SAN FRANCISCO ESTUARY INSTITUTE

REGIONAL MONITORING PROGRAM FOR TRACE SUBSTANCES

Cisnet Technical Report: Contaminant Accumulation in Eggs of Double-Crested Cormorants and Song Sparrows in San Pablo Bay

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SUMMARY

The objective of this component of the CISNET San Pablo Bay project was to understand the ecological impacts of chemical stressors upon two bird species with different foraging niches in San Pablo Bay. Double-crested cormorants were studied as an indicator for open water habitat, and song sparrows were monitored as an indicator for tidal marshes. Chemical analysis of eggs was performed to obtain integrative measures of the degree of food web contamination in San Pablo Bay and to investigate the possible effects of this contamination on egg hatchability. This study demonstrated that annual monitoring of avian eggs is a highly effective means of evaluating temporal trends and ecological risk due to persistent, bioaccumulative contaminants in both open water and marsh habitats of the San Pablo Bay ecosystem.

The cormorant egg is an excellent monitoring tool for many persistent bioaccumulative contaminants. PCBs were the only contaminant in cormorant eggs that clearly approached a known threshold for toxic effects. PCB concentrations observed in this study overlapped the lower end of the effects threshold range, with a maximum of 3800 ppb fresh weight observed in a composite sample from 2001. The results from this study indicate that PCB concentrations in San Pablo Bay may be high enough to cause low rates of mortality and deformity in cormorant embryos. Concentrations of DDE in cormorant eggs appear to be just below the threshold for impacts on reproductive success. Embryo mortality due to mercury, selenium, and other measured contaminants appears not to be a concern for cormorants. Concentrations of several contaminants, including PCBs, DDE, and selenium, were significantly higher in 2000 and 2001 than in 1999. Analysis of cormorant eggs in this study has laid an excellent foundation for continued long term trend analysis in this species.

This study also demonstrated the value of chemical analysis of song sparrow eggs as a tool for monitoring contamination in tidal marsh food webs. Song sparrows accumulated measurable concentrations of several priority contaminants, though generally they were lower than concentrations observed in cormorants. An interesting exception to this pattern was selenium, which had higher concentrations in song sparrow

eggs (averaging 3.8 ppm dry) than in cormorant eggs (2.4 ppm dry). None of the measured chemicals measured approached a known threshold for toxic effects in song sparrows. Overall, these results indicate that the tidal marsh food webs that support song sparrows are not contaminated with persistent, bioaccumulative chemicals to a degree that would adversely affect this species. This study demonstrated that it is feasible to collect and perform chemical analysis for a broad suite of analytes in both random and fail-to-hatch eggs of song sparrows. The limited number of song sparrow egg samples collected precluded a detailed evaluation of spatial and temporal patterns.

INTRODUCTION

Toxic contamination is one of the most important anthropogenic stressors in the San Pablo Bay ecosystem. Data collected by the Regional Monitoring Program for Trace Substances in the San Francisco Estuary (RMP) (SFEI 2002) and in other studies suggest that toxic contaminant concentrations in the San Pablo Bay ecosystem are high enough to cause adverse effects on biota. Contaminants of particular concern in this region are mercury, selenium, and polychlorinated biphenyls (PCBs) (Urquhart and Regalado 1991, Davis 1997, Schwarzbach et al. 1997, Schwarzbach and Adelsbach 2002). Each of these contaminants accumulates to high concentrations at the top of the food web and causes embryotoxicity. Embryos of birds are considered among the most sensitive life stages to the adverse effects of each of these contaminants (Schwarzbach and Adelsbach 2002). Eggs of locally breeding birds are therefore the first place to look for accumulation and possible effects of these persistent toxic contaminants in the San Pablo Bay region.

The objective of this component of the CISNET San Pablo Bay project was to understand the ecological impacts of chemical stressors upon two bird species with different foraging niches in San Pablo Bay. Chemical analysis of eggs was performed to obtain integrative measures of the degree of food web contamination in San Pablo Bay and to investigate the possible effects of this contamination on egg hatchability. This study demonstrated that annual monitoring of avian eggs is a highly effective means of evaluating temporal trends and ecological risk due to persistent, bioaccumulative contaminants in both open water and marsh habitats of the San Pablo Bay ecosystem.

The two bird species studied were double-crested cormorants (*Phalacrocorax auritus*) and song sparrows (*Melospiza melodia*). Double-crested cormorants were studied as an indicator for the open waters of San Pablo Bay. Reproductive performance and PCB accumulation and effects have been previously studied in a cormorant colony in San Pablo Bay (Davis 1997, Stenzel et al. 1991). Cormorants in this colony eat fish from San Pablo Bay and are resident in the Bay year round. In a study performed in 1995, PCB concentrations in eggs from this colony were correlated with reduced egg mass, reduced spleen mass, and induced cytochrome P450 and appeared to be above the threshold for causing embryomortality (Davis et al. 1997). Prior to the present study, mercury and selenium had not been studied in these birds.

Song sparrows were monitored as an indicator for the ecological condition of marshes in the San Pablo Bay ecosystem. Song sparrows have small home ranges (less than 1 hectare) within the marshes. Song sparrows primarily consume insects associated with marsh vegetation. Prior to the present study, no sampling of contaminants in song sparrows had been performed in the Bay region, and few data on contaminants in marsh birds of the region were available in general.

For this project contaminants measured by the RMP that accumulate in bird eggs were targeted, including those mentioned above and other trace elements and organochlorine pesticides. Contaminant concentrations were measured in randomly selected eggs and in eggs that failed to hatch in order to investigate the link between contamination and embryomortality. Egg hatchability and reproductive performance of these species were assessed as indicators of the overall condition of the San Pablo Bay ecosystem. This contaminant monitoring was linked with a broader study by Point Reyes Bird Observatory of sparrow reproductive success (Nur et al. xx).

METHODS

A large colony of double-crested cormorants is present on the Richmond-San Rafael Bridge, which crosses San Pablo Bay (Stenzel et al. 1991). The colony was visited biweekly during the breeding season to map nests and track nest contents and incubation status. Eggs were collected in all three years of the project (1999-2001). Cormorant colony visits took place in May and June.

Due to the expense of chemical analysis, compositing strategies were employed. For cormorants, two composites each containing 10 freshly laid eggs, collected at random, were prepared. In addition a composite of 10 eggs that underwent normal incubation but failed to hatch was analyzed to determine whether these eggs have higher contaminant concentrations relative to the composites of randomly selected eggs. Fail-to-hatch eggs were collected in 1999 and 2000.

