Organochlorine Contaminants in Eggs of Tern Species and the Western Snowy Plover Nesting in San Diego Bay

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Introduction

Previous studies have raised concerns about the organochlorine pesticide concentrations in the eggs of tern species in Southern California including the California least tern (*Sterna antillarum browni*, Boardman 1988) and Caspian tern (*Sterna caspia*, Ohlendorf et al. 1985). In the former study it was found that egg concentrations had decreased from levels found in the 1960's and 1970's, but that concentrations were still at levels of concern for reproductive effects with a maximum concentration for total DDT's of 23.6 parts per million (ppm). The latter study, conducted in San Diego Bay, reported numerous dented or crushed Caspian tern eggs. Concentrations of up to 56 ppm DDE (a DDT derivative) were found in eggs from this colony, and eggs which failed to hatch comprised nearly 23% of all eggs laid.

Studies have shown a decrease in eggshell thicknesses since 1947 when DDT was introduced. Henny et al. (1984) found a negative correlation between DDE and eggshell thickness. A negative correlation was also found for polychlorinated byphenyl (PCB) residues and eggshell thickness. Speich et al. (1992) found a decrease in the eggshell thickness of great blue herons (*Ardea herodias*) and glaucous-winged gulls (*Larus glaucescens*) in western Washington, but reproductive failures were not identified. Measurable concentrations of DDT or its breakdown products were found in all of the colonies examined in that study, but the levels were below those where reproductive failure would be expected.

During nest monitoring efforts in 1993 and 1994 conducted at the same south San Diego Bay location as the study mentioned above, crushed and dented eggshells were again seen among Caspian tern nests (D. Stadtlander, pers. comm.). This phenomenon was noted for black skimmers (*Rynchops niger*) with greater frequency than for Caspian terns (Stadtlander 1993). Because of concerns raised by these observations and previous studies, unhatched eggs of these and several other species were collected for chemical analysis and comparisons. The collections were made opportunistically, and funding for analysis was limited, so the resulting sample sizes were small. The additional species collected were the California least tern (a federally listed endangered species), elegant tern (*Sterna elegans*), gull-billed tern (*Sterna nilotica*), Forster's tern (*Sterna forsteri*), and western snowy plover (*Charadrius alexandrinus nivosus*). The plover is a federally listed threatened species, and information regarding pesticide exposure is important for the recovery of both this species and the California least tern.

Materials and Methods

San Diego Bay is located in the southwest corner of San Diego County near the Mexican border (Figure 1). It is separated from the Pacific Ocean by a narrow peninsula which broadens at the north end, and upon which the City of Coronado and the Naval Air Station, North Island are located. The Bay is approximately 15 miles long and 1/4 to 2 ½ miles wide.

The eggs analyzed in this study were eggs which failed to hatch at several San Diego Bay colonies. All black skimmer, Caspian tern, Forster's tern, elegant tern, gull-billed tern , and western snowy plover eggs were from the Salt Works located in south San Diego Bay. One of the California least tern eggs was also collected there. California least tern eggs were collected in mid-Bay at colonies on the D Street fill at Sweetwater Marsh National Wildlife Refuge and from the Naval Amphibious Base. California least tern eggs were also collected at North Island Naval Air Station in the north end of San Diego Bay.

The eggs were collected by monitors of those colonies or Fish and Wildlife Service Environmental Contaminants personnel. Eggs were wrapped in foil in the field, kept cool, then refrigerated until the contents were removed. To remove the contents, the eggs were bisected at the equator using a scalpel. Egg contents were placed in chemically clean jars and frozen until submitted to the analytical laboratory. In the case of the California least tern, western snowy plover and Forster's tern, some eggs were composited to obtain adequate material for chemical analysis. The three mid-Bay California least tern samples were all composites of four eggs. The 1994 California least tern sample was originally a composite of four eggs. However, the sample jar was damaged in handling and part of the sample was lost. The two Forster's tern samples from 1994 were each composites of two eggs. The western snowy plover sample was a composite of three eggs.

