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Characterizing Exposure and Potential Impacts of Contaminants on Seabirds Nesting at South San Diego Bay Unit of the San Diego National Wildlife Refuge (Salt Works, San Diego Bay)

Final Report

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by

Catherine Zeeman, PhD
Sharon K. Taylor, DVM, PhD
Judy Gibson
Annie Little
and
Carol Gorbics

Environmental Contaminants Division
Carlsbad Fish and Wildlife Office

for

Scott Sobiech, Deputy Field Office Supervisor
Carlsbad Fish and Wildlife Office
Carlsbad, CA
Congressional District - CA-51 and CA-53

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ABSTRACT

In 2005, a two-year USFWS study (1261-1N74) was initiated to characterize contaminant exposure by seabirds that nest in colonies at the South Bay Salt Works, within the boundaries of the South San Diego Bay Unit of the San Diego Bay National Wildlife Refuge (NWR), CA. This study was conducted in response to observations by seabird colony monitors that black skimmers, in particular have an apparent high incidence of cracked and dented eggs, and post-hatch chick mortality. Egg cracking and denting and chick mortality during and after hatching may be contaminant-related. Concerns were raised, that all of the seabird species nesting at the Salt Works may be experiencing some level of reproductive impairment related to contaminant exposure. This study entailed the collection and analysis of failed eggs of black skimmer, Caspian terns, elegant terns and federally endangered California least terns, and of forage fish that are potentially consumed by seabirds while nesting at the Salt Works. Fifteen skimmer eggs, five Caspian tern eggs, five elegant tern and ten least tern eggs, and 20 composite forage fish samples were collected at the Salt Works during the 2005 nesting season. All of the seabird eggs were evaluated for standard metrics and eggshell thickness. Five composite samples of least tern eggs (2 per sample) and individual eggs of black skimmer (N=15), Caspian tern (N=5) and elegant tern eggs (N=5) were submitted to laboratories under contract with the Service's Analytical Control Facility (catalog # 1040073) for chemical analysis. Composite whole body samples of forage fish were submitted for chemical analyses as well. Samples of forage fish included 5 composites of California killifish, 3 composites of topsmelt, and 12 composites of longjaw mudsucker (gobiideae). Eggs and fish were analyzed for lipid content, metals, organochlorine pesticides, organotins, polychlorinated biphenyl (PCB) congeners, and polybrominated diphenyl ethers (PBDEs).

Results of eggshell analyses indicate that eggshell thicknesses for failed eggs of black skimmer, Caspian terns, elegant terns, and perhaps California least terns, collected in 2005, were lower than normal, as compared with thicknesses measured in eggs collected before 1945. Concentrations of organochlorines associated with eggshell thinning and other aspects of reproductive impairment appeared to be lower in Caspian tern and least tern eggs, collected in 2005 compared with concentrations observed in eggs collected in the 1980’s and 1990’s. However, fresh weight (fw) concentrations of total DDTs (>99% DDE) and PCBs in failed skimmer eggs were still as high as 6,259 ng/g (mean 1,819 ng/g) and 6,800 ng/g (mean 2,500 ng/g) respectively. Four of the black skimmer eggs had DDT concentrations greater than 3,000 ng/g. Concentrations of total DDT and PCBs measured in the failed skimmer eggs exceeded levels associated with adverse effects, such as reduced eggshell thickness (DDTs) and embryotoxicity (PCBs) in sensitive avian species.

PBDEs were detected in all of the seabird egg samples and in a fraction of the forage fish samples collected at the South Bay Salt works. The range of lipid-based concentrations of PBDEs observed in Caspian tern eggs from this study was from 5,360 to 17,559 ng/g-lipid, which overlapped with the range reported for eggs of Caspian terns from San Francisco Bay colonies. But, even higher concentrations (2,577 - 42,731 ng/g-lipid) were observed in failed black skimmer eggs collected from the South Bay Salt Works colony. Unfortunately, data on effect levels for PBDEs in seabird eggs are lacking. When concentrations exceed thresholds for effects, PBDEs and similar compounds like PCBs can alter blood thyroid hormone homeostasis and/or vitamin A stores. This effect can alter development, reproductive success, and other physiological processes in birds.

Concentrations of organochlorines, especially PCBs and DDT, and PBDEs measured in forage fish from around the South Bay Salt works were all one-to-two orders of magnitude lower than DDT, PCB and PBDE concentrations observed in seabird eggs. The occurrence of oranochlorines and PBDEs in forage fish samples was evidence that these contaminants are present in sediments around the Salt Works and that they are bioavailable and accumulating in fish that are part of the food web for nesting seabirds.

Although numerous elements were detected in seabird eggs and forage fish, none were present at in eggs at concentrations of concern. Mercury concentrations in eggs ranged from approximately 0.10 µg/g fresh weight to 0.60 µg/g fw, which are below levels associated with adverse effects for seabirds. Selenium concentrations in eggs ranged from approximately 0.40 µg/g fw to 0.94 µg/g fw, which is typical of background concentrations. Mercury and selenium were detected in forage fish, indicating that both are present in local sediment, and they are bioavailable and accumulating in the tissues of fish that are part of the food web for nesting seabirds. Wet weight concentrations of mercury and selenium measured in fish ($\leq$ 0.09 µg/g and $\leq$ 0.32 µg/g, respectively) were below dietary concentrations associated with adverse reproductive effects in birds.

Of all the contaminants studied, those posing the greatest risk of adverse effect in seabirds nesting at the South Bay Salt works appear to be DDT and its metabolites, PCBs and possibly PBDEs. This observation is based on the frequency and concentrations at which these substances were detected both in avian eggs and in fish that may be consumed by the seabirds. Black skimmers tended to have the highest concentrations, followed by Caspian terns, then elegant terns, and then California least terns. Failed eggs of black skimmer, Caspian terns, elegant terns showed signs (decreased thickness) of impacts associated with exposure to DDE. The DDT, combined with low levels of other organochlorine pesticides, and elevated levels of PCBs and PBDEs may all contribute to the cracking, denting and chick mortality observed.

It is recommended that additional investigations be conducted to: (1) characterize the occurrence and potential sources of organochlorine pesticides and PCBs in Otay River sediments, which are a source of contaminants in resident forage fish; (2) quantify evidence of reproductive impairment in black skimmers as representatives of the most contaminant-exposed and most impacted of the seabird species nesting at the South Bay Salt Works; and, (3) to help confirm occurrence or non-occurrence of potential contaminant related impacts (eggshell thinning) on the federally endangered California least tern.

Keywords

San Diego Bay National Wildlife Refuge, South Bay Salt Works, seabirds, forage fish, contaminants, metals, organochlorine pesticides, PCBs, PBDEs, Black skimmer, Caspian tern, elegant tern, California least tern

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List of Acronyms/Abbreviations

ACF: Analytical Control Facility
ATSDR: Agency for Toxic Substances and Disease Registry
CFWO: Carlsbad Fish and Wildlife Office
cm: centimeters
DDE: Dichlordiphenyldichloroethylene
DDT: Dichlordiphenyltrichloroethane
dw: dry weight
EC: Environmental Contaminants
ECDMS: Environmental Contaminants Data Management System
Fw: fresh weight
FY: Fiscal Year
g: gram
GERG: Geochemical and Environmental Research Group
na: not analyzed
nd: not detected
ng: nanogram
µg: microgram
NWR: National Wildlife refuge
PBDE: Polybrominated Diphenyl Ether
PCB: Polychlorinated Biphenyl
ppb: parts per billion (ng/g)
ppm: parts per million (µg/g)
QA/QC: Quality Assurance/Quality Control
USDOI: U.S. Department of the Interior
USEPA: U.S. Environmental Protection Agency
USFWS: U.S. Fish and Wildlife service
ww: wet weight

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I. INTRODUCTION

Portions of the South Bay (a.k.a. Western) Salt Works property and neighboring mudflats in South San Diego Bay constitute part of the South San Diego Bay Unit of the San Diego National Wildlife Refuge (NWR), CA. This refuge was established to protect, manage, and restore habitats for federally-listed endangered and threatened species and migratory birds, and to maintain and enhance the biological diversity of native plants and animals. Levees at the South Bay Salt Works are used for nesting by a variety of seabirds species including Caspian terns (*Sterna caspia*), elegant terns (*Sterna elegans*), black skimmers(*Rynchops niger*), gull-billed terns (*Sterna nilotica*), Forster's terns (*Sterna forsteri*), and California least terns (*Sterna antillarum browni*). The California least tern is a federally endangered species and the elegant tern is a Fish and Wildlife Service Species of Management Concern as well as a California Department of Fish and Game Species of Special Concern.

Monitoring surveys on birds nesting at the South Bay Salt Works have resulted in observations of potential contaminant-related impacts on the reproduction of some species. Seabird nesting colonies at the Salt Works were routinely monitored between 1993 and 1999, by staff of the Carlsbad Fish and Wildlife Office (CFWO). Over that time, CFWO staff reported finding numerous eggs of elegant terns, Caspian terns, and black skimmers in particular that were crushed or had cracks, dents, and dimpling (Stadtlander 1993; Terp and Pavelka 1999). In addition, staff from the Refuge frequently report of high mortality among day-old skimmer chicks, which occurred again in the 2008 (Brian Collins, personal communication). The apparent high incidence of egg cracking, crushing, and denting suggests that seabirds nesting at the South Bay Saltworks are producing eggs with thin shells, which can lead to reproductive impairment. Eggshell thinning and chick mortality during and immediately after hatching may be contaminant-related, and the risk for such effects, among other species, could potentially extend to those that nest in the same area and belong to the same feeding guild.

Studies conducted in the 1980’s and early 1990's produced limited evidence that concentrations of contaminants associated with embryotoxicity and eggshell thinning were present at levels of concern in eggs of Caspian terns, black skimmers and others that nest at South Bay Salt Works. Ohlendorf et al. (1985) found concentrations of DDE in Caspian tern eggs collected in 1981, that averaged 9,300 ng/g, or parts per billion wet weight (ppb ww) in randomly collected eggs and 10,000 ppb ww in failed to hatch eggs. The mean concentrations in both sets of eggs exceed levels associated with adverse reproductive effects in a variety of avian species (Blus 1996). More recently, the U.S. Fish and Wildlife Service analyzed eggs of California least terns, western snowy plovers, and other species that nest in South San Diego Bay for organochlorine compounds. Samples included failed-to-hatch eggs collected and archived during the 1993 and 1994 nesting season and others collected in 1991 (as part of a 1992 Endangered Species Contaminants Survey). Chemical analyses were funded through EC investigation 1130-1N20, the Level III pre-acquisition survey, and FY96 Emergency Analytical Funds. These analytical results confirmed the presence of detectable levels of DDE (range = 310 to 7,200 ppb ww) and PCBs (range = 250 to 14,000 ppb ww) in the sampled eggs (Roberts 1997). The maximum DDE and PCB concentrations are both within ranges associated with adverse effects in sensitive species (Blus 1996, Hoffman et al. 1996). In addition to the potential for legacy contaminants, certain metals and organochlorine compounds which potentially can have adverse reproductive effects in avian wildlife, there is also growing concern about the potential for exposure and adverse effects caused by more recently introduced substances. Among these are the polybrominated diphenyl ethers (PBDEs), which are used as flame retardants in common commercial products. The PBDEs are highly bioaccumulative and concentrations measured from fish to human adipose tissue have been increasing rapidly over time (ATSDR 2002). There are no known natural sources of PBDEs, so releases of these compounds are expected to be greatest in areas where they are extensively used, which includes areas with dense residential and industrial development. Land use in San Diego is such that releases of PBDEs into the local environment may potentially be significant. PBDEs are structurally similar to PCBs, and they have been shown to act additively in neurologic (behavior) and thyroid hormone function tests with small mammals (ATSDR 2002, McDonald 2004) and avian species (Fernie et al. 2005). Because of their increasing prevalence in the environment, the potential for significant releases into the local environment, and the potential to act additively with PCBs, PBDEs may be an important class of contaminants to consider for the avian species that forage in South San Diego Bay.

Short of direct application, transfer from the female parent is the primary source of contaminants in eggs. The source of contaminants in adults is usually through their diet, particularly for substances that, through bioaccumulation and trophic transfer, reach high levels in tissues of food chain organisms. Recognizing this, Roberts (1997) recommended that studies be conducted to characterize prey preferences and contaminant levels in prey species (specifically whole body samples) to help explain contaminant levels measured in avian eggs. Studies were later conducted on prey preferences by Caspian terns and black skimmers (Horn and Dahdul 1998, Horn and Dahdul 1999). However, data are still lacking on contaminant levels in fish species that terns and skimmers consume from South San Diego Bay (e.g., Pacific sardine, topsmelt, goby species and killifish).

This two year study, initiated in FY05, was funded by the FWS (1261-1N71) to support additional analysis of reproductive success, contaminant exposure and impacts on black skimmers, Caspian terns, and, possibly, California least terns that nest in colonies at the South Bay Salt Works. This study was conducted to better quantify the potential impacts, more fully characterize contaminant exposure by developing embryos, and to analyze results obtained from eggs through characterizing contaminant levels in fish species consumed by the parents.

II. METHODS

Nonviable and abandoned skimmer and tern eggs, and forage fish were collected at the South Bay Salt works between June and September 2005. This period encompassed the nesting season for these species. Fish samples were collected toward the end of the nesting season to minimize the impacts of disturbance, which included nest / chick abandonment and aggressive behavior by adult birds toward nestlings. Eggs were collected from colonies established on salt pond levees, and forage fish were collected from multiple locations in and around the Salt Works where nesting terns and skimmers are known to forage (Figure 1).

A. Eggs

All of the eggs collected were failed to hatch, which was evident by nest abandonment, crushing, or not having hatched after sufficient time for incubation. Skimmer, Caspian tern and elegant tern eggs were collected from a single location by CFWO EC staff (along a single levee). The nest areas were visited only when regularly scheduled bi-weekly surveys were being conducted for the San Diego NWR. A limited number of Caspian tern and elegant tern eggs were randomly selected from among nests that had been abandoned when the entire colony re-located to a different part of the levee. The skimmer colony extended onto parts of the levee unoccupied by the Caspian and elegant terns, and therefore it was possible to obtain more eggs over multiple visits, without disturbing the terns. The skimmer eggs were randomly selected from those that were abandoned (often pushed out of the nest), the shell was dented, or showed signs of an unsuccessful hatch. Dented eggs that were selected, exhibited crushing due to the weight of the parent. Eggs that appeared to be crushed by other factors such as predation were not selected. California least tern eggs were collected during ongoing monitoring of the colony for nest success. Eggs and nests were marked when first noticed, then checked on subsequent visits for evidence that they have been turned and / or have hatched. Eggs that were intact, but had not hatched after more than 28 days were considered nonviable and thus collected for this study. A total of 35 seabird eggs were collected over the 2005 nesting season. Of these eggs, 5 were Caspian tern, 5 were elegant tern, 10 were California least tern and 15 were black skimmer.

All eggs were placed in cartons and transported immediately to the CFWO lab for processing by EC staff using standard protocols adopted for studies on the impacts of PCBs in the Hudson River (Hudson River Natural Resources Trustees 2002).

At CFWO, eggs were gently cleaned with distilled water, weighed, and breadth and width were measured to the nearest 0.1 mm using a dial caliper. For those eggs that were not cracked, the volume was measured as the weight of water displaced by the egg. A scalpel, pre-rinsed with dilute nitric acid followed by distilled water, reagent grade acetone and reagent grade hexane was used to cut the shell around the equator. Contents were viewed for evidence of embryo development and malpositioning (if a chick was present) before transfer to a chemically pre-cleaned I-Chem jar. If an embryo was present, it was further evaluated for evidence of conspicuous malformations (e.g., missing limbs, malformed beaks). To minimize potential loss of sample and for cross-contamination that could result from physical manipulation, embryos were not evaluated for subtle malformations that required measurements. Eggs were in various stages of decomposition, which made the assessment of some of the embryos difficult, if not impossible. Once observations were recorded, egg contents were placed in a freezer for storage until they could be submitted for chemical analysis by a laboratory under contract with the Service's Analytical Control Facility (ACF). Eggs of the Caspian tern, elegant tern and skimmer were large enough for each egg to be an individual sample (1.e., 1 egg / sample). Although ten least tern eggs were collected, their small size required them to be composited into five samples of two eggs each (2 eggs / sample).

