



Fig. 1. (A) A female albino Red-headed Woodpecker, (B) her normal mate, and (C) a normally-pigmented nestling in the nest cavity just prior to fledging.

sexes in Red-headed Woodpeckers (Jackson 1976, *Condor* 78: 67-76). Both the albino and normal adult removed fecal sacs from the nest. Other behavior of the albino seemed typical for the species. Jackson and Schardien observed the albino flycatching from a perch on a utility pole and using the top of the pole as a "chopping block" at which to dismember its prey.

At least one of the nestlings fledged successfully on the morning of 19 June. This and the other young had juvenal plumage that seemed normal for the species.

We visited the site of this nest again in 1978, hoping to observe this unusual bird during another nesting attempt. Unfortunately the nest tree had been removed for a parking lot and we observed no Red-headed Woodpeckers in the vicinity.—Received 5 September 1978, accepted 26 November 1978.

Density and Volume Corrections of Eggs of Seven Passerine Birds

T. H. MANNING

RR4, Merrickville, Ontario, Canada K0G 1N0

Few measurements of the density of fresh eggs of passerine birds are recorded in the literature and, as far as I know, none showing the loss of density during the egg-laying period. The eggs used in this study were from nests located near Merrickville, about 50 km south of Ottawa, Ontario. Each clutch was probably laid by a different female. The Barn Swallow nests were in a single barn; the Red-winged Blackbird nests in three small marshes. (Scientific names of all species are given in Table 2.) The other nests were scattered over an area of about 6 km². The six Starling eggs were found on a recently mown lawn. The five Brown-headed Cowbird eggs were from four well-separated host nests and therefore probably laid by four different females.

The eggs were weighed, while sheltered from the wind in a transparent acrylic cylinder, with 10-g and 5-g Pesola balances reading to 0.2 g and 0.1 g, respectively. Length and breadth of the eggs were measured with dial calipers reading to 0.1 mm. To measure density, the eggs were placed in a solution of common salt (NaCl), the density of which was adjusted by the addition of fresh water and saturated salt solution until the eggs were just waterborne. The density of the solution was then measured with a hydrometer, graduated to 0.002 g·cm⁻³ and readable to 0.0005. Care was taken to mix the salt solution thoroughly and to see that the egg and hydrometer bulb floated at about the same level. As the egg and the hydrometer were in the same solution, the readings were not affected by

temperature or impurities in the water. The eggs were rinsed in fresh water, dried, and numbered with small dots of red nail polish before being returned to the nest.

The above method of density measurement is accurate, and for small eggs, such as the Barn Swallow (for which a change in density of 0.002 corresponds to a change in weight of only 0.004 g), superior to methods based on weight and volume. Unfortunately it cannot be used satisfactorily for many eggs with very different densities, as this would involve too many large changes in the strength of the salt solution. Also there was some evidence that hatching success was reduced, particularly in the smaller eggs.

Loss of density during laying and incubating periods.—To determine the daily loss of density during the laying period, I measured the density of the eggs on the day they were laid and again 24 h later. Presumably other eggs in the clutch lost similar amounts during the 24-h period, but to avoid large changes in the strength of the salt solution they were not tested. I have assembled the results (Table 1) using the start of incubation (the laying of the last egg) as the base. Counting the days backward from the last egg rather than forward from the first egg gave distinctly better agreement between the density losses of eggs in different sized clutches. For instance, first eggs of the three 4-egg clutches of the American Robin and Red-winged Blackbird had a mean density loss of 0.0002 for the first day after the start of laying, whereas the two 2-egg clutches of those species had a mean loss of 0.0058. The data for the first day of incubation (Table 1) were obtained from the last egg laid. The mean daily density loss for the incubation period up to the time of pipping was calculated from weight loss measurements (Manning in prep.).

The gradual increase in the daily density loss of eggs of the American Robin and the Red-winged Blackbird during the laying period (Table 1) parallels the increase in incubation constancy of the latter species (Holcomb 1974) and is probably the result of that increase. After the clutch is complete, incubation constancy appears to vary little, and the cause of the difference between the density loss on the first day of incubation and the subsequent mean daily loss is obscure, unless it is associated with the increase in vascularity of the brood patch, which occurs after the third day of incubation (Holcomb 1975).

The Barn Swallow eggs lost density more rapidly than those of the American Robin and Red-winged Blackbird at the start of the laying period, but had a lower loss during incubation (Table 1). The first difference is no doubt associated with the longer incubation period of the swallow (Rahn and Ar 1974); the second may have been due, at least in part, to the position of the nest—immediately under a hot iron roof. Indeed, throughout the incubation period those swallows were seldom seen on their nests during the day, and the density loss of the first egg in a single nest in a cooler location was only 0.0005, though for succeeding eggs the losses were normal.

