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EFFECTS OF HEPTACHLOR ON AMERICAN KESTRELS IN THE COLUMBIA BASIN, OREGON

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Abstract: Wheat seeds treated with heptachlor to control wireworms (*Ctenicara pruinina*) resulted in American kestrels (*Falco sparverius*) in the Columbia Basin accumulating residues of heptachlor epoxide (HE) that reduced productivity and caused some adult mortality. The kestrel is more sensitive to HE residues in eggs than the Canada goose (*Branta canadensis moffitti*), i.e., reduced productivity occurs at >1.5 ppm in kestrel eggs vs. >10 ppm in Canada goose eggs. Neither kestrel eggshells nor Canada goose eggshells were thinned by HE. The reduced use of heptachlor in 1979, because of a partial ban, resulted in an immediate lowering of HE concentrations in kestrel eggs the following year.

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The history of heptachlor as a wheat seed treatment to control wireworms in Umatilla and Morrow counties, Oregon, is poorly understood. Through 1970, it was listed in the *Pacific Northwest Insect Control Handbook* (Anon., various dates) after aldrin and dieldrin with an application rate on seed of 1 oz/bushel. It was not listed in 1971, 1972, and 1973. Then from 1974 to date, heptachlor was listed at 2 oz/bushel (≃2,000 ppm).

In 1976 and 1977, die-offs of several species of birds occurred in Umatilla and Morrow counties, Oregon. Residues of heptachlor epoxide (HE) that are considered lethal (Stickel et al. 1979) were found in brains of ring-necked pheasants (*Phasianus colchicus*), black-billed magpies (*Pica pica*), California quail (*Callipepla californica*), Canada geese, and a golden eagle (*Aquila chrysaetos*) (Blus et al. 1979). This history of wildlife mortality associated with heptachlor prompted a detailed study of the Canada goose population nesting on the Umatilla National Wildlife Refuge (NWR) (Blus et al. 1979). HE in eggs was correlated with hatching success; 95% of the nests in which sample eggs contained ≤1 ppm HE were successful compared with only 20% of those with eggs that contained >10 ppm. The source of HE in geese appeared to be ingestion of seeds treated with heptachlor for wireworm control.

The present study involving the American kestrel was designed to complement the Canada goose investigation. We reasoned that Canada geese were obtaining heptachlor directly from the ingestion of treated seeds; however, if American kestrels obtained heptachlor, it would indicate that residues moved through food chains. American kestrels eat mostly insects, especially grasshoppers, but also mice, small birds, and some lizards and amphibians (Brown and Amadon 1968).

Biological technicians collecting field data for this study included B. E. Foreman, G. A. Green, R. A. Grove, K. D. Hansen, E. G. Huff, and R. R. Sheehy. C. M. Bunck provided statistical assistance. J. E. Kurtz and G. M. Constantino, refuge managers at Umatilla NWR, kindly allowed use of the refuge facilities.

METHODS

In spring 1978, 217 nest boxes were placed in Umatilla and Morrow counties to attract nesting kestrels. The boxes were generally placed in riparian zones that meandered through the wheat-growing region. The boxes were similar to those used for wood ducks (*Aix sponsa*) and identical to those used in the evaluation of a DDT-spray project in the forests of the Pacific Northwest a few years earlier (Henny 1977). The front and back were constructed from 1×12's and the sides from 1×8's with the cavity 45–50 cm deep. A 7.5-cm diameter hole was drilled 5–8 cm from the top. The top was removable and secured with a wire. About 3 cm of shavings or sawdust was added to each box when it was cleaned each spring. The number of viable boxes checked from 1978 to 1980 and the percentage occupied by nesting kestrels were: 1978, 217 (40%); 1979, 174 (52%); and 1980, 153 (57%).

