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Florida Bald Eagle (*Haliaeetus leucocephalus*) Egg Characteristics

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The Bald Eagle (*Haliaeetus leucocephalus*), south of the 40th parallel, was declared endangered by the U.S. Fish and Wildlife Service in 1967 owing to an observed population decline in the 48 contiguous states, which was first noticed in Florida. A population of eagles in western peninsular Florida showed a sharp decline by 1957–58 (Broley 1958), and in eastern-central Florida the species declined by two-thirds between 1951–61 (Howell 1963). Those declines were later attributed to poisoning or the weakening effects on eggshells caused by chlorinated hydrocarbon pesticide residues, notably DDE (Nisbet 1989). Eggs with shells thinned by DDE broke before hatching, destroying the egg and resulting in lowered productivity. From 1984–91 biologists with the George Miksch Sutton Avian Research Center collected entire clutches of Bald Eagle eggs from Florida nests as part of a project to restore nesting populations of this species to the southeastern U.S. (Sherrod et al. 1989). The eggs were incubated and hatchlings were reared in Oklahoma, and the young were released by hacking in eight southeastern states. This paper describes the physical characteristics of 395 Bald Eagle eggs and the analysis of pesticide residues in 15 unhatched eggs collected during that project. We report the results of testing for correlations between egg characteristics, location of collection, year, sex of the eagle hatched, and information on organochlorine pesticides and eggshell thickness.

Study Area and Methods

Eggs were collected from nine counties in north-central Florida (Fig. 1). At collection, each egg was marked with a unique number, measured for length and breadth with a caliper to the nearest 0.01 mm, and weighed to the nearest 0.1 g (balance) or 0.01 g (electronic scale). After incubation, the shells of hatched eggs were air-dried and their thickness measured. Unhatched eggs were frozen for as long as a year, a method of preservation which does not change the level of pesticide concentrations even if thawing and microbial degradation occur (Stickel et al. 1984). Unhatched eggs were opened, the contents removed, the shells were air-dried, and the shell thickness measured.

Thickness measurements were made on fragments of shell from three evenly spaced places near the equator. Fragments were clamped in a hemostat and viewed with a binocular microscope at 100×. One microscope eyepiece was equipped with a micrometer calibrated with a stage micrometer. Each shell sample was viewed with the microscope on its edge, the number of calibrations spanning the fragment recorded, and the thickness calculated using a constant conversion factor obtained from the calibration (Enderson et al. 1982). The three thickness measurements of each egg were averaged.

Shell membranes of hatched eggs usually shrank, becoming detached from the shell and so they could not be measured as part of the shell's thickness. Shell membranes from unhatched eggs sometimes remained attached after drying and, where possible, shells were measured with attached membranes, then the membranes removed and shell thickness re-measured. This gave shell thicknesses with and without membranes for 37 eggs. This allowed us to correct for loss of shell thickness caused when shell membranes become detached. Detachment of the shell membranes after drying slightly reduces the measured total shell thickness because the mammillary tips from the shell come away attached to the outer shell membrane during detachment (Terepka 1963).

Calculated egg volumes presented here include the shell volume, a method preferable to trying to determine inside volume (Stickel et al. 1973). The calculated volume formula was determined to be within −8 to +7 percent of measured volumes for this species (Stickel et al 1973). Shell thicknesses may decrease during embryo development as the embryo uses calcium from the shell for bone formation (Romanoff and Romanoff 1949). However, most of the decrease apparently occurs in the mammillae core (Bond et al. 1988) and does not contribute significantly to shell thinning (Bunck et al. 1985). Calculated egg volume (V) was estimated using the formula $V = 0.508LB^2$ (Stickel et al. 1973), where L = length of egg (cm) and B = breadth of egg (cm). Calculated fresh egg mass (M) was estimated as $M = 0.56227LB^2$. The coefficient of 0.56227 yielded the best estimate of hatching date, assuming a period from the beginning of incubation to pip of 33.5 d.