Additional eggs are considered here which were collected in 1991 and submitted as part of the 1992 Endangered Species Contaminants Survey. Due to the need to conduct inorganic and organic analyses, samples sizes were smaller and the resulting detection limits were higher. Otherwise, protocols for handling and analysis were the same as for the other samples. Measurable concentrations were only found for p,p'DDE and total PCB's so those results are incorporated here. California least tern eggs in that sample set were obtained from D Street fill in mid-Bay (1), Tijuana Slough National Wildlife Refuge just south of San Diego Bay (5), and for comparison Seal Beach National Wildlife Refuge in Orange County (5). Three western snowy plover eggs were collected from Newport Beach in Orange County and were included in that sample set. Sample sizes for the other years and analyses are found in the Results and Tables 1-4.

Eggshells were dried for two to three months after processing before being measured for thickness. Eggshell thickness measurements were taken with a modified Mitutoyo micrometer. A total of four measurements were taken around the equator of the egg, and a mean was calculated for each egg. Measurements included the shell and the membrane. Due to the condition of some of the eggs when they were collected, measurements were not possible. However, more eggs were available than could be submitted for chemical analysis; those measurements are included here.

The analyses were conducted at laboratories under contract with the Fish and Wildlife Service's Patuxent Analytical Control Facility. This facility provided logistical support as well as quality assurance/quality control review. In addition, the analyses for the 1993 and 1994 Salt Works eggs were conducted at the Patuxent Laboratory. Analyses of the 1991 south San Diego Bay samples were conducted by the Mississippi State Chemical Laboratory at Mississippi State University. Analyses of the samples from mid-Bay and North Island as well as the additional samples from Tijuana Slough and Orange County were conducted at the Geochemical and Environmental Research Group at Texas A & M University. Analysis methods are provided in the appendix. Concentrations provided in the results below are unadjusted wet weight unless otherwise noted.

Results

The following analytes were not detected in any of the samples analyzed from San Diego Bay: alpha-BHC; alpha-chlordane; beta-BHC; delta-BHC (the 1993 and 1994 birds were not tested for this analyte); endrin; gamma-BHC; gamma-chlordane; HCB; heptachlor (only the mid-Bay and North Island least tern eggs were analyzed for this pesticide); mirex; o,p'DDD; o,p'DDE; and o,p'DDT.

A relatively low frequency of detections was found for aldrin (2 of 7); cis-nonachlor (2 of 32); dieldrin (4 of 32); p,p'DDD (1 of 32); and p,p'DDT (6 of 32). The specific numbers of eggs, species, and concentrations of these detected quantities are presented in Table 1 in unadjusted wet weight concentrations.

Higher frequencies of detectable quantities were found for heptachlor epoxide (12 of 32), oxychlordane (13 of 32), and trans-nonachlor (14 of 32). With the exception of one least tern egg from the North Island in 1992, all other detected concentrations of heptachlor epoxide were from eggs collected at the Salt Works. The concentrations detected for all species in all years were low, however. The California least tern egg from the North Island had a concentration of 0.02 ppm (unadjusted wet weight concentration). The other California least tern composite sample from the Salt Works had a concentration of 0.024 ppm. The five black skimmer eggs from the Salt Works had concentrations of 0.01-0.026 ppm, and the two Caspian tern eggs had concentrations of 0.018-0.020 ppm. The highest concentration for this analyte was found in one of the composite Forster's tern egg samples at 0.044 ppm. The other two samples for this species (one single egg and one composite) had concentrations of 0.01 and 0.017 ppm (respectively).

All detections of oxychlordane were for eggs collected from the Salt Works. All of the concentrations were relatively low with the exception of one black skimmer egg with a concentration of 0.15 ppm. The other six black skimmer eggs had concentrations of 0.017-0.05 ppm. Three Caspian tern eggs had concentrations of 0.011-0.022 ppm. The Forster's tern single egg sample had a concentration of 0.01 ppm, and the two egg composite had a concentration of 0.017 ppm. The only western snowy plover sample submitted (which was a three egg composite) had a detected concentration of 0.012 ppm.