Eggshells were placed in cartons to dry at room temperature for a minimum of 30 days. Once dry, the thickness of each eggshell (shell + shell membrane) was measured at four points around the girth with a Starrett electronic digital micrometer, which was fitted with ball attachments, and was accurate to 0.01 mm. Some eggshells had hardened yolk residue that could not be removed even at the time the contents were harvested. This was generally confined to one side of the shell and was able to be avoided when taking measurements for shell thickness.

Figure 1. Sample locations for the 2005 South Bay Saltworks seabird study, San Diego Bay NWR, San Diego CA.

B. Forage fish

Forage fish in the size ranges consumed by terns and skimmers were collected from locations around the Salt Works where terns and skimmers were commonly seen feeding (Stadtlander and Konecny 1994; Zeeman, personal observations). These areas included the shallow waters of San Diego Bay adjacent to the Salt Works ponds, the Otay River, two low salinity salt ponds (10 and 11), and the Palomar ditch on the eastern edge of the Salt Works (Figure 1). Attempts were made to obtain fish from salt ponds nearest the nesting colonies, but were unsuccessful due to the apparent lack of fish in these higher salinity waters. Fish in the size range of 7.0 to 13.0 cm standard length were selectively collected as potential prey species for the skimmers and the larger tern species (Caspian and elegant) (Horn and Dahdul 1998 and 1999). Smaller fish around 5.0 cm standard length were collected, as potential prey for the least tern. The fish species that were collected were topsmelt (*Atherinops affinis*), California killifish (*Fundulus parvipinnis*) and longjaw mudsucker, a goby (*Gillichthys mirabilis*). The killifish and the mudsucker are of particular interest because they are a resident species and thus exhibit strong site fidelity, so that contaminant levels in these species will reflect that site. Both of these species occur in the diet of skimmers and terns, but may not be the primary prey selection (Horn and Dahdul 1998 and 1999). Topsmelt are planktivores that maybe resident in South San Diego Bay, and were of interest because they constitute a major portion of the tern and skimmer diets.

Topsmelt, killifish, and longjaw mudsucker were collected using baited minnow traps and seines. At each sample station, fish were sorted according to species and placed in plastic zipper lock bags and transported in coolers to CFWO for further processing. At the CFWO lab, fish were rinsed with distilled water, their standard length measured to the nearest 0.01 cm, and then they were sorted by general size category if necessary (i.e., large or small, when there were distinct differences). All fish were less than 11.0 cm standard length. All fish of a single species and from a single station were placed in chemically pre-cleaned I-Chem jars and stored frozen until they could be submitted for chemical analysis by a laboratory under contract with the Service's ACF. Each fish sample, was thus composed of a whole body composite of multiple individuals of one species from one sample location.

C. Chemical analyses

Overall, a total of 5 composite least tern egg samples (10 eggs @ 2 eggs / sample), 5 Caspian tern eggs, 5 elegant tern eggs, and 15 black skimmer eggs were processed for chemical analyses. Twenty composite whole body samples of fish were submitted for chemical analyses as well. Fish samples included 12 samples of longjaw mudsucker, 5 samples of California killifish, and 3 samples of topsmelt. Samples were submitted under ACF Catalog Number 1040073 to Geochemistry and Environmental Research Group (GERG), College Station, Texas to be analyzed for organic contaminants. Samples were split, and the splits submitted to Laboratory and Environmental Testing, Incorporated in Columbia, Missouri for metals analysis. Laboratories under contract with ACF use methods required in their Scope of Work, and meet quality assurance and quality control (QA/QC) standards.

Samples were analyzed for moisture, lipid, metals, organochlorine pesticides, organotins, PBDEs, and PCBs as homologs, congeners and aroclors. The target analytes and respective detection limits are listed in Table 1 through Table 4.

Table 1. Target inorganic analytes*.

Al (Aluminum)[1]	Mg (Magnesium)[6]
As (Arsenic)[2]	Mn (Manganese)[4]
B (Boron)[1]	Mo (Molybdenum)[1]
Ba (Barium)[2]	Ni (Nickel)[4]
Be (Beryllium)[3]	Pb (Lead)[2]
Cd (Cadmium)[3]	Se (Selenium)[2]
Cr (Chromium total)[4]	Sr (Strontium)[2]
Cu (Copper)[5]	V (Vanadium)[4]
Fe (Iron)[1]	Zn (Zinc)[4]
Hg (Mercury)[3]	

* Wet weight detection limit = (1) 0.40-2.0 ppm, ([2]) 0.04-0.20 ppm, (3) 0.02- .09 ppm, (4) 0.10-0.40 ppm, (5) 0.06-0.30 ppm, and (6) 0.60-3.0 ppm

Table 2. Target organochlorine and organotin analytes[1].

Aldrin	
Chlordanes (alpha- and gamma-)	Heptachlor
Chlorpyrifos	Heptachlor epoxide
Dichlordiphenyldichloroethanes (o,p'- and p,p' -DDD)	Mirex
Dichlordiphenyldichloroethylenes (o,p'- and p,p' -DDE)	Nonachlor - (cis- and trans-)
Dichlordiphenyltrichloroethanes (o,p'- and p,p' -DDT)	Oxychlordane
Dieldrin	PCBs (Aroclors 1242, 1248, 1254, 1260 , 1268)
Endosulfan II	Pentachloro-anisole
Endrin	Tetrachlorobenzenes (1,2,3,4- and 1,2,4,5-)
Hexachlorobenzene (HCB)	Toxaphene
Hexachlorocycloxanes (alpha-, beta-, delta-, and gamma-BHC)	
Organotins (mono-, di-, tri- and tetra-)	

1. Wet weight detection limits for toxaphene & total PCBs = 11 - 19 ppb for avian eggs and 0.9 - 10 ppb for fish whole bodies. The wet weight detection limit for organotins = 10 ppb (no range). The wet weight detection limit for all other analytes = 0.6 - 1.0 ppb for avian eggs, and 0.04 - 0.5 ppb for fish whole bodies.

Table 3. Target polybrominated diphenyl ethers (PBDE) as total PBDEs and congeners grouped by homolog class (Mono-, Di-, etc.).

Mono BDEs[1]	Tri BDEs[1]	Tetra BDEs[1]	Penta BDEs[2]	Hexa BDEs[3]
BDE# 1	BDE# 17	BDE# 47	BDE# 85	BDE# 138
BDE# 2	BDE# 25	BDE# 49	BDE# 99	BDE# 153
BDE# 3	BDE# 28	BDE# 66	BDE# 100	BDE# 154
Di BDEs[1]	BDE# 30	BDE# 71	BDE# 116	BDE# 155
BDE# 7	BDE# 32	BDE# 75	BDE# 118	BDE# 166
BDE# 8/11	BDE# 33	BDE# 77	BDE# 119	Hepta BDEs[4]
BDE# 10	BDE# 35		BDE# 126	BDE# 181
BDE# 12	BDE# 37			BDE# 183
BDE# 13				BDE# 190
BDE# 15				Total PBDE[5]

1. Wet weight detection limits (ppb) = 1.44 - 2.45 for avian eggs; 0.11 - 1.25 for fish whole bodies.
2. Wet weight detection limits (ppb) = 2.16 - 3.68 for avian eggs; 0.16 - 1.88 for fish whole bodies.
3. Wet weight detection limit (ppb) = 2.87 - 4.90 for avian eggs; 0.21 - 2.50 for fish whole bodies.
4. Wet weight detection limits (ppb) = 3.59 - 6.13 for avian eggs; 0.27 - 3.13 for fish whole bodies.
5. Wet weight detection limits (ppb) = 3.79 - 49.0 for avian eggs; 2.13 - 25.00 for fish whole bodies.

Table 4. Target polychlorinated biphenyl (PCB) congener and homolog analytes.

Congeners[1]

Mono-Cls	Tetra-CLs	Penta-Cls	Hexa-Cls	Hepta-Cls, cont.
# 1	# 40	# 82	# 128	# 176/137
Di-Cl	# 41/64	# 83	# 129	# 177
# 7/9	# 42/59/37	# 84	# 130	# 178
# 8/5	# 44	# 85	# 135	# 180
# 15	# 45	# 87/115	# 136	# 183
Tri-Cls	# 46	# 92	# 138/160	# 185
# 16/32	# 47/75	# 95/80	# 141/179	# 187
# 18/17	# 48	# 97	# 146	# 189
# 22/51	# 49	# 99	# 149/123	# 191
# 24/27	# 52	# 101/90	# 151	# 193
# 25	# 53	# 105	# 153/132	Octa-Cls
# 26	# 60/56	# 107	# 156	# 194
# 28	# 63	# 107	# 157/173/201	# 195/208
# 29	# 66	# 110	# 158	# 196
# 30	# 67	# 114	# 166	# 197
# 31	# 69	# 118	# 167	# 199
# 33/20	# 70	# 119	# 169	# 200
# 39	# 72	# 126	Hepta-Cls	# 205
	# 74/61		# 170/190	Nona-Cls
	# 77		# 171/202	# 206
	# 81		# 172	# 207
			# 174	Deca-Cl
			# 175	# 209

Homolog classes[2]

Cl1 Homologs	Cl6 Homologs
Cl2 Homologs	Cl7 Homologs
Cl3 Homologs	Cl8 Homologs
Cl4 Homologs	Cl9 Homologs
Cl5 Homologs	Cl10 Homologs

1. Wet weight detection limits (ppb) = 0.12 - 0.20 for avian eggs; 0.01 - 0.10 for fish whole bodies.
2. Wet weight detection limits (ppb) 11.5 - 19.6 for eggs; 0.85 - 10.0 for fish.

D. Data analysis

Shell thickness for each egg was reported as the mean of four individual measurements. The mean, standard deviation and 95% confidence interval was then computed for each species.

Results of chemical analyses were provided in both wet weight (ww) and dry weight (dw) values. Only wet weight concentrations were considered in this study to enable comparisons with results from other studies. The percent moisture for each sample is provided to enable conversion to wet weight concentrations, if desired using:

$$\text{Dry weight concentration} = \text{wet weight concentration} \times [1 - (0.01 \times \%\ \text{moisture})]^{-1}$$

Contaminant levels in eggs were evaluated as fresh weight concentrations. This was done to allow for adjustment for moisture loss that can occur due to the delay in time between when the egg was laid and when it was collected. Contaminant levels measured in bird eggs were adjusted accordingly using equations from the published literature (e.g., Stickel et al. 1973 and Hoyt 1979), and from direct measurements with intact eggs.

Concentrations of selected organic contaminants were also normalized for the fraction of lipid (% lipid / 100), to enable comparisons with results from studies that report results on a gram-lipid basis (e.g., She et al. 2008).

Results of analyses for inorganic contaminants are all reported as µg/g, or parts per million (ppm). Concentrations of organic analytes tended to be much lower than concentrations of inorganic analytes. Consequently, results of analyses for organic contaminants were all reported as ng/g or parts per billion (ppb). Lipid normalized results were reported as ng/g-lipid.

Polychlorinated biphenyls (PCBs) and PBDEs are chemical classes for which concentrations of many individual constituents were measured. The organochlorine pesticide DDT and its metabolites (DDE and DDD) also occur as a mixture. While it was desirable to know the measured concentrations of the individual compounds (e.g., congeners), it was also desirable to have an estimate of the concentrations of the mixtures as a whole. The concentration of total PCBs was estimated three ways; 1) as the sum of the detected aroclors (as reported by the laboratory); 2) as the sum of the homologs, using ½ the detection limit as a surrogate for non-detects; and, 3) the sum of the congeners using ½ the detection limit as a surrogate for non-detects. The total DDT concentration was also estimated using ½ the detection limit. Total PBDE concentrations were estimated as the sum of the concentrations of detected congeners only, because for some samples the sum of ½ the detection limits was greater than the sum of the detected concentrations.

Arithmetic means and standard deviations were used to characterize eggshell thickness and contaminant levels measured in eggs and forage fish.

III. RESULTS AND DISCUSSION

Basic features of forage fish and egg samples collected for this study are shown for reference in Appendix A, Tables A1 and A2. All of the forage fish were within the size range desired for evaluating potential dietary exposure by skimmers and terns to bioaccumulative contaminants. By design, all of the eggs that were collected were abandoned, therefore failed to hatch either due to the abandonment alone or due to other factors that may or may not be related to contaminant exposure. Because of the protocol used to collect least tern eggs, it could be determined that of the ten eggs that were laid but had not hatched within 28 days, 7 exhibited signs of fertilization (from a blastodisc to late-stage embryo).

A. Egg characteristics

The state of decomposition in the eggs made it difficult to ascertain details of condition for many of the eggs. However, all 5 of the elegant tern eggs appeared to be fertilized before they were abandoned. The Caspian tern eggs were addled, but embryos more than a few days old would have been distinguishable. Consequently, if fertilized, the elegant tern eggs were abandoned during a very early stage of development. Of the fifteen skimmer eggs evaluated, 12 were fertile with embryos at various stages of development. It was difficult to assess for gross deformities. However, the positions of the chicks in the eggs were normal. Two of the skimmer eggs had fully developed chicks that started to hatch but were unsuccessful. There were no obvious physical signs for why hatching failed.

Eggshell thickness for dented black skimmer eggs (N=9) was 0.201 mm, and the mean for all of the skimmer eggs that were collected was 0.204 mm (± 0.021 mm, SD). This is less than the mean (0.24 mm) reported by King et al. (1991) for skimmer eggs collected in 1984 from a contaminated site in Texas and the mean (0.25 mm) for skimmer eggs collected in Texas before widespread use of DDT.

The mean eggshell thickness for Caspian tern eggs was 0.310 mm (± 0.021 mm, SD). This is between the thickness reported by Ohlendorf et al. (1985) for randomly collected Caspian tern eggs from San Diego Bay in 1981 (0.334 mm ± 0.018), and thicknesses observed in the same study for abnormal shells (0.297 mm ± 0.050). According to Ohlendorf et al. (1985) eggshell thickness for normal Caspian tern eggs from San Diego Bay prior to 1945 is (0.346 mm ± 0.015). Based on thickness, it appears that at least a portion of the Caspian tern eggs collected in 2005 may be abnormal. None of the five eggs that were collected for this study showed visible signs of thinning, such as cracks, or dents. However, the eggs may have been abandoned before cracking and denting might have occurred.

The mean shell thickness for elegant tern eggs collected in 2005 (0.280 ± 0.016 mm SD) is lower than the means reported for elegant tern eggs collected in 1981 by Ohlendorf et al. (1985; 0.312 ± 0.028 for failed to hatch eggs and 0.315 ± 0.028 for randomly collected eggs). Like the Caspian terns, elegant tern eggs collected in 2005 may have abnormally thin shells, even though there were no visible signs.

The mean eggshell thickness for ten least tern eggs collected from San Diego in 2005 was 0.110 ± 0.013 mm. Data are lacking on eggshell thickness for California least tern. However, Blus and Prouty (1979) report on the thickness of least tern eggs collected in the early 1970's from South Carolina. In 1975, the mean thickness for South Carolina least terns eggs was 0.145 mm ± 0.005, and was not distinguishable from mean thickness for eggs measured before 1947 (mean 0.152 mm ± 0.002). The data from South Carolina suggest that the shells of failed to hatch eggs from San Diego are abnormally thin. Alternatively, the differences may reflect variation between subspecies, because as discussed later contaminant levels in the least tern eggs are low, compared with levels observed in eggs of other tern species.

Overall, the thickness of failed skimmer abandoned eggs of black skimmer, and Caspian, elegant and least terns appear to be thinner than those produced before widespread use of DDT, (and other organochlorine compounds). Thicknesses are comparable to what was observed with failed to hatch eggs in 1981, even though levels of legacy contaminants typically associated with thinning have declined.

B. Contaminant levels

Results of chemical analyses are summarized in Appendix tables A1-A8**.** Because of the volume, the raw results are not provided as part of this report. The raw data and QA/QC review are available in a 500 page report that can be obtained, upon request from CFWO. Once unlocked, raw data may also be accessed through the Service's Environmental Contaminants Data Base System (ECDMS) under catalog # 1040073.

