EGG WEIGHTS FROM EGG MEASUREMENTS.[1]

BY W. H. BERGTOLD.

THE length of avian incubation periods differs widely according to the species. This fact has always interested ornithologists, who rightly maintained that there must be a definite and deep seated reason for such differences in this all important biologic process.

One explanation put forth for these various incubation periods was that they were associated with differences in egg size, a small egg requiring only a short period and vice versa.

In a previous publication[2] the writer considered this explanation in detail. After careful study it was felt that by "egg size" really was meant egg weight because it seemed highly improbable that the vitally important process of a bird's development could be closely correlated with the known infinitude of different egg measurements, when there was no similar variety of incubation lengths.

There are available in literature, so far as the writer has been able to learn, data relating to the weights of only about sixty bird species. Sixty recorded egg weights out of approximately twenty thousand known bird species, are, manifestly, wholly inadequate to throw much light on a possible relation between the incubation length and the egg size. Conceivably this great dearth of data relating to the weight of avian eggs might be negated by devising a way of getting an egg's original weight from its empty shell, which, if successful, would give initial weights of the thousands of eggs now contained in the world's egg collections. It is probable that the eggs of ten thousand bird species are in these collections. If it were possible to ascertain the original weights of all these eggs from the empty shells one conceivably could gather a mass of data amply sufficient to settle the question as to whether or not a relation exists between an egg's weight and the time it takes to incubate it.

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[2] Incubation Period of Birds, Denver, 1917.

It is the object of this study to devise a way, if possible, to calculate the weight of a fresh egg from its empty shell.

Starting with the empty shell there are several ways of attacking the problem, two of which have been studied and tested by the writer.

The first is to determine the egg capacity by filling it with some liquid of known specific gravity. Distilled water would be the easiest, but it softens the egg membrane and in so doing diminishes the egg capacity.

Two other liquids were considered in connection with this method, viz., mercury (sp. gr. 13.6) and chloroform (sp. gr. 1.5), neither having any action on the shell, its membrane, or its pigment. When the egg's capacity for any particular liquid is learned it can be translated into distilled water capacity, and by multiplying this by the specific gravity of an egg, its approximate weight becomes known after adding the shell weight.

The risk of breaking a valuable egg by the weight of a mercury filling was considered too great to justify its use, hence this liquid was not tried out. It was, however, found to be quite otherwise with chloroform, for with it no objectionable effects were anticipated, or developed. The equation used in this method is as follows: $\frac{W - S}{A} \times B + S = X$, where W = weight of egg filled with chloroform, S = weight of empty shell, A = specific gravity of chloroform (1.5 +), B = assumed specific gravity of egg, X = original weight of the egg. This method gives results which probably do not exceed a plus error of more than 5%. If one were to employ it extensively there would be no mechanical difficulty in devising and constructing an apparatus to fill and evacuate an egg rapidly.

Results from chloroform method.*

Species	Size L	Size B	Weight shell	Weight shell and chloroform	Weight of egg	Estimated weight
Killdeer	37.50	27.00	0.85	19.22	13.10	13.63
Robin	28.50	22.00	0.38	10.37	7.31	7.33

The second method was studied to determine whether or not the original weight of an egg could be deduced from its measurements.

* All weights and measurements are in grams and millimeters.

The first step taken in this phase of the present investigation was to consult trained mathematicians on the mathematics of an egg-shaped body. They produced an equation, which, using the length and breadth of an egg only, gives the cubic volume of an egg, from which, it was anticipated, there would be no trouble to arrive at the original weight of the egg. But it proved, in practice, to be quite otherwise. It proved otherwise because very little seems to be known about the variability of the several egg characters except the measurements. Such variability strongly influences the egg weight, whence it is patent that one should know as much about them as is possible in order successfully to devise a method to achieve the end desired and sought in this study.

There are but two previous publications known to the writer which give attempts to construct an equation wherewith one can ascertain the original weight of an egg from its measurements, both by Hoxie.[1] His final equation, as tested by the writer on fresh eggs gives a plus error varying from five to twenty percent. Moreover it does not seem well founded mathematically because it uses but one measurement, and especially because it ignores the breadth, which is the egg's most stable mensural character.[2] In the end the conclusion was reached that Hoxie's method gives too wide a range of error to warrant further trial and study.

Any equation for uses just outlined must give the cubic capacity of an egg less the space occupied by the shell and its membrane. The writer knows no way to estimate this deduction without destroying the egg as a specimen. Therefore it has been assumed in this study that the space taken up by the shell and its membrane is negligible.

If the cubic capacity be known, the original egg weight can be calculated from terms of distilled water, through the specific gravity of an egg. In introducing the specific gravity of an egg into the calculation one encounters a real difficulty because, so far as the writer has been able to learn, there are no data whatsoever, in ornithological literature, bearing on the specific gravity of eggs, and only a small amount in agricultural literature on that of hen eggs.[3]

[1] Ornithologist and Oologist, Dec. 1887, and Nov. 1890.

