CURRENT IMPACT OF DDE ON BLACK-CROWNED NIGHT-HERONS IN THE INTERMOUNTAIN WEST

CHARLES J. HENNY, U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, 480 SW Airport Road, Corvallis, OR 97333
LAWRENCE J. BLUS, U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, 480 SW Airport Road, Corvallis, OR 97333
ALEXANDER J. KRYNITSKY, U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, MD 20708
CHRISTINE M. BUNCK, U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, MD 20708

Abstract: Organochlorine contamination was studied in eight black-crowned night-heron (*Nycticorax nycticorax*) populations nesting in Washington, Oregon, and Nevada in 1978–80. DDE was detected in 220 eggs sampled; eggshell thickness was negatively correlated with residues of DDE and polychlorinated biphenyls (PCB's). Other contaminants were detected in 35% or fewer of the eggs. Except for the two Columbia River colonies in which local DDE contamination was a probable compounding factor, a strong north–south clinal pattern of DDE residues among colonies existed. Southern colonies were most contaminated, and observed productivity was below population maintenance in one colony (Ruby Lake). At DDE levels in eggs above 8 ppm, clutch size and productivity decreased, and the incidence of cracked eggs increased. No evidence of breeding-ground DDE-DDT contamination was found except along the Columbia River.

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DDT and its metabolites may have played a role in the decline of black-crowned night-herons in the northeastern United States (Ohlendorf et al. 1978). For example, Anderson and Hickey (1972) reported 18% shell thinning by 1952 in New Jersey. The use of DDT in the United States was banned in 1972, and by the mid- to late 1970's, production rates at several locations in eastern North America (Wisconsin, Québec, Rhode Island, and Massachusetts) appeared normal, eggshell thickness was normal or near-normal, and/or residues of organochlorine pesticides were lower (Hoefler 1980, Tremblay and Ellison 1980, Custer et al. 1983), with the possible exception being Lake Ontario (Price 1977). Similar improvements have been reported for other species, including the osprey (*Pandion haliaetus*) (Henny 1977, Spitzer et al. 1978).

An adult black-crowned night-heron died at Ruby Lake National Wildlife Refuge near Elko, Nev., in 1975—3 years after the DDT ban. Its brain contained 230 ppm DDE and 1.1 ppm DDT (wet weight) (Ohlendorf et al. 1979). Although DDE concentrations in eggs from the northeast were diminishing in the late 1970's, the mortality at Ruby Lake in 1975 led us to suspect that DDE was still a problem for bird populations in the Intermountain West. Most birds nesting in the region are migratory, and many winter in Latin America. We studied two colonies in 1978 and extended our efforts to eight colonies by 1980.

This study was designated to (1) determine levels of DDE and other organochlorine residues in black-crowned night-heron eggs; (2) evaluate the most common contaminants in relation to shell thickness and egg breakage; (3) evaluate regional patterns and trends of DDE residues; (4) evaluate DDE in eggs in relation to productivity; (5) evaluate the source of the contaminants; and (6) evaluate residues in herons found dead to determine if pesticides were implicated.

National Wildlife Refuge personnel who provided field assistance included S. H. Bouffard, J. E. Cornely, and S. P. Thomp-

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] Procedures

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10-g portion of homogenized tissue or egg was mixed with anhydrous sodium sulfate and extracted in a Soxhlet apparatus. The extraction, sample cleanup, and separation of pesticides from PCB's followed Cromartie et al. (1975). However, the SilicAR separation in a few of the samples needed further separation into four fractions to ensure isolation of dieldrin and endrin into an individual fraction (Kaiser et al. 1980). Samples were analyzed on a Hewlett Packard model 5713 or 5840A gas-liquid chromatograph equipped with an electron-capture detector, automatic sampler digital processor, and a 1.5% SP-2250/1.95% SP-2401 column at 198 C. Residues in 10% of the samples were confirmed with a Finnigan model 4000 gas-liquid chromatograph–mass spectrometer operating under conditions described by Kaiser et al. (1980).

The average percent recoveries from spiked mallard (*Anas platyrhynchos*) tissue ranged from 65% for *trans*-nonachlor to 85–108% for all other pesticides and PCB's. Residue values were not corrected for rates of recovery. Only the 1979 samples were analyzed for lindane and β-BHC.

The lower limit of residue quantification was 0.1 ppm for pesticides and 0.5 ppm for PCB's. The lower limit of quantification was divided in half and used for samples in which a contaminant was not detected, to calculate geometric means. We converted contents of eggs to an approximate fresh wet weight using egg volume (Stickel et al. 1973); residue concentrations are expressed on a fresh wet weight basis.

Statistical Analyses

The frequencies of occurrence (the number above the detection limit) for certain organochlorines were compared among colonies and among years using chi-square tests. If differences ($P \leq 0.05$) were found, the cell chi-square values were used to identify the colonies or years that were different. Colony comparisons were done for each year separately to avoid confounding colony differences with time. The chi-square test was also used to determine if the nesting success data from each colony could be pooled to evaluate the influence of DDE on production. Standard regression techniques were used to evaluate the relationship of DDE (log-transformed) with eggshell thickness and with latitude of the nesting colony. To test for significant changes in DDE residues from 1979 to 1980, we considered the regression of DDE (log-transformed) on latitude. For these data, a regression approach is somewhat more flexible than analysis of variance, because regression provides a statistical comparison of overall DDE levels between years.

RESULTS AND DISCUSSION

History of Nesting Colonies

Historically, black-crowned night-herons nested at Moses Lake, Wash., from at least the early 1920's (Congdon 1925, Brown 1926, Kitchen 1930, Edson 1932); by 1978, the Moses Lake colony, now nesting on Potholes Reservoir, was estimated to contain 1,000–1,500 pairs (Fitzner et al. 1979). At Foundation Island in the Columbia River, 51 nests were counted in 1978 (Thompson and Tabor 1981), but only 41 nests in 1979. No earlier estimates are available.

