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Dieldrin and DDT: Effects on Sparrow Hawk Eggshells and Reproduction

Abstract. *Patterns of reproductive failure in declining populations of several European and North American raptorial species were duplicated experimentally with captive American sparrow hawks* Falco sparverius *that were given a diet containing two commonly used organochlorine insecticides. Major effects on reproduction were increased egg disappearance, increased egg destruction by parent birds, and reduced eggshell thickness.*

Marked declines in populations and reproductive success of several species of North American and European raptors have occurred during the past two decades (*1–3*). These declines have been attributed to effects of organochlorine insecticides which these birds obtained from their food and accumulated in their tissues (*1, 3–5*). Reproductive failures of some species were associated with significant decreases in eggshell thickness (*6, 7*) and, especially in British species, with marked increase in frequency of egg-eating and of egg breakage in the nests (*5, 8*). These changes were ascribed to alterations in calcium metabolism of adult birds (*7*).

We have investigated effects of two sublethal dietary levels of DDT and dieldrin (*9*), in combination, on reproductive success of captive American sparrow hawks *Falco sparverius* and the influence of these chemicals on eggshell thickness.

The sparrow hawk was selected because it had been bred successfully in captivity on a limited scale (*10*), was relatively abundant, was easily handled and sexed, and was closely related to the peregrine falcon *F. peregrinus*, a declining species of raptor (*1*).

The principal experimental group consisted of 27 pairs of hawks, all obtained as fledglings in the summer of 1964 from the Northeast and maintained as pairs since early in 1965. Nine pairs of these birds were randomly assigned to each of three treatments —control, low dosage, and high dosage (*11*). An additional group of nine pairs of hawks that had a heterogeneous history and were housed at a different location were randomly assigned, three pairs each, to the same treatments as the principal group. Females of this latter group were birds caught from the wild in Florida in the winter of 1965–66; males were produced by the parent colony in 1965 before dosage began on 11 March 1966.

Low dosage represented amounts equal to residues often found in raptor food items in the field (*12*). High dosage was calculated to be just short of lethal to adults and it was equivalent to that obtainable in the field, at least in some areas containing prey items with unusually high pesticide residues (*13*).

Birds of both sexes were carried over from one year of the experiment to the next. Females that died during the experiment were not replaced. Males that died during the experiment were replaced at the onset of each reproductive season. Dosed males that died were replaced with males of the same treatment when available; otherwise, they were replaced with nondosed males.

In 1968, reproduction of first-generation (yearling) hawks was investigated. These hawks were produced by the experimental colony in 1967 and were retained on the same diet as their parents. The 24 pairs of hawks used in this experiment were selected on the basis of body condition. In pairing them, the heaviest females were mated with the heaviest males to insure successful pairing. Siblings were not paired with each other. Dosages were randomly assigned to pens. In respect to age and history of pesticide exposure, yearling hawks were our most homogeneous group.

Table 1. Reproductive success of treated sparrow hawks. Data were analyzed by chi-square and presented as numbers of birds or eggs. Abbreviations: C, control; L, low dosage; H, high dosage (*11*).

Category	Parental group												Yearling group 1968		
	Northeastern females						Florida females								
	1967			1968			1967			1968					
	C	L	H	C	L	H	C	L	H	C	L	H	C	L	H
Pairs (clutches)	8	8	7	8	8	7	2	3	3	2	2	3	8	8	8
Eggs laid	40	40	33	39	40	32	10	14	13	10	10	13	41	33	42
Eggs taken for study	0	0	0	8	8	7	0	0	0	2	2	3	8	6	8
Eggs incubated	40	40	33	31	32	25	10	14	13	8	8	10	33	27	34
Eggs disappeared*	1	7†	9†	2	8†	10†	0	2	2	0	0	0	0	7†	4†
Eggs remaining	39	33	24	29	24	15	10	12	11	8	8	10	33	20	30
Infertile eggs‡	1	0	3	1	2	2	0	1	3	1	0	0	2	1	2
Dead embryos	6	9	2	13	6	3	0	2	0	2	5	6	3	0	9§
Eggs hatched															
of eggs incubated	32	24‖	19†	15	16	10	10	9†	8†	5	3	4	28	19	19†
Young fledged															
of eggs incubated	30	22¶	18¶	13	13	4§	7	8	7	4	3	4	28	19	13§
of eggs hatched	30	22	18	13	13	4§	7	8	7	4	3	4	28	19	13§

* May include disappearance of some young early in the post-hatching period. † Significant difference between dosed group and controls at $P < .05$. ‡ Refers to eggs without obvious embryonic development. § Significant difference between dosed group and controls and also from other dosed group at $P < .05$. ‖ Significant difference between dosed group and controls at $P \approx .06$. ¶ Significant difference between dosed group and controls at $P \approx .07$.

