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BROWN PELICAN POPULATIONS AND POLLUTANTS IN TEXAS 1975–1981

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Only a decade ago the population of Brown Pelicans (*Pelecanus occidentalis*) nesting in Texas was considered nonviable. From the mid-1950s through 1974 no more than 50 pelicans remained from a population that once numbered about 5000 individuals. During those years, there were few attempts at reproduction, and nesting pelicans seldom produced enough young to compensate for adult mortality. The history, status, and role of pesticides in the decline of this endangered species on the Gulf Coast from the early 1960s through 1974 was reviewed in an earlier paper (King et al. 1977). Our studies since 1974 indicate that reproductive success has improved and the population is increasing. The purpose of this paper is to present data gathered from 1975 through 1981 on environmental contaminants and to interpret contaminant influence on current Brown Pelican reproductive success and population status.

METHODS

We made year-round observations of known Brown Pelican habitats in coastal Texas to document numbers of nesting and wintering birds. Weekly observations were made throughout the nesting season from the onset of courtship through fledging. We observed the colonies from a distance of at least 200 m to minimize the effects of human disturbance. From 1975 through 1979, the nesting areas were not entered until most birds had been incubating for 2–3 weeks. In 1980 and 1981, we did not approach individual nests until young pelicans could be seen in most nests with the aid of binoculars. We then entered the colonies and examined unhatched eggs to assess viability. Abandoned eggs were collected for the analysis of contaminant residues and to measure shell thicknesses. Whole eggs were weighed and measured. The contents were removed, frozen, and stored in chemically cleaned jars.

Shell thicknesses of eggs collected from 1975 to 1981 were compared with those of museum eggs collected before the widespread use of DDT (pre-1947), and also, with measurements of eggs collected in 1970 reported by King et al. (1977). Only eggs from Texas colonies were used for comparisons of shell thickness. Because only addled eggs from abandoned nests were collected for residue analyses and measurements of shell thickness, our collection was not a random sample. Pollutant residues may have been biased towards higher levels, and shell-thickness values may have been lower than those obtained from a random collection of viable eggs.

Nestling pelicans were banded and color-marked just prior to fledging. Each pelican was banded with a Fish and Wildlife Service band on one leg and a rigid, colored, plastic band on the other leg. Colored bands were coded by year but not by the colony from which the young fledged.

During the study, two moribund pelicans were recovered from Corpus Christi Bay. Both pelicans died within 24 h of capture despite concerted efforts to keep them alive. The

birds were necropsied and brain and carcass tissues were saved for residue analyses. Pelican food items, including regurgitated fish, also were salvaged for residue analyses.

Analysis for chemical residues was conducted at the Patuxent Wildlife Research Center at Laurel, Maryland. Individual egg and tissue samples were analyzed for several organochlorine compounds based on methods described by Cromartie et al. (1975). Polychlorinated styrenes were quantified only in 1980 samples. The lower limit of quantification was 0.1 ppm for all organochlorine pesticides and 0.5 ppm for PCBs. The lower limit of quantification for residues in pelican food items collected from 1977 to 1979, was 0.1 ppm; samples from 1980 were analyzed to the nearest 0.01 ppm. All residues are expressed on a wet-weight basis.

Metal residues were quantified in samples collected from 1975 through 1978. Residues of arsenic, selenium, and zinc were measured under the standard conditions recommended by Perkin-Elmer, Norwalk, Conn. (1976). The lower detection limits of arsenic, selenium, and zinc were 0.05, 0.01, and 0.01 ppm, respectively. A 5-g sample for mercury analysis was digested by methods described by Monk (1961). Total mercury was determined by cold vapor atomic absorption spectrophotometry (Hatch and Ott 1968). The lower limit of reportable mercury residues was 0.02 ppm.

