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ORGANOCHLORINE RESIDUES AND SHELL CHARACTERISTICS OF ROSEATE TERN EGGS, 1981

By Thomas W. Custer, Ian C. T. Nisbet, and Alexander J. Krynitsky

Roseate Terns (*Sterna dougallii*) breed in two areas in the Western Hemisphere: in northeastern North America between Long Island, New York, and Nova Scotia, and around the Caribbean Sea from the Florida Keys and the Bahamas to the Netherlands Lesser Antilles (Bent 1921, Bond 1956, Nisbet 1980). Both populations are small, and concern recently has been expressed about their status (Nisbet 1980, Buckley and Buckley 1981). The northeastern population has decreased from a peak of about 8500 pairs in the 1940s to between 2500 and 3000 pairs in 1978–1982, and has become largely concentrated into 4 colonies (Nisbet 1980). The Caribbean population has been affected by egg collecting and other forms of human disturbance in its main stronghold in the U.S. Virgin Islands (U.S. Virgin Islands Bureau of Fish and Wildlife 1976–1979, Norton 1980, 1981).

One factor which may have affected the northeastern population is chemical pollution. Hays and Risebrough (1972) reported high levels of polychlorinated biphenyls (PCBs) and 1,1-dichloro-2,2-bis(p-chlorophenyl) ethylene (DDE) in 3 Roseate Tern chicks found with congenital abnormalities at Great Gull Island, New York, in 1970. High levels of PCBs were also found in chicks found dead at Bird Island, Massachusetts, in 1970 (Nisbet 1981). A close relative, the Common Tern (*S. hirundo*), is relatively sensitive to the effects of DDE; elevated residues of DDE in eggs are associated with eggshell-thinning (Switzer et al. 1973), reduction in the porosity of eggshells, and embryonic mortality (Fox 1976).

The present paper reports the results of a survey of organochlorine residues in Roseate Terns in 1981. The main objectives of the survey were to determine the levels of organochlorine contamination in eggs of the Roseate Tern in its major colonies and to investigate whether changes in eggshell characteristics similar to those reported by Fox (1976) may have occurred in this species. A secondary objective was to determine geographic patterns of organochlorine contamination within the northeastern U.S. population of Roseate Terns and to compare them with patterns observed in Common Terns.

METHODS

Roseate Tern eggs were collected between 18 May and 15 June 1981, at 5 colonies in the northeastern U.S. and 1 colony in the U.S. Virgin Islands (Table 1). The northeastern colonies were described by Erwin and Korschgen (1979; colony #s 351014, 351044, 352015, 352017,

TABLE 1. Occurrence of organochlorine residues (ppm wet weight) in Roseate Tern eggs, 1981.

Location (n)[1]	Date of collection	Range (number with residue)	
		DDE	PCBs
Dead Neck, MA (10)	1 June	nd[2]–0.90 (9)	0.79–9.04 (10)
Monomoy NWR, MA (7)	15 June	0.14–0.30 (7)	1.29–5.53 (7)
Bird Island, MA (10)	19 May	nd–0.17 (7)	1.70–5.40 (10)
Falkner's Island, CT (10)	18 May	0.13–0.49 (10)	1.17–2.15 (10)
Great Gull Island, NY (7)	24 May	nd–0.31 (6)	1.07–2.26 (7)
Dog Island, U.S. Virgin Islands (8)	20 May	nd (0)	nd (0)

[1] n = number of eggs.
[2] nd = not detected.

352045). Dog Island (18°18′N, 64°49′W) is a 4.9 ha island off the coast of St. Thomas, V.I., and supported at least 400 pairs of Roseate Terns in 1981 (Norton 1981).

One egg was collected from each nest. All 27 eggs collected in Massachusetts, 9 of 10 eggs at Falkner's Island, and 5 of 7 eggs on Great Gull Island were determined to be the first egg in the clutch (A-egg), either because they were the only eggs in the nests or by flotation (Hays and LeCroy 1971). One egg from Falkner's Island, 2 eggs from Great Gull Island, and all 8 eggs from Dog Island were collected randomly from 2-egg clutches. Except at Dead Neck and Monomoy, all eggs were laid in the first few days of the season and were collected when fresh. At Dead Neck, eggs were laid during 21–31 May and were collected on 1 June when deserted (5), rolled out of nests (2), or fresh (3). At Monomoy, eggs were laid in early June and were deserted soon afterwards; eggs were collected on 15 June and had been incubated for up to 8 days, based on the size of the embryos in relation to Common Tern embryo sizes (Hays and LeCroy 1971).

Eggs collected at Dead Neck, and Bird, Falkner's, and Great Gull Island were cleaned lightly to remove adhering vegetation and feces, and were then kept for 6 days in a desiccator at a constant temperature of 23 ± 1°C over anhydrous calcium chloride. The average rate of weight loss provides a measure of the water vapor conductance of the eggshell and hence of its porosity (Ar et al. 1974). For comparative purposes, we calculated for each egg the percentage of its fresh weight lost per day. Eggs from each colony were assigned alternately to 1 of 2 desiccators; no significant differences in rate of weight loss were observed between eggs in the 2 desiccators.

