Heavy Metal Residues in the Eggs of Wild American Kestrels (*Falco sparverius* Linn)

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Introduction

In preparation for laboratory research aimed at determining the biological effects of environmental contaminants on the American kestrel (LINCER 1972), eggs of the wild population were monitored to identify those chemicals deserving close scrutiny. Because of the recent interest in heavy metal residues in birds of prey (HENDRIKSSON et al. 1966, KRANTZ et al. 1970, POSTUPALSKY 1971, KEITH and GRUCHY 1972, WIEMEYER et al. 1972, BELISLE et al. 1972) this group of chemicals received initial attention.

Methods

To establish an easily-accessible source from which eggs for residue monitoring and young for laboratory experiments could be obtained, wild kestrels were encouraged to use nest-boxes. During the late winters and early springs of 1969 and 1970 a total of 85 wooden nest-boxes were placed in an approximately 155 sq. km area, which is delineated, for the most part, by U.S.G.S. map entitled "Ithaca East, N.Y." Details concerning placement of nest-boxes and field observations have been reported elsewhere (LINCER 1972). Because of the possible effect of embryonic development on eggshell thickness (KREITZER 1972), eggs were collected five days after the last egg of the clutch was laid. Eggs were measured for breadth and length to the nearest 0.1 mm with a Mitytoyo No. 505-633 caliper equipped with a vernier, then either stored temporarily in a refrigerator (+5 C) or blown immediately to remove contents. Shells were broken in half at the equator, and washed with lukewarm water; care being taken not to disturb shell membranes. The shells were allowed to drain for approximately 30 seconds before measuring the shell thickness to the nearest .005 mm at the equator with an Ames No. 25ME thickness gauge. A minimum of four measurements were taken on each shell half. High and/or low extremes were discarded and a mean shell thickness recorded. Ratcliffe's Index (RI) was calculated and equals the weight of the dried eggshell (mg) divided by the length times the breadth in millimeters (RATCLIFFE 1970).

Atomic absorption analyses for heavy metals were run on hand-mixed portions of the egg samples by the second author and his associates at SUNY, Binghamton, New York. Pollutants were quantified in terms of ppm, fresh weight. Original fresh weight

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was estimated using the equation: 0.55 x length in centimeters x (breadth in centimeters)^2 provided by WALKER et al. (1967).

Mercury analyses were done in duplicate on samples weighing 2-6 g, fresh weight basis, using the flameless AA procedure of HATCH and OTT (1968) (H_2SO_4-H_2O_2 digestion and hydroxylamine-$SnCl_2$ reduction to Hg^o vapor). A "Mercometer" Model 2006-1, sensitive to a nanogram of Hg^o, was made available for these analyses by the manufacturer (Anti-Pollution Technology Corp., Holland, Michigan). Freshly prepared standard solutions of $HgCl_2$ put through the entire procedure were the basis for calibration. This procedure was previously found to give at least 90% recovery for Hg on other biological samples high in protein. Precision was excellent, considering the non-homogeneity of many partially developed eggs and the low mercury concentrations. From all the duplicates, a relative standard deviation of ±13% was calculated for the average of each pair.

Copper, cadmium, and lead analyses were done mostly in duplicate, with reasonable precision. The samples, ranging from 1 to 6 g. on a fresh weight basis, were digested in aqua regia and evaporated twice to near dryness with HCl, the final evaporation also containing 75 mg KCl as a matrix salt. The residue was taken up in 10.0 ml of 0.01 M HCl and this solution was analyzed for Cu, Cd, and Pb using the Perkin-Elmer Model 303 Atomic Absorption Spectrophotometer. Standard metal solutions in 0.01 M HCl were the basis for calibration, there being insufficient sample solution for internal calibration by standard addition. No recovery studies of the method were run on egg samples, but based on other studies recoveries of at least 80% may be expected.

Results and Discussion

The residue analyses of kestrel eggs from the Ithaca, New York area indicated that heavy metal content was, in general, relatively low (Table 1). Levels of organochlorine insecticides and polychlorinated biphenyls were appreciably higher (LINCER 1972, in prep.) and therefore most of the subsequent toxicological work addressed itself to this group of chemicals. Although these eggs were not randomly chosen for the heavy metal analyses, their average RI (.917) is only 5% smaller than the overall RI (.968) for 46 kestrel eggs collected during 1970, which was approximately 8% thinner than the pre-DDT thickness reported by ANDERSON and HICKEY (1972). In view of the possible contributory effect of heavy metal residues to eggshell-thinning, correlations were run between each metal and the respective eggshell thickness and RI (Table 2). No obvious inverse relationships appeared with mercury, copper nor lead. The possible correlative nature of

cadmium reported for eggshell-thinning in Cooper's hawks (SNYDER et al. 1973) could not be supported nor challenged because of small sample size and conflicting data when actual shell thickness and RI were compared.

TABLE 1

Heavy metal residues and eggshell thicknesses of field-collected kestrel eggs. Ithaca, New York - 1970. Values in table refer to $\bar{x} \pm$ s.d.(s.e.)