Statistical comparisons of residue levels and eggshell thicknesses were made using an analysis of variance. For samples in which no residues were detected, a value of one-half the lower detection limit was assigned and residues were then log–transformed for statistical tests. Residue levels were compared between years using Scheffe's Multiple Comparison procedure (Neter and Wasserman 1974). Spearman's Rank Correlations were calculated among residues and shell thickness values. Unless otherwise stated, a significance level of 0.05 was used.

RESULTS AND DISCUSSION

Population status.—Our observations, and reports incidental to other surveys (winter waterfowl survey, Audubon Christmas Bird Counts), indicated that fewer than 100 pelicans spent the winter months along the Texas Coast during 1970–1981. Wintering pelicans usually were concentrated in 2 areas; from 16 to 39 individuals were recorded on the central coast in the San Antonio–Corpus Christi Bay areas, and up to 40 individuals were recorded in the Lower Laguna Madre near Port Isabel (Fig. 1). Infrequent sightings of 1 to 3 pelicans were made in the Freeport–Galveston Bay area. Most pelicans wintering on the central coast were adults, whereas most observed near Port Isabel were subadults.

Each year, pelican numbers increased slowly during the spring and summer months and peaked in Aug. or Sept. The maximum number of pelicans seen annually varied from 90 individuals in 1975 to about 500 individuals in 1979 (Table 1). Most of the pelicans observed during late summer were unbanded subadults. Because almost all nestling pelicans from Texas and Louisiana were banded before they fledged, we suspect that the large influx of unbanded subadults were pelicans from Mexican colonies.

Nesting populations.—The number of pelicans nesting in Texas increased from 18 pairs in 1975 to 57 in 1981 (Table 1). Pelicans established

TABLE 1

BROWN PELICAN POPULATIONS AND REPRODUCTIVE PERFORMANCE IN TEXAS, 1975–1981

Year	Estimated number			Maximum number of individuals[a]
	Nesting pairs	Young fledged	Young per pair	
1975	18	9	0.5	90
1976	16	16	1.0	90
1977	17	34	2.0	112
1978	23–25[b]	37[c]	1.5–1.6	350
1979	33–38[b]	46[d]	1.2–1.4	500
1980	40–54[b]	76	1.4–1.9	400–450
1981	57	46	0.8	430–470

[a] Includes nesting pelicans, fledged young, and immigrants. Peak populations were recorded in July or Aug. each year.
[b] Nest abandonment and possible renesting made more precise counts impossible.
[c] Thirty-eight young reached fledging size but one was blind in one eye and was collected for a zoo.
[d] One tame juvenile pelican was reported at several locations on the central coast. After several unsuccessful attempts to integrate the bird into the wild population, it was placed in a zoo.

colonies at eight locations along the coastal bend between Aransas and Corpus Christi bays (Fig. 1). They nested on 5 islands in the San Antonio–Aransas Bay area: North, Carroll, Deadman, False Live Oak Point, and Long Reef. In Corpus Christi Bay, they nested only on Pelican Island. For the first time since the population crash in the late 1950s, Brown Pelicans nested on the upper Texas coast in 1980 and 1981. A lone pair built a nest both years on a small dredge-material island in Cedar Lakes within the boundaries of San Bernard National Wildlife Refuge.

Nesting activities frequently began 2–3 weeks earlier at the Aransas Bay area than at Pelican Island in Corpus Christi Bay. Courtship and nest site selection at Aransas Bay usually were initiated in mid- to late Feb. with most birds incubating by mid–March. Nesting activities were more synchronized at Aransas Bay than at Pelican Island. Most pairs were incubating by late March at Pelican Island, but a few late nesting birds were still incubating eggs in late June. Although renesting of Brown Pelicans has been documented by Schreiber (1979), we were unable to determine if pelicans that abandoned their nests at Aransas Bay renested at Corpus Christi Bay.