Egg volumes were measured to the nearest milliliter by water displacement before the contents were removed. Eggs were refrigerated until the contents could be removed, placed in chemically cleaned jars (acetone and hexane rinsed), and kept frozen at about −18°C pending analysis. Eggshells were gently rinsed with tap water and air dried. Residue concentrations were adjusted to fresh wet weight assuming a specific gravity of 1.0 (Stickel et al. 1973).

Sample preparation, extraction, Florisil cleanup, and silicic acid chromatography for organochlorine residues were conducted as previously described (Cromartie et al. 1975), except that silica gel (100–200 mesh, grade 923, Davison Chemical Division, W. R. Grace & Co.) was substituted for SilicAR® for the separation of pesticides and PCBs. In addition, fractions I and II were combined for most of the samples and they were not analyzed for HCB or mirex. Residues were quantified by electron-capture, gas-liquid chromatography (EC-GLC) by using a 1.83 m 1.5/1.95% SP-2250/2401 column. Recoveries of pesticides and PCBs from fortified chicken eggs ranged from 90 to 103% except about 50% for *trans*-nonachlor. The lower limit of reportable residues was .1 ppm for organochlorine pesticides (DDE, DDD, DDT, dieldrin, heptachlor epoxide, oxychlordane, *cis*-chlordane, *cis*-nonachlor, *trans*-nonachlor, endrin, and toxaphene) and .5 ppm for PCBs on a wet-weight basis.

Eggshell thickness was measured to the nearest .01 mm with a modified Starrett micrometer after the shells had dried at room temperature for at least a month. Three measurements were taken at the equator of each egg and included the shell and shell membrane. Measurements were averaged to yield a single value for each egg. The dried eggshells were weighed to the nearest milligram.

Eggshell characteristics and organochlorine concentrations were compared among colonies by using one-way analysis of variance; statistical significance of differences was determined by using Tukey's multiple comparison method (Neter and Wasserman 1974). For samples in which no residues could be detected, a value of one-half the reportable limit was assigned for statistical analysis. Residue concentrations were log-transformed before statistical analysis, and the antilogs (i.e., geometric means) are presented in Table 2.

RESULTS

Eggs from Dog Island had no detectable organochlorine compounds (Table 1). The 44 eggs collected from the 5 northeastern U.S. colonies all contained PCBs and 39 contained DDE. The maximum concentrations of DDE and PCBs were .90 ppm and 9.04 ppm. No other organochlorine compounds (see Methods) were detected in the eggs.

Among the 5 northeastern U.S. colonies, there were no significant differences in geometric mean concentrations of PCBs (Table 2). Geometric mean concentrations of DDE were significantly higher in eggs from Falkner's Island and Dead Neck than from Bird Island. There were no significant differences ($P > .05$) among colonies in shell thickness, shell weight, or percentage moisture loss per day; eggshells from the northeastern U.S. colonies, however, were significantly thinner than those from the U.S. Virgin Islands (mean ± SE for the 5 northeastern U.S. colonies was .212 ± .002 mm versus .221 ± .003 mm for Dog Island, $P < .05$). Except for a significant correlation (Pearson correlation coefficient, $P < .01$) between shell thickness and shell weight, there were no significant correlations among the eggshell characteristics or between these characteristics and log-PCBs or log-DDE concentrations.

DISCUSSION

Concentrations of organochlorine compounds in Roseate Terns in the northeastern U.S. were considerably lower than those in Common Terns from the same area. At Great Gull Island, the geometric mean levels of DDE and PCBs in Roseate Tern eggs in 1981 were .15 and 1.72 ppm versus .72 and 4.48 ppm in Common Tern eggs in 1980 (Custer et al. 1983b). At Bird Island, the arithmetic mean levels of DDE and PCBs in Roseate Tern eggs in 1981 were .09 and 2.86 ppm versus .20 and 9.5 ppm in Common Tern eggs in 1981 (Nisbet and Reynolds in press). At Monomoy, the geometric mean levels of DDE and PCBs in Roseate Tern eggs in 1981 were .16 and 1.96 ppm versus .29 and 3.95 ppm in Common Tern eggs in 1976 (Nisbet and Reynolds in press). One factor which may explain the lower residue levels in Roseate Terns than in Common Terns from the same colonies is that Roseate Terns usually feed in less polluted waters than Common Terns; they either feed in deeper onshore sites or farther offshore (Nisbet 1981). For example, in Buzzards Bay, Massachusetts, Roseate Terns fed primarily in 2 discrete areas and avoided the parts of the bay most heavily polluted with PCBs from point sources at New Bedford (Nisbet 1981, Nisbet and Reynolds in press).