Three-mile Island was created by the John Day Dam on the Columbia River in 1968; by 1977 and 1978, Thompson and Tabor (1981) reported 26 and 31 nests there, respectively. We counted 31 nests on the island in 1979 and 32 nests in 1980. The increase in heron numbers at the colony may be a function of the growth of

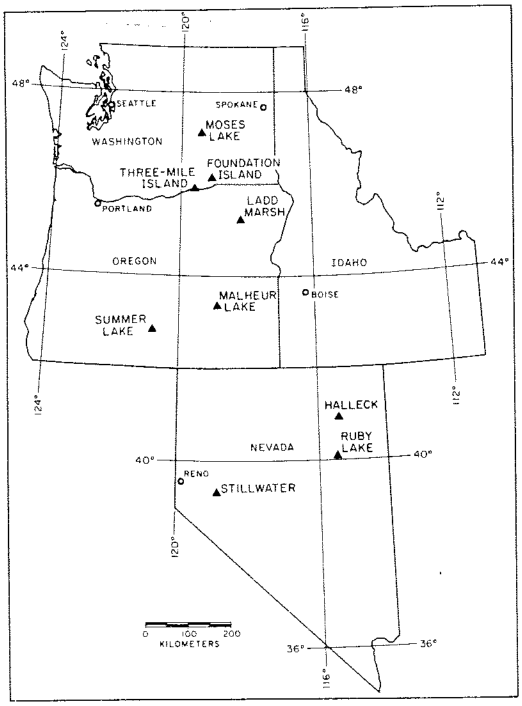

Fig. 1. The location of the black-crowned night-heron colonies studied.

son. State biologists included G. B. Herron and N. Saake, Nev. Dep. of Wildl.; R. S. Rohweder and S. Denny, Oreg. Dep. of Fish and Wildl.; and B. C. Thompson, Wash. Dep. of Game. S. R. Gray and J. R. Putman were biological technicians working on this study. L. N. Locke of the Natl. Wildl. Health Lab. conducted the necropsies. C. H. Trost, R. E. Fitzner, and S. H. Bouffard kindly permitted use of their band recovery information. L. F. Kiff, West. Found. of Vertebr. Zool., Los Angeles, Calif.; S. A. Rohwer, Thomas Burke Memorial Mus., Seattle, Wash.; G. D. Alcorn, Univ. of Puget Sound Mus., Tacoma, Wash.; and the staff of the Univ. of Oreg. Mus., Eugene, Oreg., assisted in obtaining information for pre-DDT-era eggs housed at their facilities. Comments on the initial draft of the manuscript by T. W. Custer and D. R. Clark were most helpful.

METHODS

Sampling Procedures

In 1978, we collected black-crowned night-heron eggs at two colonies along the Columbia River (Three-mile Island, Oreg.; Foundation Island, Wash.) (Fig. 1). In 1979, the study was enlarged to include Moses Lake, Wash.; Ladd Marsh, Oreg.; Malheur Lake, Oreg.; and Ruby Lake, Nev. In 1980, three of the more northern colonies were not sampled, but the effort continued at Three-mile Island, Malheur Lake, and Ruby Lake, and additional studies were initiated at Summer Lake, Oreg., and Stillwater, Nev. During the 3-year study, one randomly selected egg was collected from each of 220 nests; the remainder of the clutch was monitored three or four times to determine if young survived to about 2 weeks of age. Young wander from the nest about this time and were considered "fledged." Estimates of the size of the nesting populations were also routinely made.

The sample eggs were kept refrigerated until they were opened. The contents were placed in a chemically cleaned jar and frozen for later analysis. Shell thickness (shell and shell membranes) was measured at three sites on the equator with a micrometer graduated in units of 0.01 mm.

Dead herons found during the study were necropsied at the National Wildlife Health Laboratory, Madison, Wis. Brains of selected individuals were analyzed for organochlorines. Regurgitated prey from young herons and whole fish samples were collected at several colonies to evaluate breeding-ground contamination.

Chemical Analyses

The analyses of samples for organochlorine pesticides, their metabolites, and PCB's were conducted at the Patuxent Wildlife Research Center, Laurel, Md. A the nesting substrate (now mulberry [*Morus* sp.]; in earlier years, some herons nested in big sagebrush [*Artemisia tridentata*] [R. S. Rohweder, pers. commun.]). Ladd Marsh, south of LaGrande, Oreg., contained 12 nests in 1979; no earlier estimates are available. The Malheur Lake colony has existed since at least 1918, when 500 pairs nested in several colonies (Thompson et al. 1979). During the drought years of the 1930's and early 1960's, the population was greatly reduced. From 1965 to 1978, the population fluctuated between 250 and 1,000 pairs (Thompson et al. 1979). We estimated 730 pairs in 1979, but only 320 pairs in 1980. The Summer Lake colony contained 80 nests in 1980, but only a few scattered individuals were seen in 1979.

Early Ruby Lake population estimates are not available, although 163 black-crowned night-herons were killed by permit at Gallagher Fish Hatchery adjacent to Ruby Lake in 1970 (files, U.S. Fish and Wildl. Serv., Portland, Oreg.). We counted 37 nests and estimated 50 pairs in 1979, and 43 nests and 46 pairs in 1980. Immediately adjacent to the Ruby Lake colony is a smaller colony at Franklin Lake; some annual movement may occur between these colonies, depending upon water conditions. Another larger colony (108 pairs in 1981) was on private land about 35 km east of Elko and 100 km north of Ruby Lake on the Humboldt River near Halleck, Nev. The estimated number of nests at Stillwater ranged from 125 to 300 between 1965 and 1971 (Stillwater Natl. Wildl. Refuge files).

