J. Field Ornithol., 55(1):18–30

REPRODUCTIVE SUCCESS OF BLACK SKIMMERS IN TEXAS RELATIVE TO ENVIRONMENTAL POLLUTANTS

By Donald H. White, Christine A. Mitchell, and Douglas M. Swineford

Data from the Texas Colonial Waterbird Censuses (Texas Colonial Waterbird Society 1982) indicate that the breeding population of Black Skimmers (*Rynchops niger*) in Texas may be slowly declining. Numbers of breeding pairs for the Texas coast between 1974 and 1980 declined 24%, from 11,540 to 8760. We found only 4 reports that mention fledging success of Black Skimmers, and each in a different context; 3 of the studies were done on the eastern U.S. coast (Erwin 1977, Blus and Stafford 1980, Burger 1982) and 1 on the Gulf coast (DePue 1974).

In 1978, we found levels of DDE residues as high as 43 ppm (wet weight) in skimmer eggs from Nueces Bay, Corpus Christi, Texas, that were in the range causing reproductive problems in other avian species (L. F. Stickel 1973, W. H. Stickel 1975). Because of concern that DDE may contribute to the apparent decline of skimmers in Texas, we studied their reproductive status and evaluated the effects of organochlorine pollutants, such as DDE, on reproduction.

STUDY AREAS AND METHODS

We studied nesting skimmers on dredged-material islands at 3 sites along 200 km of the south Texas coast (Fig. 1). The unnamed islands were about .1–1 ha in size, composed mainly of oyster shell and sand in varying proportions. Low vegetation, predominantly sea oxeye (*Borrichia frutescens*), sea purslane (*Sesuvium portulacastrum*), and glasswort (*Salicornia* spp.), covered from 25–75% of each island. Colonies studied existed at least since 1973 (Texas Colonial Waterbird Society 1982). The colony in Nueces Bay at Corpus Christi, Nueces County (27°52′N, 93°30′W) was flanked by industrial development on the south and by agricultural lands on the north. The 3 nesting islands were small (about .1 ha) and ca. 45 cm above mean high tide and the substrates consisted mostly of coarse oystershell. The Port Mansfield, Willacy County (26°14′N, 97°18′W) site was in the Laguna Madre ca. .8 km E of the outlets of 2 major agricultural drainage canals (Fig. 1). The 2 islands were .5–1 ha in size with sloping sandy beaches and elevations of up to several m above high tide level. The colony at Laguna Vista, Cameron County (26°06′N, 97°18′W) was in the Laguna Madre ca. 20 km S of the Arroyo Colorado, a heavily contaminated waterway that traverses the Rio Grande Valley (White et al. 1983b). The 2 islands there had sand beaches and were similar in size and elevation to those at Port Mansfield, but the interiors contained a dense clay that became extremely gummy when wet.

We studied skimmers only at Corpus Christi in 1978, expanding our studies in 1979–1981 to include Port Mansfield and Laguna Vista. Eggs