Trans-nonachlor was not detected in any of the samples collected at the Salt Works in 1993 or 1994. Three black skimmer eggs collected at the Salt Works in 1991 had concentrations of 0.03-

0.04 ppm, and one sample had a concentration of 0.19 ppm. Three Forster's tern eggs had concentrations of 0.02-0.04 ppm. One Caspian tern had a concentration of 0.07 ppm, and the only gull-billed tern egg analyzed had a concentration of 0.03 ppm. One California least tern egg from the Salt Works had a concentration of 0.03 ppm, and a composite sample from mid-Bay had a concentration of 0.056 ppm. Three eggs from the North Island had concentrations of 0.023-0.077 ppm.

All of the samples analyzed had detectable quantities of p,p'DDE (Table 2). The location of collection was the Salt Works unless indicated otherwise below the sample number.

All of the samples analyzed also had detectable concentrations of PCB's. Due to a change in laboratory protocols, the 1990-1991 samples were analyzed for total PCB concentrations, but the 1993-1994 samples were only analyzed for PCB-1254 (Table 3). The location of collection was the Salt Works unless indicated otherwise below the sample number.

Eggshell measurements were available for 37 of the 48 eggs sampled in this study (Table 4). The location of collection was the Salt Works unless indicated otherwise below the sample number. Eggs of the California least tern were measured at two additional sites for comparison. Eggshell thicknesses from eggs collected at Mariners' Point on Mission Bay (north of San Diego Bay) in 1991 ranged from 0.129-0.163 mm with a mean of 0.147 mm. A total of 37 eggs were measured from Camp Pendleton, a significant nesting site in north San Diego County, in 1991 and 1992. Thickness from this site ranged from 0.119-0.175 mm with a mean of 0.147 mm. The San Diego Bay sample sets provided in Table 4 had means of 0.144 mm to 0.152 mm.

Discussion

The concentrations measured for the detected pesticides in Table 1 fall well below the maximum concentrations measured by Ohlendorf et al. (1985) in San Diego Bay. Concentrations for aldrin were not provided in that study, but it appears that the concentrations of this group of pesticides have decreased in the decade between sampling in the Ohlendorf et al. (1985) study and the sample collection in this study. Maximum concentrations measured in that study were an order of magnitude or more higher than the results provided herein (Table 1). The concentrations of aldrin and dieldrin we measured fall well below all levels where reproductive depression or failure were seen as provided by Peakall (1996). The p,p'DDT and p,p'DDD concentrations we measured are one to two orders of magnitude below the concentrations of p,p'DDE measured in the same samples. These analytes are therefore not expected to be responsible for measurable impacts to the species sampled given the relative concentrations.

The concentrations of heptachlor epoxide were up to an order of magnitude below those measured in Ohlendorf et al. (1985) in San Diego Bay. Similarly, the concentrations of oxychlordane in all but one of the eggs were from 75% to an order of magnitude or more below those previous measurements. Heptachlor epoxide and oxychlordane concentrations measured by Ohlendorf et al. (1988) in Caspian Terns in San Francisco Bay were similar when detected, but the detection frequencies there were very low. One black skimmer egg in this study had a concentration of oxychlordane approaching the maximum measured in Caspian terns in San Diego Bay by Ohlendorf et al. (1985). This same black skimmer egg had a concentration of trans-nonachlor exceeding the maximum measured in that study for Caspian terns. All other trans-nonachlor concentrations measured in this study fell below the Ohlendorf et al. (1985) maximum, but by lesser amounts due to the low overall concentrations of this analyte. Trans-nonachlor concentrations were higher in San Francisco Bay Caspian terns (Ohlendorf et al. 1988) than the concentrations measured here except for the single black skimmer egg previously mentioned. With the exception of this one black skimmer egg, concentrations for all three of these analytes also were well below concentrations measured in black-crowned night-herons in several areas in the west (Ohlendorf et al. 1988, Henny et al. 1984). The concentrations measured in this study were also well below those measured for peregrine falcons (*Falco peregrinus*) on the East Coast, but were similar to concentrations measured in that species on the West Coast (Jarman et al. 1993). Ohlendorf et al. (1988) considered these analytes to be of less importance in comparison to the concentrations of DDE they measured. The same black skimmer egg with the highest concentrations of oxychlordane and trans-nonachlor also had the highest concentrations of p,p'DDE and total PCB's. While the oxychlordane and trans-nonachlor levels are not of particular concern, the p,p'DDE and PCB levels are as discussed below.