Boxes were visited at about 2-week intervals. Nests other than those of kestrels or owls were removed. One randomly selected egg was collected from each nest in 1978 and 1979 and from most nests in 1980 for residue analysis. Because a decline in HE residues became apparent in 1980, the number of nest boxes monitored in 1981 was decreased, and 1 egg was collected from each of only 50% of the nests. The clutches were monitored for hatching and fledging success. All young and some adults were banded.

Production information obtained from nests from which an egg was collected during the first 3 years was used to evaluate the effects of organochlorine residues in the sample egg on the success or failure of each nesting attempt. Because an egg was collected for organochlorine analysis, some productivity values were not directly comparable to other published studies. Productivity data collected in 1981 were not used because some nest boxes were moved (placed closer together) to study minimum space requirements for the kestrel; however, the 1981 residue data are used to evaluate trends.

Eggs were refrigerated until they were opened. The contents were placed in chemically cleaned jars and frozen for later analysis. Shell thickness (shell and shell membranes) was measured at 3 sites on the equator of each egg with a micrometer graduated in units of 0.01 mm.

Residue analyses were conducted at the Patuxent Wildlife Research Center, Laurel, Maryland. Each sample was analyzed for a series of organochlorine contaminants, including *p,p'*-DDT, *p,p'*-DDD, *p,p'*-DDE, dieldrin, endrin, hexachlorobenzene (HCB), mirex, toxaphene, HE, *cis*-chlordane, oxychlordane, *cis*-nonachlor, *trans*-nonachlor, and polychlorinated biphenyls (PCBs). In addition, eggs collected in 1980 were analyzed for γ-BHC (lindane), and those collected in 1978 and 1981 were analyzed for both lindane and β-BHC.

Samples were homogenized and subsamples were extracted by Soxhlet apparatus, cleaned by Florisil column chromatography, and PCB's separated from pesticides by silicic acid column chromatography. Residues were quantified by electron-capture gas–liquid chromatography using either a 1.5/1.95% OV-17/QF-1 or a 1.5/1.95% SP-2250/2401 column. Recoveries of pesticides and PCB's from fortified chicken eggs averaged 94% by these procedures (Cromartie et al. 1975, Kaiser et al. 1980). Reported results were not corrected for recovery.

Residues in about 10% of the samples were confirmed by gas chromatography–mass spectrometry. The lower limit of reportable residues was 0.1 ppm for all pesticides and 0.5 ppm for PCB's. The lower limit of quantification was divided in half and used to calculate geometric means for samples in which a contaminant was not detected. We converted contents of eggs to an approximate fresh wet weight using egg volume (Stickel et al. 1973); residue

Table 1. Residues of heptachlor epoxide and DDE (ppm wet weight) in eggs of American kestrels from the Columbia Basin, Oregon, 1978–81.

		Heptachlor epoxide			DDE		
Year	*N*	Geo. mean[a]	95% CI	High	Geo. mean	95% CI	High
1978	83	0.20[A]	0.15–0.27	4.7	0.46[A]	0.32–0.68	100
1979	85	0.44[B]	0.31–0.61	9.1	0.35[A]	0.26–0.47	37
1980	65	0.14[A]	0.10–0.20	3.3	0.40[A]	0.30–0.55	12
1981	28	0.10[A]	0.06–0.15	1.7	0.20[A]	0.12–0.34	3.5

[a] For each chemical, yearly geometric means that do not differ from each other (Bonferroni Multiple Comparison Method, $P = 0.05$) share the same superscript letters.

concentrations are expressed on a fresh wet-weight basis.

We used a 1-way analysis of variance and the Bonferroni multiple-comparison procedure to test for significant ($P \leq 0.05$) changes among years in log-transformed egg residues of DDE and HE.

RESULTS AND DISCUSSION

Residues of Heptachlor Epoxide and DDE

Eggs were collected from 261 kestrel nests during the 4-year study (Table 1). DDE was the most common contaminant detected; it was found in 226 (87%) of 261 eggs. Residues were generally low and showed no significant annual changes ($F_{3,257}$, 2.40, NS).