[2] Curtis, R. M., Maine Agric. Exp. Station, Univ. Maine Bull. 228, June, 1914.

[3] The specific gravity of hens' eggs is recorded as varying from 1.072 to 1.092: the writer determined it, on seventy-two eggs, as being (avg.) 1.075.

Therefore, at the very beginning of this investigation it became necessary to know something about the specific gravity of bird eggs, which was done to a limited extent by studying all the fresh eggs which the writer was able to secure through the efforts of his friends and himself.

The fresh eggs of all birds, wild and domestic, differ widely in weight according to the species, and even with eggs from the same bird individual. These variations are due to differences in the egg's length, breadth, white, yolk, shell, shell membrane and air space. It is very evident that the specific gravity of an egg is related to each and all of these characters.

It is well now to consider them in order to see how little is known about them. Variations in the length and breadth are too well known to need any discussion in the present paper, it being necessary only to say that such variations are paralleled closely by differences in the weight of the egg. However, this has not yet been demonstrated to any great extent, and would make a nice piece of original research. One thing relative to egg measurements is quite unknown to ornithologists, namely that with a hen's egg its breadth is the least variable mensural character, and has been found to be in high correlation with the weight of the egg. It remains to be determined whether or not this be true of the eggs of other birds.

The amount of shell varies according to the species, in Ducks (sp.) it is 14% of the egg weight, with Plover (sp.) 10%, and Hens 10%. In eighteen of our native birds the writer found that the shell and its dried membrane made from 3% to 15% of the total egg weight. When considering the shell it is necessary to recall that the smaller the egg the greater, relatively, is its shell area, and pari passu the greater relatively the amount of shell. It is possible that the thinner shell of a small egg is offset by the thicker shell of the larger egg. This has not as yet been determined.

By common consent it is assumed that the air space of an egg varies in size with different species and in different individual eggs, yet up to date it has not been demonstrated. Skiagraphs of fresh eggs of the domestic hen were made for the writer and showed clearly, and beyond all question, that the air space in all the eggs examined were far from uniform in size. It is desirable that data on this point in relation to other bird eggs be accumulated, and made potentially useful for future students.

It was not possible through lack of time to make X-rays of all the eggs covered by Table No. 1.

With hen eggs the yolk, white and shell membrane, together, make about 64% of the total egg weight. The chemical composition of the first two of these constituents is subject to marked variation and, too, the water content fluctuates widely (5). It is obvious that alterations in such egg characters will be followed by changes in the specific gravity of the eggs, and that in the absence of definite knowledge of such fluctuations any equation designed to recover the original weight of the egg will fail to be rigidly correct in its results, when they are compared with the weight of the egg when first laid. In the face of these difficulties it was found expedient, as said before, to learn the specific gravities of the eggs of as many of our native birds as possible.

Besides the characters just mentioned which modify the specific gravity of an egg, two other conditions are powerfully active in altering it, viz., the age of an unincubated egg, and the time an egg may have been incubated. An unspoiled hen egg has its specific gravity lowered, thirty days after having been laid, from 1.090 to 1.035, that is about 61%. The diminution in an old unincubated egg is due, most likely, to loss of water which is followed by an increase in the air space. The lowering of the specific gravity in an incubated egg is, in all probability, caused by the development of the embryo through metabolic changes in the egg albumins.

In order to reach reasonably conclusive knowledge concerning all variations in the characters of an egg so that such knowledge might be used in constructing an equation exact for the end sought in this study, it would be necessary to destroy a large number of the eggs of our native birds, something the writer was loath to do. Therefore, all variations in egg characters were disregarded in this investigation, except those relating to measurements. In the face of the varying egg specific gravity found to obtain in our birds, by the writer, it became necessary to assume a specific gravity which could be considered as applicable to all eggs. This was taken as 1.043 which is the average found by the writer in the eggs of nineteen species of our native birds, a total of thirty-two eggs having been studied. It will be seen on reference to Table No. 1 that the specific gravities of the eggs available varied between 1.020 and 1.065. It seems highly probable that the specific gravity of all bird eggs is well above 1.050, those ranging below that level being low because not fresh or having been subjected to more or less incubation. This is substantiated, in part at least, by the fact that when some of the eggs studied were blown they showed definite indications of developing embryos. The higher specific gravity of the eggs of our domestic hen also points to a higher specific gravity than that taken for use in the equation developed in this investigation.

