Pesticide Residues in Eggs of Wild Birds: Adjustment for Loss of Moisture and Lipid

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Eggs of wild birds collected for the purpose of measuring concentrations of organochlorine pesticides or other pollutants vary from nearly fresh to nearly dry, so that objective comparisons cannot be made on the basis of weight of the contents at the time of collection. STICKEL et al. (1965) showed that residue concentrations in partially dried osprey eggs from the field were exaggerated as much as 8 times by this artifact. Bias toward high residues may occur even when concentrations are expressed as parts per million of lipid, since developing embryos use the fat in the egg for energy. More than one-third of the fat in a hen's egg is depleted during development of the chick (ROMANOFF 1932). Valid interpretation of residue data depends upon adjustment for these losses.

The volume of the egg can be used as the standard for adjustment, since the volume does not change as weight is lost. As a practical procedure for comparisons between species, a factor of 1.0 can be used with volume to obtain an estimate of fresh wet weight for computation of residue concentration (STICKEL et al. 1966). Estimates obtained by this method are useful approximations. The variation introduced by species differences in specific gravity of the egg contents and volume of airspace and shell appear to be relatively minor by comparison with the erratic and large distortions that result when no adjustments are made.

Volume is measured by water displacement and therefore includes the volume of the shell. Inside volume of blown eggs can be measured by pouring fluid into the egg (BERGTOLD 1929). Blowing eggs, however, prevents study of the embryos and it also is difficult to blow eggs that contain well developed chicks. For general comparisons, therefore, outside volumes may be preferable.

It is not always feasible to obtain a direct measurement of volume. We have therefore derived equations that use egg measurements to estimate egg volumes more accurately than is done by the more general formulas that have been proposed. These are presented here for bald eagles *(Haliaeetus leucocephalus)*, ospreys *(Pandion haliaetus)*, and eastern brown pelicans *(Pelecanus occidentalis)*.

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The equations for estimating volume depend upon a linear relationship between volume and length and breadth of the egg. Length (L), breadth (B), length times breadth (LB), and length times breadth squared (LB^2) were each significantly correlated with volume, as would be expected.

The best estimates for volume of eagle eggs were derived from the relationship of volume to LB, whereas the best estimates for osprey and pelican eggs related volume to LB^2. The equations and the reliability of the estimates they produced are summarized in Table 1. The simpler formulas shown in the table employ the best single factors. These are 0.508 for eagles, 0.510 for ospreys, and 0.506 for pelicans. All are very close to the factor of 0.512 first suggested by Pearl and Surface (PEARL and SURFACE 1914) based upon an adjustment of the equation for computing the volume of the prolate spheroid. Consequently, formulas employing larger factors, reviewed and summarized by ROMANOFF and ROMANOFF (1949) will overestimate volumes of eggs of these species. Estimating volume from measurements, however, is obviously less desirable than measuring volume directly, since it introduces another source of variability.

TABLE 1

Estimates of egg volume from egg dimension 1/

				Percentage discrepancy from measured volume		
Species	n	Equation	r	mean 2/	s	range
Eagle	24	$v^*=3.73\ LB-35.3$	0.980	1.91	2.3	-7 to +10
		$v=0.46\ LB^2+11.6$	0.971	2.21	2.9	-6 to +13
		$v=2.857\ LB$	--	3.17	4.3	-5 to +22
		$v=0.508\ LB^2$	--	2.83	2.3	-8 to +7
Osprey	25	$v^*=0.48\ LB^2+3.69$	0.957	2.00	1.4	-4 to +5
		$v=3.16\ LB-22.7$	0.921	2.72	1.7	-7 to +5
		$v=2.36\ LB$	--	2.56	2.7	-8 to +9
		$v=0.510\ LB^2$	--	2.08	1.6	-5 to +5
Brown Pelican	27	$v^*=0.484\ LB^2+3.201$	0.969	1.47	1.4	-7 to +4
		$v=3.100\ LB-22.663$	0.940	2.10	1.8	-6 to +7
		$v=2.49\ LB$	--	2.35	2.1	-9 to +8
		$v=0.502\ LB^2$	--	1.52	1.4	-4 to +7

1/ Key to symbols: n = number of eggs used to derive equation, v = volume (ml), L = length (cm), B = breadth (cm), r = coefficient of correlation, s = standard deviation, * = best estimate obtained using this equation.

2/ Mean of all discrepancies, ignoring sign. Means of discrepancies that consider sign would be zero in all cases, as is inherent in the calculations.

If an adequate sample of freshly laid eggs can be obtained, it is possible to compensate for moisture loss by another method, but this will not be applicable to other species. In this method, the wet weight of the contents of the fresh egg can be estimated by multiplying the volume of the egg by an appropriate factor. This factor will be lower than the specific gravity of the wet contents of the egg, because of the airspace. For nine brown pelican eggs, this factor was 0.944. The regression equation was 1.021 x volume - 7.005 ($r = 0.993$; $P = 0.01$). The wet weight of the contents also can be estimated by a regression equation using LB^2 directly without first estimating the volume. On the basis of 13 eggs, this equation was $0.460\ LB^2 + 2.312$ ($r = 0.993$; $P = 0.01$). Adjustments to fresh lipid weight could be made similarly by determining a factor for lipid weight in relation to volume of fresh eggs.

If eggs are collected before incubation, so that all weight loss is due to moisture loss and not to loss of solids or lipids, other methods of adjustments can be considered. Any component of the egg whose weight does not change with time could be used to estimate the original weight of the egg contents. It would be necessary to have good measurements from fresh eggs of each species for such comparisons. If these were available, then

$$T_1 = \frac{F_2}{b_1} = \frac{N_2}{c_1}$$

where

T_1 = total original weight of egg contents

b_1 = proportion of fat in fresh egg

c_1 = proportion of nonfat dry solids in fresh egg

F_2 = weight of fat in sample egg

N_2 = weight of nonfat dry solids in sample egg.

This method has not been tested and is presented only as a suggestion for trial. The percentage of fats and solids in fresh eggs and the chemical methodology for determining them may be too variable for use in this way.

Summary

Eggs of wild birds collected for the purpose of measuring concentrations of pesticides or other pollutants vary from nearly

fresh to nearly dry so that objective comparisons cannot be made on the basis of weight of the contents at the time of collection. Residue concentrations in the nearly dry eggs can be greatly exaggerated by this artifact.

Valid interpretation of residue data depends upon compensation for these losses. A method is presented for making adjustments on the basis of volume of the egg, and formulas are derived for estimating the volume of eggs of eagles, ospreys, and pelicans from egg measurements. The possibility of adjustments on the basis of percentage of moisture, solids, or fat in fresh eggs is discussed also.

Literature Cited

BERGTOLD, W. H.: Auk 46, 466 (1929)

PEARL, R., and F. M. SURFACE: U.S. Dept. Agricul., Bur. Animal Indus. Bull. 110, 171 (1914).

ROMANOFF, A. L.: Biol. Bull. 62, 54 (1932).

ROMANOFF, A. L., and A. J. ROMANOFF: The avian egg. John Wiley & Sons Inc., N.Y. xiii+918 pp (1949).

STICKEL, L. F., N. J. CHURA, P. A. STEWART, C. M. MENZIE, R. M. PROUTY, and W. L. REICHEL: Trans. 31st No. Amer. Wildl. Natural Resources Conf. 190 (1966).

STICKEL, L. F., F. C. SCHMID, W. L. REICHEL, and P. L. AMES: Fish and Wildl. Serv. Cir. 226, 4 (1965).