Unhatched eggs were considered fertile if they showed any sign of embryonic development upon dissection Hatch order within clutches was recorded based on pipping date and time. Hatch order was assumed to be identical with laying order because female eagles lay eggs a few days apart and begin incubation with the first eggs, making hatching within a clutch asynchronous (Gerrard and Bortolotti 1988). However, time of pipping was only accurate within ca. 12 hr because eggs were checked twice daily for pipping.

Sex of fledgling-age eagles was determined from measurements of bill depth and toepad length following the methods of Walborn (1991).

Egg length, breadth, volume, length/breadth ratio, calculated fresh mass, and shell thickness were checked for

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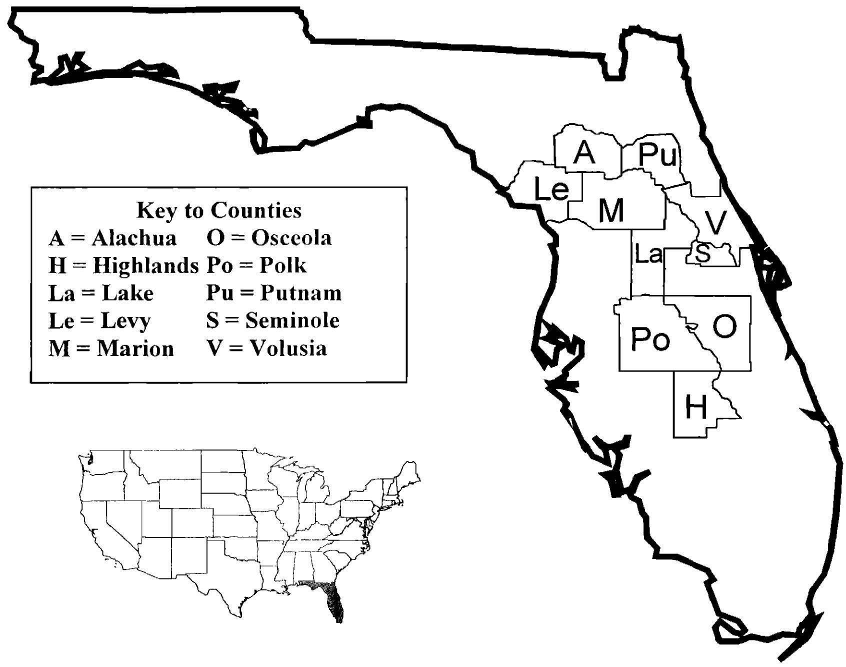

Figure 1. Florida Bald Eagle study area and counties of egg collections.

correlations with year and the latitude of the Florida county where collected to determine any latitude trend. Analysis of variance was used to compare shell thickness, volume, and hatch order by sex; volume and shell thickness (for all and for both sexes) by hatch order; and volume and shell thickness with fertility. Statistical tests were made using Systat statistical package, version 7.0.

Organochlorine and polychlorinated biphenyl pesticide residues of the contents of 15 unhatched eggs were analyzed by Hazleton Labs using Food and Drug Administration (1973) methods. The reported residues are based on calculated fresh egg masses.

Results

No significant correlations were found between egg length, breadth, volume, length/breadth ratio, calculated fresh mass, and shell thickness and the year of collection or the latitude of the Florida county where collected (Table 1). There was a significant increase of eggshell thickness from 1984–91 (F = 0.073, df = 392, $P < 0.05$) However, the increase was not significant if data for 1984 were excluded. The 1984 sample size (N = 18) is biased by the inclusion of an unusually thin-shelled two-egg clutch with very high pesticide residues. One of these two eggs was found broken in the nest; the other failed to develop. The eggshells we collected were 4.5% thinner than the pre-1947 Florida sample (N = 211) measured by Anderson and Hickey (1972).

Residue analysis results for 23 chlorinated hydrocarbons, percent moisture and percent lipids for 15 un-

Table 1. Summary of Florida Bald Eagle egg characteristics.