Heptachlor epoxide was found in 63% of the eggs in 1978, 78% in 1979, 43% in 1980, and 29% in 1981. Geometric means of HE showed significant annual changes during the study ($F_{3,257}$, 12.87, $P < 0.001$). Egg residues increased from 1978 to 1979 ($P < 0.05$), then decreased from 1979 to 1980 ($P < 0.05$). No significant difference was detected between 1980 and 1981. Before the 1978 placement of the nest boxes in the region, only a small kestrel population was present, probably because of the lack of nesting sites. The lower residues in 1978 probably resulted from attracting pioneering kestrels not previously exposed to heptachlor in the region. Many kestrels nesting in the boxes in 1978 returned to the same vicinity in 1979 and were thus exposed for a 2nd year to heptachlor-contaminated prey. In response to documented wildlife effects (Blus et al. 1979), the use of heptachlor-treated wheat seed was banned on irrigated lands within 10–20 km of the Columbia River in fall 1979. However, even before the ban, publicity regarding wildlife problems associated with HE use seemed to result in reduced use throughout the basin in 1979. Thus, decreased HE residues in the 1980 eggs were an immediate response to the reduced use of heptachlor during the previous late-summer and fall planting season.

Residue declines in populations may be a function of 3 factors: (1) individual birds purging their bodies of contaminants in response to decreased intake of contaminants, (2) population turnover, i.e., new uncontaminated birds entering the population, or (3) a combination of the above. Three adult females were initially banded in 1978 (Table 2). Two were recaptured in 1979 (a year when HE residues in eggs increased in the population); eggs from 1 bird showed an increase in HE residues (1.29 vs. 3.44 ppm) and the other a slight decrease (0.24 vs. 0.15 ppm). However, when the other 1978 female was recaptured in 1981, HE residues in her eggs had declined (0.47 vs. none detected). Two yearling females entered the breeding

Table 2. Residues (ppm wet weight) in eggs of American kestrels from the Columbia Basin, Oregon, in different years (based on recaptures of banded females).

Female	Year	Eggs laid	Young fledged	DDE	HE	Oxychlordane
Banded as adults						
1	1978	5	2		0.24	
	1979	5	4		0.15	
2	1978	5	4	0.69	1.29	0.18
	1979	5	0	1.05	3.44	0.18
3	1978	5	3	3.66	0.47	0.35
	1981	4	0	0.86		
4	1979	5	?			
	1980[a]	5	3	0.43		
	1981	6	2			
Banded as nestlings						
5	1980	(nestling)				
	1981	5	3	0.40		
6	1980	(nestling)				
	1981	6	4	0.12		

[a] Adult female not recaptured in 1980, but may be same bird because it was in the same nest box.

population in 1981 with no HE residues in their eggs. Thus, from recapture information, the HE residue decline during the last 2 years of the study was a function of both factors operating in combination.

Heptachlor Epoxide and Oxychlordane

Technical-grade heptachlor contains 74% heptachlor, 2.5% *trans*-chlordane, and 15% *cis*-chlordane (Stickel et al. 1979); oxychlordane is an oxidation product of both *trans*-chlordane and *cis*-chlordane in rats (Tashiro and Matsumura 1977). Although the annual occurrence of HE and oxychlordane in kestrel eggs varied, as HE concentrations in eggs increased, the incidence of oxychlordane also increased (Table 3). Furthermore, based on eggs in which both contaminants were detected, HE and oxychlordane were significantly ($P < 0.001$) correlated ($\hat{Y} = 0.157 + 0.077X$, $r = 0.615$, $N = 82$). The most likely source of the oxychlordane (detected in 31% of the eggs) was the technical-grade heptachlor used in the Columbia Basin.