The equation finally used in this study and chosen as best meeting the aim of the present bit of research is as follows:

$$\frac{11}{21} \times (L \times B^2) \times S = W,$$

where L = length, B = breadth, S = specific gravity, and W = calculated weight. If the measurements be in metric W is the weight in milligrams. If the measurements are in inches or fractions thereof, the equation becomes

$$\frac{11}{21} \times (L \times B^2) \times \frac{252.5}{437.5} \times S = W \text{ (in oz. avdp.)}.$$

The differences between the actual weight and the calculated weight as brought out by this equation did not exceed, in practically all of the eggs tested, more than 5%, an error probably due to the eggs having been more or less incubated, or not fresh.

This equation, as tested on data gleaned from general literature[1] gives the following answer: a guinea hen's egg is said to weigh 1.40 oz., its length is given as 1.88 inches and its breadth as 1.50 inches. The calculated weight worked out from these data emerges as 1.34 oz.

The results obtained from data gathered on recently collected eggs are exemplified in Table No. 1.

[1] New International Encyclop. Vol. VI, p. 681.

TABLE NO. 1.*

Species	Size L	Size B	Weight Egg	Weight Shell	Weight Estimated	Sp. Gr
Green-winged Teal	49.00	35.00	32.64	2.55	33.01	1.058
Blue-winged Teal	45.00	33.00	27.32	2.06	26.95	1.067
Coot	52.00	34.50	32.01	2.93	34.03	1.046
	44.00	33.50	25.51	2.45	27.15	1.046
Killdeer	37.50	27.00	13.01	0.87	15.03	xxxxx
Gambel's Quail	31.50	25.00	9.32	0.91	10.75	xxxxx
	33.50	25.00	10.52	0.95	11.51	xxxxx
Mourning Dove	28.50	21.00	6.26	xxxx	6.91	xxxxx
	27.00	19.50	5.26	xxxx	5.64	xxxxx
	27.50	20.50	5.96	0.27	6.33	1.040
	30:00	21.50	7.99	xxxx	7.62	1.052
	29.00	22.00	7.64	xxxx	7.71	1.041
	29.00	20.50	6.52	xxxx	7.70	1.040
Marsh Hawk	47.50	36.00	33.22	2.55	33.85	1.038
Flicker	28.00	21.50	6.92	0.55	7.11	1.063
Magpie	34.50	24.00	10.20	xxxx	10.92	1.041
	33.50	23.50	9.80	xxxx	10.17	1.032
	34.00	24.00	10.15	xxxxx	10.77	1.030
	33.00	23.50	9.35	xxxx	10.01	1.032
	34.00	24.00	10.75	xxxx	10.77	1.030
Cowbird	22.00	17.00	3.00	xxxx	3.49	1.021
	21.00	16.50	3.07	xxxxx	3.14	1.030
	21.50	17.50	3.11	xxxx	3.62	xxxxx
Yellow-headed Bl'kbird	26.50	18.50	4.87	0.26	4.98	1.052
	26.00	18.50	4.68	0.27	4.89	1.042
Red-winged Blackbird	28.00	17.50	4.56	0.22	4.71	1.022
	25.00	17.50	3.99	xxxx	4.20	1.053
Meadowlark	27.50	21.00	5.77	0.39	6.67	xxxxx
Vesper Sparrow	19.50	15.00	2.26	0.17	2.41	xxxxx
	20.00	16.50	2.99	xxxx	2.99	1.064
Lark Sparrow	21.00	15.50	2.77	0.23	2.77	1.026
	21.00	15.50	2.58	0.19	2.77	1.024
Lazuli Bunting	20.00	14.00	2.15	0.12	2.15	1.039
English Sparrow	21.50	15.00	2.27	0.24	2.66	xxxxx
Barn Swallow	20.00	14.50	2.20	0.33	2.31	1.048
Yellow Warbler	17.00	12.50	1.42	xxxx	1.45	1.036
Long-tailed Chat	22.50	17.00	3.43	0.23	3.57	1.059
Catbird	24.00	18.00	4.07	0.27	4.27	1.063
House Wren	17.00	13.00	1.47	0.11	1.58	1.065
Robin	28.50	22.00	7.31	0.38	7.58	1.027
	25.50	18.50	4.66	xxxx	4.74	1.024

* All measurements and weights are in millimeters and grams; decimals of estimated weights are approximate only.

The plus errors in the calculated weights are probably due to the air space unavoidably being calculated as egg content.

Many egg weights recorded in literature are probably grossly below the true original weight because the eggs were either not fresh or had been more or less incubated.

SUMMARY.

The original weight of an egg can be determined, within a maximum error of 5% by the equation devised and used in this investigation. Hence the weights of a huge number of eggs are now potentially available for study. This number of potentially available egg weights is amply sufficient to decide if there be, in truth, any relation between the egg's weight, and its incubation period.

To work this out would make a valuable bit of original research for someone with time and inclination to do it.

1159 Race St.,
Denver, Colo.