

NESTING ECOLOGY OF ROSEATE SPOONBILLS AT NUECES BAY, TEXAS

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ABSTRACT.—We conducted a study in 1978–1980 of the nesting ecology of Roseate Spoonbills (*Ajaia ajaja*) in a relatively polluted environment at Nueces Bay, Texas. For 154 marked nests, the average clutch size was 3.0 eggs; 73% of the eggs hatched, and 87% of the nests were successful (hatched at least 1 young). The average nest success rate (total fledglings:total eggs) was 50% or 1.5 fledglings per total nests. Incubation began the day after the first egg was laid, and the incubation period for each egg was 22 days. Eggs hatched in the order that they were laid; the first and second eggs hatched on consecutive days, and the second, third, and fourth eggs hatched every other day. Nest composition and size were highly consistent, but nest placement varied considerably and was dependent on the vegetative configuration of the dredge-material islands. Growth rate of nestlings conformed to a “standard” growth curve, where body weight of nestlings at fledging equaled that of adults. There was no difference in weight gain among siblings based on actual age. Nestlings fledged at about 6 weeks of age, when feather development was complete. At fledging, the bills of juveniles had almost reached adult width, but bill length was only 67% that of adults.

In general, environmental pollutants were low (<2 ppm) in spoonbill eggs, though a few eggs contained elevated concentrations of DDE (up to 15 ppm, wet weight). Some eggshells were 5% thinner than those in museum collections, but the degree of thinning was not within the range known to cause population declines. We conclude that organochlorine pollutants are not adversely affecting spoonbill reproduction at Nueces Bay, Texas, though the area is surrounded by industries and agricultural lands. Apparently, spoonbills are less sensitive to these contaminants than are other aquatic species. Received 8 April 1981, accepted 2 September 1981.

ALTHOUGH Roseate Spoonbills (*Ajaia ajaja*) probably never were abundant in Texas, they were virtually extirpated there between 1850 and 1919 because of encroaching civilization and exploitation by the millinery trade (Allen 1942). With the advent of laws to protect colonial nesting birds, however, Roseate Spoonbill numbers have gradually increased in Texas to about 2,500 breeding pairs (Blacklock et al. 1979). About 150–200 pairs of spoonbills have nested in Nueces Bay at Corpus Christi, Texas in recent years. In addition, 17 other species of marine and estuarine birds regularly nest there. Nueces Bay is bounded on the south by an industrial complex including oil refineries, chemical plants, and a zinc-smelting plant; other industries and agricultural lands border much of the northern shore. Thus, the potential for pollution problems is great in Nueces Bay because of industrial effluents and pesticide runoff from surrounding crop lands.

Other than the early work of Allen (1942), very little is known of the reproductive biology of Roseate Spoonbills on the Texas Gulf Coast. A preliminary study in 1977 indicated that DDE (the major metabolite of technical DDT) in a few spoonbill eggs from Nueces Bay was within the range known to cause reproductive problems in other avian species (Stickel 1973, 1975). Therefore, we began a 3-yr study in 1978 to learn more of the nesting ecology of Roseate Spoonbills and to evaluate the effects of organochlorine pollutants on reproduction.

METHODS

Our study area in Nueces Bay (27°52'N, 97°30'W) (Fig. 1) consisted of three unnamed dredge-material islands from 1 to 2 ha in size, composed mainly of oyster shell and sand. Low vegetation (<0.5 m), dominated by coast becopa (*Bacopa monnieri*), glasswort (*Salicornia*), and sea oxeye (*Borrchia frutescens*), covered most of each island, and some small (1–3 m)

