CONCENTRATIONS AND DISTRIBUTIONS OF p,p′-DDE, DIELDRIN, AND HEPTACHLOR EPOXIDE IN PHEASANTS IN EAST-CENTRAL ILLINOIS

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ABSTRACT.—Selected organs and tissues from 147 pheasants (*Phasianus colchicus*), collected in east-central Illinois during 1968, were analyzed by gas chromatography for p,p′-DDE, dieldrin, and heptachlor epoxide. p,p′-DDE was detected in 97 percent of the birds, dieldrin in 69 percent, and heptachlor epoxide in 75 percent. Mean concentrations of p,p′-DDE were greatest in livers (0.28±0.04 ppm); those of dieldrin and of heptachlor epoxide were greatest in subcutaneous fat (0.42±0.10 and 0.24±0.06 ppm, respectively). The highest individual concentrations were 3.26 ppm for p,p′-DDE, 5.76 ppm for dieldrin, and 4.76 ppm for heptachlor epoxide. Regressions indicated the entire body became contaminated by the respective toxicants when concentrations of p,p′-DDE in liver, or dieldrin or heptachlor epoxide in subcutaneous fat were greater than 6 ppm. Concentrations were greater during the summer months than at other times of the year, but sex- and age-associated differences were not demonstrated.

The chlorinated hydrocarbon insecticides have been in common use since the mid-1940's, when DDT was first used extensively. Since that time, millions of pounds of these toxicants have been applied to the earth's soils, waters, and air. Because of their stability, the chlorinated hydrocarbons, or their metabolites, often remain in the environment for several years, eventually finding their way into many species of plants and animals. It is this characteristic that makes the chlorinated hydrocarbon insecticides potentially dangerous to numerous organisms other than the target species.

The purpose of this study was to determine the presence, concentrations, and distributions of p,p′-DDE (a metabolite of DDT), dieldrin (a metabolite of aldrin and also a commercial insecticide), and heptachlor epoxide (a metabolite of heptachlor) in the bodies of pheasants in east-central Illinois, taking into consideration sex, age, and activity of the birds through the annual cycle. East-central Illinois supports the highest pheasant populations in the state (Labisky 1969:7) and also represents some of Illinois' most intensively cultivated farmland. Corn (*Zea mays*) and soybeans (*Glycine Max*) are the principal crops.

DDT, compared with other insecticides, was used extensively in Illinois agriculture — to control the corn borer (*Pyrausta nubilalis*) — from the late 1940's to the mid-1950's. Since the late 1950's, little DDT has been used for agricultural purposes in Illinois. Aldrin and, to a lesser extent, heptachlor were the most-used insecticides — for the control of a host of soil insects — in more recent years; these two chemicals were applied at rates of 1 to 1.5 pounds of technical material per acre. However, the use of both aldrin and heptachlor in Illinois de-

creased 25 percent from 1966 to 1968. Dieldrin was used sporadically from the mid-1950's to about 1964. (Information from H. B. Petty, Illinois Natural History Survey and University of Illinois College of Agriculture, Urbana.)

Methods

The pheasants used for this study were collected in Ford, Livingston, and Champaign counties during various periods in the annual cycle, in 1968 (Table 1). The birds were collected by nightlighting (Labisky 1968*a*) during the winter, prebreeding, and fall periods; by salvaging hens killed or mangled by hay mowers during the incubating period; and by shooting birds with an air-powered rifle during all other periods. In addition, 20 of the birds collected during the winter and prebreeding periods were taken with a shotgun, and 6 birds, representing four periods, were found dead along roads. The pheasants were aged as juveniles or adults by bursal examination. Juvenile birds collected during the growth and fall periods were further aged, to the nearest week, according to advancement of molt of the primary feathers (Labisky 1968*b*, p. 465).

Most of the pheasants were killed during the first 2 hours after sunrise. The birds that were collected by nightlighting were held overnight in padded crates, then sacrificed. With few exceptions, all birds were placed in polyethylene bags and then stored under refrigeration, immediately after they were sacrificed.