Eggshell Thickness

Lincer (1975) and Henny (1977) reported a significant relationship between log-transformed DDE and eggshell thickness in American kestrels. Therefore, the DDE encountered in 87% of the kestrel eggs was expected to result in some shell thinning, which indeed occurred. A significant relationship ($P < 0.001$) between log-transformed DDE and eggshell thickness was shown ($\hat{Y} = 0.192 - 0.009 \log_{10}X$, $r = -0.41$, $N = 230$). We were further interested in knowing if HE was responsible for thinning eggshells. Blus et al. (1979) were unable to demonstrate that HE caused shell thinning in Canada goose eggs. DDE and HE in the kestrel eggs were not ($P > 0.05$) correlated with each other ($\hat{Y} = 0.734 + 0.015X$, $r = 0.08$, $N = 233$). The lack of correlation was probably because the kestrels from the study area winter primarily in Mexico (Henny, unpubl. data) and accumulate DDE on the wintering grounds. HE, however, is accumulated independently on the nesting

Table 3. The relationship between heptachlor epoxide residue levels and occurrence of oxychlordane in American kestrel eggs from the Columbia Basin, Oregon, 1978–81.

Year	N	N eggs with HE (N with oxychlordane ≥0.10 ppm)[a]				
		0.10–0.25	0.26–0.50	0.51–1.00	1.01–2.00	>2.00
1978	83	21 (5)	15 (6)	6 (4)	6 (5)	6 (6)
1979	85	16 (2)	5 (0)	15 (8)	13 (11)	16 (16)
1980	65	6 (1)	9 (4)	6 (3)	4 (3)	3 (3)
1981	28	2 (1)	3 (2)	1 (0)	2 (2)	
Totals		45 (9)	32 (12)	28 (15)	25 (21)	25 (25)
Oxychlordane present		20%	38%	54%	84%	100%

[a] HE categories (ppm wet weight) were divided to provide approximately equal sample sizes.

grounds in Oregon. Lincer and Sherburne (1974) also hypothesized that kestrels nesting in New York accumulated DDE on their wintering grounds. Therefore, the eggs were evaluated to determine if HE was related to shell thickness. No change ($P > 0.05$) in shell thickness occurred in relation to log-transformed egg residues of HE ($\hat{Y} = 0.195 - 0.002 \log_{10}X$, $r = 0.08$, $N = 230$).

Nesting Success and Heptachlor Epoxide

If the data from the first 3 years of the study could be pooled, the ability to detect significant effects of HE on productivity might improve. However, to pool the years, it must be assumed that HE is the only factor responsible for significant annual changes in productivity. Using the data from the negligible effect zone (Table 4), which included those nests with residues ≤1.50 ppm HE in the eggs, we found no difference ($\chi^2 = 0.13$, 2 df, $P > 0.90$) in the percentage of nests that were successful (fledged at least 1 young) in 1978 (79%), 1979 (82%), or 1980 (77%). Thus, the 3 years of data were pooled to evaluate productivity.

The success of nesting attempts and the number of young produced per successful nest and per nesting attempt remained

Table 4. Nesting success of American kestrels in relation to heptachlor epoxide in the eggs, Columbia Basin, Oregon, 1978–80.

Young fledged per nest	N nests according to HE residues (ppm wet weight)				
	0–0.50	0.51–1.50	1.51–3.00	3.01–6.00	>6.0
0	31	9	7	11	2
1	9	4		1	
2	25	4	3	1	
3	34	8		2	
4	46	13	2	2	
5	7	1		1	
6		1			
Total nests	152	40	12	18	2
Mean clutch size	5.0	5.0	4.8	4.8	5.5
Total young fledged	380	99	14	22	0
Nests successful, %[a]	80	78	42	39	0
Mean no. of young					
Per successful nest	3.14	3.19	2.80	3.14	
Per nesting attempt	2.50	2.48	1.17	1.22	

[a] Fledged at least 1 young. Percent nests successful decreased above 1.5 ppm ($\chi^2 = 24.3$, 1 df, $P < 0.01$).

