Environmental Contaminants in Piscivorous Birds at the Salton Sea, 1992-93

Prepared by the

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Introduction

Annual colonial nesting bird surveys conducted at the Salton Sea from 1987-1991(U.S. Fish and Wildlife Service (USFWS) unpublished data) documented a sharp decline in many nesting species known to use the Salton Sea including the Black Skimmer (*Rynchops niger*), Great Egret (*Casmerodius alba*), and Snowy Egret (*Egretta thula*). Although double-crested cormorants (*Phalacrocorax auritus*) were previously documented nesting at the Salton Sea, none nested there from 1989 through 1991. A smaller scale study in 1991 (Audet *et al.*, 1997) indicated that these species were exposed to contaminants (e.g., selenium and p,p DDE), and that additional studies of this situation were warranted. We hypothesize that this exposure may be contributing to changes in reproduction. Of particular concern was the fact that Brown Pelicans (*Pelecanus occidentalis*), a federally listed endangered species, were beginning to use the Salton Sea in much greater numbers and may be exposed to the same contaminants that may have been affecting other piscivorous birds.

The Carlsbad Fish and Wildlife Office (CFWO) and the Salton Sea National Wildlife Refuge (SSNWR) jointly conducted this study to evaluate the role of environmental contaminants in the decline of reproduction in piscivorous birds at the Salton Sea. This included the collection of tissue samples for chemical analysis and nest monitoring activities in the first year of the study. The second year of the study focused on the Black Skimmer as this species was believed to best represent the exposure to contaminants experience by the Brown Pelican.

Information gathered in this study forms a baseline against which data collected under current inflow conditions (100,000 acre-feet/year of water has been transferred out of the watershed to the Metropolitan Water District since these samples were collected) or future inflow conditions (there is a water transfer of 200,000 acre-feet/year or more pending between Imperial Irrigation District and San Diego County Water Authority) may be compared. Because the reduction in inflows are anticipated to occur largely as a result of reduction and/or reuse of surface run-off from agricultural fields, we anticipate increases in the aquatic concentrations and bioavailability of some contaminants. This will ultimately affect the exposures of the apex predators in the system, piscivorous birds. This information, in combination with data gathered in the future, should enhance our ability to implement adaptive management in the restoration of the Salton Sea.

Methods and Materials

In 1992 specific focus was given to the issue of differences in exposure to organic contaminants in different developmental stages. This was carried out by sampling Black-crowned Night-herons (*Nycticorax nycticorax*) at three stages of development: eggs collected early in the incubation period (early embryo exposure), embryos near pipping (embryo exposure as it relates to eggs that survive to hatching), and approximately 10 day old chicks that have consumed locally available prey. The eggs collected early in incubation were analyzed for inorganics, the others were only analyzed for organochlorine compounds.

The Black-crowned Night-heron samples were collected by CFWO and SSNWR staffs during the breeding season in 1992 at the Whitewater River delta colony (Figure 1). Eggs (n=10) were collected and processed at the SSNWR headquarters by bisecting the eggs and placing the contents into chemically clean jars. The samples were frozen pending chemical analysis. Pip embryos (n=10) were handled similarly, except the embryos were sacrificed by decapitation and the livers were removed prior to freezing for a concurrent cytochrome P-450 study being conducted by the Patuxent Wildlife Research Center. The chicks (n=10) were collected from the nests and sacrificed by cervical dislocation. Livers were removed from the chicks for the cytochrome P-450 analysis. The embryos and chicks were wrapped in aluminum foil, placed in plastic bags, and frozen. All samples remained frozen until shipment to the analytical laboratory.

Additional egg samples were collected from Black Skimmer nests (n=5) at the Salton Sea, White-faced Ibis (*Plegadis chihi*) nests (n=5) at Finney Lake of the California Department of Fish and Game s Imperial Wildlife Area (IWA), and Great Egrets (n=8) during nest monitoring activities at the Mallard Road colony at the Wister Unit of IWA (Figure 1). These eggs were processed as above and remained frozen until shipment to the analytical laboratory.

