Wilson Bull., 91(1), 1979, pp. 62–71

ORGANOCHLORINE POLLUTANTS AND POPULATION STATUS OF LEAST TERNS IN SOUTH CAROLINA

LAWRENCE J. BLUS AND RICHARD M. PROUTY

Most populations of Least Terns (*Sterna albifrons*) in the United States are reportedly declining or experiencing poor reproductive success (Fisk 1975, Massey 1974). The California race (*S. a. browni*) is classified as "endangered" by the U.S. Fish and Wildlife Service (Wilbur 1974) and the eastern race (*S. a. antillarum*) is classified as "threatened" by the State of Florida. Interior Least Tern (*S. a. athalassos*) populations are apparently experiencing much the same problems as those of the other races (R. Downing, pers. comm.). Little Tern (*S. a. albifrons*) populations in Great Britain and Ireland have steadily decreased since the early 1930's (Norman and Saunders 1969).

Sprunt and Chamberlain (1949), in the last evaluation of the Least Tern in South Carolina described its population status as "completely satisfactory." Recent concern about the future of the Least Tern and the need for updating its status in South Carolina prompted us to study its population status and reproductive success in that state, particularly in relation to organochlorine pollutants.

METHODS

We studied Least Tern colonies on the Cape Romain National Wildlife Refuge (CRNWR) and surrounding areas in South Carolina from 1971 through 1975. Each year, we were in the field from April to August. Because most of our effort was directed toward studying Brown Pelicans (*Pelecanus occidentalis*) and other estuarine birds, we spent only a limited amount of time surveying for new Least Tern colonies and studying those that were located. But when a colony was located, we attempted to count all nests with eggs or young; empty nest scrapes were sometimes also counted. We visited several colonies only once a season, and we rarely visited a colony more often than once a week. Because of our infrequent visits and the difficulty in locating the young, we were only able to roughly estimate reproductive success (fledglings per nest) as follows: good $= \geqslant 1$, fair $=$ 0.50–0.99, poor $= <$ 0.50, and failed $=$ 0.00.

Eggs were collected from 4 colonies in 1972–1975. We took 1 egg from 38 nests selected for sampling and collected 6 eggs that were washed out of nests by tidewaters. We collected eggs in all sections of each sampled colony in order to obtain a representative sample. We weighed and measured the eggs soon after collection. The contents of the eggs were placed in glass bottles that were previously rinsed with a dilute nitric acid solution, deionized water, hexane, and acetone; aluminum foil-lined caps were attached; and then the samples were frozen. The shells were thoroughly washed with tap water and allowed to dry at room temperature. Shell thickness (shell and shell membranes) was measured at 3 sites on the waist of each egg with a micrometer

graduated to 0.01 mm. The mean of the 3 measurements was used to represent the thickness of the shell.

Contents of eggs were analyzed for organochlorine residues by electron capture gas chromatography. A 4% SE-30/6% QF-1 column was used for the 1972 samples and a 1.5% OV-17/1.95% QF-1 column was used for the 1974 and 1975 samples (Cromartie et al. 1975). The level of sensitivity was 0.50 μg/g for PCB's and 0.10 μg/g for other organochlorines.

RESULTS

Surveys of nesting colonies and reproductive success.—We found Least Tern nesting colonies in 6 different sites on the CRNWR (3 on Cape Island, 2 on Raccoon Key, and 1 on Anderson Creek Shellbank), and on 4 nearby islands on the Atlantic Coast (Table 1). Fisk (1975) reported Least Terns nesting several miles inland from Charleston, South Carolina in 1974. They reportedly nested on black polyethylene plastic at an agricultural research station. In 1976 and 1977, Least Terns established 3 colonies on flat-roofed buildings in Charleston (E. J. Fisk, pers. comm.). All other known colonies of Least Terns in South Carolina are on coastal islands; adults are rarely seen inland (Sprunt and Chamberlain 1949).

