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DDE RESIDUES AND EGGSHELL THINNING IN LOGGERHEAD SHRIKES

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Relationships among high DDE concentrations, eggshell thinning, and population declines in birds have received much attention in recent years (Ratcliffe 1970, Anderson and Hickey 1972, Cooke 1973, Stickel 1975). Most severely affected are bird- and fish-eating species of Falconiformes and Pelecaniformes. DDE, a metabolite of DDT, apparently interferes with deposition of calcium carbonate in the shell gland, with consequences manifested as thinned eggshells, increased egg breakage, and production of few young.

In this paper we present evidence that the Loggerhead Shrike (*Lanius ludovicianus*) has suffered much the same fate as many of the large predators and that the causative agent is possibly p,p′-DDE. Shrike populations have declined in much of the Midwest (Mayfield 1949, Petersen 1965, Erdman 1970, Graber et al. 1973). Graber et al (1973:7–8) concluded that "there apparently were two levels of change in the shrike population of northern and central Illinois—a relatively slow decline since about 1900, probably related to the removal of hedges in many areas, and a very rapid decline to near zero between 1957 and 1965 from causes unknown. It is possible, of course, that this change is temporary, but as of 1972 we have seen no sign of recovery by the shrike population." Erdman (1970:150) speculated that the decline of this passerine in Wisconsin was caused by pesticides.

METHODS

We conducted our study on low-density populations (mean of 7.4 shrikes counted per day of driving in April) of Loggerhead Shrikes in southern Illinois (15 counties south of Cumberland County) in 1971 and 1972. Sixty-nine birds were collected during 4 periods of the year—January, April, July, and September. Twenty clutches (104 eggs) that we considered complete were collected in April and May. After being weighed, each egg was opened by cutting the shell along the long axis. Samples of fat (subcutaneous and visceral combined) were excised from the birds and, along with the entire contents of the eggs, were saved for analysis.

The length and breadth of eggs were estimated to the nearest 0.01 mm with a vernier dial caliper graduated in 0.05-mm intervals. The air-dried shells were weighed to the nearest 1 mg. Mean thickness of each shell with membrane attached was estimated to the nearest 1 μ by taking 6 measurements (2 each at the large end, small end, and equator) with a micrometer graduated in 0.01-mm intervals. The same techniques were used to determine the length, breadth, and weight of 36 shrike eggs examined in the Chicago Museum of Natural History. However, measurements for 49 eggs in other archival collections were made to the nearest 0.05 mm and 10 mg. Museum eggs were used only if their blow holes were $\leqslant$2 mm and if they were taken from "complete" clutches in southern Illinois prior to 1940.

TABLE 1

DDE IN FAT OF LOGGERHEAD SHRIKES COLLECTED IN SOUTHERN ILLINOIS IN 1971–1972

Statistic	Age and sex		
	Adult females	Adult males	Juveniles[1]
	April and July		
Number of birds	23	18	8
Mean ± SE	21.04 ± 3.51	37.44 ± 9.07	15.04 ± 8.97
Median	15.00	26.39	9.25
Range	3.07–75.00	<0.01–150.00	5.45–33.33
	September and January		
Number of birds	7	10	3
Mean ± SE	13.73 ± 9.25	10.59 ± 3.84	11.11 ± 11.11
Median	2.38	3.31	<0.01
Range	<0.01–66.6	<0.01–28.57	<0.01–33.33

[1] Sexes combined.

Sixteen shrike nests found in 1972 were not disturbed. Each was revisited at 3- to 7-day intervals to determine the rate of survival of nests and eggs, and the number of fledglings produced per successful clutch.