In 1993 the study focused on Black Skimmers (n=39), with a small number of eggs (n=5) from Caspian Terns (*Sterna caspia*). Eggs were collected from four colonies that were being monitored by SSNWR staff. Eggs were collected and processed as above by SSNWR staff, frozen, and transported to CFWO for shipment to the analytical laboratory.

Sediment samples were collected from each of three foraging areas used by Black Skimmers nesting at the four colonies being monitored in 1993. Two surface sediment samples were collected from each area using a petit ponar dredge, removed using clean instruments, and placed in chemically clean jars. Material in contact with the dredge was avoided to prevent cross contamination. The samples were frozen until transport to CFWO and shipment to the analytical laboratory.

Laboratory analysis for trace elements was conducted using cold vapor atomic absorption for mercury and graphite furnace atomic absorption for selenium. Organic analyses were conducted using packed or megabore column electron capture gas chromatography or by gas-liquid chromatograph equipped with an electron capture detector. Confirmation was by gas chromatography/mass spectrometry where required.

Only descriptive statistics were used in summarizing the data. If the number of non-detect results exceeded 50% of the samples for a sample group, no geometric means were calculated and only ranges are provided. In all other cases, substitute values of one half of the detection limit were used in calculating the geometric means for analytes by group. All means provided are geometric means. We analyzed the data based on individual colonies and species for comparison.

Results

The results are presented in Tables 1 to 3.

The results of the inorganic analyses are presented in Table 1. Caspian Terns had the lowest mean selenium concentration (2.60 µg/g dry weight (DW)), and Black-crowned Night-herons had the highest (6.18 µg/g DW). While individual colonies of Black Skimmers had higher mean concentrations than Black-crowned Night-herons, the species means for each year were the same (5.87 µg/g DW). White-faced Ibises and Great Egrets had intermediate mean concentrations (3.62 and 4.95 µg/g DW, respectively).

For analyzed for mercury concentrations in 1992, Black Skimmers had a higher mean (0.485 µg/g DW, Table 1) than White-faced Ibis (0.247 µg/g DW, Table 1).

In 1993 two sediment samples were collected for selenium analysis from each of three foraging areas in the vicinity of the four Black Skimmer colonies sampled. The Johnson drain area at the north end of the Salton Sea had selenium concentrations (1.32-3.11 µg/g DW), Morton Bay (between the Mullet Island and Morton Bay colonies on the southeast corner of the Sea) had intermediate concentrations (1.13-1.36 µg/g DW), and Obsidian Butte (south and west of Morton Bay) sediments had the lowest selenium concentrations (0.191-0.953 µg/g DW).

Organic analyses were conducted on bird eggs and chicks. Several organic compounds were detected at low to moderate concentrations and frequencies. Table 2 presents the means and maximums (in µg/g wet weight (WW)) and the frequencies of detection for these compounds.

Table 3 presents all the results for those compounds detected at moderate to high detection frequencies. Geometric means and ranges (in µg/g WW) are provided for these compounds.

Discussion

<u>Inorganics</u>

Selenium concentrations vary in the five species evaluated. Caspian Terns had the lowest mean and maximum concentrations, and the Black-crowned Night-herons had the highest mean. The Black Skimmer had the second highest mean and the highest maximum concentration ($\bar{x}$=5.87 µg/g DW, maximum=8.92 µg/g DW for all Black Skimmers combined). This is somewhat surprising given that Black Skimmers and Caspian Terns are nesting and foraging in similar areas. Black Skimmer results were similar between the two years; the mean concentrations were the same.

