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Authors: Sundlof, Stephen F., Forrester, Donald J., Thompson, Neal P., and Collopy, Michael W.

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RESIDUES OF CHLORINATED HYDROCARBONS IN TISSUES OF RAPTORS IN FLORIDA

Stephen F. Sundlof,[1] Donald J. Forrester,[2] Neal P. Thompson,[3] and Michael W. Collopy[4]

ABSTRACT: Dead or moribund raptors ($n = 75$) representing 11 species were collected between 1971 and 1981 from various locations in Florida. Samples of brain, muscle, liver and adipose tissue were analyzed for DDT, DDE, DDD, dieldrin, and PCB's. Detectable concentrations of DDT or its metabolites were found in 100% of all samples of muscle and liver, and 77% all samples of brain. Dieldrin was determined to be present in 91%, 93%, 87% and 78% of all samples of brain, muscle, liver and adipose tissue, respectively. Lethal or hazardous concentrations of dieldrin were found in brain samples from three birds, but DDT and PCB's were present at sublethal concentrations. When species were grouped according to their dietary habits, it was not possible to identify any trends in pesticide concentrations.

INTRODUCTION

Global contamination of the environment by chemically stable chlorinated hydrocarbon compounds has been recognized as one of the unfortunate side effects of an industrial society. As one method for assessing nationwide environmental contamination, tissues from birds have been analyzed for organochlorine residues through the National Pesticide Monitoring Program (White, 1979a, b). Environmental contamination by DDT and related chemicals is thought to be partly responsible for declining populations of raptors by interfering with reproduction (Wiemeyer and Porter, 1970; Spitzer et al., 1978; Wiemeyer et al., 1978). DDT and dieldrin also have been implicated as the direct cause of death in several species of raptors (Bernard, 1962; Coon et al., 1970; Mulhern et al., 1970; Belisle et al., 1972; Porter and Wiemeyer, 1972; Wiemeyer et al., 1975; Henny et al., 1976; Prouty et al., 1977; Kaiser et al., 1980; Wiemeyer and Cromartie, 1981; Prouty et al., 1982). Since sales in the United States were halted for DDT in 1972, dieldrin in 1974 (Klaassen, 1980) and PCB's in 1979 (Craddock, pers. comm.), researchers have attempted to determine whether tissue residues of these compounds have declined in raptor populations. Prouty et al. (1977) found no decline in DDE residues in carcasses of bald eagles (*Haliaeetus leucocephalus*) collected in 1973 and 1974; however, Spitzer et al. (1978) found that the mean concentration of DDE in eggs of ospreys (*Pandion haliaetus*) declined by a factor of five from 1969 to 1976 and by a factor of three from 1973 to 1976; dieldrin declined by a factor of four between 1969 and 1976, and no apparent decline in mean concentrations of PCB's occurred during this time period. Johnston (1978) determined concentrations of dieldrin, DDT, and related compounds in adipose tissue, uropygial glands, and brains of 71 raptors (representing 14 different species) in Florida. He found no significant change in concentrations of pesticides in birds collected between 1973 and 1976. As a follow up to Johnston's study, tissues from 75 raptors collected between 1971 and 1981 in Flo-

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[1] Department of Physiological Sciences, College of Veterinary Medicine, University of Florida, Gainesville, Florida 32610, USA.

[2] Department of Infectious Diseases, College of Veterinary Medicine, University of Florida, Gainesville, Florida 32610, USA.

[3] Department of Food Science and Human Nutrition, University of Florida, Gainesville, Florida 32611, USA.

[4] Department of Wildlife and Range Sciences, School of Forest Resources and Conservation, University of Florida, Gainesville, Florida 32611, USA.

TABLE 1. Location of 75 raptors collected in Florida between 1971 and 1981.

County	Species of raptor[a]										
	American kestrel	Barred owl	Black vulture	Common barn-owl	Cooper's hawk	Eastern screech-owl	Great horned owl	Osprey	Red-shouldered hawk	Red-tailed hawk	Sharp-shinned hawk
Alachua	1	4	1	0	0	4	2	0	2	2	1
Citrus	1	0	0	0	0	1	0	1	0	0	0
Duval	0	0	0	0	1	0	1	0	0	0	0
Gadsden	0	0	0	0	0	0	0	0	1	0	0
Hernando	0	1	0	0	0	0	0	0	0	0	0
Hillsborough	0	1	0	1	0	4	0	2	1	0	0
Lafayette	0	0	0	0	0	1	0	0	0	0	0
Lake	0	1	0	0	0	0	0	1	2	0	0
Levy	0	1	0	0	0	0	0	0	0	0	0
Marion	0	1	0	0	0	0	0	0	0	0	0
Palm Beach	1	0	0	0	0	0	0	0	0	0	0
Pasco	0	1	0	0	0	1	0	0	0	0	0
Pinellas	15	0	0	0	0	8	0	0	1	0	1
Polk	0	0	0	0	0	0	0	0	0	0	1
Putnam	0	1	0	0	0	1	0	0	0	0	0
Sumter	0	1	0	0	0	0	0	0	0	0	0
Taylor	0	0	0	0	0	0	0	0	1	0	0
Union	0	0	0	0	0	0	0	0	1	0	0
Unknown	0	0	0	0	0	0	1	0	0	0	0
Totals	18	12	1	1	1	20	4	4	9	2	3

[a] American kestrel = *Falco sparverius*, Barred owl = *Strix varia*, Black vulture = *Coragyps atratus*, Common barn-owl = *Tyto alba*, Cooper's hawk = *Accipiter cooperii*, Eastern screech-owl = *Otus asio*, Great horned owl = *Bubo virginianus*, Osprey = *Pandion haliaetus*, Red-shouldered hawk = *Buteo lineatus*, Red-tailed hawk = *Buteo jamaicensis*, Sharp-shinned hawk = *Accipiter striatus*.

rida were analyzed for DDT and its metabolites, dieldrin, and PCB's, with major emphasis on the years 1974–1978.

