SEASONAL VARIATION OF BODY CONDITION AND ORGANOCHLORINES IN WILD DUCKS FROM CALIFORNIA AND MEXICO

MIGUEL A. MORA, Department of Wildlife and Fisheries Biology, University of California, Davis, CA 95616
DANIEL W. ANDERSON, Department of Wildlife and Fisheries Biology, University of California, Davis, CA 95616
MICHAEL E. MOUNT, Department of Clinical Pathology, University of California, Davis, CA 95616

Abstract: Significant ($P < 0.01$) seasonal variations in the body weights and extractable lipid levels of northern pintails (*Anas acuta*) were observed. Prior to the breeding season, birds gained weight. During mid-winter weight losses occurred but differed in degree on different wintering areas. Most organochlorine (OC) levels in wintering northern pintails (and some gadwalls, *A. strepera*) were similar to resident black-bellied (*Dendrocygna autumnalis*) and fulvous (*D. bicolor*) whistling-ducks when collected in the same area (Sinaloa, Mex.). DDE (a metabolite of DDT) was the most commonly found and was detected in all samples ($N = 111$) but one (a whistling-duck). It was highest ($P < 0.01$) in winter-collected samples, indicating accumulation on southern wintering grounds, especially southern California and northern Baja California (among our samples from northern Calif. to southcentral Mex.). DDE concentrations in pintails from Salton Sea, California, were not different from nearby San Quintín in Baja California but were higher than Culiacán, Sinaloa; Lerma, Mexico; and Lower Klamath National Wildlife Refuge (LKNWR), California. Body burdens of DDE in pintails decreased through the breeding season at 1 breeding and migration-stopover area with a past history of OC contaminant problems (LKNWR). The HCB residues were more frequent ($P < 0.005$) in pintails from Salton Sea, but BHC isomers and heptachlor epoxide residue frequencies were not different ($P > 0.05$) among the 5 sample areas. Yet, BHC levels were significantly highest ($P < 0.005$) from the Culiacán sample. Dieldrin was most commonly found in samples of pintails and whistling-ducks also from the Culiacán area, all suggesting local BHC and dieldrin contaminant sources there. Overall, however, no OC levels in the ducks we sampled were high enough to suggest overt adverse effects on reproduction and survival although 2 individual ducks from Culiacán had considerably higher dieldrin levels than any of the other samples.

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Acquisition of toxic pollutants by migratory birds is well documented (Anderson and Hickey 1969; Johnson et al. 1971; Babcock and Flickinger 1977; Flickinger 1979; White et al. 1979, 1983*a*; Anderson et al. 1984; Ohlendorf and Miller 1984). In some instances recent contamination by chemical pollutants has been suggested to be due to pesticide use on wintering grounds in Latin America (White et al. 1981, Henny et al. 1982, Prouty et al. 1982). Kiff and Peakall (1981:952) stated: "... serious DDT pollution still exists in Mexico." Other findings have suggested important sites of pollutant acquisition (including restricted materials) still within the United States (Ohlendorf et al. 1978; Clark and Krynitsky 1983; White et al. 1983*a*,*b*; Risebrough et al. 1986).

About 75% of the Pacific Flyway total of northern pintails winter in California and about 20% farther south, along the Pacific coast of Mexico (Bellrose 1980:265, Saunders and Saunders 1981). Important areas in Mexico for northern pintails, gadwalls, and other waterfowl are located along the coasts of Sonora, Sinaloa, and Nayarit. Black-bellied and fulvous whistling-ducks are resident in these same areas. The presence of these wetlands near irrigated agriculture, as in California (Ohlendorf and Miller 1984), results in heavy waterfowl use. Thus, we selected 3 important waterfowl wintering areas from Mexico and 2 other areas from California (1 breeding area with a known history of contaminant problems) to assess contaminant loads in ducks migrating between the United States and Mexico.

The purposes of this study were to: (1) examine variations in northern pintail body condition, (2) document temporal variation and acquisition of organochlorine pollutants in northern pintails from selected regions of California and Mexico, and (3) contrast residue patterns of migrant pintails and resident whistling-ducks within a particular wintering area.