Reproductive success.—Average clutch size varied from 2.0 (N = 18) in 1975 to 3.25 (N = 16) in 1976. Estimates of fledging success varied from 0.5 in 1975 to 2.0 in 1977 (Table 1) and probably were low because we were unable to document renesting attempts. Henny (1972) calculated that recruitment necessary to maintain a stable population was between 1.2 and 1.5 young per pair. Schreiber (1979) discussed recruitment in detail, and his data suggested that normal nesting success was close to, or

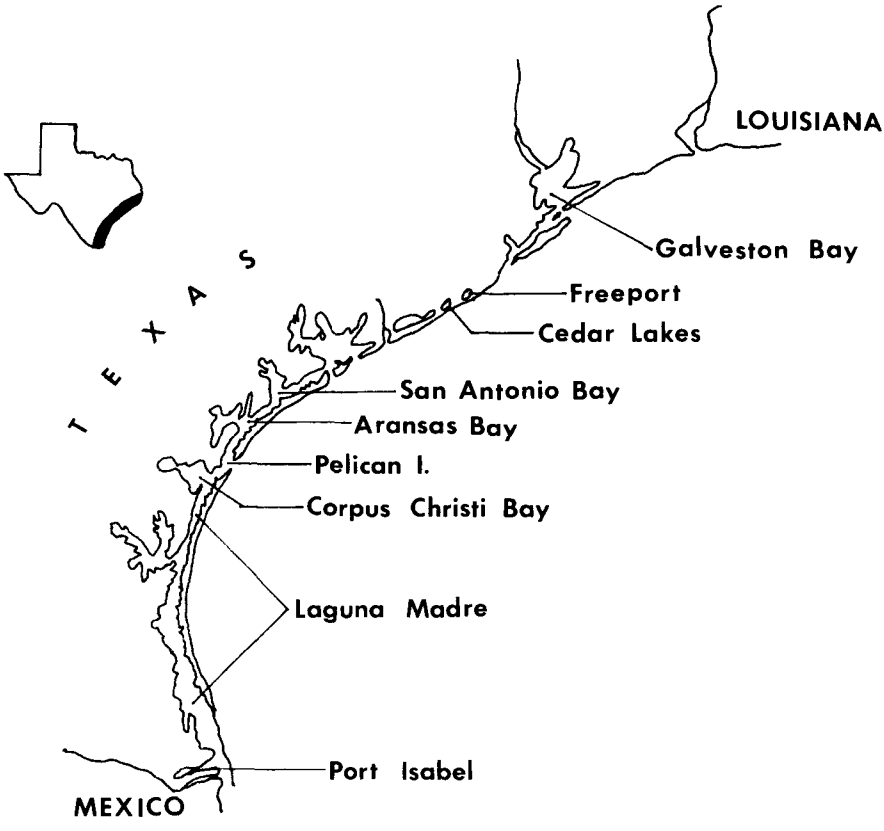

FIG. 1. Locations of Brown Pelican colonies and wintering areas on the Texas Coast.

slightly below, one young fledged per pair per year. By either estimate, recruitment in Texas colonies was adequate during all years, except perhaps in 1975.

Reproduction in terms of total young produced has improved greatly in recent years. For example, in the 11-year period from 1964 to 1974, only 46 pelicans were fledged from Texas colonies (King et al. 1977). In contrast, more than five times as many young (264) were fledged between 1975 and 1981.

Sighting rates of color-banded fledgling pelicans observed on and near the colonies in subsequent nesting seasons indicate that many subadult Texas pelicans do not return to nesting sites during the first breeding season following fledging (Table 2). Greater numbers of each year's cohort usually were observed in the second and third year after fledging. This

TABLE 2

RESIGHTING RATES[a] OF TEXAS COLOR-BANDED BROWN PELICANS COMPARED WITH THOSE IN SOUTH CAROLINA AND CALIFORNIA

Age class	Estimated % survival[b]		
	Texas	South Carolina	California
1st-year	22	40	50
2nd-year	27	30	37
3rd-year	23	25	32
4th-year	19	20	27

[a] Resighting rate = % of total young banded that were observed in each following year.