MATERIALS AND METHODS

Three different tissues representing three major organ systems were chosen for analysis of residues of chlorinated hydrocarbons in raptors from Florida. Muscle was chosen because it represents a major portion of the body mass and therefore, most closely reflects the total body burden of the compound. Liver was chosen because it is a major site of metabolism and excretion of chlorinated hydrocarbon compounds, and because it is the first organ exposed to these substances following absorption from the gastrointestinal tract. Brain was chosen because of the correlation between clinical disease and brain concentrations of chlorinated hydrocarbon compounds (Heinz et al., 1979). A limited number of adipose tissue samples were also analyzed.

Sampling methods: Most birds were obtained from north-central Florida. Table 1 shows the various counties and species of birds collected in Florida between 1971 and 1981. Most birds were fresh road-kills, some were illegal kills, and a few were birds found in a weakened condition. Whenever possible, historical information was recorded pertaining to the physical condition of the bird when it was found. During necropsy, tissues were removed from carcasses, wrapped first in aluminum foil, then sealed in plastic bags to minimize dehydration during storage at −20 C. Ten to 15 g samples of liver, brain and breast muscle were analyzed for chlorinated hydrocarbons. All data are reported based on wet sample weights and no attempts were made to compensate for dehydration of samples during storage.

Analytical methods: Two analytical methods were utilized to quantitatively determine concentrations of chlorinated hydrocarbon compounds in tissues. Samples of muscle, liver, brain and fat from raptors collected prior to May 1975 were extracted and analyzed according to the methods of Thompson et al. (1977). This included the use of a Varian 2100 gas chromatograph equipped with a 1.8 m × 0.6 cm o.d. glass column containing 1:1 6.4% OV-210/1.6% OV-17 on Chromosorb W and a tritium electron capture detector.

For birds collected from May 1975 through February 1981, brain was the only tissue analyzed. DDT and metabolites were measured according to the method of Smrek and Needham (1982). This method has been utilized also for analysis of PCB's, but because of inconsistent recovery of PCB's by this method in our laboratory, no results for PCB residues are reported in tissues from birds collected after 1975. Similarly, dieldrin was not analyzed in samples from birds collected after 1975. For analysis of samples, a Hewlett Packard model 5880 gas chromatograph equipped with a 6′ × ¼″ o.d. glass column containing 1.5% SP2250/1.95% SP2401 on 100/120 mesh Supelcoport and a nickel 63 electron capture detector was utilized. Recovery of DDE, DDD and DDT from brain was determined to be 94%, 100% and 97%, respectively. Confirmation of the identity of these compounds was accomplished by the addition of authentic DDE, DDD and DDT to the samples, and subsequent chromatography at various conditions of column temperature and carrier gas flow rate. Concentrations of DDE, DDD and DDT less than 0.01 μg/g were considered non-detectable. To ensure that methods 1 and 2 yielded comparable results, brain samples analyzed by method 2 were subjected to confirmatory analysis by method 1. Variation between the two methods was less than 10%. Only the *p*, *p*′ isomers of DDT and metabolites were analyzed.

RESULTS

Concentrations of DDT, dieldrin and PCB's are presented in Tables 2–4. In individual birds collected over the 11-yr period, detectable concentrations of DDT or its metabolites were found in all samples of muscle ($n = 42$), liver ($n = 39$) and adipose tissue ($n = 9$) and 77% of all samples of brain ($n = 65$). Of the tissues which were analyzed for dieldrin, detectable concentrations were present in 97%, 93%, 87% and 78% of the samples of brain ($n = 32$), muscle ($n = 42$), liver ($n = 39$) and adipose tissue ($n = 9$), respectively. PCB's were detected in all samples of brain ($n = 32$), muscle ($n = 42$), liver ($n = 39$) and adipose tissue ($n = 9$) which were analyzed for these substances. The chromatographic profile of the PCB's most closely resembled that of Aroclor 1260. Variation in concentrations of chlorinated hydrocarbon compounds between individual birds was quite large, often spanning several orders of magnitude. Because of the small number of individuals within a species collected during a single year, the various species of raptors were grouped together based on their dietary habits in order to compare yearly fluctuations in tissue concentrations of chlorinated hydrocarbon compounds. Birds were classified as insectivores (eastern screech-owls and American kestrels), piscivores (ospreys) or omnivores (all remaining species). Yearly comparisons were made of muscle total DDT, dieldrin and PCB concentrations in raptors collected from 1971 through 1976. No trends indicating increasing or declining concentrations of DDE, dieldrin or PCB within the population were noted (Figs. 1–3).

DISCUSSION

Of the 32 brains analyzed for dieldrin, two contained concentrations considered to be in the hazardous range (5.0–8.9 ppm, Ohlendorf et al., 1981). Only one bird, a red-shouldered hawk, was found to contain a sufficient concentration of dieldrin in the brain to cause death (>9 ppm, Ohlendorf et al., 1981). Historical observations reported by the individual who discovered this bird in a weakened condition, indicated a possible poisoning. Information on the three birds containing toxic concentrations of dieldrin is presented in Table 5. Minimum lethal concentrations of dieldrin in brain tissue of bald eagles have been reported to range from 3.9 μg/g (Prouty et al., 1977) to 8 μg/g (Coon et al., 1970). Lethal concentrations of dieldrin between these values also have been reported in bald eagles (Belisle et al., 1972; Kaiser et al., 1980). Death in an osprey was attributed to poisoning by dieldrin when it was determined that concentra-

TABLE 2. Concentrations of chlorinated hydrocarbons in brain, muscle and liver of insectivorous raptors in Florida, 1971–1978.

