Chemical Residues in Cormorants from New York Harbor and Control Location

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50 Wolf Road

Albany, NY 12233-4756

Prepared by:

Katharine C. Parsons, Ph.D.

Manomet Center for Conservation Sciences

Manomet, MA 02345-1770

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1. INTRODUCTION

The Double-crested Cormorant (*Phalacrocorax auritus*) is at the top of the New York-New Jersey Harbor estuary aquatic food web, and, as a result, may be one species most highly affected by chemical contaminant exposures. Double-crested Cormorants normally contain the greatest concentrations of chemical contaminants among several waterbirds tested in the Great Lakes (Weseloh et al. 1995) although fish-eating mergansers were not examined. Cormorant populations underwent a major decline in population nationwide following the introduction of DDT in 1946 and was likely one of the first bird species to be substantially impacted by this contaminant. Analysis of egg tissues determined that DDT contamination was associated with cormorant reproductive failures in California (Gress et al. 1972) and Lake Huron (Weseloh et al. 1983) in the 1960s and 1970s. The weight of nesting birds crushed the eggs due to egg-shell thinning caused by excessive DDT concentrations. Egg concentrations of DDT residues ranged from 24-32 ug/g and were associated with 11-30% thinning of egg shells.

On other Great Lakes, the combination of PCB and dioxins has produced reproductive failures and congenital anomalies of cormorant colonies, particularly for Lake Ontario and in Green Bay, Lake Michigan. Price and Weseloh (1986) noted complete reproductive failures of cormorants in Canadian waters of Lake Ontario between 1954 and 1977. Since 1977, the breeding population has been reestablished and there has been a marked expansion of the populations (Price and Weseloh 1986, Weseloh 1995). For Lake Ontario, the number of cormorant nests expanded from less than 100 in 1979 to over 10,000 in 1993, and the expansion is consistent with declining concentrations of DDT, PCB and dioxins. Similar declines in DDT, PCBs and dioxins have been associated with increasing reproductive success, and population expansion, in cormorants for the other Great Lakes (Ludwig 1984, Weseloh et al. 1986, Weseloh et al. 1988, Weseloh 1995).

Tillitt et al. (1992) and Yamashita et al. (1993) have suggested causative concentrations of PCB or planar PCB expressed as H4IIE rat hepatoma cell bioassay derived 2,3,7,8-TCDD equivalents, and 2,3,7,8-TCDD which can be associated with specific rates of Double-crested Cormorant embryo mortality. Other investigators have provided similar concentration-effect relationships for other species of waterbirds. For species common to the harbor estuary, sample citations are Gilbertson et al. (1991) and Norstrom et al. (1982) for Herring Gulls (*Larus argentatus*), and Hoffman et al. (1993) for Black-crowned Night-Herons (*Nycticorax nycticorax*) and Common Terns (*Sterna hirundo*).

Despite the resurgence of Double-crested Cormorant populations, bill deformities, and occasionally other hatching anomalies, still persist in cormorant populations, particularly for Green Bay, Lake Michigan (Fox et al. 1991a). In relatively uncontaminated populations of cormorants, bill anomalies are present at rates of less than 2 per 10,000 chicks. Chicks from Green Bay had a bill anomaly rate of 52 per 10,000 chicks whereas colonies from Lake Michigan and three of the other four Great Lakes had bill anomaly rates ranging from 2.4 to 12.3 chicks per 10,000 chicks. Green Bay has a mix of chemical contaminants including PCB and dioxins (Heinz et al. 1985, Stalling et al. 1985). The bill anomalies appear to be associated with three of the more toxic non-ortho PCB congeners and possibly 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) (Fox et al. 1991a). The organic chemical mix at Green Bay is similar to that found in New York-New Jersey Harbor estuary fish (Skinner et al. 1996, 1997).

Given the sensitivity of this species to organochlorine contaminants in the food web, the cormorant is a key ecosystem indicator for the Great Lakes (Fox et al. 1991a, 1991b), and should be equally an indicator of ecosystem health in the harbor estuary. Breeding colonies of Double-crested Cormorants are present at several sites within the harbor estuary, including Swinburne Island and Shooters Island (Parsons et al. 1991). These colonies are logical sites for the assessment of chemical residues in eggs of cormorants or the evaluation of bill deformities in young cormorants. Cormorants within the basin are known to feed on harbor estuary fish during their breeding and rearing seasons; some birds are resident throughout the year.

Although they have maintained a nesting population in the New York Harbor estuary, cormorants in the estuary have experienced less than optimum reproductive success (Parsons 1994), and occurrence of deformed chicks has been documented during contaminants studies in the 1990s (Parsons, unpublished data). PCB, particularly the coplanar dioxin-like congeners, dioxins and DDE are suspected to be the main causes of historical lowered reproduction and fitness of cormorants nesting in the harbor estuary, as they were in Great Lakes populations of cormorants. Cormorant populations in the harbor estuary have remained stable in recent years although other populations on or around Long Island have been increasing in size since 1985 (Sommers et al. 1996). This observation suggests that contaminants may be adversely affecting reproduction, or that some other factors are contributing to less than optimal reproductive success.

No information is available on current levels of persistent toxic contaminants present in tissues of harbor estuary cormorant populations. The USFWS (Cortland, NY office) conducted sampling of cormorant eggs and blood in 1995 but analytical results and findings are not yet available. As the top predator in the basin ecosystem, cormorant populations may be expected to have the greatest body burdens of persistent bioaccumulative toxic substances such as PCB, dioxins, DDE and chlordane. For this study, chemical analyses of eggs, and blood, down and feathers collected from young pre-fledging birds.

Objectives of this study are: 1) measure concentrations of bioaccumulative chemical compounds in Double-crested Cormorant eggs, blood, and feathers to determine whether chemical contaminants are present at levels of concern; 2) provide baseline information on current levels of toxic substances present in New York-New Jersey Harbor estuary cormorant populations which may be used in tracking long term contaminant trends; 3) assess the feasibility and potential benefit of developing a long term cormorant monitoring project to assist in the evaluation of harbor estuary ecosystem health; and 4) assess and compare the potential impact of chemical contaminants on reproductive success and bill deformities in Double-crested Cormorant populations.

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2. FIELD AND LABORATORY METHODS

STUDY SITES

Shooters Island (SH; 40° 38' N, 74° 09' W; Richmond County, New York; Hudson and Union Counties, New Jersey) is a 15 ha island located at the confluence of Newark Bay and Arthur Kill and Kill Van Kull channels in New York Harbor. It is currently owned by the City of New York and the City of Bayonne. Double-crested Cormorants first nested on Shooters in 1990 (66 birds). By 1993, cormorant numbers peaked at 280 (NYSDEC 1994), but declined to approximately 200 birds by the mid 1990s (Parsons 1997).

Shooters Island was accessed by boat from the Elizabeth Marina in Elizabeth, New Jersey. In 1999 the entire cormorant colony nested on an abandoned dry dock tower just west of the island at a height of approximately 11 m. An extension ladder and climbing equipment were necessary to access the nests. Approximately five securing stations were set up along the structure to secure the ladder. Due to researcher safety concerns, nests were chosen for monitoring based on accessibility from the ladder. Numbered metal tags were placed on reachable nests for identification purposes. We determined reproductive endpoints in a total of 61 nests; 20 of those nests were chosen for sample collection. Approximately 75% of all nests on the dry dock were studied. Nest contents were inspected by hand or with a pole and attached mirror.

Swinburne Island (SW; 40° 34' N 74° 03’ W; Richmond County, New York) is a 4 ha island located in the lower bay of New York Harbor. It is a saltwater non-barrier Island owned and managed by the National Park Service. In 1989, two cormorants were first observed nesting on the island. By 1998 cormorant numbers had increased to 35-40 pairs (P. Kerliner, pers. comm.).

Access to Swinburne Island involved a 7 km boat trip from Great Kills, Staten Island. Landing on the island required the use of a canoe when a shallow boat was not available. In 1999, cormorants nested in six trees on the island. Nests were chosen based on accessibility from the ladder. Trees were numbered and each nest tagged with orange flagging and numbered uniquely. We determined reproductive endpoints in a total of 40 nests; 20 of those nests were chosen for sample collection.

Gardiners Island is located in Long Island Sound off the eastern tip of Long Island (GA; 41° 06' N; 72° 07' W; Suffolk County, New York). It is a 1,000 ha privately owned non-barrier island. Records of cormorants nesting on Gardiners Island date back to 1985 when 420 individuals were recorded. The population steadily increased to a total of 3000 individuals in 1993 (NYSDEC 1994). Subsequent years place the numbers around 1000-2000 pairs (M. Scheibel, pers. comm.).

In 1999, the cormorant colony on Gardiners spanned two small peninsulas, an islet and upland trees. Birds nested both in the trees and on the ground. Accessible study nests were randomly chosen in trees and at ground level. We determined reproductive endpoints in a total of 50 nests; 20 of those nests were chosen for sample collection.

Cormorant Productivity

We determined productivity of Double-crested Cormorants by following the success of marked nests. Colonies were not visited or visits were terminated when it rained, when wind speed was greater than 8 m/s, or when ambient temperatures were above 38°C or below 13°C.

Nests were visited approximately weekly with the greatest interval between nest checks spanning18 days (due to inclement weather). Because of the nesting configuration of the birds at Shooters and Swinburne Islands, the visitation schedule included short, multiple visits to the colony in order to minimize disturbance. Visits were also limited to morning hours to prevent young from overexposure to heat and cold stress. During nest checks and sample collections at Gardiners Island, we followed regular paths through the colony and did not return to a section of the colony within 1 hr of passing through.

Nest contents were recorded at each visit. In general, information was obtained during laying, incubation, hatching, and nestling periods at each visit. Eggs were marked with a unique symbol as they were laid using a non-toxic marker. Nestlings were banded with size 9 numbered poultry bands at approximately 2 weeks of age in order to identify individuals after they left the nest. At approximately 3 weeks of age, cormorant nestlings are capable of leaving the nest, but not capable of flight, and will form creches with young from other nests (Hatch and Weseloh, 1999). A US Fish and Wildlife Service band size 8 was placed on the tarsus when chicks were approximately 3 weeks old (or between 1000-1500 grams) when the tarsus was large enough to hold a band. Banding coincided with blood sampling. The condition of nestlings in accessible nests was recorded at each visit. Nestling mortality factors were assessed as possible. During sequential nest visits, eggs and young known to have died were documented as either present in or around the nest, or missing. Dead offspring available for examination were assessed for obvious signs of predation (broken eggs, contents at least partially removed; nestlings with severe trauma) and inviability/starvation (intact eggs failing to hatch; intact nestlings usually found dead in the nest). Missing offspring were presumed to have been taken by a predator.

Collection of Specimens for Chemical Analysis

Equipment used for collecting samples was prepared at Waquoit Bay National Estuarine Research Reserve Laboratory in Waquoit, Massachusetts. All sample preparation work was conducted under a chemical hood. Acetone (Certified ACS, Fisher Scientific, Pittsburgh, PA) and hexane (Certified ACS, Fisher Scientific, Pittsburgh, PA) were dispensed into separate Teflon wash bottles to rinse equipment. Dull sides of squares of aluminum foil were rinsed, and excess chemicals ran off into a waste jar through a glass funnel. This procedure was repeated with hexane. The foil squares were air-dried (<5 min.) and folded with the rinsed side in for storage. Rinsed foils were then wrapped in a rinsed foil outerwrap and placed into a Ziploc® bag.

Eggs

Stainless steel instruments for egg contents extraction were prepared by holding instruments over the funnel and pipetting acetone and hexane over the instruments. Instruments were allowed to air dry and then stored in rinsed aluminum foil. ICHEM jars (300 series, Nalge Company, New Castle, DE) are already chemically clean, and did not need preparation.

Egg Collection. One intact, newly laid egg was collected from the selected study nests in each colony. Samples for each island were SH=16; SW=13; GA=15. Fresh eggs minimize variability in concentrations of contaminants, lipid, and moisture associated with egg development. Eggs lose moisture during incubation, affecting concentrations of egg constituents (Stickel et al. 1973). Eggs were considered fresh when they floated upright in fresh water.

In the field, eggs were wrapped in acetone and hexane rinsed aluminum foil and labeled with the date, nest number, and colony. Wrapped eggs were placed in individual plastic labeled Ziploc® bags. Eggs were transported to the laboratory on ice in a cooler with a foam insert with egg-sized holes cut in the foam to cradle the eggs. Eggs were stored (< 48 hr) in a refrigerator (4°C) until processed.

Egg Processing. After egg collection in the field, eggs were processed at The College of Staten Island of The City University of New York (Staten Island, New York) Laboratory. An Ainsworth model 300 balance (Denver Instruments, Arvada CO) was plugged in and allowed to adjust 1 ½ to 2 hours before calibrating. It was then calibrated with a 200g calibration weight (ASTM Class2, Denver Instruments) before measurements were taken. If debris was present on the egg, it was rinsed in cool water while gently scrubbing. Care was taken not to allow eggs to soak in water. Eggs were then dried with a paper towel.

Egg Measurements. Total egg weight (to 0.01 g) was measured. Three measurements each of egg length and maximum egg width were taken with metal, acetone-hexane rinsed calipers (to 0.01 mm). We computed the average of three measurements for a final measurement. Total egg volume was measured by water displacement. A clean, dry beaker was tared and an immersion chamber filled with demineralized water. Water level was calibrated with the wire loops in the water chamber. The egg was immersed in the chamber with acetone-hexane rinsed wire loops until the top of the egg was just at the water surface. The beaker and water were weighed, and the tared beaker weight was subtracted for the egg contents weight. To calculate egg volume, we assumed that the egg contents were the same density as water. We obtained two measurements with this method and averaged them. Only two measurements were taken in order to minimize time the eggs spent in the water.

Egg Contents Extraction. ICHEM jars were tared with a completed label and no lid. The jars were placed in the center of the square of aluminum foil with edges turned up. This precaution was used in case egg contents should spill outside of the jar. Eggs were scored at the equator with an acetone-hexane rinsed hacksaw blade to cut the shell. Prior to use, hacksaw blades were pre-soaked in acetone. Once the shell was cut, eggshell membranes were cut through with an acetone-hexane rinsed scalpel, and egg contents were poured and gently scraped into the chemically clean jar. The membranes were left intact within the shell. The weight of the egg contents was measured along with the jar and completed label (no lid), and the tare weight was subtracted to compute egg contents weight.

If the egg was developed despite selecting for fresh eggs in the field, the age of embryo was estimated (Powell et. al. 1998) and the embryo was examined for gross deformities. Using a dissecting scope, the embryo was examined for particular bill deformities such as crossed bills or lack of jaws, but also lack of skull bones, clubfeet, rotated ankles, or dwarfed appendages (Gilbertson et al. 1991).

ICHEM jars have a chemically cleaned Teflon-lined lid. The lid was used as a primary seal, then Teflon tape was placed around the lid and jar junction and the end was sealed with chain of custody security tape. Contents were stored frozen at –18°C until shipment overnight on dry ice to the analytical laboratory. Chain of Custody forms and Fish/Wildlife Collection records accompanied samples in shipment.

Measurement of Eggshell Thickness. Eggshells were rinsed gently with cool water and allowed to dry inverted on paper towels. Each shell half was then labeled with permanent marker (year, colony name, and nest number). Shells were allowed to dry for 4.5 – 5 months. Eggshell thickness of both membranes and shell was measured to 0.01 mm with a micrometer (No. 1010, Starrett, Athol, MA). We measured four random points near the equator and averaged these measurements for final eggshell thickness. Weight of dry shells (to 0.001 g) was determined (Ainsworth 300, Denver Instrument, Arvada, CO).

BLOOD

Glass syringes and pipettes (for plasma transfer) were prepared at Waquoit Bay National Estuarine Research Reserve Laboratory in Waquoit, Massachusetts. Acetone, then hexane, was squirted into pipettes and the excess was allowed to run into waste jars. Needles and Vacutainer® tubes (Becton and Dickinson, Franklin Lakes, NJ) were not rinsed since they must remain sterile and may have additives.

Blood samples were taken from cormorant chicks at 3 weeks of age. Chicks were weighed to the nearest 25g using a 1kg or 2.5 kg Pesola® (Switzerland) scale. Tarsus and culmen length were measured with dial calipers. The puncture site on the jugular vein was cleaned with a sterile alcohol swab. The brachial vein was used if difficulty was encountered in obtaining blood from the jugular vein. A hub of sodium heparin (Elkins-Sinn, Inc. Cherry Hill, N. J.) was drawn into a glass syringe fitted with a 23g needle. This needle was then discarded, and a new needle placed on the glass syringe. In keeping with humane practices (Gaunt and Oring 1997), no more than 1% body weight of a bird (up to 10 ml) was collected. A sample of 1.5 – 2.0 ml blood was placed in a non-additive added royal blue topped Vacutainer® for metals analysis and the remainder of blood, approximately 7 ml was placed into a 100 U.S.P. unit sodium heparin green-topped Vacutainer® tube (Becton and Dickinson, Franklin Lakes, NJ). The Vacutainer® tops were removed and samples placed directly into the tubes. The samples were mixed by rolling the tubes between the fingers, and care was taken to avoid inverting the tubes. Tubes were then placed upright on ice for transport to field housing.

Blood Processing. Blood samples were processed the same day of collection. Heparinized blood samples (green-topped Vacutainer® tube) were spun at 1200rpm for 10 minutes in an IEC HN-SII Benchtop Centrifuge with swinging buckets (Fisher Scientific, Pittsburgh, PA). Plasma was removed with an acetone-hexane rinsed pipette. Notations were made if the sample was lipemic or if hemolysis occurred. Plasma was decanted into another green-topped tube for storage at –18°C in a locked freezer (general lab freezer set at –18°C, REVCO, Asheville, NC). Blue-topped Vacutainer® tubes were not spun, as whole blood was needed for metals analysis. The tops of both blue and green Vacutainer® tubes were wrapped with Teflon tape and a masking tape security seal placed over loose ends. For samples previous to 1 July 1999, this tape was put in place after samples were frozen. In samples after 1 July 1999, this sealing method was employed at the time of sample processing prior to freezing. Samples were shipped overnight Federal Express on dry ice to the Hale Creek Field Station for storage, sample preparation and shipment to the contract laboratory. Chain of Custody forms and Fish/Wildlife Collection records accompanied samples in shipment.

Feathers

At three weeks of age when chicks were sampled for blood, both down and secondary feathers were collected for metals analysis. Because breast feathers were not present at age of blood sampling and secondary flight feathers were not fully developed, down and secondary feathers were sampled. Post-natal down (1 g) was collected from the breast of three week old cormorant chicks with acetone-hexane rinsed scissors. Samples were placed into a Whirl-Pak™(Nasco, Fort Atikinson, WI) bag labeled with date, colony, nest number and chick identification (band number). When possible, the largest secondary flight feather from each side was obtained and placed into a Whirl-Pak™ bag. Care was taken to not cut any post-natal down feathers.

Feather samples were stored in a light-inhibiting box until shipment to the contract laboratory. Chain of Custody forms and Fish/Wildlife Collection records accompanied samples in shipment.

Chemical Analyses

Metals. Cormorant tissues were analyzed for mercury and cadmium by Frontier Geosciences, Inc. Mercury analyses were performed using cold vapor atomic fluorescence spectrometry. Methylmercury analyses were performed using aqueous phase ethylation, purging onto a carbo trap, isothermal isolation and CVAFs. Cadmium was analyzed using inductively coupled plasma-mass spectrometry. Further details may be found in the appendices.

Polynuclear Aromatic Hydrocarbons. Cormorant tissues were analyzed for polynuclear aromatic hydrocarbons by Axys Analytical Services, Inc. Samples were spiked with a suite of perdeuterated PAH surrogate standards and were solvent extracted. The raw extract was fractionated on silica into polar and non-polar fractions. The polar fraction was analyzed for polycyclic aromatic hydrocarbons by high resolution gas chromatography/high resolution mass spectrometry. Further details may be found in the appendices.

Chlorinated Pesticides. Cormorant tissues were analyzed for chlorinated pesticides by Axys Analytical Services, Inc. Samples were spiked with six isotopically labeled surrogate standards and solvent extracted. The extract was separated into two fractions using Florisil and each fraction was analyzed for a suite of organochlorine pesticides by high resolution gas chromatography/high resolution mass spectrometry. Further details may be found in the appendices.

Polychlorinated Biphenyls, Dioxins and Furans. Cormorant tissues were analyzed for PCBs, dioxins and furans by Axys Analytical Services, Inc. Samples were spiked with isotopically labeled surrogate standards and solvent extracted by shaking with a solution of ethanol, hexane and saturated ammonium sulphate. The hexane extract was backwashed with water, concentrated and lipid content determined. The extract was loaded onto a carbon/Celite column and eluted as two fractions. One fraction was subsequently eluted through a Florisil column to yield two new fractions (F1/F2 and F3/F4). Each fraction was concentrated to a small volume, transferred to an autosampler vial and an aliquot of recovery (internal) standard added. The F3/F4 fraction was analyzed for the most polar chlorinated pesticides by GC/ECD or by HRGC/HRMS. The second fraction from the carbon/Celite column was loaded onto an alumina column and again eluted into two separate fractions. The first fraction collected was combined with the F1/F2 fraction from the Florisil column and analyzed for PCBs by HRGC/HRMS or by HRGC/LRMS. The second fraction was collected, concentrated and analyzed for polychlorinated dibenzodioxins and furans. Further details may be found in the appendices.

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3. REPRODUCTIVE SUCCESS

RESULTS

In all analyses of reproductive success, the nest was considered the basic unit of analysis. The fate of individual eggs and nestlings are not independent from each other if they occur in the same nest. Frequency data such as the proportions of successful and unsuccessful nests, the distribution of egg and nestling production, and the distribution of egg and nestling mortality were all analyzed with chi-square tests of independence. The survival of nestlings as measured by chick days (a continuous variable; see below) was examined with ANOVA. Unless otherwise noted, α=0.05.

Sample sizes for productivity endpoints are provided in Table 3.1. Although larger samples are available if all nests are included in analysis of productivity endpoints, we detected a difference in the number of eggs laid in nests selected for egg collection compared to nests not selected in two of three colonies (paired t-tests: GA t_{44}=-2.01, P=0.0502; SH t_{63}=-2.20, P=0.0313; SW t_{39}=-1.09, P=0.2833). In both cases, the number of eggs laid was larger in nests selected for egg collection than in nests not selected. Therefore, all productivity analyses were performed on nests not selected for egg collection.