Song sparrow nests occur in marshes throughout the San Pablo Bay region. For this study, sparrow eggs were collected from three marshes (see Figure xx in Nur et al. 2003). Egg fate in nests was tracked to allow collection of randomly selected, potentially viable eggs and fail-to-hatch eggs. Compositing was performed to provide adequate sample mass for chemical analysis and to obtain information on egg contamination in a cost-effective manner. The number of eggs targeted for each composite was 7. The sampling design called for two composites of random eggs and one of fail-to-hatch eggs from each location. It was not always possible to obtain this many eggs from each location. In the first year, several eggs were lost due to breakage of these fragile specimens after collection. Sample processing methods were modified to prevent breakage in the following years.

Cormorant and sparrow eggs were refrigerated until they were opened using clean techniques in a clean laboratory. Egg mass and volume were measured. Incubation stage of each egg was noted. Egg contents were transferred to clean jars for compositing. Multiple aliquots or each composite sample were prepared for chemical analysis, with extra aliquots archived for possible reanalysis.

Cormorant and sparrow eggs were analyzed for chemical contaminants by RMP subcontractors using methods that have been used in bioaccumulation monitoring in the RMP for the past several years (Davis et al. 2002, Greenfield et al. 2003). Trace elements analyzed included mercury (cold-vapor atomic fluorescence), selenium (hydride generation atomic absorption), arsenic (graphite furnace atomic absorption), and silver, cadmium, chromium, copper, lead, nickel, and zinc (inductively coupled plasma atomic emission or mass spectrometry). Trace organics analyzed included PCBs and organochlorine pesticides (dual column gas chromatography with electron capture detection).

Chemical analyses were performed in adherence to the data quality objectives and other guidelines included in the RMP Quality Assurance Project Plan (Lowe et al. 1999). Quality assurance measures included analysis of duplicates, matrix spikes, and standard reference materials. In general, all data quality objectives were met. The only problems encountered were with the precision of data for several lower priority metals (aluminum, cadmium, chromium, manganese, and silver) due to incomplete mixing of the small amount of sample material available and the low concentrations present. Trace element detection limits for several samples in 2001 were elevated due to the small amount of sample mass. For the organics, the only problem encountered was high recoveries of the PCB 207 used as a surrogate for the PCB congeners. High recoveries of this surrogate were thought to be due to the presence of PCB 207 in the field samples. In other analyses by the organics lab with lower concentrations, recoveries of PCB 207 have historically been very consistent. PCB congener data were not surrogate corrected when the 207 recoveries were high. This problem is not considered to be the cause of the interannual variation observed in the cormorant eggs (see RESULTS AND DISCUSSION).

Chemical concentrations in eggs are presented on a fresh weight basis. Since eggs were collected at various stages of incubation, the fresh weight was estimated based on the egg volume via the method of Stickel et al. (1973).

The complete set of concentration data for cormorant and sparrow eggs is provided in Appendix 1.

RESULTS AND DISCUSSION

Cormorants

Data Summary

Consistent with their high trophic position and the tendency of many contaminants of concern to biomagnify in the food web, cormorants accumulated easily measurable concentrations of several important contaminants. Concentrations of DDE and PCBs were 1000 times higher than their reporting limits. These concentrations were also an order of magnitude or more higher than measured in other biota samples from San Pablo Bay, including song sparrow eggs and fish sampled in this study, and sport fish sampled in the Regional Monitoring Program (Davis et al. 2002). The cormorant egg is an excellent monitoring tool for these contaminants.

Cormorant eggs also contained easily measurable, though lower, concentrations of other organics of concern: dieldrin, chlordanes, and polybrominated diphenyl ethers (PBDEs). Concentrations of these chemicals were 10 to 20 times higher than detection limits. As for DDE and PCBs, the concentrations observed in the eggs were significantly higher than those measured in song sparrow eggs and fish from San Pablo Bay. Eggs of piscivorous birds are excellent indicators of contamination of the Estuary by persistent, hydrophobic organic chemicals in general.

Cormorant eggs had easily measurable concentrations of mercury and selenium, the two trace elements of greatest concern in San Pablo Bay. The concentrations observed, however, were lower than those observed in other biota, so other matrices may be more sensitive indicators for these elements. Leopard shark and striped bass accumulate higher mercury concentrations than those observed in cormorant eggs (Davis et al. 2002). Higher selenium concentrations have been observed in diving duck muscle (J.A. Davis, unpublished), song sparrow eggs (this study), and white sturgeon muscle (SFEI 1999) than were measured in cormorant eggs. While cormorant eggs are valuable for assessing trends in mercury and selenium, the strength of the contamination signal is only moderate. The mercury and selenium concentrations measured in cormorant eggs in this study in 2001 and 2001 (averaging 0.35 ppm fresh and 2.7 ppm dry, respectively) were nearly identical to those measured by Schwarzbach and Adelsbach (2002) in the Bay in 2000 and 2001 (averaging 0.31 ppm fresh and 2.6 ppm dry).

PBDEs are brominated flame retardants that are of growing concern in San Francisco Bay and worldwide due to their increasing use, persistence, and tendency to accumulate in food webs. PBDEs were analyzed in 2001 and detected at substantial concentrations in the cormorant eggs. The most abundant congener, PBDE 47, was detected at an average of 180 ppb fresh in cormorant eggs. This is approximately one-fifth of the average concentration of PCB 153 (820 ppb fresh), the most abundant PCB congener in the eggs. PBDE concentrations are probably increasing in the Bay (She et al. xx); continued monitoring of cormorant eggs will be a valuable tool in assessing this trend.

Possible Effects of Contaminants

PCBs were the only contaminant in cormorant eggs that clearly approached a known threshold for toxic effects. Based on a broad literature review of PCB effects in birds, Hoffman et al. (1996) concluded that total PCB concentrations in the range of 8 to 25 ppm in eggs can lead to decreased hatching success for cormorants, terns, doves, and eagles. Whether this applies to sums of Aroclors or congeners was not specified. Yamashita et al. (1993) found that PCB concentrations (as sum of congeners) at 7 ppm were associated with 25% embryo mortality and deformities in 10% of double-crested cormorant embryos. The rate of deformities increased from 2% to 10% as concentrations increased from 3600 ppb to 7300 ppb. Concentrations observed in this study overlapped the lower end of this range, with a maximum of 3800 ppb observed in a composite sample from 2001 (Figure 1). The results from this study indicate that PCB concentrations in San Pablo Bay may be high enough to cause low rates of mortality and deformity in cormorant embryos. This finding is consistent with the results of an earlier study of PCB effects in San Francisco Bay cormorants (Davis et al. 1997) that found a degree of cytochrome P450 induction in embryos associated with low rates of mortality and deformities in laboratory studies. Composites of fail-to-hatch cormorant eggs were collected in 1999 and 2000, but these composites were not consistently elevated in PCBs compared to the randomly collected eggs; higher concentrations in fail-to-hatch eggs would be expected if PCBs were a primary cause of egg mortality.