Least Terns are colonial nesters that select barren sand or shell beaches for nesting. The terns scrape out a cavity in the bare sand or arrange a pile of small shells where they lay their eggs. Marples and Marples (1934) indicated that Little Terns characteristically excavate more scrapes than required for nesting. On 18 June 1975, we found 555 fresh scrapes and 71 nests with eggs on the southwest point of Cape Island; 220 active nests were eventually found in this colony. On the same date, 379 fresh scrapes and 25 nests with eggs were noted in the colony on Cape Island Point; 26 active nests were eventually found. Similar ratios of scrapes to active nests were also found in the other colonies.

Seven of the 10 nesting areas of Least Terns located in South Carolina were near—but did not overlap—those of the Black Skimmer (*Rynchops nigra*) and Gull-billed Tern (*Gelochelidon nilotica*). The minimum distance between Least Tern nests and nests of their larger associates was about 15 m. The Least Tern nested near the Wilson's Plover (*Charadrius wilsonia*) in 3 colonies, although we only found about 8 plover nests. In North Carolina, nesting areas of Least Terns also did not overlap those of other colonial nesting species (Soots and Parnell 1975).

The color of the small eggs and young of the Least Tern is such an effective camouflage that it is difficult to locate them against the background of sand and shells. Censusing is difficult because the terns tend to nest in loose aggregations where their nests may be 3 to 4 m apart, the colony may be divided into several discontinuous subcolonies, and because the

precocial young usually leave the colony when only a few days old. The most effective method of finding nesting colonies is to check for adult activity on likely looking beaches, shell banks, or dredge islands.

Migrating Least Terns arrive in South Carolina as early as 15 March (Sprunt and Chamberlain 1949); they apparently initiate reproductive behavior sometime in April. We found empty scrapes as early as 3 May in an area that later contained active nests. Eggs were found as early as 17 May and young as early as 6 June. We found eggs as late as 24 July.

The number of eggs in 396 clutches ranged from 1 to 3 ($\bar{x} = 1.73$). These clutches were in colonies that were censused several times before hatching. Of the 396 clutches, 116 (29.3%) contained 1 egg, 272 (68.7%) contained 2 eggs; and 8 (2.0%) contained 3 eggs. The peak of hatching was between 21 June and 8 July in the colony on Cape Island Point in 1971, and between 10 and 24 July in 2 colonies, Cape Island Point and Cape Island (southwest point), in 1975. The nesting season of the Least Tern is relatively short and although this species may renest when their eggs are lost (Schönert 1961), they do not extend their nesting season into August and September in South Carolina as the Gull-billed Tern and Black Skimmer sometimes do after repeated nesting failures.

We estimated good reproductive success in 1 colony, fair success in another colony, and we classified reproductive success in the remaining colonies as poor, unknown, or failed (Table 1). Even in the 2 colonies where reproductive success was estimated as good or fair, we observed no young in the colony after the peak of hatch. For example, 102 nests were counted on 21 June and 112 young (28 out of nests) were observed on Cape Island Point in 1971; we estimated the colony contained 150 nests. On our next visit on 8 July and subsequent visits, no active nests or young were observed. Also, 220 nests were counted on 2 July on the southwest point of Cape Island; 137 nests and 44 young (28 out of nests) were observed on 10 July. On the next visit on 24 July and subsequent visits, no active nests or young were observed. The colony on the southwest point of Cape Island in 1975 contained the largest number of active nests (220) of any colony that we censused.

Least Tern nests are susceptible to flooding, predation, and disturbance. We observed tidal flooding of nests in 4 colonies, and suspected that at least some of the nests in other colonies were also susceptible to flooding. In the second week of June 1975, all nests in 2 colonies on Cape Island were destroyed by tidal flooding. Of the 61 active nests present on Cape Island Point on 28 May, only 9 abandoned eggs (2 depredated) remained on 12 June. By 18 June, many of the Least Terns had renested; we found 71