In addition, because our ability to access the colonies differed between colonies (due to weather and boat access), we tested for differences in data “quality” from each colony. The variables CHKEGG and CHKYNG were defined as the maximum number of days between nest checks during the egg and nestling phases of nesting, respectively. Because CHKEGG and CHKYNG were not normally distributed and had unequal variances, we used a Kruskal-Wallis test to examine differences in nest check intervals between colonies. No differences between colonies were detected in CHKEGG (x^2_2=4.4, P=0.109), however between colony differences were detected in CHKYNG (x^2_2=12.5, P=0.002). The difference was due to the small nest check intervals at Gardiner's Island compared to the other two colonies. Although it was not possible to eliminate this sampling bias, it will be considered in the interpretation of results. For example, if productivity on Gardiners Island is high relative to other sites, it may reflect better information resulting from more frequent nest visits. Conversely if productivity on Gardiners is low, we will evaluate the possible contribution of increased disturbance to nesting success.

We examined the proportions of successful and unsuccessful nests at each colony. Nests defined as successful at hatching eggs had at least one young observed throughout the study. Nests defined as successful at fledging young had at least one nestling that survived a minimum of 21 days (young known to have survived 21 da and young not known to have died at less than 21 da). Tests of independence showed that in both analyses, Gardiners Island produced more failing nests than the other sites (Table 3.2).

Two production endpoints (number of eggs laid ELAID, maximum number of young observed MAXYNG) and two nestling survival endpoints (total chick days TOTCHDA, maximum chick days MAXCHDA) per nest were evaluated. Chick days were calculated per nestling as the number of days the chick was known to be alive. Total chick days were the sum of chick days for all nestlings per nest. Maximum chick days were the maximum number of chick days observed for any nestling in a nest.

Eggs laid and maximum young were discrete variables that were not distributed normally (Table 3.3). Colony differences were examined with a Kruskal-Wallis test. Number of eggs laid did not differ between colonies (x^2_2=4.8, P=0.091), but maximum number of young was higher at Swinburne Island than at the other two colonies (x^2_2=14.9, P=0.0006; without SW x^2_1=2.1, P=0.147).

Total chick days and maximum chick days were continuous variables but also largely non-normal. A square root transformation improved normality and Bartlett's test on transformed variables was not significant (total chick days x^2_2=3.6, P=0.16; maximum chick days x^2_2=0.13, P=0.94). Differences were detected between colonies in both variables (total chick days $F_{2,77}$=13.5, P<0.0001; maximum chick days $F_{2,77}$=9.0, P<0.0001) (Figure 3.1).

Offspring mortality data were examined to elucidate patterns across colonies. Offspring (eggs or young) found dead in the nest or dead on the ground near the nest were compared to offspring missing from the nest (Table 3.4). No differences were detected in the proportions of nests showing either pattern of mortality for eggs (x^2_2=0.29, P=0.86) or young (x^2_2=4.6, P=0.10).

Discussion

Productivity of Double-crested Cormorants nesting in coastal New York varied between sites; birds nesting on Swinburne Island were generally more successful than cormorants on Shooters or Gardiner's Islands. Although the number of eggs laid per nest was not different between sites, the maximum number of young observed per nest (a measure of hatching success) and two measures of chick survival (total chick days and maximum chick day) were highest on Swinburne and lowest on Shooters Islands.

The number of eggs laid per nest was comparable to clutch sizes reported for cormorants across North America (reviewed in Hatch and Weseloh 1999), although the distribution of clutch sizes in the present study was somewhat skewed toward smaller clutches compared to an extensive study of cormorants nesting in Ontario (Peck and James 1983). Hatching success on Gardiner's Island, in particular appeared low compared to regional studies of cormorant reproduction (Hatch and Weseloh 1999). Eggs from a majority of study nests on both Gardiner's and Shooters Islands failed to hatch as a result of being lost from the nest—suggesting predation. On Gardiner's Island, both Herring and Great Black-backed Gulls (*Larus argentatus, L. marinus*) nested in close proximity to cormorants and potentially impacted nesting success (Kury and Gochfeld 1975).

Chick survival was highest on Swinburne Island where average maximum chick day and total chick days were twice that observed at the other two sites. Chick survival on Shooters Island in the early 1990s was comparable to that reported for Swinburne Island in 1999 (Parsons 1994). Although some studies suggest that chick mortality may be low relative to hatching failures (Hatch and Weseloh 1999), and that as few as 5% of hatched cormorants are lost before fledging (Drent et al. 1964), the present study found this pattern only at Swinburne Island. Although some nestlings were observed for up to four weeks after hatching, most nestlings at Shooters and Gardiner's Islands survived for less than two weeks. No differences were detected among colonies in the proportion of young that died in or near the nest (typically considered to be inviable nestlings) and the proportion of young missing from the nest (considered to have been predated).

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Table 3.1. Sample sizes available for analysis of nesting productivity of Double-crested Cormorants in coastal New York, 1999. Shown are the number of nests with known information on the number of eggs laid, the number of nests in which an egg was collected for contaminant analysis, the number of nests with known information on the maximum number of young observed in the nest, and the number of nests with known information on the total and maximum number of chick days.

		Number of Nests				
	Colony	Eggs Laid	Eggs Collected	Max Young	Total Chick Days	Max Chick Days
All nests	Gardiner's	46	15	43	21	21
	Shooters	65	16	51	50	50
	Swinburne	41	13	39	38	38
Nests w/o egg collection	Gardiner's	31	0	30	13	13
	Shooters	49	0	41	40	40
	Swinburne	28	0	27	27	27

Table 3.2. Hatching and fledging success of Double-crested Cormorants in coastal New York, 1999. Comparisons across colonies made with chi-square (χ^2) test of independence. Given are the number of nests on Gardiner's Island, Shooters Island, and Swinburne Island that succeeded or failed to hatch and fledge nestlings, and cell chi-square values.

	Number of nests (cell chi-square)			
	Gardiners	Shooters	Swinburne	
Hatching				
Success	14 (4.3)	38 (0.7)	27 (1.3)	x^2_2=32
Failure	16 (17.8)	3 (3.1)	0 (5.2)	P<0.0001
Fledging				
Success	5 (2.8)	30 (0.1)	24 (0.7)	x^2_2=14
Failure	9 (8.4)	8 (0.3)	3 (2.2)	P=0.0007

Table 3.3. Egg and nestling production of Double-crested Cormorants in coastal New York, 1999. Given are the number of nests containing 0-4 offspring (eggs or young) at Gardiner's Island, Shooters Island, and Swinburne Island. Comparisons across colonies were performed with chi-square test of independence. Egg production did not differ between colonies but nestling production (Max Young) did.

	Number of nests					
Offspring	0	1	2	3	4	
Eggs Laid						
Gardiners		2	5	13	11	x^2_2=4.8
Shooters		2	9	27	11	P=0.091
Swinburne		0	4	10	14	
Max Young						
Gardiners	16	0	4	5	5	x^2_2=14.9
Shooters	3	11	17	9	1	P=0.0006
Swinburne	0	2	7	14	4	

Table 3.4. Egg and nestling mortality of Double-crested Cormorants in coastal New York, 1999. Given are the number of nests where inviable eggs and young were found at the nest, or were missing. Comparisons were made with chi-square test of independence. Offspring mortality did not differ across colonies.

	Number of nests			
	Gardiners	Shooters	Swinburne	
Eggs failing to hatch				
Found at nest	7	11	4	x^2_2=0.29
Missing from nest	17	36	11	P=0.86
Young failing to fledge				
Found at nest	7	1	3	x^2_2=4.6
Missing from nest	12	15	9	P=0.10

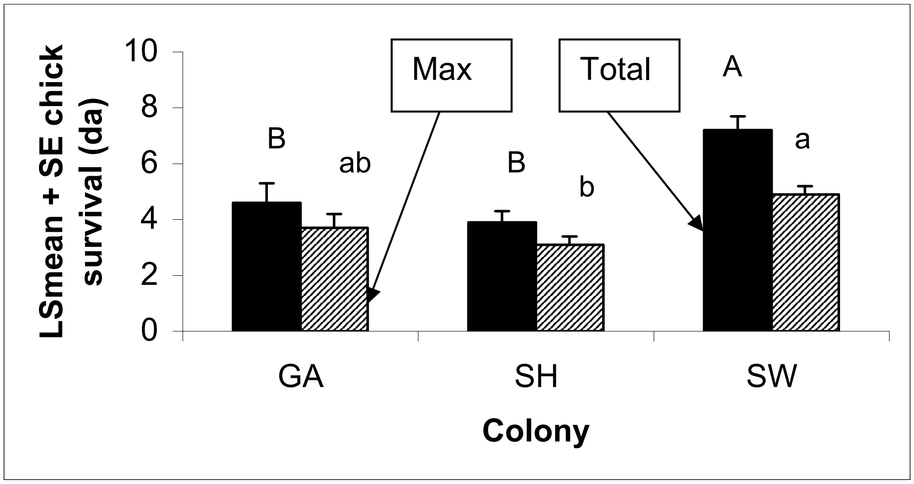

Figure 3.1. Chick survival of Double-crested Cormorants in coastal New York, 1999. Comparisons between colonies of total chick days and maximum chick days (square root transformed) were made with ANOVA and Tukey mean separation procedure. Shown are least square means + SE. Unlike superscripts indicate significant differences. In general, nestlings on Swinburne Island survived longer than birds at the other two sites.

4. METALS

RESULTS

Descriptive statistics of total mercury, methylmercury, and cadmium concentrations detected in Double-crested Cormorant tissues are provided in Tables 4.1-4.3. Results are reported as non-lipid adjusted ng/g wet weight; detection limits ranged from 0.3 to 4.2 in eggs, 1.4 to 2.9 in whole blood, 0.58 to 1.3 in down, and 0.33 to 430 in feathers (see Appendix 1—Quality Assurance). Cadmium was not detected in any feather or blood samples. Metals were detected in most other samples; non-detects were adjusted to zero. Data from many sample populations were not distributed normally and did not show homogeneity of variance across colony sites. Log transformations of concentration data improved normality and stabilized variance sufficiently to allow use of parametric analysis. Unless otherwise noted, $\alpha=0.05$. In analyses where multiple comparisons were made within related data sets, alpha levels were adjusted according to Sidak's method to control experimentwise error rate ($\alpha'=1-(1-\alpha)^{1/k}$ where k=number of comparisons).

Cormorant nestlings selected for down, feather, and whole blood sampling were not of uniform size across colony sites (Table 4.4). Tissue samples were taken from nestlings significantly smaller on Shooters Island compared to Swinburne Island. Nevertheless, no correlations were detected between nestling size and metal concentrations at any island (Table 4.5).

In general, metal concentrations were not correlated between tissue type except total mercury in down was positively correlated with mercury in whole blood (Table 4.6).

In contrast, metal concentrations differed between tissue types in all cases (Table 4.7; Figure 4.1).

Concentrations of egg and down mercury and cadmium were not related to each other within colonies (Table 4.8), nor throughout the study area (Table 4.9). Methylmercury averaged 87-130% of total mercury in egg, down, feather, and whole blood tissues (Table 4.10).

Cadmium concentrations in eggs differed across colonies, but no other comparison of metal/tissue showed spatial differences (Table 4.11; Figure 4.2). Cadmium levels in cormorant eggs on Gardiner's Island were significantly lower than levels detected on Shooters and Swinburne Islands.

Chick survival was negatively correlated with blood concentrations of total mercury and egg concentrations of methylmercury (Table 4.12). No other relationships between reproductive endpoints, including a measure of egg production (Eggs Laid), hatching success (Maximum Young Observed) and chick survival (Maximum Chick Days), were detected.

DISCUSSION

Mercury and methylmercury were detected in all cormorant egg, down, feather and blood samples collected from sites in coastal New York. Total mercury was comprised largely of methylmercury in all tissue types (87-100%). In contrast, cadmium was detected in most egg samples, all down samples, but not detected in any feather or blood samples.

Mercury concentrations in eggs were similar to levels detected in cormorant eggs in the maritime region of Canada (Pearce et al. 1979), South Dakota (Greichus et al 1973), and Washington (Henny et al. 1989). Levels detected in cormorant eggs from some colonies in the Great Lakes in the early 1970s were 1.5-2.5 times higher than the present study (Weseloh et al. 1983), but levels declined in eggs collected from the US Great Lakes during the late 1970s (Heinz et al. 1985).

Mercury levels were detected in nestling feathers in a study at Clear Lake, California (Wolfe and Norman 1998). Mean concentrations over a two-year period ranged from 2.95-4.05 ug/g wet weight. Cormorants sampled at inland reservoirs in New Mexico showed similar levels of mercury in feathers (Caldwell et al. 1999). Both studies detected feather levels of mercury that are somewhat lower than concentrations detected in New York cormorants. However, blood samples in New Mexico are about twice as high (approximately 0.35 ug/g wet weight; Caldwell et al. 1999) as levels detected in New York. Comparable assessments of mercury levels in cormorant down samples do not exist.

In addition, it is unknown in cormorants what levels of mercury in tissues are associated with adverse effects. In other fish-eating birds, egg mercury concentrations up to approximately 2.0 ug/g were not associated with reduced hatching or other reproductive effects (Fimreite 1974, Gilman 1977, King et al. 1991). Feather concentrations up to 32.4 ug/g have not been associated with detrimental effects in Great Skuas (*Catharacta skua*; Thompson et al. 1991).

If these approximate thresholds are relevant to the potentially species-specific responses of Double-crested Cormorants, it appears unlikely that mercury exposure in any of the sites sampled in New York contributed significantly to acute toxicity in cormorants, although sublethal effects are unknown.

Cadmium levels detected in cormorant eggs and down in the present study were low. Cadmium detected in cormorant eggs and adult feathers in Minnesota averaged 390 and 957 ng/g dry weight, respectively (Burger and Gochfeld 1996), approximately an order of magnitude greater than concentrations detected in this study. Cadmium concentrations in eggs tend to be lower than in other tissues, such as kidney and liver (Furness 1996) and therefore egg cadmium concentrations are generally negligible. Furthermore, because concentrations detected in feathers may result from multiple routes of exposure (including deposition onto feather surfaces), levels are not always indicative of dietary exposure (Furness 1996). Threshold levels of 40 ug/g in liver and 100 ug/g in kidney have been proposed to protect avian species from deleterious effects of cadmium exposure (Furness 1996). Few conclusions can be drawn regarding potential effects of cadmium on cormorants because no data exist from liver and kidney tissue (tissues assessed in most toxicological studies to date).

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Table 4.1. Total mercury concentrations in tissues of Double-crested Cormorants collected in coastal New York, 1999. Eggs, down, feathers and whole blood were collected from study nests on Gardiner's Island (GA), Shooters Island (SH), and Swinburne Island (SW). Given are n samples, percent detection, minimum, maximum, range, median, mean (geometric mean GM) and standard deviation (s). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P). Homogeneity of variance among islands was tested with Levene's test (F; probability P).

Double-crested Cormorants—Total mercury ng/g wet weight											
		n	%detc	min	max	range	median	mean (GM)	s	S-W	P
Eggs	GA	15	100	90.4	840	750	294	341 (273)	237	0.884	0.099
	SH	14	100	85.4	1130	1050	242	338 (260)	295	0.745	0.002
	SW	13	100	154	673	5190	285	342 (296)	193	0.862	0.081
									Levene's test $F_{2,39}$=0.22		0.800
Down	GA	12	100	2070	10100	8030	2856	3731 (3294)	2267	0.722	0.001
	SH	10	100	2540	5560	3020	3205	3672 (3533)	1044	0.887	0.155
	SW	12	100	2390	5060	2670	3440	3600 (3498)	826.4	0.951	0.649
									Levene's test $F_{2,31}$=2.43		0.105
Feath	GA	12	100	3340	8330	4990	4870	5150 (4950)	1560	0.908	0.202
	SH	11	100	2310	13800	11490	4530	5630 (4970)	3270	0.836	0.028
	SW	12	100	3350	5840	2490	4490	4590 (4540)	721	0.972	0.927
									Levene's test $F_{2,32}$=5.08		0.012
Blood	GA	12	100	72.5	198	125.5	138.5	139.6 (133.0)	42	0.951	0.646
	SH	11	100	65.9	401	335.1	200	195 (175.9)	89.2	0.918	0.305
	SW	14	100	99.7	198	98.3	174	168.3 (165.7)	28	0.881	0.060
									Levene's test $F_{2,34}$=3.85		0.031

Table 4.2. Methylmercury concentrations in tissues of Double-crested Cormorants collected in coastal New York, 1999. Eggs, down, feathers and whole blood were collected from study nests on Gardiner's Island (GA), Shooters Island (SH), and Swinburne Island (SW). Given are n samples, percent detection, minimum, maximum, range, median, mean and standard deviation (s). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

Double-crested Cormorants—Methylmercury ng/g wet weight											
		n	%detc	min	max	range	median	mean	s	S-W	P
Eggs	GA	3	100	120	364	244	146	210	134	0.829	0.186
	SH	3	100	175	320	145	194	230	78.8	0.846	0.231
	SW	3	100	146	525	379	175	282	211	0.807	0.131
Down	GA	2	100	2330	7340	5010	4835	4835	3543	1	1
	SH	2	100	3160	5900	2740	4530	4530	1938	1	1
	SW	2	100	2890	4330	1440	3610	3610	1018	1	1
Feath	GA	2	100	3960	4510	550	4240	4240	389	1	1
	SH	2	100	2750	3310	560	3030	3030	396	1	1
	SW	2	100	3260	4400	1140	3830	3830	806	1	1
Blood	GA	2	100	96.6	164	67.4	130.3	130.3	47.7	1	1
	SH	2	100	160	167	7	163.5	163.5	4.9	1	1
	SW	2	100	169	204	35	186.5	186.5	24.7	1	1

Table 4.3. Total cadmium concentrations in tissues of Double-crested Cormorants collected in coastal New York, 1999. Eggs, down, feathers and whole blood were collected from study nests on Gardiner's Island (GA), Shooters Island (SH), and Swinburne Island (SW). Given are n samples, percent detection, minimum, maximum, range, median, mean (geometric mean GM) and standard deviation (s). In samples where percent detection >50, non-detect values were adjusted to one-half the detection limit. Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P). Homogeneity of variance among islands was tested with Levene's test (F; probability P).

Double-crested Cormorants—Total cadmium ng/g wet weight											
		n	%detc	min	max	range	median	mean (GM)	s	S-W	P
Eggs	GA	15	40	ND	3.7						
	SH	14	93	ND	15.8	15.5	3.0	4.9 (3.1)	4.9	0.806	0.006
	SW	13	100	0.9	12.7	11.8	4.3	4.3 (3.5)	3.2	0.847	0.026
Down	GA	12	100	14	609	595	69.5	128.1 (65.0)	175.9	0.672	0.001
	SH	10	100	13	295	282	111	132.4 (90.0)	101.4	0.912	0.293
	SW	12	100	13	252	239	37.5	76.6 (47.5)	81.8	0.763	0.004
									Levene's test $F_{2,31}$=1.11		0.342
Feath	GA	12	0								
	SH	11	0								
	SW	12	0								
Blood	GA	12	0								
	SH	11	0								
	SW	14	0								

Table 4.4. Size of Double-crested Cormorants sampled in coastal New York, 1999. Shown are n nestlings, minimum, maximum, median, mean and standard deviation (s) tarsus length (mm) from study nests on Gardiner's Island (GA), Shooters Island (SH), and Swinburne Island (SW). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P). Homogeneity of variance among islands was tested with Levene's test (F; probability P). Colony differences in tarsus length were determined with ANOVA and Tukey mean separation procedure.

Island	n	minimum	maximum	median	mean	s	S-W	P
GA	12	60.1	68.3	64.4	64.1	2.2	0.968	0.892
SH	11	59.5	68.4	61.0	62.1	2.7	0.850	0.043
SW	12	60.4	71.1	66.3	65.9	3.1	0.989	0.999
							Levene's test $F_{2, 32}$=0.85	0.439
							ANOVA $F_{2, 32}$=5.89	0.007
							Tukey mean separation procedure	
							SW^{A}	
							GA^{AB}	
							SH^{B}	

Table 4.5. Results of correlation analysis of nestling tarsus and metal concentrations (log transformed) within tissues of Double-crested Cormorants collected at colonies in coastal New York, 1999. Islands sampled include Gardiner's Island, Shooters Island, and Swinburne Island. Given are n samples, tissue/analyte, Pearson correlation coefficient (r), and probability (P).

Island	Analyte/tissue	n	r	P
Gardiner's Island	Total Hg-feathers	12	0.247	0.437
	Total Hg-down	12	0.062	0.848
	Total Hg-whole blood	12	0.295	0.353
	Total Cd-down	12	-0.433	0.159
Shooters Island	Total Hg-feathers	11	0.308	0.357
	Total Hg-down	10	0.062	0.864
	Total Hg-whole blood	11	0.449	0.166
	Total Cd-down	10	-0.220	0.542
Swinburne Island	Total Hg-feathers	12	-0.465	0.127
	Total Hg-down	12	-0.141	0.662
	Total Hg-whole blood	12	0.385	0.217
	Total Cd-down	12	0.413	0.183

Table 4.6. Results of correlation analysis of tissue types and metal concentrations (log transformed) within tissues of Double-crested Cormorants collected in coastal New York, 1999. Given are Pearson correlation coefficient (r) (n samples) and probability (P).

Total mercury	Down	Feather	Whole blood
Egg	r=0.440 (13)	r=-0.039 (14)	r=0.307 (15)
	P=0.133	P=0.894	P=0.265
Down		r=0.243 (34)	r=0.456 (34)
		P=0.166	P=0.007
Feather			r=0.267 (35)
			P=0.121
Total cadmium			
Egg	r=-0.285 (22)		
	P=0.199		

Table 4.7. Comparisons of metal concentrations within different tissues of Double-crested Cormorants collected in coastal New York, 1999. Comparisons were made with Wilcoxon Signed Rank test. Given are the statistic S (n samples) and probability (P).