unchanged for the 2 lower HE categories (0.0–0.50 and 0.51–1.50 ppm) (Table 4). Above 1.50 ppm, productivity decreased as HE residues increased. Based on the patterns in the production information (Table 4), the residues of HE in the kestrel eggs were divided into 2 categories—the negligible effect zone (≤1.50 ppm) and the effect zone (>1.50 ppm). The effect zone is defined as that in which reduced reproductive success on a population basis occurs as a result of the contaminant of concern. The cutoff point (1.50 ppm of HE) should not be construed as rigid or fixed except for descriptive purposes. Other investigators may place the cutoff point slightly higher or lower. The total number of kestrel nests and percentage with HE residues in the effect zone during the 4-year study were: 1978, 83, 11%; 1979, 85, 22%; 1980, 65, 8%; and 1981, 28, 4%.

The 20 nests with the highest HE residues (>3.0 ppm) and with production data available were evaluated to determine if the failure of the nests resulted from eggs failing to hatch or mortality of nestlings after hatching. Seven of the 20 nests were successful in fledging at least 1 young, but eggs from a minimum of 11 nests hatched. At 4 unsuccessful nests, all of the nestlings died within a few days after hatching (3–5, 2, 2, and 2 days). Because the number of young fledged per successful nest (Table 4) showed no appreciable change with increasing concentrations of HE in the eggs, partial failures did not seem to occur. Thus, nesting attempts showed either a normal success pattern or total failure. The total failures resulted from either the eggs not hatching at all or complete mortality of the brood during the 1st week.

Nesting Success and DDE

Because DDE was found in most eggs, it could have had a negative and confounding influence on productivity. To evaluate the potential DDE influence, we reviewed the 16 nests in which >5 ppm was detected in the eggs (Table 5). DDE residues of 5–12 ppm had little or no influence on productivity, i.e., 11 of 13 nests (85%) were successful in fledging at least 1 young and 1 of the unsuccessful nests had HE residues in the effect zone. Production rates were 2.91 young/successful nest and 2.46 young/nesting attempt, which compares favorably with the lowest HE categories (Table 4). Only 1 young was produced from the 3 nests with the highest DDE residues, but eggs from the 2 unsuccessful nests contained HE in the effect zone.

Table 5. Records of the 16 American kestrel nests with the highest egg residues of DDE (ppm wet weight), Columbia Basin, Oregon, 1978–80.

Clutch size	Young fledged	Eggshell thickness (mm)	DDE	DDT	HE
5	4	0.190	5.1	0.45	0.51
4	0	0.190	5.4		1.7[a]
3+	2	0.190	5.7		0.43
5	2	0.194	5.7		0.13
6	5	0.204	5.8		0.47
5	4	0.172	8.4	0.74	0.43
6	0	0.168	8.9		0.14
5	1	0.155	9.6		
5	4	0.165	10	0.28	
5	3	0.176	11		0.18
4	1	0.175	11	0.27	0.48
5	3	0.174	11	1.4	
5	3	0.180	12	0.52	
5	0	0.179	37	0.77	5.8[a]
5	0	0.159	38	5.6	4.3[a]
4	1	0.163	100	0.18	0.25

[a] HE effect zone.

The data on kestrel eggs (Table 5) were divided into 3 DDE categories, with the following shell thickness (mm) measurements ($\bar{x} \pm$ SE): 5–6 ppm, 0.194 ± 0.003; 8–12 ppm, 0.171 ± 0.003; and 36–100 ppm, 0.167 ± 0.006. Compared with the pre-1947 eggshell thickness of 0.211 mm in interior and northern North America (Anderson and Hickey 1972), the categories average 8, 19, and 21% shell thinning, respectively.

Table 6. Other contaminants[a] detected in American kestrel eggs from the Columbia Basin, Oregon, 1978–81.