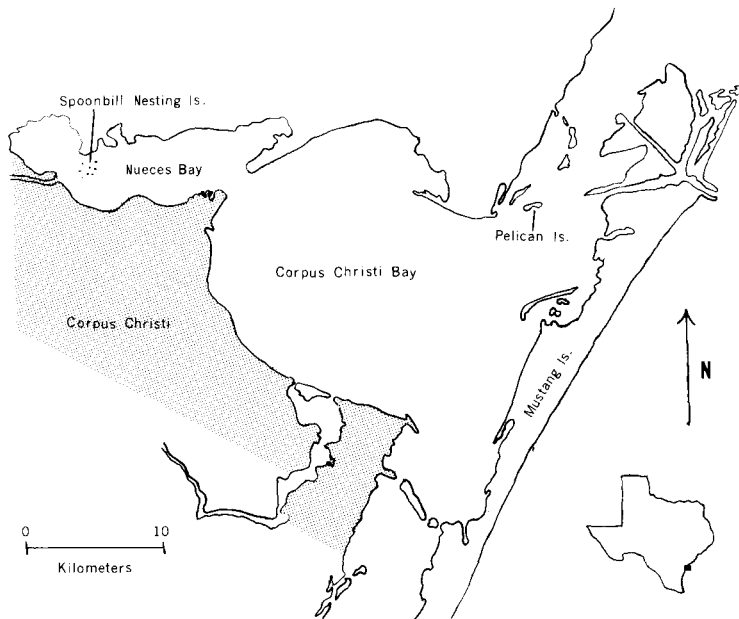


Fig. 1. Roseate Spoonbill study area, Nueces Bay, Texas.

trees and shrubs [retama (*Parkinsonia aculeata*), paloverde (*Cercidium macrum*), saltbush (*Baccharis angustifolia*)] were present on two of them. Associated nesting birds were Great Egrets (*Casmerodius albus*), Snowy Egrets (*Egretta thula*), Cattle Egrets (*Bubulcus ibis*), Great Blue Herons (*Ardea herodias*), Louisiana Herons (*Hydranassa tricolor*), Black-crowned Night Herons (*Nycticorax nycticorax*), and Laughing Gulls (*Larus atricilla*).

In the breeding seasons of 1978–1980 we marked spoonbill nests with numbered stakes at the onset of egg laying; eggs within nests were marked with the assigned nest number and the egg sequence number if known. Nests were visited weekly thereafter, and observations and measurements relating to nesting ecology were recorded. During the week of peak hatching in 1980, we visited nests every other day, except once on 2 consecutive days, to mark hatchlings so that body measurements of known-age nestlings could be recorded throughout the early developmental stage. Body weights were taken with a dietetic scale accurate to ± 2 g, and feather development was documented by taking color slides of the various age groups. Our data for feather development from hatching to fledging of known-age spoonbill chicks follow the terminology of Welty (1962).

In 1980 we estimated productivity or nest success (total fledglings : total eggs) on an island adjacent to our study sites in Nueces Bay as a measure of investigator bias. This island was visited only twice. On the first visit (early incubation stage), we counted all nests and the eggs. On the second visit (just be-

fore fledging), we counted all the young that were present and the eggs in nests that failed to hatch. Thus, we compared nest success on a relatively undisturbed island with that on the three islands that were visited weekly.

We collected the intact eggs that failed to hatch in our marked nests and one egg each from a series of clutches on islands adjacent to our study sites for organochlorine and lipid analyses. Organochlorine and lipid analyses were conducted at the Patuxent Wildlife Research Center, Laurel, Maryland (1977–1979 samples) and at Raltech Scientific Services, Madison, Wisconsin (1980 samples). A detailed description of Patuxent's analytical methods is included in Cromartie et al. (1975) and Kaiser et al. (1980). Similar analytical procedures were used at Raltech. Residues in 5% of the samples were confirmed by mass spectrometry. Quantification limits were 0.1 ppm for organochlorine pesticides and 0.5 ppm for polychlorinated biphenyls (PCBs) on a wet weight basis. We compared our eggshell thicknesses with those of prepesticide-era eggs from the Texas coast housed at the Welder Wildlife Foundation to determine whether or not shell thinning had occurred. Eggshells we collected were dried at room temperature for at least 30 days, then weighed and measured with the shell membranes intact. Thickness measurements of all eggs were determined with a modified Starrett Model 1010 M micrometer accurate to 0.01 mm. External egg dimensions were measured with calipers, and volumes were estimated following Hoyt (1979).