After the pheasants had thoroughly cooled, they were dissected to obtain samples of the organs and tissues to be analyzed for the toxicants. Subcutaneous fat was taken from along the posteroventral surface of the sternum and around the neck; visceral fat was obtained from deposits on the gizzard and in omentums of the intestine. In most instances, the samples of fat weighed a minimum of 2 grams. Some of the pheasants, notably growing birds and molting hens, had quantities of fat insufficient to be sampled.

Samples of muscle were obtained from the *femoris* and from the *pectoralis thoracica,* designated as leg muscle and sternal muscle, respectively. The muscle samples usually weighed from 10 to 20 grams, though those from growing birds were necessarily smaller (2-8 grams).

Internal organs that were analyzed were the liver, brain, gizzard lining, gizzard muscle, heart, kidneys, lungs, pancreas, and, during the nesting season, ovary, oviduct, and testes. Details of the dissecting procedures have been described elsewhere (Anderson 1969: 981). The entire organ, or pair of organs, was saved for analysis.

The samples were weighed immediately after being removed from the birds and were then placed individually in polyethylene bags and stored in a freezer for 1 to 9 months before being analyzed.

All samples were extracted with a 50:50 mixture of acetonitrile and hexane, then put through a florisil column for cleanup. The analyses for p,p′-DDE, dieldrin, and heptachlor epoxide were performed with a Beckman model GC-4 gas chromatograph equipped with an electron capture detector. Columns were packed with 1 percent EPON

TABLE 1.—Data for 147 pheasants from which selected organs and tissues were excised and analpzed for p,p′-DDE, dieldrin, and heptachlor expoxide, 1968, east-central Illinois.

Hens				Cocks			
Period	Date	Number ♀ of Hens	Mean Age (months)	Period	Date	Number of Cocks	Mean Age (months)
Juveniles				Juveniles			
Winter	Feb. 13-21	9	*ca.* 8	Winter	Feb. 13-21	8	*ca.* 8
Adults				Adults			
Winter	Feb. 13-22	12	>20	Winter	Feb. 13-21	4	>20
Prebreeding	Apr. 3-9	8	>10	Prebreeding	Apr. 2-9	10	>10
Breeding (Laying)	Apr. 22-May 29	12	>11	Breeding	Apr. 22-May 29	9	>11
Incubating	June 8-24	12	>12				
Molting	July 16-Aug. 5	10	>13	Molting	July 11-Aug. 15	10	>13
Fall	Oct. 14-25	8	>16	Fall	Oct. 10-25	8	>16
Juveniles				Juveniles			
Growth	July 24-Aug. 5	5	1.6 ± 0.1	Growth	July 11-Aug. 4	7	1.6 ± 0.1
Fall	Oct. 15-26	7	4.4 ± 0.1	Fall	Oct. 14-26	8	4.4 ± 0.2

resin 1001 and 0.5 percent Viton A fluoroelastomer on a solid support of 100-120 mesh chromosorb W. The lower limit of detection was considered to be 0.01 ppm.

Results

The levels of p,p′-DDE, of dieldrin, and of heptachlor epoxide in the various organs and tissues are presented in mean concentrations, in highest individual concentrations, and in frequencies of occurrence in Table 2-4. Predictably, these three parameters tended to be directly related to each other — if one was relatively high or low, so were the others. Concentration in the individual organs and tissues were high variable, with coefficients of variation ranging from 119 to 641 percent for p,p′-DDE, from 147 to 694 percent for dieldrin, and from 185 to 390 percent for heptachlor epoxide.

Of the 147 pheasants examined, p,p′-DDE was detected in 97 percent, dieldrin in 69 percent, and heptachlor epoxide in 75 percent. Ninety-nine percent of the birds contained detectable levels of at least one of the toxicants, 88 percent contained at least two, and 54 percent contained all three.

The levels of p,p′-DDE were highest in livers, followed closely by those in subcutaneous fat and in visceral fat, and distantly by those in lungs and in ovaries (Table 2). Levels of dieldrin and heptachlor epoxide were highest in subcutaneous fat, followed by those in visceral fat; levels in ovaries were a distant third (Tables 3 and 4). The highest individual concentrations were 3.26 ppm for p,p′-DDE (in liver),

Table 2.—Levels of p.p′-DDE in selected organs and tissues of pheasants collected in east-central Illinois in 1968. The samples consisted of birds of both sexes and of all ages (see Table 1).