Some intercolony mixing occurs. A nestling banded at Malheur in 1967 was found dead at Ruby Lake in April 1970. Also, a nestling banded at Moses Lake in 1964 was found dead near Foundation Island in May 1967. Population trends are not readily discernible from the limited population data available. Furthermore, intercolony movement may be a confounding factor. For example, the apparent decline at Malheur from 730 to 320 pairs between 1979 and 1980 may be partially explained by the increase in pairs nesting 150 km away at Summer Lake from few, if any, in 1979 to 80 in 1980.

Incidence of Organochlorine Residues in Eggs

DDT Group.—Measurable residues of DDE were found in all 220 eggs analyzed, residues of DDD in 57 eggs, and residues of DDT in 60 eggs (Table 1). In 1979, DDT was found more frequently ($P = 0.020$) at southern than at northern colonies. In 1980, a similar pattern was observed, but differences were not significant. Fewer northern colonies were sampled in 1980. At the Ruby Lake colony, the frequency of occurrence for DDT declined from 1979 to 1980 ($P = 0.007$). This decline was also observed in the other two colonies sampled in both years, but was not significant.

Chlordane Group.—Heptachlor epoxide was detected in 60 eggs, and was more frequently encountered in 1979 and 1980 at Three-mile Island and in 1979 at Foundation Island ($P < 0.001$) than at other locations. Foundation Island was not sampled in 1980. Heptachlor was used as a seed treatment for wheat in portions of the Columbia Basin, especially near Three-mile Island (Blus et al. 1979). Stickel et al. (1979) reported that technical heptachlor contains 74% heptachlor, 2.5% *trans*-chlordane, and 15% *cis*-chlordane. Tashiro and Matsumura (1977) reported oxychlordane as an oxidation product of both *trans*-chlordane and *cis*-chlordane in rats. Thus, *cis*-chlordane and oxychlordane might be expected as a result of the local use of technical-grade heptachlor in the Columbia Basin. Oxychlordane was de-

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Table 1. Black-crowned night-heron egg residues (ppm fresh wet weight) by geographic area, 1978–80.

Location and year	*N*	DDE	DDD	DDT	Dieldrin	Heptachlor epoxide	OXY[a]	CICH	TRNO	CINO	TOXA	β-BHC	PCB's
Moses Lake													
1979	23	23 (2.17)[b]	4	4	7	3	6	4	8	1	2	1	7
Foundation Island													
1978	7	7 (6.05)	2	4 (0.14)	5 (0.30)	4 (0.12)	4 (0.13)	3	4 (0.10)	1	1	NA[c]	6 (1.23)
1979	21	21 (5.69)	6	9	13 (0.20)	9	12 (0.14)	7	8	2	0	7	11 (0.53)
Three-mile Island													
1978	10	10 (3.71)	1	2	2	6 (0.12)	6 (0.11)	1	1	0	2	NA	8 (1.19)
1979	19	19 (3.39)	8	2	6	14 (0.24)	13 (0.20)	6	9	1	1	1	12 (0.72)
1980	9	9 (3.35)	3	0	3	8 (0.19)	7 (0.14)	3	2	1	2	NA	5 (0.69)
Ladd Marsh													
1979	11	11 (2.63)	1	3	2	2	3	2	3	1	1	0	2
Malheur Lake													
1979	20	20 (4.70)	8	9	6	1	3	1	5	0	2	4	6
1980	21	21 (2.73)	4	5	5	1	1	1	1	1	1	NA	4
Summer Lake													
1980	20	20 (2.67)	2	2	6	4	6	6	8	5	1	NA	10 (0.81)
Ruby Lake													
1979	27	27 (8.21)	10	14 (0.17)	7	5	7	0	4	0	0	11	19 (1.70)
1980	25	25 (4.13)	5	4	4	3	7	1	2	0	2	NA	18 (1.45)
Stillwater													
1980	7	7 (5.08)	3	2	0	0	1	0	0	0	0	NA	2

[a] OXY = oxychlordane, CICH = *cis*-chlordane, TRNO = *trans*-nonachlor, CINO = *cis*-nonachlor, TOXA = toxaphene.
[b] Number of samples with contaminant detected; (geometric mean) if >50% of eggs with residues above the detection limit.
[c] NA = samples not analyzed for β-BHC in 1978 and 1980.

tected in 76 eggs and *cis*-chlordane in 35 eggs. In 1979, oxychlordane ($P = 0.002$) and *cis*-chlordane ($P = 0.002$) were found more frequently at Three-mile Island and Foundation Island. Oxychlordane ($P = 0.001$) was more often detected at Three-mile Island in 1980, whereas *cis*-chlordane ($P = 0.037$) was more commonly encountered at Three-mile Island and Summer Lake. Three-mile Island and Foundation Island accounted for 30% (66 eggs) of the eggs collected during this study, but included 68% of the heptachlor epoxide detections (41 eggs), 55% of the oxychlordane detections (42 eggs), and 57% of the *cis*-chlordane detections (20 eggs).

Trans-nonachlor and *cis*-nonachlor were detected in 55 and 13 eggs, respectively. In 1980, *trans*-nonachlor ($P = 0.009$) and *cis*-nonachlor ($P = 0.034$) were found most frequently at Summer Lake.

Other Pesticides.—Dieldrin was detected in 66 eggs, and in 1979 it was found more frequently at Foundation Island ($P = 0.034$). Hexachlorobenzene is used as a seed treatment for cereal grains in the Columbia Basin, and all seven detections (highest 0.38 ppm) were from the Basin (one Moses Lake, three Foundation Island, three Three-mile Island; not listed in Table 1). Although β-BHC was assayed only in 1979, 24 eggs contained the contaminant. It was most frequently detected at Ruby Lake ($P = 0.002$). Toxaphene was detected in 15 eggs, with no apparent regional pattern. Endrin was detected in only three eggs: 0.11 ppm at Foundation Island in 1978 and 0.13 and 0.33 ppm at Ruby Lake in 1979 (not listed in Table 1). Mirex and lindane were not detected during the study.