TABLE 1

CENSUSES OF LEAST TERN COLONIES, CAPE ROMAIN NATIONAL WILDLIFE REFUGE AND SURROUNDING AREAS

Colony	Year	Number of active nests[1]	Estimated reproductive success[2]
Cape Island Point	1971	102+	Good
	1972	Apparently inactive	—
	1973	2+	Poor
	1974	99	Poor
	1975	26	Poor
Cape Island (southwest point)	1971	Not censused	—
	1972–73	Apparently inactive	—
	1974	69	Unknown
	1975	220	Fair
Cape Island (south end)	1972	Terns nesting–not censused	—
		Inactive other years	—
Raccoon Key (north end)	1971	Not censused	—
	1972	32	Failed
	1973	19	Poor
	1974	1+	Poor
	1975	Apparently inactive	—
Raccoon Key (south end)	1972	1+	Unknown
		Inactive other years	
Anderson Creek Shellbank	1971	Not censused	—
	1972	11	Poor
	1973	2	Unknown
	1974	Not censused	—
	1975	Inactive	—
Capers Island (Charleston County)	1974	3+	Unknown
		Not censused other years	—
Sullivans Island	1971–73	Not censused	—
	1974	13	Poor
	1975	Nests not censused; 10 fledglings on beach on 18 July (see text)	—
Bird Key (Stono River)	1971–72	Not censused	—
	1973	66+	Unknown
	1974	3+	Poor
	1975	8	Poor
Deveaux Bank	1971–74	Apparently inactive	—
	1975	1+	Failed

[1] Maximum number of nests counted during one day; a "+" indicates that the census was incomplete.
[2] See text for explanation.

active nests on the southwest point and 9 active nests on Cape Island Point. A number of terns losing nests on Cape Island Point apparently moved to the southwest point to renest. By 10 July, some nests on the southwest point were flooded and 8 abandoned eggs were located; although the flooding was relatively minor and a number of active nests and recently hatched young were present.

We noticed some evidence of predation of Least Tern eggs and young, but we found no sign of predation on the few dead adults located. Ghost crabs (*Ocypode quadrata*) are numerous in most Least Tern colonies and are probably important predators of eggs and young. Several young terns were observed hiding in crab burrows. Ghost crabs are suspected of taking eggs and young of birds (Beckett 1966, Sprunt 1948), and we observed a ghost crab preying on a young Gull-billed Tern. Rats (*Rattus* spp.), raccoons (*Procyon lotor*), snakes, and several birds of prey were also observed on the nesting islands and are potential predators of Least Terns.

In contrast to other colonial birds in South Carolina, Least Terns sometimes nest in areas heavily used by man. The colony on Sullivans Island was on a beach regularly used by bathers and dogs. Success in 1974 was apparently poor, but 10 fledglings were observed near the colony site on the only visit in 1975. Massey (1974) indicated that Least Terns may move some distance soon after fledging; thus, it is uncertain that the fledglings observed on Sullivans Island were actually raised there. Other sources of disturbance to nesting terns include livestock (Capers Island) and loggerhead turtles (*Caretta caretta*).

Eggshell thickness.—The mean eggshell thickness of Least Tern eggs ranged from 2 to 7% thinner than the thickness of eggs collected before 1947 (Table 2). Individual eggshell thickness ranged from 0.13 to 0.18 mm in the pre-1947 sample and from 0.13 to 0.17 mm in the sample collected in the 1970's. Although multiple range tests (Duncan 1955, Kramer 1956) indicated a significant difference ($P < 0.05$) between the pre-1947 mean and the 1974 mean, further statistical testing revealed that the sample size was insufficient to detect a change of 10% when probability = 0.05, power = 0.8, and the coefficient of variation = 7.9% (Sokal and Rohlf 1969:247, Klaas et al. 1974). We observed no extremely thin-shelled, cracked, or crushed eggs.

Organochlorine residues.—Residues of DDE and PCB's were found in each of the 44 eggs analyzed (Table 3). Low levels of mirex, dieldrin, *trans*-nonachlor, and toxaphene were found in a few eggs. Residues analyzed for, but not detected, included hexachlorobenzene, *cis*-nonachlor, *cis*-chlordane, oxychlordane, heptachlor epoxide, and endrin.

