J. Orn. 129, 1988: S. 366—369

Length, Breadth, and Elongation of Avian Eggs from the Tables of Schönwetter

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In this study we examine how egg length and breadth vary as a function of egg mass in non-Passeriformes and Passeriformes based on the values which Schönwetter (1960—1983) has described. Furthermore, the ratio of egg length to egg breadth or elongation is derived for various orders, as well as the variability of the constant, k, used commonly to calculate egg mass from length and breadth dimensions. As described previously, the length, breadth, shell mass, shell thickness, and egg mass for 7146 species and subspecies were entered into a computer (Rahn & Paganelli 1988). In this report we examine only the length and breadth and their derivative, the elongation, as well as the k constant.

Non-Passeriformes. The individual values of length and breadth are plotted for all extant species or subspecies (n = 3217) against their egg mass (range 0.3 to 1600 g) in figure 1. In addition we have added the 36 values for members of the extinct orders Dinornithiformes (Moas) and Aepyornithiformes (Elephant Birds), extending the egg mass range to 12.7 kg. The regression equations, however, exclude the extinct orders and are as follows:

$$L = 14.7\ W^{0.341 \pm 0.0007},\ r^2 = 0.98,\ \underset{\cdot}{\dot{X}}\ SEE = 1.055 \ldots\ldots\ (1)$$

and

$$B = 11.3\ W^{0.327 \pm 0.0003},\ r^2 = 0.99,\ \underset{\cdot}{\dot{X}}\ SEE = 1.026 \ldots\ldots\ (2)$$

where L = egg length, mm
B = egg breadth, mm
W = egg mass, g
r^2 = coefficient of determination
and $\underset{\cdot}{\dot{X}}$ SEE = antilog of standard error of regression by which the mean value is multiplied or divided.

Two aspects of this regression are of interest. First, visual inspection shows that the mean variation of length is twice that for the breadth, reflecting the differences in SEE and indicating a greater constraint placed on breadth than on length dimension when eggs are formed in the shell gland. This was previously recognized by Preston (1969) who examined these dimensions in 63 families of North American species or subspecies (total n = 10,000). The coefficient of variation was 3 % for breadth and 4 % for length.

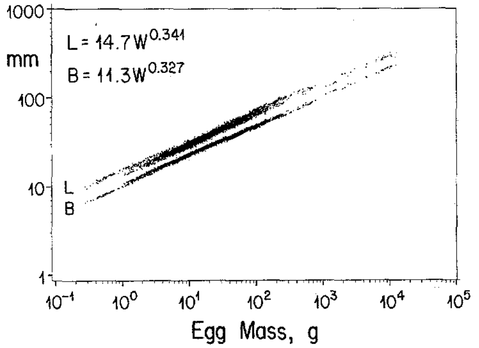


Fig. 1. Egg length and egg breadth of non-Passeriformes eggs regressed against egg mass.

The other point of interest is the highly significant difference of the exponents for length and breadth. True spheres regressed against mass would have an exponent of 0.333, yet the exponent for egg length is slightly larger (0.341) and for breadth slightly smaller (0.327), indicating that the elongation (length/breadth) increases slightly as egg mass increases (see below).

Passeriformes. Similar regressions for the order Passeriformes (n = 3929) are as follows:

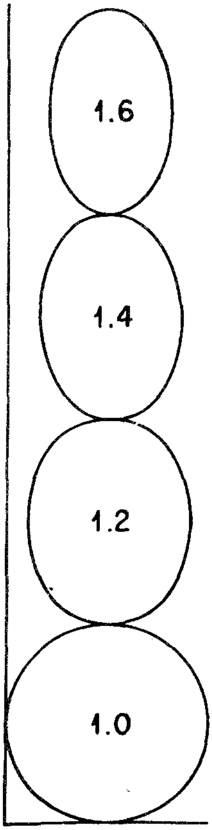
$$L = 15.1\ W^{0.345 \pm 0.0007},\ r^2 = 0.98,\ \underset{\cdot}{X}\ \mathrm{SEE} = 1.031\ \ldots\ldots\ (3)$$

and

$$B = 11.3\ W^{0.325 \pm 0.0003},\ r^2 = 0.99,\ \underset{\cdot}{X}\ \mathrm{SEE} = 1.015\ \ldots\ldots\ (4)$$

It will be noted that this regression is essentially the same as for the non-Passeriformes. The only difference is the small egg mass range from 0.6 g to 36 g (excepting the 2 species of Lyrebirds [Menuridae], whose egg mass is 60 g). Again we see that the SEE for length is twice that for breadth.