Total mercury	Down	Feather	Whole blood
Egg	S=-45.5 (13)	S=-52.5 (14)	S=49 (15)
	P=0.0002	P=0.0001	P=0.0034
Down		S=-220.5 (34)	S=297.5 (34)
		P<0.0001	P<0.0001
Feather			S=315 (35)
			P<0.0001
Total cadmium			
Egg	S=-126.5 (22)		
	P<0.0001		

Table 4.8. Results of correlation analysis of log transformed total mercury and cadmium within tissues of Double-crested Cormorants collected at colonies in coastal New York, 1999. Given are n samples, Pearson correlation coefficient, and probability (P) of metals found in eggs and down.

Colony	Tissue	n samples	Pearson correlation coefficient	P
Gardiner's Island	Egg	15	-0.187	0.561
	Down	12	-0.043	0.895
Shooters Island	Egg	14	-0.053	0.877
	Down	10	-0.137	0.705
Swinburne Island	Egg	13	-0.518	0.126
	Down	12	0.570	0.053

Table 4.9. Results of correlation analysis of total mercury and cadmium (log transformed) within tissues of Double-crested Cormorants collected in coastal New York, 1999. Given are n samples, Pearson correlation coefficient, and probability (P) of metals found in eggs and down.

Tissue	n samples	Pearson Correlation Coefficient	P
Egg	33	-0.127	0.483
Down	34	0.071	0.690

Table 4.10. Relationship between methylmercury and total mercury in tissues of Double-crested Cormorants in coastal New York, 1999. Given are mean ± standard deviation (n) percent methylmercury for eggs, down, feathers and whole blood.

Egg	Down	Feathers	Whole Blood
97.7 ± 0.5 (9)	130.0 ± 43.1 (6)	86.7 ± 33.8 (6)	95.5 ± 20.9 (6)

Table 4.11. Colony differences in analyte concentration of Double-crested Cormorant tissues collected in coastal New York, 1999. Given are results of ANOVA performed on log transformed data. Means were separated by Tukey mean separation procedure ($P<0.05$) in significant models.

Analyte/Tissue	Model DF	Error DF	F	P	Tukey Mean Separation
Total Hg—Egg	2	32	0.10	0.906	
Total Hg—Down	2	31	0.13	0.876	
Total Hg—Feather	2	32	0.26	0.771	
Total Hg—Whole blood	2	34	2.13	0.134	
Total Cd—Egg	2	39	14.0	0.0001	SW^{A}
					SH^{A}
					GA^{B}
Total Cd—Down	2	31	0.96	0.394	

Table 4.12. Results of correlation analysis of reproductive endpoints and total mercury, total cadmium, and methylmercury within tissues of Double-crested Cormorants collected in coastal New York, 1999. Given are n samples, Spearman correlation coefficient, and probability (P). Alpha'=0.017 (Sidak's method).

Tissue	Reproductive Endpoints	n samples	Spearman correlation coefficient	P
Egg-THg	Eggs Laid	33	0.030	0.867
	Max Young Observed	25	0.248	0.232
	Max Chick Days	19	0.037	0.880
Egg-TCd	Eggs Laid	42	0.088	0.579
	Max Young Observed	34	0.186	0.293
	Max Chick Days			
Egg-MHg	Eggs Laid	9	-0.742	0.022
	Max Young Observed	9	-0.534	0.139
	Max Chick Days	9	-0.793	0.011
Blood-THg	Eggs Laid	37	0.098	0.563
	Max Young Observed	36	0.030	0.862
	Max Chick Days	36	-0.414	0.012
Blood-MHg	Eggs Laid	6	0.093	0.862
	Max Young Observed	6	0.494	0.320
	Max Chick Days	6	0.657	0.156
Down-THg	Eggs Laid	34	0.130	0.464
	Max Young Observed	33	0.046	0.800
	Max Chick Days	33	-0.051	0.779
Down-TCd	Eggs Laid	34	-0.118	0.506
	Max Young Observed	33	-0.074	0.682
	Max Chick Days	33	-0.335	0.057
Down-MHg	Eggs Laid	6	0.309	0.552
	Max Young Observed	6	-0.293	0.573
	Max Chick Days	6	-0.714	0.111
Feather-THg	Eggs Laid	35	-0.062	0.723
	Max Young Observed	34	-0.018	0.919
	Max Chick Days	34	0.053	0.765
Feather-MHg	Eggs Laid	6	-0.414	0.414
	Max Young Observed	6	0.123	0.816
	Max Chick Days	6	-0.657	0.156

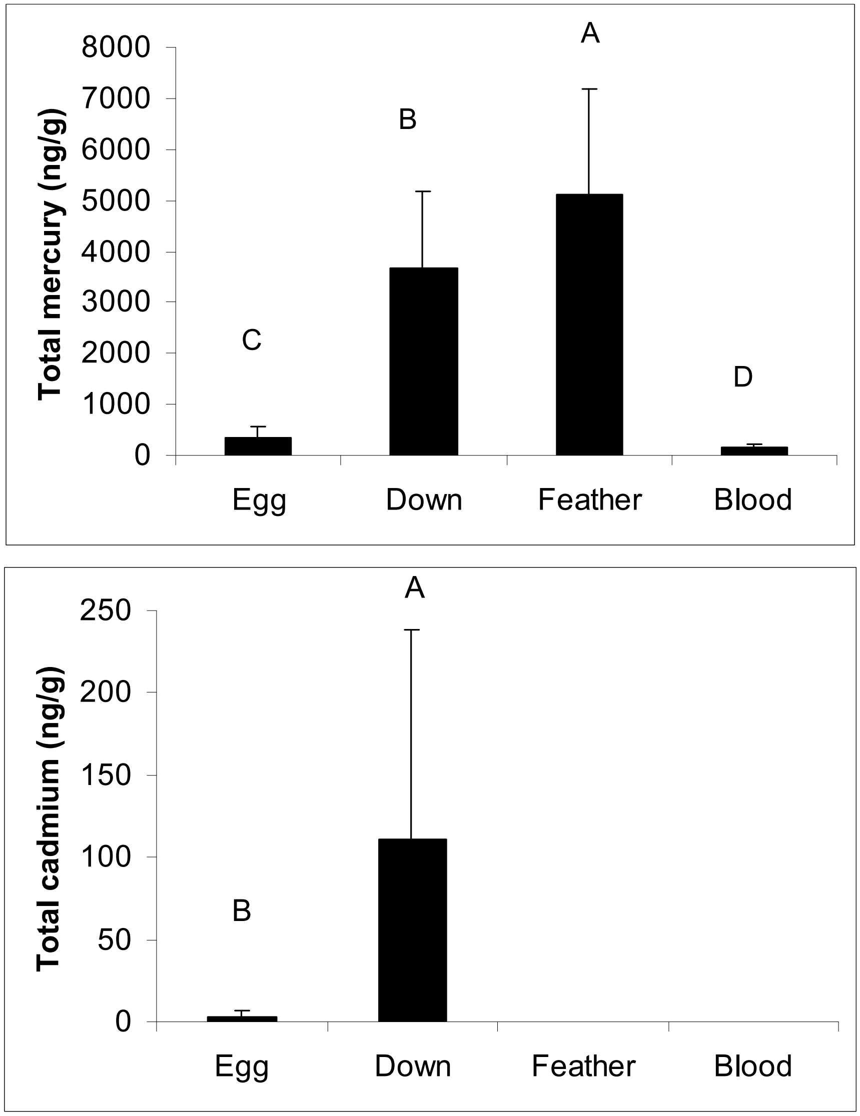

Figure 4.1. Comparison of metal concentrations in different tissues of Double-crested Cormorants in coastal New York, 1999. Shown are a) total mercury (mean + standard deviation ng/g wet weight) and b) total cadmium (mean + standard deviation ng/g wet weight) in egg, down, feather, and whole blood. Mercury and cadmium concentrations differed between tissue types (see text).

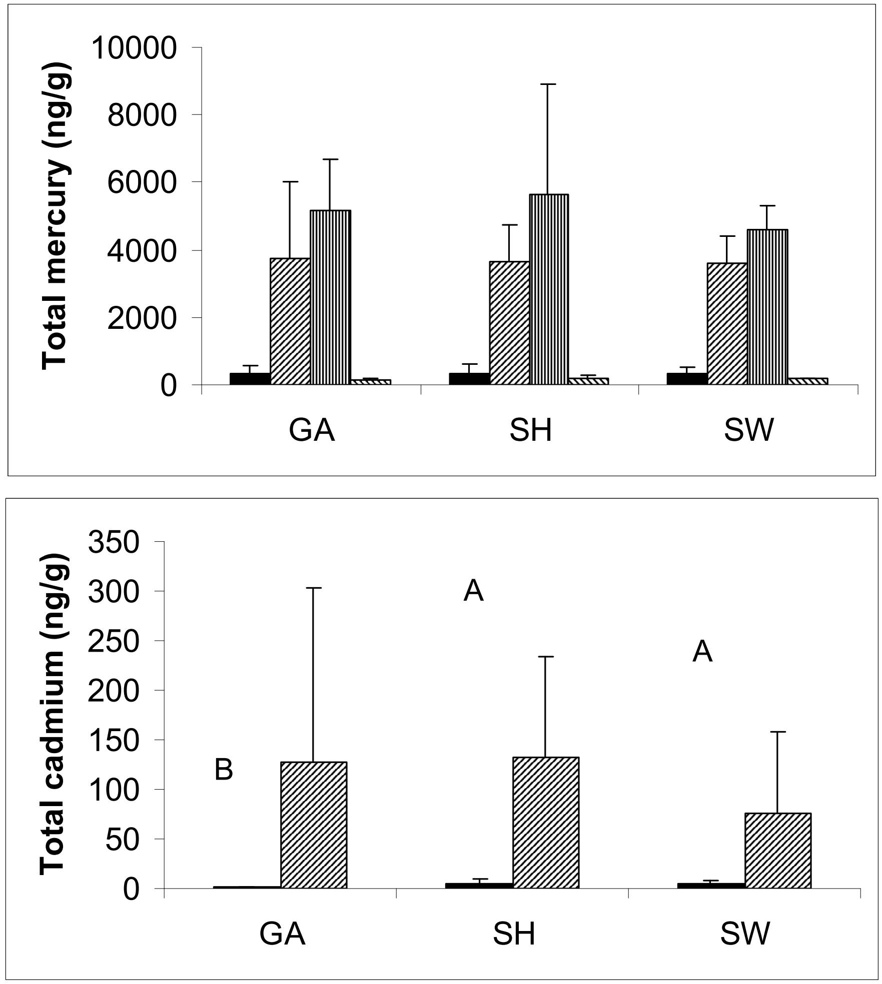

Figure 4.2. Comparison of metal concentrations in tissues of Double-crested Cormorant from different colonies in coastal New York, 1999. Shown are a) total mercury (mean + standard deviation ng/g wet weight) and b) total cadmium (mean + standard deviation ng/g wet weight) in egg (black), down (left cross hatch), feather (vertical stripes), and whole blood (right cross hatch) from Gardiner's Island (GA), Shooters Island (SH) and Swinburne Island (SW). Differences between colonies were detected only in egg cadmium (see text).

5. POLYNUCLEAR AROMATIC HYDROCARBONS

RESULTS

Double-crested Cormorant egg and plasma tissues were analyzed for 28 polynuclear aromatic hydrocarbons (PAHs) including 1-Methylnaphthalene, 1-Methylphenanthrene, 2,3,5-Trimethylnaphthalene, 2,6-Dimethylnaphthalene, 2-Methylnaphthalene, Acenaphthene, Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo[b/j/k]fluoranthenes, Benzo[e]pyrene, Benzo[ghi]perylene, Biphenyl, C1 Naphthalene, C1 Phenanthrenes/Anthracenes, C2 Naphthalene, C2 Phenanthrenes/Anthracenes, C3 Naphthalene, Chrysene, Dibenz[ah]anthracene, Fluoranthene, Fluorene, Indeno[1,2,3-cd]pyrene, Naphthalene, Perylene, Phenanthrene, and Pyrene. Results are reported as non-lipid adjusted ng/g wet weight; detection limits ranged from 0.00259 to 0.1 in eggs and 0.0265 to 0.437 in plasma (see Appendix 1—Quality Assurance). Non-detects were adjusted to zero.

Due to laboratory problems, no results were obtained for 2-Methylnaphthalene, C1 Phenanthrenes/Anthracenes, C2 Phenanthrenes/Anthracenes and Perylene (see QA discussion). In addition, Dibenz[ah]anthracene and Indeno[1,2,3-cd]pyrene were non-detectable in all samples (both tissue types) from all sites.

Descriptive statistics of all PAHs detected in at least one sample from at least one site (22 analytes) are provided in Tables 5.1-5.6. Data from many sample populations were not distributed normally and did not show homogeneity of variance across colony sites. Transformations of concentration data improved normality and stabilized variance but not sufficiently to allow use of parametric analysis (Levene's test $P<0.05$). Therefore, the non-parametric Spearman correlation was used to examine nestling size and PAH concentration, and the relationship between egg and plasma PAH concentration. Comparisons between colonies were performed on ranked concentration data (ANOVA, Tukey mean separation procedure). Total PAH concentration was calculated by summing Acenaphthene, Acenaphthylene, Anthracene, Benz[a]anthracene, Benzo[a]pyrene, Benzo[b/j/k]fluoranthenes, Benzo[e]pyrene, Benzo[ghi]perylene, Biphenyl, Chrysene, Dibenz[ah]anthracene, Fluoranthene, Fluorene, Indeno[1,2,3-cd]pyrene, Naphthalene, Perylene, Phenanthrene, and Pyrene . Unless otherwise noted, α=0.05.

Cormorant nestlings selected for plasma sampling were not of uniform size across colony sites (see Table 4.4). Tissue samples were taken from nestlings significantly smaller on Shooters Island compared to Swinburne Island. Nevertheless, no correlations were detected between nestling size and total PAH concentrations at any island (Table 5.7). Similarly, egg and plasma PAH concentrations were not correlated (Table 5.8).

Total PAH was higher in eggs at Gardiner's Island and Shooters Island than at Swinburne Island (Figure 5.1). In addition, Naphthalene, the PAH analyte contributing the greatest concentration to total PAH (30-42% of total PAH), was higher in Gardiner's Island eggs than in eggs collected at Swinburne Island (Figure 5.1). Other analytes were less important (contributing 14% or less to total PAH). Similarly, plasma total PAH and Naphthalene (23-30% of total PAH) concentrations were higher in Gardiner's Island cormorants than in nestlings from Shooters or Swinburne Islands (Figure 5.2). Biphenyl was higher in plasma from Gardiner's and Shooters Islands compared to Swinburne, but phenanthrene did not differ between sites (Figure 5.2).

No relationships between total PAH concentrations in eggs or plasma and reproductive endpoints, including a measure of egg production (Eggs Laid), hatching success (Maximum Young Observed) and chick survival (Maximum Chick Days), were detected (Table 5.9).

Discussion

Polynuclear aromatic hydrocarbons were found in all egg and plasma tissues sampled at three cormorant colonies in coastal New York. Naphthalene comprised nearly 70% of total PAHs in egg tissues and was 53-65% of total PAHs in plasma. Phenanthrene (8-17%) and biphenyl (6-11%) were also important components of total PAHs in plasma.

Very few studies exist to aid in interpretation of these data. King et al. (1987) assessed a limited number of PAHs in Double-crested Cormorant adult carcasses collected in Galveston Bay, Texas. Although most analytes were not detected in a majority of the samples, the lower limit of quantification was high relative to the present study and those analytes detected occurred in concentrations up to several orders of magnitude greater than samples collected in coastal New York (e.g., benzo[a]pyrene, benzo[g,h,i]perylene). The analyte detected most frequently in Texas was naphthalene (65%; range=0.02-0.04 ppm), which occurred at concentrations approximately one order of magnitude greater than New York samples.

Similarly, in a study of Tree Swallows (*Tachycineta bicolor*) and House Wrens (*Troglodytes aedon*) near a petroleum refinery in Wyoming, Custer et al. (2001) were unable to detect many PAH analytes but total concentrations of PAHs in nestling carcasses were similar to levels detected in cormorant eggs collected at Gardiner's and Shooters Islands.

Polynuclear aromatic hydrocarbons are highly embryotoxic—exposure to 0.036-0.018 ng/g total PAH in Mallard eggs can result in the death of the embryo, produce terrata, and/or retard embryo growth (Eisler 1987). Cormorant eggs from all sites in the present study had PAH concentrations exceeding this level, but no adverse effects thresholds are available that are specific to cormorants.

Benzo[a]pyrene, chrysene and 7,12-dimethylbenz[a]anthracene, in particular, are highly toxic to avian embryos (Hoffman and Gay 1981). Chrysene was present in most cormorant eggs and all plasma samples and contributed approximately 1-1.5% to total PAHs in plasma. Benzo[a]pyrene was present only in plasma but was a negligible component of total PAHs.

Total concentrations in eggs were higher at Shooters Island and Gardiner's Island than at Swinburne Island, and plasma concentrations were highest at Shooters Island compared to the other two sites, but no relationships between PAHs or tarsus length, and reproductive success were detected (Tables 7 and 9).

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Table 5.1. Polynuclear aromatic hydrocarbon concentrations (ng/g wet weight) in eggs of Double-crested Cormorants collected at Gardiner's Island, 1999. Given are n samples, percent detection, percent total PAH, minimum, maximum, range, mean, and standard deviation (s). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

	n	%detect	% total	minimum	maximum	range	mean	s	S-W	P
1-Methylnaphthalene	15	100	4.6	0.213	0.739	0.526	0.406	0.156	0.938	0.357
1-Methylphenanthrene	15	100	1.5	0.039	0.362	0.323	0.136	0.093	0.860	0.024
2,3,5-Trimethylnaphthalene	15	100	2.0	0.117	0.280	0.163	0.165	0.054	0.773	0.002
2,6-Dimethylnaphthalene	15	100	2.7	0.116	0.459	0.343	0.230	0.097	0.782	0.002
Acenaphthene	15	100	1.4	0.057	0.374	0.317	0.122	0.076	0.651	<0.0001
Acenaphthylene	15	100	1.5	0.093	0.196	0.103	0.125	0.031	0.861	0.025
Anthracene	15	100	1.0	0.064	0.124	0.060	0.081	0.016	0.862	0.026
Benz[a]anthracene	15	80	0.2	0	0.308	0.031	0.018	0.010	0.826	0.008
Benzo[a]pyrene	15	0								
Benzo[b/j/k]fluoranthenes	15	0								
Benzo[e]pyrene	15	7	0.02	0	0.018	0.018	0.001	0.005	0.284	<0.0001
Benzo[ghi]perylene	15	80	0.2	0	0.035	0.035	0.018	0.012	0.924	0.223
Biphenyl	15	100	2.4	0.161	0.331	0.170	0.208	0.050	0.845	0.015
C1 Naphthalene	15	100	11.1	0.513	1.79	1.28	0.995	0.392	0.927	0.245
C2 Naphthalene	15	100	9.1	0.511	1.31	0.799	0.787	0.202	0.919	0.187
C3 Naphthalene	15	100	8.7	0.440	1.34	0.900	0.725	0.239	0.892	0.071
Chrysene	15	93	0.3	0	0.047	0.047	0.026	0.011	0.934	0.316
Fluoranthene	15	100	2.1	0.101	0.490	0.389	0.187	0.095	0.718	0.0004
Fluorene	15	100	1.0	0.040	0.138	0.098	0.082	0.029	0.963	0.752
Naphthalene	15	100	41.5	1.95	6.48	4.53	3.67	1.32	0.937	0.346
Phenanthrene	15	100	3.7	0.212	0.423	0.211	0.321	0.062	0.910	0.137
Pyrene	15	100	4.9	0.077	3.25	3.17	0.467	0.830	0.518	<0.0001

Table 5.2. Polynuclear aromatic hydrocarbon concentrations (ng/g wet weight) in eggs of Double-crested Cormorants collected at Shooters Island, 1999. Given are n samples, percent detection, percent of total PAH, minimum, maximum, range, mean, and standard deviation (s). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

	n	%detect	% total	minimum	maximum	range	mean	s	S-W	P
1-Methylnaphthalene	14	100	6.4	0.309	5.56	5.251	1.42	1.64	0.729	0.0008
1-Methylphenanthrene	14	93	1.6	0	0.945	0.945	0.229	0.258	0.767	0.002
2,3,5-Trimethylnaphthalene	14	100	2.4	0.093	0.772	0.679	0.368	0.193	0.965	0.797
2,6-Dimethylnaphthalene	14	100	2.6	0.160	1.76	1.60	0.526	0.521	0.729	0.0007
Acenaphthene	14	100	3.0	0.078	1.46	1.38	0.587	0.522	0.831	0.012
Acenaphthylene	14	100	3.4	0.084	1.94	1.86	0.457	0.462	0.642	<0.0001
Anthracene	14	100	2.4	0.113	0.984	0.871	0.318	0.234	0.776	0.003
Benz[a]anthracene	14	71	0.3	0	0.139	0.139	0.035	0.037	0.827	0.011
Benzo[a]pyrene	14	0								
Benzo[b/j/k]fluoranthenes	14	7								
Benzo[e]pyrene	14	14	0.03	0	0.043	0.043	0.005	0.013	0.446	<0.0001
Benzo[ghi]perylene	14	43	0.09	0	0.039	0.039	0.011	0.014	0.771	0.002
Biphenyl	14	100	2.9	0.177	1.73	1.55	0.506	0.414	0.746	0.001
C1 Naphthalene	14	100	14.2	0.693	11.8	11.1	3.09	3.45	0.732	0.0008
C2 Naphthalene	14	100	13.2	0.600	11.1	10.5	2.96	3.38	0.732	0.0008
C3 Naphthalene	14	100	10.6	0.502	4.55	4.05	1.67	1.05	0.858	0.028
Chrysene	14	43	0.1	0	0.067	0.067	0.014	0.020	0.736	0.0009
Fluoranthene	14	100	1.3	0.117	0.261	0.144	0.169	0.044	0.929	0.295
Fluorene	14	100	1.1	0.065	0.489	0.424	0.183	0.124	0.858	0.029
Naphthalene	14	100	30.3	2.64	9.60	6.96	4.605	2.19	0.848	0.021
Phenanthrene	14	100	3.0	0.274	0.840	0.566	0.426	0.162	0.838	0.015
Pyrene	14	100	1.2	0.102	0.313	0.211	0.153	0.055	0.786	0.003