Selenium concentrations in eggs overall were slightly elevated as compared to the background levels provided by the National Irrigation Water Quality Program (NIWQP 1998) of < 5 µg/g

DW. Eisler (1985) provides background concentrations of 0.19-2.1 g/g fresh wet weight for a variety of bird species. In 1993 most groups had maximums that exceeded this range, but not in 1992. All of the egg concentrations, except for two Caspian Tern eggs, fell into the level of concern or above the toxicity threshold for water bird eggs provided by NIWQP (1998). This is the threshold at which hatchability effects as a result of selenium concentrations in the egg begin to occur. We believe that some piscivorous birds at the Salton Sea may be experiencing low level reproductive impacts (i.e., eggs failing to hatch) as a result of selenium exposure. This was also the case for Black-necked Stilts at the Salton Sea (Bennett 1998), but confirmation of this hypothesis is difficult because it requires intensive nest monitoring to determine the fate of each egg in every nest sampled. This level of monitoring was not part of this study.

Heinz (1996) identified a concentration of 3 g/g WW in eggs as a general causative threshold of reproductive impairment. All but one of the eggs analyzed for this study fell below that concentration. However, Heinz (1996) did identify a concentration as low as 1.46 g/g WW as being associated with impaired reproduction in some cases. Four of ten Black-crowned Night-heron eggs exceeded this in 1992. In 1993 16 of 30 Black Skimmers exceeded this concentration. Skorupa and Ohlendorf (1991) identified a population threshold for lowered hatchability of 8 g/g DW in eggs. All of the group means fell below this concentration.

Henny and Herron (1989) found no indication that selenium was having an effect on reproduction in White-faced Ibis at mean concentrations of 1.91-5.40 g/g DW. Our group means ranged somewhat higher than this. Skorupa (1998) identified 6 g/g DW as the embryo toxicity threshold in black-necked stilts. Other species such as those sampled here are not as well characterized. However, many of the eggs collected in this study did exceed this threshold, suggesting the potential for selenium induced reproductive impacts. Bennett (1998) determined that there may be a reduction in nesting proficiency of black-necked stilts at the Salton Sea that is related to their egg selenium concentrations. Studies conducted by Molina (1994) on Black Skimmers determined hatching success and clutch size for the same colonies as were sampled here. The patterns of hatching success and clutch size did not appear to match the corresponding pattern of selenium concentrations for those groups that we sampled. While the potential for reproductive impairment for piscivorous birds exists at the Salton Sea, no measurable impairment was found that could be attributed to selenium in this study.

Selenium is still of concern at the Salton Sea. Current plans for water conservation in the Imperial Valley include the possible use of tail water recovery systems. Tail water currently comprises a significant portion of the inflows to the Salton Sea and functions to dilute the more selenium concentrated discharges from subsurface drains upon mixing of the two in the surface drains. As a result, water conservation in the Imperial Valley has the potential to increase surface water selenium concentrations and decrease the water volumes flowing into the Salton Sea. This would likely result in measurable impacts to breeding birds foraging in aquatic habitats in and near the Salton Sea depending on the magnitude of the selenium concentration increases. Future monitoring of piscivorous birds should occur as water conservation efforts are carried out.

Sediment selenium concentrations at two of the three sites sampled fell within background for freshwater sediments. However, one sample from Johnson drain did exceed this background level. It was not possible to correlate concentrations in eggs with those in sediments due to inadequate sample size. Future studies should include larger numbers of sediment samples along with representative samples of food chain organisms to demonstrate the exposure pathway for these species.

Mercury was analyzed in the eggs of Black Skimmers and White-faced Ibises in 1992. Black Skimmers had the higher mean concentration, but White-faced Ibises had the higher maximum. The maximum concentrations for both species fall into the level of concern range provided by the NIWQP (1998). None of the concentrations exceeded the toxicity threshold provided in that document.

Eisler (1987) states that biota concentrations from areas not directly affected by anthropogenic sources of mercury generally fall below 1 g/g WW. Although we did not have adequate information to calculate fresh wet weights for the eggs sampled, all wet weight concentrations fell below that concentration. Thompson (1996) summarized several studies that evaluated a variety of reproductive parameters relative to mercury concentrations in eggs. The concentrations found in this study were below any cited by Thompson (1996) that had identified a reproductive impact. Thompson concluded that concentrations up to 0.5 g/g WW (approximately 2.5 g/g DW) have little detrimental effect on reproduction. We can therefore conclude that mercury contamination in birds is not likely to cause reproductive or other impacts in the Salton Sea watershed.