TABLE 1. Roseate Spoonbill nest measurements, Nueces Bay, Texas.

Parameter	<i>n</i>	$\bar{x} \pm SE$	Range
Nest width (cm)	16	55.6 \pm 1.8	43-71
Nest depth (cm)	10	10.7 \pm 0.3	10-13
Nest height (cm) (atop low vegetation)	28	23.9 \pm 2.4	10-51
Nest height (cm) (in trees/shrubs)	12	70.6 \pm 13.3	33-168

RESULTS AND DISCUSSION

Nesting chronology.—Adult spoonbills in full breeding plumage began congregating on the Nueces Bay dredge islands around mid-March each year; by late March, 100 or more adults were present. Birds were not paired at this time, and they loafed in large groups on the shores of the islands. By mid-April, several hundred adults were present in the area, and some pairing had occurred. We never saw breeding spoonbills in other than full adult plumage, though Dunstan (1976) reported sub-adult-plumaged birds nesting in Florida. Rudimentary nests were found on 5 May in 1978, and egg-laying began around 20 May; in 1979 and 1980 the average nest building and egg-laying dates were 15 April and 25 April.

Allen (1942) estimated the incubation period to be 23-24 days for Texas spoonbills, but he was unsure of the deposition rate and when incubation began. Our data from marked eggs in 29 nests indicate that laying occurred at the rate of one egg every other day, with no variation from this pattern. The time in the nest until hatching was 23 days for the first egg and 22 days for the second, third, and fourth eggs. Because incubation began the day after the first egg was laid, the incubation period for each egg was 22 days. Eggs hatched in the order that they were laid; the first and second eggs hatched on consecutive days, and the hatching interval between the second, third, and fourth eggs was every other day.

By early July, young spoonbills were able to fly several hundred meters to adjacent islands; thus, we estimated that fledging occurred at about 6 weeks of age. By early August, adults and young began to disperse from the islands and by September few birds of any age remained there. We observed small mixed-age flocks of spoonbills in Nueces Bay and other areas of the south Texas coast during the win-

ter months each year, but by mid-October most of the birds had dispersed, presumably southward into Mexico (Allen 1942).

Nest composition and placement.—Spoonbills constructed their nests atop low vegetation and in trees and shrubs with plant material that was abundant on the nesting islands or nearby shoreline. The base of each nest consisted of large dead twigs of saltbush, paloverde, and retama loosely fitted together to form a crude platform about 6 cm deep. Upon this platform, live and dead stems of sea oxeye, saltbush, and grasses (*Paspalum*) were intertwined into a coarse lining about 5 cm deep. The activities of the birds on the nest eventually formed a wide, shallow depression in which the eggs were laid. The external dimensions of nests (width and depth) were consistent, as seen by the small standard errors in Table 1. A brief description of spoonbill nests is given in Bent (1963) and Oberholser (1974), but no mention is made of specific vegetative components or nest measurements. Nest placement on the breeding islands was determined by the vegetative profile; spoonbills nested where low vegetation was most prevalent or in and around trees and shrubs. The height of nests atop low vegetation was much less variable than that of nests in trees and shrubs (Table 1). This was due to the uniform configuration of low vegetation, i.e. density and height, in contrast to the highly variable arrangement of limbs in trees and shrubs.

Nest success.—Clutch size in 1978 was significantly ($P < 0.001$, analysis of variance) lower than in 1979 and 1980 because of fewer 4-egg clutches and more 2-egg clutches in the 1978 sample (Table 2). Six nests (4%) contained 1 egg, 20 (13%) contained 2 eggs, 92 (60%) contained 3 eggs, 34 (22%) contained 4 eggs, and 2 (1%) contained 5 eggs. Allen (1942) recorded a lower average clutch size of 2.6 for a Texas spoonbill colony in 1940, but the proportion of 3-egg clutches in his 1-yr study was identical to ours.

