He thus obtained an expression for internal volume, which could be simplified to:

$$V = .4866\ ld^2 \qquad \ldots\ldots\ldots\ldots\ldots(2)$$

for rapid calculation. In 38 eggs of known volume the greatest error obtained from this expression was 4%, the mean error ± 1.6%.

Stonehouse independently obtained very similar results using the relation:

$$V = \pi l(dk)^2 \qquad \ldots\ldots\ldots\ldots\ldots(3)$$

which equates egg volume to that of a cylinder of height l and radius proportional to d. Stonehouse determined values of constant k empirically by water displacement. In 140 eggs of ten species of tropical seabirds k varied between .399 and .405. Using a mean value of k = .404, the expression was recast in the form:

$$V = .512\ ld^2 \qquad \ldots\ldots\ldots\ldots\ldots(4)$$

Calculated values of V, compared with volumes determined by displacement, showed mean errors similar to those of Coulson's method, i.e. a mean of less than 2% and no single error greater than 4%. Stonehouse's expression provides external volumes, while Coulson's gives internal volumes; theoretically, for given values of l and d, volumes obtained from expressions (2) and (4) would differ by the volume of the shell.

An attempt has now been made to relate values of k [in expression (3)] to egg shape, using a sample of 50 eggs of the Black Swan, *Cygnus atratus*, from a population breeding on the shore of Lake Ellesmere, Canterbury, New Zealand. Eggs of this species are large (Cutten 1966), oval or pointed-oval, and tend to be symmetrical about their short axis. Length and maximum diameters of the eggs were measured by vernier gauge to .01 cm. Volumes were determined by water displacement to an estimated accuracy of 1%. A value of k was determined for each egg by substituting empirical values of V, l and d in expression (3).

In this sample k varied between .396 and .410, with values grouped more or less symmetrically about a mean of .404. Volumes of individual eggs showed departures from calculated values (using $k = .404$) of 0 to $\pm 4\%$. The mean error for the sample was 1.1% and 47 out of 50 calculated values showed error of less than $2\frac{1}{2}\%$.

Eggs with a high calculated value of k $(.407 - .410)$, volumes of which were slightly underestimated by expression (4), were markedly rounded at both ends, approaching the cylindrical form represented hypothetically when $k = .500$. Those with low values of k $(.396 - .401)$ were distinctly pointed at both ends, with calculated volumes erring on the high side. It was possible on shape alone to sort the sample visually into three groups with high, average and low values of k; if greater accuracy in calculating volumes were required, it would have been possible to assign modified mean values of k to eggs in the extreme groups, thereby reducing the occurrence of extreme error (i.e. at the 4% level). No correlation was found between values of k and length, diameter, or ratios of length to diameter.

Further investigations of k are proceeding in eggs of different shapes. I thank the Secretary, North Canterbury Acclimatization Society, and Mr L. W. Hoff, Ranger, for providing the eggs used in this study.

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*Manuscript Received April 14, 1965.*