						Concentration (μg/g wet weight of tissue)[a]						
Species and date collected	County	Age[b]	Sex	Wt. (g)	Sample[c]	DDE	DDD	DDT	Total[d] DDT	DDT[e] equivalents	Dieldrin	PCB
American kestrel												
12/25/71	Palm Beach	A	F	80	L	11.00	1.60	0.00	13.00		0.40	5.30
					M	9.80	0.00	0.00	9.80		0.44	8.90
11/12/74	Pinellas	A	M	100	B	1.20	0.00	0.00	1.20	0.08	4.10	0.92
					L	4.00	0.00	0.00	4.00		15.00	2.40
					M	2.20	0.00	0.00	2.20		7.20	2.10
11/26/74	Pinellas	A	M	100	B	0.70	0.00	0.00	0.70	0.05	0.91	1.80
					L	1.80	0.00	0.00	1.80		2.30	5.00
					M	2.80	0.00	0.00	2.80		2.70	8.10
11/26/74	Pinellas	A	F	100	B	0.40	0.00	0.00	0.40	0.03	0.21	15.00
					L	0.38	0.00	0.00	0.38		0.49	12.00
					M	0.70	0.00	0.00	0.70		0.53	19.00
12/3/74	Pinellas	A	M	102	B	0.71	0.14	0.19	1.00	0.27	1.40	0.51
					L	3.30	0.00	0.00	3.30		5.80	1.60
					M	2.60	0.00	0.00	2.60		5.10	1.00
12/3/74	Pinellas	A	M	101	B	1.40	0.22	0.00	1.60	0.14	0.34	2.30
					L	3.50	0.00	0.00	3.50		1.40	1.10
					M	9.30	0.54	0.00	9.80		2.30	5.40
12/05/74	Pinellas	A	M	100	B	0.18	0.00	0.00	0.18	0.01	0.32	1.00
					L	1.30	0.00	0.00	1.30		1.50	12.00
					M	0.22	0.00	0.00	0.22		0.30	2.90
12/14/74	Pinellas	U[f]	M	100	B	1.70	0.00	0.00	1.70	0.11	1.40	5.20
					L	1.90	0.00	0.00	1.90		1.70	7.30
					M	3.60	0.28	0.39	4.30		2.60	13.00
12/15/74	Pinellas	A	F	U	B	0.07	0.00	0.00	0.07	0.00	0.80	2.80
					L	0.42	0.00	0.00	0.42		7.00	21.00
					M	0.44	0.00	0.00	0.44		9.50	28.00
1/1/75	Pinellas	A	M	98	B	0.90	0.00	0.00	0.90	0.06	1.10	1.40
					L	1.50	0.00	0.00	1.50		1.90	2.40
					M	2.80	0.00	0.00	2.80		2.80	4.90
1/1/75	Pinellas	A	M	101	B	0.93	0.00	0.00	0.93	0.06	6.80	0.49
					L	2.10	0.00	0.00	2.10		1.00	2.00
					M	5.20	0.00	0.00	5.20		4.00	2.20
1/10/75	Pinellas	A	M	100	B	0.84	0.00	0.00	0.84	0.06	4.00	4.10
					L	1.50	0.00	0.00	1.50		7.00	6.30
					M	4.20	0.00	0.00	4.20		9.30	8.70
1/16/75	Pinellas	U	F	103	B	1.30	0.00	0.00	1.30	0.09	1.70	2.30
					L	6.40	0.00	0.00	6.40		6.00	11.00
					M	3.10	0.00	0.00	3.10		3.10	5.20
2/23/75	Pinellas	U	M	100	B	1.00	0.00	0.00	1.00	0.07	0.96	3.60
					L	1.90	0.00	0.00	1.90		1.50	6.70
					M	1.40	0.00	0.00	1.40		1.10	2.80
3/6/75	Pinellas	U	U	U	B	0.86	0.00	0.00	0.86	0.06	0.75	2.80
					L	2.40	0.00	0.00	2.40		2.50	5.60
					M	3.00	0.00	0.00	3.00		2.50	8.80
4/22/76	Pinellas	A	F	97	B	0.00	0.00	0.00	0.00	0.00	N.A.[g]	N.A.

TABLE 2. Continued.

Species and date collected	County	Age[b]	Sex	Wt. (g)	Sample[c]	Concentration (μg/g wet weight of tissue)[a] DDE	DDD	DDT	Total[d] DDT	DDT[e] equivalents	Dieldrin	PCB
1/14/77	Citrus	A	M	105	B	0.00	0.00	0.00	0.00	0.00	N.A.	N.A.
1/23/77	Alachua	A	M	108	B	0.00	0.00	0.00	0.00	0.00	N.A.	N.A.
Eastern screech-owl												
7/10/74	Alachua	A	F	100	B	13.00	0.00	0.00	13.00	0.87	1.00	3.80
					L	45.00	0.00	0.00	45.00		2.40	5.80
					M	20.00	0.23	0.68	21.00		1.20	3.80
9/30/74	Alachua	A	F	110	L	1.70	0.00	0.10	1.80		0.02	0.58
					M	1.10	0.00	0.08	1.20		0.01	0.38
10/31/74	Hillsborough	U	U	U	L	0.15	0.00	0.00	0.15		0.02	0.09
					M	0.13	0.00	0.00	0.13		0.01	0.11
3/1/75	Hillsborough	A	M	80	M	2.00	0.00	0.03	2.00		0.04	1.70
					L	2.20	0.00	0.00	2.20		0.09	0.92
5/18/75	Pinellas	A	F	100	B	69.00	0.00	0.00	69.00	4.60	N.A.	N.A.
6/11/75	Hillsborough	J	M	60	B	5.50	0.00	0.00	5.50	0.37	N.A.	N.A.
6/11/75	Hillsborough	A	M	106	B	2.40	0.00	0.00	2.40	0.16	N.A.	N.A.
6/20/75	Pinellas	A	M	70	B	0.56	0.00	0.00	0.56	0.04	N.A.	N.A.
6/30/75	Pinellas	A	F	99	B	0.00	0.00	0.00	0.00	0.00	N.A.	N.A.
9/24/75	Pasco	J	M	60	B	1.60	0.56	0.28	2.40	0.50	N.A.	N.A.
12/28/75	Pinellas	A	F	78	B	0.10	0.00	0.00	0.10	0.01	N.A.	N.A.
5/7/76	Lafayette	A	M	76	B	11.00	0.00	0.00	11.00	0.74	N.A.	N.A.
5/16/76	Pinellas	J	U	68	B	2.00	0.00	0.60	2.60	0.73	N.A.	N.A.
5/17/76	Pinellas	J	M	67	B	18.00	2.40	0.00	20.00	1.70	N.A.	N.A.
5/31/76	Pinellas	J	U	75	B	3.20	0.00	0.00	3.20	0.21	N.A.	N.A.
6/13/76	Pinellas	A	M	88	B	13.00	0.00	0.00	13.00	0.87	N.A.	N.A.
1/12/77	Citrus	A	F	112	B	0.00	0.00	0.00	0.00	0.00	N.A.	N.A.
12/13/77	Putnam	A	F	112	B	0.00	0.00	0.00	0.00	0.00	N.A.	N.A.
1/11/78	Alachua	A	F	123	B	0.00	0.00	0.00	0.00	0.00	N.A.	N.A.
4/4/78	Alachua	A	F	191	B	0.15	0.00	0.00	0.15	0.01	N.A.	N.A.