Density of fresh eggs.—It is evident from the foregoing that to obtain the density of fresh eggs they must be measured as soon as possible after they are laid. In many, probably most, species some incubation occurs before the clutch is complete and density measurements taken at that stage can be misleading. At the same time too many visits to a nest to check for newly-laid eggs is time consuming and undesirable. Therefore, there is likely to be a period of a few hours between laying and measuring. I have not attempted to correct the densities (Table 2) for the loss during this period, because the time of laying is not accurately known. For the Barn Swallow, American Robin, and Red-winged Blackbird the correction would average about 0.0002/h (Table 1). The Barn Swallows appeared to lay early, probably about 0600, which would indicate an average density loss of 0.0009 before measurement. This is a small amount, but it is more than twice the standard error (Table 2). The American Robins laid later and more irregularly, probably about 1200 on the average, so the correction would be 0.0005. The laying time of the Red-winged Blackbird seemed to be intermediate. The average density lost by the Starling eggs before weighing was probably less than 0.001, as the weather had been cold and damp.

TABLE 1. Mean daily loss of density ($10^4 \text{ g} \cdot \text{cm}^{-3}$) by eggs during laying and incubation. The number of eggs measured are in parentheses.

Species	Days before start of incubation					1st day of incubation	During incubation
	5	4	3	2	1		
Barn Swallow	41(2)	39(6)	37(10)	50(11)	62(12)	57(12)	86(44)
American Robin			17(5)	42(7)	58(9)	84(10)	123(26)
Red-winged Blackbird			16(3)	46(4)	65(5)	72(4)	119(59)

TABLE 2. Mean eastern standard time (EST) of measurement, weight, true volume, and density (with coefficient of variation) of fresh eggs. Means, standard errors, and coefficients of variation are based on individual eggs and total variances.

Species	N		EST, h ^a	Weight (W), g ^b	True volume (W/D), cm ³ b	Density (D), g·cm ⁻³	
	Eggs	Clutches				Mean ± SE	CV ^c
Eastern Phoebe	9	2	9.7 (3.4)	2.13 ± 0.054	2.03 ± 0.052	1.0505 ± 0.00071	0.203
<i>Sayornis phoebe</i>							
Barn Swallow	44	10	10.6 (2.3)	2.04 ± 0.026	1.94 ± 0.025	1.0518 ± 0.00037	0.233
<i>Hirundo rustica</i>							
American Robin	33	10	14.5 (1.6)	6.42 ± 0.082	6.07 ± 0.077	1.0577 ± 0.00053	0.270
<i>Turdus migratorius</i>							
Starling	6	—	—	7.06 ± 0.263	6.66 ± 0.247	1.0611 ± 0.00158	0.105
<i>Sturnus vulgaris</i>							
Red-winged Blackbird	67	20	13.0 (3.3)	4.09 ± 0.041	3.88 ± 0.039	1.0551 ± 0.00029	0.224
<i>Agelaius phoeniceus</i>							
Common Grackle	12	3	14.1 (2.8)	6.70 ± 0.146	6.32 ± 0.137	1.0606 ± 0.00065	0.212
<i>Quiscalus quiscula</i>							
Brown-headed Cowbird	5	4 ^d	9.4 (1.5)	3.44 ± 0.084	3.25 ± 0.078	1.0588 ± 0.00153	0.323
<i>Molothrus ater</i>							

^a Mean, standard deviation in parentheses.

^b Mean ± standard error.

^c Coefficient of variation.

^d Host nests.

TABLE 3. The correction ($k\pi/6$) to the volume index (LB^2) needed to obtain the true volume of eggs, and the difference ($[1 - k]\pi LB^2/6$) between the ellipsoidal volume and the true volume. Means and standard errors are based on individual eggs and total variances.

Species	N		$k\pi/6$	$(1 - k)\pi LB^2/6$	
	Eggs	Clutches		Mean \pm SE	As percent of true volume
Eastern Phoebe	8	2	0.5117 \pm 0.00480	0.046 \pm 0.0194	2.23
Barn Swallow	46	10	0.5070 \pm 0.00142	0.063 \pm 0.0054	3.27
American Robin	35	11	0.5036 \pm 0.00172	0.242 \pm 0.0207	4.07
Starling	6	—	0.5130 \pm 0.00227	0.138 \pm 0.0306	2.07
Red-winged Blackbird	75	22	0.5065 \pm 0.00098	0.127 \pm 0.0076	3.33
Common Grackle	17	4	0.5091 \pm 0.00213	0.184 \pm 0.0278	2.89
Brown-headed Cowbird	5	4 ^a	0.5181 \pm 0.00314	0.033 \pm 0.0189	1.02
All species	192	—	0.5071 \pm 0.00068	—	3.27 ^b

^a Host nests.