The range of p,p'DDE concentrations reported here were below the mean for Caspian terns presented by Ohlendorf et al. (1985). Concentrations in Caspian terns in that study ranged as high as 56 ppm. The highest concentration measured in this study was 7.2 ppm and was found in the same black skimmer egg as the highest concentrations of oxychlordane and trans-nonachlor. The highest concentration measured in a Caspian tern egg in this study was 6.4 ppm. Both the Caspian tern egg and black skimmer egg mentioned above were collected in 1991 at the Salt Works colonies. Concentrations of p,p'DDE detected were somewhat lower in 1993 and 1994. The highest concentrations for black skimmer and Caspian tern eggs in 1993 and 1994 were 3.6 and 2.9 ppm, respectively. This is near the low end of concentrations measured in Caspian terns by Ohlendorf et al. (1985). Henny et al. (1984) found that at concentrations above 8 ppm, clutch size and productivity were reduced in black-crowned night-herons (*Nycticorax nycticorax*), and there was a higher incidence of cracked eggshells. Henny and Herron (1989) subsequently identified 4 ppm as a critical level in white-faced ibis (*Plegadis chihi*) eggs with similar impacts at concentrations above this level. One of the 1993 black skimmer eggs approached this level at 3.6 ppm. Decreased eggshell thickness and hatching success were found in common terns with dented eggs and mean DDE concentrations around 6.7 ppm (Fox 1976). The 1991 Caspian tern egg approached and one of the black skimmer eggs exceeded this threshold.

None of the 1993 or 1994 eggs exceeded the 4 ppm level in their DDE concentrations. However, when eggshell thicknesses were measured for Caspian terns, two of the nine eggs had thicknesses approaching the abnormal range given by Ohlendorf et al. (1985). Six of the nine eggshells measured herein were close to the mean provided for the randomly collected eggs in that study. Only one eggshell had a thickness exceeding the mean for eggs collected in 1941-1945 provided in that study for comparison. Numerous black skimmer and Caspian tern eggs were collected which were dented or crushed in 1993 and 1994, but because of the condition of the eggshell and/or its contents, accurate thickness measurements could not be made. While eggshell thinning has not been demonstrated for these two species at the concentrations measured here, measurable thinning has been detected in other species at DDE concentrations as low as 0.1 ppm (Blus 1996). Thinning has also varied within a species at different colonies with similar levels of DDE concentrations (Blus 1996). The data suggest that a greater effect occurs at lower DDE concentrations making the relationship between eggshell thinning and DDE concentrations difficult to establish, particularly with small sample sizes. The DDE concentrations measured here exceed the Blus (1996) calculated no effect level for brown pelican (*Pelecanis occidentalis*) eggs of 0.1 ppm and some exceed the level for peregrine falcon eggs of 2 ppm.

Eggshell strength may also be affected by DDE. Henny and Bennett (1990) found that shell strength deteriorated more quickly than shell thickness with increasing concentrations of DDE. Although shell thickness is the more easily measured parameter, Bennett et al. (1988) found that decreases in shell strength were more readily identified than changes in thickness in sulfanilamide-treated versus control eggs of the northern bobwhite (*Colinus virginianus*). This suggests that while eggshell thickness measurements are convenient, this parameter may overestimate the concentrations of DDE needed for measurable impacts. This could be a factor in our finding that damaged eggshells occurred in 1993 and 1994 in black skimmers and Caspian terns despite DDE concentrations below 4 ppm and eggshell thicknesses for Caspian terns (for which comparison data were available) that appeared to be normal in seven of nine eggs. Two of the nine eggshells did have below-normal thicknesses, and greater study is needed to determine the incidence of reductions in eggshell strength and/or thickness in these species nesting in South San Diego Bay. Larger sample sizes would afford a greater opportunity to examine the relationship between eggshell parameters and DDE in these populations.