1. Metals

Beryllium, molybdenum, nickel and vanadium were below the limits of detection in all egg samples and cadmium, boron, chromium, lead and barium were detected rarely. The remaining metals (As, Cu, Fe, Hg, Mg, Mn, Se, Sr and Zn) were detected in all egg samples with no clear differences between species.

Chromium was detected in least tern eggs collected from two southern California colonies, including one in San Diego in 1988 (Collins 1992; 0.43 ppm ww) and from San Diego Bay colonies in 1994 (Hothem & Powell 2000; 0.13 - 0.15 ppm ww assuming 25% moisture). Least tern eggs collected in 1988 also had detectable but low concentrations of cadmium, nickel and lead (0.02 ppm, 0.31 ppm and 0.11 ppm ww respectively, Collins, 1992). Cadmium and lead were not detected in eggs collected in 1994 (Hothem and Powell 2000), and none of these elements were detected in least tern eggs from this 2005 study. Metals such as chromium, cadmium, nickel, lead, and zinc do not have a strong tendency for accumulation in the aquatic food chain, so that the occurrence of these metals in egg samples from the 1980’s may reflect exposure by the parent to metals in the air. Accordingly, the apparent decline over time may reflect declines in emissions into the urban San Diego air from automobiles and burning.

Mercury and selenium were detected in all of the eggs at concentrations that do not appear to have changed over time. Mean mercury concentrations measured in skimmer and tern eggs collected in 2005 ranged from 0.19 ppm fw in black skimmer eggs to 0.51 ppm fw in Caspian tern eggs. Mean selenium concentrations ranged from 0.50 ppm fw in least terns and skimmers to 0.63 ppm fw in elegant tern eggs. Least tern eggs collected by Hothem and Powell (2000) from San Diego Bay colonies in 1994 had estimated wet weight concentrations (assuming 75%

moisture) of mercury (0.14 ppm - 0.25 ppm) and selenium (0.61 ppm - 1.2 ppm ww) that are comparable to the mean mercury (0.21- 0.27 ppm ww) and selenium (0.39 - 0.62 ppm ww) concentrations observed in least tern eggs from this 2005 study. The apparent lack of change over time for these two elements may reflect (1) that releases to the environment have not changed over time, and / or (2) primary releases may have declined, but secondary releases from sediment and subsequent accumulation in the aquatic food web continue. The primary route of exposure by avian species to mercury and selenium is via the food chain.

Although many elements were detected in all of the eggs analyzed, selenium and mercury are the two that are most often implicated in cases of impaired avian reproduction. Mercury is a neurotoxin that at high levels of exposure can cause altered behavior, ataxia, apatite loss, weight loss and death. At lower exposure levels it can cause reproductive impairments measured as reduced egg production, egg viability, egg hatchability, embryo survival and chick survival. Mercury concentrations between 0.50 ppm and 2.0 ppm ww in eggs are sufficient to produce the reproductive effects in non-marine birds. However, much higher concentrations are required to cause adverse effects in piscivorous seabirds (Thompson 1996). Mercury concentrations measured in black skimmer and tern eggs from the Salt Works approach ranges associated with adverse reproductive effects in sensitive avian species. As seabirds, skimmers, and terns are among the less sensitive species and were not expected to exhibit adverse effects from mercury at the observed concentrations.

Selenium is an essential nutrient at low concentrations and is toxic when present at excessive levels. Selenium toxicity in wild birds has been associated with mortality, impaired reproduction (egg hatchability), and teratogenesis, and histopathological lesions with alterations in hepatic glutathione (Hoffman 2002). The selenium concentrations observed in eggs from this study are less than 1.0 ppm ww, which puts them in the range of background for selenium in avian eggs, and below concentrations (i.e. approaching 5.0 ppm ww) associated with adverse effects in sensitive species (USDOI 1998).

Most of the metals were detected in one or more of the whole body fish samples. Beryllium and Molybdenum were the only below the limits of detection in all samples. Mercury and selenium were the only metals that were observed in fish tissue at concentrations less than those observed in bird eggs. Mean mercury concentrations in fish tissue ranged from 0.02 - 0.04 ppm ww as compared with mean mercury concentrations in eggs that ranged from 0.19 - 0.51 ppm ww. Similarly, mean selenium concentrations in fish tissue ranged from 0.22 - 0.27 ppm ww as compared with mean concentrations in bird eggs that ranged from 0.5 - 0.6 ppm ww. These data indicate that of all the metals considered, mercury and selenium are the only ones with evidence of the potential for uptake and transfer to avian eggs, with biomagnifications.

Concentrations of mercury and selenium measured in fish whole bodies are below dietary thresholds for toxic effects in avian species, which tend to be >0.1 ppm ww for mercury and >0.6 ppm ww for selenium (USDOI 1998).

2) Organotins

A fraction of samples was analyzed for organotins, which are considered a legacy pollutant common in ports, where they were used as an antifouling agent on boat and ship hulls. Organotins were detected in one skimmer egg from this study, which indicated that they are present in the system. The fact that organotins were detected in only one egg in this study and not in any of the fish samples, indicates that while present, concentrations of organotins are low enough that they only occasionally reach detectable concentrations in the tissues upper trophic level species such as seabirds.

3) Organochlorine pesticides and PCBs

Nearly every target organochlorine analyte was detected in one or more of the samples. Of the 29 analytes, 24 were detected in skimmer eggs, Caspian and elegant tern eggs, while 20 were present at detectable levels in least tern eggs. More analytes (28) were detected in fish, albeit at lower concentrations than those observed in avian eggs. Highest mean concentrations for all analytes were observed in either killifish (10 analytes) or longjaw mudsucker (16 analytes). Concentrations in topsmelt may be lower than in the other species because, either as a planktivore it is feeding at a lower trophic level and / or it is not as exposed as killifish and mudsucker to higher contaminant levels often associated with sediment.

Overall, concentrations of organochlorines in fish tissues are much lower than concentrations in avian eggs, which reflects the high potential that these contaminants have for bioaccumulation in the seabird food web. Diet to egg transfer factors will vary depending on the contaminant and the biology and the diet of the avian species. However, in general, and using PCBs and DDTs as an example, concentrations of the organochlorine compounds in skimmer and tern eggs tended to be more than ten times the concentrations of those same contaminants in forage fish.

Toxaphene was not detected in any of the samples analyzed for that compound. Aldrin, delta BHC, gamma BHC, endosulfan II, endrin, gamma chlordane, heptachlor, and mirex were detected infrequently. The majority of the rest were detected at low concentrations (e.g., maximum <5 ppb ww). In general, highest concentrations were detected in skimmer or Caspian tern eggs, followed by elegant tern and least tern. Concentrations of organochlorines in fish tissue were always lower than concentrations measured in avian eggs. Concentrations of five target analytes were between 11 and 33 ppb ww. These were 1,2,4,5 - tetrachlorobenzene (maximum concentration of 31.5 ppb in a Caspian tern egg), cis-nonachlor (maximum concentration of 15.9 ppb in a Caspian tern egg), trans-nonachlor (maximum concentration of 65.4 ppb in a skimmer egg), dieldrin (maximum concentration of 22.9 ppb in a skimmer egg), and oxychlordane (maximum concentration of 56 ppb in a skimmer egg). Data on effect levels in eggs were too limited to ascertain if the observed concentrations of these five organochlorines are biologically significant.

Concentrations of most target organochlorine analytes were orders of magnitude lower than concentrations of DDT and its metabolites (DDD and DDE) and PCBs, which are summarized (means and ranges) by species in Table 5. Concentrations of total DDTs (sum of DDE+DDD+DDT) in eggs were between 355 ppb and 6,805 ppb fw for skimmers, 1,420 - 2,119 ppb fw for Caspian terns, 516 - 603 ppb for elegant terns and 206 - 457 ppb for least terns. Total DDTs concentrations in fish samples were lower (approximately 10 ppb to 200 ppb ww). The metabolite DDE, and to a much lesser extent DDD, constituted more than 99% of the total DDTs in avian eggs and more than 80% of the total in fish whole bodies. The small contribution of parent compound, suggests that there may be residual DDT in the environment, but most has been converted to metabolites since the use of DDT itself was banned in the United States in 1970. An elevated ratio of DDT to DDE + DDD would be indicative of recent exposure to the parent compound.

When measured against aroclor standards, the mix of PCBs was most like Aroclor 1268. The concentration of the mixture, as aroclors was comparable to total PCB concentrations measured as congeners and homologs (Table 5). It is often preferable to measure PCBs as congeners because the detection limits for congeners is low enough to allow for the detection when concentrations are low. In this case, PCB concentrations were high enough to provide agreement between the different analytical approaches. Total PCB concentrations in avian eggs ranged from approximately 400 ppb fw (minimum in least tern eggs) to 6,800 ppb fw (maximum in skimmer eggs). Total PCB concentrations in fish samples ranged from approximately 20 ppb ww (minimum in killifish whole bodies) and 215 ppb (maximum in mudsucker whole bodies).

In addition to better detection limits, using congeners also allows for "fingerprinting" for identifying potential sources in the event of a spill or release, and for assessing potential for dioxin-like toxicity. Samples were analyzed for 96 individual congeners. Nearly all were detected in one or more samples. Congeners 81, 114, 126 and 169 were not detected in any samples. Of these, three (81, 126, 169) are congeners that exhibit dioxin-like toxicity. Another dioxin-like congener (77) was detected in only one fish sample. Although there are numerous PCB congeners with dioxin-like toxicity, congeners 77, 81, 126 and 169 are the most potent (Van den Berg et al. 1998). Consequently, the congeners of greatest concern for dioxin-like toxicity were below the limits of detection (up to 0.20 ng/g) in samples collected for this study. The Congeners 153/132, 180, 138/160 and 118 were consistently the primary contributors to total PCB concentrations in avian eggs. They were also major contributors in fish samples, but the distribution was spread more evenly across many congeners in fish. Congener 118 exhibits dioxin-like toxicity, but its potency for dioxin-like toxicity is low and its maximum effective concentration for dioxin-like toxicity (in skimmer eggs) would be below 0.002 ng/g.

Concentrations of DDTs and PCBs measured in least tern eggs collected in for this study reflect some decline over time. Hothem and Zador (1995) analyzed California least tern eggs collected in 1981-1987 from one colony in San Diego Bay. The DDE and PCB concentrations measured in least tern eggs from the 1980s were, respectively between 31 and 1,700 ppb ww and 710 - 3,100 ppb ww. Least tern eggs collected from San Diego Bay colonies in 1994 - 1996 by Hothem and Powell had somewhat lower concentrations of DDE (230 - 562 ppb ww) and PCBs (789 - 1,610 ppb ww). For least tern eggs collected in 2005 (this study) concentrations of total DDTs (which were >99% DDE) were between 206 ppb ww and 457 ppb ww, and concentrations of PCBs were between 387 ppb and 1,336 ppb ww. The ranges of total DDT and PCB concentrations observed in eggs from 2005 overlap with the lower end of ranges observed in eggs from the 1980's and are comparable to ranges observed in eggs collected in the mid-1990's.

Concentrations of DDTs and PCBs in Caspian tern elegant tern eggs appear to be declining as well. Ohlendorf et al. (1985) provide analytical results of multiple organochlorine pesticides from failed Caspian tern and elegant tern eggs collected in 1981 from a colony in San Diego Bay. Failed Caspian tern eggs collected in 1981 had DDE concentrations between 2,100 ppb fw and 56,000 ppb fw, PCB concentrations between 220 ppb fw and 8,400 ppb fw and levels of dieldrin and chlordane compounds ranging from below detection to 100s of ppb ww. Ranges of concentrations of organochlorine compounds measured in Caspian tern eggs collected in 2005 overlapped with the lower end of the ranges reported for eggs from 1981. Total DDT and PCB concentrations observed in abandoned Caspian tern eggs collected in 2005 were, respectively between 1,420 and 2,120 ppb, and between 880 - 2,590 ppb ww. Concentrations of dieldrin and chlordane compounds were less than 50 ppb ww.

Table 5. Summary wet weight concentrations (means and ranges) as ng/g (ppb) of total PCBs and total DDTs detected in avian egg and whole body fish samples collected in 2005 from South Bay Salt Works, San Diego Bay NWR, San Diego CA.

		Total PCBs	Total DDT
Black Skimmer	congeners	2,543 (666 - 6,786)	1,819 (355 - 6,259)
	homologs	2,559 (682 - 6,806)	
	aroclor	2,487 (667 - 6,805)	
Caspian tern	congeners	1,979 (872 - 2,584)	1,846 (1,420 - 2,119)
	homologs	1,987 (888 - 2,587)	
	aroclor	1,985 (877 - 2,590)	
Elegant tern	congeners	650 (576 - 723)	555 (516 - 603)
	homologs	668 (595 - 739)	
	aroclor	651 (578 - 725)	
California least tern	congeners	942 (385 - 1,326)	402 (206 - 457)
	homologs	980 (421 - 1,353)	
	aroclor	949 (387 - 1,336)	
killifish	congeners	56.9 (23.0 - 98.0)	23.1 (3.68 - 51.0)
	homologs	61.3 (24.6 - 107)	
	aroclor	57.3 (23.8 - 97.9)	
mudsucker	congeners	86.4 (21.1 - 244)	56.0 (3.27 - 227)
	homologs	75.1 (22.5 - 217)	
	aroclor	74.2 (21.3 - 216)	
topsmelt	congeners	57.9 (31.1 - 111)	19.6 (4.00 - 47.7)
	homologs	61.1 (33.7 - 113)	
	aroclor	59.8 (33.2 - 113)	

Failed elegant tern eggs collected in 1981 had detectable levels of fewer analytes, and lower concentrations than those observed in failed Caspian tern eggs (Ohlendorf et al. 1985). The ranges of DDE and PCB concentrations in elegant tern eggs from 1981 were respectively, 3,100 ppb ww - 5,500 ppb ww and 1,100 ppb - 2,200 ppb ww. Similarly, in 2005 fewer and lower concentrations of organochlorines were detected in eggs of elegant terns than were observed in eggs of Caspian terns. Concentrations of total DDTs (520 ppb - 600 ppb ww) and PCBs (580 ppb - 730 ppb ww) in elegant tern eggs collected in 2005 were much lower than the concentrations observed in elegant tern eggs from 1981.

Concentrations of organochlorines detected in black skimmers eggs were very similar to those measured in Caspian tern eggs (Table 5). However, black skimmer eggs had broader ranges, with higher maximum concentrations of PCB and DDTs than were observed with Caspian terns. The maximum total DDT concentration for Caspian tern eggs was 2,119 ppb fw. Five of the fifteen black skimmer eggs had higher total DDT concentrations, and of those, four had concentrations between 3,000 ppb and 6,258 ppb fw. Similarly, five black skimmer eggs had PCB concentrations that exceeded the maximum (2,590 ppb fw) observed in Caspian tern eggs. If black skimmers that nest at the South Bay Salt works are having similar exposures to organochlorine compounds as Caspian terns, it may be assumed that organochlorine levels measured in skimmer eggs are lower than may have occurred in the past. However, at least a portion of the black skimmers appear to have greater exposure to DDTs and PCBs than even the Caspian terns.

Concentrations of DDTs and PCBs in fish tissue also appear to be lower than in the past. Ohlendorf et al. (1985) measured concentrations of PCBs and DDE in fish dropped at Caspian tern nests during their San Diego Bay study in 1981. At that time, concentrations of DDE in various species of fish, including topsmelt ranged from 110 ppb ww to 3,000 ppb ww. Some samples also had 100 ppb of the DDT metabolite, DDD and 1,100 ppb ww of PCBs. Concentrations of total DDT, which includes DDD, measured in forage fish collected in 2005 averaged less than 56 ppb and were all were all below 230 ppb ww. In addition, mean concentrations of PCBs in forage fish were below 86 ppb ww and all were below 245 ppb ww.