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METHODS

Sample Collection and Study Areas

We collected pintails early (1 May) and after the 1981 breeding season (8 Jul) at LKNWR, California ($N = 26$). The Klamath Basin was previously an area of heavy pesticide use in the 1960's, and associated cases of pesticide poisoning in birds were reported (Keith 1966, Godsil and Johnson 1968). Adult pintails collected at LKNWR represented only a small portion of the total pintail breeding range—and in reality a more northern migration-stopover area for most migrating pintails (see Bellrose [1980:267]). We collected nonbreeding pintails during early- and late-winter periods (Dec 1981–Jan 1982, and late Feb–early Mar 1982) in southern California and Mexico ($N = 60$) (Fig. 1). Whistling-ducks ($N = 19$) were collected during early and late periods in the Culiacán, Sinaloa area, and 6 gadwalls were collected during the late period from the same area (Fig. 1). We collected gadwalls during the 2nd period, in February, because pintails had already departed the area at that time.

All specimens were collected by shooting and then were labelled, sealed in plastic bags, and frozen until further processing (up to 3 months later). Carcass homogenates were prepared by removing feathers, head, wings, feet, and esophageal contents and then grinding until homogenized to a uniform paste in a meat grinder. Carcass weights were obtained in the laboratory after removal of esophageal contents.

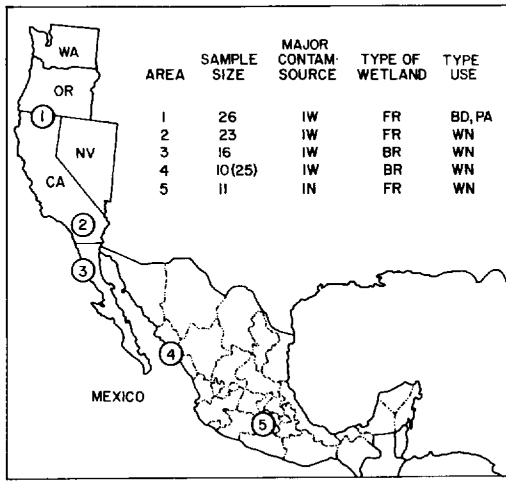

Fig. 1. Locations of waterfowl collections for pollutant studies in 1981–82; 1 = Lower Klamath National Wildlife Refuge, 2 = Salton Sea, 3 = San Quintín, 4 = Culiacán, and 5 = Lerma. The insert gives a brief description of each area: IW = irrigation waste water and agricultural drainage as a major source of water, IN = industrial sources nearby, FR = fresh water marshes, BR = brackish water marsh, BD = breeding area, PA = migrational passage area, and WN = major wintering area. Sample sizes are given for northern pintails, except those in parentheses, which are other species.

Chemical Analysis

Extraction.—A grinding extraction apparatus as described by Grussendorf et al. (1970) was used with the following modifications: 5–10 g of fresh-ground, homogenized carcass were placed into 50-ml stainless steel centrifuge tubes, mixed with 5 g of anhydrous sodium sulfate (previously cleaned with acetone and hexane) and filled with 20 ml of hexane (distilled in glass). Then the tubes were sealed with a pressure-lock cap, placed on a ball-mill action shaker (custom made) for 25 minutes, and centrifuged at 1,000 rpm for 5 minutes to sediment the solids and separate the lipid extract. The extract was decanted and stored in test tubes in a refrigerator until further analysis.

Cleanup.—A 2-unit microcolumn separation and concentration apparatus was used (Solomon 1979). The procedure (Solomon 1979) was adjusted to enhance recoveries as follows: Florisil 80/100 mesh (Supelco Inc., Bellafonte, Pa.) was previously activated by heating in an oven at 135 C for ≥48 hours before use. Microcolumns were filled with 0.5 g of activated florisil and rinsed with hexane. Fractions (0.2 and 0.3 ml) of lipid extract were placed on the florisil and eluted with 10 ml of a solution 96% hexane + 4% ether. This solution was prepared by adding 2% ethanol to the ether to increase recoveries. Eluant fractions were collected in centrifuge tubes and concentrated to about 1 ml of final cleanup volume with the use of helium. Average recoveries for a standardized mixture of 10 organochlorines was 92%.