[b] Texas = this study; data indicate that many 1st- and 2nd-year pelicans do not return to their breeding areas in the subsequent nesting season. South Carolina = data based on Henny's (1972) mortality estimates adjusted for band loss. California = Anderson and Gress (1983), hypothetical survival rates.

phenomenon precludes accurate estimates of survival through the first and second year. Pelican survival to the third and fourth year, however, are in close agreement with estimates of survival rates for South Carolina and California populations (Henny 1972, Anderson and Gress 1983).

Organochlorine residues.—From 2 to 57 addled eggs were salvaged each year for residue analyses and eggshell thickness comparisons. DDT and its metabolites, primarly DDE, were detected in all eggs and geometric mean levels of DDE varied from 0.9 to 2.3 ppm annually (Appendix 1) and were lowest in 1976 and 1979. There has been a decline in DDE residues over the past decade with levels observed in the 1975–81 samples about one-half those (3.2 ppm) reported by King et al. (1977) for eggs collected in 1970.

Although DDE in Texas pelican eggs declined from 1970 to 1975–81, mean residues remained higher than those reported most recently in eggs from South Carolina and Louisiana. Average DDE residues in South Carolina eggs declined from 5.4 ppm in 1969 to about 0.8 ppm in 1977 (Blus et al. 1979b, Mendenhall and Prouty 1979), then showed little change through 1980 (Patuxent Wildlife Research Center, unpublished data). In Louisiana, declining DDE residues also leveled off at less than 1.0 ppm between 1974 and 1976 (Blus et al. 1979a).

Current levels of DDE apparently pose a minimal threat to pelican reproduction. The parent compound, DDT, was confirmed in one or more eggs each year except 1977, indicating recent exposure to the compound. With the exception of slightly elevated DDE levels found in the small sample of eggs collected in 1977 and 1978, the residues in our samples were similar to the 1.67 ppm reported by Schreiber and Risebrough (1972) for eggs in stable Florida populations. The maximum DDE residue in

pelican eggs from successful South Carolina nests was 3.7 ppm, and egg residue levels that exceeded 3.0 ppm were associated with substantially impaired reproductive success (Blus 1982). About 7% of the eggs in our collection contained DDE residues that approached the 3.0 ppm critical level. In contrast, more than 70% of the eggs collected in 1970 had 3.0 ppm or more DDE (King et al. 1977).

Dieldrin residues were detected in all eggs collected from 1975 through 1978. Residues averaged 0.3 ppm or less in all years and were below levels reported in pelican eggs from South Carolina, Florida, and Louisiana (Blus et al. 1977, 1979a, b). The critical level of dieldrin in pelican eggs associated with impaired reproductive success exceeds one ppm (Blus 1982). Current levels of dieldrin in Texas pelicans apparently do not pose a threat to reproductive success and survival.

Other organochlorine insecticides including chlordane-related compounds, HCB, and toxaphene were infrequently detected, usually at <1.0 ppm, and were not considered biologically significant. Endrin was recovered in pelican eggs only in 1975 when 15 of 18 eggs contained from 0.1 to 0.3 ppm. The presence of endrin in 1975 is of special interest because endrin in Louisiana pelican eggs also peaked that year and maximum residues coincided with a die-off in 1975 of large numbers of White (*Pelecanus erythrorhynchos*) and Brown pelicans in Louisiana (Nesbitt et al. 1978, Blus et al. 1979a).

PCBs, like DDE, were recovered in all eggs with one exception (Appendix 1). Residues in 1976 samples were lower than those of other years. PCB concentrations that averaged 9.37 ppm in 1970 (King et al. 1977) declined more than eight-fold by 1981. The decline in PCB residues in Texas Brown Pelican eggs is in notable contrast to the relatively stable levels reported in pelican eggs from South Carolina and Louisiana (Mendenhall and Prouty 1979, Blus et al. 1979a).