Elongation. In figure 2 the mean elongations (length/breadth) for 27 orders including the Passeriformes are arranged by decreasing elongation from 1.61 to 1.21, showing the number



Elong.	Orders	n	Elong.	C.V. %
1.6	Apterygif.	6	1.61	1
	Gaviif.	5	1.61	2
1.5	Pelecanif.	87	1.53	5
	Apodif.	115	1.53	4
1.4	Casuariif.	12	1.48	3
	Podicipedif.	23	1.47	2
	Rheif.	6	1.44	1
	Procellariif.	93	1.42	7
	Anserif.	169	1.42	5
	Ciconiif.	131	1.41	6
	Charadriif.	370	1.41	4
1.3	Caprimulgif.	103	1.39	4
	Gallif.	339	1.37	7
	Gruif.	241	1.37	7
	Columbif.	283	1.36	4
	Passerif.	3 931	1.36	7
	Tinamif.	59	1.33	6
	Cuculif.	140	1.32	6
	Picif.	254	1.32	5
	Spheniscif.	19	1.31	5
1.2	Coliif.	11	1.29	2
	Falconif.	316	1.28	4
	Psittacif.	164	1.26	6
	Coraciif.	178	1.25	9
	Trogonif.	24	1.24	4
	Struthionif.	6	1.21	2
	Strigif.	127	1.21	4

Fig. 2. The mean elongation (length/breadth), the number of species or subspecies, and their coefficient of variation for 27 orders arranged according to decreasing values from 1.61 to 1.21. On the left are shown various elongations when applied to perfect elipses, keeping the length constant.

of species or subspecies for each order as well as the coefficient of variation, C. V. (expressed as %) which does not exceed 7 %. The overall mean value for non-Passeriformes and Passeriformes is the same, namely 1.36. However, within some orders the mean value of elongation for individual families can vary greatly. Among the Procellariiformes (1.42), the Diomedeidae have a mean value of 1.57, while the Pelecanoididae, 1.27. Among the Ciconiiformes (1.41) the Phoenicopteridae (Flamingos) have the largest elongation of any family, namely, 1.67, while among the Coraciiformes (1.25) the Meropidae (Bee-eaters) have the smallest elongation of all families, namely, 1.17. The Megapodiidae among the Galliformes (1.37) have a mean value of 1.60. In the order Passeriformes the range of elongation is not as extensive, ranging from 1.46 in the Ptilonorhynchidae (now Parasidaeidae) to 1.28 in the Rhinocryptidae.

PRESTON (1969) in his survey of North American species obtained similar values. For non-Passeriformes the mean value for 44 families was 1.41; the largest value in the Gaviidae, 1.60; the smallest value for the Strigidae, 1.19. For 19 families of the Passeriformes his mean value was 1.35.

Elongation as a function of egg mass. As can be predicted from the differences in the exponents of length and breadth (equations 1 and 2) the mean elongation increases slightly with egg mass. For the non-Passeriformes the regression of elongation as a function of egg mass is as follows:

$$E = 1.30\ W^{0.014 \pm 0.001},\ r^2 = 0.05,\ \dot{X}\ \mathrm{SEE} = 1.08 \ldots\ldots. (5)$$

where E = elongation, L/B.

While r^2 is negligible, the regression is highly significant, P = <0.001. For example, it predicts that the mean elongation increases from 1.30 for 1 g eggs to 1.43 for 1000 g eggs. However, this general equation obscures the fact that while in some families elongation does not change much with increase in egg mass, in others it increases greatly and in some it actually decreases, i. e., larger eggs become rounder (fig. 3). Among the Passeriformes negative slopes are found in the following families: Formicariidae, Cinclidae, Certhidae, and Dicaeidae. The fact that positive and negative slopes of elongation occurred among eggs of non-Passeriformes was described earlier by v. HAARTMAN (1971). Using the same data base he graphed changes in elongation with increasing egg mass for 25 families and discussed at length the possible functional significance of these trends.