Concentrations of DDE in cormorant eggs appear to be just below the threshold for impacts on reproductive success. The lowest concentration of DDE associated with impaired reproduction in double-crested cormorants was reported by Weseloh et al. (1983), who found reduced numbers of young produced per active nest (0.3) associated with colony mean DDE concentrations of 5 ppm fww. Eggshell thinning, a well-known effect of DDE in wild bird populations (Blus 1996), has a much higher threshold (24 ppm fww) associated with sufficient thinning to reduce populations of double-crested cormorants (Gress et al. 1973). The maximum concentration observed in this study was 3.0 ppm fww in a sample from 2001 (Figure 2). Fail-to-hatch cormorant eggs were not consistently elevated in DDE relative to random eggs.

Mercury is a high priority contaminant in San Pablo Bay due to documented contamination of sport fish and certain species of wildlife. Two controlled feeding studies that have established accepted thresholds for evaluating risks associated with mercury in wild bird eggs are Heinz (1979), which found low to moderate effects on hatchability of mallard eggs with 0.8 ppm fww, and Fimreite (1971), which found low hatchability in pheasant eggs with concentrations of 0.5 to 1.5 ppm fww. The sensitivity of double-crested cormorant embryos to mercury exposure has recently been evaluated in egg injection experiments by Heinz (2002), which indicate that double-crested cormorants are less sensitive to mercury than mallards. This suggests that concentrations below 0.8 ppm fww in double-crested cormorants would not be expected to cause embryomortality. The highest concentration observed in a composite sample in this study was 0.38 ppm fww (Figure 3), well below the mallard threshold. Schwarzbach and Adelsbach (2002) also measured mercury in double-crested cormorant eggs from San Francisco Bay in 2000 and 2001. The highest site mean they observed was 0.55 ppm fww, still well below the mallard threshold. They also concluded that embryo mortality due to mercury exposure appears not to be a concern for cormorants. Consistent with this, fail-to-hatch cormorant eggs were not consistently elevated in mercury relative to random eggs.

Food web accumulation of selenium is also a concern in the San Pablo Bay region (Luoma and Presser 2000). USFWS (Beckon et al. 2000) has established guidelines for interpreting the ecological risk associated with concentrations of selenium in various environmental matrices. For avian eggs, risks to sensitive species are not likely for concentrations lower than 6 ppm dry weight. Concentrations between 6 and 10 ppm dry may pose risk to sensitive species. Concentrations above 10 ppm dry weight are more likely to adversely affect a broader range of species, with sensitive species at greater risk. These guidelines are lower than that suggested by Heinz (1996): 3 ppm wet weight, which translates to approximately 15 ppm dry weight in cormorant eggs. The maximum concentration observed in a composite sample of cormorant eggs in this study was 2.9 ppm dry (Figure 4), well below the 6 – 10 ppm range of concern. Schwarzbach and Adelsbach (2002) observed similar concentrations in double-crested cormorant eggs from the Bay region collected in 2000 and 2001, with a mean of 2.6 ppm dry in 8 eggs, and similarly concluded that selenium contamination was not a cause for concern in populations of this species in San Francisco Bay. Fail-to-hatch cormorant eggs were not consistently elevated in selenium relative to random eggs.

None of the other contaminants approached thresholds for toxic effects as compiled in Beyer et al. (1996) or showed a clear pattern of elevation in fail-to-hatch eggs.

Temporal Trends

Concentrations of several contaminants, including PCBs, DDE, and selenium, were significantly higher in 2000 and 2001 than in 1999 (Figures 1, 2, and 4). Mercury concentrations followed the same pattern, but were not significantly different between years (Figure 3). Other metals that do not biomagnify did not show this pattern. A hypothesis that might explain the concurrent increases in several bioaccumulative contaminants is that cormorants shifted to a higher trophic position in 2000 and 2001 relative to 1999. An increase in the actual mass of these contaminants in San Pablo Bay is not likely given the lack of new inputs and the intense mixing of sediment that occurs in this ecosystem (Davis 2003).

Analysis of cormorant eggs in this study has laid an excellent foundation for continued long term trend analysis in this species. Based on this success, the Regional Monitoring Program is continuing this monitoring and expanded it into other regions of San Francisco Bay beginning in 2002.

Song Sparrows

Data Summary

This study also demonstrated the value of chemical analysis of song sparrow eggs as a tool for monitoring contamination in tidal marsh food webs. Song sparrows accumulated measurable concentrations of several priority contaminants, though generally they were lower than concentrations observed in cormorants. Average concentrations of PCBs and DDE were over an order of magnitude higher in cormorants (averaging 2600 ppb fresh and 2300 ppb fresh, respectively), over the three years sampled, than in song sparrows (200 ppb fresh and 120 ppb fresh). Mercury was about 4 times higher in cormorants (0.297 ppm fresh versus 0.067 ppm fresh).

An interesting exception to this pattern was selenium, which had higher concentrations in song sparrow eggs (averaging 3.8 ppm dry) than in cormorant eggs (2.4 ppm dry). Possible explanations for this observation include higher selenium concentrations in the song sparrow food web or interspecific variation in selenium retention and deposition in the egg.

Concentrations of other contaminants in sparrow eggs were either well below known thresholds or not detectable.

Possible Effects of Contaminants

None of the chemicals measured approached a known threshold for toxic effects. Selenium concentrations, while high in song sparrows relative to cormorants, had a mean of 3.8 ppm dry and a maximum of 4.6 ppm dry (Figure 5), while the threshold for effects is 6 ppm dry (Beckon et al. 2000). While this may seem to be close to the concentration of concern, selenium is an essential micronutrient needed for the synthesis of glutathione peroxidase, an important antioxidant enzyme (Luoma and Presser 2000). The margin between required concentrations and toxic concentrations is narrow for selenium. The concentrations observed in song sparrows, therefore, do not appear to be cause for concern.