Gas Chromatographic Conditions.—

Cleaned-up samples were analyzed for organochlorines with the use of a gas chromatograph, Varian model 3700, equipped with an electron capture detector, Ni^{63}. Two columns were used: (1) glass packed, 4 m, 2-mm ID, Supelco 3% OV-210, 80/100 mesh on Chromosorb W-HP and (2) glass packed, 2 m, 2-mm ID, Supelco 1.95% OV-210/1.5% OV-17, 80/100 mesh on Chromosorb G-HP. Column temperatures were: (1) 180 C and (2) 200 C; injection port 250 C; detector 300 C. Nitrogen was used as carrier gas with flow rates of 35 ml/minute for Column 1 and 30 ml/minute for Column 2. Individual peaks were identified by the use of standards and confirmed by injection on 2 separate columns with different liquid phases. Quantification of peaks was determined by the use of an automatic integrator, Varian CDS-111.

Samples were analyzed for residues of hexachlorobenzene (HCB), benzene hexachloride (BHC) isomers, heptachlor (HEPT), heptachlor epoxide (HEP), oxychlordane, *trans*-nonachlor, *p,p'*-DDE, *p,p'*-DDD, *p,p'*-DDT, dieldrin (DLD), and endrin (END). Ten pintails from LKNWR (early breeding) were analyzed for DDE only. Polychlorinated biphenyls (PCB's) were detected in some samples, but more concentration of the cleanup extract would have been required to quantify them, so we do not report them here. Oxychlordane, *trans*-nonachlor, and endosulfan were found in a few samples (<10%). One unknown peak also appeared in most of the chromatograms, but it could not be identified with the standards used at the time of this study. The lowest limit of detection was 1 ppb but varied somewhat for several different OC's.

Other Analyses.—Carcass lipid content was determined with a Cahn electrobalance, sensitive to small amounts of lipids, by pouring ≤8 μl of lipid extract in small aluminum pans and weighing the remaining lipids after evaporation of the hexane. Moisture was determined by placing ≤10 g of sample in an oven at 65 C for ≥48 hours or until constant weight was achieved.

Statistical Procedures

Results are presented as parts/billion on dry-weight bases (ppb dw). Comparisons of individual OC's are related to the total number of samples with residues detected above the limits of sensitivity and not to the total number of samples collected. Residue data were logarithmically transformed to achieve normality; therefore, geometric means (±95% CI), rather than arithmetic means, are reported here unless otherwise stated. Results for DDT are reported as the sum of *p,p'*-DDD and *p,p'*-DDT to facilitate the analysis and because of conversion of DDT to DDD in stored samples (Jefferies and Walker 1966).

One-way analysis of variance (ANOVA) was employed on normal or transformed data to test for residue differences and body condition among areas, date of collection, and among species. Two-sample comparisons (t-tests) were used when appropriate to test for residue differences between areas or sexes. Chi-square tests were used to compare frequencies of HCB, BHC, HEP, DLD, and END among areas. Statistical tests are described in the MINITAB statistical package (Ryan et al. 1976). Unless otherwise noted, statistical significance was considered at the $P = 0.05$ level.

RESULTS

Body Condition

Annual variations in body condition (as indicated by lipids as a percentage of body wt) in both sexes were similar (comparing sexes at a given location) except that females appeared to lose proportionately more weight through the breeding season and to gain weight proportionately faster prior to breeding (Figs. 2 and 3). Body weight varied significantly ($P < 0.001$) with body lipid levels. Lipid differences between adult males and females were significant in March on the wintering grounds. Pooled monthly condition data (body wt and % lipids) of northern pintails, regardless of area of collection, showed a general pattern of lipid and weight loss in mid-winter (Jan and Feb) and lipid and weight increases in late winter (Feb and Mar) (Figs. 2 and 3). Yet in January, northern pintails from 3 collection sites also had different, low lipid levels (Fig. 3, lower arrow). Our late-winter measurements for March 1982 (San Quintín and Salton Sea) when compared to similar measurements at LKNWR from 1979 to 1981 (Pederson and Pederson 1983; W vs. BR, fig. 2) suggested that male northern pintails on the wintering grounds were much lighter than males on breeding grounds at about the same time of year.