Table 5.3. Polynuclear aromatic hydrocarbon concentrations (ng/g wet weight) in eggs of Double-crested Cormorants collected at Swinburne Island, 1999. Given are n samples, percent detection, percent of total PAH, minimum, maximum, range, mean, and standard deviation (s). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

	n	%detect	% total	minimum	maximum	range	mean	s	S-W	P
1-Methylnaphthalene	13	100	5.2	0.279	0.501	0.222	0.360	0.073	0.905	0.157
1-Methylphenanthrene	13	100	1.2	0.066	0.091	0.025	0.079	0.009	0.879	0.068
2,3,5-Trimethylnaphthalene	13	100	1.7	0.076	0.165	0.089	0.121	0.032	0.891	0.100
2,6-Dimethylnaphthalene	13	100	3.3	0.103	0.644	0.541	0.230	0.141	0.723	0.001
Acenaphthene	13	92	1.2	0	0.156	0.156	0.086	0.038	0.957	0.705
Acenaphthylene	13	100	2.1	0.070	0.217	0.147	0.145	0.047	0.961	0.771
Anthracene	13	100	2.0	0.082	0.196	0.114	0.133	0.035	0.926	0.304
Benz[a]anthracene	13	100	0.4	0.017	0.043	0.026	0.028	0.008	0.965	0.835
Benzo[a]pyrene	13	0								
Benzo[b/j/k]fluoranthenes	13	0								
Benzo[e]pyrene	13	8	0.01	0	0.015	0.015	0.001	0.004	0.311	<0.0001
Benzo[ghi]perylene	13	100	0.3	0.014	0.041	0.027	0.021	0.008	0.811	0.009
Biphenyl	13	100	2.5	0.144	0.222	0.078	0.172	0.029	0.829	0.016
C1 Naphthalene	13	100	13.9	0.783	1.32	0.537	0.953	0.174	0.868	0.050
C2 Naphthalene	13	100	10.2	0.454	1.10	0.646	0.702	0.190	0.941	0.465
C3 Naphthalene	13	100	8.6	0.394	0.778	0.384	0.596	0.154	0.861	0.040
Chrysene	13	92	0.4	0	0.040	0.040	0.025	0.009	0.871	0.054
Fluoranthene	13	100	2.0	0.122	0.154	0.032	0.134	0.010	0.934	0.379
Fluorene	13	100	1.1	0.057	0.102	0.045	0.072	0.011	0.856	0.034
Naphthalene	13	100	37.0	2.07	2.97	0.900	2.53	0.349	0.839	0.021
Phenanthrene	13	100	4.8	0.264	0.363	0.099	0.320	0.027	0.951	0.619
Pyrene	13	100	1.9	0.107	0.160	0.053	0.127	0.015	0.931	0.348

Table 5.4. Polynuclear aromatic hydrocarbon concentrations (ng/g wet weight) in plasma of Double-crested Cormorants collected at Gardiner's Island, 1999. Given are n samples, percent detection, percent total PAH, minimum, maximum, range, mean, and standard deviation (s). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

	n	%detect	% total	minimum	maximum	range	mean	s	S-W	P
1-Methylnaphthalene	10	100	6.0	2.48	5.40	2.92	3.34	0.995	0.842	0.046
1-Methylphenanthrene	10	100	0.9	0.341	0.891	0.550	0.495	0.171	0.817	0.023
2,3,5-Trimethylnaphthalene	10	100	2.0	0.714	1.81	1.10	1.16	0.376	0.910	0.280
2,6-Dimethylnaphthalene	10	100	2.6	1.05	2.13	1.08	1.47	0.358	0.918	0.337
Acenaphthene	10	70	2.0	0.567	2.35	1.783	1.06	0.523	0.814	0.022
Acenaphthylene	10	100	0.5	0	0.851	0.851	0.269	0.293	0.853	0.064
Anthracene	10	70	0.3	0.127	0.335	0.208	0.195	0.067	0.865	0.088
Benz[a]anthracene	10	30	0.1	0	0.157	0.157	0.058	0.050	0.912	0.292
Benzo[a]pyrene	10	70	0.06	0	0.173	0.173	0.033	0.059	0.643	0.0002
Benzo[b/j/k]fluoranthenes	10	80	0.2	0	0.270	0.270	0.105	0.092	0.927	0.418
Benzo[e]pyrene	10	100	0.2	0	0.266	0.266	0.124	0.086	0.955	0.733
Benzo[ghi]perylene	10	100	0.3	0.079	0.402	0.323	0.143	0.095	0.620	<0.0001
Biphenyl	10	100	4.0	1.42	4.94	3.52	2.26	1.02	0.722	0.002
C1 Naphthalene	10	100	14.6	5.68	13.6	7.92	8.12	2.46	0.847	0.052
C2 Naphthalene	10	100	12.0	4.81	9.67	4.86	6.68	1.74	0.850	0.058
C3 Naphthalene	10	100	16.3	4.07	38.5	34.4	9.90	10.4	0.573	<0.0001
Chrysene	10	100	0.4	0.107	0.432	0.325	0.204	0.100	0.861	0.079
Fluoranthene	10	100	1.4	0.542	1.30	0.758	0.795	0.240	0.801	0.015
Fluorene	10	100	0.9	0.281	1.0	0.719	0.545	0.202	0.882	0.138
Naphthalene	10	100	30.2	7.81	30.7	22.9	17.533	7.71	0.941	0.568
Phenanthrene	10	100	3.6	1.54	3.54	2.0	2.01	0.721	0.676	0.0005
Pyrene	10	100	1.4	0.564	1.26	0.696	0.759	0.210	0.816	0.022

Table 5.5. Polynuclear aromatic hydrocarbon concentrations (ng/g wet weight) in plasma of Double-crested Cormorants collected at Shooters Island, 1999. Given are n samples, percent detection, percent total PAH, minimum, maximum, range, mean, and standard deviation (s). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

	n	%detect	% total	minimum	maximum	range	mean	s	S-W	P
1-Methylnaphthalene	10	100	6.4	1.22	3.10	1.88	2.11	0.714	0.888	0.160
1-Methylphenanthrene	10	100	1.8	0.368	0.756	0.388	0.547	0.121	0.938	0.529
2,3,5-Trimethylnaphthalene	10	100	2.5	0.648	0.972	0.324	0.758	0.089	0.847	0.054
2,6-Dimethylnaphthalene	10	100	3.0	0.58	1.57	0.990	0.992	0.336	0.943	0.583
Acenaphthene	10	60	1.3	0	1.37	1.37	0.525	0.588	0.775	0.007
Acenaphthylene	10	100	1.0	0.201	0.573	0.372	0.329	0.148	0.782	0.009
Anthracene	10	100	0.8	0.142	0.521	0.379	0.226	0.112	0.706	0.001
Benz[a]anthracene	10	80	0.2	0	0.095	0.095	0.056	0.033	0.880	0.131
Benzo[a]pyrene	10	90	0.02	0	0.105	0.105	0.011	0.033	0.366	<0.0001
Benzo[b/j/k]fluoranthenes	10	40	0.2	0	0.193	0.193	0.066	0.086	0.712	0.001
Benzo[e]pyrene	10	50	0.2	0	0.157	0.157	0.067	0.075	0.740	0.003
Benzo[ghi]perylene	10	40	0.1	0	0.198	0.198	0.057	0.077	0.743	0.003
Biphenyl	10	100	4.6	0.785	2.6	1.82	1.57	0.750	0.818	0.024
C1 Naphthalene	10	100	17.0	3.17	8.34	5.17	5.64	1.99	0.869	0.099
C2 Naphthalene	10	100	13.4	2.36	6.45	4.09	4.45	1.56	0.918	0.339
C3 Naphthalene	10	100	12.7	2.82	6.17	3.35	4.15	1.17	0.904	0.243
Chrysene	10	100	0.6	0.112	0.243	0.131	0.179	0.052	0.878	0.123
Fluoranthene	10	100	2.2	0.574	0.773	0.199	0.657	0.055	0.939	0.540
Fluorene	10	100	1.0	0.253	0.378	0.125	0.308	0.045	0.924	0.396
Naphthalene	10	100	22.8	5.52	10.8	5.28	7.28	1.67	0.848	0.056
Phenanthrene	10	100	6.1	1.40	2.10	0.700	1.84	0.230	0.924	0.394
Pyrene	10	100	2.2	0.562	0.858	0.296	0.648	0.095	0.828	0.032

Table 5.6. Polynuclear aromatic hydrocarbon concentrations (ng/g wet weight) in plasma of Double-crested Cormorants collected at Swinburne Island, 1999. Given are n samples, percent detection, percent total PAH, minimum, maximum, range, mean, and standard deviation (s). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

	n	%detect	% total	minimum	maximum	range	mean	s	S-W	P
1-Methylnaphthalene	12	100	6.2	1.42	3.14	1.72	1.84	0.448	0.712	0.001
1-Methylphenanthrene	11	100	2.1	0.432	0.994	0.562	0.683	0.169	0.947	0.609
2,3,5-Trimethylnaphthalene	12	100	1.9	0.485	1.36	0.875	0.714	0.297	0.764	0.004
2,6-Dimethylnaphthalene	12	100	2.8	0.668	1.24	0.572	0.887	0.201	0.866	0.058
Acenaphthene	11	45	0.3	0	0.523	0.523	0.138	0.184	0.787	0.006
Acenaphthylene	12	92	1.2	0	1.04	1.04	0.346	0.252	0.804	0.011
Anthracene	12	100	0.7	0.089	0.270	0.181	0.196	0.055	0.945	0.559
Benz[a]anthracene	12	92	0.2	0	0.155	0.155	0.081	0.044	0.932	0.398
Benzo[a]pyrene	12	17	0.03	0	0.105	0.105	0.015	0.036	0.486	<0.0001
Benzo[b/j/k]fluoranthenes	12	58	0.3	0	0.324	0.324	0.110	0.108	0.849	0.036
Benzo[e]pyrene	12	92	0.2	0	0.173	0.173	0.090	0.050	0.966	0.864
Benzo[ghi]perylene	12	75	0.2	0	0.263	0.263	0.083	0.071	0.815	0.014
Biphenyl	12	100	2.9	0.641	1.13	0.489	0.852	0.130	0.965	0.855
C1 Naphthalene	12	100	15.9	3.89	8.56	4.67	4.78	1.25	0.619	0.0002
C2 Naphthalene	12	100	13.2	3.21	6.3	3.09	4.42	1.15	0.850	0.036
C3 Naphthalene	11	100	12.1	2.62	7.61	4.99	4.12	1.54	0.774	0.004
Chrysene	12	100	0.6	0.127	0.456	0.329	0.214	0.097	0.809	0.012
Fluoranthene	12	100	2.0	0.296	1.01	0.714	0.626	0.160	0.841	0.029
Fluorene	12	100	1.0	0.208	0.638	0.430	0.353	0.150	0.770	0.004
Naphthalene	12	100	26.3	5.99	15.0	9.01	8.01	2.83	0.648	0.0003
Phenanthrene	12	100	7.3	1.61	2.80	1.19	2.22	0.359	0.965	0.857
Pyrene	12	100	2.3	0.357	1.09	0.733	0.707	0.169	0.888	0.111

Table 5.7. Results of correlation analysis of nestling tarsus and plasma total polynuclear aromatic hydrocarbons of Double-crested Cormorants sampled at colonies in coastal New York, 1999. Given are n samples, Spearman correlation coefficient (r), and probability (P).

Colony	n	r	P
Gardiner's Island	10	0.621	0.055
Shooters Island	10	0.164	0.650
Swinburne Island	10	0.394	0.260

Table 5.8. Results of correlation analysis of egg and plasma total polynuclear aromatic hydrocarbons of Double-crested Cormorants sampled at colonies in coastal New York, 1999. Given are n samples, correlation coefficient (r), and probability (P).

Colony	n	r	P
Gardiner's Island	6	-0.429	0.397
Shooters Island	7	0.643	0.119
Swinburne Island	7	-0.393	0.383

Table 5.9. Results of correlation analysis of reproductive endpoints and total PAHs within tissues of Double-crested Cormorants collected in coastal New York, 1999. Given are n samples, Spearman correlation coefficient, and probability (P). Alpha'=0.017 (Sidak's method).

Tissue	Reproductive Endpoints	n samples	Spearman correlation coefficient	P
Egg	Eggs Laid	42	0.060	0.705
	Max Young Observed	34	-0.086	0.629
	Max Chick Days	28	-0.111	0.573
Plasma	Eggs Laid	30	0.260	0.165
	Max Young Observed	29	0.229	0.231
	Max Chick Days	29	0.305	0.107

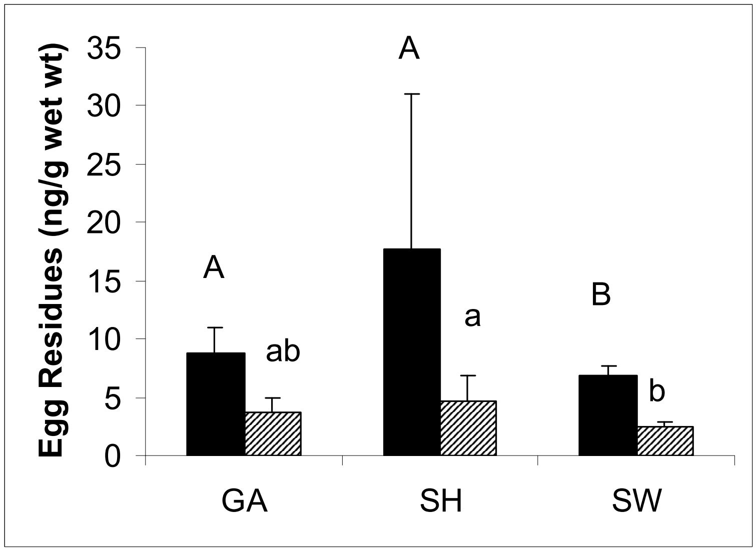
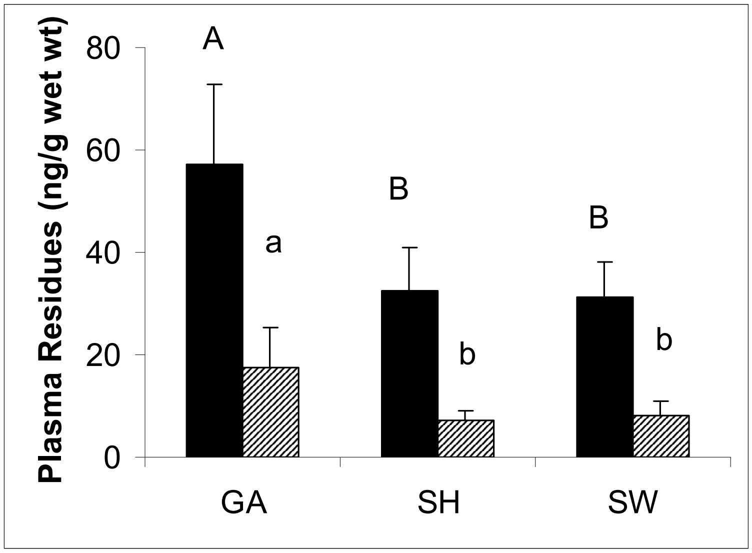


Figure 5.1. Comparison of polynuclear aromatic hydrocarbons in eggs of Double-crested Cormorant from different colonies in coastal New York, 1999. Shown are mean + standard deviation concentration (ng/g wet weight) total polynuclear aromatic hydrocarbons (solid) and naphthalene (hatched) detected in eggs from Gardiner's Island (GA), Shooters Island (SH), and Swinburne Island (SW). Unlike letters indicate colony differences.



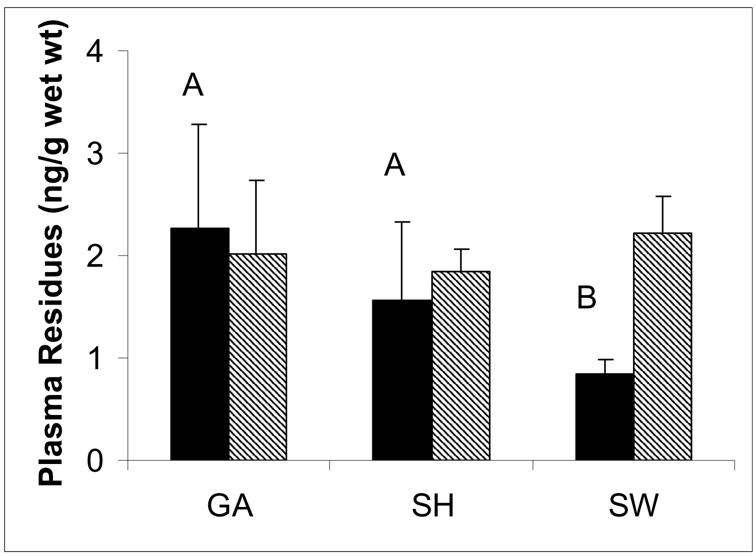


Figure 5.2. Comparison of polynuclear aromatic hydrocarbons in plasma of Double-crested Cormorant from different colonies in coastal New York, 1999. Shown are mean + standard deviation concentration (ng/g wet weight): top graph) total polynuclear aromatic hydrocarbons (solid) and naphthalene (hatched); bottom graph) biphenyl (solid) and phenanthrene (hatched) detected in eggs from Gardiner's Island (GA), Shooters Island (SH), and Swinburne Island (SW). Unlike letters indicate colony differences.

6. CHLORINATED PESTICIDES

RESULTS

Double-crested Cormorant egg and plasma tissues were analyzed for 29 organochlorine pesticides including DDT and analogues (2,4'-DDT, 4,4'-DDT, 2,4'-DDD, 4,4'-DDD, 2,4'-DDE, 4,4'-DDE, methoxychlor), hexachlorocyclohexane (α-BHC, β-BHC, δ-BHC, γ-BHC), mirex and photomirex, chlordane and related compounds (oxychlordane, α-chlordane, γ-chlordane, trans-nonachlor, cis-nonachlor, heptachlor, heptachlor epoxide), aldrin and related compounds (aldrin, dieldrin, endrin, endrin aldehyde, endrin ketone), endosulfan and related compounds (endosulfan sulfate, α-endosulfan, β-endosulfan) and hexachlorobenzene (HCB). Results are reported as non-lipid adjusted pg/g wet weight; detection limits ranged from 3.6-15,000 in eggs and 0.6-71.6 in plasma (see Appendix 1—Quality Assurance). Non-detects were adjusted to zero.

Due to laboratory problems, the concentration of heptachlor in one Swinburne Island egg sample (nest #6) and the concentration of heptachlor epoxide in one Shooters Island egg sample (nest #20) were eliminated from the dataset. β-endosulfan was non-detectable in all egg samples from all sites and endrin aldehyde was non-detectable in all plasma samples from all sites.

Descriptive statistics of all chlorinated pesticides detected in at least one sample from at least one site (28 analytes) are provided in Tables 6.1-6.6. Data from many sample populations were not distributed normally and did not show homogeneity of variance across colony sites.

Pesticide data were grouped by major chemical class (see above) to examine spatial patterns in tissue concentrations (Table 6.7 and 6.8). Log transformations of summed concentration data improved normality and stabilized variance sufficiently to allow use of parametric analysis (Levene's test $P<0.05$). The Pearson correlation was used to examine nestling size and summed pesticide concentrations (log transformed) of major groups. Comparisons between colonies were performed on summed concentration (log transformed) data (ANOVA, Tukey mean separation procedure). Unless otherwise noted, $\alpha=0.05$.

Cormorant nestlings selected for plasma sampling were not of uniform size across colony sites (see Table 4.4). Tissue samples were taken from nestlings significantly smaller on Shooters Island compared to Swinburne Island. Nevertheless, no correlations were detected between nestling size and total pesticide concentrations at any island (Table 6.9).

Chemical groups of chlorinated pesticides in eggs correlated with each other in many instances, especially in eggs from Shooters Island where mean concentrations were higher (Table 6.10). Summed concentrations of pesticides in plasma showed less co-linearity; none was detected in samples from Gardiner's Island (Table 6.11).

The relative contribution of different analytes to total concentrations of each chemical group differed between colony-sites (Figures 6.1 and 6.2). Although the Σ DDT group was dominated by 4,4'-DDE in both plasma and egg tissues at all sites, more parent compound (4,4'-DDT; 4,4'-DDD) was present in samples from Shooters Island than the other two sites. In addition, both plasma and egg samples from Gardiner's Island show greater contribution of heptachlor epoxide to Σ chlordane than at the other two sites. The Σ HCH group was dominated at Shooters Island by β-BHC whereas α-BHC was relatively greater at Gardiner's and Swinburne Islands, especially in plasma samples. The Σ mirex group was dominated by mirex in both tissue types at all sites. Plasma and egg samples differed in the Σ aldrin group where egg concentrations from all sites resulted largely from dieldrin contamination, whereas plasma concentrations also contained endrin (except at Swinburne Island).

Summed organochlorine pesticides in general were higher in eggs from Shooters Island and lower in eggs from Gardiner's Island; samples from Swinburne Island were intermediate (Figure 6.3). Similarly, plasma summed concentrations of organochlorine pesticides in samples from Shooters Island were higher than samples from Swinburne and Gardiner's Islands (Figure 6.4). Total concentrations of the DDT and aldrin groups were especially high in samples from Shooters Island compared to the other two sites.

Egg shell thickness did not differ between colonies ($F_{2,39}=1.79$; $P=0.181$) (Table 6.12), but thickness was negatively correlated with egg concentrations of 2,4' DDE and 4,4' DDE (Table 6.13).

No relationships between egg concentrations of chlorinated pesticides and reproductive endpoints were detected (Table 6.14). Chick survival was negatively correlated with plasma concentrations of total chlordane, total aldrin and total endosulfan (Table 6.15).

Discussion

Chlorinated pesticides occurred in cormorant tissues from coastal New York, but generally not at levels expected to produce adverse effects. DDE occurred at the greatest concentrations of all pesticides analyzed and was highest in cormorants from the two New York Harbor sites (Shooters and Swinburne Islands); mean values in eggs ranged from 1.78 to 3.6 ug/g wet weight. The mean concentration of DDE in cormorant eggs from Gardiner's Island was 0.8 ug/g wet weight. A pesticide manufacturing company operated in Newark Bay for many decades and it is likely that pesticide contamination in the harbor cormorants is, in part, a result of this point source.