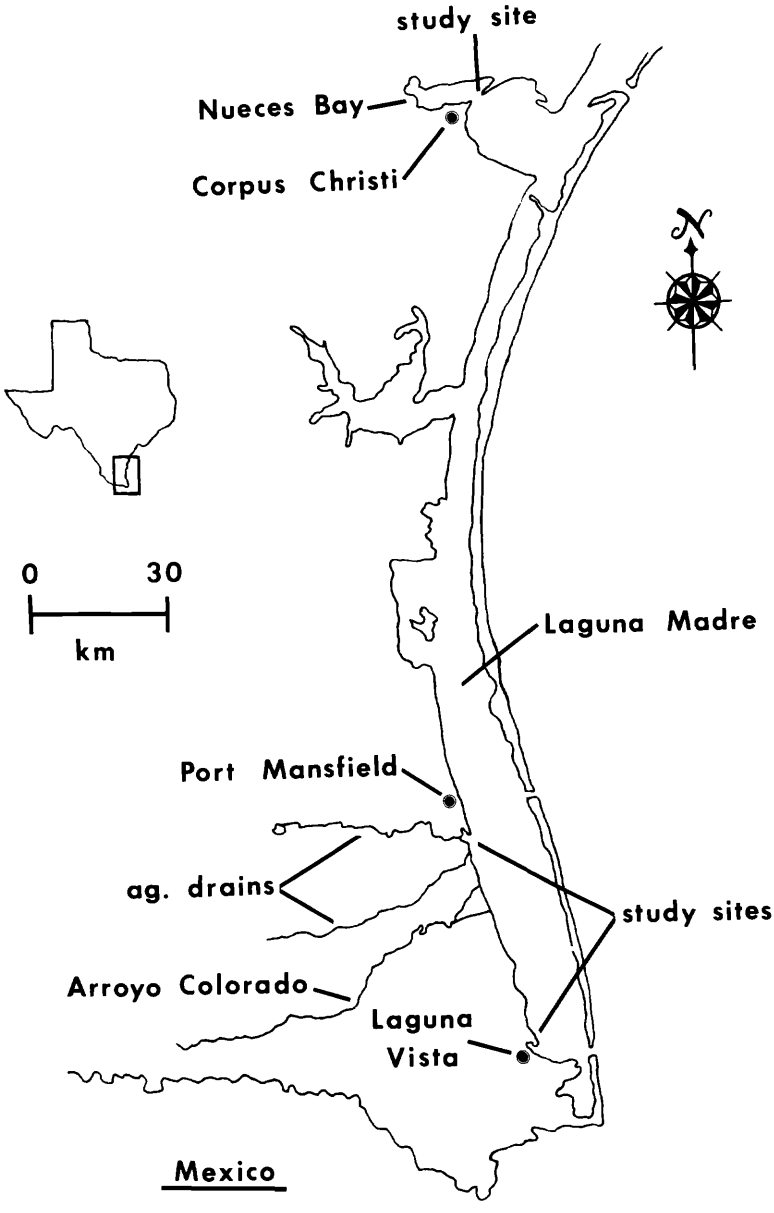

FIGURE 1. Black Skimmer study sites on the Texas coast, 1978–1981.

within scrapes each year were marked with the assigned nest number using a felt-tipped pen. After 1979 we also marked scrapes with 20-cm spikes flagged with numbered tan ribbons. Because chicks were mobile after hatching, we erected .3 m high 30-cm wire-mesh fences around some of the colonies in 1979–1981 to facilitate chick counts; some islands were small enough that fences were unnecessary. Colonies were visited weekly to determine fate of eggs and young and to census adults. Chicks were ligatured with soft pipe cleaners at 1 colony in 1979 to evaluate food habits; food items found in nest scrapes also were identified. Fledging success was determined on a colony basis (total fledglings per total pairs) since chicks could not be assigned to individual nest scrapes. Nesting associates at colonies included: Laughing Gulls (*Larus atricilla*), Gull-billed Terns (*Sterna nilotica*), Caspian Terns (*Sterna caspia*), and/or Forster's Terns (*Sterna forsteri*), but never more than a few pairs of each species.

We collected 1 egg each from 205 clutches on islands adjacent to our study sites (usually <1 km away) for egg measurements and organochlorine residue and lipid analyses. Chemical analyses were conducted at the Patuxent Wildlife Research Center, Laurel, Maryland, following Cromartie et al. (1975) and Kaiser et al. (1980). Residues in 10% of the samples were confirmed by mass spectrometry. Quantification limits were .1 ppm for organochlorine pesticides and .5 ppm for polychlorinated biphenyls (PCBs) on a wet-weight basis. To determine if shell thinning had occurred, we compared shell thicknesses with those of pre-1931 eggs from Texas housed at the Western Foundation of Vertebrate Zoology, Los Angeles, California. Shells of eggs we collected were air-dried for at least 30 days, then weighed and measured with shell membranes intact. Thickness measurements were determined with a micrometer accurate to .01 mm. External egg dimensions were measured with calipers; volumes were calculated following Hoyt (1979).

RESULTS

Nesting chronology.—Skimmers arrived on the breeding islands toward the last week of March each year. Arrival times were highly consistent during this period for all colonies among years. Upon arrival, they usually congregated on islands where they later initiated nesting. We found that skimmers often nested very near the high tide mark, often resulting in inundation of nests by storm tides, excessive rain, or wave action, as shown by other workers (Pettingill 1937, DePue 1974, Burger 1982). At least 1 renest attempt followed soon after the washouts in all instances and always at the same sites, but renest attempts were not initiated after early August (Fig. 2). Washouts were of 2 types, e.g., in 1978 at Corpus Christi, total destruction of nests occurred twice and no chicks were fledged; however, in 1979 at Port Mansfield, a partial washout occurred, and young were fledged from both initial and second nest attempts. Renesting occurred within a week and numbers of pairs renesting at particular sites remained relatively constant for both partial