Organs and Tissues	Number of Birds	Concentrations (ppm)		Frequency of Occurrence (percent)
		Mean	Highest	
Fat, subcutaneous	106	0.26 ± 0.03	1.67	75
Fat, visceral	100	0.22 ± 0.04	2.17	66
Muscle, leg	145	<0.01	0.13	8
Muscle, sternal	147	0.01 ± 0.005	0.73	6
Liver	147	0.28 ± 0.04	3.26	84
Brain	145	0.01 ± 0.004	0.59	3
Gizzard lining	146	0.01 ± 0.003	0.33	1
Gizzard muscle	147	0.01 ± 0.001	0.12	14
Heart	146	0.01 ± 0.002	0.16	13
Kidneys	143	0.02 ± 0.005	0.42	19
Lungs	144	0.05 ± 0.01	0.48	37
Pancreas	142	0.01 ± 0.005	0.50	4
Ovary*	28	0.06 ± 0.02	0.36	25
Oviduct*	31	0.02 ± 0.009	0.25	23
Testes†	28	0.01 ± 0.004	0.10	18

* The ovary and oviduct were taken from hens collected during the prebreeding, breeding (laying), and incubating periods only.

† Testes were taken from cocks collected during the prebreeding, breeding, and molting periods only.

TABLE 3.—Levels of dieldrin in selected organs and tissues of pheasants collected in east-central Illinois in 1968. The samples consisted of birds of both sexes and of all ages (see Table 1).

Organs and Tissues	Number of Birds	Concentrations (ppm)		Frequency of Occurrence (percent)
		Mean	Highest	
Fat, subcutaneous	106	0.42 ± 0.10	5.76	62
Fat, visceral	100	0.40 ± 0.09	5.09	57
Muscle, leg	145	<0.01	0.09	16
Muscle, sternal	147	<0.01	0.12	14
Liver	147	0.01 ± 0.006	0.48	10
Brain	145	0.02 ± 0.005	0.53	14
Gizzard lining	146	0.03 ± 0.004	2.14	13
Gizzard muscle	147	0.01 ± 0.003	0.37	22
Heart	146	0.02 ± 0.005	0.68	22
Kidneys	143	0.02 ± 0.004	0.33	20
Lungs	144	0.02 ± 0.005	0.42	28
Pancreas	142	0.03 ± 0.007	0.46	12
Ovary*	28	0.14 ± 0.04	0.71	57
Oviduct*	31	0.04 ± 0.020	0.56	35
Testes†	28	0.01 ± 0.004	0.08	21

* The ovary and oviduct were taken from hens collected during the prebreeding, breeding (laying), and incubating periods only.
† Testes were taken from cocks collected during the prebreeding, breeding, and molting periods only.

TABLE 4.—Levels of heptachlor epoxide in selected organs and tissues of pheasants collected in east-central Illinois in 1968. The samples consisted of birds of both sexes and of all ages (see Table 1).

Organs and Tissues	Number of Birds	Concentrations (ppm)		Frequency of Occurrence (percent)
		Mean	Highest	
Fat, subcutaneous	106	0.24 ± 0.06	4.76	59
Fat, visceral	100	0.20 ± 0.06	4.23	59
Muscle, leg	145	<0.01	0.05	6
Muscle, sternal	147	<0.01	0.33	6
Liver	147	0.03 ± 0.009	1.27	43
Brain	145	<0.01	0.05	3
Gizzard lining	146	<0.01	0.25	1
Gizzard muscle	147	<0.01	0.08	10
Heart	146	<0.01	0.08	5
Kidneys	143	0.01 ± 0.003	0.37	14
Lungs	144	<0.01	0.09	7
Pancreas	142	<0.01	0.09	1
Ovary*	28	0.05 ± 0.02	0.32	36
Oviduct*	31	<0.01	0.04	19
Testes†	28	<0.01	0.02	7

* The ovary and oviduct were taken from hens collected during the prebreeding, breeding (laying), and incubating periods only.
† Testes were taken from cocks collected during the prebreeding, breeding, and molting periods only.