DDE in cormorant eggs from the maritime region of Canada and coastal Maine in the 1960s to early 1970s ranged from approximately 6 to 30 ug/g wet weight (Kury 1969, Zitko et al. 1972). A later study in east coastal Canada documented mean DDE levels at 1.5-8.5 ug/g wet weight (Pearce et al. 1979). Peak concentrations in cormorant eggs from the Great Lakes in the early 1970s were 15 to 20 ug/g wet weight (Weseloh et al. 1983, Ryckman et al. 1998). Studies in the 1990s showed levels had subsided in Great Lakes cormorant eggs (approximately 2.5-4.0 ug/g wet weight; Ryckman et al. 1998, Custer et al. 1999). Levels of DDE in cormorant eggs from colonies in coastal New York are comparable to levels currently seen in the Great Lakes, as are concentrations of DDD and DDT (Meadows et al. 1996, Custer et al. 1999).

DDE can adversely impact avian reproduction, especially as a result of egg shell thinning. Shell thinning of 20% has been documented at 10 ug/g DDE concentrations in cormorant eggs (Pearce et al. 1979), but other studies have reported less thinning at higher concentrations (e.g. Gress et al. 1973, Weseloh et al. 1983). Although DDE concentrations were negatively correlated with shell thickness in the present study, mean DDE concentrations were generally below levels expected to produce thinning sufficient to impact hatching. Shells from Shooter's Island averaged 10% thinner than pre-1947 shell thickness (Anderson and Hickey 1972). However, three eggs (21%) from Shooters Island had shells that were $\geq$ 20% thinned (the threshold for deleterious effects, Blus 1996). All eggs from the other two sites had < 20% thinning. DDE concentration was not associated with other reproductive endpoints, although DDE has been associated with reduced reproductive success in cormorants from the Great Lakes (Custer et al. 1999).

All other chlorinated pesticides detected in cormorant tissues from coastal New York occurred at concentrations generally below levels reported in other environmental field studies and known to impact avian reproduction, although information specific to Double-crested Cormorants is not available for all analytes. Dieldrin has been documented in cormorant eggs at levels up to 0.7 ug/g wet weight in studies conducted in the 1960s and 1970s (Vermeer and Reynolds 1970, Pearce et al. 1979, Weseloh et al. 1983, Ryckman et al. 1998). Recent investigations in the Great Lakes reported levels ranging from 0.02-0.09 ug/g wet weight (Meadows et al. 1996, Ryckman et al. 1998). A Green Bay, Wisconsin study reported dieldrin concentrations at 0.25 ug/g wet weight but determined that no adverse reproductive effects resulted from exposure to dieldrin (Custer et al. 1999). In Mallard (*Anas platyrhynchos*), levels of 45.2 ug/g in eggs was associated with a 40% drop in hatching (Peakall 1996). Mean dieldrin levels in the present study ranged from 0.03 to 0.43 ug/g.

Similarly, heptachlor epoxide was documented at relatively high levels in cormorant eggs from the Great Lakes in the 1970s (0.26 ug/g wet weight), but levels detected in the 1990s were < 0.1 ug/g (Ryckman et al. 1998). Mean heptachlor epoxide concentrations in Green Bay were 0.08 ug/g (Custer et al. 1999). Levels detected in the present study ranged from 0.015-0.138 ug/g. Heptachlor epoxide concentrations greater than 10 ug/g caused significant declines in reproductive success in Canada Goose (*Branta canadensis*) and Japanese Quail (*Coturnix japonica*), but lower levels (1.5 ug/g) caused adverse reproductive effects in American Kestrel (*Falco sparverius*; summarized in Wiemeyer 1996).

Levels of the following pesticides detected in cormorant eggs in coastal New York were less than or comparable to levels detected in cormorants sampled in the Great Lakes and prairie regions of North America: β-BHC (Vermeer and Reynolds 1970, Custer et al. 1999), γ-BHC (lindane; Creichus et al. 1973, Custer et al. 1999), mirex and photomirex (Ryckman et al. 1998, Custer et al. 1999), oxychlordane (Meadows et al. 1996, Ryckman et al. 1998, Custer et al. 1999), HCB (Zitko 1976, Meadows et al. 1996, Ryckman et al. 1998, Custer et al. 1999), trans-nonachlor (Meadows et al. 1996, Ryckman et al. 1998, Custer et al. 1999), endrin (Custer et al. 1999). Cis-nonachlor was high in Shooters Island cormorant eggs relative to other studies (Meadows et al. 1996, Ryckman et al. 1998, Custer et al. 1999). No threshold data are available to predict adverse effects to cormorants, but levels determined for other avian species are orders of magnitude greater than levels detected in the present study (see review in Wiemeyer 1996).

No studies exist to aid in interpretation of pesticide levels in cormorant plasma, although information on nestling carcasses (Kury 1969, Stalling et al. 1985, Somers et al. 1993, Custer et al. 2001) and livers is available (Kuiken et al. 1999). Plasma levels reported in the present study were generally orders of magnitude lower than levels detected in nestling carcasses and livers. It is unclear whether the negative relationships detected between plasma concentrations of Σaldrin (largely dieldrin), Σchlordane (approximately 50% oxychlordane, 30% cis-nonachlor), Σendosulfan and nestling survival represent significant impacts of pesticides on reproduction.

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Table 6.1. Chlorinated pesticide concentrations (pg/g wet weight) in eggs of Double-crested Cormorants collected at Gardiner's Island, 1999. Given are n samples, percent detection, minimum, maximum, range, median, mean, and standard deviation (s). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

	n	%detect	minimum	maximum	range	median	mean	s	S-W	P
2,4'-DDT	15	93	0	748	748	237	238	164	0.780	0.002
4,4'-DDT	15	100	580	15700	15100	4460	5670	4360	0.905	0.115
2,4'-DDD	15	53	0	1000	1000	87	134	254	0.554	<0.0001
4,4'-DDD	15	100	109	13700	13600	2000	2330	3320	0.576	<0.0001
2,4'-DDE	15	47	0	353						
4,4'-DDE	15	100	200000	3630000	3430000	630000	823000	847000	0.649	<0.0001
methoxychlor	15	0								
α-BHC	15	100	413	1570	1160	744	783	328	0.905	0.115
β-BHC	15	100	138	2580	2440	633	900	773	0.819	0.007
γ-BHC	15	100	178	730	552	312	357	174	0.882	0.051
δ-BHC	15	0								
mirex	15	100	1250	6770	5520	3070	3340	1670	0.940	0.383
photomirex	15	100	106	581	475	245	278	151	0.914	0.157
oxychlordane	15	100	1970	23200	21200	6760	8080	5430	0.832	0.010
γ-chlordane	15	87	0	290	290	147	143	87	0.962	0.735
α-chlordane	15	100	210	944	734	446	473	225	0.921	0.203
trans-nonachlor	15	100	139	756	617	393	383	173	0.939	0.368
cis-nonachlor	15	100	1420	6290	4870	2820	3340	1580	0.905	0.114
heptachlor	15	0								
heptachlor epoxide	15	100	1130	9650	8520	4890	4930	2870	0.918	0.180
aldrin	15	20	0	52						
dieldrin	15	100	2720	22900	20200	9200	10500	7240	0.875	0.040
endrin	15	7	0	78						
endrin aldehyde	15	7	0	162						
endrin ketone	15	7	0	38						
α-endosulfan	15	7	0	240						
endosulfan sulfate	15	87	0	461	461	79	124	123	0.819	0.007
hexachlorobenzene	15	100	2080	13500	11400	5390	5650	3100	0.876	0.042

Table 6.2. Chlorinated pesticide concentrations (pg/g wet weight) in eggs of Double-crested Cormorants collected at Swinburne Island, 1999. Given are n samples, percent detection, minimum, maximum, range, median, mean, and standard deviation (s). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

	n	%detect	minimum	maximum	range	median	mean	s	S-W	P
2,4'-DDT	13	92	0	439	439	248	252	118	0.969	0.883
4,4'-DDT	13	100	995	16700	15700	5750	7280	5150	0.905	0.157
2,4'-DDD	13	92	0	515	515	147	164	127	0.842	0.022
4,4'-DDD	13	100	433	6820	6390	2450	2930	1890	0.918	0.235
2,4'-DDE	13	46	0	977	0	0	0	0		
4,4'-DDE	13	100	300000	5700000	5400000	1360000	1780000	1500000	0.761	0.003
methoxychlor	13	8	0	33						
α-BHC	13	92	0	1240	1240	791	745	303	0.918	0.233
β-BHC	13	92	0	4230	4230	1020	1410	1240	0.817	0.011
γ-BHC	13	92	0	1700	1700	438	542	407	0.781	0.004
δ-BHC	13	8	0	33						
mirex	13	100	3750	190000	186000	9850	23700	50200	0.393	<0.0001
photomirex	13	100	194	27300	27100	754	2690	7390	0.341	<0.0001
oxychlordane	13	100	7460	9040	82900	27200	39500	28500	0.882	0.075
γ-chlordane	13	92	0	676	676	348	364	190	0.974	0.938
α-chlordane	13	92	0	3460	3460	1550	1720	1020	0.975	0.943
trans-nonachlor	13	92	0	2810	2810	844	1070	767	0.931	0.353
cis-nonachlor	13	100	2510	43400	40900	9000	12600	11800	0.730	0.001
heptachlor	12	8	0	22						
heptachlor epoxide	13	100	2310	42400	40100	5790	9860	10900	0.640	0.0001
aldrin	13	38	0	95						
dieldrin	13	100	3640	189000	185000	13400	33100	49700	0.584	<0.0001
endrin	13	8	0	72						
endrin aldehyde	13	8	0	24						
endrin ketone	13	8	0	48						
α-endosulfan	13	0								
endosulfan sulfate	13	38	0	101						
hexachlorobenzene	13	100	2350	35200	32900	8260	10700	9010	0.801	0.007

Table 6.3. Chlorinated pesticide concentrations (pg/g wet weight) in eggs of Double-crested Cormorants collected at Shooters Island, 1999. Given are n samples, percent detection, minimum, maximum, range, median, mean, and standard deviation (s). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

	n	%detect	minimum	maximum	range	median	mean	s	S-W	P
2,4'-DDT	14	100	254	13900	13600	732	2600	4220	0.590	<0.0001
4,4'-DDT	14	100	3190	50200	47000	17200	18800	14000	0.924	0.253
2,4'-DDD	14	100	120	60500	60400	358	6440	16000	0.447	<0.0001
4,4'-DDD	14	100	2590	2150000	2150000	7470	181000	569000	0.349	<0.0001
2,4'-DDE	14	64	0	28900	28900	208	2640	7610	0.384	<0.0001
4,4'-DDE	14	100	487000	12100000	11600000	2520000	3660000	3280000	0.821	0.009
methoxychlor	14	7	0	30						
α-BHC	14	93	0	1320	1320	777	735	379	0.935	0.358
β-BHC	14	100	376	11600	11200	2230	3490	3420	0.792	0.004
γ-BHC	14	93	0	2690	2690	623	781	657	0.800	0.005
δ-BHC	14	14	0	40						
mirex	14	100	781	43400	42600	8050	10600	10900	0.747	0.001
photomirex	14	100	82	3480	3400	400	752	900	0.692	0.0003
oxychlordane	14	100	747	491000	490000	38700	87400	126000	0.619	<0.0001
γ-chlordane	14	100	160	4060	3900	474	989	1080	0.710	0.0005
α-chlordane	14	100	1090	47600	46500	4450	11400	13800	0.763	0.002
trans-nonachlor	14	100	324	28700	28400	2330	8220	9870	0.769	0.002
cis-nonachlor	14	100	4080	81100	72000	12400	19600	20000	0.701	0.0004
heptachlor	14	7	0	17						
heptachlor epoxide	13	100	2490	43100	40600	12100	15300	12100	0.891	0.101
aldrin	14	36	0	76						
dieldrin	14	100	5640	102000	96400	28600	34300	26400	0.861	0.031
endrin	14	29	0	236						
endrin aldehyde	14	0								
endrin ketone	14	0								
α-endosulfan	14	0								
endosulfan sulfate	14	43								
hexachlorobenzene	14	100	2280	49300	47000	10100	15700	13800	0.800	0.005

Table 6.4. Chlorinated pesticide concentrations (pg/g wet weight) in plasma of Double-crested Cormorants collected at Gardiner's Island, 1999. Given are n samples, percent detection, minimum, maximum, range, median, mean, and standard deviation (s). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

	n	%detect	minimum	maximum	range	median	mean	s	S-W	P
2,4'-DDT	10	50	0	32.0	32.0	2.39	5.60	9.81	0.623	0.0001
4,4'-DDT	10	100	16.4	159	143	31.9	45.8	42.2	0.668	0.0004
2,4'-DDD	10	0								
4,4'-DDD	10	100	1.84	48.0	46.2	5.21	12.2	15.4	0.718	0.002
2,4'-DDE	10	0								
4,4'-DDE	10	100	1070	6400	5330	3700	3750	1610	0.977	0.945
methoxychlor	10	10	0	5.58						
α-BHC	10	100	11.3	74.0	62.7	30.3	35.7	18.9	0.903	0.237
β-BHC	10	80	0	19.8	19.8	14.6	12.5	7.21	0.824	0.029
γ-BHC	10	90	0	31.0	31.0	10.55	13.2	9.14	0.849	0.056
δ-BHC	10	0								
mirex	10	100	10.7	56.1	45.4	26.7	31.6	16.3	0.923	0.383
photomirex	10	100	0.880	7.00	6.12	2.06	3.23	2.28	0.850	0.059
oxychlordane	10	100	69.9	283	213	117	128	61.5	0.797	0.013
γ-chlordane	10	0								
α-chlordane	10	80	0	40.0	40.0	8.08	12.9	12.9	0.886	0.152
trans-nonachlor	10	60	0	37.0	37.0	6.88	11.3	12.9	0.852	0.062
cis-nonachlor	10	100	20.0	187	167	60.7	74.8	51.6	0.879	0.126
heptachlor	10	80	0	202	202	1.11	40.6	83.5	0.521	<0.0001
heptachlor epoxide	10	100	27.6	74.8	47.2	51.9	52.6	14.0	0.989	0.996
aldrin	10	20	0	20.9						
dieldrin	10	100	111	223	112	159	158	29.8	0.916	0.322
endrin	10	20	0	200						
endrin ketone	10	10	0	8.07						
α-endosulfan	10	20	0	200						
β-endosulfan	10	0								
endosulfan sulfate	10	80	0	13.6	13.6	7.68	7.12	4.56	0.930	0.446
hexachlorobenzene	10	100	91.0	171	80.0	144	140	23.8	0.954	0.714

Table 6.5. Chlorinated pesticide concentrations (pg/g wet weight) in plasma of Double-crested Cormorants collected at Swinburne Island, 1999. Given are n samples, percent detection, minimum, maximum, range, median, mean, and standard deviation (s). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

	n	%detect	minimum	maximum	range	median	mean	s	S-W	P
2,4'-DDT	13	31	163							
4,4'-DDT	13	69	0	311	311	129	129	110	0.911	0.189
2,4'-DDD	13	0								
4,4'-DDD	13	92	0	110	110	64.0	62.0	30.1	0.948	0.570
2,4'-DDE	13	0								
4,4'-DDE	13	100	3400	16800	13400	9890	9490	3560	0.972	0.916
methoxychlor	13	0								
α-BHC	13	92	0	60.0	60.0	40.0	37.2	16.7	0.949	0.586
β-BHC	13	46	0	43.8						
γ-BHC	13	46	0	59.0						
δ-BHC	13	0								
mirex	13	100	56.0	168	112	86.0	103	44.3	0.836	0.019
photomirex	13	92	0	13.4	13.4	6.90	6.70	3.60	0.980	0.982
oxychlordane	13	100	262	1060	798	581	599	239	0.943	0.496
γ-chlordane	13	69	0	20.0	20.0	5.00	6.77	6.58	0.899	0.132
α-chlordane	13	100	28.0	67.0	39.0	43.0	42.1	10.6	0.925	0.295
trans-nonachlor	13	100	14.0	85.0	71.0	27.0	33.4	18.5	0.814	0.010
cis-nonachlor	13	100	185	351	166	263	272	53.7	0.934	0.383
heptachlor	13	0								
heptachlor epoxide	13	100	73.0	219	146	150	138	51.3	0.894	0.112
aldrin	13	23	0	5.00						
dieldrin	13	100	262	632	370	428	429	116	0.967	0.850
endrin	13	0								
endrin aldehyde	13	0								
endrin ketone	13	0								
α-endosulfan	13	31	0	200						
endosulfan sulfate	13	31	0	6.00						
hexachlorobenzene	13	100	97	304	207	166	169	50.9	0.879	0.069

Table 6.6. Chlorinated pesticide concentrations (pg/g wet weight) in plasma of Double-crested Cormorants collected at Shooters Island, 1999. Given are n samples, percent detection, minimum, maximum, range, median, mean, and standard deviation (s). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

	n	%detect	minimum	maximum	range	median	mean	s	S-W	P
2,4'-DDT	11	91	0	310	310	42.0	78.8	92.8	0.705	0.0005
4,4'-DDT	11	100	128	2240	2110	811	1020	660	0.934	0.454
2,4'-DDD	11	82	0	422	422	25.0	126	155	0.785	0.006
4,4'-DDD	11	100	168	8000	7830	735	2540	3220	0.711	0.0007
2,4'-DDE	11	64	0	178	178	38.0	62.2	71.0	0.816	0.015
4,4'-DDE	11	100	12800	88900	76100	42000	44100	23400	0.962	0.793
methoxychlor	11	18	0	40.0						
α-BHC	11	100	18.0	55.0	37.0	26.0	30.5	11.5	0.878	0.097
β-BHC	11	100	32.0	289	257	53.0	92.9	76.5	0.776	0.005
γ-BHC	11	100	25.0	78.0	53.0	37.0	43.6	17.2	0.859	0.056
δ-BHC	11	9	0	476						
mirex	11	100	61.0	320	259	145	152	79.8	0.877	0.095
photomirex	11	100	3.00	17.0	14.0	10.0	8.89	4.03	0.952	0.672
oxychlordane	11	100	1570	6260	4690	2850	3300	1460	0.905	0.210
γ-chlordane	11	91	0	154	154	35.0	48.9	43.3	0.872	0.082
α-chlordane	11	100	105	1810	1700	368	720	658	0.830	0.023
trans-nonachlor	11	100	65.0	1570	1500	163	536	568	0.779	0.005
cis-nonachlor	11	100	766	3580	2810	1620	1940	991	0.903	0.201
heptachlor	11	0								
heptachlor epoxide	11	91	0	2500	2500	732	978	783	0.937	0.483
aldrin	11	64	0	15.0	15.0	7.0	6.63	5.80	0.864	0.065
dieldrin	11	91	0	4690	4690	1700	2060	1370	0.958	0.741
endrin	11	46	0	200						
endrin aldehyde	11	9	0	476						
endrin ketone	11	18	0	476						
α-endosulfan	11	82	0	3110	3110	196	425	894	0.410	<0.0001
endosulfan sulfate	11	55	0	476	476	7.00	64.5	148	0.514	<0.0001
hexachlorobenzene	11	100	209	1220	1010	457	563	326	0.879	0.101

Table 6.7. Summed chlorinated pesticide concentrations of major pesticide groups (see text) in eggs of Double-crested Cormorants collected at sites in coastal New York, 1999. Given are mean and standard deviation (pg/g wet weight). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

	ΣDDT	ΣHCH	Σmirex	Σchlordane	Σaldrin	Σendosulfan
Gardiner's Island						
x	831000	2040	3620	17300	10600	140
s	850000	1040	1830	9250	7240	130
S-W	0.652	0.889	0.940	0.905	0.876	0.869
P	<0.0001	0.064	0.377	0.113	0.041	0.033
Swinburne Island						
x	1790000	2700	26400	62900	33200	30
S	1500000	1780	57500	46500	49700	40
S-W	0.761	0.860	0.386	0.838	0.585	0.733
P	0.003	0.038	<0.0001	0.026	<0.0001	0.001
Shooters Island						
x	3870000	5010	11400	148000	34400	30
s	3580000	3540	11800	183000	26500	40
S-W	0.812	0.905	0.742	0.687	0.861	0.735
P	0.007	0.135	0.001	0.0004	0.032	0.0009

Table 6.8. Summed chlorinated pesticide concentrations of major pesticide groups (see text) in plasma of Double-crested Cormorants collected at sites in coastal New York, 1999. Given are mean and standard deviation (pg/g wet weight). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

	ΣDDT	ΣHCH	Σmirex	Σchlordane	Σaldrin	Σendosulfan
Gardiner's Island						
x	3820	61.3	34.8	320	198	46.9
s	1640	18.1	18.3	148	76.1	80.2
S-W	0.976	0.927	0.913	0.924	0.780	0.540
P	0.941	0.419	0.299	0.392	0.008	<0.0001
Swinburne Island						
x	9700	68.1	109	109	430	61.5
S	3640	41.4	47.1	314	116	95.1
S-W	0.965	0.962	0.840	0.953	0.968	0.610
P	0.835	0.781	0.021	0.650	0.864	<0.0001
Shooters Island						
x	48000	210	161	7520	2200	533
s	24500	167	83.4	3630	1280	951
S-W	0.958	0.743	0.885	0.953	0.946	0.489
P	0.745	0.002	0.119	0.688	0.597	<0.0001

Table 6.9. Results of correlation analysis of tarsus length and plasma total chlorinated pesticide concentrations of Double-crested Cormorants sampled at colonies in coastal New York, 1999. Given are n samples, correlation coefficient (r), and probability (P).

Colony	Pesticide group	r	P
Gardiner's Island (n=10)	ΣDDT	0.068	0.853
	ΣHCH	0.214	0.553
	Σmirex	0.134	0.712
	Σchlordane	-0.236	0.511
	Σaldrin	-0.328	0.354
Swinburne Island (n=12)	ΣDDT	-0.040	0.903
	ΣHCH	-0.045	0.891
	Σmirex	0.106	0.742
	Σchlordane	-0.069	0.831
	Σaldrin	0.142	0.659
Shooters Island (n=11)	ΣDDT	-0.527	0.096
	ΣHCH	-0.669	0.024
	Σmirex	-0.420	0.198
	Σchlordane	-0.275	0.413
	Σaldrin	-0.089	0.796

Table 6.10. Results of correlation analysis of egg concentrations of major pesticide groups in Double-crested Cormorants sampled at colonies in coastal New York, 1999. Given are Pearson correlation coefficient (r), and probability (P). Alpha=0.05.