Hatching success varied significantly ($P < 0.02$, Chi-square test) among years, ranging from 58% to 88% (Table 2). The 58% hatching success recorded in 1980 was low when compared to the success rates of the other 2 yr, but there was no difference in hatching success between 1979 and 1980. We were able to account for 92% of the eggs that were laid in 1980. Lowered hatching in 1980 was due main-

TABLE 2. Summary of reproductive success of Roseate Spoonbills at Nueces Bay, Texas, 1978–1980.

Parameter	1978 (<i>n</i> = 72)	1979 (<i>n</i> = 35)	1980 (<i>n</i> = 47)	Total (<i>n</i> = 154)
Clutch size				
Mean	2.8	3.3	3.3	3.0
Mode	3	3	3	3
Range	1–4	1–5	2–5	1–5
Survival rates				
Percentage successful nests ^a	88	97	79	87
Percentage eggs hatched	79	88	58	73
Eggs hatched/nest	2.2	2.9	1.9	2.2
Young to 1 week/nest	2.1	2.7	1.4	2.0
Young to 2 weeks/nest	1.9	2.3	1.3	1.8
Nest success				
Rate (%) ^b	54	52	36	50
Fledglings/total nests	1.5	1.7	1.2	1.5

^a Percentage nests that hatched at least one young.

^b Total fledglings/total eggs.

ly to death of embryos during incubation (31%). In 1978 this category accounted for 7% of the egg loss and 1% in 1979. Of the embryonic deaths, 78% occurred in the late stages of development. There was no evidence that the last egg in the clutch contributed more to the overall mortality than earlier eggs, because mortality was evenly divided among eggs of a clutch. The combined proportion of eggs that disappeared and rolled out of nests each year was similar, averaging 13%. Most of the spoonbill pairs were able to hatch at least one young, as evidenced by the high percentage of successful nests for each year (Table 2). There were fewer ($P < 0.005$, Chi-square test) successful nests in 1980 than in the other 2 yr because of lowered hatchability in 1980; no difference ($P > 0.05$) existed between 1978 and 1979. Clutch size had no significant effect ($P > 0.05$, Chi-square test) on the ability of spoonbills to hatch at least one young: 100% of the pairs with 1-egg clutches, 80% with 2-egg clutches, 87% with 3-egg clutches, 88% with 4-egg clutches, and 100% with 5-egg clutches hatched at least one young. In addition, spoonbills having various clutch sizes did not differ significantly ($P > 0.05$) in their ability to raise at least one young to 2 weeks of age: 100% of those with 1 egg, 89% with 2 eggs, 93% with 3 eggs, 87% with 4 eggs, and 100% with 5 eggs had at least one live nestling 2 weeks after hatching.

Total mortality of nestlings from hatching to fledging was 32%, 41%, and 37% for 1978,

1979, and 1980, respectively ($\bar{x} = 32\%$; $n = 41$). Mortality of nestlings each year was greatest during the first 2 weeks after hatching; 14% of the nestlings were lost during this period in 1978, 21% in 1979, and 32% in 1980 ($\bar{x} = 18\%$, $n = 23$). Half of the birds that died within the first 2 weeks during the study period were found dead in or near their nests; the other half disappeared between our visits to the colony, and their fate is unknown. Only once did we see evidence of predation; two nests in 1980 contained the partial remains of several hatchlings that appeared to have been removed from the eggs as they were pipping.

Spoonbills fledged fewer ($P < 0.01$, Chi-square test) young in 1980 than in 1978 or 1979 because of lowered hatchability in 1980 (Table 2); there was no difference ($P > 0.05$) in productivity between 1978 and 1979. Though hatchability was lower in 1980, the adults lost only 0.7 young per nest that did hatch; this was identical to the average loss per nest in 1978 but much lower than the 1.2 young per nest that failed to fledge in 1979 (Table 2).

Nest success in 1980 on the island we visited only twice (see Methods) was estimated at 1.3 fledglings per nest ($n = 18$ nests), similar to the 1.2 fledglings per nest produced in 1980 on our more frequently visited islands. Because there was no difference ($P > 0.05$) in nest success rates between the two areas, our frequent visits to a portion of the breeding colony in 1980 did not appear to impair reproduction.