Residues of DDE declined each year of the study so that residues in 1975

TABLE 2

EGGSHELL THICKNESS OF LEAST TERN EGGS

Eggshell thickness (mm)			
Pre-1947	1972	1974	1975
0.152±[1]	0.145±	0.142±	0.149±
0.002	0.005	0.002	0.004
(61) A	(11) A	(20) A	(15) A

[1] Mean ± standard error, sample size in parentheses. When means share a common letter, this indicates that those means are not significantly different ($P > 0.05$) from one another as calculated by multiple range tests (Duncan 1955, Kramer 1956) or the multiple range tests indicated significant differences but other tests (Sokal and Rohlf 1969; Klaas et al. 1974) revealed the sample size was too small (see text).

were nearly 50% lower than in 1972. Although multiple range tests (Duncan 1955, Kramer 1956) indicated a significant difference ($P < 0.05$) between means for DDE in each of the 3 years (Table 3), further statistical testing revealed that, except for the comparison of the 1972 and 1975 means, the sample size was insufficient to detect the observed percentage change in means when probability = 0.05, power = 0.8, and the coefficient of variation = 37% (Sokal and Rohlf 1969:247). Significant differences ($P < 0.05$) were found between mean PCB residues in each of the 3 years,

TABLE 3

RESIDUES OF ORGANOCHLORINE POLLUTANTS IN LEAST TERN EGGS

		μg/g (fresh wet weight)[1]	
Year	Sample size	DDE	PCB's
1972	9	0.63[2] A[3]	0.40 A
		0.48–0.80	0.18–0.65
		0.39–1.06	0.25–1.10
1974	20	0.48 AB	1.08 B
		0.39–0.57	0.95–1.22
		0.19–1.22	0.67–1.90
1975	15	0.33 B	0.62 C
		0.27–0.39	0.51–0.75
		0.22–0.53	0.25–1.03

[1] Other organochlorine residues detected included mirex (0.12 μg/g in 1 egg), *trans*-nonachlor (0.10 μg/g in 1 egg), dieldrin (0.10 μg/g in 1 egg), and toxaphene (0.10 μg/g in 1 egg and 0.40 μg/g in another).
[2] Geometric mean (first line), 95% confidence limits (second line), and range (third line).
[3] See Table 2 and text for explanation of letters.

and the sample size was sufficient to detect the observed percentage change in means when probability = 0.05, power = 0.8, and coefficient of variation = 39%. In contrast to the steady decline in DDE residues, PCB residues increased from 1972 to 1974 then declined in 1975 (Table 3).

DISCUSSION

We found no evidence of a decline in South Carolina Least Tern populations since the 1940's. Sprunt and Chamberlain (1949) indicated the Least Tern had recovered from exploitation by 1927; they estimated 600 breeding pairs occurred within 80 km of Charleston. We were among cooperators surveying nesting colonies of Least Terns along the entire South Carolina coast; these surveys recorded 691 breeding pairs in 1974 and 628 pairs in 1975 (Fisk 1975, E. J. Fisk, pers. comm.). The population figures before the 1970's were based mainly on estimates, and covered only a portion of the coastline. Apparently, the South Carolina population was never very large. Least Terns in South Carolina are probably not producing sufficient young to maintain a stable population, but our data are severely limited and intensive research on reproductive success and age specific mortality rates are required to determine population status. Because of the logistical problems of studying Least Terns, there is little quantitative information on reproductive success of these birds. A colony of Least Terns near Gulfport, Mississippi, apparently experienced an excellent rate of reproductive success in 1976; over 400 young and nearly 200 nests with eggs were observed in late June (Jackson 1976).

Declines of Least Tern populations have been documented in other states. A single island in Georgia contained an estimated 2500 breeding pairs in 1925 (Tomkins 1959); 2 nests were located in the entire state in 1974 (Fisk 1975). An estimated 25,000 terns occupied the North Carolina coast in 1939 (Pearson et al. 1942). The estimate by Pearson et al. seems much too high since they found only 830 nests. Downing (1973) estimated 1138 pairs of Least Terns in North Carolina in 1973 whereas Fisk (1975) estimated 463 pairs in 1974. The North Carolina population has probably declined over the last 40 years due to loss of several nesting colonies, but the decline has probably been far less drastic than commonly believed (Nisbet 1973). The decline of the Georgia population was probably caused by man-made alterations in nesting grounds that permitted invasion of raccoons and other predators (Tomkins 1959). Human interference has also played a major role in the decline of Least Tern populations in California (Massey 1974, Wilbur 1974), Massachusetts and other localities on the Atlantic Coast (Nisbet 1973), and in Great Britain and Ireland (Norman and Saunders 1969).