The egg injection work of Heinz (2002) suggests that some passerines may be quite sensitive to mercury. He found that grackles (*Quiscalus quiscula*) were more much more sensitive to mercury than mallards, with an injected concentration of 0.1 ppm fresh causing significant mortality relative to controls. While this injected concentration does not directly translate to a concentration of 0.1 ppm fresh in an egg from a wild population, the experiment does suggest that some passerines could exhibit adverse effects at concentrations well below the accepted 0.8 ppm fresh mallard threshold. Song sparrow egg mercury concentrations averaged 0.067 ppm fresh, with a maximum of 0.111 ppm fresh (Figure 6).

None of the other contaminants appeared to be anywhere near known thresholds. Passerines are generally considered to be relatively insensitive to the effects of PCBs. In three recent studies, concentrations in tree swallows of approximately 10 ppm were required to cause reduced reproductive success (Custer et al. 1998, Bishop et al. 1999, McCarty and Secord 1999). The average PCB concentration in song sparrows was 0.21 ppm fresh (Figure 7). For DDE, in the most sensitive species studied (brown pelicans), concentrations of 3 ppm fresh are required for effects on eggshell thickness and embryo survival. The average DDE concentration in song sparrows in this study was 0.12 ppm fresh (Figure 8).

Consistent with the sparrow eggs being below known effects thresholds, the fail-to-hatch eggs analyzed were not consistently elevated relative to the randomly collected eggs.

Overall, these results indicate that the tidal marsh food webs that support song sparrows are not contaminated with persistent, bioaccumulative chemicals to a degree that would adversely affect this species. This study demonstrated that it is feasible to collect and perform chemical analysis for a broad suite of analytes in both random and fail-to-hatch eggs of song sparrows. While the marshes studied appear to be relatively clean, in more contaminated marshes song sparrow eggs might reach concentrations that approach levels of concern, particularly for selenium, and possibly mercury as well.

Temporal Trends

Too few samples were collected to allow a robust analysis of interannual trends. However, concentrations of DDE and PCBs in the Petaluma River marsh in 2001 were significantly lower than in other locations sampled in 2000 and 2001 (Figures 7 and 8). If this difference was real, it suggests that the sparrows in the Petaluma River marsh shifted trophic position or otherwise shifted to less contaminated prey in 2001. A sudden, simultaneous decrease in PCB and DDE concentrations in the marsh is not likely. No other interannual differences were apparent in the dataset.

Spatial Patterns

The small sample size also precluded a robust analysis of spatial patterns. The low concentrations measured at the Petaluma River marsh in 2001, however, again suggested significant spatial variation. Concentrations at the Petaluma River marsh in 2001 were significantly lower than those measured at China Camp in the same year (Figures 7 and 8). Given the absence of this pattern in 2000, this again suggests that the sparrows in the Petaluma River marsh shifted trophic position or otherwise shifted to less contaminated prey in 2001.

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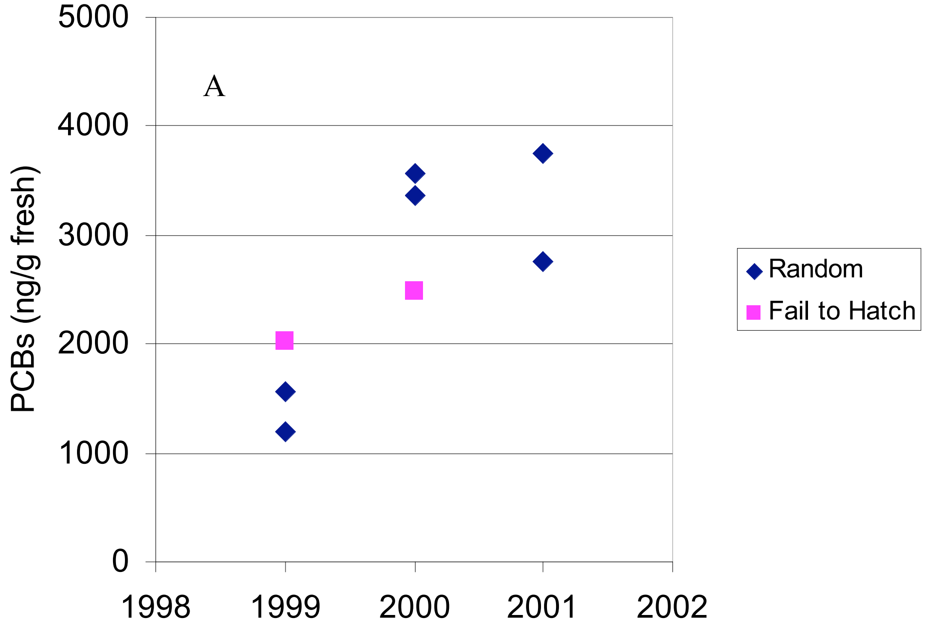
Figure 1. A) PCB concentrations (sum of congeners, ng/g fresh weight) in random and fail-to-hatch cormorant eggs from the Richmond Bridge. Each point represents a composite of 10 eggs. B) The same data, showing means and standard errors.



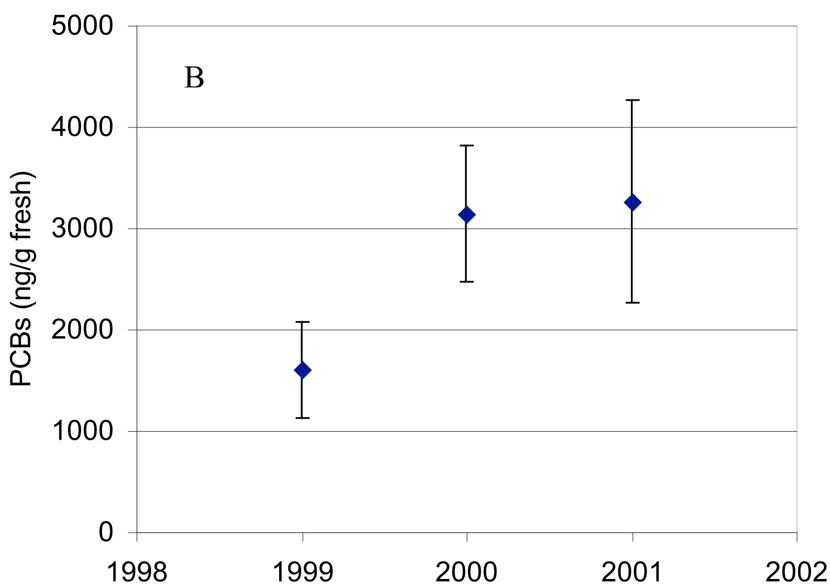


Figure 2. A) p,p'-DDE concentrations (ng/g fresh weight) in random and fail-to-hatch cormorant eggs from the Richmond Bridge. Each point represents a composite of 10 eggs. B) The same data, showing means and standard errors.