Organochlorines in Northern Pintails

DDE varied seasonally, was found in all pintails analyzed ($N = 86$, Tables 1 and 2), and

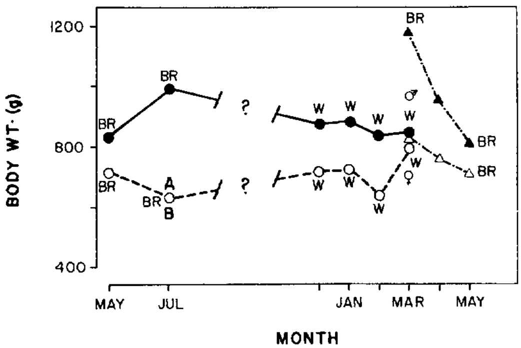

Fig. 2. Seasonal variation in body weights of northern pintails collected in the western United States and Mexico, 1981–82. Symbols are defined as follows: W = wintering area collection, BR = breeding area collection, A = mean for fully grown juvenile males, and B = mean for fully grown juvenile females from Lower Klamath National Wildlife Refuge; closed circles = male mean values and open circles = female mean values. Triangles are inserted to show comparable data from another study (Pederson and Pederson 1983) inserted to show additional weight variations discussed in the text. Hatch marks indicate discontinuous data and question marks indicate a period where data were not obtained.

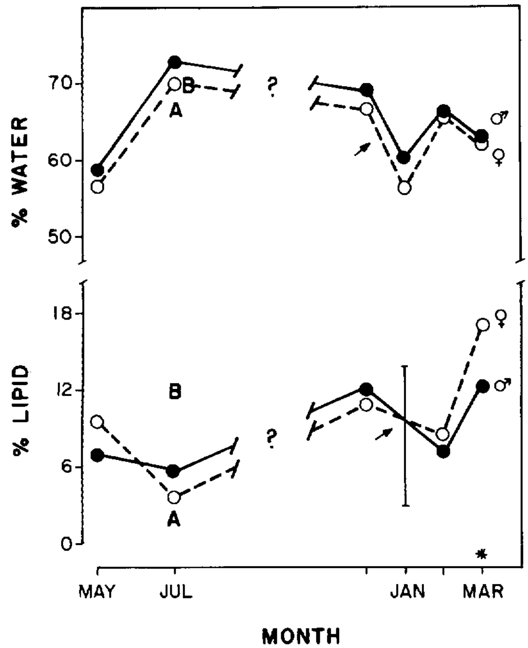

Fig. 3. Seasonal variation in total body lipids and moisture (as percentages of whole body wts) of northern pintails collected in the western United States and Mexico, 1981–82. Several locations were combined in the December–February samples. The lower arrow and vertical line indicate the range of highest variability among areas. At *, adult male/female % lipid differences were significantly different ($P < 0.05$). Other symbols and explanations used here are as given in Fig. 2.

ranged from 11 to 9,785 ppb dw. No overall differences were found between males and females, but DDE residue levels were significantly different ($P < 0.001$) among areas, both on a dry-weight and a lipid-weight basis.

DDE concentrations did not differ significantly from early–late winter in any of the areas where this comparison was possible (Table 2). At Lower Klamath, DDE residues did not differ by age or sex; however, concentrations declined significantly from the laying and incubation period to the postbreeding period (Table 1).

DDE levels were higher in pintails from Salton Sea National Wildlife Refuge than other locations during winter (Table 2, all $P \leq 0.05$) except San Quintín. Lowest levels were found in the 2 most distant areas of sampling (see Fig. 1), LKNWR and Lerma. Concentrations from these 2 extremes differed significantly from the other areas ($P < 0.01$) but not from one another.

DDT levels were low and followed the same pattern as DDE among regions and during the annual cycle. DDT was present in 57 pintails (Tables 1 and 2) (75% of total analyzed, $N = 76$, range = 8–1,510 ppb dw) and the incidence varied among areas from 64 to 88%. Significant differences were found among areas but not between sexes or between times of collection. Mean residue levels were about equal for the 1st and 2nd periods at Salton Sea and somewhat higher in San Quintín for the 1st period than for the 2nd (Table 2). The highest DDT levels were found at the Salton Sea, and these differed significantly from LKNWR ($P < 0.01$) and Lerma ($P < 0.001$). Concentration levels for San Quintín and Culiacán did not differ significantly from the other areas. DDE:DDT ratios in pintails varied from about 0.4 to 40 (Tables 1 and 2), suggesting highly variable sources of DDT.