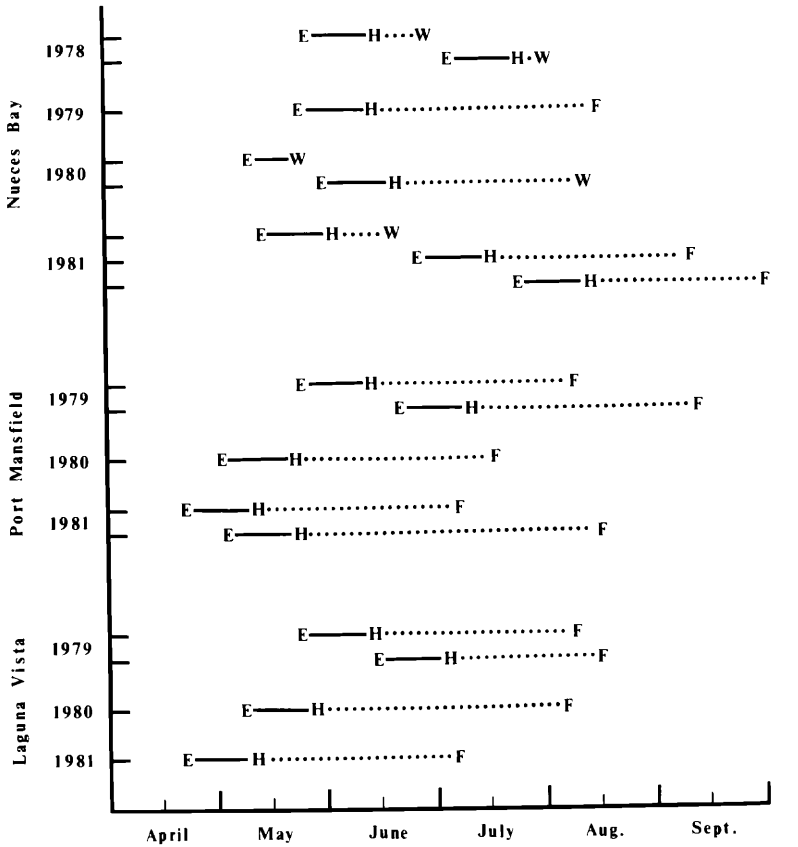

FIGURE 2. Mean dates of egglaying (E), hatching (H), and fledging (F) for Black Skimmers in Texas, 1978–1981. W = complete washouts from storm tides. Some colonies have more than one nesting sequence; these are renest attempts due to complete or partial washouts.

and complete washouts, i.e., the number of new nests with eggs was similar to the number that was destroyed. Also, no new colonies were established on previously unused islands after washouts occurred, suggesting strong nest-site tenacity.

Egg-laying began between mid-April and mid-May. There was a high degree of consistency in the initiation of egg-laying among colonies, but much variation occurred among years (Fig. 2), suggesting that the factor or factors responsible for initiation of egg-laying affected birds equally each year. It was 3 weeks (21 days) from the time when eggs first appeared in nests until the onset of hatching (Fig. 2), but because nests were visited only once a week, we could not determine exact incubation periods or egg initiation dates. DePue (1974) reported a mean incu-

TABLE 1. Average clutch size per nest attempt of Black Skimmers at 3 sites in Texas, 1978–1981.

Nest attempt	n[a]	$\bar{x} \pm SE$	Mode (%)[b]	Range
First	255	3.4 ± 0.05a[c]	4 (47)	1–6
Second	45	2.7 ± 0.10b	3 (60)	1–3
Third	19	2.4 ± 0.18b	3 (58)	1–3

[a] n = number of nests from which good clutch size data existed.
[b] Percentage of clutches with modal number.
[c] Means sharing a common letter were not different using ANOVA ($P > .05$).

bation time of 21 days for skimmers in Texas, with a range of 20 to 23 days. Skimmers in Virginia had a mean incubation time of 22.9 ± 2.2 days (Erwin 1977).

Most skimmer chicks fledged by the end of August or early September at about 4 weeks of age, although some took up to 5 weeks (Fig. 2). Within the first week after chicks fledged, they apparently left the breeding islands, for we seldom saw flying young in the vicinity during our visits. Extensive searches to locate fledged young each year near the colonies were unsuccessful. Shortly after fledglings left, the adults departed also, unlike skimmers in New York which formed mixed-aged flocks that remained on nesting islands for up to several months (Gochfeld 1978).