There was no evidence of eggshell changes in Roseate Terns associated with organochlorine contamination. Nisbet (1981) weighed shells collected at Muskeget Island, Massachusetts, between 1875 and 1931. The mean weight (± standard error) of 20 A-eggshells (identified as such by relative size, which is at least 93% reliable [Nisbet 1981, Nisbet unpubl. data]) was 1.216 ± .024 g. The mean weight of A-eggshells collected in the northeastern U.S. in 1981 was not significantly different from this value (1.219 ± .011 g, $P > .05$, Table 2). Eggshells from the northeastern U.S. colonies were significantly thinner than those from the U.S. Virgin Islands; however, this pattern may be natural geographic variation rather than a result of environmental contamination, since there were not significant correlations between eggshell characteristics and either DDE or PCB concentrations. Studies of Common Terns have suggested that eggshell thickness, eggshell porosity, and hatchability are not affected until DDE concentrations exceed about 4 ppm (Switzer et al. 1973, Fox 1976, Nisbet and Reynolds in press); none of the Roseate Tern eggs in our study exceeded 1 ppm DDE (Table 1).

Hays and Risebrough (1972) analyzed 3 abnormal Roseate Tern chicks

TABLE 2. Geometric means (ppm wet weight) of organochlorine residues in eggs of Roseate Terns and arithmetic mean shell thickness (mm), shell weight (g), and percentage moisture loss per day.

Location	DDE[1]	PCBs[2]	Shell thickness[3]	Shell weight[2]	Percent moisture loss per day[2]
Falkner's Island, CT	0.24 A	1.74	0.212	1.199	0.402
Dead Neck, MA	0.18 A	2.03	0.209	1.224	0.463
Monomoy NWR, MA	0.16 AB	1.96	0.218	1.219	—
Great Gull Island, NY	0.11 AB	1.47	0.208	1.234	0.460
Bird Island, MA	0.08 B	2.72	0.215	1.247	0.401
Dog Island, U.S. Virgin Islands	nd[4]	nd	0.221	—	—

[1] Tukey's multiple comparison method, $\alpha = .05$. Means not sharing the same letter are significantly different. Dog Island was not included in the analysis.

[2] No significant differences among colonies (1-way ANOVA, $P > .10$). Dog Island was not included in the analyses. Monomoy NWR also was not included in analysis of percent moisture loss per day.

[3] No significant differences among colonies (1-way ANOVA, $.10 > P > .05$).

[4] nd = not detected.

found at Great Gull Island in 1971 and found whole-body concentrations of .47–3.2 ppm DDE and 7.8–63 ppm PCBs. All the measured concentrations of both DDE and PCBs in 1971 were higher than those in any of the 10 eggs from this colony analyzed in 1981 (Table 1). Because of small sample size and lack of residue data from normal chicks, it is not clear whether the difference indicates that the overall level of contamination was much higher in 1971, or that levels were especially high in the abnormal chicks. Gochfeld (1975) reported that the prevalence of developmental defects in terns on Long Island decreased after 1971. In addition, DDE levels have decreased along the Atlantic coast since the late 1960s and early 1970s in American Black Ducks (*Anas rubripes*, Haseltine et al. 1980), Ospreys (*Pandion haliaetus*, Spitzer et al. 1978), Brown Pelicans (*Pelecanus occidentalis*, Mendenhall and Prouty 1979), Black-crowned Night-Herons (*Nycticorax nycticorax*, Custer et al. 1983a), and Common Terns (Nisbet and Reynolds in press).

It is noteworthy that none of the eggs from Dog Island contained organochlorine compounds at a concentration equal to the level of detection. This indicates that the marine environment of the U.S. Virgin Islands is exceptionally free from DDE and PCB contamination. Earlier, Reimold (1975) reported DDE and PCBs in fish and crustaceans collected around the coasts of the U.S. Virgin Islands. Harvey and Steinhauer (1976) reported PCBs in samples of surface water collected at a number of stations in the North Atlantic to the north and east of the Virgin Islands.

In conclusion, our results suggest that levels of organochlorine compounds in Roseate Terns in 1981 were not high enough to have measurable effects on eggshell characteristics. However, our results do not rule out the possibility that levels in 1971 or earlier might have been high enough to have caused adverse effects (Hays and Risebrough 1972).

SUMMARY

Samples of Roseate Tern eggs were collected in 1981 from 5 of the largest colonies in the northeastern U.S. and from one large colony in the U.S. Virgin Islands. No organochlorine compounds were detected in eggs from the U.S. Virgin Islands. PCBs were found in all eggs and DDE was found in most eggs from the northeastern U.S., but concentrations were substantially lower than in Common Terns from the same colonies. There were no significant correlations between eggshell characteristics and organochlorine concentrations. DDE concentrations in Roseate Tern eggs were well below those reported to induce adverse effects in Common Terns.

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U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Gulf Coast Field Station, Victoria, Texas 77902 (TWC); *Clement Associates, Inc., 1515 Wilson Boulevard, 7th floor, Arlington, Virginia 22209* (ICTN); *Patuxent Wildlife Research Center, Laurel, Maryland 20708* (AJK). Received 7 Mar. 1983; accepted 30 Aug. 1983.