Hexachlorobenzene (Tables 1 and 2) was present in 45% of the pintails analyzed ($N = 76$). It was found mainly in samples from Salton Sea (83%, $\chi^2 = 26.9$, $P < 0.005$), with a small number also in the other areas. Nevertheless, we found no differences in concentrations between Salton Sea and San Quintín.

BHC isomers (α BHC, β BHC, and γ BHC [lindane]) were added together when present and reported as total "BHC" (Tables 1 and 2). BHC was present in 79% of the pintails. The levels were usually low (2–210 ppb dw), and no differences were found between males and females, or between early and late collections for any area. BHC frequencies were not different ($\chi^2 = 8.87$), among the 5 areas, but the concentrations were higher for Culiacán and differed

Table 1. Organochlorine residues (ppb dw) in northern pintails from Lower Klamath National Wildlife Refuge, California, 1981. (HCB = hexachlorobenzene, BHC = benzene hexachloride, HEP = heptachlor epoxide, and DLD = dieldrin.)

				Residue[a,b]												
				DDE		DDT			HCB		BHC		HEP		DLD	
Period	Age[c]	% lipid	% water	N[d]	$\bar{x}$	N	$\bar{x}$	DDE:DDT[e]	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$	N	$\bar{x}$
Early breeding	Ad	8.3	66.7	10	183 (77–431)											
Post-breeding	Ad	5.2	68.0	6	143	5	81	2.10	2	136	6	53	2	16		ND
	Juv	2.4	71.3	10	36	9	69	0.58	1	221	5	29	8	20	2	27
	Both[f]	5.3	68.7	16	60 (32–115)	14	73 (44–122)	0.94	3	160	11	40 (24–69)	10	19 (16–24)	2	27

[a] Residues are given as geometric $\bar{x}$'s (95% CI are given in parentheses for each period). For sample size of ≤3 only the arithmetic $\bar{x}$'s are given, N = samples analyzed, and ND = not detected.
[b] Endrin found in 2 samples from the post-breeding period, $\bar{x}$ = 56 ppb dw.
[c] Males and females combined, as no sex differences were found.
[d] No. under DDE also equals total no. of samples analyzed.
[e] Ratios from samples with both DDE and DDT.
[f] Ages combined because their residues were not significantly different.

significantly from LKNWR ($P < 0.001$), Salton Sea ($P < 0.001$), San Quintín, and Lerma.

Heptachlor epoxide was present in small amounts (Tables 1 and 2) in 67% of the samples (range = 3–312 ppb dw). There were no differences in frequencies and concentrations among areas or between early vs. late collections.

Dieldrin in pintails was found only in small amounts in 2 juveniles from LKNWR (Table 1), 3 adults from Salton Sea, and 3 adults from Culiacán (Table 2). One pintail from Culiacán, however, had 2,612 ppb dw in the carcass.

Organochlorines in Whistling-Ducks

No significant differences in concentration of DDE or other OC's were found between early and late winter collections of black-bellied whistling-ducks. DDE was present in 14 of 15 black-bellied whistling-ducks analyzed, but DDT was present in only 5 samples (Table 3). BHC isomers were present in all samples except 1, but no significant differences were found between sexes or between early vs. late periods of collection. Dieldrin was one of the major compounds found in black-bellied whistling-ducks, occurring in 73% of the samples. Although not significant, dieldrin levels were lower during the 1st period than during the 2nd. One whistling-duck also had unusually high levels of dieldrin (1,038 ppb dw) and some endrin (26 ppb dw).

DDE residues in fulvous whistling-ducks were not different from those in black-bellied whistling-ducks (Table 3). DDT was present in 1 sample and HCB, BHC, and heptachlor epoxide in 4 specimens at low levels. Dieldrin and endrin were present in 2 samples in small amounts.

Nonresident vs. Resident Waterfowl in the Culiacán Area

DDE residue levels on a dry-weight basis were not significantly different among the 4 waterfowl species collected in Culiacán, Sinaloa (Table 3). DDT occurred in 80% of pintails, 50% of gadwalls, and 32% of whistling-ducks, but the levels were similar.