Clutch size.—There was no significant difference ($P > .05$) in clutch size for the first attempt among study sites or years, therefore all values were combined (Table 1). Clutch size decreased, however, with successive nest attempts; that of the second and third attempts was less (one-way ANOVA, $F = 31.45$, df = 2, 316, $P < .001$) than the first, but there was no difference ($P > .05$) in clutch size between second and third attempts (Table 1). There was a shift in the mode from 4 eggs to 3 eggs in successive nest attempts. Clutches contained from 1–6 eggs, but the proportion of each clutch size varied among nest attempts. In the first attempts, 3 (1%) clutches contained 1 egg, 25 (10%) contained 2 eggs, 102 (40%) contained 3 eggs, 121 (47%) contained 4 eggs, 3 (1%) contained 5 eggs, and 1 (<1%) contained 6 eggs; in the second attempts, 2 (4%) clutches had 1 egg, 13 (29%) had 2, and 27 (60%) had 3; in the single third attempt, there were 3 (16%) clutches with 1 egg, 5 (26%) with 2 eggs, and 11 (58%) with 3 eggs. The overall clutch size for all sites combined was 3.3, ranging from 2.8 to 3.6 (Table 2). Clutch size of skimmers on the eastern U.S. coast averaged 3.6 (Erwin 1977) and 3.8 (Blus and Stafford 1980), but those reports failed to mention if successive nest attempts were used in the calculations.

Fate of eggs.—We had adequate data on the fate of eggs at 4 colonies during 1979–1981. Excluding those from washouts, an average of 5% (26/510) of the eggs were found broken or crushed in nest scrapes during censuses. There was a greater proportion ($\chi^2 = 32.01$, 1 df, $P <$

TABLE 2. Reproductive summary of Black Skimmers at 3 sites in Texas, 1978–1981.

Location	Years	Nesting pairs	Nest attempts	Mean clutch size	Mean fledglings/ pair
Corpus Christi	1978	65	2[a]	3.2	0.0
	1979	51	1	3.5	0.8
	1980	122	2[b]	3.5	1.3
	1981	31	3[bc]	2.8	0.3
Port Mansfield	1979	84	2[c]	3.4	1.0
	1980	36	1	3.6	1.5
	1981	65	2[c]	3.3	1.4
Laguna Vista	1979	30	2[c]	3.0	0.6
	1980	28	1	3.2	1.4
	1981	30	1	3.4	2.0
Overall	1978–1981	542	17	3.3	1.0

[a] Both nest attempts were total washouts.
[b] One nest attempt was a total washout.
[c] One nest attempt was a partial washout.

.01) of broken eggs at the Corpus Christi colony, probably due to the extremely coarse substrate. Eggs in nests that appeared to be depredated were infrequent; an average of only 1% (3/510) were in this category, although some eggs could have been completely removed by predators. On a few occasions we saw Laughing Gulls peck skimmer eggs outside our study areas, but we never saw evidence of mammalian or reptilian predators. Excluding washouts, an average of 8% (42/510) of the eggs rolled out of marked nests or were abandoned and an additional 7% (38/510) failed to hatch. Hatching success averaged about 45% (230/510). The fate of about 33% (170/510) of the eggs is unknown, although some eggs may have been assigned to this category because they hatched and the chicks left the nests before our next visit. Activities of the young at the nests may have buried some eggs, for on several occasions we found eggs partly covered by sand.

Fledging success.—Fledging success for all years averaged .6 fledglings per pair at Corpus Christi and 1.3 fledglings per pair at Port Mansfield and at Laguna Vista. No skimmer chicks were fledged in the Corpus Christi colony in 1978 (Table 2). High storm tides destroyed 2 nest attempts, both during the peak hatching period. Skimmers nesting on other islands in the bay also were washed out. After failure of second nests, no further nesting was observed. Again in 1980 and 1981 at the Corpus Christi site, storm tides caused failure of first nest attempts, but in second and third attempts, .8 and .3 fledglings per pair, respectively, were produced (Table 2). Because of flooding, overall fledging success at Corpus Christi was lower, but not significantly ($P > .05$), than at the 2 sites where only partial washouts occurred. There was no difference

($P > .05$) in fledging success between Port Mansfield and Laguna Vista colonies. A significant negative correlation (Spearman's rank correlation, $r = -.64$, 8 df, $P < .05$) existed between number of nest attempts and fledging success on a colony basis, i.e., as nest attempts increased, fledging success decreased. Also, there was a significant positive correlation (Spearman's rank correlation, $r = .65$, 8 df, $P < .05$) between clutch size and fledging success on a colony basis, but no significant relationship ($P > .05$) existed between colony size and fledging success. We saw no evidence of mortality or injury to chicks in the colonies where wire-mesh fences were used to facilitate censuses.