[a] All values are rounded to two significant digits.
[b] A = adult, J = juvenile.
[c] L = liver, M = muscle, B = brain.
[d] Total DDT is the sum of the tissue concentrations of DDE, DDD and DDT.
[e] DDT equivalents = DDT + (0.067 × DDE) + (0.20 × DDD) according to the equation of Stickel et al. (1970).
[f] U = unknown.
[g] N.A. = not analyzed.

tions in brain tissue were in excess of 7 μg/g (Wiemeyer et al., 1975). In Japanese quail (*Coturnix coturnix japonica*) and rock doves (*Columba livia*), concentrations of dieldrin in brain tissues of 17 and 10 μg/g, respectively, also have been associated with mortality (Robinson et al., 1967).

Lethal concentrations of DDE in brains of raptors have been reported to exceed 200 μg/g (Belisle et al., 1972; Porter and Wiemeyer, 1972; Henny et al., 1976; Prouty et al., 1982). The highest concentration of DDE in the 62 raptors sampled in this study was 69 μg/g in the brain of an eastern screech-owl collected in 1975. Based on the equation of Stickel et al. (1970), this amounts to 4.6 μg/g as DDT equivalents, less than one-half of the lowest concentration associated with mortality. Consequently, it is unlikely that any of these birds died as a direct result of DDT poisoning.

The highest concentration of PCB's

TABLE 3. Concentrations of chlorinated hydrocarbons in brain, muscle, liver and fat of omnivorous raptors in Florida, 1971–1981.

Species and date collected	County	Age[b]	Sex	Wt. (g)	Sample[c]	DDE	DDD	DDT	Total[d] DDT	DDT[e] equivalents	Dieldrin	PCB
						Concentration (μg/g wet weight of tissue)[a]						
Barred owl												
6/8/73	Alachua	A	F	550	L	28.00	0.39	0.00	28.00		3.80	64.00
					M	7.90	0.25	0.51	8.70		0.87	15.00
12/28/73	Marion	A	F	860	B	0.31	0.03	0.00	0.34	0.03	0.23	0.29
					F	30.00	0.00	0.58	31.00		0.00	2.30
					L	1.70	0.00	0.01	1.80		0.00	0.23
					M	0.93	0.03	0.00	0.96		0.00	0.04
1/1/74	Lake	U[f]	U	U	B	0.08	0.00	0.00	0.08	0.01	0.10	0.06
					L	0.23	0.01	0.00	0.24		0.28	0.17
					M	0.08	0.00	0.00	0.08		0.08	0.06
3/1/75	Hillsborough	A	M	450	B	0.55	0.01	0.00	0.56	0.04	0.00	0.36
					L	1.30	0.00	0.00	1.30		0.00	0.55
					M	0.43	0.02	0.03	0.48		0.00	0.22
4/1/75	Putnam	A	F	662	F	2.10	0.00	0.00	2.10		0.00	1.80
					L	0.34	0.00	0.00	0.34		0.00	0.81
					M	0.12	0.00	0.00	0.12		0.00	0.15
10/7/75	Hernando	A	U	650	B	0.00	0.00	0.00	0.00	0.00	N.A.[g]	N.A.
11/21/75	Pasco	A	F	863	B	0.00	0.00	0.00	0.00	0.00	N.A.	N.A.
3/4/76	Alachua	A	M	720	B	0.00	0.00	0.00	0.00	0.00	N.A.	N.A.
8/29/76	Sumpter	A	U	790	B	0.00	0.00	0.00	0.00	0.00	N.A.	N.A.
9/24/76	Levy	A	U	750	B	0.00	0.00	0.00	0.00	0.00	N.A.	N.A.
10/15/76	Alachua	A	F	760	B	0.90	0.00	0.00	0.90	0.06	N.A.	N.A.
12/24/77	Alachua	A	F	822	B	0.00	0.00	0.00	0.00	0.00	N.A.	N.A.
Black vulture												
3/28/72	Alachua	U	U	U	F	3.00	0.98	0.52	4.50		0.71	3.80
					M	0.13	0.03	0.00	0.16		0.02	0.29
Common barn-owl												
3/12/75	Hillsborough	A	M	400	L	0.11	0.00	0.00	0.11		0.18	0.45
					M	1.50	0.00	0.00	1.50		0.26	2.10
					F	2.30	0.00	0.00	2.30		0.72	3.60
Cooper's hawk												
1/1/75	Duval	U	U	U	B	8.90	0.00	0.00	8.90	0.60	2.40	0.32
					L	23.00	0.00	0.00	23.00		5.60	2.00
					M	5.70	0.00	0.00	5.70		1.40	1.50
Great horned owl												
11/27/73	Alachua	A	M	700	L	8.90	0.00	0.00	8.90		0.00	1.60
1/27/74	Alachua	A	F	890	B	26.00	0.00	0.00	26.00	1.70	1.10	12.00
					L	53.00	0.00	0.00	53.00		2.00	26.00
					M	1.70	0.00	0.00	1.70		0.6	0.83
7/11/74	Duval	A	F	900	B	6.50	0.25	0.00	6.80	0.49	0.36	2.50
					L	12.00	0.00	0.00	12.00		5.40	15.00
					M	2.30	0.00	0.00	2.30		0.13	0.59
6/25/76		U	U	U	B	0.00	0.00	0.00	0.00	0.00	N.A.	N.A.
Red-shouldered hawk												
6/1/74	Lake	A	M	360	B	1.00	0.00	0.00	1.00	0.07	6.00	0.28
					M	1.20	0.00	0.00	1.20		4.20	0.95

TABLE 3. Continued.