Concentrations of DDT and PCBs in longjaw mudsucker collected from Pond 11 of the Salt Works appear to be lower than concentrations of DDT and PCBs in longjaw mudsucker collected from the Otay River. The mudsucker has high site fidelity. Members of this species spend their entire juvenile and adult life within the same marsh, and typically live within a 30 - 50 meter home range. They establish mud burrows in the banks of marsh channels, which puts them in constant and close contact with sediment. The mudsuckers captured in Pond 11, are presumed to be resident in that pond. Mudsuckers captured from the Otay River are presumed to be resident in the River. The mean concentrations of total DDTs and PCBs in mudsuckers from the Otay River were respectively, 84.7 ppb ww and 83.2 ppb ww. In comparison, mean concentrations of DDTs and PCBs in mudsuckers from Pond 11 were respectively 9.8 ppb ww and 60.8 ppb ww. The standard deviations are such that the differences may not be statistically significant. However, the differences between the means suggest that the Otay River has higher levels of contaminants in its sediments than does Pond 11. Such would not be surprising because pond 11 receives water from San Diego Bay, whereas the Otay River is the recipient of runoff from land with heavy agricultural and urban use, including formerly farmed lands in the immediate vicinity of the South Bay Salt Works.

Whether concentrations of DDTs and PCBs measured in avian eggs collected for this study are sufficient to cause reproductive impairment is uncertain. Examples of reproductive impairment by DDTs and PCBs, among other organochlorine compounds, include reduced egg production, defective eggshells, reduced hatchability, embryotoxicity, aberrant incubation behavior by adults, and mortality of chicks and adults (Blus 1996; Hoffman et al. 1996). In birds, a common, and possibly the most sensitive adverse reproductive effect associated exposure to DDT, and especially its metabolite DDE, is eggshell thinning. Concentrations of DDE in eggs greater than 3,700 ppb ww have been associated with total reproductive failure in pelicans, which are more sensitive than other species to the eggshell thinning effects of DDE (Blus 1984). Total DDT concentrations (99% DDE) in some of the failed skimmer eggs in this study were over 3,700 ppb. Such concentrations may not be sufficient for total reproductive failure in terns and skimmer, but they may be sufficient for some level of impairment. Ohlendorf et al. (1985) reported evidence of reproductive impairment in Caspian terns which had an overall mean DDE concentration of 9,300 ppb ww in their eggs (10,000 ppb ww in failed eggs). The authors observed an unusually high incidence of chicks that died during hatching, and the shells of failed eggs were significantly thinner than shells collected before DDT became widely used. More recently collected eggs have lower concentrations than those observed by Ohlendorf et al. (1985), but there remains evidence that the shells of failed eggs are unusually thin.

The total PCB concentrations measured in skimmer and tern eggs from the South Bay Salt Works are respectively below 6,000 ppb ww and 3,000 ppb ww. Embryo toxicity is a common sensitive adverse effect associated with in ovo exposure to PCBs. Total PCB concentrations greater than 5,000 ppb have been associated with reduced hatching in chickens, which are among the most sensitive of the avian species. However, total PCB concentrations between 6,000 ppb and 26,000 ppb have been associated with reduced hatchability in wild populations of Forster's tern (Hoffman et al. 1996). Although below 6,000 ppb the higher total PCB concentrations measured in failed skimmer eggs may be approaching levels at which hatchability is adversely affected.

Compared with the skimmers and Caspian terns, concentrations of DDTs and PCBs detected in least tern eggs appear to be below levels that would cause measurable reproductive impairment. However, preliminary data indicate that least tern eggshells are unusually thin, even though concentrations of DDT and other organochlorine compounds are relatively low. The least tern shells may be thin due to interactive effects of multiple contaminants, including yet-to-be identified compounds with eggshell thinning properties. Alternatively, eggshells of California least tern are believed to be thin compared with shell thickness for a different subspecies in South Carolina. Data on eggshell thickness of California least terns from California might show that the thicknesses of eggs collected at the Salt Works are typical for this species.

Mean concentrations of total DDTs measured in fish whole bodies were <56 ppb ww, which is below dietary levels of DDE alone (approximately 150 ppb) associated with adverse reproductive effects in sensitive avian species (USEPA 1995). Mean concentrations of PCBs in fish whole bodies were below 1,000 ppb ww (or approximately 4,000 ppb dry weight). These concentrations may approach dietary effect levels for gallinaceous birds (2,000 ppb dry weight), but are below levels associated with adverse effects in other species (>20,000 ppb; USEPA 1995).

4) Polybrominated diphenyl ethers (PBDEs)

At least one polybrominated diphenyl ether (PBDE) congener was detected in every sample analyzed (Table A7). However, of the 38 congeners targeted for analysis, only eight were detected (congeners #28, 47, 49, 66, 99, 100, 153, and 154). As was observed with organochlorine compounds, more congeners were detected in black skimmer and Caspian tern eggs than in elegant tern and least tern eggs (Table A8). Total PBDE concentrations were also highest in black skimmer eggs (223 ppb - 1653 ppb fw), followed by Caspian terns (332 ppb - 1184 ppb fw), elegant tern eggs (126 ppb - 271 ppb fw) and least tern eggs (79 ppb - 227 ppb fw). The same congeners were detected, with lower frequencies and at lower concentrations in fish whole bodies, which had total PBDE concentrations (sums of the detected congeners) ranging from approximately 2 ppb in killifish to a mean of 9.2 ppb (maximum 50 ppb ww) in longjaw mudsuckers. The five major congeners were BDE-47, -99, -100, -153 and -154, and BDE-47 was the dominant congener in all samples. The congener pattern observed in samples collected for this study was also observed in tern eggs from San Francisco Bay colonies, where it is considered comparable to the congener pattern of the penta-BDE commercial mixture (She et al. 2008) used in common household and commercial products.

Seabirds from colonies in San Francisco Bay were monitored during the 2000 - 2003 nesting seasons by She et al. (2008) for PBDEs and PCBs. Results of that study are reported as lipid normalized concentrations (ng/g lipid). To allow for comparisons, PBDE concentrations observed in this study were adjusted for lipid content of the samples. Means and ranges of concentrations from the two studies are summarized in Table 6. Note that the mean concentrations are only roughly comparable because She et al. (2008) applied a least squares method to log-transformed values, versus using a simple arithmetic mean for preliminary analyses in this study. Lipid-based concentrations of PBDEs measured in Caspian tern eggs from San Diego Bay were within the range reported for the same species in San Francisco Bay. Lipid-based concentrations of PBDEs measured in California least terns from San Diego Bay were lower than those observed in least terns from San Francisco Bay. PBDE concentrations measured in failed black skimmer eggs from this study were higher than concentrations observed in Caspian terns from either location.

Table 6. Comparison of total PBDE concentrations (ng / g-lipid) measured in seabird eggs from San Diego Bay (this study) and from San Francisco Bay (She et al. 2008).

Species	San Diego Bay[1]	San Francisco Bay[2]
Caspian tern	13,609 (5,360 -17,559)	5,160 (1,200 - 26,300)
California least tern	2,210 (1,272 - 3,607)	5,870 (4,210 - 7,820)
Elegant tern	3,196 (1,940 - 5,520)	
Black skimmer	17,360 (2,557 - 42,731)	

1. Eggs collected during the 2005 nesting season
2. Eggs collected during the most recent of nesting seasons studied (2003 for Caspian terns and 2002 for California least terns)

Polybrominated diphenyl ethers, and similar compounds like PCBs, alter blood thyroid hormone homeostasis and / or vitamin A stores, which in turn can alter development, immuno-competence, reproductive success and other physiological process. Studies by Fernie et al. (2005) indicate that the endocrine disruption can occur in kestrels exposed to environmentally meaningful concentrations of PBDEs (approximately 1,500 ppb in the egg, and the equivalent of 100 ppb wet weight in the post-hatch diet. Some of the failed black skimmer eggs collected at the South Bay Salt Works had concentrations approaching effect levels for kestrels. However, concentrations in fish (for post-hatch exposure) were lower (all less than 50 ppb). Whether PBDE concentrations that affect kestrels are the same as the concentrations that would affect seabirds is uncertain because data on seabird sensitivity to PBDEs are lacking.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

1. Failed and abandoned black skimmer, Caspian tern, and elegant tern eggs collected in 2005 from colonies at the South Bay Salt Works, San Diego Bay NWR had unusually thin eggshells. Failed and abandoned California least tern eggs collected from the South Bay Salt Work colony may be thin as well, but this needs to be confirmed with historic (pre-DDT use) data specific to California least terns.

2. Shell thickness of failed and abandoned skimmer and tern eggs collected in 2005 from the South Bay Salt Works were comparable to levels that were observed with failed to hatch eggs of the same species from San Diego bay colonies in 1981, even though levels of organochlorine pesticides in eggs appear to have declined.

3. Data on cadmium, chromium, lead, and nickel in least tern eggs indicate that exposure to these metals has declined over time. This may reflect declines in emissions of these metals into the air associated with regulations on automobile exhaust and burning.

4. Mercury and selenium were the only metals analyzed that exhibited evidence for accumulation in food web organisms and dietary uptake, with transfer to eggs by adult seabirds. Mercury and selenium levels measured in fish samples from 2005 are below dietary thresholds for adverse effects in avian species. Selenium concentrations transferred to seabird eggs are typical of background and mercury concentrations measured in seabird eggs are below levels associated with adverse effects in marine birds.

5. Although not the only organochlorines detected in samples, DDT and its metabolites, and PCBs are the organochlorine compounds of greatest concern due to their frequency of detection and the concentrations at which they occurred. Concentrations of total DDT and PCBs in Salt Works seabird eggs have declined since the 1980's. However, concentrations of total DDT in some of the failed black skimmer eggs approach, and perhaps exceed thresholds for significant eggshell thinning and reproductive failure. Concentrations of PCBs in failed black skimmer eggs approach levels associated with reduced hatchability.

6. Like the seabird eggs, DDTs and PCBs were the most often detected organochlorine compounds in forage fish. The occurrence of DDT and PCBs in forage fish is evidence that these compounds are present in the system (sediment), and that they are available and accumulating in the food web of seabirds that rely on forage fish for food.

7. Concentrations of DDTs and PCBs measured in forage fish from the Otay River appear to be higher than concentrations of DDTs and PCBs measured in forage fish from Salt Works Pond 11, suggesting that the Otay River may have higher concentrations of these contaminants in its sediments.

8. Polybrominate diphenyl ethers (PBDEs) were present at detectable levels in both forage fish bodies and seabird eggs, indicating that they are present in the system and available

for uptake and accumulation in the food web of seabirds that nest at the South Bay Salt Works.

9. Lipid-based concentrations of PBDEs in eggs of Caspian terns from San Diego Bay are comparable to those observed in Caspian terns from San Francisco Bay colonies. Lipid-based concentrations in failed eggs of black skimmers from San Diego Bay are higher. Concentrations of PBDEs in some of the failed black skimmer eggs approach levels associated with adverse effects in kestrels.

10. In general, all four seabird species studied in 2005 showed signs of eggshell thinning. However, failed eggs of black skimmers had detectable levels of more contaminants and higher concentrations than did elegant terns or California least terns. Concentrations of DDTs, PCBs and PBDEs in black skimmer eggs approach levels associated with adverse effects in other species, and may help explain the occurrence of eggshell thinning, and yet-to-be quantified high incidence of denting and post-hatch mortality of chicks.

B. Recommendations

1. To support habitat management decisions that involve the Otay River and adjoining upland habitat, it is recommended that additional investigations be conducted to characterize the occurrence and potential sources of organochlorine pesticides and PCBs in Otay River sediments.

2. Additional investigations are recommended to quantify evidence of reproductive impairment in black skimmers as representatives of the most contaminant-exposed and most impacted of the seabird species nesting at the South Bay Salt Works.

3. It is recommended that additional data be collected on eggshell thickness in California lest tern, to help confirm occurrence or non-occurrence of potential contaminant related impacts on this species.

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APPENDIX A. Data summaries.

Table A1. Parameters for forage fish collected in 2005 from waterways on and around the South Bay Salt Works, San Diego Bay NWR, San Diego CA.

Table A2. Condition and parameters for black skimmer (BKS), Caspian tern (CT), elegant tern (ET) and California least tern eggs (SWCLT) collected in 2005 from the South Bay Salt Works, San Diego bay NWR, San Diego CA.

Table A3. Data summary on concentrations (ppm fresh weight) of inorganic analytes detected in biota samples collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA.

Table A4. Data summary on concentrations (ppb fresh weight) of organochlorine pesticides and organotins detected in biota samples collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA.

Table A5. Data summary on concentrations (ppb fresh weight) of PCB homologs detected in biota samples collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA.

Table A6. Data summary on concentrations (ppb fresh weight) of PCB congeners detected in seabird eggs collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA.

Table A7. Data summary on concentrations (ppb fresh weight) of PCB congeners detected in forage fish whole bodies collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA.

Table A8. Data summary on concentrations (ppb fresh weight) of PBDE congeners detected in biota collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA

Table A1. Parameters for forage fish collected in 2005 from waterways on and around the South Bay Salt Works, San Diego Bay NWR, San Diego CA.

Catalog Sample Number	Common Name	Location	Mean standard length	% moisture	% lipid (wet weight)
FF-SW2	California killifish	San Diego Bay[1]	5 cm	73	3
KF11W	California killifish	Pond 11	7 cm	76	1.1
KFOR1	California killifish	Otay R., mouth	7 cm	75	0.9
KFOR11	California killifish	Otay R., upriver[2]	6 cm	75	1.4
KFOR4	California killifish	Otay R., mid-river[3]	5 cm	73	1.5
LM11N-L	longjaw mudsucker	Pond 11	11 cm	73	2.1
LM11N-S	longjaw mudsucker	Pond 11	9 cm	73	2.6
LM11W-L	longjaw mudsucker	Pond 11	11 cm	73	2.5
LM11W-S	longjaw mudsucker	Pond 11	8 cm	73	2.5
LMOR10-L	longjaw mudsucker	Otay R., upriver[2]	11 cm	78	1.3
LMOR10-S	longjaw mudsucker	Otay R., upriver[2]	8 cm	77	2.6
LMOR11-L	longjaw mudsucker	Otay R., upriver[2]	11 cm	74	2.6
LMOR11-S	longjaw mudsucker	Otay R., upriver[2]	9 cm	78	1.9
LMOR2	longjaw mudsucker	Otay R., mouth	9 cm	77	1.6
LMOR3	longjaw mudsucker	Otay R., mouth	8 cm	76	1.7
LMOR5	longjaw mudsucker	Otay R., mid-river[3]	8 cm	77	1.8
LMPAL	longjaw mudsucker	Palomar ditch	9 cm	77	2.2
TS11N	topsmelt	Pond 10	7 cm	70	2.5
TSOR1	topsmelt	San Diego Bay[1]	8 cm	73	1.2
FF-SW1	topsmelt	Pond 11	3 cm	80	1.1

1. San Diego Bay, off northwest corner of Pond 12
2. Otay River, near Pond 22
3. Otay River, between Ponds 10/11 and Ponds 12/23. Also near salt works water intake (Pond 10).

Table A2. Condition and parameters for black skimmer (BKS), Caspian tern (CT), elegant tern (ET) and California least tern eggs (SWCLT) collected in 2005 from the South Bay Salt Works, San Diego bay NWR, San Diego CA.

Catalog Sample Number[1]	Egg condition[2]	% moisture	% lipid (wet weight)	egg shell thickness (mm)
BKS-2	intact w/ early embryo	78	4.3	0.181
BKS-3	dented w/ early embryo	66	7.5	0.201
BKS-4	intact w/ blastodisc	76	5.6	0.204
BKS-5	dented, desiccated, mid-stage embryo	49	11.8	0.192
BKS-7	dented w/ early embryo	63	7.3	0.200
BKS-8	dented w / late stage embryo	72	4.9	0.217
BKS-9	intact, not fertilized	77	5.5	0.242
BKS-10	dented w/ mid stage embryo	72	7.3	0.201
BKS-11	dented w/late stage embryo	66	8.5	0.207
BKS-15	intact, addled	70	8.4	0.249
BKS-16	pipped but failed to hatch	79	3.9	0.215
BKS-17	pipped but failed to hatch	79	3.6	0.200
BKS-19	intact w / late-stage embryo	79	3.7	0.176
BKS-20	intact, not fertilized	74	6.8	0.193
BKS-21	dented, desiccated w / early embryo	7.3	26.3	0.178
CT-1	intact, addled	76	6.3	0.315
CT-2	intact, addled	76	7.4	0.338
CT-3	intact, addled	76	6.5	0.290
CT-4	intact, addled	76	5.9	0.327
CT-5	intact, addled	71	7.2	0.292
ET-1	intact, addled	76	6.5	0.302
ET-2	intact w / early embryo	74	8	0.267
ET-3	intact w / early embryo	75	6.8	0.274
ET-6	intact, not fertilized	77	4.9	0.287
ET-7	intact w / blastodisc	74	6.5	0.266
SWCLT- 12[3]	intact, addled	72	6.5	0.13
SWCLT- 36[3]	intact w/ early embryo	70	10.6	0.103
SWCLT- 4[3]	intact, desiccated w / late embryo	74	3	0.109
SWCLT- 57[3]	intact, not fertilized	75	5.9	0.112
SWCLT- 89[3]	intact, not fertilized	69	10.4	0.117

1. BKS = black skimmer, CT = Caspian tern, ET = elegant tern, SWCLT = California least tern.
2. Dented eggs were crushed on one side, but still had an intact shell membrane.
3. Least tern samples are composites of two eggs, matched according to condition.