Egg measurements.—Average measurements of skimmer eggs from the Texas coast are given in Table 3; most eggs were fresh or incubated less than 1 week. Lengths, breadths, and whole weights of eggs were similar to those reported for other areas (Bent 1921, Grant and Hogg 1976), but we found no published record of volumes, dry shell weights, or lipid contents. Percent variability (lowest value/highest value $\times 100$) among clutches was greater than that within clutches in those characteristics where comparisons could be made (Table 3), suggesting that individual females were more inclined to lay eggs of similar size and composition than were females as a whole. Percent lipid among clutches was highly variable and differed significantly (one-way ANOVA, $F = 25.27$, df = 2, 202, $P < .001$) among study sites, probably as a reflection of local diets, but there was no difference ($P > .05$) in lipid levels of fresh and well-incubated eggs. Eggs from Laguna Vista were shorter (one-way ANOVA, $F = 5.61$, df = 1, 143, $P < .05$) and weighed less ($F = 15.55$, df = 1, 143, $P < .001$) than those from Corpus Christi.

Organochlorine residues and shell thickness.—Chemical analysis of egg contents indicated that DDE (the major metabolite of DDT) and polychlorinated biphenyls (PCBs) were the predominant organochlorine pollutants occurring in skimmer eggs (Table 4). Of 205 eggs analyzed, 99.5% contained detectable levels of DDE and 77% of PCBs. Because residue data were highly variable, geometric means rather than arithmetic means are presented in Table 4 as a better indicator of egg pollutant levels on a colony basis. Other organochlorine pesticides detected in skimmer eggs less frequently were chlordane isomers, dieldrin, toxaphene, and heptachlor epoxide, but residues were usually <.5 ppm and not considered biologically significant. Overall, PCBs were highest (one-way ANOVA, $F = 4.78$, df = 2, 202, $P < .01$) in eggs from the industrialized city of Corpus Christi, but residues were 5-fold lower than the level in eggs having no effect on Mallard (*Anas platyrhynchos*) reproduction (Custer and Heinz 1980).

In contrast, DDE residues in some skimmer eggs were elevated, ranging up to 51 ppm (Table 4). For all years combined, DDE residues were significantly higher (one-way ANOVA, $F = 4.75$, df = 2, 202, $P < .01$) in eggs from Laguna Vista near the heavily farmed Rio Grande Valley. Thirty-five percent of the females at all 3 sites laid eggs containing ≥ 10 ppm DDE (Table 4), but we found no significant relationship ($P > .05$)

TABLE 3. Measurements of Black Skimmer eggs from the Texas coast, 1978–1981.

Characteristic	$\bar{x} \pm SE$[a]	Range	Intra-clutch variability (%)[b]	Inter-clutch variability (%)[a]
Length (mm)	45.6 ± 0.14	40.4–50.9	5	21
Breadth (mm)	34.1 ± 0.07	31.5–36.8	3	14
Whole weight (g)	27.0 ± 0.16	21.5–34.9	5	38
Volume (ml)	27.0 ± 0.15	22.6–32.7	4	31
Shell weight (g)	1.8 ± 0.01	1.4–2.1	7	33
Percentage lipid	8.2 ± 0.08	5.7–14.4	—[c]	60

[a] n = 1 egg each from 205 separate clutches. Eggs on the extreme right of the clutch as we faced the scrapes were selected. Variability = low value/high value × 100.

[b] n = 10 complete clutches, 32 eggs. Variability = mean low value/mean high value × 100.

[c] No lipid determinations made for the 10 complete clutches.

between residues in eggs vs. fledging success or clutch size on a colony basis. We were unable to compare DDE residues vs. hatching success at most colonies because young could not be assigned to specific nests.

To determine if DDE was implicated in shell thinning of Black Skimmers, we compared shell thicknesses with those of eggs collected in Texas before widespread pesticide use began in the 1940's. Significant thinning was detected in 5 instances, ranging from 8–12% (Table 5). There was a significant (linear regression analysis, $r = -.65$, 8 df, $P < .05$) negative relationship between mean DDE residues and mean shell thickness on a colony basis, but there was no significant ($P > .05$) relationship between log DDE residues and shell thickness of individual eggs for all years combined.