PCB residues have also been found to be negatively correlated with eggshell thickness by King et al. (1978) in reddish egrets (*Egretta rufescens*) and brown pelicans. Concentrations of PCB's measured in that study were within the ranges detected in this study. Concentrations measured by Ohlendorf et al. (1985) were similar to the 1991 Caspian tern and black skimmer eggs, but were higher than the 1993 and 1994 eggs. The one most heavily contaminated black skimmer egg had the highest concentration of total PCB's at 14 ppm. The concentration measured in the 1991 Caspian tern egg was also similar to that found in San Francisco Bay Caspian terns by Ohlendorf et al. (1988). Eggs collected in 1993 and 1994 in San Diego Bay had lower concentrations than in those collected in the earlier study from San Francisco Bay. Forster's terns in all years of this study had lower egg concentrations than the mean for San Francisco Bay. Elegant tern eggs in this study had concentrations below those measured previously in San Diego Bay by Ohlendorf et al. (1985).

Several laboratory studies have identified reproductive impacts such as decreased hatching in chickens with egg concentrations of PCB's as low as 1ppm (Hoffman et al. 1996). Many field studies indicate that measurable PCB concentrations are accompanied by DDE or dioxins at levels of concern (Hoffman et al. 1996), complicating the interpretation of the cause of reproductive impairment. This is also the case here. Additional studies are needed to ascertain if synergistic effects of these contaminants are occurring thus increasing the potential for reproductive impacts despite the relatively low concentrations of individual compounds found in this study.

There is scant comparative data for the California least tern and western snowy plover. Concentrations of both DDE and PCB's were relatively low for least terns, with the highest concentration for the former being found in North Island and for the latter in mid-Bay. The mid-Bay area is the most highly industrialized with shipyards, commercial ports and the Naval Station. However, sample sizes were small and a larger sampling effort would be required to truly identify trends. Analysis of prey items collected at the different colonies would also be helpful in identifying differences in exposure in the different parts of the Bay. The concentrations measured were similar to egg concentrations measured in Seal Beach and Tijuana Slough (see Tables 2 and 3). Concentrations of DDE and PCB's for western snowy plovers in this small sample set were all below 1 ppm in the Salt Works. This species is insectivorous and may have lower exposure to these contaminants in their prey. Additional sampling would be needed to confirm this, but concern for this species relative to organochlorine compounds is low for this site.

The Salt Works colonies showed obvious indications of reproductive effects in the number of cracked or dented eggs which were seen 1993 and 1994 (Stadtlander 1993; D. Stadtlander, pers. comm.). Additional studies combining larger samples with contemporaneous determinations of reproductive success and correlated with eggshell strength and thickness measurements are needed to determine the potential cause of the impacts to the Caspian tern and black skimmer populations nesting at the Salt Works. Prey preference studies and analysis of prey items would be helpful in identifying the pathway for contaminants into these species' eggs and why these two species appear to be more greatly affected than the other species nesting in this area. Such studies may also identify a dietary deficiency which could contribute to the types of eggshell quality problems that have been found in South San Diego Bay.