Table A3. Data summary on concentrations (ppm fresh weight) of inorganic analytes detected in biota samples collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA.

	Black skimmer eggs				**Caspian tern eggs**			
Analyte	Mean	range	SD	detects (out of 15)	mean	range	SD	detects (out of 5)
Al	3.74	nd - 35.7	9.25	4	-	1.05	-	1
As	0.11	0.06 - 0.21	0.05	15	0.11	0.08 - 0.17	0.03	5
B	-	1.04	-	1	-	nd	-	0
Ba	0.06	nd - 0.28	0.07	7	-	nd	-	0
Be	-	nd	-	0	-	nd	-	0
Cd	-	nd	-	0	-	nd	-	0
Cr	0.06	nd - 0.09	0.02	2	-	nd	-	0
Cu	1.18	0.75 - 2.02	0.38	15	0.86	0.78 - 1.03	0.10	5
Fe	34.0	18.2 - 84.6	15.9	15	30.1	15.5 - 36.8	8.81	5
Hg	0.19	0.10 - 0.36	0.08	15	0.51	0.40 - 0.57	0.07	5
Mg	188	95.8 - 656	136	15	119	96.8 - 138	18.4	5
Mn	0.32	0.18 - 0.75	0.15	15	0.32	0.17 - 0.38	0.09	5
Mo	-	nd	-	0	-	nd	-	0
Ni	-	nd	-	0	-	nd	-	0
Pb	0.03	nd - 0.06	0.02	2	-	nd	-	0
Se	0.50	0.36 - 0.94	0.17	15	0.58	0.44 - 0.67	0.09	5
Sr	2.13	0.83 - 3.69	1.04	15	0.62	0.32 - 1.55	0.53	5
V	-	nd	-	0	-	nd	-	0
Zn	14.5	10.2 - 23.2	3.58	15	14.0	12.2 - 16.4	1.77	5

	Elegant tern eggs				**California least tern eggs**			
Analyte	mean	range	SD	detects (out of 5)	mean	range	SD	detects (out of 5)
Al	-	nd	-	0	-	nd	-	0
As	0.14	0.14-0.16	0.03	5	0.13	0.07 - 0.19	0.05	5
B	-	nd	-	0	-	nd	-	0
Ba	-	nd	-	0	-	nd	-	0
Be	-	nd	-	0	-	nd	-	0
Cd	-	nd	-	0	-	0.03	-	1
Cr	-	nd	-	0	-	nd	-	0
Cu	0.88	0.75 - 1.00	0.10	5	1.35	0.88 - 1.84	0.39	5
Fe	32.7	30.7 - 34.7	1.77	5	38.5	25.5 - 47.2	8.11	5
Hg	0.39	0.34 -0.45	0.05	5	0.24	0.21 - 0.27	0.03	5
Mg	132	125 - 140	6.3	5	142	108 - 164	21.4	5
Mn	0.30	0.20 - 0.37	0.06	5	0.77	0.50 - 1.06	0.23	5
Mo	-	nd	-	0	-	nd	-	0
Ni	-	nd	-	0	-	nd	-	0
Pb	-	nd	-	0	0.04	nd - 0.08	0.03	1
Se	0.63	0.56 - 0.68	0.05	5	0.50	0.39 - 0.62	0.09	5
Sr	0.44	0.56 - 0.60	0.09	5	2.54	0.99 – 6.26	2.25	5
V	-	nd	-	0	-	nd	-	0
Zn	14.6	12.2 - 16.3	1.57	5	19.7	15.8 - 23.6	3.59	5

Table A3, cont. Data summary on concentrations (ppm fresh weight) of inorganic analytes detected in biota samples collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA.

	California killifish whole bodies				**Longjaw mudsucker whole bodies**			
Analyte	mean	range	SD	detects (out of 5)	mean	range	SD	detects (out of 5)
Al	58.2	nd - 181	72.0	4	24.1	nd - 80.7	23.1	11
As	1.63	1.80 - 2.80	0.76	5	1.92	1.00 - 3.60	0.95	12
B	-	1.00		1	0.51	nd - 1.00	0.30	6
Ba	2.44	1.60 - 3.20	0.67	5	0.58	0.31 - 0.83	0.17	12
Be	-	nd	-	0	-	nd	-	0
Cd	0.05	0.05 - 0.07	0.01	5	0.05	0.03 - 0.07	0.02	12
Cr	0.10	nd - 0.20	0.06	3	0.09	nd - 0.20	0.07	4
Cu	1.59	0.94 - 2.90	0.76	5	0.72	0.46 - 0.92	0.15	12
Fe	66.8	15.0 - 165	59.1	5	37.5	16.0 - 81.5	19.4	12
Hg	0.02	nd - 0.05	0.02	2	0.04	nd - 0.09	0.02	9
Mg	595	549 - 651	41.1	5	488	433 - 586	42.3	12
Mn	10.2	7.10 - 18.5	4.74	5	14.9	6.00 - 32.6	8.07	12
Mo	-	nd	-	0	-	nd	-	0
Ni	0.13	nd - 0.20	0.07	4	0.09	nd - 0.20	0.04	8
Pb	0.07	nd - 0.17	0.06	3	0.13	nd - 0.40	0.10	11
Se	0.25	0.21 - 0.31	0.04	5	0.22	0.16 - 0.26	0.02	12
Sr	113	81 - 137	21.5	5	51.8	38.8 - 77.8	10.3	12
V	0.17	nd - 0.37	0.13	3	0.23	nd - 0.56	0.18	8
Zn	28.2	24.3 - 30.4	2.48	5	23.1	21.0 - 27.0	2.18	12

	Topsmelt whole bodies			
Analyte	mean	range	SD	detects (out of 3)
Al	42.3	31.0 - 54.0	54.0	3
As	0.83	0.67 - 0.92	0.92	3
B	0.62	nd - 1.00	1.00	2
Ba	0.99	0.44 - 1.90	1.90	3
Be	-	nd	-	0
Cd	0.05	0.04 - 0.06	0.06	3
Cr	0.15	nd - 0.20	0.20	2
Cu	1.37	0.82 - 1.90	1.90	3
Fe	50.4	39.0 - 60.4	60.4	3
Hg	0.04	0.02 - 0.06	0.06	3
Mg	694	670 - 726	726	3
Mn	3.97	2.30 - 6.20	6.20	3
Mo	-	nd	-	0
Ni	0.17	0.10 - 0.20	0.20	3
Pb	-	nd	-	0
Se	0.27	0.24 - 0.32	0.32	3
Sr	51.4	31.6 - 67.7	67.7	3
V	0.15	nd - 0.20	0.20	2
Zn	28.0	23.1 - 32.8	32.8	3

Table A4. Data summary on concentrations (ppb fresh weight) of organochlorine pesticides and organotins detected in biota samples collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA.

	Black skimmer eggs				Caspian tern eggs			
Analyte	mean	range	SD	detects (out of 15)	mean	range	SD	Detects (out of 5)
1,2,3,4-Tetrachlorobenzene	0.52	nd - 1.58	0.43	3	0.68	nd - 1.21	0.41	2
1,2,4,5-Tetrachlorobenzene	11.8	7.40 - 17.6	3.34	15	22.6	11.5 - 31.5	7.52	5
Aldrin	-	nd	-	0	-	nd	-	0
alpha BHC	0.75	nd - 1.41	0.33	13	0.93	0.51 - 1.19	0.25	5
alpha chlordane	1.36	nd - 3.43	1.11	10	2.73	0.73 - 5.12	1.75	5
beta BHC	3.16	1.37 - 6.61	1.46	15	6.09	4.77 - 9.15	1.78	5
chlorpyrifos	0.55	nd - 2.00	0.48	4	2.05	nd - 3.71	1.19	4
cis-nonachlor	4.52	1.64 - 14.3	3.35	15	9.51	4.45 - 15.9	4.30	5
DDD o,p'	12.2	3.40 - 33.9	8.65	15	11.7	9.79 - 14.4	2.29	5
DDD p,p'-	2.55	0.55 - 5.94	1.80	15	4.52	2.86 - 8.04	2.12	5
DDE o,p'-	0.61	nd - 2.08	0.47	9	0.65	nd - 1.01	0.33	3
DDE p,p'-	1799	347 - 6201	1688	15	1826	1402 - 2101	294	5
DDT o,p'-	4.84	nd - 16.5	5.18	10	2.75	nd - 7.02	2.72	3
DDT p,p'-	0.70	nd - 2.16	0.62	5	5.62	2.86 - 9.85	3.23	5
delta BHC	-	nd	-	0	-	nd	-	0
dieldrin	8.20	2.86 - 22.9	5.60	15	9.05	2.90 - 14.0	3.98	5
endosulfan II	0.41	nd - 1.27	0.28	2	2.78	2.05 - 3.26	0.445	5
endrin	-	1.05	-	1	4.59	2.08 - 6.85	2.14	5
gamma BHC	-	nd	-	0	-	nd	-	0
gamma chlordane	0.41	nd - 1.03	0.21	4	-	nd	-	0
HCB	2.50	1.17 - 4.95	1.00	15	3.72	2.22 - 5.28	1.09	5
Heptachlor	-	nd	-	0	-	3.03	-	1
heptachlor epoxide	1.46	nd - 3.18	0.97	12	2.56	1.71 - 3.65	0.739	5
mirex	1.33	nd - 3.03	0.93	10	2.28	0.79 - 4.54	1.39	5
oxychlordane	15.7	2.08 - 56.1	15.1	15	7.33	4.22 - 9.52	1.93	5
PCB-1268	2487	667 - 6805	1869	15	1985	877 - 2590	680	5
pentachloro-anisole	0.54	nd - 0.96	0.22	8	0.85	0.65 - 1.18	0.21	5
toxaphene	-	nd	-	0	na	na	na	
trans-nonachlor	19.4	4.69 - 65.4	16.5	15	33.5	8.03 - 47.1	14.9	5
PCB-TOTAL (1268)	2487	667 - 6805	1869	15	1985	877 - 2590	680	5
Sum DDT	1819	355 - 6259	1700		1846	1420 - 2119	297	
monobutyltin	-	32.2	-	1/5	na	na	na	
dibutyltin	-	31.4	-	1/5	na	na	na	
tributyltin	-	70.2	-	1/5	na	na	na	
tetrabutyltin	-	81.8	-	1/5	na	na	na	

na = not analyzed

Table A4, cont. Data summary on concentrations (ppb fresh weight) of organochlorine pesticides and organotins detected in one or more biota samples collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA.

Analyte	Elegant tern eggs				California least tern eggs			
	mean	range	SD	Detects (out of 5)	mean	range	SD	Detects (out of 5)
1,2,3,4-Tetrachlorobenzene	0.75	nd - 1.65	0.56	2	1.03	nd - 1.59	0.57	3
1,2,4,5-Tetrachlorobenzene	26.4	23.3 - 28.6	1.95	5	15.3	7.81 - 25.0	11	5
Aldrin	-	nd	-	0	-	nd	-	0
alpha BHC	1.19	1.11 - 1.26	0.07	5	0.93	nd - 0.88	0.40	4
alpha chlordane	2.44	2.00 - 3.22	0.52	5	2.92	1.34 - 3.73	1.63	5
beta BHC	2.39	1.75 - 3.12	0.61	5	2.65	1.04 - 3.04	1.32	5
chlorpyrifos	1.52	nd - 3.09	1.17	3	-	nd	-	0
cis-nonachlor	3.43	1.95 - 4.78	1.14	5	7.76	3.71 - 10.8	4.43	5
DDD o,p'	4.48	2.51 - 6.3	1.58	5	6.88	1.98 - 9.52	4.39	5
DDD p,p'-	1.22	nd - 1.85	0.59	4	-	2.08	-	1
DDE o,p'-	0.77	nd - 1.18	0.36	3	-	0.52	-	1
DDE p,p'-	548	510 - 597	35.7	5	391	203 - 443	205	5
DDT o,p'-	-	2.45	-	1	2.54	0.45 - 3.30	1.63	5
DDT p,p'-	1.91	nd - 3.41	1.35	4	-	nd	-	0
delta BHC	-	nd	-	0	-	nd	-	0
dieldrin	4.27	3.50 - 4.75	0.52	5	4.88	2.62 - 5.54	2.53	5
endosulfan II	-	1.11	-	1	-	nd	-	0
endrin	1.08	nd - 2.76	1.04	2	-	nd	-	0
gamma BHC	-	nd	-	0	-	nd	-	0
gamma chlordane	-	nd	-	0	0.69	0.33 - 1.36	0.47	2
HCB	2.43	2.06 - 2.81	0.29	5	3.88	1.85 - 3.84	1.87	5
Heptachlor	-	1.34	-	1	-	nd	-	0
heptachlor epoxide	0.73	nd - 1.25	0.37	3	-	0.52	-	1
mirex	-	1.08	-	1	-	nd	-	0
oxychlordane	1.58	1.31 - 1.75	0.17	5	3.35	1.63 - 3.38	1.41	5
PCB-1268	651	578 - 725	66.3	5	949	387 - 1336	591	5
pentachloro-anisole	0.55	nd - 0.79		2	0.64	0.33 - 1.07	0.43	2
toxaphene	na	na			-	nd	-	0
trans-nonachlor	10.9	9.07 - 12.7	0.21	5	17	8.04 - 19.0	9.29	5
PCB-TOTAL (1268)	651	578 - 725	66.3	5	949	387 - 1336	591	5
Sum DDT	555	516 - 603	36		402	206 - 457	210	5
monobutyltin	na	na	na		na	na	na	
dibutyltin	na	na	na		na	na	na	
tributyltin	na	na	na		na	na	na	
tetrabutyltin	na	na	na		na	na	na	

Table A4, cont. Data summary on concentrations (ppb fresh weight) of organochlorine pesticides and organotins detected in biota samples collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA.