	ΣHCH	Σmirex	Σchlordane	Σendosulfan
Gardiner's Island				
ΣDDT	n.s.	n.s.	r=0.724 P=0.0023	r=0.668 P=0.007
ΣHCH		n.s	r=0.633 P=0.011	n.s
Σmirex			r=0.579 P=0.024	n.s.
Σchlordane				r=0.748 P=0.001
Swinburne Island				
ΣDDT	n.s.	n.s.	r=0.884 P=0.0001	r=0.742 P=0.004
ΣHCH		n.s	n.s.	n.s
Σmirex			n.s.	n.s.
Σchlordane				r=0.757 P=0.004
Shooters Island				
ΣDDT	r=0.615 P=0.019	r=0.728 P=0.003	r=0.886 P=<0.0001	r=0.824 P=0.0003
ΣHCH		r=0.633 P=0.015	r=0.655 P=0.015	r=0.770 P=0.001
Σmirex			r=0.878 P=0.0001	r=0.833 P=0.0002
Σchlordane				r=0.927 P=<0.0001

Table 6.11. Results of correlation analysis of plasma concentrations of major pesticide groups in Double-crested Cormorants sampled at colonies in coastal New York, 1999. Given are Pearson correlation coefficient (r), and probability (P). Alpha=0.05.

	ΣHCH	Σmirex	Σchlordane	Σendosulfan
Gardiner's Island				
ΣDDT	n.s	n.s.	n.s.	n.s.
ΣHCH		n.s	n.s.	n.s
Σmirex			n.s.	n.s.
Σchlordane				n.s.
Swinburne Island				
ΣDDT	r=0.613 P=0.034	n.s.	r=0.783 P=0.002	r=0.583 P=0.036
ΣHCH		n.s	r=0.730 P=0.007	r=0.827 P=0.0009
Σmirex			n.s.	n.s.
Σchlordane				r=0.701 P=0.008
Shooters Island				
ΣDDT	r=0.635 P=0.039	r=0.705 P=0.016	n.s.	n.s.
ΣHCH		n.s.	n.s.	n.s.
Σmirex			n.s.	n.s.
Σchlordane				r=0.715 P= 0.013

Table 6.12. Egg shell thickness of Double-crested Cormorants sampled at colonies in coastal New York, 1999. Given are mean + standard deviation (n eggs), minimum, and maximum shell thickness (mm).

	Mean ± s (n)	Minimum	Maximum
Gardiner's Island	0.411 ± 0.0177 (15)	0.380	0.440
Shooters Island	0.396 ± 0.0369 (14)	0.340	0.470
Swinburne Island	0.414 ± 0.0198 (13)	0.380	0.460

Table 6.13. Results of correlation analysis of egg concentrations of 2,4' DDE and 4,4' DDE and egg shell thickness in Double-crested Cormorants sampled at colonies in coastal New York, 1999. Given are Spearman correlation coefficient (r), and probability (P) for n=42 eggs. Alpha'=0.025 (Sidak's method).

	r	P
2,4'-DDE	-0.488	0.001
4,4'-DDE	-0.391	0.011

Table 6.14. Results of correlation analysis of reproductive endpoints and chlorinated pesticides in eggs of Double-crested Cormorants collected in coastal New York, 1999. Given are n samples, Spearman correlation coefficient, and probability (P). Alpha'=0.017 (Sidak's method).

Tissue	Reproductive Endpoints	n samples	Spearman correlation coefficient	P
Σ DDT	Eggs Laid	42	0.088	0.581
	Max Young Observed	34	0.050	0.780
	Max Chick Days	28	-0.033	0.868
Σ HCH	Eggs Laid	42	0.153	0.332
	Max Young Observed	34	-0.047	0.793
	Max Chick Days	28	-0.082	0.679
Σ mirex	Eggs Laid	42	0.115	0.467
	Max Young Observed	34	-0.091	0.607
	Max Chick Days	28	0.009	0.966
Σ chlordane	Eggs Laid	42	0.096	0.544
	Max Young Observed	34	0.138	0.436
	Max Chick Days	28	-0.048	0.810
Σ aldrin	Eggs Laid	42	0.081	0.611
	Max Young Observed	34	0.108	0.543
	Max Chick Days	28	0.011	0.955
Σ endosulfan	Eggs Laid	42	-0.297	0.056
	Max Young Observed	34	-0.208	0.237
	Max Chick Days	28	0.208	0.289

Table 6.15. Results of correlation analysis of reproductive endpoints and chlorinated pesticides in plasma of Double-crested Cormorants collected in coastal New York, 1999. Given are n samples, Spearman correlation coefficient, and probability (P). Alpha'=0.017 (Sidak's method).

Tissue	Reproductive Endpoints	n samples	Spearman correlation coefficient	P
Σ DDT	Eggs Laid	34	-0.203	0.250
	Max Young Observed	33	-0.260	0.145
	Max Chick Days	33	-0.314	0.075
Σ HCH	Eggs Laid	34	-0.168	0.342
	Max Young Observed	33	-0.073	0.685
	Max Chick Days	33	-0.288	0.104
Σ mirex	Eggs Laid	34	-0.263	0.133
	Max Young Observed	33	-0.218	0.223
	Max Chick Days	33	-0.200	0.264
Σ chlordane	Eggs Laid	34	-0.201	0.254
	Max Young Observed	33	-0.266	0.134
	Max Chick Days	33	-0.470	0.006
Σ aldrin	Eggs Laid	34	-0.163	0.358
	Max Young Observed	33	-0.261	0.142
	Max Chick Days	33	-0.433	0.012
Σ endosulfan	Eggs Laid	34	-0.178	0.315
	Max Young Observed	33	-0.155	0.391
	Max Chick Days	33	-0.465	0.006

Figure 6.1. Comparison of organochlorine pesticide analytes in eggs of Double-crested Cormorant from different colonies in coastal New York, 1999. Shown are the percent contributions of individual analytes to summed concentrations of major chemical groups: A. Σ DDT; B. Σ chlordane (ACHLOR=α-chlordane; CNONA=cis-nonachlor; TNONA=trans-nonachlor; HEPEP=heptachlor epoxide; OXYCHL=oxychlordane); C. Σ HCH (DBHC=δ-BHC; GBHC=γ-BHC; BBHC=β-BHC; ABHC=α-BHC); D. Σ mirex (PHMIR=photomirex); E. Σ aldrin (DIELD=dieldrin).

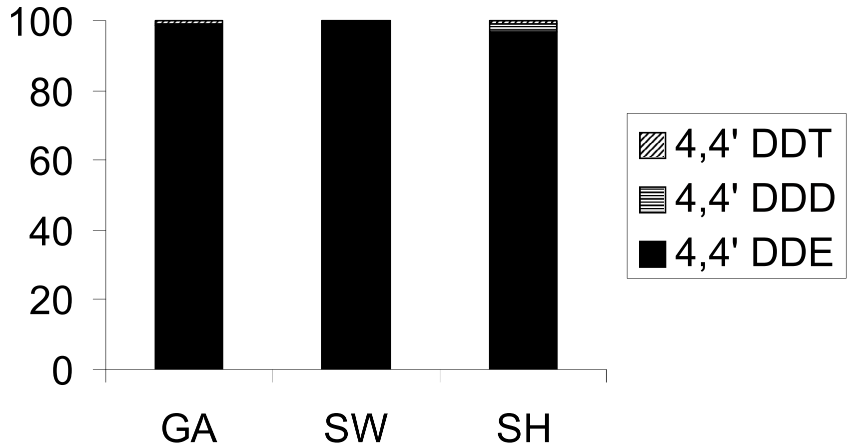


Figure 6.1A
Σ DDT eggs

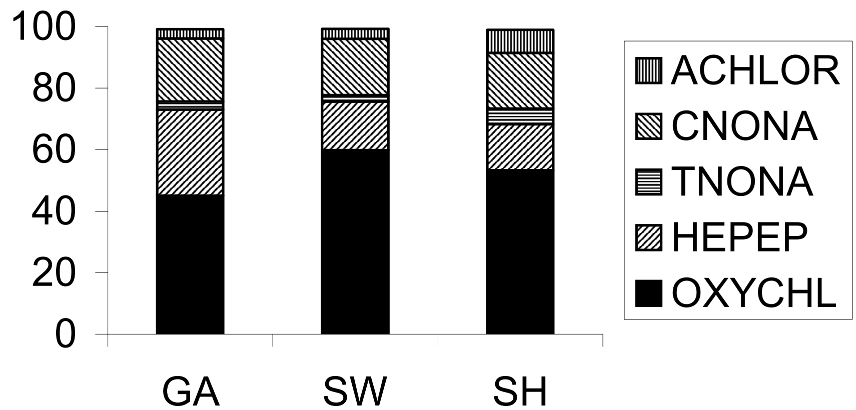


Figure 6.1B
Σ chlordane eggs

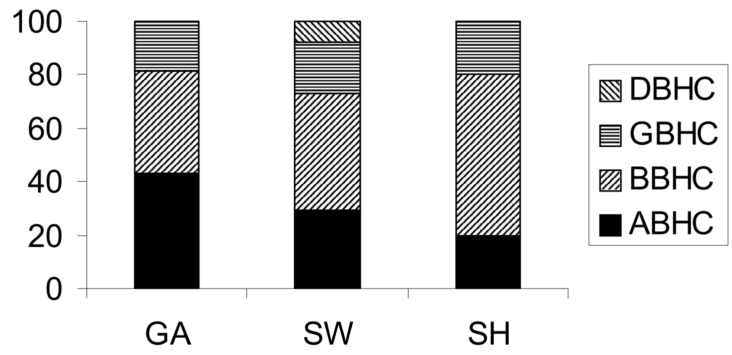


Figure 6.1C
∑ HCH

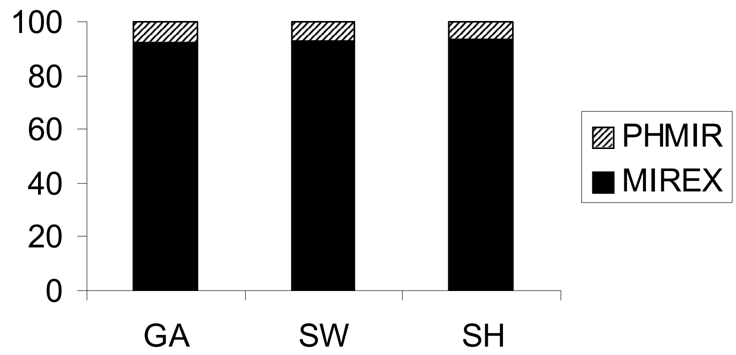


Figure 6.1D
∑ mirex

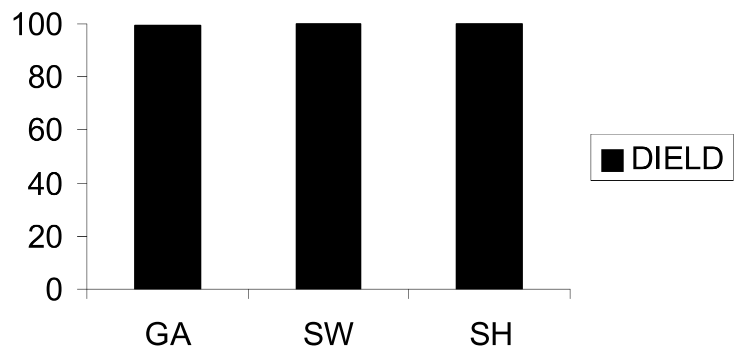


Figure 6.1E
∑ aldrin

Figure 6.2. Comparison of organochlorine pesticide analytes in plasma of Double-crested Cormorant from different colonies in coastal New York, 1999. Shown are the percent contributions of individual analytes to summed concentrations of major chemical groups: A. Σ DDT; B. Σ chlordane (ACHLOR=α-chlordane; CNONA=cis-nonachlor; TNONA=trans-nonachlor; HEPEP=heptachlor epoxide; OXYCHL=oxychlordane); C. Σ HCH (DBHC=δ-BHC; GBHC=γ-BHC; BBHC=β-BHC; ABHC=α-BHC); D. Σ mirex (PHMIR=photomirex); E. Σ aldrin (ENKET=endrin ketone; ENDRN=endrin; DIELD=dieldrin).

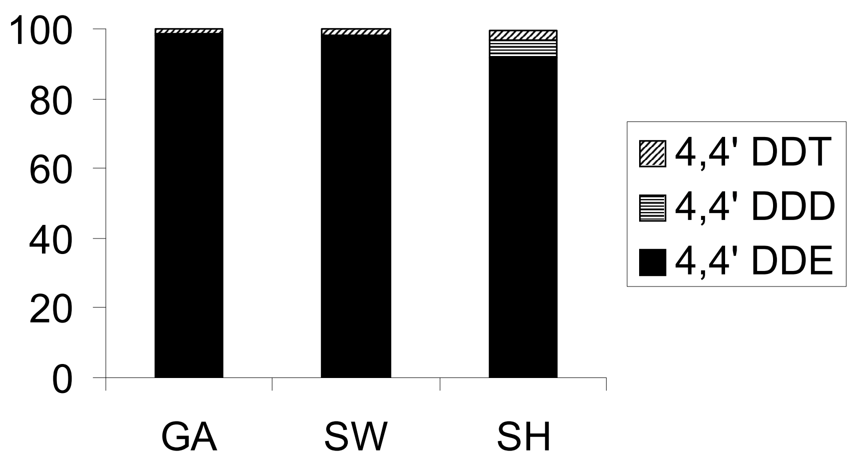


Figure 6.2A
Σ DDT plasma

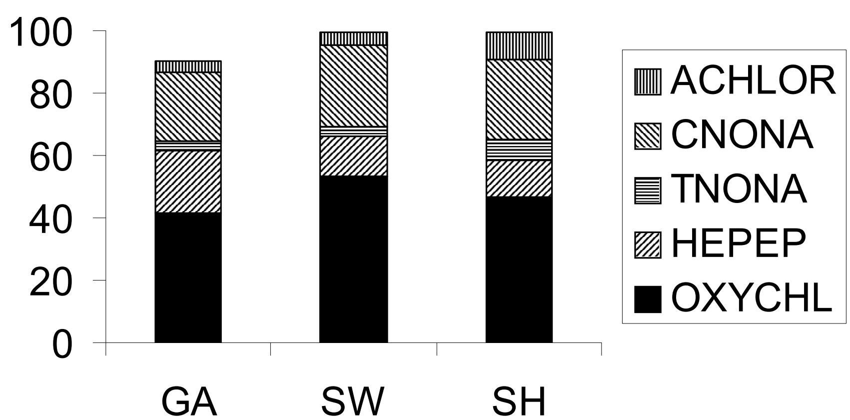


Figure 6.2B
Σ chlordane plasma

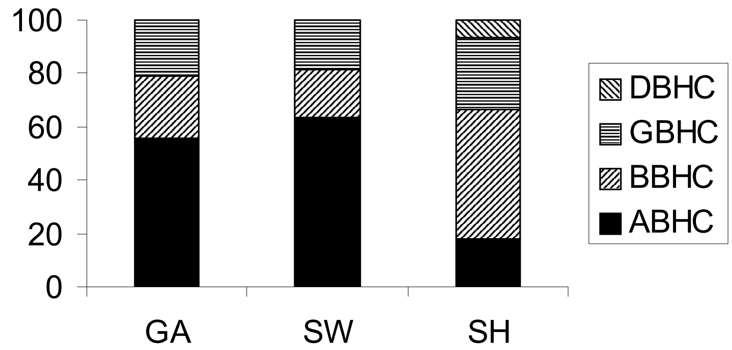


Figure 6.2C
Σ HCH plasma

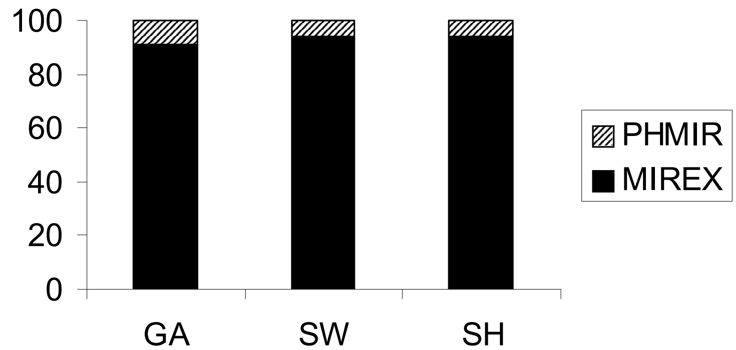


Figure 6.2D
Σ mirex plasma

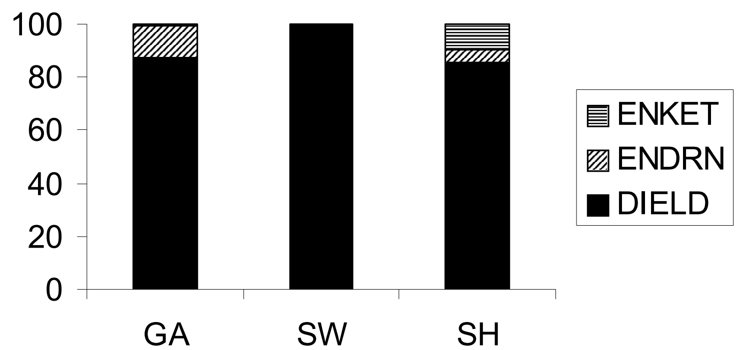
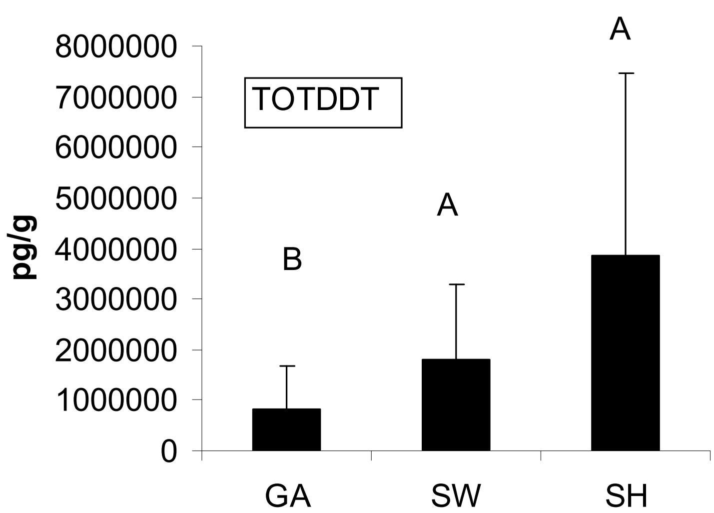
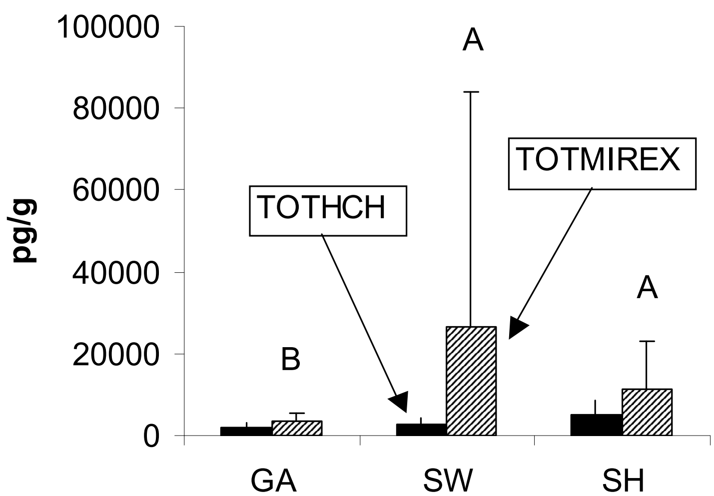


Figure 6.2E
Σ aldrin plasma

Figure 6.3. Comparison of chlorinated pesticides in eggs of Double-crested Cormorant from different colonies in coastal New York, 1999. Shown are mean + standard deviation concentration (pg/g wet weight) total major pesticide group (see text) detected in eggs from Gardiner's Island (GA), Shooters Island (SH), and Swinburne Island (SW). TOTDDT=Σ DDT; TOTHCH=Σ HCH; TOTMIREX=Σ mirex; TOTCHL=Σ chlordane; TOTDRN=Σ aldrin. Unlike letters indicate colony differences.