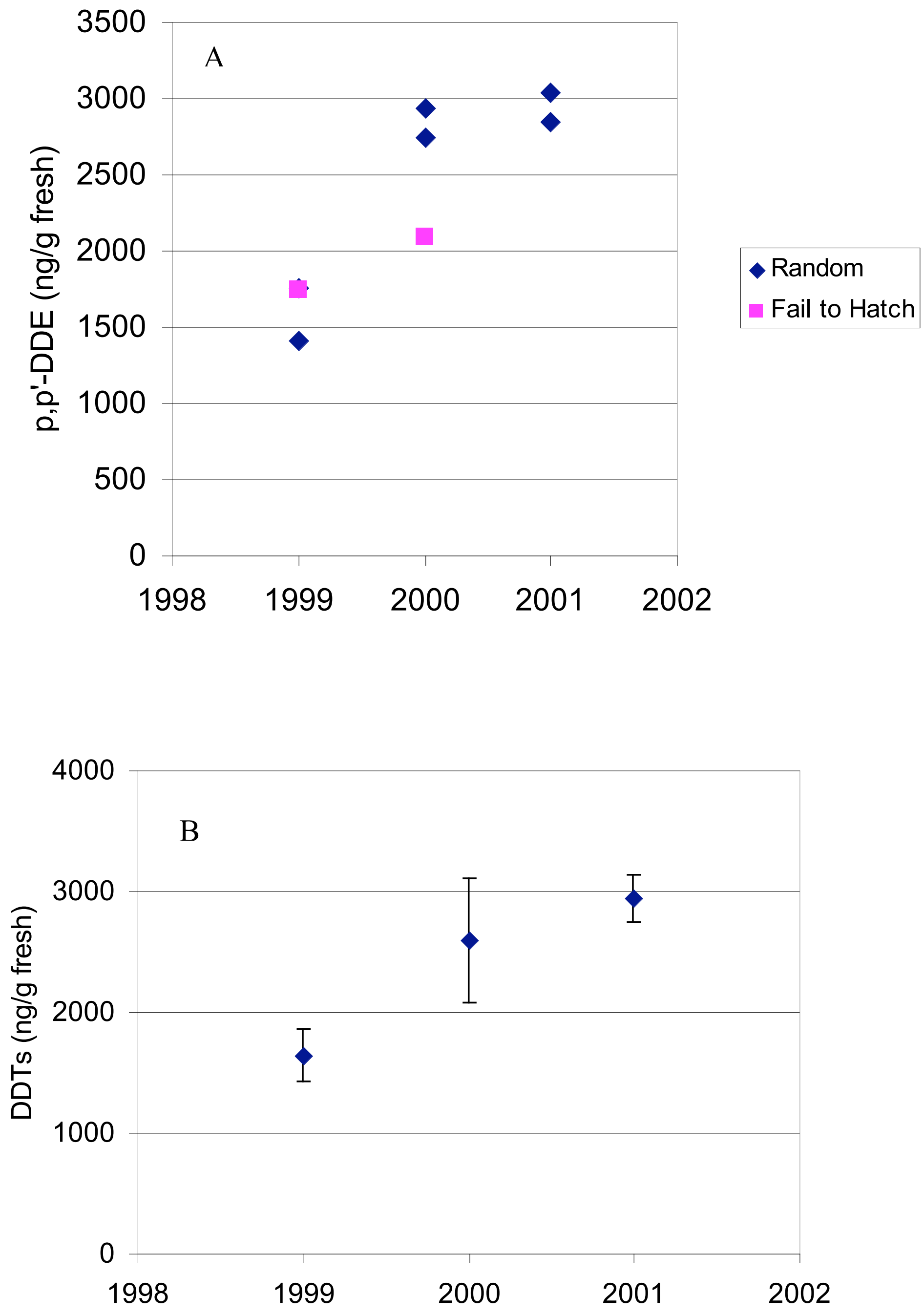
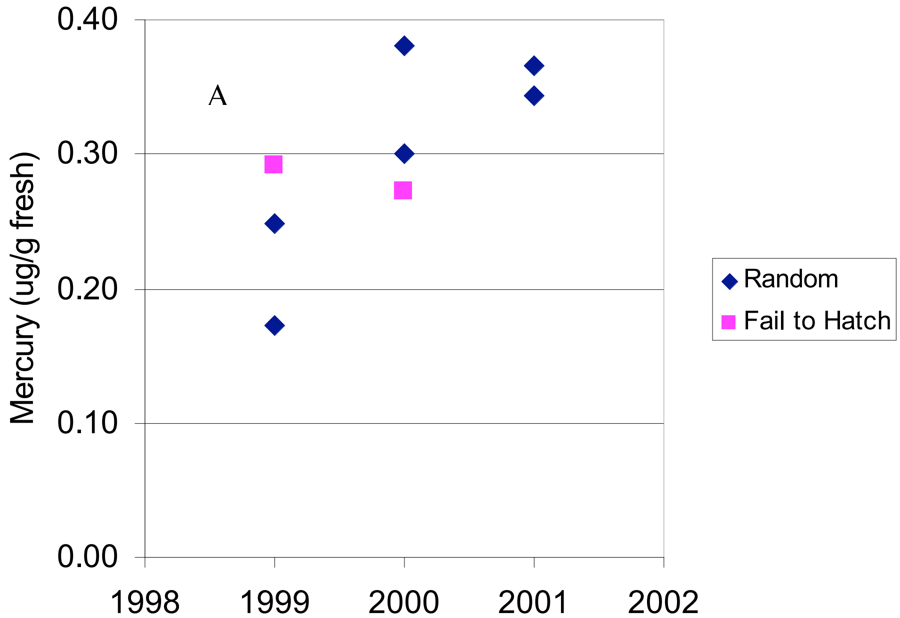


Figure 3. Mercury concentrations (ug/g fresh weight) in random and fail-to-hatch cormorant eggs from the Richmond Bridge. Each point represents a composite of 10 eggs. B) The same data, showing means and standard errors.