Growth and development of young.—The Ro-

TABLE 3. Feather development of known-age Roseate Spoonbill chicks ($n = 10$).

Feather tract	Age (days)							
	1	5	7	9	14	21	35	42
Alar	Down	Primary sheaths emerge				Sheaths rupture		Complete
	Down		Secondary and alula sheaths emerge			Sheaths rupture		Complete
	Down			Tertial and covert sheaths emerge		Sheaths rupture		Complete
Humeral	Down			Sheaths emerge		Sheaths rupture		Complete
Spinal	Down				Central sheaths emerge	Sheaths rupture		Complete
	Down					Lower sheaths emerge and rupture		Complete
	Down					Upper sheaths emerge	Sheaths rupture	Complete
Femoral	Down					Sheaths emerge and rupture		Complete
Crural	Down					Sheaths emerge and rupture		Complete
Caudal	Down					Sheaths emerge and rupture		Complete
Ventral	Down					Sheaths emerge and rupture		Complete
Capital	Down					Sheaths emerge and rupture	Sheaths rupture	Complete

TABLE 4. Bill measurements of known-age Roseate Spoonbill chicks and adult museum specimens.

Age (days)	<i>n</i>	Length (mm)	Cumulative increase (%)	Breadth (mm) ^a	Cumulative increase (%)
1	2	20.0 ± 0.0 ^b	12	8.8 ± 0.0	15
9	4	38.5 ± 1.9	23	11.8 ± 0.8	22
12	3	48.3 ± 1.7	28	14.3 ± 0.3	27
16	6	61.6 ± 1.2	36	19.5 ± 0.5	37
17	3	66.0 ± 2.7	39	22.3 ± 0.9	42
19	2	67.0 ± 3.0	39	22.0 ± 1.0	42
39	3	114.3 ± 1.3	67	44.7 ± 0.9	85
56 ^c	1	124	73	50	95
Adult ^d	8	170.0 ± 2.4	100	52.7 ± 1.2	100

^a Breadth measurements were taken at widest part of bill near tip.

^b $\bar{x} \pm SE$.

^c Measurements were taken from an individual approximately 8 weeks old found dead on study island in 1980.

^d Museum specimens at the National Museum of Natural History, Washington, D.C.

seate Spoonbill is a semi-altricial species. The skin, mandibles, and legs of newly hatched chicks are a uniform, deep salmon pink; the feather tracts are covered with thick white down that becomes dry and fluffy about 12 h after hatching, giving the appearance that the entire body is covered with down. About 2 days after hatching, the legs and feet begin to darken, so that by fledging, they generally are a dark gray-brown. The bill remains basically flesh-colored until fledging, though there is a darkening from the mid-bill to the base beginning about 5 days after hatching. The eyes open when the chicks are about 2 days old; at this time the iris is entirely black and remains so until fledging. Our account of eye and bill color in nestlings differs somewhat from that of Allen (1942), who stated that the bills of late nestlings are light yellow and the irises are yellow.

Allen (1942) and Bent (1963) discussed at length plumages and molts in Roseate Spoonbills after fledging, but little attention was given to feather development in nestlings. Sheaths of the flight feathers and their coverts are the first to emerge, beginning around day 5 (Table 3). The rest of the body remains mostly down-covered until about day 21. At this time, the sheaths of the alar tract begin to rupture, and feather sheaths of the other major tracts begin to emerge and rupture. Feather growth continues steadily for the next 3 weeks, and development is complete about 42 days after hatching; birds then are capable of sustained flight and are regarded as fledglings. At fledging, feathers of the alar, humeral, crural, and

caudal tracts are light pink; the spinal, femoral, ventral, and capital tracts are white. The tips of the primary feathers are blackish at fledging, first appearing about 28 days after hatching. Roseate Spoonbills do not usually attain full adult plumage until they are 3 yr old, but plumage development may vary widely among individuals (Allen 1942).