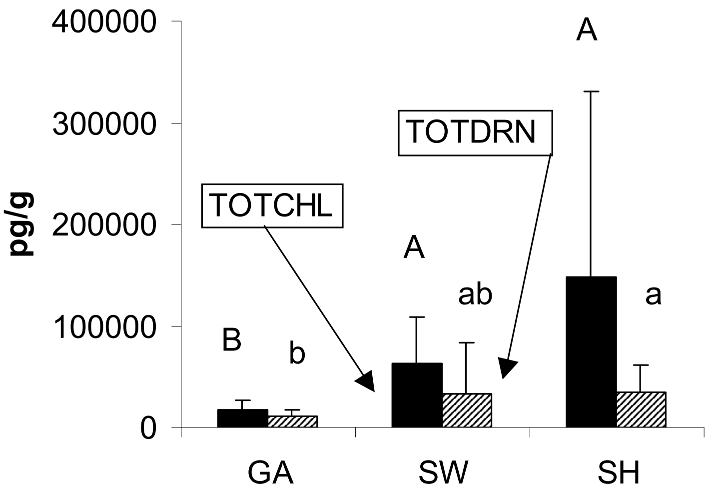

400000
300000
200000
100000
0
pg/g
TOTCHL
TOTDRN
A
A
ab
a
B
b
GA
SW
SH

Figure 6.4. Comparison of chlorinated pesticides in plasma of Double-crested Cormorant from different colonies in coastal New York, 1999. S

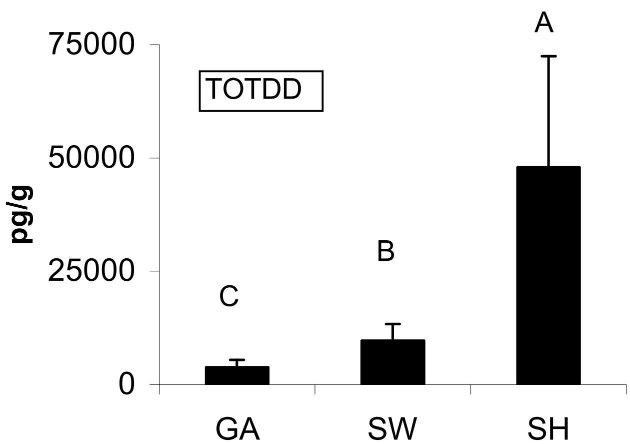
Figure 4 -- plasma

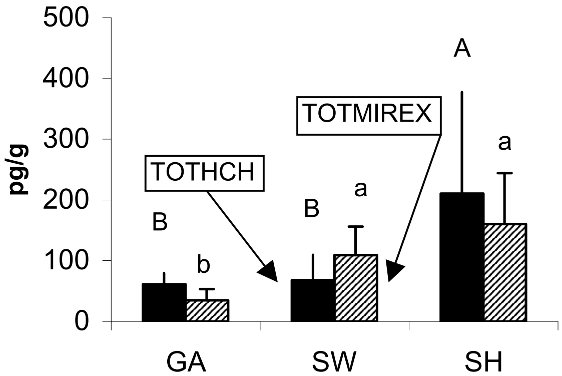
standard deviation concentration (pg/g wet weight) total major p

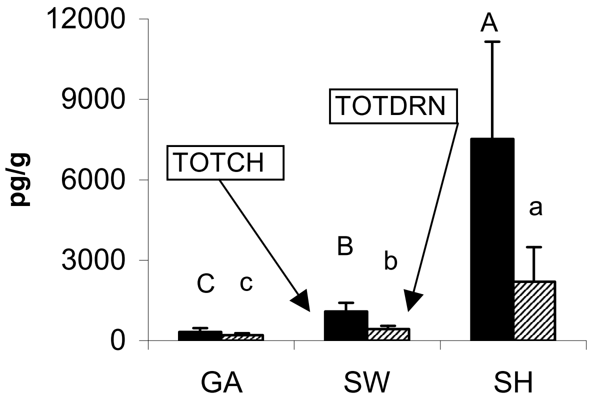
detected in plasma from Gardiner's Island (GA), Shooters Islan(

Island (SW). TOTDDT=Σ DDT; TOTHCH=Σ HCH; TOTMIREX=

chlordane; TOTDRN=Σ aldrin. Unlike letters indicate colony differences.




500
400
300
200
100
0
pg/g
A
TOTMIREX
a
TOTHCH
B
B
a
b
GA
SW
SH


12000
9000
6000
3000
0
pg/g
A
TOTDRN
TOTCH
a
B
C
c
b
GA
SW
SH

POLYCHLORINATED BIPHENYL AROCLORS

RESULTS

Double-crested Cormorant egg and plasma tissues were analyzed for four PCB Aroclors including AR1242, AR1248, AR1254 and AR1260. Results are reported as non-lipid adjusted ng/g wet weight; detection limits ranged from 0.0329-15.9 in eggs and 0.00272-1.65 in plasma (see Appendix 1—Quality Assurance). Non-detects were adjusted to zero. AR1248 was not detected in any samples from any site.

Descriptive statistics of all PCB Aroclors detected in at least one sample from at least one site are provided in Tables 7.1-7.2. Data from several sample populations of egg tissue were not distributed normally.

PCB Aroclor data were summed to provide a total concentration variable to examine spatial patterns in tissue concentrations (Tables 7.1-7.2). Log transformations of summed concentration data in plasma stabilized variance sufficiently to allow use of parametric analysis (Levene's test $P<0.05$). The Pearson correlation was used to examine nestling size and PCB Aroclors in plasma. Comparisons between colonies were performed on total PCB Aroclor concentration data (ANOVA, Tukey mean separation procedure). Plasma concentration data were log transformed. Unless otherwise noted, $\alpha=0.05$.

Cormorant nestlings selected for plasma sampling were not of uniform size across colony sites (see Table 4.4). Tissue samples were taken from nestlings significantly smaller on Shooters Island compared to Swinburne Island. Nevertheless, no correlations were detected between nestling size and PCB Aroclor concentrations at any island (Table 7.3). In addition, ANCOVA showed colony differences but detected no relationship between tarsus length and total PCB Aroclor concentrations (F_{colony}=35.8, P<0.0001; F_{tarsus}=2.72, P=0.110)

PCB Aroclors in eggs and plasma correlated with each other in most instances (Tables 7.4-7.5). The relative contribution of different Aroclors to total PCB concentrations did not differ between colony-sites (Figure 7.1). PCB Aroclors 1260 and 1254 dominated total PCB Aroclor concentrations at all sites in both tissue types.

Total PCB Aroclor concentrations were highest in eggs and plasma from Shooters Island and lowest in eggs and plasma from Gardiner's Island; samples from Swinburne Island were intermediate (Figure 7.2). PCB Aroclor total concentrations in plasma were especially high in samples from Shooters Island compared to the other two sites.

No relationships between total PCB Aroclor concentrations in eggs or plasma and reproductive endpoints, including a measure of egg production (Eggs Laid), hatching success (Maximum Young Observed) and chick survival (Maximum Chick Days), were detected (Table 7.6).

Discussion

Mean Aroclor concentrations were greatest in eggs and plasma from Shooters Island compared to the other two sites, and in eggs, comprised largely of AR1254. In contrast, plasma samples from all sites and eggs from Swinburne and Gardiner's Islands were dominated by AR1260.

Few environmental field data on AR1260 concentrations exist for birds and most dosing studies have focused on AR1254 (see review in Hoffman et al. 1996). AR1254 concentrations in Double-crested Cormorant eggs from colonies in the maritime region of Canada were 5-10 times greater than levels detected in the present study (Zitko et al. 1972). Similarly, levels of AR1254 detected in adult cormorant muscle, liver, and fat were orders of magnitude greater than nestling plasma concentrations detected in the present study (Zitko and Hutzinger 1972).

Dosing studies have failed to detect adverse reproductive effects at egg concentrations ranging from 10-81 ug/g AR1254 in Atlantic Puffins (*Fratercula artica* ; Harris and Osborn 1981), 4-18 ug/g AR1248 in Screech Owls (*Otus asio*; McLane and Hughes 1980), and 105 ug/g AR1242 in Mallards (*Anas platyrhynchos*; Haseltine and Prouty 1980). Egg injections resulting in 5 ug/g AR1248 produced approximately 80% mortality of chicken embryos (Brunstrom and Orberg 1982), but chickens are known to be highly sensitive to chlorinated hydrocarbons (Hoffman et al. 1996). AR1254 concentrations of 30 ug/g in Mallard ducklings also failed to produce adverse effects (Custer and Heinz 1980). No conclusions can be drawn regarding the potential effects of PCB Aroclors on cormorants in this study due to the lack of information available from the literature to interpret residue data.

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Table 7.1. Polychlorinated biphenyl (Aroclor) concentrations (ng/g wet weight) in eggs of Double-crested Cormorants collected at colonies in coastal New York, 1999. Given are n samples, percent detection, minimum, maximum, range, median, mean, and standard deviation (s). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

	n	%detect	minimum	maximum	range	median	mean	s	S-W	P
Gardiner's Island										
AR1242	15	100	12.0	87.0	75.0	32.0	37.9	23.8	0.865	0.029
AR1248	15	0								
AR1254	15	100	450	2740	2290	1230	1270	670	0.938	0.363
AR1260	15	100	920	6690	5770	2100	2360	1490	0.825	0.008
Total PCB Aroclors	15		1390	9506	8120	3480	3670	2140	0.870	0.033
Swinburne Island										
AR1242	13	100	38.0	734	696	289	337	203	0.971	0.903
AR1248	13	0								
AR1254	13	100	1040	7910	6870	4690	4760	2370	0.934	0.380
AR1260	13	100	2050	11800	9750	7830	7592	3376	0.917	0.229
Total PCB Aroclors	13		3208	20300	17100	14300	12700	5850	0.926	0.301
Shooters Island										
AR1242	14	100	80.0	1840	1760	567	687	535	0.845	0.019
AR1248	14	0								
AR1254	14	100	588	23700	23100	8470	8930	5730	0.914	0.183
AR1260	14	100	2150	43700	41550	13800	1510	9980	0.831	0.012
Total PCB Aroclors	14		3380	69200	65900	22400	24700	15800	0.844	0.019

Table 7.2. Polychlorinated biphenyl (Aroclor) concentrations (ng/g wet weight) in plasma of Double-crested Cormorants collected at colonies in coastal New York, 1999. Given are n samples, percent detection, minimum, maximum, range, median, mean, and standard deviation (s). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

	n	%detect	minimum	maximum	range	median	mean	s	S-W	P
Gardiner's Island										
AR1242	11	100	0.307	1.16	0.853	0.519	0.658	0.293	0.905	0.214
AR1248	11	0								
AR1254	11	100	6.81	28.2	21.4	14.5	16.1	6.91	0.909	0.236
AR1260	11	100	7.91	34.1	26.2	16.6	18.7	9.16	0.902	0.197
Total PCB Aroclors	11		15.0	61.3	46.3	31.8	35.5	15.4	0.926	0.368
Swinburne Island										
AR1242	13	100	1.74	9.05	7.31	4.26	5.15	2.03	0.949	0.578
AR1248	13	0								
AR1254	13	100	15.4	58.3	42.9	43.5	42.1	11.0	0.928	0.319
AR1260	13	100	22.1	86.2	64.1	60.2	59.8	18.5	0.967	0.854
Total PCB Aroclors	13		39.2	145	106	115	107	29.2	0.936	0.402
Shooters Island										
AR1242	11	100	8.30	34.3	26.0	14.7	17.3	8.97	0.811	0.013
AR1248	11	0								
AR1254	11	100	51.2	196	145	112	115	45.2	0.937	0.484
AR1260	11	100	96.5	390	294	176	190	86.0	0.889	0.134
Total PCB Aroclors	11		158	544	387	318	323	124	0.951	0.654

Table 7.3. Results of correlation analysis of tarsus length and plasma total PCB Aroclor concentrations of Double-crested Cormorants sampled at colonies in coastal New York, 1999. Given are n samples, correlation coefficient (r), and probability (P).

Colony	PCB Aroclor	r	P
Gardiner's Island	AR1242	0.384	0.244
	AR1254	0.371	0.262
	AR1260	0.110	0.747
Swinburne Island	AR1242	-0.256	0.447
	AR1254	-0.373	0.259
	AR1260	-0.432	0.185
Shooters Island	AR1242	-0.385	0.217
	AR1254	-0.345	0.273
	AR1260	-0.267	0.402

Table 7.4. Results of correlation analysis of egg concentrations of PCB Aroclors of Double-crested Cormorants sampled at colonies in coastal New York, 1999. Given are Pearson correlation coefficient (r), and probability (P).

	AR1254	AR1260
Gardiner's Island		
AR1242	r=0.842	r=0.800
	P<0.0001	P=0.0003
AR1254		r=0.879
		P<0.0001
Swinburne Island		
AR1242	r=0.846	r=0.960
	P=0.0003	P<0.0001
AR1254		r=0.905
		P<0.0001
Shooters Island		
AR1242	r=0.754	r=0.763
	P=0.002	P=0.002
AR1254		r=0.749
		P=0.002

Table 7.5. Results of correlation analysis of plasma concentrations of PCB Aroclors of Double-crested Cormorants sampled at colonies in coastal New York, 1999. Given are Pearson correlation coefficient (r), and probability (P).

	AR1254	AR1260
Gardiner's Island		
AR1242	r=0.638	r=0.592
	P=0.0351	P=0.055
AR1254		r=0.783
		P=0.004
Swinburne Island		
AR1242	r=0.811	r=0.568
	P=0.0008	P=0.043
AR1254		r=0.737
		P=0.004
Shooters Island		
AR1242	r=0.846	r=0.434
	P=0.001	P=0.182
AR1254		r=0.587
		P=0.058

Table 7.6. Results of correlation analysis of reproductive endpoints and total PCB Aroclors within tissues of Double-crested Cormorants collected in coastal New York, 1999. Given are n samples, Spearman correlation coefficient, and probability (P). Alpha'=0.017 (Sidak's method).

Tissue	Reproductive Endpoints	n samples	Spearman correlation coefficient	P
Egg	Eggs Laid	42	0.071	0.653
	Max Young Observed	34	0.102	0.566
	Max Chick Days	28	-0.129	0.513
Plasma	Eggs Laid	30	-0.149	0.393
	Max Young Observed	29	-0.250	0.154
	Max Chick Days	29	-0.295	0.090

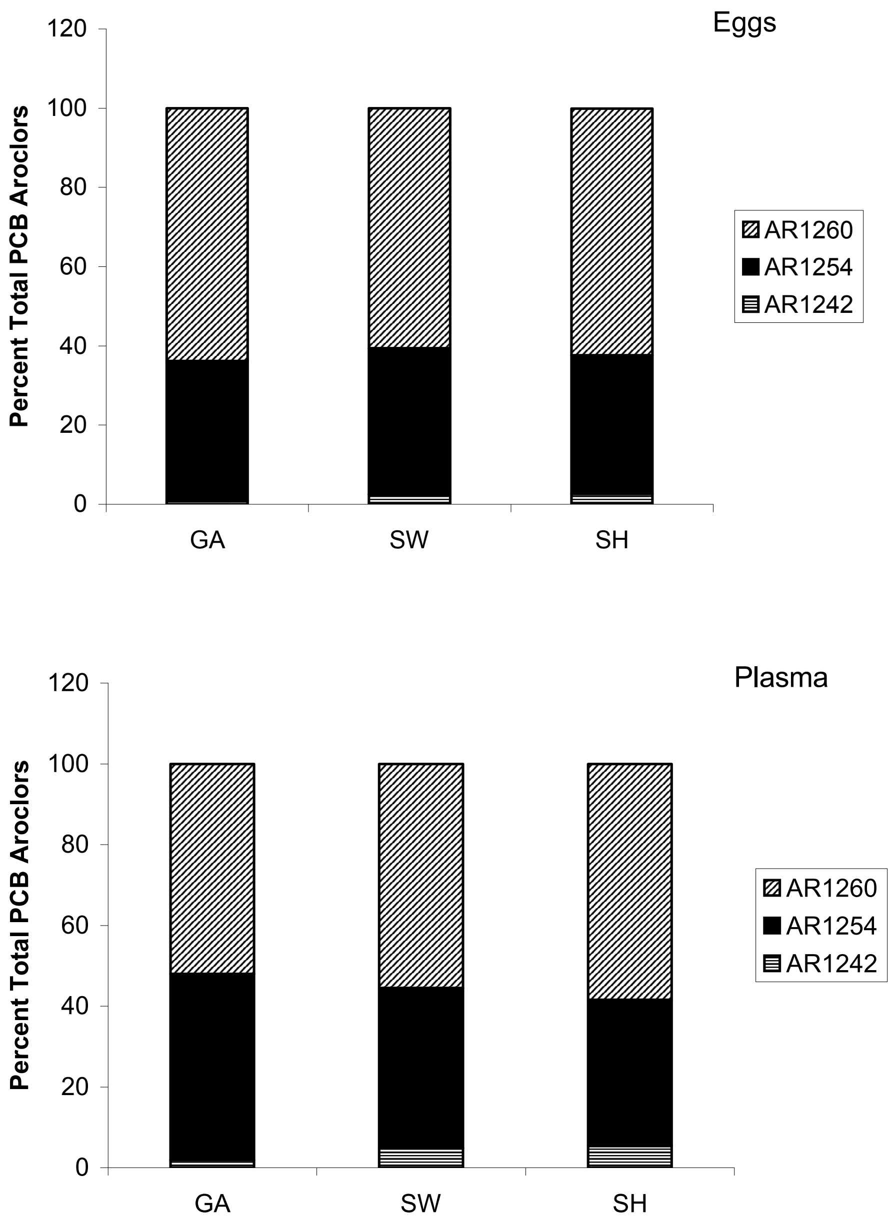

Figure 7.1. Comparison of PCB Aroclors in eggs and plasma of Double-crested Cormorant from different colonies in coastal New York, 1999. Shown are the percent contributions of individual Aroclors to summed concentrations of major chemical groups:

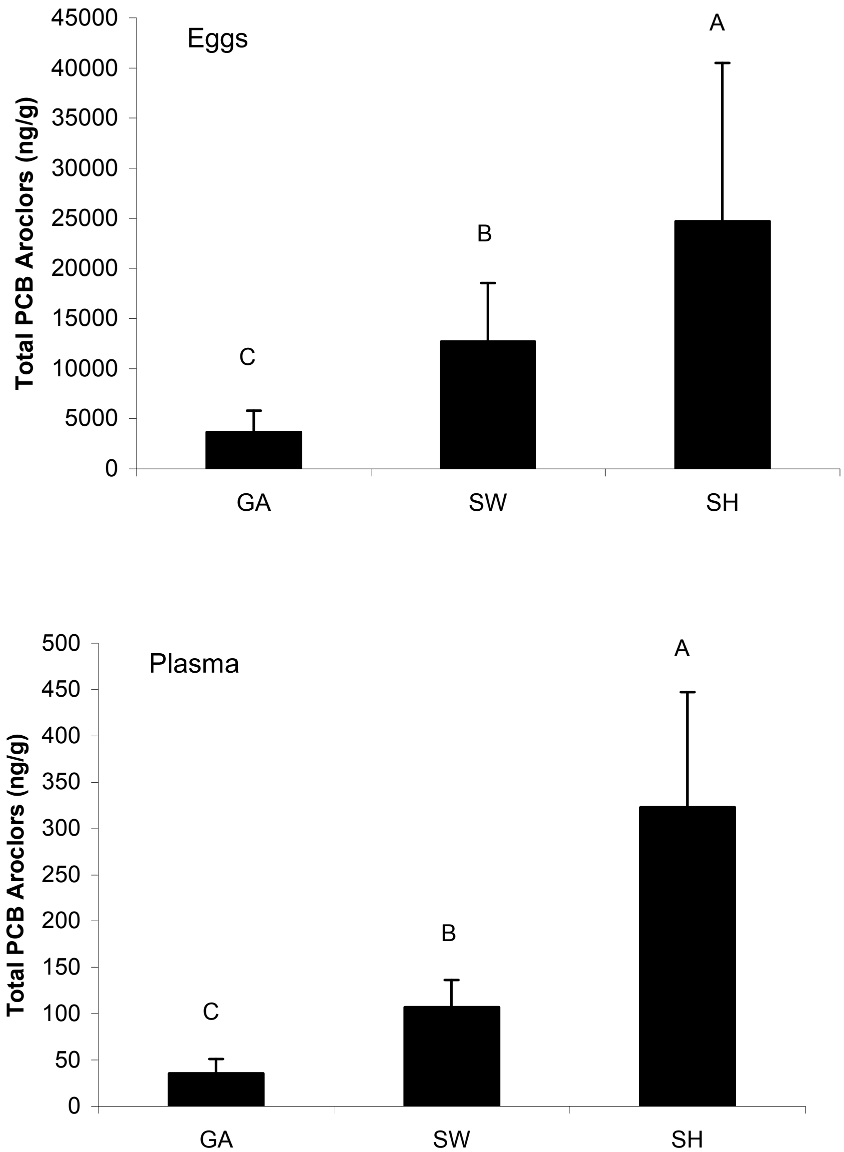

Figure 7.2. Comparison of total PCB Aroclors in eggs and plasma of Double-crested Cormorant from different colonies in coastal New York, 1999. Shown are mean + standard deviation concentration (ng/g wet weight) total PCB Aroclors (see text) detected in eggs and plasma from Gardiner's Island (GA), Shooters Island (SH), and Swinburne Island (SW). Unlike letters indicate colony differences.

8. POLYCHLORINATED BIPHENYL CONGENERS

RESULTS

Double-crested Cormorant egg and plasma tissues were analyzed for 209 PCB congeners. Results are reported as non-lipid adjusted ng/g wet weight. Detection limits ranged from 0.0017 to 8.89 ng/g in eggs and 0.000300 to 0.0402 ng/g in plasma (see Appendix 1—Quality Assurance). Non-detects (approximately 23-24% of all samples) were adjusted to zero. An additional 23-24% of all samples were reported as zero. Coeluting congeners are identified in Appendix 1—Quality Assurance. Descriptive statistics of all PCB congeners are provided in Tables 8.1-8.10.

The following congeners were not detected in any egg samples from any site: 2, 5, 7, 9, 10, 12, 13, 14, 28, 29, 30, 33, 39, 41, 47, 51, 53, 55, 57, 62, 65, 69, 70, 71, 74, 75, 76, 78, 87, 91, 95, 97, 98, 99, 100, 101, 102, 106, 108, 112, 113, 115, 116, 117, 119, 124, 125, 138, 140, 142, 143, 145, 149, 151, 154, 157, 160, 161, 163, 166, 168, 173, 185, 193, 199, 200 (Table 8.11). The following congeners were not detected in any plasma samples from any site: 5, 10, 12, 13, 14, 23, 24, 28, 29, 30, 33, 34, 35, 38, 39, 41, 46, 47, 51, 53, 55, 57, 58, 62, 65, 69, 70, 71, 74, 75, 76, 78, 80, 87, 89, 91, 95, 97, 98, 99, 100, 101, 102, 104, 106, 108, 112, 113, 115, 116, 117, 119, 122, 124, 125, 138, 140, 142, 143, 145, 149, 151, 152, 154, 157, 160, 161, 163, 166, 168, 173, 185, 186, 192, 193, 199, 200 (Table 8.12).

PCB congener data were summed to provide a total concentration variable to examine spatial patterns in tissue concentrations (Table 8.13). Log transformations of summed concentration data in plasma stabilized variance sufficiently to allow use of parametric analysis (Levene's test $P>0.05$). The Pearson correlation was used to compare nestling size and PCB congener concentratons. Comparisons between colonies were performed on total PCB congener concentration data (ANOVA, Tukey mean separation procedure). Plasma concentration data were log transformed. Unless otherwise noted, α=0.05.