^b Mean weighted by egg numbers.

The regression equation for mean egg density (D) on mean egg weight (W) of the seven species is $D = 1.047W^{0.0067-0.00150}$ ($r = 0.89$). The observed densities (Table 2) average 0.0096 above those predicted from the observed weights by Equation 6 of Paganelli et al. (1974) and 0.0054 below those predicted by a similar equation given by Rahn et al. (personal communication).

Volume correction.—When the true volume of an egg is unknown, the length (L) \times breadth² (B^2) may be used as an index (LB^2). To convert this index to true volume (V) it must be multiplied by $k\pi/6$, where $\pi/6$ is a constant (0.5236) giving the ellipsoidal volume and k is a variable, measuring departures from the ellipsoid (Barth 1967, Manning 1978). In the present case the true volume was calculated from weight and density (Table 2) and $k\pi/6$ determined as V/LB^2 (Table 3). Fresh eggs are not needed for this, and the egg numbers therefore differ in Tables 2 and 3. As $\pi/6$ is a constant and the effect of k , though very variable, is relatively small (Table 3), an average $k\pi/6$ for a species may be used to estimate the true volume of eggs, such as those in museum collections, the weight and density of which cannot be directly measured. Actually there are no significant differences among the species means in Table 3, and the best estimate is the weighted mean of the seven (0.5071). The two species with the largest series of measurements are the Barn Swallow and the Red-winged Blackbird. Although these two species are from different families, their mean volume corrections are similar, and it appears from measurements of asymmetry and bicone (Preston 1969), which are combined in the correction k , that this similarity may be general among passerine families.

The penultimate column of Table 3 gives the amount that must be subtracted from the ellipsoidal volume to obtain the true volume. The weighted mean of the coefficients of variation for these measurements is 59.2. This high figure is similar to the mean (65.6) obtained for the coefficient of variation of the volume correction calculated from Preston's data for asymmetry and bicone of 40 Canada Goose

TABLE 4. Partitioning of density variance between eggs within clutches and clutches as a whole. Density values are in 10^5 g \cdot cm⁻³.

	Degrees of freedom	Variance	95% confidence limits	% of total variance	Coefficient of variation
Barn Swallow					
Eggs	34	0.159	0.104–0.273	26.4	0.120
Clutches	9	0.443****	0.190–1.561	73.6 \pm 11.1	0.200
American Robin					
Eggs	23	0.362	0.218–0.711	44.3	0.180
Clutches	9	0.454****	0.140–1.771	55.7 \pm 17.0	0.201
Red-winged Blackbird					
Eggs	47	0.375	0.260–0.589	67.1	0.184
Clutches	19	0.184***	0.044–0.522	32.9 \pm 13.7	0.128

*** = $P < 0.005$.

**** = $P < 0.001$.

TABLE 5. Partitioning of the volume correction ($k\pi/6$) variance between eggs within clutches and clutches as a whole. Values are in $\text{cm}^3 \cdot \text{cm}^{-3}$.

	Degrees of freedom	Variance	95% confidence limits	% of total variance
Barn Swallow				
Eggs	45	0.432	0.286–0.730	46.4
Clutches	9	0.499****	0.173–1.814	53.6 ± 15.6
American Robin				
Eggs	24	0.687	0.433–1.141	66.5
Clutches	10	0.346*	0.000–1.535	35.5 ± 19.3
Red-winged Blackbird				
Eggs	53	0.542	0.383–0.826	75.9
Clutches	21	0.172**	0.012–0.558	24.1 ± 12.8

* = $P < 0.05$.
 ** = $P < 0.025$.
 **** = $P < 0.001$.

(*Branta canadensis*) eggs (Manning 1978). How much of the variation is attributable to instrumental and personal error is unknown in both instances.

Partitioning of variance of density and volume correction.—The clutch components of the variance of density and volume correction ($k\pi/6$) are significant in the three species tested (Tables 4 and 5), and as k corrects the ellipsoidal volume for the effect of asymmetry and bicone, it may be inferred that the variances of those measurements also have significant clutch components. As the number of eggs per clutch varied, the confidence limits for the clutch component of the variances are not exact (Sokal and Rohlf 1969). The same applies to the standard errors of the percentages of total variance, which were calculated according to Equation 4 of Swiger et al. (1964) for intraclass correlation. These two sets of statistics do, however, give an idea of likely variations. Judging by the confidence limits, there are no significant differences between species for the clutch components of the variances for either density or volume correction (Tables 4 and 5). The egg component of the density variance, however, is significantly higher in the Red-winged Blackbird than in the Barn Swallow (Bartlett's test; $P \approx 0.025$).

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