Species and date collected	County	Age[b]	Sex	Wt. (g)	Sample[c]	Concentration (μg/g wet weight of tissue)[a]						
						DDE	DDD	DDT	Total[d] DDT	DDT[e] equivalents	Dieldrin	PCB
6/13/74	Alachua	A	M	420	B	0.09	0.00	0.00	0.09	0.01	0.00	0.37
					L	0.23	0.00	0.00	0.23		0.01	0.31
					M	0.11	0.00	0.00	0.11		0.31	0.13
7/7/74	Alachua	A	F	390	B	0.57	0.00	0.00	0.57	0.04	0.61	2.70
					L	1.50	0.12	0.30	1.90		1.10	3.50
					M	0.20	0.00	0.00	0.20		0.12	0.64
9/22/74	Lake	A	M	420	B	0.21	0.00	0.00	0.21	0.01	0.27	0.46
					L	0.71	0.00	0.00	0.71		0.74	0.58
					M	0.31	0.00	0.00	0.31		0.27	0.19
12/15/74	Pinellas	J	U	500	B	1.30	0.00	0.52	1.80	0.61	11.00	1.80
					L	1.60	0.50	0.00	2.10		11.00	0.25
					M	2.50	0.37	0.16	3.00		14.00	0.31
2/5/75	Hillsborough	A	F	500	B	0.13	0.00	0.00	0.13	0.01	2.60	1.50
					L	0.23	0.00	0.00	0.23		3.40	3.50
					M	0.53	0.00	0.00	0.53		4.20	7.90
2/21/77	Taylor	A	F	U	B	1.30	0.00	0.00	1.30	0.09	N.A.	N.A.
9/2/77	Union	A	F	370	B	0.50	0.00	0.00	0.50	0.03	N.A.	N.A.
1/31/81	Gadsden	A	F	660	B	0.80	0.00	1.20	2.00	1.30	N.A.	N.A.
Red-tailed hawk												
12/28/74	Alachua	J	F	1,130	B	0.02	0.00	0.00	0.02	0.00	0.01	0.14
					F	1.90	0.14	0.23	2.30		0.32	1.60
					L	0.12	0.01	0.00	0.13		0.16	0.34
					M	0.09	0.01	0.02	0.12		0.02	0.11
1/21/75	Alachua	A	F	1,220	B	0.04	0.00	0.00	0.04	0.00	0.03	0.08
					L	0.04	0.01	0.00	0.05		0.02	0.10
					M	0.06	0.01	0.01	0.08		0.02	0.15
Sharp-shinned hawk												
12/25/71	Polk	A	F	110	F	19.00	0.00	0.00	19.00		0.45	6.30
					L	0.24	0.00	0.00	0.24		0.01	0.23
					M	0.66	0.00	0.00	0.66		0.02	0.56
10/24/74	Pinellas	A	M	110	B	0.25	0.00	0.00	0.25	0.02	0.04	0.05
					F	22.00	0.00	0.67	23.00		1.50	2.50
					L	2.10	0.00	0.13	2.20		0.16	0.33
					M	0.70	0.00	0.00	0.70		0.08	0.26
12/18/77	Alachua	A	F	127	B	8.50	0.00	0.00	8.50	0.57	N.A.	N.A.

[a] All values are rounded to two significant digits.
[b] A = adult, J = juvenile.
[c] L = liver, M = muscle, B = brain, F = fat.
[d] Total DDT is the sum of the tissue concentrations of DDE, DDD and DDT.
[e] DDT equivalents = DDT + (0.067 × DDE) + (0.20 × DDD) according to the equation of Stickel et al. (1970).
[f] U = unknown.
[g] N.A. = not analyzed.

found in any tissue was 64 μg/g in the liver of a barred owl. Lethal carcass concentrations (lipid weight basis) of PCB's in raptors have been projected to be about 26,000 μg/g (Wiemeyer and Cromartie, 1981). As with DDT and metabolites, it is highly unlikely that PCB's were the proximate cause of death in any of the 42 birds sampled in this study.

Concentrations of DDT and metabo-

TABLE 4. Concentrations of chlorinated hydrocarbons in brain, muscle, liver and fat of ospreys in Florida, 1974–1975.

Species and date collected	County	Age[b]	Sex	Wt. (g)	Sample[c]	Concentration (μg/g wet weight of tissue)[a] DDE	DDD	DDT	Total[d] DDT	DDT[e] equivalents	Dieldrin	PCB
Osprey												
6/1/74	Lake	A	M	1,160	B	0.02	0.00	0.00	0.02	0.00	0.00	0.05
					F	0.91	0.43	0.12	1.50		0.08	1.00
					L	0.37	0.18	0.05	0.60		0.04	0.43
					M	0.17	0.09	0.05	0.31		0.02	0.18
10/15/74	Hillsborough	A	M	1,280	B	0.01	0.01	0.00	0.02	0.00	0.01	0.50
					F	0.81	1.30	0.00	2.10		0.07	1.20
					L	0.02	0.01	0.00	0.03		0.00	0.06
					M	0.11	0.60	0.00	0.17		0.01	0.32
5/23/75	Hillsborough	A	M	1,050	B	0.00	0.00	0.00	0.00	0.00	N.A.[f]	N.A.
6/15/75	Citrus	J	M	730	B	3.60	0.00	3.80	7.40	4.00	N.A.	N.A.