PCB's.—PCB's were detected in 50% of the eggs collected during the study. In 1979 and 1980, PCB's were more frequently ($P < 0.01$) encountered at Ruby Lake. During the 2 years of the study, 71% of 52 eggs collected at Ruby Lake contained PCB's. Although the two Columbia River colonies did not show a higher incidence of PCB detections in a statistical sense, 66% of the eggs from Three-mile Island and 61% of the eggs from Foundation Island contained PCB's. The Columbia River is known to contain fish contaminated with PCB's (Henny et al. 1981).

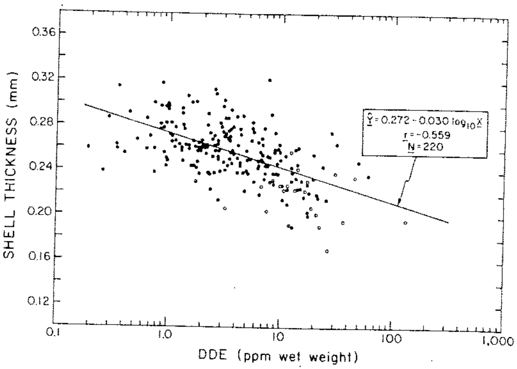

Fig. 2. The relationship between black-crowned night-heron eggshell thickness and the log-transformed residues of DDE. An open dot indicates that a cracked or crushed egg was found in the clutch.

DDE Residues and Shell Thickness

In many avian species, decreases in eggshell thickness coincided with the widespread use of organochlorine pesticides that began in the mid-1940's (Ratcliffe 1967, 1970; Hickey and Anderson 1968). The most affected species are those feeding on aquatic organisms and birds. Ohlendorf et al. (1978) analyzed 243 black-crowned night-heron clutches from the eastern United States in 1972 and 1973 and reported that DDE had the highest correlation with shell thinning ($r = 0.431$), although DDD, DDT, dieldrin, oxychlordane, *cis*-chlordane, and PCB's also showed significant relationships.

In our study, eggshell thickness was negatively correlated with the log-trans-

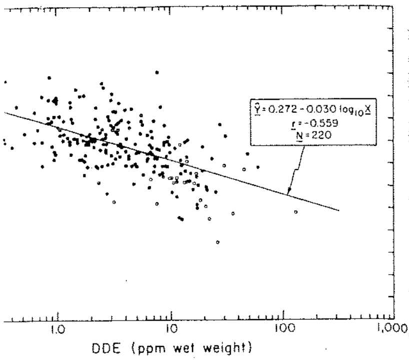

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Table 2. Residues of DDE (ppm wet weight) in black-crowned night-heron eggs in relation to eggshell thickness, clutch size, productivity, and egg breakage (all colonies and years pooled).

DDE (ppm)	Nests: Successful[c]	Nests: Totals	Nests: Percent successful	Young/successful nest[a] $\bar{x}$	SE	Clutch size[b] $\bar{x}$	SE	Shell thickness (mm) $\bar{x}$	SE	Clutches with cracked eggs
≤1.0	15	19	79	2.53	0.24	3.88	0.19	0.272	0.004	0
1.01–4.0	57	72	79	2.18	0.13	3.67	0.10	0.264	0.002	1 (1%)
4.01–8.0	24	33	73	2.08	0.17	3.70	0.16	0.253	0.004	2 (6%)
8.01–12.0	11	19	58	1.90	0.23	3.41	0.19	0.239	0.005	3 (16%)
12.01–16.0	6	11	55	1.80	0.20	3.10	0.31	0.235	0.006	3 (27%)
16.01–25.0	5	11	45	1.80	0.37	3.36	0.24	0.220	0.005	4 (36%)
25.01–50.0	2	7	29	1.50	0.50	3.00	0.22	0.232	0.014	4 (57%)
>50	0	2	0			3.00	0.00	0.217	0.020	1 (50%)

[a] One egg was collected from each nest for residue analysis; to compensate for the sample egg collected, add 0.44.
[b] Includes the sample egg collected.
[c] At least one young attained an age of about 2 weeks.

formed residues of DDE (Fig. 2). The least contaminated eggs (N = 26, <1 ppm DDE) showed near-normal shell thickness ($\bar{x}$ = 0.272 ± 0.004 mm) when compared to the pre-1947 norm of 0.275 ± 0.002 mm based on 142 eggs collected in Nevada and eastern Washington and Oregon. PCB's were the only other contaminant present in at least 50% of the eggs. The correlation between the log-transformed residues of PCB's and eggshell thickness (r = −0.264, P < 0.001) was weaker than with DDE.

Nesting Success and DDE Residues

If the data from the 3-year study were pooled, the ability to detect significant effects of DDE on productivity would be improved. However, to pool the data, the relationship between DDE and the success of nesting attempts should be similar in all colonies. To evaluate this relationship, we compared the observed number of successful nests in each colony with the expected number of successful nests based on the pooled DDE data (Table 2). The pooled data (Table 2) include all complete nest records during the study except from Summer Lake in 1980, when common ravens (*Corvus corax*) nearly eliminated production. The expected value for each colony was determined by multiplying the percent nest success (Table 2) by the number of nests in each DDE residue category. Intracolony and a pooled comparison revealed no differences (P > 0.80); these data were consistent with the hypothesis that all colonies demonstrated a similar relationship between DDE and nesting success. Thus, pooling the colonies to better understand the DDE effects seems reasonable.