Organics

o,p DDE, o,p DDT, -chlordane, and cis-nonachlor had detection frequencies which were quite low, but some general observations were made. o,p DDE was detected only in eggs analyzed by gas-liquid chromatography, and detections of this compound may have resulted from this analytical technique rather than differences in exposure. o,p DDT was detected rarely, with the exception of White-faced Ibis where it was detected in all samples. This may result from the more direct exposure of this species to agricultural chemicals by foraging directly in the agricultural fields. -chlordane was detected in half of the Obsidian Butte Black Skimmer eggs. The only other detection for this compound was one Mullet Island Black Skimmer egg. The reason for this is not clear, but may relate to the proximity of Obsidian Butte to agricultural fields. Cis-nonachlor was detected in four of the five Caspian Tern eggs. Only two other detections (in Morton Bay Black Skimmers) were seen. This may relate, in part, to different analytical techniques used for these two groups of samples. It may also involve a difference in exposure due to a difference in prey selection.

Little specific comparative information could be found for the organochlorine compounds HCB, -BHC, p,p DDD and p,p DDT. These compounds were detected in 27% to 43% of the samples, all wet weight concentrations were below 1 g/g WW, and all group means were 0.1

g/g WW

or less. Therefore, we do not consider these compounds to pose an unreasonable risk of acute toxicity or reproductive impacts.

Oxychlordane was detected in 62% of the samples analyzed. Oxychlordane concentrations in this study were similar to values in other studies with the exception of one Black Skimmer egg from Morton Bay. This high concentration of 2.5 g/g WW cannot be explained and is not representative of the rest of the data set. The group means were at or below those found for California Least Terns (*Sterna antillarum browni*) at San Francisco and San Diego Bays (Hothem and Zador 1995), Snowy Egrets at San Francisco Bay (Ohlendorf *et al.* 1988), and Black-crowned Night-herons in Washington (Henny *et al.* 1984) and at San Francisco Bay and in the San Joaquin Valley (Ohlendorf and Marois 1990). Cattle Egret (*Bubulcus ibis*) eggs collected from the Mexicali Valley, Mexico had a geometric mean of 0.010 g/g WW (Mora 1991) which is intermediate as compared to our group means. These concentrations are likely to result in only a small incremental increase in the overall effects of organochlorine contamination. We anticipate that this increase would be very minor.

Heptachlor epoxide was detected in 41% of the samples analyzed. The concentrations found were similar to or less than concentrations found in Black-crowned Night-herons in Washington (Henny *et al.* 1984), Cattle Egrets in the Mexicali Valley (Mora 1991), and Caspian Terns at San Diego Bay (Ohlendorf *et al.* 1985). Wiemeyer (1996) identified a No Observed Effect Level (NOEL) for three raptor species of 0.2-0.4 g/g WW in the egg. All of our samples were below this concentrations therefore we don t anticipate any measurable reproductive impacts from this compound.

Endrin was detected in 27% of the samples. The concentrations found were slightly higher than the concentrations found in Cattle Egrets in the Mexicali Valley (Mora 1991). Little additional comparison data could be found. However, Peakall (1996) identified endrin concentrations of 0.12-0.5 g/g WW as being capable of causing some reproductive impacts. All of the concentrations found here were well below that range of values. Endrin alone is not likely to be causing measurable impacts, but this compound could be adding incrementally to the overall impact of this group of pesticides (which also includes dieldrin).