BHC was present in nearly all the specimens collected in the Culiacán region, except for 2 pintails and 1 black-bellied whistling-duck. BHC concentrations among the 4 species were significantly different and higher for early collected pintails than for late collected gadwalls ($P < 0.001$) and black-bellied whistling-ducks ($P < 0.01$). BHC concentrations also were significantly different between gadwalls and fulvous whistling-ducks. Heptachlor epoxide was present in 21 (60%) of the samples, but no significant differences were found among species. More samples were found with dieldrin (49%, $\chi^2 = 11.3$, $P < 0.005$) in Culiacán than in other areas. No difference was found in the incidence of dieldrin in resident vs. migratory species, and the levels were relatively low, except for 2 cases mentioned above. No endrin was found in pintails or in whistling-ducks during early winter, but it was present at low levels in gadwalls (3) and in whistling-ducks (3) collected during late winter.

Table 2. Organochlorine residues (ppb dw) in northern pintails from California and Mexico, 1981–82. (HCB = hexachlorobenzene, BHC = benzene hexachloride, HEP = heptachlor epoxide, and DLD = dieldrin.)

				Residue[b]												
				DDE		DDT		Ratio DDE:	HCB		BHC		HEP		DLD	
Location	Period[a]	% lipid	% water	*N*[c]	$\bar{x}$	*N*	$\bar{x}$	DDT[d]	*N*	$\bar{x}$	*N*	$\bar{x}$	*N*	$\bar{x}$	*N*	$\bar{x}$
Salton Sea[e]	1	10	61.7	12	971 (419–2,247)	8	267 (91–784)	5.4	9	131 (31–556)	5	37 (25–57)	4	30 (10–93)	1	229
	2	14.3	57.7	11	1,422 (939–2,153)	8	244 (101–587)	8.0	10	616 (591–643)	11	41 (20–82)	10	22 (13–36)	2	97
	1 + 2	12.1	59.7	23	1,165 (743–1,828)	16	255 (139–468)	6.6	19	168 (67–423)	16	40 (25–63)	14	24 (16–36)	3	103
San Quintín	1	11.1	56.9	8	661 (242–1,802)	8	206 (114–272)	3.2	2	104	7	81 (44–149)	6	23 (7–75)		ND
	2	7.9	67.1	8	417 (92–1,889)	4	21 (1–323)	39.7	7	214 (88–517)	8	50 (27–95)	4	17 (1–50)		ND
	1 + 2	9.5	62.0	16	525 (236–1,168)	12	96 (36–257)	5.1	9	182 (92–360)	15	63 (42–95)	10	20 (9–47)		ND
Culiacán	1	14	56.5	10	360 (189–687)	8	106 (40–284)	4.2	1	507	8	120 (88–163)	7	38 (15–97)	3	877[f]
Lerma	1	4.7	66.3	9	44 (32–62)	7	45 (32–62)	1.36	2	69	8	42 (12–140)	9	13 (6–20)		ND
	2	7.3	63.9	2	113		ND	—		ND	2	53	1	26		ND
	1 + 2	6.0	65.1	11	53 (36–77)	7	19 (5–71)	—	2	17	10	44 (18–110)	10	14 (9–21)		ND

[a] 1 = early winter collection (Dec–Jan), 2 = late winter collection (Feb–Mar), and 1 + 2 = totals.
[b] Residues are abbreviated as defined in text and given as geometric $\bar{x}$'s (followed by 95% CI in parentheses). For sample size of ≤3, only the arithmetic $\bar{x}$'s are given. *N* = samples with residues, and ND = not detected.
[c] No. under DDE also equals total no. samples analyzed.
[d] Ratios from samples with both DDE and DDT.
[e] One sample contained 334 ppb dw END.
[f] One sample contained 2,612 ppb dw.

DISCUSSION

Our observations on pintail body condition in Mexico, despite the small samples, seem to indicate patterns that are generally similar to other observations on pintails in California (Miller 1986) and in female American black ducks (*A. rubripes*) (Reinecke et al. 1982). They also are similar to observations on wintering mallards (*A. platyrhynchos*) in Texas in that differences in body condition on different wintering areas are suggested although condition changes in those mallards were timed slightly differently (but similar in pattern) (Whyte et al. 1986) from the pintails we sampled. Our sampling scheme may have missed a potential autumn to early winter weight gain (Whyte et al. 1986). Without more details, however, especially on the individual breeding and social statuses of our individual samples (see Heitmeyer [1985]), we cannot speculate more about pintail condition patterns other than to state we feel more certain that this contaminant study (our major objective) represents a "typical" wild dabbling duck pattern, and hopefully is of some use in helping to predict the hazards of migratory acquisition of contaminants in wild waterfowl.