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Appendix

LABORATORY: Patuxent Analytical Control Facility

Analytical Methodology for Organochlorines for Tissue

The analytical methods, including preparation, Soxhlet extraction, and lipid removal are described by Cromartie et al., 1975. Glass extraction thimbles were used. The silica gel separation of the pesticides from PCBs was different from the above reference in that four fractions were used instead of three to enable the separation of dieldrin and endrin from the rest of the pesticides. The pesticides in each fraction were quantified with a gas-liquid chromatograph (GLC), equipped with a 63Ni electron capture detector. The GLC column used was a 30m MEGABORE coated with a 1.0 micron film of 7% cyanopropyl 7% phenyl polysiloxane. Residues in 10% of the samples were confirmed by gas chromatography/mass spectrometry (GC/MS). The nominal lower limit of detection is 0.01 ppmfor pesticides and 0.05 ppm for PCBs based on a 10 g aliquot wet weight.

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Analytical Methodology for Percent Moisture

Preweigh pan. Add aliquot to tared pan. Allow sample to dry 24 hours in an oven at 200 degrees Fahrenheit. Samples are then placed in a desiccator to cool. Record pan + dry weight.

Percent Moisture = 1 - (pan + dry - pan weight / original aliquot) * 100.

LABORATORY: Mississippi State Chemical Laboratory

Analysis For Organochlorine Pesticides and PCBs In Animal and Plant Tissue

Ten gram tissue samples are thoroughly mixed with anhydrous sodium sulfate and soxhlet extracted with hexane for seven hours. The extract is concentrated by rotary evaporation; transferred to a tared test tube, and further concentrated to dryness for lipid determination. The weighed lipid sample is dissolved in petroleum ether and extracted four times with acetonitrile saturated with petroleum ether. Residues are partitioned into petroleum ether which is washed, concentrated, and transferred to a glass chromatographic column containing 20 grams of Florisil. The column is eluted with 200 ml 6% diethyl ether/94% petroleum ether (Fraction I) followed by 200 ml 15% diethyl ether/85% petroleum ether (Fraction II). Fraction II is concentrated to appropriate volume for quantification of residues by packed or capillary column electron capture gas chromatography. Fraction I is concentrated and transferred to a Silicic acid chromatographic column for additional cleanup required for separation of PCBs from other organochlorines. Three fractions are eluted from the silicic acid column. Each is concentrated to appropriate volume for quantification of residues by packed or megabore column, electron capture gas chromatography. PCBs are found in Fraction II.

LABORATORY: Geochemical & Environmental Research Group, Texas A&M

Tissue Organics

The tissue samples were extracted by the NOAA Status and Trends Method (MacLeod et al., 1985) with minor revisions (Brooks et al., 1989; Wade et al., 1988). Briefly, the tissue samples were homogenized with a Teckmar Tissumizer. A 1 to 10-gram sample (wet weight) was extracted with the Teckmar Tissumizer by adding surrogate standards, Na2SO4, and methylene chloride in a centrifuge tube. The tissue extracts were purified by silica/alumina column chromatography to isolate the aliphatic and PAH/pesticide/PCB fractions. The PAH/pesticide/PCB fraction was further purified by HPLC in order to remove interfering lipids.

The quantitative analyses were performed by capillary gas chromatography (CGC) with a flame ionization detector for aliphatic hydrocarbons, CGC with electron capture detector for pesticides and PCB's, and a mass spectrometer detector in the SIM mode for aromatic hydrocarbons (Wade et al., 1988).

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% Dry Weight

Approximately 1 gram of wet sample is weighed into a clean, labeled, preweighed 10 ml beaker. The beaker is placed in a forced air oven at approximately 75 degrees Celsius for 24 hours. The beaker with the dry sample is then weighed and the % dry weight is calculated by the formula:

$$\frac{\text{(wt. dry sample and beaker) - (wt. beaker) (100)}}{\text{(wt. wet sample and beaker) - (wt. beaker)}}$$

Figure 1. San Diego Bay

Table 1. Concentrations of Infrequently Detected Analytes in Tern Eggs from San Diego Bay