5.76 ppm for dieldrin (in subcutaneous fat), and 4.76 ppm for heptachlor epoxide (in subcutaneous fat), which occurred in adult hens collected during the incubating period.

Concentrations of p,p′-DDE in livers, and of dieldrin and of heptachlor epoxide in subcutaneous fat, were found to be directly related to the percentage of the selected organs and tissues that were contaminated by these toxicants. These relationships, which were significant at the 0.001 level of probability, are illustrated with dieldrin in Figure 1. The regression lines indicated that all of the organs and tissues analyzed might be expected to be contaminated by the respective toxicants if concentrations of p,p′-DDE in liver, or dieldrin or heptachlor epoxide in subcutaneous fat, were greater than 6 ppm.

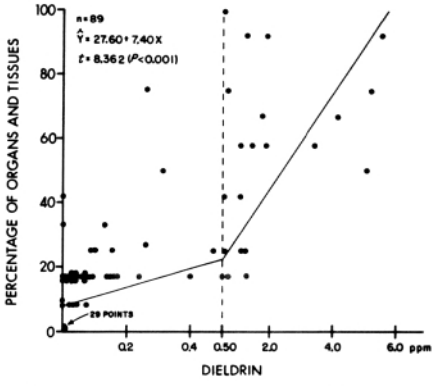

FIGURE 1. Relationship, as determined by linear regression, between concentrations of dieldrin in subcutaneous fat of pheasants and the percentage of selected organs and tissues that contained detectable levels (had concentrations of 0.01 ppm or greater) of this toxicant, east-central Illinois, 1968. The organs and tissues are: subcutaneous fat, visceral fat, leg muscle, sternal muscle, liver, brain, gizzard lining, gizzard muscle, heart, kidneys, lungs, and pancreas. Note that the scale on the horizontal axis changes by a factor of 10 at 0.50 ppm.

Mean concentrations of the three toxicants did not differ significantly among pheasants representing the different sex-age groups (Table 5). Failure of some of the differences, particularly the larger ones, to be significant is attributed to large variations that occurred in the data. Adult hens were perhaps carrying higher levels of dieldrin and heptachlor epoxide than juvenile hens (Table 5).

Seasonal changes in levels of p,p′-DDE, of dieldrin, and of heptachlor epoxide in the pheasants are presented graphically in Figures 2 and 3. In both sexes, the levels of the three toxicants began to increase during late April and May (breeding period) and, in hens, reached their highest levels during June (incubating period); cocks were not collected during June. With the possible exception of heptachlor epoxide, the levels decreased from July and early August (molting period) to October (fall period).

In 120 pheasant eggs, collected in east-central Illinois in 1966, the frequencies of occurrence of p,p′-DDE, dieldrin, and heptachlor epoxide were 99, 99, and 51 percent, respectively. Concentrations in the entire egg, excluding shell and membrane, averaged 0.15±0.02 ppm for p,p′-DDE and 0.30±0.08 ppm for dieldrin. The highest individual concentrations were 0.61 ppm for p,p′-DDE, 2.82 ppm for dieldrin, and 0.40 ppm for heptachlor epoxide. (Data from Greenberg and Edwards 1970.)

TABLE 5.—Mean concentrations (ppm) of p,p′-DDE, dieldrin, and heptachlor epoxide in pheasants of four sex-age groups, east-central Illinois, 1968. Sample sizes are in parentheses.