The bills of newly hatched spoonbill chicks are not spatulate as in the adults; instead, the chicks have short stubby bills that are soft and leathery. At 9 days of age, the bill near the tip begins to broaden and flatten; at 16 days it begins to take on the characteristic form of the adult. The cumulative increase (% of adult size) in length and breadth is almost identical up to about 19 days of age (Table 4). At 39 days, however, when the birds are near fledging (6 weeks), there is a significant ($P < 0.01$, *t*-test) bill growth differential; the breadth is 85% of the adults' but the length is only 67%. This growth differential apparently continues after the chicks fledge; the bill of one freshly dead specimen about 8 weeks old had grown to 95% of the adults' in breadth, but to only 73% in length (Table 4).

At hatching, chicks weighed an average of 50 g and gained an average of only 9 g for the next 3 days (Fig. 2); on day 4, however, weight began to increase rapidly. By day 16 the chicks had reached about half the adult weight (Oberholser 1974, J. Remsen pers. comm.). Because nestling weights were not obtained beyond day 19, we estimated the overall growth curve for Roseate Spoonbills using the Gompertz growth equation (Ricklefs 1967). The estimated

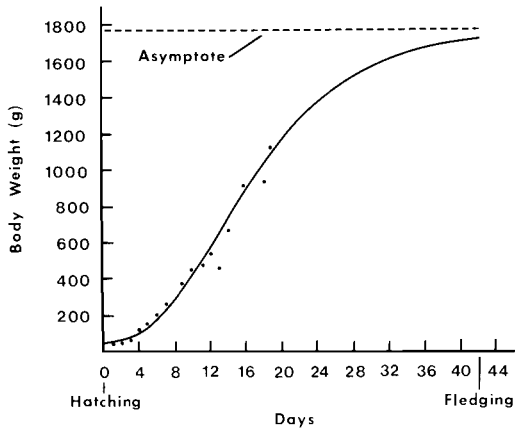


Fig. 2. Growth curve of Roseate Spoonbill nestlings. Some data points represent a single chick, but others may be an average of up to 8.

asymptote, or fledging weight, closely resembled known adult weight; therefore, the growth curve may be referred to as "standard" (i.e. body weight of nestlings equaled that of adults at fledging; Ricklefs 1968). Initially, there was a weight difference among siblings, as hatching occurred asynchronously; in most instances, however, siblings were visibly indistinguishable in size after about 2½ weeks. Data from known-age siblings in three nests are illustrated in Fig. 3. During development, the first chick in nest 118 weighed slightly more than the second chick based on days after hatching, but the reverse was true in nest 244; in nest 237 the third chick weighed slightly more than the others up to about 14 days. Because our growth data on siblings were sparse, we did not attempt a statistical analysis; our limited results suggest, however, that weight gain differences were negligible on an actual age basis. Thus, siblings probably had an equal chance for survival, because fledging weights were similar.

Egg measurements.—Average measurements of Roseate Spoonbill eggs from Nueces Bay, Texas are given in Table 5. Lengths and breadths have been published previously (Bent 1963, Oberholser 1974) and are almost identical to our data. We found no published record, however, of whole weights, volumes, shell weights, or lipid contents of spoonbill eggs. The averages in Table 5 represent measurements of eggs in various stages of develop-

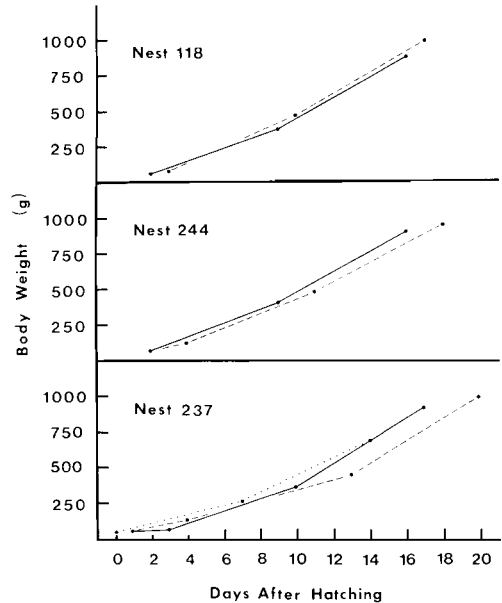


Fig. 3. Weight gain of Roseate Spoonbill siblings from three nests. Dashed, solid, and dotted lines represent first, second, and third chicks, respectively.