Samples of fat and egg contents were saponified in a KOH-ethanol solution, put through a florisil column and, if not sufficiently cleaned, subjected to acetonitrile partitioning. The samples were then analyzed for p,p′-DDE, dieldrin, and heptachlor epoxide with a Beckman model GC-4 gas chromatograph equipped with an electron capture detector. Columns were packed with 1% EPON 1001 resin and 0.5% Viton A fluoroelastomer on a solid support of 100–120 mesh Chromosorb W. The column was operated at 190°C with ultra-pure helium as the carrier gas flowing at about 45 cc per min; the detector temperature was 250°C. The lower limit of detection was considered to be 0.01 ppm on a wet-weight basis; recovery was 90%.

Statistical tests used in this study are analysis of variance and linear correlation (Snedecor 1956:160, 268–270).

RESULTS

Pesticide concentrations.—Detectable concentrations of p,p′-DDE (hereafter called "DDE") were present in fat of 88% of the 69 Loggerhead Shrikes examined. The frequency of occurrence was 93% for 30 adult females, 86% for 28 adult males, and 82% for 11 juveniles. Mean concentrations of DDE were 21.89 ± 3.11 ppm (median = 13.88 ppm) for all birds, 19.33 ± 3.44 ppm for adult females, 27.85 ± 6.41 ppm for adult males, and 13.96 ± 3.90 ppm for juveniles.

Shrikes collected in April and July—i.e., local breeders and their young—contained greater concentrations of DDE than did shrikes collected in Sep-

TABLE 2

CHARACTERISTICS OF EGGS OF LOGGERHEAD SHRIKES COLLECTED IN SOUTHERN ILLINOIS: 1875–1895 AND 1971–1972

Characteristic	Mean ± SE		*F* Value
	1875–1895	1971–1972	
(1) Length (mm)	24.72 ± 0.11 (84)[1]	24.95 ± 0.11 (61)	2.14
(2) Breadth (mm)	18.67 ± 0.04 (85)	18.52 ± 0.07 (61)	3.53
(3) Weight (mg)	251 ± 2 (83)	244 ± 2 (98)	2.79
(4) Size Index (1) × (2)	451 ± 2 (84)	462 ± 3 (61)	0.03
(5) Thickness Index (3)/(4)	0.544 ± 0.003 (83)	0.530 ± 0.005 (57)	6.61[2]
(6) Thickness (μ)	—	92 ± 0.4 (95)	
(7) Weight of whole egg (g)	—	4.25 ± 0.05 (104)	
(8) DDE (ppm)[3]	—	3.09 ± 0.09 (104)	

[1] Number of eggs.
[2] Significant ($P < 0.05$).
[3] Median = 1.79, range = 0.48–34.14.

tember and January (Table 1). The difference between the means for adult males was significant ($P < 0.05$).

The contents of the 104 eggs analyzed contained a mean concentration of 3.09 ppm of DDE (Table 2). A clutch of 6 eggs collected in 1971 had a mean of 17 ppm, with 1 egg containing a high of 34 ppm. Dieldrin and heptachlor epoxide were not detected in the eggs or the samples of fat.

Physical characteristics of eggs.—The mean value for the shell thickness index was 2.57% less for shrike eggs collected in 1971 and 1972 than for eggs of this species collected between 1875 and 1895 (Table 2). This difference was significant ($P < 0.05$). Mean values for other physical characteristics—length, breadth, weight, and size index—did not differ significantly between the recently collected and older eggs.

Linear correlation indicated that a negative relationship existed between concentrations of DDE and the thickness of shells for the recent eggs: $\hat{Y} = 92.610 - 2.412 \log_{10} X$, $r = -0.208$ with 93 df ($P < 0.05$). Correlations between concentrations of DDE and other physical characteristics were not significant.

Rothstein (1972) found that the number of eggs in the clutch and the degree of embryonic development influenced eggshell thickness in Cedar Waxwings (*Bombycilla cedrorum*). This was not true of the shrike eggs collected in 1971 and 1972. In clutches with ≤5 eggs, mean ± SE eggshell thickness was 92.4 ± 0.8 μ for 17 eggs without development and 94.0 ± 1.5 μ for 4 eggs with development. In clutches of 6–7 eggs, mean thickness was 89.9 ± 6

μ for 12 eggs without development and 92.0 ± 0.5 μ for 57 eggs with development. None of the differences among these means was significant ($F = 1.86$ with 3 and 86 df).