During the course of this study, 2 adult female pelicans were found moribund, and brain and carcass samples were salvaged for residue analyses. Lethal residues of DDT plus DDD in the brain generally exceed 20–30 ppm (Bernard 1963, Stickel et al. 1966, Hill et al. 1971). DDT residues in the brain tissues of our pelican samples were 1.1 and 0.5 ppm; therefore, death was not a result of DDT poisoning. No other organochlorine insecticide residues were detected in the brain. One sample contained low (1.0 ppm) residues of PCB. Although brain residues were relatively low, DDT carcass levels (14 and 26 ppm) were higher than those reported by Blus et al. (1977) in tissues of four Georgia and Florida pelicans found dead ($\bar{x} = 5.4$, range = 0.9–13.0 ppm).

Organochlorine residues were not detected in the 19 pelican food items (regurgitated fish; *Brevoortia patronus* and *Anchoa mitchilli*) collected

between 1977 and 1979 that were analyzed to the nearest 0.1 ppm. Eleven of 12 Gulf Menhaden (*B. patronus*) collected in 1980 and analyzed to the nearest 0.01 ppm contained an average of 0.06 ppm DDE. There was no difference in DDE levels between the Carroll Island and Pelican Island samples. In addition to DDE and DDD, one sample from Carroll Island also contained 0.03 ppm DDT. Low levels (<0.04 ppm) of chlordane, HCB, dieldrin, and octachlorostyrene were found in fewer than one-half of the fish. PCB was detected in 6 of 12 samples at <0.25 ppm.

Both DDE and DDT were detected in fish and in pelican eggs collected in 1980. DDT and metabolite residues may have been magnified 23 times from fish (0.06 ppm) to pelican eggs (1.36 ppm), but interpretation of this apparent biomagnification is complicated by the migratory habits of the pelicans and their prey.

As the use of DDT was suspended in 1972, we found it of interest that pelican food items contained both DDD and DDT in addition to DDE. The presence of DDT suggested that the fish were recently exposed to that compound. In the past, we hypothesized that Brown Pelicans nesting in Texas acquired most of their DDE burdens on wintering areas in Mexico. Because DDT was recovered in food fish from Texas waters, contamination from local sources was apparent.

Metal and selenium residues.—Mercury, arsenic, and selenium residues in Texas pelican eggs averaged 0.5 ppm or less (Appendix 2). Mercury ranged from 0.04 to 0.60 ppm and was recovered in all eggs. Residues were generally below levels associated with decreased hatchability and nestling survival of other species of birds (Fimreite 1971, Spann et al. 1972, Vermeer et al. 1973, Connors et al. 1975, Heinz 1976). From 1974 to 1978, mean mercury levels in Texas pelican eggs (0.04–0.28 ppm) were similar to, or lower than, those reported in pelican eggs collected from South Carolina and Florida (Blus et al. 1977). In contrast, mercury values were slightly greater in Texas pelican eggs than levels in Louisiana eggs (Blus et al. 1975). Mercury residues below 0.25 ppm in eggs of some species may represent background levels (Faber and Hickey 1973). About 73% of the eggs in our sample contained mercury residues below 0.25 ppm.

Mean selenium residues varied from 0.21 to 0.50 ppm and were 1.3 to 3.6 times greater than those in South Carolina and Florida eggs (Blus et al. 1977). The toxicity of selenium at the maximum level found in this study, 0.65 ppm, has not been determined. Selenium residues in the eggs of healthy chickens maintained on an adequate diet averaged about 0.30 ppm (Latshaw 1975). The maximum arsenic residue found in Texas pelican eggs was 0.26 ppm, slightly below the mean level (0.31 ppm) in South Carolina eggs but greater than average levels (0.10 ppm) in eggs from

Florida colonies (Blus et al. 1977). Levels of zinc were below those found in eggs from a stable Common Tern (*Sterna hirundo*) colony on Great Gull Island, New York (Connors et al. 1975). The residue levels of arsenic and zinc were low and probably represent background levels that had little effect on pelican reproduction or survival.