ment, although most of the eggs were either fresh and unincubated ($n = 33$) or incubated about 5 days or less ($n = 17$). Although there was considerable interclutch variability among some egg parameters, most of the measurements were clustered closely around the means, as evidenced by the extremely small standard errors (Table 5). Variability in whole egg weights was due mainly to water loss during incubation (Ar and Rahn 1980). Fresh eggs averaged 5.5 g heavier than advanced eggs (incubated about 16 days or more), a significant difference ($P < 0.05$, analysis of variance). There was no difference ($P > 0.05$), however, in dry shell weights of fresh and advanced eggs. Percentage lipid showed the greatest variation of the egg parameters measured (Table 5), but there was no difference ($P > 0.05$) in lipid levels of fresh and advanced eggs. There also were no differences ($P > 0.05$) in egg measurements or lipid content among the first, second, third, or fourth eggs ($n = 22$ nests). In all instances there was less variation in egg measurements within clutches than among clutches, indicating that individual females were more inclined to lay eggs of similar

TABLE 5. Measurements of Roseate Spoonbill eggs from Nueces Bay, Texas, 1977–1980.

Parameter	$\bar{x} \pm SE^a$	Range	Interclutch variability (%) ^a	Intraclutch variability (%) ^b
Length (mm)	64.4 ± 0.3	56.9–71.2	20	13
Breadth (mm)	43.7 ± 0.1	41.3–47.9	14	8
Whole weight (g)	62.1 ± 0.5	52.4–77.0	32	24
Volume (ml)	61.8 ± 0.5	52.0–75.4	31	18
Shell weight (g)	5.7 ± 0.1	3.8–7.0	46	37
Percentage lipid ^c	5.5 ± 0.1	2.9–7.5	61	38

^a $n =$ one egg each from 70 separate clutches.

^b $n =$ 10 complete clutches, 33 eggs.

^c Lipid reported only for 1977, 1978, and 1979 samples; $n =$ 45 eggs.

size and composition than were females as a whole.

Organochlorine residues and shell thickness.—Chemical analysis of egg contents indicated that DDE and PCBs were the predominant organochlorine pollutants occurring in spoonbill eggs; DDE was present in all of the samples and PCBs were found in 90% of the eggs (Table 6). In general, organochlorine concentrations were low (<2 ppm), though a few of the eggs contained fairly high levels of DDE (up to 15 ppm). Because the residue data were highly skewed, medians rather than means are presented in Table 6 as a better indicator of pollutant levels in eggs. There was no difference ($P > 0.05$, t -test) in DDE concentrations between addled and fresh eggs that would implicate DDE in egg failure. Other organochlo-

rine pesticides detected in spoonbill eggs were dieldrin and chlordane isomers, but these compounds occurred in concentrations less than 0.5 ppm in all instances.

There was no significant difference ($P > 0.05$, analysis of variance) in eggshell thickness of our collections and that of the 1920's (Table 7). Eggshells in 1977–1979 were 5% thinner than those from the pre-DDT era, but the percentage difference was within the range of intraclutch variation (11%) and is not biologically significant. Ohlendorf et al. (1979) reported no significant eggshell thinning in spoonbill eggs collected from Louisiana and Texas between 1947 and 1973. Embryonic development during incubation is believed to decrease shell thickness in some species (Kreitzer 1972), because the developing chick derives the major portion of its calcium from the shell (Simkiss 1967). We found no difference ($P > 0.05$), however, in eggshell thickness of spoonbill eggs in various stages of development (unincubated, 1/4, 2/4, 3/4, and 4/4). Lindvall and Low (1980) found that incubation stage had no measurable effect on eggshell thickness in Western Grebes (*Aechmophorus occidentalis*).

TABLE 6. Organochlorine residues (ppm, wet weight) in Roseate Spoonbill eggs from Nueces Bay, Texas.