Year	*N*	Oxychlordane	HCB	DDT	Dieldrin	*trans*-nonachlor
1978	83	26 (1.2)[b]	9 (2.3)	12 (5.6)	9 (3.9)	7 (0.82)
1979	85	38 (0.86)	6 (0.53)	5 (0.77)	11 (2.7)	8 (0.48)
1980	65	14 (0.48)	4 (2.4)	2 (0.54)	4 (0.30)	2 (0.34)
1981	28	5 (0.20)	3 (0.24)		1 (0.10)	

[a] Other contaminants detected (≥0.10 ppm) besides those listed included: 1978, 6 eggs with β-BHC (5.5), 3 eggs with *cis*-chlordane (0.16), 2 eggs with lindane (0.17), and 1 egg with DDD (0.69); 1979, 1 egg with DDD (0.12); 1980, 3 eggs with PCB's (1.0).
[b] Number of eggs with contaminant detected (highest concentration detected, ppm wet weight).

Adult Mortality

One pair of kestrels nesting in 1979 was unique in 2 ways: (1) the 9.1 ppm of HE in the egg collected was the highest obtained during this study, and (2) the adult female was later found dead with a lethal (Stickel et al. 1979) HE concentration (28 ppm) in her brain. The adult female was caught in the nest box and banded on 11 May 1979. At that time she had laid 4 eggs and a 5th was in her oviduct. She was found dead in the box with a dead 1–2-day-old chick on 23 June. No other eggs or young were present at the time. Based on the age of the dead young, she probably died on about 10 or 11 June. Residues (ppm wet weight) in the egg collected on 11 May and her brain were respectively 9.1 and 28 HE; 0.63 and 2.5 oxychlordane; 0.33 and 0.95 *trans*-nonachlor; none detected and 0.14 *cis*-nonachlor; 0.33 and 0.35 DDE; and none detected and 0.21 HCB.

Other Contaminants

Of the other contaminants detected (Table 6), dieldrin, HCB, and β-BHC are important. These 3 contaminants were found in eggs in concentrations up to 3.9, 2.4, and 5.5 ppm, respectively. Only 5 eggs contained dieldrin at concentrations above 1 ppm: 3.9, 3.8, 2.7, 2.4, and 2.2. The numbers of young fledged from each nest were 4, 0, 3, 0, and 3, respectively. The eggs from the 2 nesting attempts that failed also contained DDE, 0.17 and 1.0 ppm; HE, 0.35 and 1.7 ppm; and oxychlordane, 0.11 and 0.15 ppm. Possibly 1 or 2 of the 233 nests were impacted by dieldrin. However, HE in one of these eggs was in the effect zone. Normally, about 80% (4 of 5) of all nests yield fledged young (Table 4).

Residues of HCB were found in 5 eggs at concentrations above or equal to 0.50 ppm: 2.4, 2.3, 0.86, 0.53, and 0.50. These nests were all successful and fledged 5, 4, 3, 4, and 3 young, respectively. All but 1 egg laid in this series yielded fledged young. One female nestling, from the clutch containing 0.86 ppm HCB, died at about 3 weeks of age. HCB at the concentrations found in this study did not affect productivity.

Residues of β-BHC at concentrations over 0.50 ppm were found in only 1 egg. The nest contained an egg with 5.5 ppm, but it was successful and fledged 3 young.

The above findings suggest that dieldrin, HCB, and β-BHC were not significantly confounding the analysis of the impact of HE on American kestrel productivity. *Trans*-nonachlor, *cis*-chlordane, lindane, and PCB's were found infrequently and at low concentrations.

CONCLUSIONS

Blus et al. (1979) showed that HE was responsible for adult mortality and reduced hatching success of Canada geese nesting in the Columbia Basin. Our study provides evidence that productivity of the American kestrel was also adversely impacted by HE. Adult mortality was more difficult to document with kestrels than with the larger geese. We know the adult female that laid the egg containing the highest HE concentration died on the nest with a lethal amount of HE in her brain. Geese were believed to have fed on the heptachlor-treated seeds directly, whereas American kestrels are not seed eaters. Thus, the presence of HE in kestrel eggs indicates contamination of food chains in the region.