Food habits and organochlorine residues.—During our weekly visits we collected 72 potential food items found in or near skimmer nest scrapes. Ninety-four percent of the items identified were small fishes. The percent occurrence of the various species were: sheepshead minnow (*Cyprinodon variegatus*), 37%; white mullet (*Mugil curema*), 19%; killifish (*Fundulus* spp.), 13%; tidewater silversides (*Menidia peninsulae*), 13%; gulf menhaden (*Brevoortia patronus*), 6%; Atlantic needlefish (*Strongylura marina*), 3%; Texas pipefish (*Syngnathus affinis*), 1%; halfbeak (*Hyporhamphus unifasciatus*), 1%; and black drum (*Pogonias cromis*), 1%. We analyzed 10 individual fish taken from ligatured chicks and 32 pooled samples of fish collected where adults were feeding at Port Mansfield for organochlorine residues. DDE was detected in 87% of the fish samples, ranging from .1–1.5 ppm, wet weight. The highest mean level of DDE was detected in white mullet (.72 ppm), the second most prominent species found in association with skimmer nest scrapes. The overall average of DDE residues in the fish samples combined was .64 ppm. Toxaphene occurred in 16% of the fish samples, ranging from .1–.4 ppm, and was the only other organochlorine pesticide detected in fishes.

TABLE 4. Organochlorine residues (ppm, wet weight) in Black Skimmer eggs from the Texas coast, 1978–1981.

Location	Year (n)[a]	DDE	% ≥ 10 ppm DDE	PCBs
Corpus Christi	1978 (12)	11.5[b] (12)[c] 1.9–43[d]	67	7.2 (12) 4.3–12
	1979 (40)	4.6 (40) 1.3–48	25	4.1 (40) 1.4–9
	1980 (21)	3.3 (21) 1.3–18	19	3.2 (21) 1.0–20
	1981 (15)	4.0 (15) 1.3–13	20	2.6 (15) 0.8–5
Port Mansfield	1979 (24)	9.2 (24) 3.5–22	54	0.8 (16) 0.5–1.4
	1980 (21)	5.9 (21) 2.1–19	24	1.2 (7) 0.5–2.4
	1981 (15)	4.8 (15) 2.5–11	13	ND[e]
Laguna Vista	1979 (22)	5.6 (21) 0.9–37	32	1.4 (20) 0.5–5
	1980 (20)	9.4 (20) 2.8–51	50	2.3 (19) 0.7–5.5
	1981 (15)	9.8 (15) 3.8–21	60	1.7 (7) 0.9–5

[a] Number of clutches from which one egg was analyzed.
[b] Geometric mean.
[c] Number of eggs containing detectable residues.
[d] Extreme values.
[e] ND = not detected.

DISCUSSION

DePue (1974) estimated that skimmers with an average clutch size of 3.2 produced .9 fledglings per pair during a 2-year study at Baffin Bay, Texas. Over 2 years in Virginia, only .4 fledglings per pair were produced from individually enclosed nests; clutch size averaged 3.6 (Erwin 1977). In South Carolina during 1971–1975, Blus and Stafford (1980) estimated that .5–1.0 or more young per pair were fledged from an average clutch size of 3.8, but according to the authors, censuses were

TABLE 5. Eggshell thicknesses (mm) of Black Skimmer eggs from the Texas coast.

Location (year)		n[a]	$\bar{x} \pm SE$	Percent change
Texas coast	(1882–1930)[b]	28	0.24 ± 0.004	—
Corpus Christi	(1978)	12	0.21 ± 0.003[c]	−12
	(1979)	40	0.22 ± 0.002[c]	−8
	(1980)	19	0.24 ± 0.003	0
	(1981)	15	0.23 ± 0.004	−4
Port Mansfield	(1979)	24	0.23 ± 0.003	−4
	(1980)	21	0.23 ± 0.003	−4
	(1981)	13	0.22 ± 0.003[c]	−8
Laguna Vista	(1979)	22	0.23 ± 0.003	−4
	(1980)	20	0.22 ± 0.003[c]	−8
	(1981)	15	0.22 ± 0.005[c]	−8

[a] n = number of clutches.

[b] Pre-DDT era; measurements for all years were combined.

[c] Significantly different from pre-DDT era (1882–1930) shells; t's = 4.96–6.91, df = 38–66, $P < .001$.

infrequent and irregular. Burger (1982) studied skimmers on marsh islands over 5 years in New Jersey and found that fledging success in colonies where young were produced ranged from .01–.4 fledglings per nest; no clutch size was reported. Burger reported a high degree of colony loss from storm tides and predators each year.

In our study, fledging success also was highly variable and was significantly correlated with the number of nest attempts and with clutch size. Renest attempts were less successful and clutch sizes were smaller than in first attempts. Storm tides were solely responsible for colony abandonment and destruction since predation in Texas colonies, unlike in New Jersey (Burger 1982), appeared minimal. Erwin (1977) witnessed no predation of skimmer eggs in Virginia, although Laughing Gulls and Herring Gulls (*Larus argentatus*) nested close by. Effects of flooding on fledging success appeared to have been greater at Corpus Christi, probably because the islands were smaller, lower, and less vegetated than at Port Mansfield and Laguna Vista.