Nest success.—As determined by Mayfield's (1961) day exposure method, survival of nests studied in 1972 was 79% during incubation (n = 13), 91% during the nestling period (n = 13), and 72% from start of incubation to fledging. Survival of eggs was 75% during incubation (n = 74) and 83% during the period of hatching (n = 54). Survival of young during the nestling period was 88% (n = 57). Thus, 55% of the eggs present at the beginning of incubation produced young that eventually fledged. A mean of 3.9 young fledged per successful nest (n = 9).

DISCUSSION

Data obtained during this study strongly suggest that Loggerhead Shrikes in Illinois have acquired appreciable amounts of DDE and that eggshell thickness has been adversely affected. However, the shrikes were not as severely contaminated with DDE as some raptorial and piscivorous species—birds well known for the eggshell thinning syndrome, poor reproductive success, and population declines. For example, mean concentrations (wet-weight basis) in Peregrines (*Falco peregrinus*) in Alaska were 38.2 ppm in fat of juveniles, 622.0 ppm in fat of adults, and 12.48 ppm in eggs (Cade et al. 1968: 175). Mean concentrations in eggs from North America and western Europe were 8.6 ppm for 16 species of Falconiformes and 17.7 ppm for 5 species of Pelecaniformes, as calculated from data presented by Stickel (1973:260–267).

The shrike's high position in the food pyramid is almost certainly the overriding factor leading to DDE accumulation in the species. The recent finding by Graber et al. (1973:12), who examined stomachs of the birds we analyzed for pesticides, that shrikes frequently consume ground beetles (Carabidae) is particularly relevant. Because of the predaceous habits of these insects, they themselves might be expected to accumulate pesticides, which would be passed on to shrikes and other predators that feed on the beetles.

The relationship between eggshell thinning and high DDE concentrations in shrikes parallels the well-documented eggshell thinning syndrome in the Peregrine, Bald Eagle (*Haliaeetus leucocephalus*), Brown Pelican (*Pelecanus occidentalis*), and certain other birds (Ratcliffe 1970, Anderson and Hickey 1972, Faber and Hickey 1973, Blus 1974). Like these species, the eggshell thinning in shrikes occurred concurrently with declining or reduced populations. However, our data on nesting success reveal that shrikes were highly successful in producing fledglings in the low-density population in southern Illinois in 1972. Graber et al. (1973:9) reported similar findings for shrikes in central Illinois in 1958–64 (population now extirpated) and in south-

eastern Illinois in 1967. Broken eggs, crushed embryos, or other indications of atypical egg mortality were not detected (Richard R. Graber, pers. comm.).

We conclude that the factor or factors that caused the decline of the Loggerhead Shrike population in Illinois were more closely associated with survival of fledged juveniles or adults than with reproduction. We have not demonstrated that the causative factor was DDE. Nevertheless, suspicion can be directed toward this environmental toxicant because (1) it has contaminated the shrike population and (2) a relationship exists between it and the malfunction of at least 1 physiological process—eggshell thickness—in the species.

SUMMARY

Investigations in southern Illinois in 1971 and 1972 suggest that the Loggerhead Shrike has been contaminated with DDE and that the species has experienced eggshell thinning. Mean concentrations of DDE were 21.89 ppm in fat of 69 birds and 3.09 ppm in the contents of 104 eggs. A negative correlation was found between concentrations of DDE and eggshell thickness, and the mean value for the shell thickness index was 2.57% less for eggs collected during the study than for eggs in archival collections. However, nesting success was high, suggesting that the factor—DDE or other—causing the recent decline of the shrike population in Illinois was more closely associated with survival of fledged juveniles or adults than with reproduction.

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