Most insecticide residues were positively associated with each other and with PCB levels (Appendix 3). The only significant association between metal residues was a positive relation between arsenic and selenium.

Oil pollution.—Because of their gregarious behavior, feeding habits, and preference for shallow coastal waters, pelicans are highly vulnerable to oil pollution (Clapp et al. 1982). Despite the relatively small number of pelicans in Texas, there have been numerous observations of oiled birds. The 3 June 1979 blowout and resultant spill from the Ixtoc I oil well in the Bay of Campeche, Mexico, caused considerable concern for the welfare of Brown Pelicans in Mexico and Texas. Although pelicans occasionally were seen outside the barrier islands, their primary nesting, feeding, and loafing areas were within the various bay systems. Booms kept most of the oil from entering Corpus Christi and Aransas bays. Despite these preventive measures, 8 Brown Pelicans were observed with oil on their feathers, but no pelicans were found completely debilitated by oil. In another incident, a pipeline rupture in Oct. 1976 resulted in the fatal oiling of one adult pelican (King et al. 1979).

Eggshell thinning.—Annual mean shell thickness of eggs analyzed for pollutant residues varied from 0.48 to 0.54 mm, about 4–14% thinner than normal (Table 3). The mean shell thickness of eggs collected from 1975 to 1981 was no different than that reported by King et al. (1977) for eggshells collected in 1970, but current thickness remained significantly ($P < 0.01$) less than that of eggs collected before the wide-spread use of DDT (pre-1947). An inverse correlation between eggshell thickness and DDE and PCB residues was reported in 1970 samples (King et al. 1977); however, only a weak correlation ($P < 0.06$) was found between shell thickness and DDE residues in eggs collected from 1975 to 1981 (Appendix 3).

SUMMARY

The population status, reproductive success, and levels of environmental contaminants in Brown Pelicans (*Pelecanus occidentalis*) in Texas were studied from 1975 through 1981. Breeding populations increased from 18 pairs in 1975 to 57 pairs in 1981. All unhatched eggs salvaged for analyses of contaminant residues contained DDT metabolites. Mean DDE levels varied from 0.9 to 2.4 ppm and about 7% of the samples had residues that approached critical levels that could affect reproductive success. DDE levels did not decline from 1975 to 1981 and residues leveled off at higher values than those in South Carolina and Louisiana pelican populations. PCB residues also remained stable. Endrin was detected only in 1975,

TABLE 3
SHELL MEASUREMENTS OF TEXAS BROWN PELICAN EGGS

Collection date (N)	Mean thickness (range) mm	% change from pre-1947 value
Pre-1947 (43)[a]	0.56 (NA)[b]	—
1970 (14)	0.50 (0.41–0.60)	−11
1975 (18)	0.50 (0.44–0.55)	−11
1976 (9)	0.52 (0.50–0.59)	−7
1977 (2)	0.54 (0.53–0.55)	−4
1978 (4)	0.48 (0.41–0.52)	−14
1979 (9)	0.48 (0.44–0.53)	−14
1980 (4)	0.53 (0.46–0.61)	−5
1981 (57)	0.51 (0.44–0.59)	−9

[a] N = number of eggs measured. Pre-1947 data from Anderson and Hickey (1970), 1970 data from King et al. (1977).
[b] NA = data not available.

and paralleled peak levels in Louisiana pelican eggs and coincided with the 1975 endrin-caused die-off of White and Brown pelicans in Louisiana. Residues of mercury, arsenic, selenium, and zinc were low and probably had little effect on pelican reproduction and survival. Mean eggshell thickness was 4–14% thinner than normal, but we found no evidence that shell thinning adversely affected reproduction. Observations of color-marked young indicated that not all one- and two-year-old pelicans returned to Texas nesting areas. Subadult survival through the third and fourth year was similar to survival rates of South Carolina and California Brown Pelicans. Overall reproductive success improved and the population is increasing.