Of the frequently detected organochlorine compounds (Table 3) trans-nonachlor had the lowest overall concentrations. The highest mean concentration found in this study was that for the White-faced Ibis. This may be the result this species habit of foraging in agricultural fields. These concentrations were less than those found in Black-crowned Night-herons at San Francisco Bay (Ohlendorf and Marois 1990) and Foundation Island in Washington (Henny *et al.* 1984), Forster s Terns and Snowy Egrets from San Francisco Bay (Ohlendorf *et al.* 1988), Caspian Terns from Elkhorn Slough (Ohlendorf *et al.* 1988) and California Least Terns from San Francisco and San Diego Bays (Hothem and Zador 1995). These concentrations were also below those found in Great Egrets at the Salton Sea by Ohlendorf and Marois (1990). The concentrations of this compound present in the species sampled are not expected to result in impacts, although there was little information in the literature regarding thresholds for this compound. Ohlendorf and Marois (1990) did not consider trans-nonachlor to be among the contaminants to have the greatest potential for toxicological significance. It may, however, contribute to the cumulative impacts of organochlorine pesticide contamination.

The dieldrin concentrations measured in this study were lower than concentrations found in Great Egrets at the Salton Sea by Ohlendorf and Marois (1990). They were similar to concentrations found in Caspian Terns at San Diego Bay (Ohlendorf *et al.* 1985), California Least Terns at San Francisco and San Diego Bays (Hothem and Zador 1995), and Snowy Egrets at San Francisco Bay (Ohlendorf *et al.* 1988). The dieldrin concentrations measured here were higher than those found in Cattle Egrets from the Mexicali Valley (Mora 1991). This could be related to differences in the use of this pesticide between these two areas, but no information was available to confirm this. Peakall (1996) identified no effect levels for dieldrin in bird eggs as falling in the range of 0.36-23.2 g/g WW. Only one of our samples slightly exceeded the lowest of these values. Upon examination of the combined endrin and dieldrin residues found in this study, we do not anticipate measurable reproductive impacts in piscivorous birds at the Salton Sea to result from exposure to this group of pesticides.

PCB concentrations in this study were below those found in Caspian Terns at San Diego Bay (Ohlendorf *et al.* 1985), Caspian Terns at Elkhorn Slough (Ohlendorf *et al.* 1988), Snowy Egrets and Forster s Terns at San Francisco Bay (Ohlendorf *et al.* 1988), California Least Terns at San Francisco and San Diego Bays (Hothem and Zador 1995), and Black-crowned Night-herons at San Francisco Bay (Ohlendorf and Marois 1990). Hoffman *et al.* (1996) summarized the effects of these compounds and determined that hatching success is impacted in the range of 8-25 g/g WW for a variety of bird species. Eisler (1986) suggested that egg concentrations below 16 g/g WW (on a fresh weight basis) would not likely result in impacts. The concentrations measured here all fell below these levels suggesting that PCB s are not likely to be significantly impacting piscivorous birds at the Salton Sea. As this is not a highly industrialized area (there are some industrial discharges crossing the International Border from Mexicali), PCB s were not expected to be a major group of contaminants in the system. However, the presence of this group of contaminants in resident species (*e.g.*, Great Egret) does indicate a local source. This situation warrants monitoring as long as sewage continues to enter the United States from Mexicali, Mexico and flow into the Salton Sea.

Of all of the organochlorine compounds detected, p,p DDE was detected most frequently (in 100% of the samples) and at the highest concentrations. In previous studies at the Salton Sea of Black-crowned Night-herons and Snowy Egrets, similar concentrations were found (Ohlendorf and Marois 1990, Bennett 1998). Somewhat higher concentrations were found in Great Egrets in those two studies indicating that the concentrations found here are not unusually high for the Salton Sea area. Black-crowned Night-herons from San Francisco Bay and several sites in Washington and Oregon (Ohlendorf and Marois 1990, Henny *et al.* 1984) were noticeably lower as were concentrations for Cattle Egrets in the Mexicali Valley (Mora 1991). California Least Terns at San Francisco and San Diego Bays (Hothem and Zador 1995) and Forster s Terns and Snowy Egrets at San Francisco Bay (Ohlendorf *et al.* 1988) also had considerably lower concentrations. Caspian Terns at Elkhorn Slough (Ohlendorf *et al.* 1988) had concentrations similar to the concentrations found at the Salton Sea.