Analyte	California killifish whole bodies				Longjaw mudsucker whole bodies			
	mean	range	SD	Detects (out of 5)	mean	range	SD	Detects (out of 12)
1,2,3,4-Tetrachlorobenzene	0.17	nd - 0.25	0.09	2	0.29	nd - 1.34	0.37	11
1,2,4,5-Tetrachlorobenzene	6.88	0.11 - 17.4	6.92	5	0.76	0.11 - 4.37	1.21	12
Aldrin	-	0.25	-	1	0.14	nd - 1.12	0.32	3
alpha BHC	0.26	0.02 - 0.74	0.31	3	0.19	nd - 1.29	0.35	10
alpha chlordane	0.26	0.07 - 0.43	0.14	3	0.20	nd - 0.45	0.13	9
beta BHC	0.67	0.13 - 1.4	0.53	5	0.15	nd - 0.42	0.14	2
chlorpyrifos	1.24	0.21 - 2.44	0.83	5	1.14	nd - 7.68	2.16	11
cis-nonachlor	0.80	nd - 1.48	0.43	4	0.90	nd - 1.36	0.51	11
DDD o,p'	0.64	nd - 1.29	0.57	4	1.33	0.16 - 1.98	0.50	12
DDD p,p'-	1.61	0.13 - 4.69	1.84	5	4.19	nd - 8.14	3.07	10
DDE o,p'-	0.23	nd - 0.43	0.13	3	0.13	nd - 0.33	0.11	8
DDE p,p'-	20.4	2.43 - 44.8	16.8	5	50.2	2.58 - 222	59	12
DDT o,p'-	-	0.25	-	1	0.07	nd - 0.42	0.11	5
DDT p,p'-	0.39	nd - 0.87	0.31	3	1.18	0.45 - 3.14	0.74	12
delta BHC	-	nd	-	0	0.08	nd - 0.21	0.05	8
dieldrin	0.35	nd - 0.64	0.22	3	0.76	nd - 1.41	0.40	11
endosulfan II	-	nd	-	0	-	nd	-	0
endrin	-	0.25	-	1	0.28	nd - 0.86	0.29	6
gamma BHC	0.36	nd - 1.02	0.38	4	0.07	nd - 0.30	0.08	7
gamma chlordane	0.40	nd - 1.07	0.38	4	0.25	nd - 0.46	0.12	10
HCB	0.14	nd - 0.25	0.09	2	0.28	0.10 - 0.97	0.24	12
Heptachlor	0.54	nd - 1.86	0.75	3	0.44	nd - 0.70	0.27	9
heptachlor epoxide	0.18	nd - 0.25	0.06	3	0.15	nd - 0.28	0.08	11
mirex	0.18	nd - 0.25	0.07	3	0.15	nd - 0.37	0.11	11
oxychlordane	0.50	nd - 0.77	0.22	4	0.84	nd - 2.18	0.55	11
PCB-Total (1268)	57.3	23.8 - 97.9	28.0	5	74.2	21.3 - 216	50	12
pentachloro-anisole	0.14	nd - 0.25	0.09	2	0.15	nd - 0.24	0.06	11
toxaphene	na	na	na		na	na	na	0
trans-nonachlor	0.85	0.02 - 1.41	0.57	5	1.54	0.02 - 2.79	0.76	12
PCB-TOTAL (aroclor)	57.3	23.8 - 97.9	28.0	5	74.2	21.3 - 216	50	12
Sum DDT	23	3.68 - 51.0	19	5	56.0	3.27 - 227	60	12
Total chlordanes								
Monobutyltin	nd	nd	nd	0[1]	nd	nd	nd	0[1]
dibutyltin	nd	nd	nd	0[1]	nd	nd	nd	0[1]
tributyltin	nd	nd	nd	0[1]	nd	nd	nd	0[1]
tetrabutyltin	nd	nd	nd	0[1]	nd	nd	nd	0[1]

1. Only three samples analyzed
2. na = not analyzed

Table A4, cont. Data summary on concentrations (ppb fresh weight) of organochlorine pesticides and organotins detected in one or more biota samples collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA.

	Topsmelt whole bodies			
Analyte	mean	range	SD	detects (out of 3)
1,2,3,4-Tetrachlorobenzene	0.20	nd - 0.35	0.14	2
1,2,4,5-Tetrachlorobenzene	1.15	0.17 - 1.89	0.89	3
Aldrin	-	0.249	-	1
alpha BHC	0.10	0.07 - 0.17	0.06	3
alpha chlordane	0.23	nd - 0.48	0.22	2
beta BHC	0.61	0.22 - 1.28	0.59	3
chlorpyrifos	0.36	0.33 - 0.40	0.04	3
cis-nonachlor	0.77	0.21 - 1.56	0.71	3
DDD o,p'	0.62	0.06 - 1.48	0.75	3
DDD p,p'-	1.15	0.40 - 2.08	0.85	3
DDE o,p'-	0.11	0.05 - 0.19	0.07	3
DDE p,p'-	17.5	2.64 - 43.9	22.9	3
DDT o,p'-	0.20	nd - 0.42	0.20	2
DDT p,p'-	0.65	0.58 - 0.73	0.08	3
delta BHC	-	0.085	-	1
dieldrin	0.37	nd - 0.65	0.29	2
endosulfan II	-	nd	-	0
endrin	0.27	0.11 - 0.43	0.16	3
gamma BHC	0.18	nd - 0.31	0.12	2
gamma chlordane	0.31	0.21 - 0.38	0.09	3
HCB	0.10	nd - 0.13	0.03	2
Heptachlor	-	0.242	-	1
heptachlor epoxide	0.13	nd - 0.16	0.05	2
mirex	-	0.32	-	1
oxychlordane	0.55	0.39 - 0.73	0.17	3
PCB-1268	59.8	33.2 - 113	46.1	3
pentachloro-anisole	0.11	nd - 0.15	0.04	2
toxaphene	na	na	na	
trans-nonachlor	0.648	0.26 - 1.27	0.544	3
PCB-TOTAL (aroclor)	59.8	33.2 - 113	46.1	3
Sum DDT	19.6	4.00 - 47.7	24.4	3
monobutyltin	nd	nd	nd	0[1]
dibutyltin	nd	nd	nd	0[1]
tributyltin	nd	nd	nd	0[1]
tetrabutyltin	nd	nd	nd	0[1]

1. Only two samples analyzed
na = not analyzed
nd = not detected

Table A5. Data summary on concentrations (ppb fresh weight) of PCB homologs detected in biota samples collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA.

Homolog	**Black skimmer eggs**				**Caspian tern eggs**			
	mean	max	SD	detects (out of 15)	mean	max	SD	detects (out of 5)
Cl2-PCB	-	nd	-	0	-	nd	-	0
Cl3-PCB	-	nd	-	0	14.0	19.5	4.51	4
Cl4-PCB	82.9	211	55.4	15	123	165	36.3	5
Cl5-PCB	453	1283	357	15	375	473	116	5
Cl6-PCB	1208	3371	944	15	737	986	266	5
Cl7-PCB	683	1643	449	15	616	817	224	5
Cl8-PCB	95.5	236	66.9	15	91.3	123	34.5	5
Cl9-PCB	11.5	28.0	8.22	6	9.89	14.0	3.95	2
Total homologs	2559	6806	1875		1987	2587	674	

	Elegant tern eggs				**California least tern eggs**			
	mean	max	SD	detects (out of 5)	mean	max	SD	detects (out of 5)
Cl2-PCB	-	nd	-	0	nd	nd	-	0
Cl3-PCB	-	nd	-	0	nd	nd	-	0
Cl4-PCB	44.7	50.8	3.79	5	87.3	115	32.0	5
Cl5-PCB	123	142	12.7	5	240	333	89.5	5
Cl6-PCB	225	252	26.7	5	382	601	165	5
Cl7-PCB	201	244	34.3	5	197	243	63.2	5
Cl8-PCB	35.5	42.1	4.10	5	29.6	38.9	12.1	4
Cl9-PCB	-	nd	-	0	-	nd	-	0
Total homologs	**668**	**739**	**67.6**	5	**980**	**1353**	**348**	5

	California killifish whole bodies				**Longjaw mudsucker whole bodies**			
	mean	max	SD	detects (out of 5)	mean	max	SD	detects (out of 12)
Cl2-PCB	2.27	5.00	2.01	1	2.44	6.26	1.65	10
Cl3-PCB	5.47	11.1	3.59	4	3.34	7.22	1.57	12
Cl4-PCB	14.3	24.9	7.07	5	15.2	46.9	10.9	12
Cl5-PCB	12.0	18.9	6.13	5	17.2	46.6	11.1	12
Cl6-PCB	14.1	22.3	6.49	5	21.9	89.0	22.2	12
Cl7-PCB	4.42	7.51	2.03	3	11.3	50.5	12.7	12
Cl8-PCB	-	5.00	-	1	1.97	7.19	2.34	8
Cl9-PCB	-	nd	-	0	-	nd	-	0
Total homologs	61.3	107	31.3	5	75.1	217	50.1	12

	Topsmelt whole bodies			
	mean	max	SD	detects (out of 3)
Cl2-PCB	-	1.55	-	1
Cl3-PCB	2.46	3.31	0.881	2
Cl4-PCB	12.1	19.0	5.95	3
Cl5-PCB	15.5	29.8	12.6	3
Cl6-PCB	19.5	42.2	19.7	3
Cl7-PCB	6.30	13.9	6.65	2
Cl8-PCB	-	2.85	-	1
Cl9-PCB	-	nd	-	0
Sum homologs	61.1	113	45.0	3

Table A6. Data summary on concentrations (ppb fresh weight) of PCB congeners detected in seabird eggs collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA. - **Black Skimmer, part 1**

congener #	mean	range	SD	detects out of 15	congener#	mean	range	SD	detects out of 15
1	2.06	0.55 - 6.04	1.9	15	52	4.85	2.45- 13.4	2.77	15
7/9	-	0.63	0.15	1	53	0.21	nd - 1.40	0.40	2
8/5	1.82	nd -3.12	0.88	14	60/56	4.45	1.98 - 6.95	1.56	15
15	0.33	nd - 1.22	0.38	7	63	-	nd	-	0
16/32	-	nd	-	0	66	19.0	4.09 - 52.6	16.0	15
18/17	0.32	nd -0.85	0.32	7	67	6.04	1.33 - 10.8	2.90	15
22/51	-	nd	-	0	69	-	nd	-	0
24/27	-	0.36	-	1	70	1.50	0.50 - 3.46	0.82	15
25	0.70	nd - 2.23	0.75	10	72	0.48	nd - 6.29	1.61	14
26	-	nd	-	0	74/61	17.3	3.40 - 43.7	14.5	15
28	3.18	0.95 - 8.29	2.12	15	77	-	nd	-	0
29	-	nd	-	0	82	57.9	10.2 - 187	49.2	15
30	-	nd	-	0	83	-	nd	-	0
31	0.16	nd - 0.39	0.11	9	84	9.60	2.42 - 33.7	8.61	15
33/20	0.40	nd - 1.22	0.41	8	85	2.50	0.46 - 6.73	1.75	15
39	-	0.63	-	1	87/115	2.71	0.54 - 8.37	2.36	15
40	0.39	nd - 1.25	0.39	10	92	5.88	nd - 15.4	4.86	13
41/64	0.90	nd - 6.78	2.03	3	95/80	2.58	1.07 - 4.62	1.18	15
42/59/37	-	1.56	-	1	97	3.59	1.76 - 13.0	2.76	15
44	5.30	3.56 - 8.40	1.42	15	99	117	25.2 - 333	102	15
45	0.15	nd - 1.37	0.34	14	101/90	20.4	4.54 - 89.1	20.6	15
46	0.22	nd - 1.81	0.47	13	105	29.5	7.89 – 72.3	22.9	15
47/75	16.1	2.98 - 44.5	13.5	15	107	19.4	5.11 - 51.4	15.0	15
48	0.09	nd - 0.50	0.11	14	110	18.7	7.57 - 63.1	14.5	15
49	0.81	0.15 - 2.77	0.61	15	118	156	35.6 - 411	127	15

Table A6, cont. Data summary on concentrations (ppb fresh weight) of PCB congeners detected in seabird eggs collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA. - **Black Skimmer, part 2**

congener #	mean	range	SD	detects out of 15	congener#	mean	range	SD	detects out of 15
119	7.32	1.08 - 22.7	6.57	15	176/137	14.8	3.27 - 39.9	11.5	15
128	45.2	12.4 - 110	33.1	15	177	5.39	1.61 - 15.6	3.75	15
129	1.00	0.40 - 2.97	0.64	15	178	4.33	1.52 - 10.8	2.51	15
130	11.1	nd - 41.0	12.1	11	180	425	129 - 976	272	15
135	1.80	nd - 4.84	1.51	13	183	39.5	10.8 - 106	28.1	15
136	13.9	3.75 - 42.6	10.7	15	185	0.63	nd - 2.42	0.56	14
138/160	314	61.5 - 868	252	15	187	78.7	24.5 - 195	53.6	15
141/179	5.35	2.29 - 15.6	3.43	15	189	2.21	0.45 - 6.44	1.92	15
146	95.0	22.5 - 243	70.0	15	191	3.55	0.56 - 9.36	2.67	15
149/123	19.6	6.18 - 59.7	13.8	15	193	14.6	3.66 - 38.8	10.6	15
151	4.03	1.69 - 14.1	3.05	15	194	28.1	6.32 - 71.2	20.4	15
153/132	608	90.5 - 1728	485	15	195/208	9.85	2.20 - 25.9	7.29	15
156	21.8	0.82 - 71.9	22.4	15	196	27.9	7.19 - 70.0	19.9	15
157/173/201	6.29	2.27 - 15.8	4.56	15	197	1.38	0.40 - 3.49	0.98	15
158	35.8	9.18 - 93.4	27.0	15	199	19.6	7.68 - 44.6	12.3	15
166	6.15	0.83 - 18.8	5.30	15	200	-	nd	-	0
167	25.3	7.08 - 60.1	17.8	15	205	2.49	0.56 - 5.49	1.73	15
170/190	57.5	14.5 - 152	42.7	15	206	9.43	2.27 - 23.1	7.09	15
171/202	18.0	6.67 - 42.3	10.8	15	207	1.71	0.14 - 4.90	1.62	15
172	12.6	3.21 - 31.5	8.79	15	209	4.63	nd - 13.6	3.90	14
174	3.86	1.45 - 11.0	2.56	15					
175	2.23	0.74 - 4.93	1.35	15	**Total**	**2543**	**6786**	**1876**	

Table A6, cont. Data summary on concentrations (ppb fresh weight) of PCB congeners detected in seabird eggs collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA. - **Caspian tern, part 1.**

congener #	mean	range	SD	detects out of 5	congener#	mean	range	SD	detects out of 5
1	4.67	1.96 - 7.00	1.91	5	52	9.78	5.47 - 15.9	3.79	5
7/9	-	nd	-	0	53	-	0.07	-	1
8/5	3.94	1.44-7.59	2.44	5	60/56	4.02	2.90 - 5.50	1.05	5
15	0.73	nd - 1.93	0.93	2	63	-	nd	-	0
16/32	-	nd	-	0	66	26.6	10.1 - 36.2	9.73	5
18/17	0.65	nd - 1.83	0.716	3	67	8.32	5.44 - 10.9	2.00	5
22/51	0.62	nd - 2.81	1.22	4	69	-	nd	-	0
24/27	-	nd	-	0	70	7.12	4.49 - 12.0	3.05	5
25	2.02	nd - 3.16	1.21	4	72	-	nd	-	0
26	1.04	0.58 -1.28	0.282	5	74/61	23.3	9.20 - 30.7	8.31	5
28	5.93	4.18 - 8.23	1.68	5	77	-	nd	-	0
29	-	nd	-	0	81	-	nd	-	0
30	-	nd	-	0	82	36.3	16.1 - 65.9	18.2	5
31	0.64	nd - 1.13	0.48	4	83	-	nd	-	0
33/20	1.53	nd - 4.14	1.76	4	84	17.1	8.19 - 22.7	5.43	5
39	2.56	nd - 5.19	2.36	3	85	2.14	1.03 - 3.16	0.83	5
40	2.74	0.42 - 6.17	2.20	5	87/115	5.36	4.74 - 6.27	0.65	5
41/64	3.37	1.24 - 9.82	3.63	5	92	10.6	4.95 - 17.6	4.59	5
42/59/37	-	nd	-	0	95/80	2.76	1.87 - 4.00	0.89	5
44	8.44	5.32 - 13.5	3.35	5	97	6.29	3.74 - 9.72	2.61	5
45	-	nd	-	0	99	77.6	32.6 - 101	27.0	5
46	-	nd	-	0	101/90	21.4	15.0 - 30.5	5.62	5
47/75	18.4	7.80 - 24.9	6.88	5	105	19.2	8.52 - 28.4	7.24	5
48	-	nd	-	0	107	19.7	12.7 - 28.1	6.56	5
49	2.34	1.42 - 3.57	1.00	5	110	24.6	17.2 - 32.9	7.22	5