Heptachlor epoxide does not thin American kestrel eggs, which is in agreement with earlier findings for Canada geese (Blus et al. 1979). However, the presence of DDE in the kestrel eggs was responsible for some shell thinning. An evaluation of DDE and the other more commonly detected contaminants found in the kestrel eggs showed minimal, if any, confounding influence on productivity. Therefore, we conclude that HE above 1.5 ppm in kestrel eggs adversely affects productivity. These data show that kestrels are more sensitive to HE in eggs than are Canada geese whose hatching success declined when HE residues were above 10 ppm (Blus et al. 1979).

Concentrations of DDE during the 4-year study fluctuated, but no significant changes occurred. However, when heptachlor use within 10–20 km of the Columbia River was restricted after the 1979 nesting season, HE residues in kestrel eggs declined ($P < 0.05$) from 1979 to 1980, and continued to decline in 1981. The percentage of kestrel nests in the HE effect zone declined from 22% in 1979 to 8% in 1980, and to 4% in 1981.

LITERATURE CITED

ANDERSON, D. W., AND J. J. HICKEY. 1972. Eggshell changes in certain North American birds. Proc. Int. Ornithol. Congr. 15:514–540.

ANONYMOUS. Various dates. Pacific Northwest insect control handbook. Compiled and edited annually by extension entomologists of Oregon State Univ., Washington State Univ., and Univ. Idaho. Oreg. State Univ. Book Stores, Inc., Corvallis.

BLUS, L. J., C. J. HENNY, D. J. LENHART, AND E. CROMARTIE. 1979. Effects of heptachlor-treated cereal grains on Canada geese in the Columbia basin. Pages 105–116 *in* R. L. Jarvis and J. C. Bartonek, eds. Management and biology of Pacific Flyway geese: a symposium. Oreg. State Univ. Book Stores, Inc., Corvallis.

BROWN, L., AND D. AMADON. 1968. Eagles, hawks, and falcons of the world. McGraw-Hill Book Co., New York, N.Y. 945 pp.

CROMARTIE, E., W. L. REICHEL, L. N. LOCKE, A. A. BELISLE, T. E. KAISER, T. G. LAMONT, B. M. MULHERN, R. M. PROUTY, AND D. M. SWINEFORD. 1975. Residues of organochlorine pesticides and polychlorinated biphenyls and autopsy data for bald eagles, 1971–72. Pestic. Monit. J. 9:11–14.

HENNY, C. J. 1977. Birds of prey, DDT, and tussock moths in Pacific Northwest. Trans. North Am. Wildl. and Nat. Resour. Conf. 42:397–411.

KAISER, T. E., W. L. REICHEL, L. N. LOCKE, E. CROMARTIE, A. J. KRYNITSKY, T. G. LAMONT, B. M. MULHERN, R. M. PROUTY, C. J. STAFFORD, AND D. M. SWINEFORD. 1980. Organochlorine pesticide, PCB, and PBB residues and necropsy data for bald eagles from 29 states—1975–77. Pestic. Monit. J. 13:145–149.

LINCER, J. L. 1975. DDE-induced eggshell thinning in the American kestrel: a comparison of the field situation and laboratory results. J. Appl. Ecol. 12:781–793.

———, AND J. A. SHERBURNE. 1974. Organochlorines in kestrel prey: a north-south dichotomy. J. Wildl. Manage. 38:427–434.

STICKEL, L. F., S. N. WIEMEYER, AND L. J. BLUS. 1973. Pesticide residues in eggs of wild birds: adjustment for loss of moisture and lipid. Bull. Environ. Contam. and Toxicol. 9:193–196.

———, W. H. STICKEL, R. D. MCARTHUR, AND D. L. HUGHES. 1979. Chlordane in birds: a study of lethal residues and loss rates. Pages 387–396 *in* W. B. Deichmann, organizer. Toxicology and occupational medicine. Elsevier/North Holland, Inc., New York, N.Y.

TASHIRO, S., AND F. MATSUMURA. 1977. Metabolic routes of *cis*- and *trans*-chlordane in rats. J. Agric. Food Chem. 25:872–880.

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