The concentrations of p,p DDE in eggs of piscivorous birds at the Salton Sea are high enough that we would anticipate some reproductive impacts. Henny *et al.* (1984) identified 8 g/g WW as a threshold above which successful reproduction in the Black-crowned Night-heron declined. Of the eggs that we sampled, 40% exceeded this threshold. Henny and Herron (1989) identified a Lowest Observed Adverse Effect Level (LOAEL) for p,p DDE in white faced ibis of 4 g/g WW. Four of the five White-faced Ibis samples we collected exceeded this value by three times or more. Blus (1996) identified a NOEL for DDE in eggs (relative to eggshell thickness impacts) of 0.1-2 g/g WW. Our values exceeded this range consistently and by one or two orders of magnitude. Although the nest monitoring did not provide an adequate sample size to indicate a statistical relationship between p,p DDE concentrations in the egg and nesting success, the residues found are definitely of concern for eggshell thinning and other reproductive impacts. Blus (1996) also stated that DDE is the constituent responsible for most impacts in the forms of eggshell thinning and population reductions. Given that this compound was found at the highest concentrations of all of those measured in these samples, it most certainly warrants additional monitoring and evaluation.

In our comparison of eggs, pip-aged embryos, and juveniles, we saw a drop in the concentrations of p,p DDE, trans-nonachlor, and PCB s across those sample groups. For p,p DDE, the larger drop was seen between eggs and pip-aged embryos. There were <50% detected results in juveniles for trans-nonachlor and PCB s, precluding this comparison. The data suggests an impact of these compounds on embryo survival, particularly for p,p DDE which was one or two orders of magnitude greater than the other two. Additional studies would be required to confirm this. Wintering ground exposure needs to be considered in managing for reduction of contaminant related impacts in migratory species.

Evaluation of the data for Black-crowned Night-heron eggs, pipping embryos, and chicks showed clear differences between the groups in their mean concentrations of p,p DDE. Decreasing trends were also seen in trans-nonachlor and PCB s, but the differences between the means were smaller. These results suggest that the embryos surviving to later developmental stages are those with the lower concentrations of organochlorine contaminants, particularly p,p DDE. Larger sample sizes would be needed to determine if differences between the age groups are significant and if organochlorine concentrations are significantly inversely correlated with embryo/chick age.

Summary and Conclusions

This study indicates that there are reasons to be concerned about contaminant exposure in piscivorous birds at the Salton Sea. Of greatest concern is p,p DDE. Although previous studies did not indicate extremely high concentrations of DDE in fish in the Salton Sea (Audet et al.

1997), the piscivorous birds studied are definitely being exposed to this contaminant. Egg concentrations suggest that reproductive impacts such as eggshell thinning are likely at least in a portion of these populations. While the Total Maximum Daily Load (TMDL) process should help to address the movement of this contaminant in the aquatic environment, continued monitoring of these species is warranted.

PCB s were found in some of the eggs sampled here. While the concentrations were greatly reduced in comparison to p,p DDE, the occurrence of these compounds in resident species is of concern and should be monitored until industrial effluent is no longer crossing the International Border in the New River and flowing to the Salton Sea.

Selenium is also still of concern as suggested by previous studies (Audet et al. 1997, Bennett 1998). While not at concentrations that would result in obvious impacts (such as deformities), the concentrations are at levels of concern and should continue to be monitored. This is particularly important if water conservation in Imperial Valley agriculture results in higher concentrations of selenium in the surface drains.

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Table 1. Results of inorganic analyses conducted on Salton Sea piscivorous bird eggs (g/g dry weight).