[a] All values are rounded to two significant digits.
[b] A = adult, J = juvenile.
[c] L = liver, M = muscle, B = brain, F = fat.
[d] Total DDT is the sum of the tissue concentrations of DDE, DDD and DDT.
[e] DDT equivalents = DDT + (0.067 × DDE) + (0.20 × DDD) according to the equation of Stickel et al. (1970).
[f] N.A. = not analyzed.

lites in brains of American kestrels collected in 1975 ($n = 6$) were compared with values reported by Johnston (1978) for American kestrels collected during the same year ($n = 3$). For American kestrels in the present study, the geometric mean concentration was 0.97 μg/g (range 0.84 to 1.33 μg/g), whereas values reported by Johnston (1978) yielded a geometric mean concentration of 0.68 μg/g (range 0.42 to 1.03 μg/g). In brains of American kestrels collected during 1976 and 1977, neither DDT nor its metabolites were detected.

Of the 11 different species of raptors examined, two (eastern screech-owls and American kestrels) were largely insectivorous. It might be expected that these species would accumulate lower concentrations of persistent chlorinated hydrocarbons than the omnivorous and piscivorous species for two reasons. First, insects have a much shorter lifespan than most vertebrates, and their potential to accumulate persistent chlorinated hydrocarbons would be diminished compared with the longer-lived vertebrates. Second, many of the vertebrate prey species, especially fish, occupy higher trophic levels than insects. At each successive trophic level, pesticide concentrations commonly increase by a factor of at least ten (Sherburne and Dimond, 1969). Comparison of concentrations of DDT and metabolites in muscle, brain, and liver between insectivorous and omnivorous raptors collected in 1974 and 1975 revealed that the insectivores contained higher concentrations than the omnivores. Individual specimens of eastern screech-owls, year-round residents of Florida, collected during three consecutive years (1974 through 1976) contained high concentrations of DDT and metabolites in all tissues analyzed. Eastern screech-owls collected after 1976 contained very low concentrations of DDT and metabolites. Concentrations of DDT and metabolites in muscle samples from American kestrels averaged 1.6 μg/g and 3.0 μg/g for birds collected in 1974 and 1975, respectively. Feeding American kestrels 10 μg/g DDE in the diet (dry weight basis) has been shown to reduce

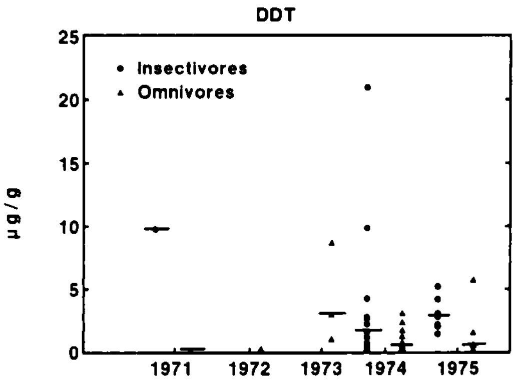

FIGURE 1. Concentrations of DDT plus metabolites in muscle of insectivorous (●) and omnivorous (▲) raptors collected from 1971–1975. —— represents the geometric mean values.

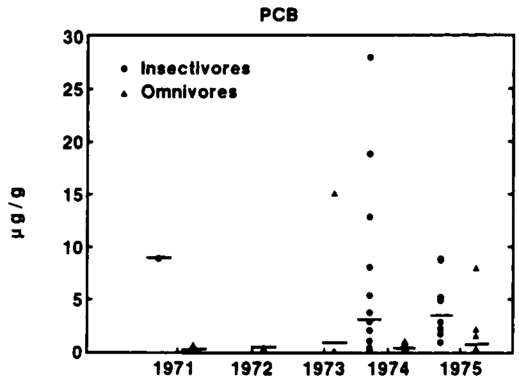

FIGURE 3. Concentrations of PCB's in muscle of insectivorous (●) and omnivorous (▲) raptors collected from 1971–1975. —— represents the geometric mean values.

egg shell thickness by 10% (Wiemeyer and Porter, 1970). Furthermore, American kestrels in the southeastern U.S. generally were exposed to higher concentrations of DDE in their prey than their northern counterparts (Lincer and Sherburne, 1974). Among the three specimens collected in 1976 and 1977, only one sample (brain) contained detectable concentrations of DDT; however, these probably were northern birds inasmuch as they were obtained during winter and early spring when migrants are present in abundance.

In ospreys, high concentrations of DDE have been associated with decreased reproduction in the Barnegat Bay area of New Jersey (Wiemeyer et al., 1978). Since 1969, average concentrations of DDE in osprey eggs collected from the Connecticut-Long Island area have decreased by a factor of five (Spitzer et al., 1978). Wiemeyer et al. (1980) determined that ospreys ($n = 6$) collected in Florida from 1968–1973, contained brain concentrations of DDT and metabolites between 0.23 and 14 µg/g (geometric mean = 2.7 µg/g) and carcass concentrations between 0.75 and 52 µg/g (geometric mean = 4.0 µg/g). Johnston (1978) reported that concentrations of DDT and metabolites in ospreys have been very low in Florida from 1973 through 1976 with geometric mean concentrations in adipose tissue and uropygial glands of 0.87 and 0.90 µg/g, respectively. Of the four ospreys collected in the current study, three were found to contain total DDT concentrations in brain tissues of 0.02 µg/g or less. One juvenile osprey collected in 1975, however, was found to contain relatively high brain concentrations of DDE (3.6 µg/g) and DDT (3.8 µg/g). The reason for these high concentrations cannot be explained by the theory that these birds accumulate DDT while wintering in those Caribbean countries which allow its use (Johnston, 1978), inasmuch as this was a young bird that had never undergone a winter migration.