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APPENDIX 1

ORGANOCHLORINE RESIDUES IN TEXAS BROWN PELICAN EGGS, 1975–1981

Year	No. eggs	Geometric mean residue ppm wet weight, (N), 95% confidence interval, and range[a]					
		DDE	DDD	DDT	Dieldrin	Chlordane[b]	PCB
1975	18	1.7 (18)A[c]	0.3 (18)AB	– (4)	0.3 (18)A	0.2 (16)A	4.0 (18)A
		1.4–2.0	0.2–0.3	–	0.3–0.4	–	3.4–4.6
		0.9–3.0	0.1–0.7	0.1–0.2	0.2–0.5	0.1–0.6	2.4–7.3
1976	9	0.9 (9)B	0.1 (8)B	– (2)	0.2 (9)AB	– (1)	0.8 (9)B
		0.7–1.1	0.1–0.2	–	0.1–0.3	–	0.4–1.6
		0.6–1.8	0.1–0.4	0.1–0.2	0.1–0.4	0.1	1.0–1.6
1977	2	2.3 (2)A	0.7 (2)A	– (1)	0.1 (2)B	ND	2.8 (2)A
		0.8–6.9	0.0–373	–	0.0–0.3		1.5–5.6
		2.3–2.6	0.4–1.2	0.8	0.1		3.0–2.7
1978	4	2.2 (4)A	0.2 (4)AB	– (1)	0.1 (4)AB	0.2 (4)A	3.5 (4)A
		1.7–2.9	0.1–0.4	–	0.1–0.2	–	2.4–5.0
		0.4–2.5	0.2–0.4	0.1	0.1–0.2	0.1–0.4	2.5–4.0
1979	9	0.9 (9)B	– (2)	– (1)	0.1 (4)B	– (2)	1.4 (9)A
		0.5–1.4	–	–	0.0–0.1	–	0.9–2.2
		0.4–2.5	0.1–0.4	0.1	0.1–0.2	0.1–0.2	0.6–2.5
1980	4	1.4 (4)A	0.1 (3)B	– (1)	0.1 (2)B	– (1)	1.8 (4)A
		0.8–2.4	0.0–0.5	–	0.0–0.2	–	1.4–2.3
		1.0–2.2	0.1–0.3	0.1	0.1–0.2	0.1	1.6–2.2
1981	57	1.3 (57)A	0.2 (48)B	– (2)	0.1 (34)B	– (15)	1.1 (56)A
		1.2–1.4	0.1–0.2	–	0.0–0.1	–	1.0–1.3
		0.5–2.5	0.1–0.8	0.2	0.1–0.3	0.1–0.5	0.6–2.8

[a] Dashes indicate that the frequency of detection was <50% and the mean was not calculated. (N) = number of samples with detectable residues. ND = No residue detected. Range = high and low extremes of detected residues. HCB was detected in 18 eggs in 1975, mean = 0.08 (0.1–0.2 ppm). Heptachlor epoxide was recovered in 6 eggs in 1975, mean = 0.15 (0.1–0.2 ppm). Endrin was found in 15 of 18 eggs in 1975, mean = 0.15 (0.1–0.3 ppm). Toxaphene was observed in 3 eggs in 1975 (0.2, 0.5, 0.5 ppm) and in one egg in 1976, 0.07 ppm.

[b] Total chlordane isomers = *cis*-chlordane + *trans*-nonachlor + *cis*-nonachlor. Samples collected in 1979 were not analyzed for *trans*-nonachlor.

[c] Means sharing the same letter suffix are not significantly different from each other.