	Hens		Cocks		
	Juveniles	Adults	Juveniles	Adults	F*
p,p′-DDE in livers					
Winter (Feb. 13-21)	0.05 ± 0.02(9)	0.28 ± 0.20(12)	0.11 ± 0.06(8)	0.07 ± 0.04(4)	0.54
Summer (July 11-Aug. 15)	0.63 ± 0.21(5)	0.40 ± 0.16(10)	0.64 ± 0.25(7)	0.38 ± 0.18(10)	1.56
Fall (Oct. 10-26)	0.21 ± 0.05(7)	0.20 ± 0.08(8)	0.15 ± 0.02(8)	0.14 ± 0.03(8)	0.49
Combined	0.24 ± 0.07(21)	0.30 ± 0.10(30)	0.28 ± 0.09(23)	0.26 ± 0.09(22)	0.13
Dieldrin in subcutaneous fat					
Winter	0.04 ± 0.03(8)	0.06 ± 0.05(12)	0.01 ± 0.005(8)	0.03 ± 0.025(4)	0.33
Fall	0.02 ± 0.020(4)	0.09 ± 0.04(8)	0.19 ± 0.07(2)	0.04 ± 0.02(4)	0.14
Combined	0.04 ± 0.02(12)	0.07 ± 0.03(20)	0.05 ± 0.03(10)	0.04 ± 0.01(8)	0.05
Heptachlor epoxide in subcutaneous fat					
Winter	0.01 ± 0.005(8)	0.11 ± 0.04(12)	0.03 ± 0.01(8)	0.01 ± 0.013(4)	2.88
Fall	0.01 ± 0.020(4)	0.52 ± 0.41(8)	0.07 ± 0.07(2)	0.02 ± 0.019(4)	0.58
Combined	0.01 ± 0.007(12)	0.29 ± 0.17(20)	0.04 ± 0.02(10)	0.02 ± 0.011(8)	1.21

* Analysis of variance; none of the differences among means were significant at the 0.05 level of probability.

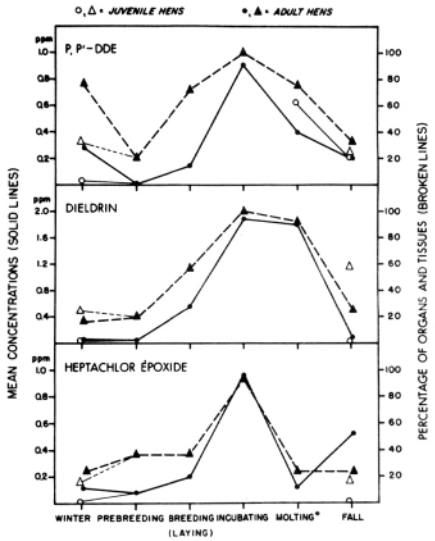

FIGURE 2. Seasonal changes in mean concentrations of p,p′-DDE in livers, of dieldrin in subcutaneous fat, and of heptachlor epoxide in subcutaneous fat, and in the percentage of selected organs and tissues that contained detectable levels (had mean concentrations of 0.01 ppm or greater) of these toxicants, hen pheasants, east-central Illinois, 1968.

*Growth period for juvenile hens.

DISCUSSION

Findings of this study indicate that all, or almost all, pheasants in east-central Illinois are contaminated with p,p′-DDE, dieldrin, or heptachlor epoxide, although the actual concentrations are low. It is noteworthy that 97 percent of the pheasants examined carried detectable concentrations of p,p′-DDE, considering the decline in the use of DDT in Illinois agriculture since the mid-1950's. Similar findings have been reported for pheasant eggs collected in east-central Illinois in 1966 (Greenberg and Edwards 1970). If pheasants are reliable indicators, these findings suggest that most of the agricultural environment in east-central Illinois was contaminated with DDT, aldrin, or heptachlor, or their metabolites, during the mid-1960's.