Table A6, cont. Data summary on concentrations (ppb fresh weight) of PCB congeners detected in seabird eggs collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA. - **Caspian tern, part 2.**

congener #	mean	range	SD	detects out of 5	congener#	mean	range	SD	detects out of 5
114	-	nd	-	0	174	6.87	2.30 - 11.6	3.51	5
118	127	40.6 - 164	50.1	5	175	2.01	0.83 - 3.19	1.01	5
119	4.08	1.26 - 5.30	1.65	5	176/137	6.48	0.93 - 9.62	3.61	5
126	-	nd	-	0	177	11.2	5.39 - 14.2	3.45	5
128	33.3	12.6 - 43.3	12.2	5	178	7.81	4.03 - 9.67	2.27	5
129	3.6	1.12 - 5.63	1.79	5	180	377	170 - 515	141	5
130	6.24	3.34 - 9.98	2.41	5	183	34.8	12.5 - 44.0	13.1	5
135	4.98	1.18 - 7.25	2.35	5	185	1.18	0.56 - 1.94	0.528	5
136	11.2	4.43 - 20.5	5.85	5	187	78.5	36.4 - 99.7	25.2	5
138/160	174	74.2 - 223	59.9	5	189	2.03	0.40 - 3.07	1.07	5
141/179	8.74	5.47 - 12.1	2.41	5	191	3.22	1.43 - 4.36	1.12	5
146	54.3	24.9 - 75.3	19.0	5	193	10.9	4.54 - 13.7	3.75	5
149/123	23.8	18.1 - 32.7	5.35	5	194	26.2	9.37 - 36.8	10.3	5
151	11.8	8.94 - 16.1	3.03	5	195/208	10.7	3.79 - 13.9	4.06	5
153/132	337	116 - 472	143	5	196	26.8	8.94 - 36.5	10.7	5
156	16.9	5.07 - 29.0	8.58	5	197	1.03	0.42 - 1.50	0.39	5
157/173/201	5.28	1.96 - 7.61	2.14	5	199	18.7	8.34 - 25.2	7.57	5
158	26.0	12.5 - 33.8	8.22	5	200	-	0.42	-	1
166	6.04	1.81 - 9.02	2.70	5	205	2.49	1.74 - 2.90	0.45	5
167	19.0	6.54 - 26.4	7.62	5	206	11.4	3.23 - 15.9	4.85	5
169	-	nd	-	0	207	1.50	0.41 - 2.13	0.66	5
170/190	45.0	17.1 - 59.0	16.7	5	209	6.32	1.81 - 9.37	2.80	5
171/202	19.2	8.19 - 26.4	7.03	5					
172	10.1	3.54 - 14.6	4.23	5	**Total**	**1979**	**872 - 2584**	**680**	5

Table A6, cont. Data summary on concentrations (ppb fresh weight) of PCB congeners detected in seabird eggs collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA. - **Elegant tern, part 1.**

congener #	mean	range	SD	detects out of 5	congener#	mean	range	SD	detects out of 5
1	4.21	1.93 - 5.66	1.40	5	52	4.73	3.19 - 6.92	1.40	5
7/9	-	nd	-	0	53	-	nd	-	0
8/5	3.21	2.34 - 4.73	0.922	5	60/56	5.73	4.95 - 7.45	0.99	5
15	0.124	nd - 0.31	0.106	4	63	-	nd	-	0
16/32	-	nd	-	0	66	8.18	7.11 - 10.9	1.56	5
18/17	0.58	nd - 1.11	0.39	4	67	3.78	3.35 - 4.10	0.35	5
22/51	1.56	nd - 3.42	1.45	3	69	-	nd	-	0
24/27	-	nd	-	0	70	3.79	2.95 - 4.23	0.51	5
25	0.91	nd - 2.67	1.11	3	72	-	nd	-	0
26	0.49	nd - 0.77	0.30	4	74/61	3.19	2.43 - 3.97	0.61	5
28	2.09	1.65 - 2.75	0.42	5	77	-	nd	-	0
29	-	nd	-	0	81	-	nd	-	0
30	-	nd	-	0	82	15.0	6.67 - 29.8	10.1	5
31	-	nd	-	0	83	-	nd	-	0
33/20	-	0.97	-	1	84	7.20	6.45 - 8.42	0.76	5
39	1.65	nd - 5.23	2.32	2	85	1.51	0.73 - 1.93	0.472	5
40	-	nd	-	0	87/115	2.12	1.06 - 3.39	0.98	5
41/64	2.51	nd - 3.72	1.49	4	92	4.02	2.66 - 5.41	1.09	5
42/59/37	-	nd	-	0	95/80	2.21	1.43 - 3.99	1.02	5
44	5.56	4.48 - 6.08	0.69	5	97	2.18	1.31 - 3.88	1.03	5
45	-	nd	-	0	99	22.5	19.5 - 27.2	3.02	5
46		2.56	-	1	101/90	8.82	7.03 - 12.7	2.22	5
47/75	2.62	1.98 - 3.74	0.70	5	105	6.41	4.96 - 9.06	1.70	5
48	-	nd	-	0	107	4.82	3.21 - 6.08	1.24	5
49	0.94	0.88 - 1.02	0.05	5	110	10.8	7.62 - 16.7	3.85	5

Table A6, cont. Data summary on concentrations (ppb fresh weight) of PCB congeners detected in seabird eggs collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA. - **Elegant tern, part 2.**

congener #	mean	range	SD	detects out of 5	congener#	mean	range	SD	detects out of 5
114	-	nd	-	0	174	2.56	2.17 - 3.09	0.41	5
118	31.5	27.8 - 37.4	3.98	5	175	1.52	0.89 - 2.99	0.88	5
119	3.25	1.82 - 4.86	1.13	5	176/137	1.10	nd - 4.40	1.86	3
126	-	nd	-	0	177	3.71	3.15 - 4.70	0.64	5
128	12.4	11.1 - 14.3	1.33	5	178	3.46	2.82 - 4.46	0.61	5
129	0.74	nd - 1.64	0.57	4	180	108	81.5 - 126	20.4	5
130	7.54	6.50 - 8.51	0.88	5	183	15.2	13.7 - 19.4	2.37	5
135	2.01	0.31 - 3.30	1.08	5	185	0.84	0.56 - 1.18	0.25	5
136	8.43	2.88 - 11.1	3.62	5	187	29.4	25.8 - 37.9	5.07	5
138/160	55.3	47.6 - 64.9	7.19	5	189	0.24	nd - 0.76	0.30	2
141/179	4.28	3.13 - 5.07	0.77	5	191	0.78	0.45 - 1.56	0.46	5
146	17.0	12.8 - 20.8	3.55	5	193	4.48	3.42 - 5.10	0.70	5
149/123	10.3	8.49 - 12.1	1.37	5	194	10.6	8.90 - 12.9	1.56	5
151	3.68	1.80 - 5.59	1.47	5	195/208	3.67	3.27 - 4.25	0.39	5
153/132	81.0	68.6 - 93.7	12.3	5	196	10.0	8.70 - 12.1	1.32	5
156	3.71	2.24 - 6.49	1.68	5	197	0.401	nd - 0.72	0.25	4
157/173/201	2.22	1.68 - 2.82	0.42	5	199	7.17	3.17 - 8.78	2.32	5
158	8.99	6.31 - 11.5	1.89	5	200	-	nd	-	0
166	1.36	0.72 - 2.53	0.73	5	205	1.37	1.10 - 1.49	0.16	5
167	8.75	6.20 - 11.5	2.04	5	206	4.26	3.49 - 5.15	0.73	5
169	-	nd	-	0	207	0.46	0.30 - 0.64	0.14	5
170/190	18.7	14.2 - 25.8	4.47	5	209	2.34	1.95 - 2.96	0.43	5
171/202	6.69	5.40 - 8.82	1.43	5					
172	4.16	3.79 - 4.75	0.47	5	**Total**	**650**	**576 - 723**	**67**	**5**

Table A6, cont. Data summary on concentrations (ppb fresh weight) of PCB congeners detected in seabird eggs collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA. - **California least tern, part 1.**

congener #	mean	range	SD	detects out of 5	congener#	mean	range	SD	detects out of 5
1	2.34	0.84 - 5.42	1.87	5	52	10.2	3.69 - 17.1	5.30	5
7/9	0.64	nd - 2.75	1.18	2	53	-	nd	-	0
8/5	1.82	nd - 3.55	1.70	3	60/56	9.62	4.93 - 17.1	4.79	5
15	-	0.85	-	1	63	-	nd	-	0
16/32	-	nd	-	0	66	11.0	4.08 - 15.3	4.31	5
18/17	0.52	0.23 - 0.95	0.28	5	67	7.82	nd - 14.0	5.13	4
22/51	-	nd	-	0	69	-	nd	-	0
24/27	-	nd	-	0	70	5.38	2.93 - 7.53	1.84	5
25	-	nd	-	0	72	1.37	nd - 5.24	2.23	2
26	-	0.22	-	1	74/61	6.39	1.92 - 8.98	2.87	5
28	1.93	0.90 - 2.76	0.76	5	77	-	nd	-	0
29	-	nd	-	0	81	-	nd	-	0
30	-	nd	-	0	82	29.6	16.1 - 44.8	10.8	5
31	0.165	0.47	0.17	1	83	-	0.385	-	1
33/20	-	nd	-	0	84	9.49	4.34 - 12.5	3.48	5
39	-	nd	-	0	85	2.45	0.38 - 5.86	2.04	5
40	-	nd	-	0	87/115	1.30	0.64 - 1.73	0.53	5
41/64	2.01	nd - 5.13	2.63	2	92	6.46	3.79 - 14.1	4.31	5
42/59/37	0.33	nd - 0.81	0.330	2	95/80	9.60	4.54 - 14.8	4.48	5
44	7.38	5.88 - 8.26	0.96	5	97	6.56	2.53 - 11.7	3.93	5
45	-	6.26	-	1	99	59.0	16.2 - 88.3	26.4	5
46	-	nd	-	0	101/90	27.8	9.65 - 53.9	17.9	5
47/75	13.4	3.28 - 21.5	7.01	5	105	9.06	3.74 - 11.3	3.23	5
48	-	nd	-	0	107	7.14	1.49 - 12.3	4.25	5
49	2.24	1.01 - 3.61	0.95	5	110	24.7	9.33 - 43.1	13.2	5

Table A6, cont. Data summary on concentrations (ppb fresh weight) of PCB congeners detected in seabird eggs collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA. - **California least tern, part 2.**

congener #	mean	range	SD	detects out of 5	congener #	mean	range	SD	detects out of 5
114	-	nd	-	0	174	3.51	1.87 - 5.92	1.70	5
118	41.6	16.2 - 53.5	14.9	5	175	2.32	1.59 - 3.26	0.641	5
119	4.31	nd - 7.67	2.98	4	176/137	6.29	1.17 - 14.2	4.84	5
126	-	nd	-	0	177	7.76	2.38 - 13.5	4.07	5
128	16.9	7.57 - 24.2	6.08	5	178	6.48	2.66 - 9.49	2.49	5
129	1.31	0.56 - 1.99	0.51	5	180	81.4	41.3 - 119	29.4	5
130	6.31	5.34 - 8.00	1.13	5	183	13.6	7.41 - 16.1	3.65	5
135	6.44	2.22 - 11.0	3.45	5	185	0.68	0.50 - 0.84	0.13	5
136	4.17	0.50 - 5.99	2.20	5	187	43.8	16.6 - 65.6	17.8	5
138/160	85.8	35.2 - 134	35.4	5	189	1.67	nd - 3.50	1.23	4
141/179	6.26	2.73 - 9.64	2.92	5	191	0.682	0.33 - 1.36	0.40	5
146	30.2	11.5 - 46.0	12.3	5	193	4.69	2.58 - 5.91	1.33	5
149/123	32.4	11.3 - 56.1	16.8	5	194	6.85	2.24 - 9.26	2.75	5
151	7.69	2.20 - 14.6	4.97	5	195/208	2.32	0.67 - 3.44	1.01	5
153/132	161	58.4 - 258	71.1	5	196	7.53	2.52 - 10.1	3.07	5
156	4.13	0.70 - 8.03	2.87	5	197	0.537	nd - 0.99	0.33	4
157/173/201	2.74	1.25 - 3.37	0.85	5	199	9.09	3.73 - 12.0	3.22	5
158	9.64	4.23 - 13.4	3.68	5	200	0.180	nd - 0.29	0.08	3
166	1.85	0.49 - 5.87	2.27	5	205	0.739	0.21 - 1.32	0.41	5
167	8.34	2.65 - 10.7	3.25	5	206	2.99	0.77 - 4.35	1.45	5
169	-	nd	-	0	207	0.352	nd - 0.67	0.218	4
170/190	13.8	5.73 - 17.2	4.74	5	209	1.88	0.38 - 2.79	0.947	5
171/202	7.13	2.99 - 10.1	2.76	5					
172	3.52	1.69 - 5.11	1.26	5	**Total**	**942**	**385 - 1326**	**351**	5

Table A7. Data summary on concentrations (ppb fresh weight) of PCB congeners detected in forage fish whole bodies collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA. - **California killifish, part 1.**

congener #	mean	range	SD	detects out of 5	congener#	mean	range	SD	detects out of 5
1	1.33	nd - 3.98	1.67	4	52	0.97	0.27 - 2.32	0.89	5
7/9	-	nd	-	0	53	-	nd	-	0
8/5	2.15	0.05 - 4.61	2.01	5	60/56	1.82	nd - 4.81	1.86	4
15	0.26	nd - 0.81	0.34	2	63	0.15	nd - 0.42	0.19	2
16/32	0.21	nd - 0.65	0.27	3	66	0.80	0.18 - 1.76	0.61	5
18/17	0.38	nd - 0.93	0.35	4	67	2.05	0.70 - 2.92	0.82	5
22/51	1.16	0.11 - 2.74	1.01	5	69	-	0.31	-	1
24/27	0.38	nd - 0.74	0.28	4	70	1.14	0.62 - 1.63	0.39	5
25	0.27	nd - 0.53	0.19	4	72	-	0.46	-	1
26	0.26	nd - 0.63	0.25	3	74/61	0.89	0.19 - 1.80	0.68	5
28	0.78	0.24 - 1.24	0.42	5	77	-	nd	-	0
29	0.12	nd - 0.22	0.08	3	81	-	nd	-	0
30	0.22	nd - 0.99	0.43	2	82	1.15	0.26 - 1.81	0.67	5
31	0.15	nd - 0.31	0.12	4	83	0.21	nd - 0.59	0.25	2
33/20	1.23	0.14 - 3.88	1.51	5	84	0.66	nd - 1.52	0.60	4
39	0.53	nd - 1.26	0.64	3	85	0.35	0.07 - 0.78	0.28	5
40	-	0.58	-	1	87/115	0.23	nd - 0.47	0.16	4
41/64	0.04	0.01 - 0.07	0.02	2	92	0.20	nd - 0.37	0.15	3
42/59/37	0.61	0.19 - 1.50	0.58	5	95/80	1.52	0.41 - 3.96	1.42	5
44	1.91	0.27 - 5.15	2.01	5	97	0.24	nd - 0.59	0.24	3
45	-	nd	-	0	99	1.97	nd - 4.08	1.65	4
46	0.77	nd - 1.86	0.75	4	101/90	1.16	0.03 - 3.77	1.50	5
47/75	0.33	nd - 1.08	0.44	3	105	0.30	0.27 - 0.36	0.04	5
48	-	0.89	-	1	107	0.63	nd - 1.08	0.45	4
49	0.66	0.09 - 1.51	0.54	5	110	1.26	0.452 - 2.25	0.67	5