Analyte	Species	Year	Location	Geometric Mean	Range
Selenium	Black-crowned Nightheron	1992	Whitewater Delta, Salton Sea	6.18 (N=10)	3.30-7.85
Selenium	White-faced Ibis	1992	Finney Lake, IWA[1]	3.62 (N=5)	3.29-4.28
Selenium	Great Egret	1992	Mallard Road, Wister Unit, IWA	4.95 (N=8)	3.45-6.17
Selenium	Black Skimmer	1992	Salton Sea	5.87 (N=5)	5.71-6.24
Selenium	Black Skimmer	1993	Johnson Drain area, Salton Sea	6.01 (N=10)	4.61-7.19
Selenium	Black Skimmer	1993	Mullet Island, Salton Sea	6.78 (N=10)	5.10-8.17
Selenium	Black Skimmer	1993	Obsidian Butte, Salton Sea	6.35 (N=10)	3.59-8.92
Selenium	Black Skimmer	1993	Morton Bay, Salton Sea	4.47 (N=9)	3.25-8.03
Selenium	Caspian Tern	1993	Mullet Island, Salton Sea	2.60 (N=5)	1.40-3.81
Mercury	Black Skimmer	1992	Salton Sea	0.485 (N=5)	0.145-1.03
Mercury	White-faced Ibis	1992	Finney Lake, IWA	0.247 (N=5)[2]	<0.1-1.20

[1] California Department of Fish and Game s Imperial Wildlife Area

[2] There was one non-detect result.

Table 2. Detection frequencies of organochlorine compounds detected at low concentrations in Salton Sea piscivorous birds eggs.

Analyte	**Detection Frequency among Species**	**Detection Frequency among Samples**	**Year with Higher Detection Frequency**	**Range of Group Means (g/g wet weight)**	**Range of Group Maximums (g/g wet weight)**
HCB	4/5	31/91	1992	0.0081-0.10	0.01-0.88
-BHC	5/5	39/91	1992	0.0097-0.022	0.01-0.26
Oxychlordan e	5/5	56/91	1992	0.0081-0.017	0.01-2.5
Heptachlor epoxide	4/5	37/91	1992	0.0087-0.013	0.01-0.06
Endrin	3/5	25/91	1992	0.022-0.033	0.01-0.06
p,p DDD	3/5	25/91	1992	0.0071-0.018	0.01-0.16
p,p DDT	5/5	33/91	1992	0.016-0.10	0.06-0.88

Table 3. Organochlorine compound concentrations (g/g wet weight) for frequently detected compounds in Salton Sea piscivorous bird eggs.

Analyte	Species[1]	Age[2]	Year	Location	Detection Frequency	Geometric Mean	Range
p,p DDE	BCNH	E	1992	Whitewater Delta, Salton Sea	10/10	6.4	1.1-25
p,p DDE	BCNH	P	1992	Whitewater Delta, Salton Sea	10/10	2.9	1.1-27
p,p DDE	BCNH	C	1992	Whitewater Delta, Salton Sea	10/10	1.3	0.28-22
p,p DDE	WFI	E	1992	Finney Lake, IWA[3]	5/5	11	1.3-23
p,p DDE	GREG	E	1992	Mallard Rd., Wister Unit, IWA	6/6	2.0	0.33-5.9
p,p DDE	BLSK	E	1992	Salton Sea	5/5	11	4.2-26
p,p DDE	BLSK	E	1993	Johnson Drain, Salton Sea	10/10	3.3	2.9-5.0
p,p DDE	BLSK	E	1993	Mullet Island, Salton Sea	10/10	3.1	0.72-9.0
p,p DDE	BLSK	E	1993	Obsidian Butte, Salton Sea	10/10	2.3	0.61-5.9
p,p DDE	BLSK	E	1993	Morton Bay, Salton Sea	10/10	0.90	0.31-2.2
p,p DDE	CATE	E	1993	Mullet Island, Salton Sea	5/5	2.0	1.3-3.7
Dieldrin	BCNH	E	1992	Whitewater Delta, Salton Sea	7/10	0.015	<0.01-0.06
Dieldrin	BCNH	P	1992	Whitewater Delta, Salton Sea	9/10	0.033	<0.01-0.40