The pooled data indicate that the percentage of nests successful, clutch size, and to some extent the number of young per successful nest decline as DDE residues increase, especially above 8 ppm (Table 2). Cracked eggs were rare in clutches with lower concentrations of DDE. We suspect that only a percentage of the cracked and broken eggs was found and that reduced clutch size among the higher DDE categories was a function of egg loss through breakage resulting from thin shells or possibly smaller clutches laid by more contaminated females. Based on museum egg

Table 3. Black-crowned night-heron productivity in relation to DDE in the eggs in 1979 and 1980.

Colony	Year	Young fledged/pair[a]		Percent successful[b]	DDE residues: Geometric mean	DDE residues: Percent >8 ppm
Moses Lake	1979	1.9	2.2	79	2.2	13
Summer Lake	1980	[c]		[c]	2.6	10
Ladd Marsh	1979	(2.2)[d]	(2.6)	(90)	(2.6)	(18)
Malheur Lake	1980	1.4	1.7	68	2.7	19
Three-mile Island	1979	2.1	2.5	83	3.4	16
Three-mile Island	1980	(1.8)	(2.2)	(80)	(3.4)	(33)
Ruby Lake	1980	0.9	1.2	67	4.1	25
Malheur Lake	1979	1.5	1.8	67	4.7	45
Stillwater	1980	[e]		[e]	(5.1)	(57)
Foundation Island	1979	1.7	2.0	78	5.7	29
Ruby Lake	1979	0.3	0.4	22	8.2	59

[a] Second column adjusted for the sample egg collected.
[b] At least one young attained an age of about 2 weeks.
[c] Common raven predation nearly eliminated production.
[d] Values in parentheses based on less than 15 samples.
[e] Not determined.

collections, the clutch size in 41 nests from eastern Washington, eastern Oregon, and Nevada averaged 3.80 (range 2–5) before 1947. The clutch size for the same period in California was 3.86 based on 35 clutches (Henny 1972). The pre-DDT-era clutch sizes were similar to the 3.88 for the lowest DDE category in this study (Table 2).

Productivity on a colony basis was generally lower in the colonies with higher DDE residues (Table 3). Eggshell thinning among the colonies ranged from 0.4% (0.274 ± 0.005) at Moses Lake (1979) to 16.4% (0.230 ± 0.005) at Ruby Lake (1979).

Regional Patterns of DDE and DDT Residues

An initial inspection of the DDE residue data from each colony suggested a possible pattern related to nesting colony latitude, i.e., the more southern colonies contained higher concentrations of DDE in the eggs. Also, DDE residues appeared to show a consistent decline from 1979 to 1980. A general linear test was used to compare the regression line from the 1979 data to that from the 1980 data. The two lines were significantly different ($P = 0.007$). The slopes were not statistically different ($P = 0.411$), but the common slope was different ($b = -0.058$, $P < 0.001$) from zero. The elevations (or intercepts) of the two lines were also different ($P = 0.002$). These results indicate that DDE residues in eggs from colonies at more northern latitudes were, on the average, lower than those in eggs from colonies at more southern latitudes. Also, DDE residues in eggs collected in 1979 were, on the average, higher than those in eggs collected in 1980.

DDE residues (geometric means) for each colony in 1979 and 1980 varied (Fig. 3). The two Columbia River colonies (Three-mile Island and Foundation Island) appeared to deviate somewhat from the observed trend. The mean level of DDE for these colonies did not decrease as much during this study as in other colonies.

The pattern of occurrence and decline over time with respect to the parent material DDT is readily apparent when colonies at the same latitude are pooled (Table 4). The DDT findings parallel those for DDE.

ggs in 1979 and 1980.

Percent successful[b]	DDE residues: Geometric mean	Percent >8 ppm
79	2.2	13
[c]	2.6	10
(90)	(2.6)	(18)
68	2.7	19
83	3.4	16
(80)	(3.4)	(33)
67	4.1	25
67	4.7	45
[c]	(5.1)	(57)
78	5.7	29
22	8.2	59

ere significantly different (P = he slopes were not statistically dif- $P = 0.411$), but the common slope ferent ($b = -0.058$, $P < 0.001$) ro. The elevations (or intercepts) wo lines were also different (P = These results indicate that DDE in eggs from colonies at more latitudes were, on the average, an those in eggs from colonies at uthern latitudes. Also, DDE resi- eggs collected in 1979 were, on age, higher than those in eggs col- 1980.

residues (geometric means) for ony in 1979 and 1980 varied (Fig. two Columbia River colonies nile Island and Foundation Is- peared to deviate somewhat from rved trend. The mean level of r these colonies did not decrease during this study as in other col-

attern of occurrence and decline e with respect to the parent ma- DT is readily apparent when col- the same latitude are pooled (Ta- The DDT findings parallel those .

Adjustments for Sample Egg

The unadjusted production rates obtained are not directly comparable to data in the literature because a sample egg was collected. To evaluate the impact of collecting one egg from a nest, a series of nests was also marked from which no eggs were collected. The removal of a sample egg had a negative effect on the number of young fledged per successful nest, but the reduction at four colonies investigated was less than one, ranging from 0.30 to 0.75. Furthermore, the collecting of a single egg did not influence the success or failure of the nesting attempt. Seventy-five percent of the nests were successful (i.e., at least one young reared to 2 weeks) when one egg was collected (65 of 87 nests), and an identical 75% were successful when no egg was collected (27 of 36 nests).

To adjust the young per successful nest for the loss of the egg collected, 0.44 young can be added per nest. This estimate was obtained by pooling the data from all colonies. To adjust young per pair for the egg collected, the percentage of the nests successful can be multiplied by 0.44 and added to the value for young per pair (Table 3).