Metal	(N)	Residues (ppm, fresh weight)	(N)	Eggshell thickness (R.I.)
Mercury[a]	(11)	0.166 ± 0.261 (0.079)[c]	(11)	.917 ± .074
Copper[b]	(10)	0.38 ± 0.27 (0.08)	(10)	.908 ± .073
Cadmium[b]	(4)	0.081 ± 0.033 (0.016)	(3)	.972 ± .010
Lead[b]	(10)	0.72 ± 0.34 (0.08)	(9)	.908 ± .073

[a] Determination by flameless atomic absorption.
[b] Determination by atomic absorption.
[c] Rejection of one unusually high mercury value of 0.940 ppm gave a mean of 0.089 ± 0.049 (0.016) on the remaining 10 eggs.

TABLE 2

Correlative relationships between kestrel eggshell thickness vs. heavy metals. Figures in table refer to correlation coefficients (degrees of freedom).

	Eggshell thickness based on:	
	Actual thickness (mm)	Ratcliffe's Index
Mercury	- .249(9)	- .205(8)
Copper	+ .533(8)	+ .386(7)
Cadmium	- .977(2)	+ .836(1)
Lead	- .109(8)	- .036(7)

As with most environmental work, that with heavy metals has been primarily residue reporting and, at best, correlative in nature. BORG et al. (1966) showed the relationship between the application of mercury-dressed seed and high levels of mercury in seed-eating birds. They demonstrated that mercury levels in Swedish raptors from 1860-70 were less than 1/10 the levels in 1964-65. HENRIKSSON et al. (1966) reported what appeared to be alarmingly high mercury levels in some tissues of Finnish white-tailed eagles (Haliaetus albicilla) especially in view of the recent toxicological studies with red-tailed hawks (FIMREITE and KARSTAD, 1971). JOHNELS and WESTERMARK(1969) showed an abrupt increase of mercury in female goshawk feathers around 1950 in response to increased mercury use in seed-dressing.

FIMREITE et al. (1970) reported mercury levels in the livers of predators of seed-eating animals. The one kestrel liver that they analyzed was somewhat intermediate for the group but lower than that in a prairie falcon (Falco mexicanus) with a level of 0.755 ppm (fresh weight). The mercury level of .166 ppm in kestrel eggs produced in Ithaca, New York are similar to those reported for praire falcons in Saskatchewan but appreciably lower than those for prairie falcons and merlins (Falco columbarius) in Alberta (FIMREITE et al. 1970). Our kestrel egg mercury levels resemble those of predaceous birds from Saskatchewan more than those from Alberta (.103 ppm and .236, respectively) and are also closer to the buteo-harrier-eagle group than the falcon-accipiter group (.133 and .288 ppm, respectively).

By comparison, the mean mercury and lead levels reported here are almost 7 and 3.5 times higher, respectively, than those reported by SNYDER et al. (1973) for Cooper's hawk eggs collected in the Arizona-New Mexico area. However, the copper and cadmium levels are only about one-half those in the accipitrine counterpart. The changes in these ratios suggest decreases in copper and cadmium and/or increases in mercury and lead as one goes from Arizona-New Mexico to Ithaca, New York.

The mean kestrel egg copper level is appreciably lower than those in bald eagle eggs collected in Wisconsin and Florida but similar to that in eggs from Maine (KRANTZ et al. 1970).

A further comparison of the kestrel egg results with those for the Cooper's hawk eggs reveals a Pb:Cd ratio around 10:1 for the former case in contrast with a ratio of only 2:1 for the other study; the ratios of Pb:Hg and Cu:Cd were essentially invariant for the two groups. The higher Pb:Cd ratio in the kestrel eggs, if not a species difference, could reflect higher atmospheric Pb:Cd ratios

in the Northeastern United States. No data for the Arizona-New Mexico area are available, but analyses of suspended particulate matter from the SUNY-Binghamton atmosphere (comparable to Ithaca, New York) in July and August 1971 averaged 0.33 ug Pb/m^3 and 0.004 ug Cd/m^3, for a ratio of 82:1 (McDUFFIE 1972). [In Manhattan, New York City, mean values for 1969 were approximately 2 ug Pb/m^3 and 0.010 ug Cd/m^3, giving a 200:1 ratio (EISENBUD and KNEIP 1971)] High atmospheric Pb:Cd ratios could raise that ratio in predaceous birds directly or through the food chain.

Without toxicological investigations with the appropriate species to support hypotheses, the biological significance of the levels of heavy metals reported here (or any other chemicals for that matter) is difficult to assess.

Because of the recent interest in the possible biological activity of mercury (PEAKALL and LOVETT 1972), its possible effect on eggshell-thinning was examined in the kestrel and the ring dove (Streptopelia risoris). This is reported elsewhere (PEAKALL and LINCER 1972), and there was no obvious effect of that particular form of mercury (di-methyl mercury) on eggshell-thinning. One should not prematurely dismiss the possible danger of dietary mercury especially since a similar dietary dose of methyl mercury resulted in the mortality of red-tailed hawks after only a month on diet (FIMREITE and KARSTAD 1971).

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