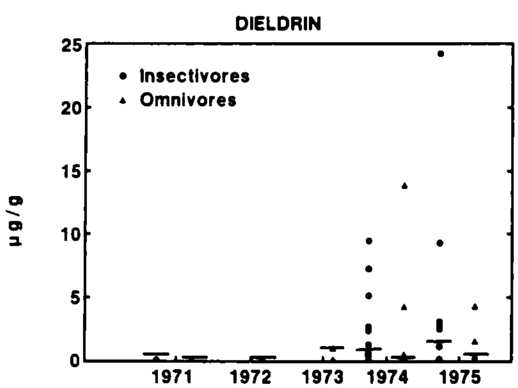

FIGURE 2. Concentrations of dieldrin in muscle of insectivorous (●) and omnivorous (▲) raptors collected from 1971–1975. —— represents the geometric mean values.

TABLE 5. Raptors from Florida with hazardous or lethal concentrations of dieldrin in the brain.

Species and date collected	County	Brain dieldrin (µg/g)	Postmortem findings
Red-shouldered hawk			
12/15/74	Pinellas	10.82	Possible poisoning
6/1/74	Lake	6.01	No abnormal findings
American kestrel			
1/1/75	Pinellas	6.82	No abnormal findings

Because concentrations of DDT in brain tissue were greater than DDE, recent exposure to the insecticide likely occurred, possibly the result of illegal use in Florida.

Even when species were grouped according to their dietary habits, it was not possible to identify any long term trends in concentrations of pesticides. For three of the four species in which the number of birds sampled was 10 or more, total concentrations of DDT in brain tissues appeared to decline after 1975 (eastern screech-owls, American kestrels, and barred owls). Screech-owls and barred owls are year-round residents in Florida, and whereas both resident and winter-migrant American kestrels are found in Florida, nearly all specimens were obtained when northern birds were present and numerous. In red-shouldered hawks, however, no such decline in brain DDT was observed. This finding is consistent with data from the National Pesticide Monitoring Program indicating no significant decline in DDE, DDT, or DDD concentrations in the wings of black ducks (*Anas rubripes*) and mallards (*Anas platyrhyncos*) collected along the Atlantic flyway in 1972 and 1976 (White, 1979b). This lack of decline in DDT concentrations may reflect the small number of birds obtained in more recent years, and suggests that more specimens are necessary to determine if, indeed, this trend is real.

In his analysis of adipose tissue, brains and uropygial glands from 71 raptors in Florida, Johnston (1978) found no evidence that concentrations of DDE and dieldrin diminished between 1971 and 1976. He also discussed possible reasons for the persistence of DDT tissue residues following the total ban of the use of DDT in the USA in 1972. One explanation was that long-lived birds may have accumulated their current body concentrations of DDT and metabolites prior to 1972. Because DDT distributes predominantly to adipose tissue, and because the only significant mechanism for excretion of intact lipids is through uropygial secretions and egg yolk, the fraction of the body burden eliminated over time is very small. The half-life of DDE in common grackles (*Quiscalus quiscalus*) has been projected to be 229 days which suggests some support for this theory (Stickel et al., 1984). Another possible explanation for residues of DDT is that several migratory species including red-shouldered hawks, red-tailed hawks and American kestrels, may have been collected while migrating to or through Florida from the West Indies or Central American countries where DDT continues to be a commonly utilized pesticide (Johnston, 1978).

Although the data presented in this paper did not indicate any definitive trends in concentrations of chlorinated hydrocarbons in populations of raptors in Florida, an obviously large variation in concentrations of these substances between individuals within a species was noted. Because of this variation, it is important that greater numbers of raptors be analyzed before truly representative population trends can be identified.

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LITERATURE CITED

BELISLE, A. A., W. L. REICHEL, L. N. LOCKE, T. G. LAMONT, B. M. MULHERN, R. M. PROUTY, R. B. DEWOLF, AND E. CROMARTIE. 1972. Residues of organochlorine pesticides, polychlorinated biphenyls, and mercury and autopsy data for bald eagles, 1969 and 1970. Pestic. Monit. J. 6: 133–138.

BERNARD, R. F. 1962. Secondary DDT poisoning in a sparrow hawk. Auk 79: 276–277.

COON, N. C., L. N. LOCKE, E. CROMARTIE, AND W. L. REICHEL. 1970. Causes of bald eagle mortality, 1960–1965. J. Wildl. Dis. 6: 72–76.

HEINZ, G. H., E. F. HILL, W. H. STICKEL, AND L. F. STICKEL. 1979. Environmental contaminant studies by the Patuxent Wildlife Research Center. Avian and Mammalian Wildlife Toxicology, ASTM STP 693, E. E. Kenega (ed.). Am. Soc. Testing and Materials, Philadelphia, Pennsylvania, pp. 9–35.

HENNY, C. J., J. R. BEAN, AND R. W. FYFE. 1976. Elevated heptachlor epoxide and DDE residues in a merlin that died after migrating. Can. Field-Nat. 90: 361–363.

JOHNSTON, D. W. 1978. Organochlorine pesticide residues in Florida birds of prey, 1969–76. Pestic. Monit. J. 12: 8–15.

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.

KLAASSEN, C. D. 1980. Nonmetallic environmental toxicants: Air pollutants, solvents and vapors, and pesticides. *In* Goodman and Gilman's The Pharmacological Basis of Therapeutics, 6th Ed., Alfred Goodman Gilman, Louis S. Goodman, and Alfred Gilman (eds.). Macmillan Publishing Co., Inc., New York, New York, pp. 1649–1650.

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

MULHERN, B. M., W. L. REICHEL, L. N. LOCKE, T. G. LAMONT, A. BELISLE, E. CROMARTIE, G. E. BAGLEY, AND R. M. PROUTY. 1970. Organochlorine residues and autopsy data from bald eagles, 1966–68. Pestic. Monit. J. 4: 141–144.

OHLENDORF, H. M., D. M. SWINEFORD, AND L. N. LOCKE. 1981. Organochlorine residues and mortality of herons. Pestic. Monit. J. 14: 125–135.