APPENDIX 2

METAL AND SELENIUM RESIDUES IN TEXAS BROWN PELICAN EGGS

Year	No. eggs	Geometric mean residue, (95% CI), and range[a]			
		Arsenic	Mercury	Selenium	Zinc
1975	18	0.10A (0.09–0.12) 0.07–0.25	0.16A (0.11–0.23) 0.07–0.54	0.45A (0.41–0.49) 0.13–0.57	NA
1976	9	0.09A (0.07–0.12) 0.05–0.14	0.11A (0.07–0.17) 0.07–0.46	0.50A (0.43–0.57) 0.37–0.65	8.82A (8.16–9.52) 7.60–10.40
1977	2	0.25B (0.20–0.33) 0.25–0.26	0.04B (0.01–0.18) 0.04–0.05	0.43A (0.01–18.8) 0.32–0.58	4.93A (0.63–38.4) 4.20–5.80
1978	4[b]	0.03 (0.02–0.07) 0.06	0.28C (0.12–0.65) 0.18–0.60	0.21B (0.13–0.33) 0.15–0.29	6.90A (3.75–12.7) 4.60–10.0

[a] Residues expressed in ppm wet weight. NA = not analyzed. Numbers in parentheses indicate 95% confidence intervals. Means sharing the same letter suffix are not significantly different from each other.

[b] Only 1 of 4 eggs contained a detectable residue.

APPENDIX 3

INTERCORRELATION OF MAJOR CONTAMINANT RESIDUES AND SHELL THICKNESS OF TEXAS BROWN PELICAN EGGS

		DDE	DDD	Dieldrin	PCB	AS	HG	SE	ZN
DDE	r[a]	1.00000	0.49600	0.33617	0.67600	−0.08991	0.40149	−0.40406	−0.22898
	P	0.0000	0.0001	0.0005	0.0001	0.6188	0.0206	0.0197	0.4117
	N	114	114	103	114	33	33	33	15
DDD	r	0.49600	1.00000	0.41751	0.18039	0.09178	0.36487	−0.07536	−0.46307
	P	0.0001	0.0000	0.0001	0.0548	0.6114	0.0368	0.6768	0.0822
	N	114	114	103	114	33	33	33	15
Dieldrin	r	0.33617	0.41751	1.00000	0.48995	−0.04758	−0.06984	0.00595	0.44425
	P	0.0005	0.0001	0.0000	0.0001	0.7926	0.6994	0.9738	0.0971
	N	103	103	103	103	33	33	33	15
PCB	r	0.67600	0.18039	0.48995	1.00000	−0.04600	0.01759	−0.34896	−0.24798
	P	0.0001	0.0548	0.0001	0.0000	0.7993	0.9226	0.0465	0.3729
	N	114	114	103	114	33	33	33	15
AS	r	−0.08991	0.09178	−0.04758	−0.04600	1.00000	−0.29143	0.42442	−0.23001
	P	0.6188	0.6114	0.7926	0.7993	0.0000	0.0999	0.0138	0.4096
	N	33	33	33	33	33	33	33	15
HG	r	0.40149	0.36487	−0.06984	0.01759	−0.29143	1.00000	−0.10692	0.26834
	P	0.0206	0.0368	0.6994	0.9226	0.0999	0.0000	0.5537	0.3335
	N	33	33	33	33	33	33	33	15
SE	r	−0.40406	−0.07536	0.00595	−0.34896	0.42442	−0.10692	1.00000	0.25873
	P	0.0197	0.6768	0.9738	0.0465	0.0138	0.5537	0.0000	0.3518
	N	33	33	33	33	33	33	33	15
ZN	r	−0.22898	−0.46307	0.44425	−0.24798	−0.23001	0.26834	0.25873	1.00000
	P	0.4117	0.0822	0.0971	0.3729	0.4096	0.3335	0.3518	0.0000
	N	15	15	15	15	15	15	15	15
THICK	r	−0.17605	−0.10805	−0.13739	−0.13875	0.02121	−0.26228	−0.01041	0.02693
	P	0.0610	0.2525	0.1664	0.1410	0.9067	0.1403	0.9542	0.9241
	N	114	114	103	114	33	33	33	15

[a] Abbreviations: r = Spearman correlation coefficient, P = significance level of correlation, N = number of observations.