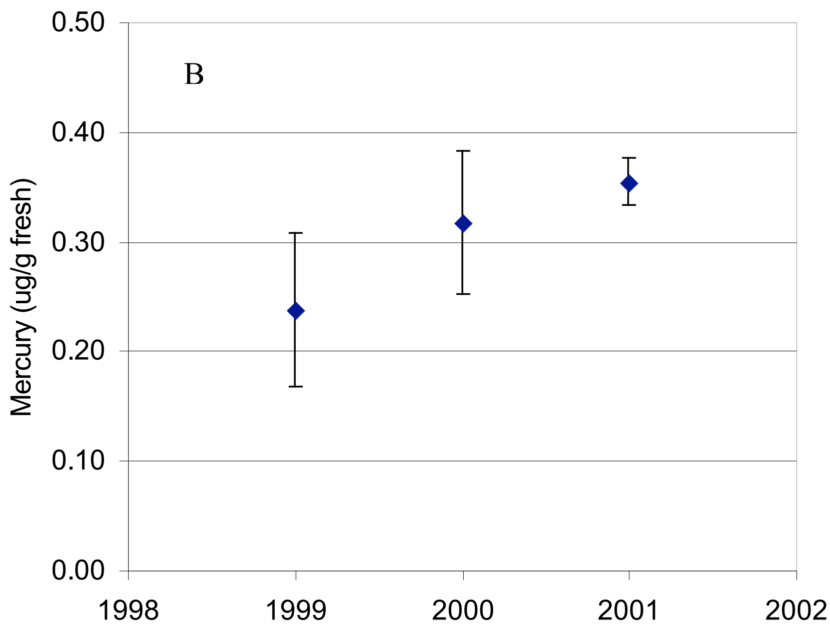
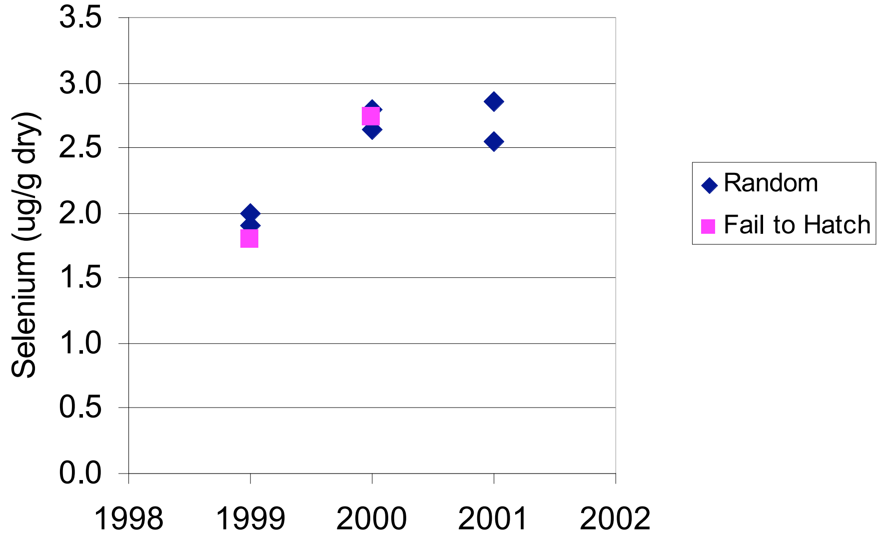


Figure 4. Selenium concentrations (ug/g dry weight) in cormorant eggs from the Richmond Bridge. Each point represents a composite of 10 eggs. B) The same data, showing means and standard errors.



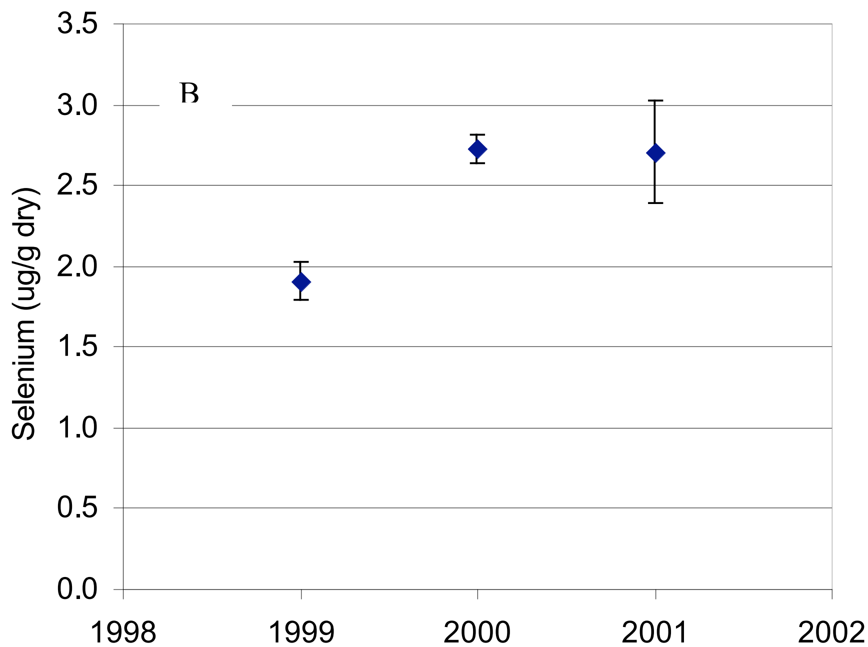


Figure 5. Selenium concentrations (µg/g dry weight) in song sparrow eggs from San Pablo Bay tidal marshes. Each bar represents a mean of replicate composites of multiple eggs (see Table 1). Error bars indicate 95% confidence intervals of the means. Random and fail-to-hatch composites showed no differences and were both included in the means.