Reproductive Status of Populations

One approach to evaluating the status of nesting black-crowned night-heron populations is to compare the observed production rates (adjusted for the sample egg collected) with a standard believed necessary to maintain a stable population. Henny (1972) tentatively concluded that 2.0–2.1 young/breeding pair would maintain a stable population. Based on this standard, the northern colonies in this study showed adequate production. Of the more contaminated southern colonies, Malheur Lake showed marginally low production rates both years, and Ruby Lake was considerably below normal (Table 3).

Some loss of young occurs during the

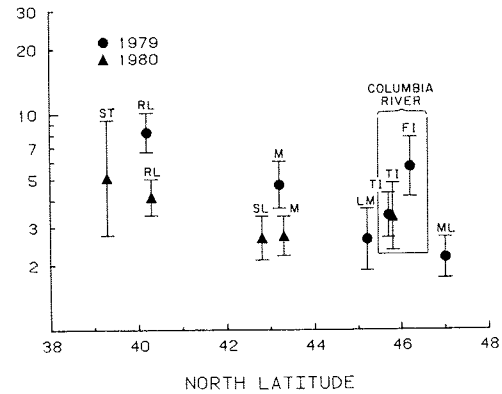

Fig. 3. The relationship between the latitude of black-crowned night-heron nesting colonies and DDE residues (geometric mean ± 1 SE) in eggs collected at the colony. The Columbia River colonies are identified because of probable additional local DDE contamination. FI, Foundation Island; TI, Three-mile Island; ML, Moses Lake; LM, Ladd Marsh; M, Malheur; RL, Ruby Lake; SL, Summer Lake; ST, Stillwater.

Table 4. Percentage of eggs containing DDT in relation to latitude of black-crowned night-heron nesting colonies.

Colony(s)	North latitude	Percent with DDT: 1978 %	1978 N	1979 %	1979 N	1980 %	1980 N
Moses Lake	47°	[a]		17	23	[a]	
Foundation Island, Three-mile Island, Ladd Marsh	45–46°	35	17	27	51	0	9
Malheur Lake, Summer Lake	42–43°	[a]		45	20	17	41
Ruby Lake, Stillwater	39–40°	[a]		52	27	19	32

[a] No data.

Table 5. Organochlorine residues (ppm wet weight) in brains of black-crowned night-herons found dead at the Gallagher Fish Hatchery, Nevada, in 1980 and 1981.

Age	Sex	Weight (g)	Date	DDE	Est. PCB's
ASY[a]	M	840	6 Aug 1980	1.7	1.5
HY	M	725	12 Oct 1980	ND	ND
ASY	M	530	4 Jul 1980	11[b]	15
ASY	M	840	25 Jul 1980	0.10	0.67
ASY	M	475	3 Jul 1980	3.1	1.3
ASY	F	460	5 Jun 1980	3.8	1.3
SY	F	475	10 Jun 1980	65[c]	2.5
ASY	M	436	18 May 1980	4.2	5.5
ASY	M	450	5 Jun 1980	4.6	36
ASY	F	700	3 Jun 1980	0.37	1.2
ASY	F	755	19 May 1980	1.4	1.2
ASY	M	901	late May 1980	4.3[d]	10
ASY	F	660	13 May 1981	4.1	4.3
SY	F	480	21 May 1981	9.7	3.4

[a] HY = hatch year, SY = second year, ASY = after second year, ND = not detected.
[b] Also 0.24 heptachlor epoxide, 0.38 *cis*-chlordane, 0.41 *trans*-nonachlor, 0.16 *cis*-nonachlor, and 0.16 estimated toxaphene.
[c] Also 0.15 hexachlorobenzene, 0.39 dieldrin, and 0.47 estimated toxaphene.
[d] Also 0.14 heptachlor epoxide and 0.12 oxychlordane.

period after the young reach banding age and before they fledge. In an attempt to evaluate this phenomenon, an intensive check was made at Three-mile Island throughout the season to determine (at least minimally) the number of banded birds that died before leaving the colony. Of 118 birds banded, 8 (6.8%) were subsequently found dead at or near the colony. Thus, our production rate estimates are known to be biased high; however, probable undocumented renesting efforts would cause the observed production rate per pair to be biased low. The black-crowned night-heron is a persistent renester (Nickell 1966). As the two production rate biases work in opposite directions, they should partially compensate for each other.

DDE and Adult Mortality

The Gallagher Fish Hatchery near Ruby Lake attracted a number of herons in 1980 and 1981; it was not open in 1979. Some night-herons presumably drowned in the raceways; additional emaciated birds were found dead in the vicinity of the hatchery. Selected individuals, usually the emaciated birds, were tested for salmonella, botulism, and lead poisoning as part of the necropsy. All tests were negative. The emaciated birds (generally those weighing <600 g) and a few of the heavier birds found in the raceways were analyzed to determine contaminant burdens. None of the brains contained residues that implicated DDE or any other organochlorine as the cause of death (Table 5).

Source of DDE-DDT Contamination

We analyzed regurgitated material from young herons to determine if DDE-DDT was being obtained locally. Also, pools of whole fish were collected at three locations. No DDT or DDE was found in regurgitated material collected at Ruby Lake (four pools), the site of the most contaminated heron population. Furthermore, a pool of whole largemouth bass (*Micropterus salmoides*)—a predacious species that is likely to accumulate contaminants if available—from Ruby Lake yielded no organochlorine residues. Additional support for no local contaminaned night-herons found dead at the Gallagher Fish

	DDE	Est. PCB's
0	1.7	1.5
)	ND	ND
	11[b]	15
	0.10	0.67
	3.1	1.3
)	3.8	1.3
)	65[c]	2.5
;0	4.2	5.5
)	4.6	36
)	0.37	1.2
;0	1.4	1.2
)80	4.3[d]	10
;1	4.1	4.3
;1	9.7	3.4

ıachlor, and 0.16 estimated toxaphene.