Year	n^a	DDE	PCBs
1977	5	2.8 ^b	0.85
		(5) ^c	(4)
1978	24	1.1–15 ^d	ND ^e –1.7
		2.5	0.83
		(24)	(18)
1979	16	0.7–7.5	ND–5.3
		1.4	0.92
		(16)	(16)
1980	25	0.4–3.8	0.4–3.5
		1.3	0.47
		(25)	(25)
		0.3–5.8	0.2–3.1

^a Number of clutches from which one egg each was analyzed.

^b Median.

^c Number of eggs containing detectable residues.

^d Range.

^e ND = not detected.

TABLE 7. Eggshell thicknesses (mm) of Roseate Spoonbill eggs from the Texas coast.

Year	n^a	$\bar{x} \pm SE$	Percentage change
1923–1924 ^b	11	0.44 ± 0.01	—
1977	10	0.42 ± 0.01	–5
1978	24	0.42 ± 0.01	–5
1979	16	0.42 ± 0.01	–5
1980	25	0.44 ± 0.01	0

^a Number of clutches.

^b Pre-DDT era; measurements from both years were combined.

CONCLUSIONS

Under normal circumstances, the proportion of eggs that produces flying young (nest success) varies widely among avian species and is dependent upon many factors (Ricklefs 1973). Nest success is known to vary from year to year within some species (Maxwell and Kale 1977, Schreiber 1979), and we found this to be true of Roseate Spoonbills. Allen (1942) reported only a 2% nesting success for a Texas spoonbill colony in 1940 because of heavy tick infestation, but in 1941 he estimated that reproduction was excellent in this colony, though no figures on nest success were given. Nest success in our study colony ranged from 36% to 54%, averaging 50%, or 1.5 fledglings per nest for the 3-yr period. Failure of the eggs to hatch and loss of young during the first 2 weeks after hatching appeared to be the greatest limiting factors in spoonbill reproduction. Rodgers (1980) reported that mortality among heron nestlings also was greatest when the chicks were 1-2 weeks of age. In 1980, the year we made frequent visits during the early part of the nesting season, productivity was lowest because of poor hatching success. Human disturbance can adversely affect reproduction, especially in the pre-egg and incubation stages (Schreiber 1979). This was not the case in our study, however; there was no difference in productivity between a portion of the colony visited frequently and one visited only twice. Our visits were most frequent after the chicks had hatched, and this probably lessened our impact, as Schreiber (1979) showed for Brown Pelicans (*Pelecanus occidentalis*).

Reproduction of Roseate Spoonbills in Nueces Bay appeared to be good, based on an overall nesting success of 50%. It is difficult to assess whether or not this figure is adequate to maintain a stable population, not only from a logistics standpoint, as discussed by Schreiber (1979), but also because of a scarcity of comparable reproductive data on this species. Spoonbills are absent from many of the areas in Texas where they formerly bred (Allen 1942), and population numbers probably are far below what they once were. Nevertheless, the present population appears to be holding steady at about 2,500 breeding pairs, according to the Texas Colonial Waterbird Census (Blacklock et al. 1979). For this reason, we believe that nest success is adequate and that the pop-

ulation is in no immediate danger of decline. The population status of this relatively uncommon species should be monitored closely, however, especially because industrial and agricultural development is increasing along the Texas Gulf Coast.

Environmental pollutants (including DDE and other organochlorine compounds) probably had little effect on spoonbill reproduction, though some eggs had fairly high concentrations of DDE. Apparently, spoonbills are less sensitive to DDE than other species, such as the Brown Pelican. Blus et al. (1974) presented convincing evidence that Brown Pelicans suffer nest failure if eggs contain more than about 2.5 ppm (wet weight) DDE; 34% of our spoonbill eggs had DDE levels of this magnitude or higher. Some eggshell thinning was detected, but it was not to the extent (15-20%) known to cause population declines in other avian species (Anderson and Hickey 1972). Levels of other pollutants, such as PCBs, dieldrin, and chlordane, were low in spoonbill eggs and are not suspected of causing reproductive problems.

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