Analyte	No. of Eggs	Species	Location	Year(s)	Concentrations Measured
Aldrin	2	Cal. least tern	North Island	1992	0.025-0.032 ppm
Cis-nonachlor	2	Cal. least tern	North Island	1992	0.024-0.037 ppm
Dieldrin	3	black skimmer	Salt Works	1991	0.01-0.02 ppm
Dieldrin	1	Cal. least tern	North Island	1992	0.033 ppm
p,p'DDD	1	black skimmer	Salt Works	1991	0.03 ppm
p,p'DDT	3	black skimmer	Salt Works	1993-4	0.016-0.026 ppm
p,p'DDT	3	Caspian tern	Salt Works	1993-4	0.014-0.033 ppm

Table 2. p,p'DDE Concentrations Measured in San Diego Bay Tern Eggs in PPM Wet Weight

Year	Species	No. of Samples	Concen-trations	Year	Species	No. of Samples	Concen-trations
1991	black skimmer	6	2.4-7.2	1993-1994	black skimmer	3	2.5-3.6
1991	Forster's tern	4	0.47-1.5	1994	Forster's tern	2 composites	0.36-1.6
1991	California least tern	1	0.34	1994	California least tern	1 composite	1.1
1990-1992	California least tern	3 midBay composites	0.62-0.95	1991	California least tern	5 (Tijuana Slough)	0.76-1.7
1992	California least tern	4 North Island	0.32-1.5	1991	California least tern	5 (Seal Beach)	0.67-3.0
1991	Caspian tern	1	6.4	1993-1994	Caspian tern	3	1.9-2.9
1991	gull-billed tern	1	2.9				
				1993	elegant tern	2	0.31-2.0
1991	western snowy plover	3 (New-port Beach)	1.13-1.76	1993	western snowy plover	1 composite	0.98

Table 3. PCB Concentrations Measured in San Diego Bay Tern Eggs in PPM Wet Weight

Year	Species	No. of Samples	Concen-trations (total)	Year	Species	No. of Samples	Concen-trations (1254)
1991	black skimmer	6	2.8-14	1993-1994	black skimmer	3	0.75-1.1
1991	Forster's tern	4	0.32-1.3	1994	Forster's tern	2 composites	0.53-1.9
1991	California least tern	1	1.2	1994	California least tern	1 composite	1.3
1990-1992	California least tern	3 midBay composites	0.82-2.7	1991	California least tern	5 (Tijuana Slough)	0.29-0.80 (total PCB's)
1992	California least tern	4 North Island	0.40-1.6	1991	California least tern	5 (Seal Beach)	0.19-1.2 (total PCB's)
1991	Caspian tern	1	4.9	1993-1994	Caspian tern	3	0.70-1.2
1991	gull-billed tern	1	1.8				
				1993	elegant tern	2	0.17-0.62
1991	western snowy plover	3 (New-port Beach)	0.25-0.38	1993	western snowy plover	1 composite	0.30

Table 4. Eggshell Thickness Measurements for San Diego Bay Terns in Millimeters

Year	Species	No. of Eggs	Thickness Measured, **mean** and range	Year	Species	No. of Eggs	Thickness Measured, **mean** and range
1991	black skimmer	6	**0.234,** 0.215-0.253	1993-1994	black skimmer	22	**0.229,** 0.211-0.258
1991	Forster's tern	12	**0.201,** 0.188-0.216	1994	Forster's tern	2	**0.208,** 0.201-0.216
1991	California least tern	2	**0.152,** 0.140-0.164	1994	California least tern	4	**0.150,** 0.144-0.158
1990-1992	California least tern	28 midBay	**0.148,** 0.134-0.156	1990-1991	California least tern	21 (Tijuana Slough)	**0.149,** 0.109-0.174
1990-1992	California least tern	27 North Island	**0.144,** 0.125-0.166	1991	California least tern	22 (Seal Beach)	**0.149,** 0.129-0.180
1991	Caspian tern	1	0.339	1993-1994	Caspian tern	9	**0.329,** 0.275-0.358
1991	gull-billed tern	1	0.299				
				1993	elegant tern	16	**0.303,** 0.279-0.339
1991	western snowy plover	3 (New-port Beach)	**0.167,** 0.165-0.170	1993	western snowy plover	3	**0.155,** 0.144-0.171