Dieldrin	BCNH	C	1992	Whitewater Delta, Salton Sea	10/10	0.020	0.01-0.07
Dieldrin	WFI	E	1992	Finney Lake, IWA	5/5	0.14	0.03-0.26
Dieldrin	GREG	E	1992	Mallard Rd., Wister Unit, IWA	2/6	------	<0.01-0.02
Dieldrin	BLSK	E	1992	Salton Sea	5/5	0.062	0.04-0.09
Dieldrin	BLSK	E	1993	Johnson Drain, Salton Sea	8/10	0.024	<0.01-0.12
Dieldrin	BLSK	E	1993	Mullet Island, Salton Sea	10/10	0.054	0.02-0.12
Dieldrin	BLSK	E	1993	Obsidian Butte, Salton Sea	10/10	0.054	0.02-0.13
Dieldrin	BLSK	E	1993	Morton Bay, Salton Sea	0/10[4]	------	<0.01
Dieldrin	CATE	E	1993	Mullet Island, Salton Sea	0/5[4]	------	<0.01
Trans-nonachlor	BCNH	E	1992	Whitewater Delta, Salton Sea	9/10	0.020	<0.01-0.12
Trans-nonachlor	BCNH	P	1992	Whitewater Delta, Salton Sea	8/10	0.014	<0.01-0.07
Trans-nonachlor	BCNH	C	1992	Whitewater Delta, Salton Sea	3/10	------	<0.01-0.02
Trans-nonachlor	WFI	E	1992	Finney Lake, IWA	5/5	0.053	0.03-0.08
Trans-nonachlor	GREG	E	1992	Mallard Rd., Wister Unit, IWA	4/6	0.012	<0.01-0.03
Trans-nonachlor	BLSK	E	1992	Salton Sea	5/5	0.024	0.02-0.03
Trans-nonachlor	BLSK	E	1993	Johnson Drain, Salton Sea	10/10	0.011	0.01-0.02

Trans-nonachlor	BLSK	E	1993	Mullet Island, Salton Sea	9/10	0.012	<0.01-0.02
Trans-nonachlor	BLSK	E	1993	Obsidian Butte, Salton Sea	10/10	0.016	0.01-0.06
Trans-nonachlor	BLSK	E	1993	Morton Bay, Salton Sea	1/10[4]	------	<0.01-0.011
Trans-nonachlor	CATE	E	1993	Mullet Island, Salton Sea	3/5[4]	0.012	<0.01-0.029
PCB s	BCNH	E	1992	Whitewater Delta, Salton Sea	8/10	0.44	<0.05-2.7
PCB s	BCNH	P	1992	Whitewater Delta, Salton Sea	8/10	0.31	<0.05-1.6
PCB s	BCNH	C	1992	Whitewater Delta, Salton Sea	3/10	------	<0.05-0.15
PCB s	WFI	E	1992	Finney Lake, IWA	1/5	------	<0.05-0.45
PCB s	GREG	E	1992	Mallard Rd., Wister Unit, IWA	4/6	0.17	<0.05-0.62
PCB s	BLSK	E	1992	Salton Sea	5/5	0.84	0.48-1.6
PCB s	BLSK	E	1993	Johnson Drain, Salton Sea	9/10	0.19	<0.05-0.30
PCB s	BLSK	E	1993	Mullet Island, Salton Sea	5/10	0.069	<0.05-0.49
PCB s	BLSK	E	1993	Obsidian Butte, Salton Sea	3/10	------	<0.05-0.93
PCB s	BLSK	E	1993	Morton Bay, Salton Sea	0/10[5]	------	<0.05
PCB s	CATE	E	1993	Mullet Island, Salton Sea	0/5[5]	------	<0.05

[1] - BCNH = Black-crowned Night-heron, WFI = White-faced Ibis, GREG = Great Egret, BLSK = Black Skimmer, and CATE = Caspian Tern

[2] - E = egg contents, P = pipping embryo, C = 10 day old chick
[3] - California Department of Fish and Game s Imperial Wildlife Area
[4] - There was a change in analysis procedure for dieldrin and trans-nonachlor for these samples.
[5] - These samples were analyzed for PCB-1260 rather than total PCB s as in the other samples.