Although DDE residues were high ($\geq 10 \leq 51$ ppm) in a large proportion (35%) of our eggs, it is difficult to assess whether or not DDE adversely affected productivity. Impaired hatching from thin-shelled eggs is the most common effect in birds, but the susceptibility of avian species to DDE contamination varies widely (Anderson and Hickey 1972, Blus et al. 1974, Longcore and Stendell 1977). Some degree of eggshell thinning was detected in most colonies (9/10), ranging from 4–12%, but thinning was below that (15–20%) believed to cause population declines in other avian species (Anderson and Hickey 1972, Blus et al. 1972, Longcore and Stendell 1977). Geometric mean DDE residues in Texas skimmer eggs were 5-fold greater than in South Carolina eggs

which showed no thinning (Blus and Stafford 1980), thus we believe DDE is implicated in thinning of Texas skimmer eggs although no significant relationship between egg residues and shell thickness occurred. Overall geometric means of DDE residues remained strikingly similar (1979, 6.5 ppm; 1980, 6.2 ppm; 1981, 6.2 ppm) during our study with no apparent decline in egg contamination levels. The problem is not restricted to the lower Texas coast. Skimmer eggs (n = 39) from Freeport, Texas, on the upper coast in 1979–1981 had a geometric mean of 10 ppm DDE, ranging up to 40 ppm; 44% of the eggs contained ≥10 ppm DDE. Eggs (n = 40) in 1980–1981 from Galveston Bay, also on the upper coast, had a mean of 6 ppm DDE, ranging up to 86 ppm (K. King, pers. comm.).

The sources of DDE contamination to Black Skimmers are unknown, but accumulation in the Texas population is much greater (4-fold) than in those of Louisiana and Mississippi (D. H. White, unpubl. data). Band recoveries from skimmers banded as juveniles in Texas, Louisiana, and Mississippi suggest that 60% of the birds spend the winter on the east and west coasts of Mexico (Bird Banding Lab, Laurel, Maryland). The DDE exposure may occur in Mexico, but it is puzzling that only the Texas population contains high residues. A more likely explanation is that the primary DDE source to skimmers is the Texas coastal area. White et al. (1983b) detected exceptionally high residues in gull and tern carcasses (up to 81 ppm, wet weight) from the Rio Grande Valley, and shorebirds overwintering near Port Mansfield, Texas, showed significant temporal accumulation of DDE after arriving from breeding grounds to the north (White et al. 1983a). Also, fishes comprising a large proportion of the skimmers' diet at Port Mansfield contained sufficient DDE to cause significant accumulation of residues in birds feeding on them for extended periods. DDE residues are known to biomagnify many-fold in the food web from prey to predator (Stickel 1973).

SUMMARY

We studied the nesting ecology of Black Skimmers along the lower Texas coast during 1978–1981 to learn more of their reproductive status and to evaluate the effects of organochlorine pollutants, such as DDE, on productivity. For 542 nests, the average clutch size was 3.3 eggs. Flooding was the major cause of colony destruction and abandonment. Clutch size in renest attempts decreased significantly from that in first attempts. Overall fledging success (fledglings/total pairs) averaged 1.0 fledgling per pair. There was a significant negative correlation between number of nest attempts and fledging success on a colony basis. Also, clutch size and fledging success were significantly correlated.

DDE residues in some skimmer eggs were high (up to 51 ppm, wet weight), with 35% of all eggs sampled containing ≥10 ppm DDE. However, eggshell thinning of only 4–12% was demonstrated on a colony basis and log DDE residues in individual eggs were not significantly

correlated with shell thickness. DDE residues in Texas eggs were 5-fold higher than in South Carolina eggs where no shell thinning was detected.

ACKNOWLEDGMENTS

We are grateful to Lloyd Kiff of the Western Foundation of Vertebrate Zoology for providing eggshell measurements from the pre-DDT era. Michael Erwin and Charles Henny provided helpful comments on an earlier draft. Cathy Lefever, Sharna King, and Tammy Preiss provided technical assistance and Clementine Glenn typed the manuscript.

LITERATURE CITED

ANDERSON, D. W., AND J. J. HICKEY. 1972. Eggshell changes in certain North American birds. Proc. Int. Ornithol. Congr. 25:514–540.

BENT, A. C. 1921. Life histories of North American gulls and terns. U.S. Natl. Mus. Bull. 113.