To determine whether a mixture of DDT and dieldrin could cause thinning of eggshells, we marked the first egg laid in each clutch, where possible, of both the parental and yearling groups in 1968, and removed it after the third egg was laid and before incubation was begun. All eggs collected were frozen, and their contents were removed later. The remaining albumen was then gently washed from the inner shell surface, so as not to disturb the shell membranes. Shells were then dried at room temperature for several weeks. Thickness of each shell plus its membranes was measured to the nearest 0.01 mm at four points around its equator with a micrometer, and these measurements were then averaged.

Reproductive success of untreated hawks in 1967 and 1968 was equal to that of a wild population, except for that of parental birds in 1968 (*14*). Reduced success of the parental group in 1968 was due mainly to embryonic mortality (Table 1) which may have been caused by bacterial infection of the eggs (*14*).

The influence of the pesticides on reproductive success was greatest in the yearling group (Table 1). Differences between yearling control and yearling dosed birds were significant ($P < .05$) at most major points of their reproductive cycle (Table 1). The same trend was apparent in the parental group in both 1967 and 1968 (Table 1), but differences between control and dosed groups were not always significant ($P < .05$).

The crucial factor responsible for reproductive failure of dosed birds was disappearance of eggs through time of hatching and may have included the disappearance of some newly hatched young. Differences in egg disappearance between dosed and control hawks were significant ($P < .05$) in most experimental groups (Table 1). Egg disappearance probably was due to breakage of thin-shelled eggs and to eating of eggs or newly hatched young by parent birds. Reproductive failures in declining populations of British raptors were similarly characterized by egg disappearance, egg breakage, and egg-eating by the parents (*8*).

Eggshells of dosed birds of the parental generation in 1968 were thinner by 8 to 10 percent on the average than those of controls of the parental group; eggshells of the first-generation dosed birds were thinner by 15 to 17 percent on the average than those of first-generation controls (Table 2). These differences were significant in both the first ($P < .01$) and parental ($P = .056$) generations of hawks. These reductions in shell thickness approached those that occurred after 1947 in declining populations of peregrine falcons both in the United States (18.8 to 26.0 percent) (*6*) and in Great Britain (19 percent) (*7*). Reductions in shell thickness also have occurred in declining populations of bald eagles *Haliaeetus leucocephalus* (18.0 to 19.8 percent) and ospreys *Pandion haliaetus* (25.1 percent) in the United States (*6*), and also in golden eagles *Aquila chrysaetos* (9 percent) and sparrow hawks *Accipiter nisus* (16 to 25 percent) in Great Britain (*7*).

The occurrence of the same pattern of reproductive failure among dosed birds for two consecutive years and in both parents and offspring strengthens the hypothesis that chlorinated-hydrocarbon pesticides have reduced the reproductive success of bird- and fish-eating raptors. The remarkable similarity in pattern of reproductive failure between our experimental hawks and wild raptor populations strongly supports the hypothesis that recent reproductive failures in several raptor populations in the United States and Western Europe were due to common physiological and behavioral responses to intake of sublethal amounts of persistent chlorinated hydrocarbons.

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Table 2. Changes in thickness of sparrow hawk eggshells. Data were analyzed by analysis of variance; Duncan's new multiple range test was used to test differences between means. Abbreviations: C, control; L, low dosage; H, high dosage (*11*).

Experimental group	Treatments							
	C		L			H		
	No.	Average shell thickness (mm)	No.	Average shell thickness (mm)	Deviation from control (%)	No.	Average shell thickness (mm)	Deviation from control (%)
Parental group*								
1967	8	0.197	5	0.177	10	10	0.165	16
1968	10	0.189	10	0.173†	8	10	0.170‡	10
First-generation group (yearlings) 1968	8	0.198	8	0.164§	17	8	0.168§	15

* Eggs of the parental group in 1967 were haphazard samples. Although they suggested the occurrence of thickness differences, they were not suitable for a reliable statistical test. The parental group contained birds from both the Northeastern United States and Florida. A randomized block design permitted the inclusion of data from both these sources for 1968. † Significant difference between dosage group and controls at $P \approx .06$. ‡ Significant difference between dosage group and controls at $P < .05$. § Significant difference between dosage group and controls at $P < .01$.

References and Notes

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