Our DDE findings in migratory and resident waterfowl from California and Mexico support the notion that DDE is still the most persistent and widely distributed pesticide residue in birds and occurs in wildlife at higher concentrations than other chemicals (Keith and Gruchy 1972). The higher DDE residue levels in pintails at Salton Sea compared to LKNWR are comparable to a north-south OC contaminants gradient previously observed in waterfowl in California (Ohlendorf and Miller 1984). But apparently the pattern reverses (lower levels) farther south in other wintering grounds in Mexico. White et al. (1985) also found a similar situation with DDE, where black skimmers (*Rynchops niger*) from Texas had high levels during breeding, but no wintering areas that

Table 3. Total organochlorine residues (ppb dw) in wild ducks collected in Culiacán, Mexico, 1981–82. (HCB = hexachlorobenzene, BHC = benzene hexachloride, HEP = heptachlor epoxide, and DLD = dieldrin.)

			Residue[a]													
	% lipid	% water	DDE N^b	DDE $\bar{x}$	DDT N	DDT $\bar{x}$	DDE: DDT[c]	HCB N	HCB $\bar{x}$	BHC N	BHC $\bar{x}$	HEP N	HEP $\bar{x}$	DLD N	DLD $\bar{x}$
Migrants															
Northern pintail	14	56.5	10	360 (189–687)	8	106 (40–284)	4.2	1	507	8	120 (88–163)	7	38 (15–97)	3	877[d]
Gadwall[e]	22.9	47.5	6	395 (219–710)	3	64	12.3		ND	6	47 (33–67)	6	28 (14–52)	1	23
Residents															
Black-bellied whistling-duck[g]	18.5	53.6	14	162 (115–229)	5	185 (75–459)	2.5	4	80 (12–556)	14	64 (47–87)	4	13 (5–35)	11	38[f] (14–100)
Fulvous whistling-duck[h]	12.5	57.0	4	306 (37–2,537)	1	60	20.4	4	31 (6–145)	4	85 (55–132)	4	26 (1–510)	2	22

[a] Geometric $\bar{x}$'s are given (with 95% CI in parentheses). For sample size of ≤3 only arithmetic $\bar{x}$'s are given. N = samples with residues, and ND = not detected.
[b] No. under DDE also equals total no. of samples analyzed, except [g] below.
[c] Ratios from samples with both DDE and DDT.
[d] One contained 2,612 ppb dw.
[e] Three contained endrin, $\bar{x}$ = 21 ppb dw.
[f] One contained 1,038 ppb dw.
[g] Total samples analyzed = 15, 1 contained 26 ppb dw endrin.
[h] Two contained endrin, $\bar{x}$ = 27 ppb dw.

were sampled in Texas or in Mexico had birds with elevated DDE levels. However, given that no statistically significant changes in DDE residues from early–late winter in our pintails occurred, early–late winter accumulation patterns cannot be established here although Salton Sea data may have indicated it with larger samples.

At the time of our 1st period of collection (in winter), pintails probably had been in the respective areas long enough to show a residue pattern reflecting the contamination level of the sampled area or another nearby region. This idea is supported by most residue data comparing resident and nonresident waterfowl in the Culiacán area. DDE, DDT, and dieldrin levels for the 4 species collected in Culiacán were not different; therefore, the pattern shown by pintails was a reasonable estimation of the amounts of pesticides acquired during the winter in that particular area. No reports of DDT use exist for the area, but its presence at the observed levels in about half of the samples indicates current or very recent use in some areas. Organochlorine residue levels, mainly DDE, were very similar for Salton Sea and San Quintín, sampled regions geographically closest to one another.

DDE residues for pintails from LKNWR were generally low, but higher for breeding adults and lower for post-breeding adults and juveniles, indicating depuration at that location. Other recent studies on waterfowl in this area also have shown low levels of contaminants (Anderson et al. 1984, Ohlendorf and Miller 1984).