BLUS, L. J., C. D. GISH, A. A. BELISLE, AND R. M. PROUTY. 1972. Logarithmic relationship of DDE residues to eggshell thinning. Nature 235:376–377.

———, B. S. NEELY, A. A. BELISLE, AND R. M. PROUTY. 1974. Organochlorine residues in Brown Pelicans: Relation to reproductive success. Environ. Pollut. 7:81–91.

———, AND C. J. STAFFORD. 1980. Breeding biology and relation of pollutants to Black Skimmers and Gull-billed Terns in South Carolina. U.S. Fish Wildl. Serv., Spec. Sci. Rep., Wildl. No. 230.

BURGER, J. 1982. The role of reproductive success in colony-site selection and abandonment in Black Skimmers (*Rynchops niger*). Auk 99:109–115.

CROMARTIE, E., W. L. REICHEL, L. N. LOCKE, A. A. BELISLE, T. E. KAISER, T. G. LAMONT, B. M. MULHERN, AND D. M. SWINEFORD. 1975. Residues of organochlorine pesticides and polychlorinated biphenyls and autopsy data for Bald Eagles, 1971–1972. Pestic. Monit. J. 9:11–14.

CUSTER, T. W., AND G. H. HEINZ. 1980. Reproductive success and nest attentiveness of Mallard ducks fed Aroclor 1254. Environ. Pollut. 21:313–318.

DEPUE, J. 1974. Nesting and reproduction of the Black Skimmer (*Rynchops niger*) on four spoil islands in the Laguna Madre, Texas. M.S. thesis, Texas A & I Univ., Kingsville.

ERWIN, R. M. 1977. Black Skimmer breeding ecology and behavior. Auk 94:709–717.

GOCHFELD, M. 1978. Colony and nest site selection by Black Skimmers. Proc. Colonial Waterbird Group 1:78–90.

GRANT, G. S., AND N. HOGG. 1976. Behavior of late nesting Black Skimmers at Salton Sea, California. Western Birds 7:73–80.

HOYT, D. F. 1979. Practical methods of estimating volume and fresh weight of bird eggs. Auk 96:73–77.

KAISER, T. E., W. L. REICHEL, L. N. LOCKE, E. CROMARTIE, A. J. KRYNITSKY, T. G. LAMONT, B. M. MULHERN, R. M. PROUTY, C. J. STAFFORD, AND D. M. SWINEFORD. 1980. Organochlorine pesticide, PCB, and PBB residues and necropsy data for Bald Eagles from 29 states—1975–1977. Pestic. Monit. J. 13:145–149.

LONGCORE, J. R., AND R. C. STENDELL. 1977. Shell thinning and reproductive impairment in Black Ducks after cessation of DDE dosage. Arch. Environ. Contam. Toxicol. 6: 293–304.

PETTINGILL, O. S. 1937. Behavior of Black Skimmers at Cardwell Island, Virginia. Auk 54:237–244.

STICKEL, L. F. 1973. Pesticide residues in birds and mammals. Pp. 254–312 *in* Environmental Pollution by Pesticides, C. A. Edwards, ed., Plenum Press, New York.

STICKEL, W. H. 1975. Some effects of pollutants in terrestrial ecosystems. Pp. 25–74 *in* Ecological Toxicology Research, A. D. McIntyre and C. F. Mills, eds., Plenum Press, New York.

TEXAS COLONIAL WATERBIRD SOCIETY. 1982. An atlas and census of Texas waterbird colonies, 1973–1980. Caesar Kleberg Wildl. Res. Instit., Texas A & I Univ., Kingsville.

WHITE, D. H., C. A. MITCHELL, AND T. E. KAISER. 1983a. Temporal accumulation of organochlorine pesticides in shorebirds wintering on the south Texas coast. Arch. Environ. Contam. Toxicol. 12:241–245.

———, C. A. MITCHELL, H. D. KENNEDY, A. J. KRYNITSKY, AND M. A. RIBICK. 1983b. Elevated DDE and toxaphene residues in fishes and birds reflect local contamination in the lower Rio Grande Valley, Texas. Southwest. Nat. 28:325–333.

U.S. Fish and Wildlife Service, School of Forest Resources, University of Georgia, Athens, Georgia 30602 (DHW); *U.S. Fish and Wildlife Service, P.O. Box 2506, Victoria, Texas 77902* (CAM); *and Patuxent Wildlife Research Center, Laurel, Maryland 20708* (DMS). Received 5 May 1983; accepted 1 Nov. 1983.