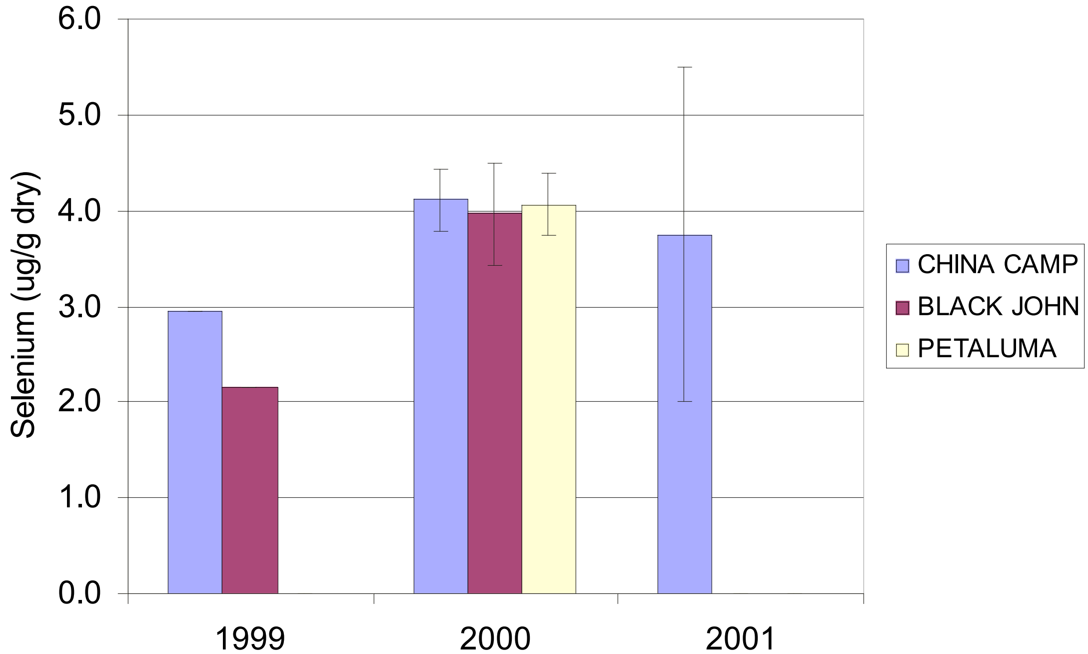


Figure 6. Mercury concentrations (µg/g fresh weight) in song sparrow eggs from San Pablo Bay tidal marshes. Each bar represents a mean of replicate composites of multiple eggs (see Table 1). Error bars indicate 95% confidence intervals of the means. Random and fail-to-hatch composites showed no differences and were both included in the means.

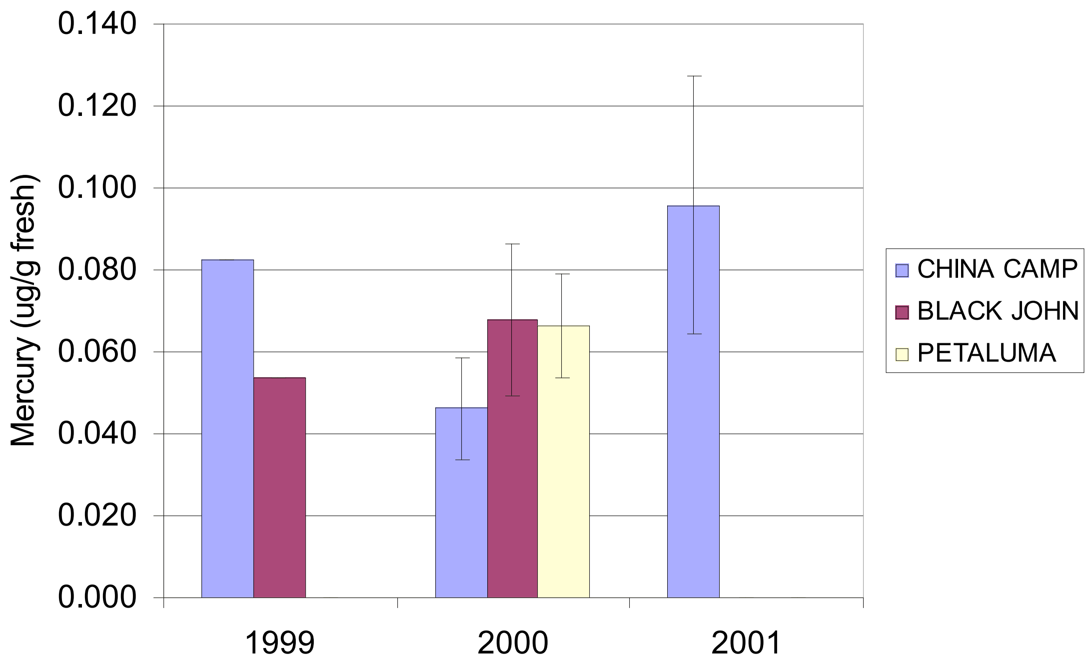


Figure 7. PCB concentrations (sum of congeners, ng/g fresh weight) in song sparrow eggs from San Pablo Bay tidal marshes. Each bar represents a mean of replicate composites of multiple eggs (see Table 1). Error bars indicate 95% confidence intervals of the means. Random and fail-to-hatch composites showed no differences and were both included in the means.

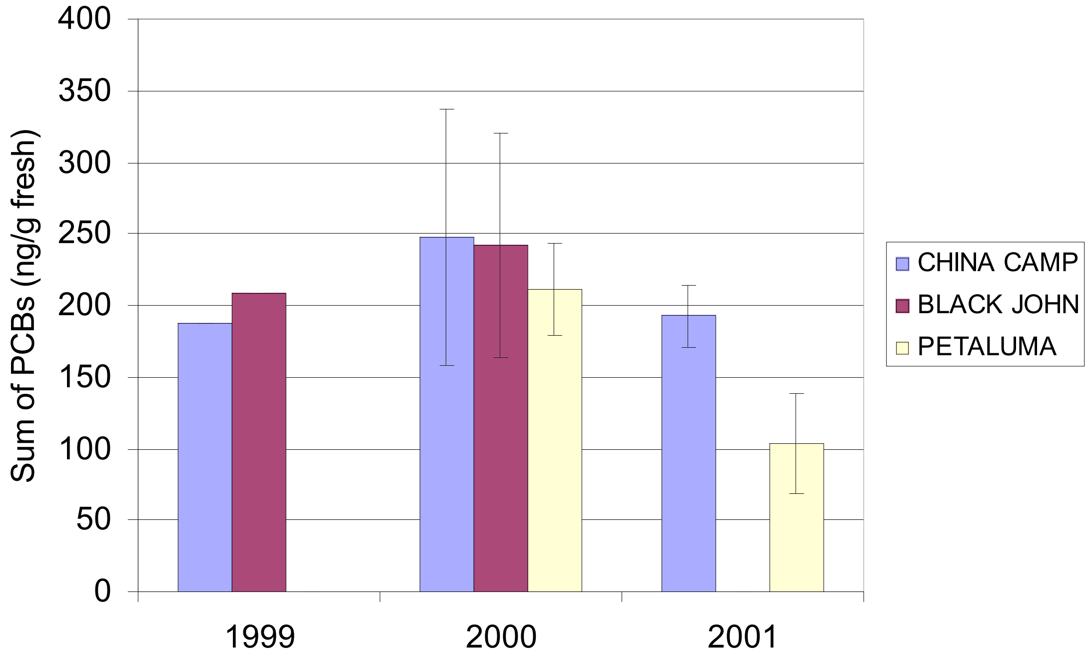
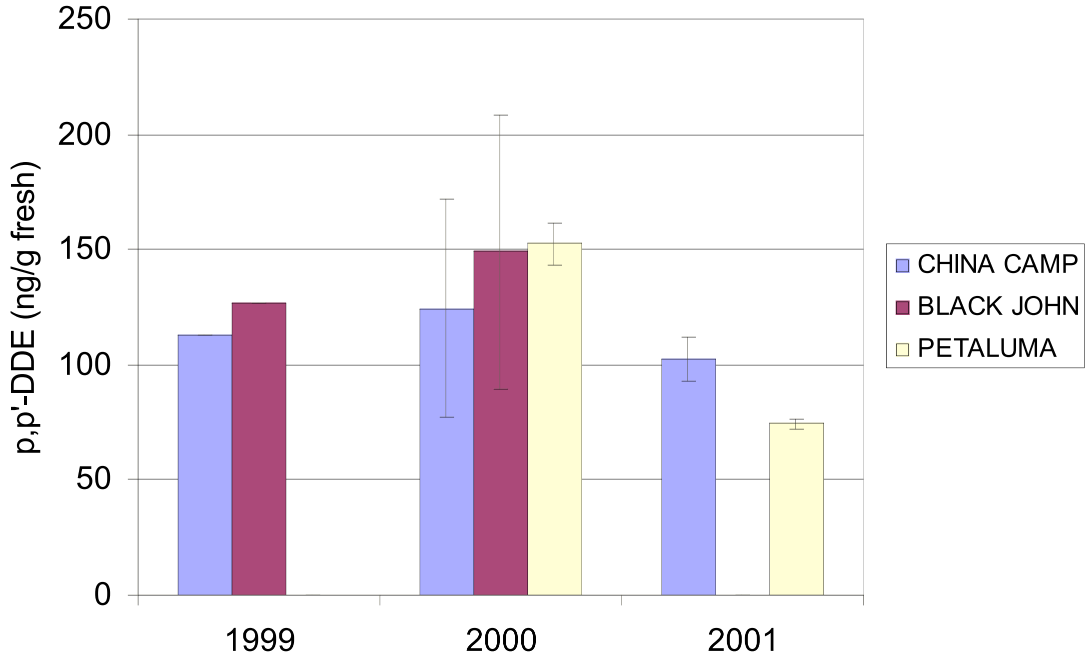