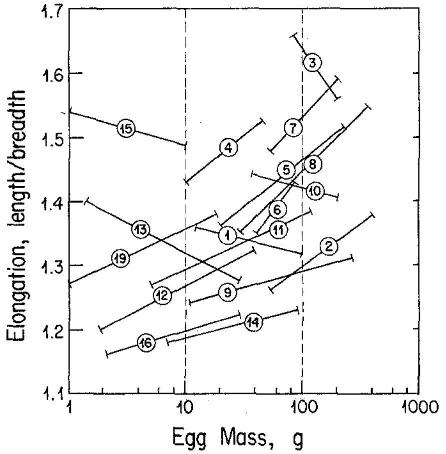


Fig. 3. Mean change of elongation slope with egg mass of certain families among non-Passerine birds. 1 — Tinamidae, 2 — Spheniscidae, 3 — Gaviidae, 4 — Podicipedidae, 5 — Procellariidae, 6 — Pelecaniidae, 7 — Sulidae, 8 — Anatidae, 9 — Accipitridae, 10 — Cracidae, 11 — Phasianidae, 12 — Psittacidae, 13 — Cuculidae, 14 — Strigidae, 15 — Apodidae, 16 — Alcedinidae, 17 — Picidae.

Calculation of egg mass. SCHÖNWETTER (1985—1986) described in detail the extensive formula on which he based his calculation of egg mass for all species in his tables, and a comparison of egg mass of 97 of his species with eggs in which egg mass was determined after replacement of the air cell with water showed excellent agreement (RAHN et al., 1985). A simpler formula, commonly used, is egg mass (g) = k ($L \times B^2$), where L and B = cm. The question resides around the particular value of k, which varies among taxa and was discussed by HOYT (1979). For non-Passeriformes (n = 3217) the mean k = 0.5419, SD = 0.0154, with a range from 0.470 to 0.642. For Passerines (n = 3929) k = 0.5223, SD = 0.0113 with a similar range. While the coefficient of variation of 2.8 and 2.2 %, respectively, for non-Passerine and Passerine eggs is small, the range is very large. For any particular species, therefore, the k value should be calculated from the L, B, and egg mass values in SCHÖNWETTER's tables.

Summary

Using SCHÖNWETTER's data base regression equations are derived expressing egg length and egg breadth as a function of egg mass for Passerines (n = 3929) and non-Passerines (n = 3217). For both groups these show a variation around the mean which is twice as large for length as for breadth. The average elongation (length/breadth) ist presented for 27 orders ranging from 1.61 in Apterygiformes and Gaviiformes to 1.21 in Strigiformes as well as examples of a few families where elongation increases or decreases as egg mass becomes larger. Egg mass can be estimated from the relationship where egg mass = k (LB^2). Mean values, SD, and range of k for both groups are given, but for any particular species are best derived from the dimensions of L, B, and egg mass in SCHÖNWETTER's tables.

Zusammenfassung

Länge, Breite und Form der Vogeleier auf der Grundlage der Tabellen von SCHÖNWETTER. — Regressionsgleichungen für Eilänge und Eibreite als Funktion der Eimasse ergeben für Passeres (3929 Arten) und Non-Passeres (3217 Arten) eine Streuung um den Mittelwert, die für Länge doppelt so hoch wie für die Breite ist. Das Verhältnis Länge : Breite reicht bei 27 Ordnungen von 1.61 bei Apterygiformes und Gaviiformes bis 1.21 bei den Strigiformes. In Beispielen für einzelne Familien steigt oder fällt der Wert mit zunehmender Eimasse. Letztere kann bestimmt werden gemäß $k \cdot (L \cdot B^2)$, wobei k eine Konstante darstellt. Mittelwerte, Standardabweichung und Konstante werden für Passeriformes und Non-Passeriformes angegeben, doch für einzelne Arten hält man sich am besten an die Werte bei SCHÖNWETTER.

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