d individuals, usually the emaciat- ls, were tested for salmonella, bot- and lead poisoning as part of the ›sy. All tests were negative. The ated birds (generally those weighing g) and a few of the heavier birds in the raceways were analyzed to nine contaminant burdens. None of ains contained residues that impli- DDE or any other organochlorine cause of death (Table 5).

e of DDE-DDT Contamination

analyzed regurgitated material young herons to determine if DDE was being obtained locally. Also of whole fish were collected at three ›ns. No DDT or DDE was found in gitated material collected at Ruby (four pools), the site of the most con- ated heron population. Further a pool of whole largemouth bass opterus salmoides)—a predacious s that is likely to accumulate con- ants if available—from Ruby Lake d no organochlorine residues. Ad- al support for no local contamina-

tion at Ruby Lake was the absence of organochlorine residues in the brain of the only fledgling heron analyzed from Ruby Lake (Table 5). Likewise, no organochlorine contamination was detected in two pools of regurgitated material from Malheur Lake.

DDE was found in two of three pools of regurgitated material from herons at Foundation Island and Three-mile Island on the Columbia River. Two pools of whole fish (northern squawfish [*Ptychocheilus oregonensis*] from Three-mile Island and largescale sucker [*Catostomus macrocheilus*] from Foundation Island) taken along the Columbia River also contained DDE and PCB's. DDE residues in the black-crowned night-herons nesting along the Columbia River appeared to be higher than expected based on the pattern observed among the other colonies (Fig. 3). We suspect that local DDE contamination in the Columbia River accounts for the higher-than-expected DDE residues in the black-crowned night-herons at the two island sites in the river. These findings support the contention that, with the exception of the Columbia River colonies, most of the DDE-DDT contamination comes from a source away from the breeding grounds.

Fifteen "wintering ground" band recoveries were reported from black-crowned night-herons banded during the nesting season in the Pacific Northwest. Black-crowned night-herons produced in Washington (46–47°N latitude) were recovered in southern Arizona (one) and the states of Sonora (one), Sinaloa (one), and Nayarit (one) in Mexico; Oregon and Idaho herons (42–45°N latitude) were recovered in the Mexican states of Sinaloa (three), Nayarit (three), Colima (one), and Vera Cruz (two); and Ruby Lake, Nev., herons (40°N latitude) were recovered in southern California (one) and Sonora (one). Many of the recoveries were from the west coast of Mexico, although two were from the southwestern United States and two were from the east coast of Mexico. The two Ruby Lake (the most contaminated colony) recoveries include one "found dead" in January east of Los Angeles (Perris) and a yearling shot in May near Moctezuma, Sonora.

The frequent occurrence of the parent material DDT (Table 4) at the most contaminated colonies suggests that the contaminants are being obtained in an area where DDT is still used. Henny et al. (1982*a*) found that bats (Chiroptera: Vespertilionidae) commonly contained concentrations of DDT for about 2 years after a DDT spray project, after which the metabolite DDE was primarily encountered. DDT is still being used in much of Latin America (Weir and Schapiro 1981). However, the significantly higher incidence of PCB's at Ruby Lake also suggests some industrial activity on their wintering area, or at least along the migration route.

Many individuals and resource agencies believe that organochlorine pesticides, particularly DDT, are no longer a major threat to wildlife populations in the United States. This conclusion probably resulted from the observed improvement in production and increases in depleted populations of birds in the eastern United States and Great Lakes Region following the DDT ban. Unfortunately, few contaminant studies were conducted on migratory birds in the Intermountain West. The observed DDE-DDT levels in eggs suggest that black-crowned night-herons from Washington, Oregon, and Nevada are still subjected to DDT on their wintering grounds. Productivity at Ruby Lake was severely depressed in 1979. We hope that the reduced residues detected between 1979 and 1980 reflect the beginning of a long-term pattern of reduced DDT on the wintering grounds. The DDE decline parallels that reported for the same time period in peregrine falcons (*Falco peregrinus*) that winter in Latin America (Henny et al. 1982*b*).

LITERATURE CITED

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

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

BROWN, D. E. 1926. Birds observed at Moses Lake, Grant County, Washington. Murrelet 7:48–51.

CONGDON, R. T. 1925. Nesting of the great blue heron in eastern Washington. Murrelet 6:25–27.

CROMARTIE, E., ET AL. 1975. Residues of organochlorine pesticides and polychlorinated biphenyls and autopsy data for bald eagles, 1971–72. Pestic. Monit. J. 9:11–14.

CUSTER, T. W., G. L. HENSLER, AND T. E. KAISER. 1983. Clutch size, reproductive success, and organochlorine contaminants in Atlantic Coast black-crowned night herons. Auk 100:699–710.

EDSON, J. M. 1932. A reconnaissance of the sage country, eastern Washington. Murrelet 13:41–46.

FITZNER, R. E., D. F. MARTIN, AND R. E. FRIEZE. 1979. First breeding record for the great egret (*Cosmerodius albus*) in Washington. Murrelet 60:33–34.

HENNY, C. J. 1972. An analysis of the population dynamics of selected avian species with special reference to changes during the modern pesticide era. U.S. Fish Wildl. Serv. Wildl. Res. Rep. 1. 99pp.

———. 1977. Research, management, and status of the osprey in North America. Pages 199–222 *in* R. D. Chancellor, ed. World Conf. on Birds of Prey. Int. Counc. Bird Preserv., London, U.K.

———, L. J. BLUS, S. V. GREGORY, AND C. J. STAFFORD. 1981. PCB's and organochlorine pesticides in wild mink and river otters from Oregon. Pages 1763–1780 *in* J. A. Chapman and D. Pursley, eds. Proc. Worldwide Furbearer Conf., Frostburg, Md.