Figure 8. p,p'-DDE concentrations (ng/g fresh weight) in song sparrow eggs from San Pablo Bay tidal marshes. Each bar represents a mean of replicate composites of multiple eggs (see Table 1). Error bars indicate 95% confidence intervals of the means. Random and fail-to-hatch composites showed no differences and were both included in the means.



Appendix 1 Ancillary (fresh weight corrected except for Wet Weight) CISNet egg data, 1999-2001.

NA = not analyzed/not available.

Station Code	Station	Date	Cruise	Species	Egg Type	# Homogenized	% Lipids - ORG	% Moisture - ORG	% Moisture - TE	Wet Weight
							%	%	%	g
RB99A	Richmond Bridge	May-99	1999	Double-Crested Cormorant	RANDOM	10	4.6	85.2	85.3	6.1
RB99B	Richmond Bridge	May-99	1999	Double-Crested Cormorant	RANDOM	10	4.6	85.3	85.1	6.2
RB99C	Richmond Bridge	May-99	1999	Double-Crested Cormorant	FAIL-TO-HATCH	9	3.7	86.4	86.1	5.1
CHINAC	China Camp	March - July 1999	1999	Samuels Song Sparrow	RANDOM	3	8.7	NA	86.3	2.2
BJOHN	Black John's Slough	March - July 1999	1999	Samuels Song Sparrow	RANDOM	7	5.0	85.8	86.4	5.1
RBV1	Richmond Bridge	May-00	2000	Double-Crested Cormorant	RANDOM	10	4.8	NA	86.2	5
RBV2	Richmond Bridge	May-00	2000	Double-Crested Cormorant	RANDOM	10	5.4	NA	85.4	5
RBN1	Richmond Bridge	May-00	2000	Double-Crested Cormorant	FAIL-TO-HATCH	10	4.2	NA	86.7	5
CCAV1	China Camp	March - July 2000	2000	Samuels Song Sparrow	RANDOM	6	5.3	NA	84.2	4.5
CCAV2	China Camp	March - July 2000	2000	Samuels Song Sparrow	RANDOM	5	5.5	NA	85.1	4.5
CCAN1	China Camp	March - July 2000	2000	Samuels Song Sparrow	FAIL-TO-HATCH	3	5.4	NA	87.0	2.5
BJAV1	Black John's Slough	March - July 2000	2000	Samuels Song Sparrow	RANDOM	6	4.8	NA	86.2	4.5
BJAV2	Black John's Slough	March - July 2000	2000	Samuels Song Sparrow	RANDOM	6	3.2	NA	85.8	4
BJAN1	Black John's Slough	March - July 2000	2000	Samuels Song Sparrow	FAIL-TO-HATCH	6	5.9	NA	83.6	4
RMAV1	Petaluma River Mouth	March - July 2000	2000	Samuels Song Sparrow	RANDOM	6	6.2	NA	84.2	4
RMAV2	Petaluma River Mouth	March - July 2000	2000	Samuels Song Sparrow	RANDOM	8	6.2	NA	83.7	4
RMAN1	Petaluma River Mouth	March - July 2000	2000	Samuels Song Sparrow	FAIL-TO-HATCH	7	5.2	NA	85.5	4
RBV1A/B	Richmond Bridge	May-01	2001	Double-Crested Cormorant	RANDOM	10	4.7	85.0	85.0	10.1
RBV2A/B	Richmond Bridge	May-01	2001	Double-Crested Cormorant	RANDOM	10	4.0	85.1	85.1	10.1
CCAV1	China Camp	March - July 2001	2001	Samuels Song Sparrow	RANDOM	7	5.3	NA	85.2	10.2
CCBV1	China Camp	March - July 2001	2001	Samuels Song Sparrow	RANDOM	6	5.1	NA	85.5	8.0
CCAN1	China Camp	March - July 2001	2001	Samuels Song Sparrow	FAIL-TO-HATCH	4	4.9	NA	NA	4.4
RMAV1	Petaluma River Mouth	March - July 2001	2001	Samuels Song Sparrow	RANDOM	6	4.1	NA	85.5	8.7
RMAN1	Petaluma River Mouth	March - July 2001	2001	Samuels Song Sparrow	FAIL-TO-HATCH	4	6.0	NA	85.3	5.8