Table A7, cont. Data summary on concentrations (ppb fresh weight) of PCB congeners detected in forage fish whole bodies collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA. - **California killifish, part 2.**

congener #	mean	range	SD	detects out of 5	congener #	mean	range	SD	detects out of 5
114	-	nd	-	0	174	0.22	0.09 - 0.48	0.16	5
118	1.58	0.56 - 2.64	0.99	5	175	0.34	nd - 0.63	0.31	3
119	0.41	nd - 0.85	0.37	3	176/137	-	0.88	-	1
126	-	nd	-	0	177	0.21	nd - 0.55	0.21	3
128	0.76	0.38 - 1.03	0.26	5	178	0.23	nd - 0.58	0.25	3
129	0.16	nd - 0.40	0.16	3	180	1.72	0.38 - 2.85	1.19	5
130	0.45	nd - 0.91	0.42	3	183	0.41	0.16 - 0.63	0.19	5
135	0.46	0.14 - 1.01	0.36	5	185	-	0.08	-	1
136	0.87	0.13 - 2.70	1.05	5	187	1.12	0.35 - 1.57	0.47	5
138/160	3.38	1.01 - 4.95	1.48	5	189	0.03	nd - 0.05	0.02	2
141/179	1.48	0.26 - 3.66	1.36	5	191	-	0.05	-	1
146	1.27	0.77 - 1.84	0.46	5	193	0.11	nd - 0.27	0.11	3
149/123	1.48	0.45 - 2.56	0.78	5	194	0.09	nd - 0.15	0.08	3
151	0.10	nd - 0.20	0.08	3	195/208	0.13	nd - 0.42	0.16	4
153/132	2.89	0.36 - 5.16	2.26	5	196	0.19	0.10 - 0.34	0.09	5
156	-	0.72	-	1	197	0.22	nd - 0.56	0.22	4
157/173/201	0.41	nd - 1.00	0.41	4	199	0.50	0.08 - 1.55	0.60	5
158	0.45	0.02 - 0.74	0.35	5	200	-	0.05	-	1
166	0.07	nd - 0.17	0.06	3	205	0.08	nd - 0.22	0.08	2
167	0.12	nd - 0.30	0.12	3	206	0.13	nd - 0.25	0.08	4
169	-	nd	-	0	207	0.07	nd - 0.20	0.08	2
170/190	0.29	0.08 - 0.44	0.17	5	209	0.10	nd - 0.22	0.08	4
171/202	0.48	nd - 1.04	0.45	4					
172	0.44	nd - 1.13	0.45	4	**Total**	**56.8**	**23.0**	**28.4**	

Table A7, cont. Data summary on concentrations (ppb fresh weight) of PCB congeners detected in forage fish whole bodies collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA. - **Longjaw mudsucker, part 1.**

congener #	mean	range	SD	detects out of 12	congener #	mean	range	SD	detects out of 12
1	13.3	nd - 134	38.6	10	52	1.14	0.12 - 2.24	0.61	12
7/9	0.41	nd - 1.51	0.64	5	53	0.78	nd - 5.46	1.49	10
8/5	1.40	0.41 - 3.50	1.11	12	60/56	0.49	nd - 2.56	0.85	8
15	0.69	nd - 1.40	0.44	10	63	0.24	nd - 0.65	0.22	8
16/32	0.28	nd - 0.48	0.12	11	66	0.75	0.24 - 1.89	0.46	12
18/17	0.16	nd - 0.30	0.12	8	67	2.18	0.22 - 15.3	4.16	12
22/51	0.44	nd - 1.94	0.49	11	69	-	nd	-	0
24/27	0.09	nd - 0.22	0.07	10	70	1.33	0.50 - 2.59	0.56	12
25	0.28	nd - 0.51	0.21	8	72	0.21	nd - 1.04	0.39	3
26	0.17	nd - 0.36	0.13	9	74/61	0.94	0.11 - 3.23	0.86	12
28	0.68	0.35 - 1.31	0.29	12	77	-	0.02	-	1
29	0.03	nd - 0.14	0.05	3	81	-	nd	-	0
30	0.65	nd - 5.07	1.50	5	82	1.69	nd - 7.32	2.00	9
31	0.13	0.01 - 0.74	0.20	12	83	1.36	nd - 3.85	1.09	9
33/20	-	0.84	-	1	84	1.05	nd - 2.47	0.85	9
39	0.38	0.03 - 1.71	0.46	12	85	0.18	nd - 0.34	0.08	11
40	0.27	nd - 0.96	0.28	9	87/115	0.38	nd - 2.92	0.81	9
41/64	0.27	nd - 1.95	0.62	3	92	0.65	nd - 4.90	1.35	10
42/59/37	0.49	0.04 - 1.21	0.33	12	95/80	0.90	0.14 - 2.02	0.52	12
44	0.80	0.40 - 1.41	0.36	12	97	0.84	nd - 1.47	0.45	11
45	0.02	nd - 0.16	0.05	11	99	2.59	nd - 9.03	2.48	10
46	1.80	0.14 - 11.7	3.26	12	101/90	1.63	nd - 3.49	1.16	10
47/75	1.03	nd - 2.30	0.65	11	105	0.46	nd - 2.01	0.52	11
48	0.11	nd - 0.89	0.25	8	107	0.37	nd - 1.48	0.43	8
49	1.43	0.14 - 3.35	0.95	12	110	1.74	0.14 - 3.78	0.95	12

Table A7, cont. Data summary on concentrations (ppb fresh weight) of PCB congeners detected in forage fish whole bodies collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA. - **Longjaw mudsucker, part 2.**

congener #	mean	range	SD	detects out of 12	congener #	mean	range	SD	detects out of 12
114	-	nd	-	0	174	0.23	nd - 0.60	0.15	11
118	2.65	0.43 - 11.4	2.87	12	175	0.06	nd - 0.34	0.11	5
119	0.66	nd - 5.52	1.54	9	176/137	0.48	nd - 3.44	1.02	5
126	-	nd	-	0	177	0.18	nd - 0.63	0.16	10
128	1.08	nd - 3.77	0.92	11	178	0.24	nd - 0.70	0.19	10
129	0.10	nd - 0.39	0.14	8	180	5.08	0.25 - 28.6	7.64	12
130	0.78	nd - 2.07	0.65	9	183	0.86	0.10 - 3.02	0.74	12
135	0.47	nd - 0.89	0.27	10	185	0.12	nd - 0.37	0.11	8
136	1.89	0.29 - 17.1	4.80	12	187	1.91	0.20 - 6.85	1.64	12
138/160	4.44	0.24 - 20.6	5.28	12	189	0.17	nd - 0.56	0.15	11
141/179	0.64	nd - 1.32	0.47	10	191	0.07	nd - 0.23	0.08	6
146	1.52	nd - 6.18	1.63	10	193	0.40	nd - 1.34	0.39	11
149/123	2.15	0.31 - 4.04	1.13	12	194	0.39	0.06 - 2.11	0.55	12
151	0.21	nd - 0.49	0.15	10	195/208	0.16	0.03 - 0.83	0.24	12
153/132	6.98	nd - 43.3	11.8	11	196	0.53	0.06 - 2.12	0.52	12
156	0.24	nd - 1.09	0.29	10	197	0.29	nd - 3.05	0.87	9
157/173/201	0.22	0.03 - 0.65	0.18	12	199	0.20	nd - 0.76	0.24	11
158	0.78	nd - 4.22	1.31	11	200	0.19	nd - 2.13	0.61	4
166	0.16	nd - 0.38	0.12	9	205	0.09	0.02 - 0.19	0.06	12
167	0.42	nd - 2.04	0.57	9	206	0.24	0.04 - 0.65	0.20	12
169	-	nd	-	0	207	0.15	nd - 0.83	0.22	11
170/190	0.68	0.04 - 3.87	1.03	12	209	0.15	0.03 - 0.62	0.18	12
171/202	0.54	nd - 1.91	0.50	10					
172	0.24	nd - 1.10	0.29	11	**Total**	**86.4**	**21.1**	**68.9**	

Table A7, cont. Data summary on concentrations (ppb fresh weight) of PCB congeners detected in forage fish whole bodies collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA. - **Topsmelt, part 1.**

congener #	mean	range	SD	detects out of 3	congener #	mean	range	SD	detects out of 3
1	0.46	0.19 - 0.68	0.25	3	52	0.68	0.09 - 1.66	0.86	3
7/9	-	0.16	-	1	53	0.44	nd - 0.89	0.45	2
8/5	0.78	0.57 - 1.01	0.22	3	60/56	-	1.02	-	1
15	0.39	0.16 - 0.64	0.24	3	63	0.32	nd - 0.70	0.35	2
16/32	0.20	nd - 0.51	0.27	2	66	0.75	0.36 - 1.22	0.44	3
18/17	-	0.08	-	1	67	1.53	1.37 - 1.77	0.21	3
22/51	0.25	nd - 0.69	0.38	2	69	-	nd	-	0
24/27	0.21	0.10 - 0.31	0.11	3	70	1.17	0.26 - 1.88	0.83	3
25	-	0.38	-	1	72	-	nd	-	0
26	0.12	nd - 0.18	0.10	2	74/61	1.03	0.53 - 1.55	0.51	3
28	0.31	0.07 - 0.55	0.24	3	77	-	nd	-	0
29	-	0.02	-	0	81	-	nd	-	0
30	0.25	nd - 0.72	0.40	2	82	0.70	0.04 - 1.32	0.64	3
31	0.23	0.05 - 0.49	0.24	3	83	-	0.39	-	1
33/20	0.36	nd - 0.70	0.35	2	84	0.93	nd - 1.44	0.80	2
39	0.42	nd - 0.82	0.40	2	85	0.36	0.14 - 0.48	0.19	3
40	-	0.98	-	1	87/115	0.32	0.08 - 0.64	0.29	3
41/64	0.22	nd - 0.55	0.29	2	92	0.28	0.23 - 0.34	0.05	3
42/59/37	0.33	nd - 0.58	0.29	2	95/80	1.60	0.79 - 2.83	1.08	3
44	0.53	0.17 - 0.83	0.33	3	97	0.74	0.21 - 1.20	0.50	3
45	-	0.28	-	1	99	2.91	0.13 - 37.4	3.93	3
46	0.44	0.34 - 0.56	0.12	3	101/90	2.33	0.01 - 4.04	2.10	3
47/75	1.02	nd - 2.77	1.52	2	105	0.33	0.17 - 0.51	0.17	3
48	-	0.15	-	1	107	0.60	0.26 - 1.12	0.46	3
49	0.95	0.23 - 1.88	0.84	3	110	1.68	0.72 - 3.24	1.36	3

Table A7, cont. Data summary on concentrations (ppb fresh weight) of PCB congeners detected in forage fish whole bodies collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA. - **Topsmelt, part 2.**

congener #	mean	range	SD	detects out of 3	congener #	mean	range	SD	detects out of 3
114	-	nd	-	0	174	0.31	0.06 - 0.51	0.23	3
118	2.31	0.74 - 5.21	2.51	3	175	0.05	nd - 0.09	0.04	2
119	0.20	nd - 0.33	0.17	2	176/137	-	0.51	-	1
126	-	nd	-	0	177	0.41	0.17 - 0.77	0.32	3
128	0.84	0.30 - 1.47	0.59	3	178	-	0.67	-	1
129	0.18	nd - 0.31	0.16	2	180	1.43	0.29 - 2.78	1.26	3
130	0.32	nd - 0.63	0.31	2	183	0.48	0.18 - 1.04	0.48	3
135	0.77	0.23 - 1.11	0.47	3	185	-	0.05	-	1
136	0.37	0.23 - 0.53	0.15	3	187	1.83	0.46 - 4.49	2.30	3
138/160	4.00	1.42 - 8.65	4.04	3	189	0.07	nd - 0.11	0.06	2
141/179	0.72	0.39 - 1.28	0.49	3	191	0.04	nd - 0.07	0.03	2
146	1.61	0.68 - 3.14	1.33	3	193	0.10	nd - 0.24	0.13	2
149/123	2.06	0.43 - 5.06	2.60	3	194	0.19	nd - 0.54	0.30	2
151	-	0.98	-	1	195/208	0.24	0.12 - 0.40	0.14	3
153/132	6.79	0.74 - 17.5	9.30	3	196	0.28	0.11 - 0.59	0.27	3
156	0.36	nd - 1.03	0.59	2	197	0.06	nd - 0.11	0.05	2
157/173/201	0.25	nd - 0.46	0.23	2	199	0.30	0.01 - 0.78	0.42	3
158	0.45	0.16 - 0.88	0.38	3	200	-	nd	-	0
166	0.12	nd - 0.26	0.12	2	205	0.11	0.03 - 0.21	0.09	3
167	0.39	0.16 - 0.80	0.35	3	206	0.20	0.06 - 0.27	0.11	3
169	-	nd	-	0	207	0.06	0.01 - 0.16	0.08	3
170/190	0.46	0.11 - 1.07	0.53	3	209	0.25	0.16 - 0.35	0.09	3
171/202	0.29	0.12 - 0.61	0.27	3					
172	0.86	0.15 - 1.42	0.65	3	**Total**	**57.9**	**31.1 - 111**	**45.8**	

Table A8. Data summary on concentrations (ppb fresh weight) of PBDE congeners detected in biota collected in 2005 from the South Bay Salt Works, San Diego Bay NWR, San Diego, CA.

Black Skimmer eggs

	mean	range	SD	detects (out of 15)
BDE# 28	17.7	nd - 34.9	9.99	14
BDE# 47	585	142 - 1161	355	15
BDE# 49	4.95	nd - 10.2	3.15	11
BDE# 66	9.64	nd - 21.4	6.22	3
BDE# 99	76.8	20.5 - 154	43.2	15
BDE# 100	104	30.6 - 213	60.8	15
BDE# 153	18.6	nd - 45.9	15.3	12
BDE# 154	14.0	nd - 32.1	11.2	12
BDE-TOTAL	829	223 - 1653	500	15

Caspian tern eggs

	mean	max	SD	detects (out of 5)
BDE# 28	31.2	10.7 - 40.3	11.9	5
BDE# 47	602	212 - 789	231	5
BDE# 49	15.8	8.43 - 20.9	5.21	5
BDE# 66	16.7	5.11 - 23.8	7.04	5
BDE# 99	92.3	44,5 - 127	33.1	5
BDE# 100	122	43.2 - 159	47.2	5
BDE# 153	15. 8	3.47 - 24.4	8.70	5
BDE# 154	13.9	4.57 - 21.8	7.07	5
BDE-TOTAL	911	332 - 1184	343	5

Elegant tern eggs

	mean	range	SD	detects (out of 5)
BDE# 28	3.12	nd - 5.01	2.01	3
BDE# 47	114	42.3 - 160	44.4	5
BDE# 49	4.16	nd - 8.32	3.20	3
BDE# 66	2.15	nd - 4.92	1.77	2
BDE# 99	29.6	16.5 - 43.9	10.2	5
BDE# 100	38.8	38.8 - 52.2	11.8	5
BDE# 153	-	nd	-	0
BDE# 154	-	nd	-	0
BDE-TOTAL	199	126 - 271	53.2	5

California least tern eggs

	mean	range	SD	detects (out of 5)
BDE# 28	3.86	nd - 8.71	3.83	2
BDE# 47	91.9	52.9 - 144	39.1	5
BDE# 49	-	4.74	-	1
BDE# 66	-	6.92	-	1
BDE# 99	27.7	14.7 - 38.3	11.0	5
BDE# 100	17.4	10.9 - 23.5	5.95	5
BDE# 153	-	nd	-	0
BDE# 154	-	nd	-	0
BDE-TOTAL	142	79.0 - 227	62.5	5

California killifish whole bodies

	mean	range	SD	detects (out of 5)
BDE# 28	-	nd	-	0
BDE# 47	1.53	nd - 3.08	1.09	4
BDE# 49	-	nd	-	0
BDE# 66	-	nd	-	0
BDE# 99	0.71	nd - 1.88	0.70	2
BDE# 100	0.49	nd - 0.94	0.35	2
BDE# 153	-	nd	-	0
BDE# 154	-	nd	-	0
BDE-TOTAL	-	nd	-	0

Longjaw mudsucker whole bodies

	mean	range	SD	detects (out of 12)
BDE# 28	0.30	nd - 1.18	0.34	5
BDE# 47	6.74	0.75 - 38.2	10.2	12
BDE# 49	0.44	nd - 1.32	0.42	7
BDE# 66	0.20	nd - 1.03	0.30	2
BDE# 99	0.42	nd - 1.53	0.50	5
BDE# 100	1.11	nd - 6.06	1.62	9
BDE# 153	-	nd	-	0
BDE# 154	-	0.63	-	1
BDE-TOTAL	9.19	nd - 49.7	13.3	9

Topsmelt whole bodies

	mean	range	SD	detects (out of 3)
BDE# 28	-	nd	-	0
BDE# 47	1.61	1.13 - 2.15	0.51	3
BDE# 49	0.31	nd - 0.50	0.17	2
BDE# 66	-	nd	-	0
BDE# 99	-	nd	-	0
BDE# 100	-	0.35	-	1
BDE# 153	-	nd	-	0
BDE# 154	-	nd	-	0
BDE-TOTAL	2.58	3.87	1.36	1