Residues of organochlorine pollutants found in eggs of Least Terns from South Carolina are low and pose no identifiable threat to the birds. Massey (1971) found DDE in abandoned eggs of Least Terns collected in Orange County, California, in 1970. She reported residues of DDE ranging from 42 to 271 μg/g on an apparent lipid basis which we converted to 6 to 41 μg/g on a wet weight basis. Although Massey (1971) made no attempt to interpret relevance of these residues, they probably posed a threat to the Least Terns in Orange County as residues of that magnitude induced adverse effects on reproductive success of Common Terns (*Sterna hirundo*) in Canada (Fox 1976). Least Tern eggs collected in Texas in 1970 contained an average of 6.9 μg/g of DDT and metabolites and 2.6 μg/g of PCB's on a wet weight basis (King et al. 1978).

The declining trend in DDE residues and erratic trend for PCB residues in eggs of Least Terns from 1972 through 1975 were similar to trends of these pollutants in Brown Pelican eggs collected in South Carolina during the same period (Blus et al. 1977, Blus et al. unpublished data). Least Tern eggs contained lower residues than those of the Brown Pelican and other estuarine birds in South Carolina (Blus et al. unpublished data).

We are guardedly optimistic about the future of Least Terns in South Carolina. The colonies on Cape Island, Raccoon Key, and Anderson Creek Shellbank are protected by the CRNWR. Capers Island is now managed by the South Carolina Conservation Department; Deveaux Bank is managed by the National Audubon Society and has been designated the Alexander Sprunt, Jr. Sanctuary. Bird Key (Stono River) is owned by the state but is not managed by the Conservation Department. The future of the colonies on Kiawah Island, Hilton Head Island (not covered in this report), and Sullivans Island is tenuous because of extensive human disturbance. A good set of management measures outlined by Buckley and Buckley (1976) should be followed to ensure protection of Least Terns nesting on developed beaches. Several of the colonies have been posted, but for best results, close surveillance must accompany the posting. The recent roof nesting adaptation of the Least Tern seems a favorable one as the birds are free from most predators and human disturbance; however, flooding is a problem. Management possibilities for roof nesters include nesting containers (several inches high) containing sand or shells and simple structures that could provide cover for the young.

SUMMARY

Least Tern nesting colonies on the Cape Romain National Wildlife Refuge and surrounding areas in South Carolina were studied from 1971 through 1975. We located 10 colonies

including 6 on the Refuge and 4 on nearby coastal islands. The number of nests in each colony ranged from several up to 220.

Least Terns began reproductive activity in April, and the egg-laying period ranged from May to July. The earliest hatching record was 6 June. Reproductive success in most colonies seemed poor. Tidal flooding of eggs, predation of eggs and young, and disturbance by domestic animals and man were responsible for most failures.

Residues of DDE, PCB's, and other organochlorine pollutants in the eggs were low and posed no identifiable threat to the Least Terns. DDE residues in eggs declined from 0.63 μg/g in 1972 to 0.33 μg/g in 1975. In contrast, PCB residue trends were erratic; mean residue values were 0.40 μg/g in 1972, 1.08 μg/g in 1974, and 0.62 μg/g in 1975.

Eggshell thickness means for 1972, 1974, and 1975 were 2 to 7% lower than the pre-1947 mean; but the differences between means were not statistically significant.

There is no evidence of a decline in Least Tern populations in South Carolina over the past 30 years such as observed in many other parts of the range of the species. A number of the current nesting islands seem secure from adverse environmental perturbations, although several colonies are on islands that are in danger of extensive development.

ACKNOWLEDGMENTS

We thank Steve Joyner, Daniel Doshier, Fred Milton, Stewart Givens, Burkett Neely, Jr., George Garris, Julie Keahey, Brad Winkler, John Shoerer, Scott Osborne, George Shegogue, and others for assistance in the field. We express appreciation to S. N. Wiemeyer, V. M. Mendenhall, and A. S. Federighi for comments on the manuscript.

LITERATURE CITED

Beckett, T. A., III. 1966. Deveaux Bank—1964 and 1965. Chat 30:93–100.

Blus, L. J., B. S. Neeley, Jr., T. G. Lamont, and B. Mulhern. 1977. Residues of organochlorines and heavy metals in tissues and eggs of Brown Pelicans, 1969–1973. Pestic. Monit. J. 11:40–53.