	Length (L) (mm)	Breadth (B) (mm)	Calculated Volume (mm^3)	L/B Ratio	Calculated Fresh Mass (g)	Shell Thickness Without Membranes (mm)
N	392	392	392	392	392	395
Minimum	64.38	48.34	82.30	1.166	90.92	0.312
Maximum	79.50	59.88	140.20	1.517	154.92	0.553
Mean	71.04	55.37	111.08	1.284	122.71	0.453
Standard Deviation	2.732	1.690	9.233	0.051	10.20	0.035

Table 2. Summary of chlorinated hydrocarbon pesticide residues in 15 unhatched Florida Bald Eagle eggs, 1984–91. Data are corrected to calculated fresh egg masses

	MEAN (ppm)	MAXIMUM (ppm)	MINIMUM (ppm)	STANDARD DEVIATION
DDE	2.47	10.10	0.66	2.35
DDD	0.05	0.58	0.0	0.14
DDT	0.24	3.89	0.0	0.94
HCB	ND*			
Alpha-BHC	ND			
Gamma-BHC (lindane)	ND			
Beta-BHC	ND			
Heptachlor	ND			
Aldrin	ND			
Octachlorostyrene	ND			
Heptachlor epoxide	0.01	0.07	0.00	0.02
Oxychlordane	0.06	0.26	0.00	0.06
Gamma-chlordane	0.04	0.15	0.00	0.04
Alpha-chlordane	ND			
Transnonachlor	0.29	1.06	0.00	0.25
Mirex	ND			
Dieldrin	0.10	0.66	0.00	0.15
Endrin	ND			
Methoxychlor	ND			
Toxaphene	ND			
PCB 1260	5.13	15.47	0.00	5.50
PCB 1248	0.02	0.24	0.00	0.06
PCB 1254	5.82	28.15	0.00	8.03
Percent moisture	80.78	83.60	76.00	2.04
Percent lipids	5.15	12.00	2.20	2.19

* ND = None detected above detection limit of 0.1 ppm or lower.

hatched eggs are presented in Table 2 as benchmark data for possible future information on this population.

DISCUSSION

Bald Eagle body size is known to increase with increasing latitude (Stalmaster 1987), but we found no correlation of egg size characteristics with the small latitude span we sampled. We speculated that eggs laid later in a clutch might be smaller than the first, but our data failed to detect such a trend. Likewise, sex of the eagles hatched did not correlate with size of the egg or hatch order.

We expected an increase in eggshell thicknesses and lessening of chlorinated hydrocarbon residues during the years of our study because most uses of DDT in the U.S.A. have been banned; however, our thickness data did not show a change over time during the period of our study. The residues for our eggs, except one egg with high DDE residues, are below the threshold levels indicated by some authors as sufficient to affect raptor productivity (Fyfe et al. 1988, Nisbet 1989, Risebrough 1989). Mean productivity of Florida Bald Eagles during the years of egg collection was 1.10 young/occupied territory (Nesbitt et al. 1998), and above the minimum of 1.0 young/occupied territory that Wiemeyer et al. (1993) considered as representing a healthy population. Based on these data, we believe that by 1984 the population of nesting Bald Eagles in the areas of Florida from which we collected eggs were reproducing at a rate that met the criteria suggested by Wiemeyer et al. (1993). This population was relatively free of pesticide contamination and that eggshell thinning was no longer a problem.

RESUMEN.—Las medidas y cálculos de las medidas de 395 huevos de águilas calvas (*Haliaeetus leucocephalus*) colectados en Florida desde 1985–91 fueron evaluadas por medio de relación estadística para el año de colección, latitud del condado donde fueron colectados, sexo del polluelo y orden de salida del huevo. No se encontraron correlaciones significantes. Se hicieron análisis de residuos de pesticidas organoclorados y bifenil policlorinados en 15 huevos sin empollar. Con excepción de una nidada, los residuos organoclorados fueron bajos.

[Traducción de César Márquez]

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