The higher residues of DDE and DDT in pintails from the Salton Sea and San Quintín areas could have several explanations: (1) DDE might still be present in the area because of past histories of heavy pesticide use and its long-term persistence (McCleneghan et al. 1981), DDT was still used in the Mexicali Valley (a region close to Salton Sea) during the late 1970's in a mixture with toxaphene (D. Covarrubias, pers. commun.); (2) although pesticide-use reports for California do not show any, perhaps there is a small illegal use of DDT (McCleneghan et al. 1981, Clark and Krynitsky 1983, Anderson et al. 1984, Ohlendorf and Miller 1984); and (3) the presence of other sources. DDE (and DDT) are known to be released in the environment as an impurity from dicofol (Risebrough et al. 1986), a widely used pesticide (as Kelthane®) in California. High DDE and DDT levels possibly associated with Kelthane® use also were found recently in some birds from New Mexico and Arizona (Clark and Krynitsky 1983). Dicofol reported use for the year 1981 in California amounted to about 234,000 kg (Calif. Dep. Food and Agric. 1982: 86).

Lower DDE and DDT residues for the other 2 areas from Mexico does not exclude the possibility that these and other pesticides may accumulate in some areas of Mexico during winter. In 1981, about 223,000 kg of OC insecticides (including DDT) were exported to Mexico (U.S. Bur. Census 1982:192). Moreover, a great proportion of agricultural pesticides are prepared and distributed by Fertilizantes Mexicanos, S.A., including sales of DDT, at least until 1978 (Fertilizantes Mexicanos, S.A. 1981). OC's are used mainly in cotton fields and other crops in north-central Mexico, Baja California, Sonora, and Sinaloa. Data on pesticide use for San Quintín, Culicán (except BHC), and Lerma for 1981 or previous years were lacking, so residue level associations with pesticide use are not possible. San Quintín may have been exposed to the same type of pesticides as the Mexicali Valley in the late 1970's. The use of BHC in the Culiacán area (where we found higher levels but the incidence was not significant from other areas) for 1980 amounted to 135,050 kg (V. Armienta, pers. commun.). The lower residue levels of DDE and DDT in Lerma may be explained by the incipient agriculture (mostly corn) surrounding the marsh area and by the suspected relatively low use of pesticides.

Dieldrin levels in the only 2 birds from LKNWR where it was detected were low; they were higher for Salton Sea and for Culiacán. Dieldrin was banned in the United States in 1975, but small amounts were found in waterfowl from Salton Sea in another study (Ohlendorf and Miller 1984), and in American white pelican (*Pelecanus erythrorhynchos*) eggs from LKNWR in 1981 (Boellstorff et al. 1985). The higher frequency of dieldrin found in Culiacán suggests local use of dieldrin or its precursor, aldrin. In a study of pesticides in water drains from irrigated lands in the vicinity of Culiacán, *p,p'*-DDT, dieldrin, and endrin, among others, were found at levels higher than those allowed in water (Albert and Armienta 1977). Residues in pintails were, however, generally below the levels known to have detrimental effects on birds (Stickel et al. 1969:178–179). Nevertheless, the much higher dieldrin levels in a few specimens may be an indication that, in some cases, aquatic birds in the area might be adversely affected. Cases of dieldrin acquisition and mortality in waterfowl, and observable toxic effects produced during stresses of migration, have been reported (Babcock and Flickinger 1977, Flickinger 1979).

The other organochlorine levels found in pintails and whistling-ducks were, in general, below those levels known to have detrimental effects on waterfowl (see White and Stickel [1975]). The levels of HCB (as with BHC, in the lower ppb ranges) were below those that would likely have an overt adverse effect on birds. HCB is known to delay egg production in chickens (Hansen et al. 1978), and it has been reported in waterfowl from the Salton Sea (Ohlendorf and Miller 1984). Heptachlor epoxide residues also were in the lower ppb ranges. It appears that the pintails we collected in early–mid-winter (all salt water or brackish habitats) may have been somewhat dehydrated because both lipid and water levels declined at this time (Fig. 3, arrows). The physiological significance of these changes is unknown, but their simultaneous occurrence may suggest that the period on salt or brackish water may be one of potential added stress making wintering waterfowl more susceptible to toxicants in those habitats. The idea deserves more exploration.

Here we show that pintails and other waterfowl accumulate certain pesticides during the winter. This pattern seems to be more related to local contaminated sources rather than to general wintering-ground contamination in Mexico, and only more detailed and more expanded studies can more precisely define such areas.

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