The failure to find other than low concentrations of p,p′-DDE, dieldrin, and heptachlor epoxide during this study (Tables 2-4) suggests that these chlorinated hydrocarbons do not pose a major threat to the pheasant population in east-central Illinois. The highest individual concentration, 5.76 ppm, was for dieldrin in subcutaneous fat. Only 3, 14, and 3 percent of the 145 brains analyzed contained detectable concentrations of p,p′-DDE, dieldrin, and heptachlor epoxide, respectively; the highest individual concentra-

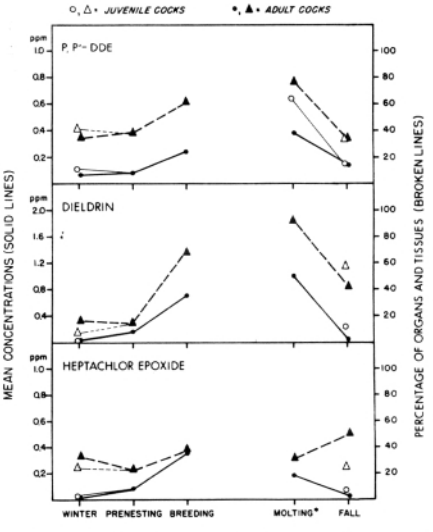

FIGURE 3. Seasonal changes in mean concentrations of p,p′-DDE in livers, of dieldrin in subcutaneous fat, and of heptachlor epoxide in subcutaneous fat, and in the percentage of selected organs and tissues that contained detectable levels (had mean concentrations of 0.01 ppm or greater) of these toxicants, cock pheasants, east-central Illinois, 1968.

*Growth period for juvenile cocks.

tions in brains were, respectively, 0.59, 0.53, and 0.05 ppm.

However, the foregoing findings do not preclude the possibility that chlorinated hydrocarbon insecticides might be impairing reproduction of pheasants in Illinois. Baxter et al. (1969: 101), after conducting dieldrin studies on penned pheasants, concluded that food consumption and egg production by a group of eight experimental hens were less than those of eight control hens. The experimental hens had not been exposed directly to dieldrin, but were hatched from a group of eggs, the yolks of which contained, according to analyses of eight eggs, 13.3 to 52.4 ppm of the toxicant (Atkins and Linder 1967: 747). The parent hens had been given 6 mg of dieldrin per week during the time these eggs were produced. A pooled sample of brains from three of the eight experimental hens contained 0.07 ppm of dieldrin (Baxter et al. 1969: 99). Of the 145 Illinois pheasants from which brains were analyzed, 15 (10 percent) contained concentrations of dieldrin that were 0.07 ppm or greater; six of these birds occurred in a sample of 12 hens collected during the incubating period. The findings by Baxter et al. need to be substantiated — or refuted — with additional research.

There is little doubt that chlorinated hydrocarbon insecticides are passed from adult hens to their offspring via the egg. p,p′-DDE, dieldrin, and heptachlor epoxide were detected in 25, 57, and 36 percent, respectively, of the ovaries analyzed (Tables 2-4). And, most of the pheasant eggs in a sample of 120 collected in east-central Illinois in 1966 contained these toxicants (Greenberg and Edwards 1970).

Although chlorinated hydrocarbons are known to concentrate in certain tissues, findings of the present study indicate that p,p′-DDE, dieldrin, and heptachlor epoxide can occur in many parts of the body (Tables 2-4). At concentrations of 6 ppm or greater of p,p′-DDE in liver or of dieldrin or heptachlor epoxide in subcutaneous fat, the respective toxicants can be expected to occur throughout the body (Fig. 1). Dieldrin appeared in brains of birds in which 50 to 100 percent of the organs and tissues analyzed were contaminated with this toxicant. It appears probable that the entire body becomes contaminated when only small amounts of p,p′-DDE, dieldrin, or heptachlor epoxide enter the birds. If sex and age affect the extent to which pheasants become contaminated with these chlorinated hydrocarbons, the effects were not demonstrated during this study (Table 5).

The increases in levels of p,p′-DDE, of dieldrin, and of heptachlor epoxide in pheasants, that began during late April and May and continued into June (Figs. 2 and 3), correspond to the time at which farmers normally treat their fields with insecticides. However, factors other than amounts of toxicant present in the environment must have contributed to the increase of p,p′-DDE in the pheasants because, as noted above, this chlorinated hydrocarbon has not been used appreciably in Illinois agriculture since the late 1950's. Perhaps greater consumption of animal material or shifts in physiological mechanisms contribut-

ed to the spring-summer increase of p,p′-DDE, as well as to those of dieldrin and heptachlor epoxide, in the pheasants.

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