———, C. MASER, J. O. WHITAKER, JR., AND T. E. KAISER. 1982*a*. Organochlorine residues in bats after a forest spraying with DDT. Northwest Sci. 56:329–337.

———, F. P. WARD, K. E. RIDDLE, AND R. M. PROUTY. 1982*b*. Migratory peregrine falcons, *Falco peregrinus*, accumulate pesticides in Latin America during winter. Can. Field-Nat. 96: 333–338.

HICKEY, J. J., AND D. W. ANDERSON. 1968. Chlorinated hydrocarbons and eggshell changes in raptorial and fish-eating birds. Science 162:271–273.

HOEFLER, J. E. 1980. The status and distribution of the black-crowned night heron in Wisconsin. M.S. Thesis, Univ. Wisconsin, Stevens Point. 69pp.

KAISER, T. E., ET AL. 1980. Organochlorine pesticide, PCB, and PBB residues and necropsy data for bald eagles from 29 states—1975–77. Pestic. Monit. J. 13:145–149.

KITCHEN, E. A. 1930. Nesting observations at Moses Lake in May. Murrelet 11:55–59.

NICKELL, W. P. 1966. The nesting of the black-crowned night heron and its associates. Jack-Pine Warbler 44:130–139.

OHLENDORF, H. M., E. E. KLAAS, AND T. E. KAISER. 1978. Environmental pollutants and eggshell thinning in the black-crowned night heron. Pages 63–82 *in* Wading birds. Natl. Audubon Soc. Res. Rep. 7.

———, D. M. SWINEFORD, AND L. N. LOCKE. 1979. Organochlorine poisoning of herons. Proc. Colonial Waterbird Group 3:176–185.

PRICE, I. M. 1977. Environmental contaminants in relation to Canadian wildlife. Trans. North Am. Wildl. and Nat. Resour. Conf. 42:382–396.

RATCLIFFE, D. A. 1967. Decrease in eggshell weight in certain birds of prey. Nature 215:208–210.

———. 1970. Changes attributable to pesticides in egg breakage frequency and eggshell thickness in some British birds. J. Appl. Ecol. 7:67–115.

SPITZER, P. R., ET AL. 1978. Productivity of ospreys in Connecticut-Long Island increases as DDE residues decline. Science 202:333–335.

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

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

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

THOMPSON, B. C., AND J. E. TABOR. 1981. Nesting populations and breeding chronologies of gulls, terns, and herons on the upper Columbia River, Oregon and Washington. Northwest Sci. 55:209–218.

THOMPSON, S. P., C. D. LITTLEFIELD, AND R. A. RYDER. 1979. Historical review and status of colonial nesting birds on Malheur National Wildlife Refuge, Oregon. Proc. Colonial Waterbird Group 3:156–164.

rica during winter. Can. Field-Nat. 96:
3.
J., AND D. W. ANDERSON. 1968. Chlo-
hydrocarbons and eggshell changes in
il and fish-eating birds. Science 162:271–
J. E. 1980. The status and distribution
black-crowned night heron in Wisconsin.
Thesis, Univ. Wisconsin, Stevens Point.
E., ET AL. 1980. Organochlorine pesti-
PCB, and PBB residues and necropsy data
ld eagles from 29 states—1975–77. Pestic.
J. 13:145–149.
E. A. 1930. Nesting observations at Mo-
ke in May. Murrelet 11:55–59.
W. P. 1966. The nesting of the black-
ed night heron and its associates. Jack-Pine
ler 44:130–139.
RF, H. M., E. E. KLAAS, AND T. E. KAISER.
Environmental pollutants and eggshell
ng in the black-crowned night heron. Pages
in Wading birds. Natl. Audubon Soc. Res.
7.
). M. SWINEFORD, AND L. N. LOCKE. 1979.
nochlorine poisoning of herons. Proc. Co-
Waterbird Group 3:176–185.
M. 1977. Environmental contaminants in
on to Canadian wildlife. Trans. North Am.
l. and Nat. Resour. Conf. 42:382–396.
E, D. A. 1967. Decrease in eggshell weight
rtain birds of prey. Nature 215:208–210.
1970. Changes attributable to pesticides in
breakage frequency and eggshell thickness
me British birds. J. Appl. Ecol. 7:67–115.
P. R., ET AL. 1978. Productivity of ospreys
Connecticut-Long Island increases as DDE
lues decline. Science 202:333–335.
, L. F., W. H. STICKEL, R. D. MCARTHUR,
D. L. HUGHES. 1979. Chlordane in birds:
udy of lethal residues and loss rates. Pages
–396 *in* W. B. Deichmann, organizer. Toxi-
gy and occupational medicine. Elsevier/
th-Holland, New York, N.Y.
S. N. WIEMEYER, AND L. J. BLUS. 1973.
ticide residues in eggs of wild birds: adjust-
nt for loss of moisture and lipid. Bull. Envi-
. Contam. Toxicol. 9:193–196.
O, S., AND F. MATSUMURA. 1977. Metabolic
tes of *cis*- and *trans*-chlordane in rats. J. Agric.
od Chem. 25:872–880.
SON, B. C., AND J. E. TABOR. 1981. Nesting
pulations and breeding chronologies of gulls,
ns, and herons on the upper Columbia River,
egon and Washington. Northwest Sci. 55:209–
3.
SON, S. P., C. D. LITTLEFIELD, AND R. A.
DER. 1979. Historical review and status of
lonial nesting birds on Malheur National
ildlife Refuge, Oregon. Proc. Colonial Water-
d Group 3:156–164.

TREMBLAY, J., AND L. N. ELLISON. 1980. Breeding success of the black-crowned night heron in the St. Lawrence estuary. Can. J. Zool. 58:1259–1263.

WEIR, D., AND M. SCHAPIRO. 1981. Circle of poison. Inst. Food and Dev. Policy. San Francisco, Calif. 99pp.

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