Buckley, P. A., and F. G. Buckley. 1976. Guidelines for protection and management of colonially nesting waterbirds. National Park Service, Boston, Mass.

Cromartie, E., W. L. Reichel, L. N. Locke, A. A. Belisle, T. E. Kaiser, T. G. Lamont, B. M. Mulhern, R. M. Prouty, 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.

Downing, R. L. 1973. A preliminary nesting survey of Least Terns and Black Skimmers in the East. Am. Birds 27:946–949.

Duncan, D. B. 1955. Multiple range and multiple *F* tests. Biometrics 11:1–42.

Fisk, E. J. 1975. Least Tern: Beleagured, opportunistic and roof-nesting. Am. Birds 29:15–16.

Fox, G. A. 1976. Eggshell quality: its ecological and physiological significance in a DDE-contaminated Common Tern population. Wilson Bull. 88:459–477.

Jackson, J. A. 1976. Some aspects of the nesting ecology of Least Terns on the Mississippi Gulf Coast. Mississippi Kite 6:25–35.

King, K. A., E. L. Flickinger, and H. H. Hildebrand. 1978. Shell thinning and pesticide residues in Texas aquatic bird eggs, 1970. Pestic. Monit. J. 12:16–21.

Klaas, E. E., H. M. Ohlendorf, and R. G. Heath. 1974. Avian eggshell thickness: variability and sampling. Wilson Bull. 86:156–164.

KRAMER, C. Y. 1956. Extensions of multiple range tests to group means with unequal numbers of replications. Biometrics 12:307–310.

MARPLES, G., AND A. MARPLES. 1934. Sea terns or sea swallows. Country Life Limited, London.

MASSEY, B. W. 1971. A breeding study of the California Least Tern—1971. California Dept. of Fish and Game, Project W-54-R, Administrative Report No. 71-9.

———. 1974. Breeding biology of the California Least Tern. Proc. Linn. Soc. N.Y. 72:1–24.

NISBET, I. C. T. 1973. Terns in Massachusetts: present numbers and historical changes. Bird-Banding 44:27–55.

NORMAN, R. K., AND D. R. SAUNDERS. 1969. Status of Little Terns in Great Britain and Ireland in 1967. Br. Birds 62:4–13.

PEARSON, T. G., C. S. BRIMLEY, AND H. H. BRIMLEY. 1942. Birds of North Carolina. N.C. Dept. of Agric., Raleigh.

SCHÖNERT, C. 1961. Zur Brutbiologie und Ethologie der Zwergseechlaulbe (*Sterna a. albifrons* Pallas). *In* Beiträge zur Kenntnis Deutscher. Vögel (H. Schildmacher, ed.). Gustav Fisher Verlag, Jena.

SOKAL, R. R., AND F. J. ROHLF. 1969. Biometry. W. H. Freeman and Co., San Francisco.

SOOTS, R. F., JR., AND J. F. PARNELL. 1975. Ecological succession of breeding birds in relation to plant succession on dredge islands in North Carolina estuaries. N.C. Sea Grant Publ. UNC-SG-75-27, Raleigh, N.C.

SPRUNT, A., JR. 1948. The tern colonies of the Dry Tortugas Keys. Auk 65:1–19.

———, AND E. B. CHAMBERLAIN. 1949. South Carolina Bird Life. Univ. South Carolina Press, Columbia.

TOMKINS, I. R. 1959. Life history notes on the Least Tern. Auk 71:313–322.

WILBUR, S. R. 1974. The literature of the California Least Tern. U.S. Bureau of Sport Fisheries and Wildlife Special Scientific Report—Wildlife No. 175. Washington, D.C.

U.S. FISH AND WILDLIFE SERVICE, PATUXENT WILDLIFE RESEARCH CENTER, PACIFIC NORTHWEST FIELD STATION, 480 S.W. AIRPORT ROAD, CORVALLIS, OR 97330, AND U.S. FISH AND WILDLIFE SERVICE, PATUXENT WILDLIFE RESEARCH CENTER, LAUREL, MD 20811. ACCEPTED 29 APR. 1978.