PORTER, R. D., AND S. N. WIEMEYER. 1972. DDE at low dietary levels kills captive American kestrels. Bull. Environ. Contam. Toxicol. 8: 193–199.

PROUTY, R. M., O. H. PATTEE, AND S. K. SCHMELING. 1982. DDT poisoning in a Cooper's hawk collected in 1980. Bull. Environ. Contam. Toxicol. 28: 319–321.

———, W. L. REICHEL, L. N. LOCKE, A. A. BELISLE, E. CROMARTIE, T. E. KAISER, T. G. LAMONT, B. M. MULHERN, AND D. M. SWINEFORD. 1977. Residues of organochlorine pesticides and polychlorinated biphenyls and autopsy data for bald eagles, 1973–74. Pestic. Monit. J. 11: 134–137.

ROBINSON, J., V. K. H. BROWN, A. RICHARDSON, AND M. ROBERTS. 1967. Residues of dieldrin (HEOD) in the tissues of experimentally poisoned birds. Life Sci. 6: 1207–1220.

SHERBURNE, J. A., AND J. B. DIMOND. 1969. DDT persistence in wild hares and mink. J. Wildl. Manage. 33: 944–948.

SMREK, A. L., AND L. L. NEEDHAM. 1982. Simplified cleanup procedures for adipose tissue containing polychlorinated biphenyls, DDT, and DDT metabolites. Bull. Environ. Contam. Toxicol. 28: 718–722.

SPITZER, P. R., R. W. RISEBROUGH, W. WALKER II, R. HERNANDEZ, A. POOLE, D. PULESTON, AND I. C. T. NISBET. 1978. Productivity of ospreys in Connecticut—Long Island increases as DDE residues decline. Science 202: 333–335.

STICKEL, W. H., L. F. STICKEL, AND F. B. COON. 1970. DDE and DDD residues correlated with mortality of experimental birds. *In* Inter-American Conference on Toxicology and Occupational Medicine, Pesticide Symposia, W. P. Deichmann (ed.). Halos and Associates, Inc., Miami, Florida, pp. 287–294.

———, ———, R. A. DRYLAND, AND D. L. HUGHES. 1984. DDE in birds: Lethal residues and loss rates. Arch. Environ. Contam. Toxicol. 13: 1–6.

THOMPSON, N. P., P. W. RANKIN, P. E. COWAN, L. E. WILLIAMS, AND S. A. NESBITT. 1977. Chlorinated hydrocarbon residues in the diet and eggs of the Florida brown pelican. Bull. Environ. Contam. Toxicol. 18: 331–339.

WHITE, D. H. 1979a. Nationwide residues of organochlorine compounds in starlings (*Sturnus vulgaris*), 1976. Pestic. Monit. J. 12: 193–197.

———. 1979b. Nationwide residues of organochlorine compounds in wings of adult mallards and black ducks, 1976–77. Pestic. Monit. J. 13: 12–16.

WIEMEYER, S. N., AND E. CROMARTIE. 1981. Relationships between brain and carcass organochlorine residues in ospreys. Bull. Environ. Contam. Toxicol. 27: 499–505.

———, T. G. LAMONT, AND L. N. LOCKE. 1980. Residues of environmental pollutants and necropsy data for eastern United States ospreys, 1964–1973. Estuaries 3: 155–167.

———, AND R. D. PORTER. 1970. DDT thins eggshells of captive American kestrels. Nature 227: 737–738.

———, P. R. SPITZER, W. C. KRANTZ, T. G. LAMONT, AND E. CROMARTIE. 1975. Effects of environmental pollutants on Connecticut and Maryland ospreys. J. Wildl. Manage. 39: 124–139.

———, D. M. SWINEFORD, P. R. SPITZER, AND P. D. MCCLAIN. 1978. Organochlorine residues in New Jersey osprey eggs. Bull. Environ. Contam. Toxicol. 19: 56–63.

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BOOK REVIEW . . .

Veterinary Anesthesia, 2nd Edition, W. V. Lumb and E. W. Jones. Lea and Febiger, Philadelphia, Pennsylvania 19106, USA. 1984. 693 pp. Price $69.50 (US) in USA, $87.00 (US) outside USA.

There are several good textbooks on veterinary anesthesiology, but none are more complete, current, or practical than the second edition of Lumb and Jones, *Veterinary Anesthesia*. The text, which begins with general principles and concepts, provides a review for those trained in anesthesiology and, for the non-anesthesiologist who finds it necessary to anesthetize animals, will serve as a foundation for understanding the more technical discussions that follow. Important basic chapters deal with the physiology of the response of the nervous, respiratory, and cardiovascular systems to anesthetic agents.

Before a discussion of the administration of anesthetics the reader is directed to a detailed discussion of artificial respiration and oxygen administration. The major portion of the text is devoted to detailed discussions of pre-anesthetic agents, injectable anesthetics, and inhalant anesthetics, along with the equipment and facilities for administering of the same. The authors have consulted nearly three hundred references on the use of single and combined drugs to attain total anesthesia.

Eighty pages of the text are devoted to the anesthesia of laboratory and zoo animals including crustacea. Many animal groups are discussed, and the reviewer is unaware of a better source which can serve as a quick reference for many of the discussed species.

The pharmacology of the immobilizing agents (etorphine, xylazine and ketamine) is detailed in other chapters in the text. This book is not meant to be a detailed treatise on immobilization, although it is discussed. It may be tempting to use multiple drugs when immobilizing and anesthetizing a wild animal. The authors discuss some of the ramifications of microsomal enzyme induction, caused by numerous drugs, which may modify the effect of an anesthetic agent. Concluding chapters include monitoring anesthesia, drugs and equipment for anesthetic emergencies, and anesthetic complications. A number of appendices list generic and trade names of drugs, sources, abbreviations and symbols. The index is thorough and easy to use. Diagrams and photos are used extensively and effectively. This is a complete and practical treatise on a complex subject.

Murray E. Fowler, School of Veterinary Medicine, University of California, Davis, California 95616, USA.