Cormorant nestlings selected for plasma sampling were not of uniform size across colony sites (see Table 4.4). Tissue samples were taken from nestlings significantly smaller on Shooters Island compared to Swinburne Island. Nevertheless, no correlations were detected between nestling size and total PCB congener concentrations at any island (Gardiner's Island: r=0.251, P=0.457; Swinburne Island: r=-0.152, P=0.638; Shooters Island: r=-0.411, P=0.210).

Toxic equivalents were highest in eggs (mean=0.322 ng/g) and plasma (mean=0.00848 ng/g) collected at Shooters Island, and were more than three times greater than samples from Gardiner's Island (Table 8.14). Samples from Swinburne Island were intermediate. Total homologue concentrations followed a similar pattern (Table 8.15).

The relative contribution of different congeners to total PCB concentrations did not differ between colony-sites (Figure 8.1). PCB congeners 83 (coeluting with 99), 118, 129 (coeluting with 138, 160, 163), 153 (coeluting with 168), and 180 (coeluting with 193) dominated total PCB congener concentrations at all sites in both tissue types. Total PCB congener concentrations were highest in eggs and plasma from Shooters Island and lowest in eggs and plasma from Gardiner's Island; samples from Swinburne Island were intermediate (Figure 8.2).

No relationships between total PCB concentrations in eggs or plasma and reproductive endpoints, including a measure of egg production (Eggs Laid), hatching success (Maximum Young Observed) and chick survival (Maximum Chick Days), were detected (Table 8.16).

Discussion

Mean total PCB concentrations in cormorant eggs collected at coastal New York sites ranged from 2,490 to 13,900 ng/g wet weight, and are very similar to total PCB concentrations detected in cormorant eggs collected from the maritime region of Canada in the mid 1970s (5,660-19,300 ng/g wet weight; Pearce et al. 1979).

In addition, current study results are comparable to levels detected in Great Lakes cormorants over the past three decades. Mean total PCBs in cormorant eggs collected from colonies in heavily contaminated portions of the Great Lakes, such as Lake Erie and Lake Huron peaked at 35,000 ng/g and 23,800 ng/g in the 1970s (Weseloh et al. 1983, Ryckman et al. 1998). By the late 1980s, several studies reported PCB concentrations ranging from 100-15,000 ng/g (Tillitt et al. 1992, Ryckman et al. 1998), including sites in Green Bay, Wisconsin—a severely impacted system (Williams et al. 1995, Custer et al. 1999). By the late 1990s, levels were an order of magnitude lower in sites from Lake Huron and Lake Superior (Kannan et al. 2001). Although these declines represent reduced environmental concentrations of PCBs in the Great Lakes, unpolluted sites in Alaska and elsewhere have yielded egg levels ranging from 80-1,000 ng/g total PCBs (Ohlendorf et al. 1982, Tillitt et al. 1992).

Total PCB levels in plasma have not been reported for cormorant nestlings making it difficult to compare our results with other studies. However nestling concentrations in other tissues have been determined in two studies. Somers et al. (1993) detected 940 ng/g wet weight in lipid from 84 juvenile cormorants collected in western Canada. Nestlings collected from several sites in the upper midwest showed 130-3,450 ng/g wet weight (geometric mean whole carcass). Plasma levels of total PCBs in the present study ranged from 25-210 ng/g wet weight.

Few cormorant studies have reported congener-specific information. Concentrations found in cormorant eggs in British Columbia and Lake Ontario (Henshel et al. 1997) were similar to the present study for congeners 77, 126, and 169, but were greater for congeners 105 and 188. Cormorant eggs sampled in Green Bay, Wisconsin in the late 1980s had higher concentrations of congeners 77, 81, 126, 169, and 105, but lower levels of congener 118, than those detected in coastal New York cormorant eggs (Williams et al. 1995). Another sampling effort in Green Bay in the 1990s reported congener concentrations lower than those detected in coastal New York for congeners 167, 189, 118, 114, 156 (coeluting with 157) and 123, however congeners 81, 126, and 105 were higher (Meadows et al. 1996).

PCBs can adversely affect bird populations in a number of ways. They may reduce egg hatchability, affect reproductive behavior and nestling growth, and cause edema, porphyria and malformations. Total PCB concentrations in eggs and TCDD-equivalents within the range of values from this study (7-9 ug/g and 150-250 pg/g TCDD-equivalents) have resulted in 25% mortality of cormorant embryos (Yamashita et al. 1993). Threshold levels that are more protective (i.e. less than 25% mortality) have been estimated as follows: 3.6-6.8 ug/g for total PCBs; 800-7900 pg/g for congener 126; 110-370 ng/g for congener 105; 350-1300 pg/g for TCDD-equivalents (summarized in Hoffman et al. 1996). Corresponding values from the present study (2.5-14 ug/g total PCBs; 1760 pg/g congener 126; 349 ng/g congener 105; 104-322 pg/g TCDD-equivalents) suggest that coastal New York cormorants are at risk for deleterious effects (e.g. 25% embryo mortality; Yamashita et al. 1993) from PCB exposure, although no relationships were detected between PCB concentrations and reproductive success.

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Table 8.1. Polychlorinated biphenyl (congeners 1-42) concentrations (ng/g wet weight) in eggs of Double-crested Cormorants collected at Gardiner's (n=15), Shooters (n=14), and Swinburne (n=13) Islands, 1999. Given are minimum, maximum, mean, and standard deviation.

	Gardiner's Island				Shooters Island				Swinburne Island			
Variable	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev
CON1	0	0	0	0	0	0.0300	0.0100	0.0100	0	0.0100	0	0
CON2	0	0	0	0	0	0	0	0	0	0	0	0
CON3	0	0.0300	0	0.0100	0	0.0300	0.0100	0.0100	0	0.0300	0	0.0100
CON4	0	0	0	0	0	0.200	0.0200	0.0600	0	0	0	0
CON5	0	0	0	0	0	0	0	0	0	0	0	0
CON6	0	0	0	0	0	0.0500	0	0.0100	0	0	0	0
CON7	0	0	0	0	0	0	0	0	0	0	0	0
CON8	0	0	0	0	0	0.130	0.0400	0.0500	0	0	0	0
CON9	0	0	0	0	0	0	0	0	0	0	0	0
CON10	0	0	0	0	0	0	0	0	0	0	0	0
CON11	0	0	0	0	0	0.0600	0.0100	0.0200	0	0.0700	0.0100	0.0200
CON12	0	0	0	0	0	0	0	0	0	0	0	0
CON13	0	0	0	0	0	0	0	0	0	0	0	0
CON14	0	0	0	0	0	0	0	0	0	0	0	0
CON15	0	0.0300	0	0.0100	0	0	0	0	0	0	0	0
CON16	0	0.0100	0	0	0	0.140	0.0300	0.0400	0	0.0100	0	0
CON17	0	0.0200	0.0100	0.0100	0	0.530	0.140	0.170	0	0.0400	0.0100	0.0100
CON18	0	0.0200	0.0100	0.0100	0.0400	3.21	0.790	0.880	0.0200	0.150	0.0800	0.0300
CON19	0	0	0	0	0	0.230	0.0700	0.0600	0	0.0300	0.0100	0.0100
CON20	2.92	22.2	9.67	6.16	20.2	475	170	133	8.53	190	86.9	52.8
CON21	0	0.290	0.0600	0.0800	0	0	0	0	0	0.0800	0.0100	0.0200
CON22	0	0.0400	0.0100	0.0100	0	0.670	0.180	0.220	0	0.120	0.0400	0.0400
CON23	0	0	0	0	0	0	0	0	0	0.0100	0	0
CON24	0	0	0	0	0	0.0100	0	0	0	0	0	0
CON25	0	0.0100	0	0	0	0.970	0.200	0.310	0	0.0500	0.0200	0.0100
CON26	0	0.100	0.0400	0.0200	0.0900	4.39	0.840	1.18	0.0400	0.380	0.250	0.120
CON27	0	0	0	0	0	0.330	0.0900	0.0900	0	0.0300	0.0100	0.0100
CON28	0	0	0	0	0	0	0	0	0	0	0	0
CON29	0	0	0	0	0	0	0	0	0	0	0	0
CON30	0	0	0	0	0	0	0	0	0	0	0	0
CON31	0.0600	0.860	0.290	0.190	0.720	42.2	9.29	10.7	0.330	3.51	1.87	1.04
CON32	0	0.0100	0	0	0	1.12	0.370	0.330	0	0.0900	0.0400	0.0300
CON33	0	0	0	0	0	0	0	0	0	0	0	0
CON34	0	0	0	0	0	0.0400	0.0100	0.0100	0	0	0	0
CON35	0	0	0	0	0	0.0300	0.0000	0.0100	0	0	0	0
CON36	0	0	0	0	0	0	0	0	0	0.0100	0	0
CON37	0	0.0200	0.0100	0.0100	0	0.610	0.210	0.180	0	0.0700	0.0300	0.0300
CON38	0	0	0	0	0	0.340	0.0800	0.0900	0	0.0500	0.0200	0.0200
CON39	0	0	0	0	0	0	0	0	0	0	0	0
CON40	0	0.0500	0.0200	0.0100	0.0500	6.73	1.84	1.93	0.0300	0.480	0.170	0.130
CON41	0	0	0	0	0	0	0	0	0	0	0	0
CON42	0	0.0300	0.0100	0.0100	0	3.51	0.870	0.970	0	0.220	0.0800	0.0800

Table 8.2. Polychlorinated biphenyl (congeners 43-85) concentrations (ng/g wet weight) in eggs of Double-crested Cormorants collected at Gardiner's (n=15), Shooters (n=14), and Swinburne (n=13) Islands, 1999. Given are minimum, maximum, mean, and standard deviation.

	Gardiner's Island				Shooters Island				Swinburne Island			
Variable	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev
CON43	0	0.0100	0	0	0	0.320	0.0500	0.100	0	0.0900	0.0100	0.0200
CON44	1.64	14.3	6.20	3.59	4.79	629	173	155	8.8	163	70.2	49.0
CON45	0	0.0100	0	0	0	2.22	0.460	0.600	0	0.100	0.0400	0.0300
CON46	0	0	0	0	0	0.290	0.0400	0.0800	0	0.0100	0	0
CON47	0	0	0	0	0	0	0	0	0	0	0	0
CON48	0	0.0300	0.0100	0.0100	0	1.09	0.230	0.280	0	0.0800	0.0200	0.0200
CON49	0.140	0.970	0.560	0.230	0.670	68.3	22.4	19.8	1.24	18.7	7.09	4.50
CON50	0	0.0100	0	0.0100	0	3.03	0.710	0.870	0.0200	0.150	0.0700	0.0300
CON51	0	0	0	0	0	0	0	0	0	0	0	0
CON52	0.170	1.19	0.610	0.300	1.14	121	31.5	32.0	1.55	15.3	7.90	3.75
CON53	0	0	0	0	0	0	0	0	0	0	0	0
CON54	0	0	0	0	0	0.0900	0.0300	0.0300	0	0.0100	0	0
CON55	0	0	0	0	0	0	0	0	0	0	0	0
CON56	0	0	0	0	0	1.57	0.250	0.430	0	0	0	0
CON57	0	0	0	0	0	0	0	0	0	0	0	0
CON58	0	0	0	0	0	0.980	0.130	0.290	0	0.0800	0.0100	0.0200
CON59	0.0800	0.700	0.280	0.170	0.170	40.7	8.97	10.1	0.340	7.44	3.34	2.29
CON60	0.670	4.22	2.08	1.17	4.46	207	59.5	51.2	1.97	37.3	18.2	11.5
CON61	7.77	43.9	20.3	10.9	27.4	873	281	206	13.3	287	146	80.4
CON62	0	0	0	0	0	0	0	0	0	0	0	0
CON63	0.200	1.69	0.650	0.410	0.600	12.6	4.88	2.96	0.640	8.35	4.21	2.44
CON64	0.0200	0.150	0.0800	0.0400	0.260	31.8	9.58	10.4	0.140	2.45	1.03	0.630
CON65	0	0	0	0	0	0	0	0	0	0	0	0
CON66	9.22	60.0	28.3	15.0	37.9	1400	443	338	19.4	331	182	101
CON67	0	0	0	0	0	0.360	0.0700	0.120	0	0	0	0
CON68	0.140	1.17	0.420	0.270	0.100	1.43	0.830	0.360	0.240	2.13	1.04	0.520
CON69	0	0	0	0	0	0	0	0	0	0	0	0
CON70	0	0	0	0	0	0	0	0	0	0	0	0
CON71	0	0	0	0	0	0	0	0	0	0	0	0
CON72	0.0600	0.380	0.150	0.0900	0	0.880	0.590	0.300	0.110	1.12	0.590	0.300
CON73	0	0	0	0	0	0.270	0.0200	0.0700	0	0.0200	0	0.0100
CON74	0	0	0	0	0	0	0	0	0	0	0	0
CON75	0	0	0	0	0	0	0	0	0	0	0	0
CON76	0	0	0	0	0	0	0	0	0	0	0	0
CON77	0.0500	0.270	0.160	0.0600	0	1.20	0.450	0.290	0	0.450	0.260	0.140
CON78	0	0	0	0	0	0	0	0	0	0	0	0
CON79	0	0.0200	0	0.0100	0	0.800	0.190	0.220	0	0.170	0.0100	0.0500
CON80	0	0	0	0	0	0	0	0	0	0	0	0
CON81	0	0.150	0.0700	0.0600	0	3.07	0.520	0.820	0	0.770	0.340	0.190
CON82	0	0.0200	0	0.01	0	1.23	0.300	0.340	0	0.0500	0.0100	0.0200
CON83	44.0	269	125	66.0	57.6	2260	864	548	98.8	775	465	231
CON84	0	0.0800	0.0400	0.0300	0.130	5.83	1.65	1.85	0.0700	0.850	0.320	0.200
CON85	1.21	7.65	3.34	1.84	2.83	270	62.3	66.2	3.33	62.5	23.6	16.7

Table 8.3. Polychlorinated biphenyl (congeners 86-127) concentrations (ng/g wet weight) in eggs of Double-crested Cormorants collected at Gardiner's (n=15), Shooters (n=14), and Swinburne (n=13) Islands, 1999. Given are minimum, maximum, mean, and standard deviation.

	Gardiner's Island				Shooters Island				Swinburne Island			
Variable	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev
CON86	1.01	3.85	2.05	0.840	1.22	112	34.5	28.8	2.37	26.5	12.2	6.96
CON87	0	0	0	0	0	0	0	0	0	0	0	0
CON88	0.0400	0.220	0.120	0.0500	0.170	11.8	3.94	3.72	0.280	1.84	0.870	0.390
CON89	0	0	0	0	0	0.120	0.0200	0.0400	0	0	0	0
CON90	1.39	7.23	4.32	1.62	3.88	173	59.3	46.9	5.24	42.9	23.8	10.7
CON91	0	0	0	0	0	0	0	0	0	0	0	0
CON92	0.420	4.14	1.70	0.870	1.00	46.2	15.3	12.1	2.04	19.3	8.41	4.56
CON93	0.290	1.06	0.670	0.240	0.650	46.9	13.8	13.1	0.580	7.88	3.71	1.93
CON94	0	0	0	0	0	0.220	0.0300	0.0700	0	0	0	0
CON95	0	0	0	0	0	0	0	0	0	0	0	0
CON96	0	0	0	0	0	0.210	0.0500	0.0600	0	0.0100	0	0
CON97	0	0	0	0	0	0	0	0	0	0	0	0
CON98	0	0	0	0	0	0	0	0	0	0	0	0
CON99	0	0	0	0	0	0	0	0	0	0	0	0
CON100	0	0	0	0	0	0	0	0	0	0	0	0
CON101	0	0	0	0	0	0	0	0	0	0	0	0
CON102	0	0	0	0	0	0	0	0	0	0	0	0
CON103	0	0.0400	0.0200	0.0100	0	1.04	0.350	0.290	0.0200	0.230	0.110	0.0500
CON104	0	0	0	0	0	0.0600	0.0100	0.0200	0	0	0	0
CON105	15.7	103	41.8	24.0	47.6	1250	349	290	27.7	340	199	100.0
CON106	0	0	0	0	0	0	0	0	0	0	0	0
CON107	0	0.310	0.0600	0.100	0	1.06	0.260	0.320	0	0.470	0.140	0.170
CON108	0	0	0	0	0	0	0	0	0	0	0	0
CON109	3.22	28.1	9.04	6.12	3.75	19.1	11.4	4.17	4.21	25.9	14.1	5.72
CON110	0.590	2.59	1.46	0.580	2.89	134	46.8	41.8	2.89	25.4	11.0	5.82
CON111	0.240	1.58	0.660	0.350	0.160	2.57	1.10	0.650	0.380	2.72	1.37	0.630
CON112	0	0	0	0	0	0	0	0	0	0	0	0
CON113	0	0	0	0	0	0	0	0	0	0	0	0
CON114	1.03	5.91	2.54	1.36	3.48	111	30.1	26.0	2.04	28.3	15.7	8.67
CON115	0	0	0	0	0	0	0	0	0	0	0	0
CON116	0	0	0	0	0	0	0	0	0	0	0	0
CON117	0	0	0	0	0	0	0	0	0	0	0	0
CON118	85.5	660	243	147	214	4310	1350	983	123	1450	880	424
CON119	0	0	0	0	0	0	0	0	0	0	0	0
CON120	0.250	1.62	0.620	0.350	0.0800	1.46	0.770	0.360	0.290	1.08	0.700	0.210
CON121	0.0100	0.0900	0.0400	0.0200	0	0.580	0.220	0.150	0.0300	0.370	0.160	0.0900
CON122	0	0.190	0.0100	0.0500	0	1.33	0.100	0.360	0	0	0	0
CON123	0.950	6.40	2.47	1.43	2.72	80.9	22.7	18.8	1.52	24.2	13.4	7.30
CON124	0	0	0	0	0	0	0	0	0	0	0	0
CON125	0	0	0	0	0	0	0	0	0	0	0	0
CON126	0.240	2.13	0.790	0.480	0.540	4.87	1.76	1.04	0	2.67	1.58	0.850
CON127	0	0.140	0.0300	0.0500	0	3.97	1.14	0.950	0	1.02	0.320	0.380

Table 8.4. Polychlorinated biphenyl (congeners 128-169) concentrations (ng/g wet weight) in eggs of Double-crested Cormorants collected at Gardiner's (n=15), Shooters (n=14), and Swinburne (n=13) Islands, 1999. Given are minimum, maximum, mean, and standard deviation.

	Gardiner's Island				Shooters Island				Swinburne Island			
Variable	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev
CON128	13.3	96.0	37.0	21.5	27.8	583	209	134	30.3	245	135	67.7
CON129	105	878	305	196	221	4580	1750	1080	255	1610	1030	461
CON130	1.19	13.5	3.74	2.99	3.50	97.1	31.5	23.2	3.61	36.2	17.8	10.5
CON131	0	0	0	0	0	0.240	0.0300	0.0700	0	0	0	0
CON132	0.0800	0.390	0.210	0.100	0.490	20.9	5.83	6.02	0.250	1.67	0.860	0.430
CON133	3.17	27.1	9.32	5.87	4.18	91.7	32.7	20.8	7.10	47.2	27.2	12.9
CON134	0	0.0700	0.0200	0.0300	0	2.91	0.810	0.750	0	0.330	0.190	0.130
CON135	1.87	9.40	4.98	2.13	1.34	75.0	35.0	19.8	5.60	29.7	16.9	6.85
CON136	0.0300	0.130	0.0700	0.0300	0.110	5.77	1.92	1.87	0.120	0.710	0.370	0.170
CON137	1.02	9.21	3.50	2.06	5.09	184	49.9	43.1	4.00	40.9	21.9	12.5
CON138	0	0	0	0	0	0	0	0	0	0	0	0
CON139	0.180	1.21	0.580	0.310	0.490	33.7	9.04	8.10	0.590	6.89	3.54	2.19
CON140	0	0	0	0	0	0	0	0	0	0	0	0
CON141	0	3.30	1.10	1.13	2.41	56.1	18.0	14.2	1.82	13.0	6.47	3.24
CON142	0	0	0	0	0	0	0	0	0	0	0	0
CON143	0	0	0	0	0	0	0	0	0	0	0	0
CON144	0.0700	0.290	0.170	0.0600	0.190	6.84	2.52	2.00	0.230	1.59	0.840	0.410
CON145	0	0	0	0	0	0	0	0	0	0	0	0
CON146	28.5	262	84.4	56.8	42.8	682	302	160	59.1	383	227	103
CON147	0.920	3.51	2.21	0.750	2.48	108	37.0	31.9	2.86	14.4	8.41	3.39
CON148	0.0500	0.280	0.120	0.0600	0	2.96	0.760	0.740	0.140	0.560	0.340	0.120
CON149	0	0	0	0	0	0	0	0	0	0	0	0
CON150	0	0.0300	0.0100	0.0100	0	0.540	0.150	0.150	0	0.100	0.0500	0.0300
CON151	0	0	0	0	0	0	0	0	0	0	0	0
CON152	0	0	0	0	0	0.0600	0.0100	0.0200	0	0.0100	0	0
CON153	218	1860	658	416	342	6750	2590	1590	365	2810	1710	769
CON154	0	0	0	0	0	0	0	0	0	0	0	0
CON155	0.0700	0.590	0.190	0.130	0	8.09	2.29	2.09	0.210	1.09	0.710	0.310
CON156	12.9	84.9	33.3	18.9	29.3	537	190	123	21.1	230	132	67.7
CON157	0	0	0	0	0	0	0	0	0	0	0	0
CON158	3.17	25.3	9.95	5.82	11.7	362	124	86.2	10.7	110	55.7	31.7
CON159	0	0.120	0.0500	0.0300	0	0.880	0.310	0.310	0	0.180	0.0400	0.0500
CON160	0	0	0	0	0	0	0	0	0	0	0	0
CON161	0	0	0	0	0	0	0	0	0	0	0	0
CON162	0.410	3.59	1.16	0.760	0.570	2.65	1.44	0.670	0.640	3.69	1.95	0.800
CON163	0	0	0	0	0	0	0	0	0	0	0	0
CON164	0	0.160	0.0500	0.0700	0	5.83	1.71	1.95	0	0.640	0.130	0.230
CON165	0.340	2.76	1.07	0.630	0.120	2.99	1.46	0.890	0.460	3.38	1.63	0.790
CON166	0	0	0	0	0	0	0	0	0	0	0	0
CON167	6.32	52.1	18.8	11.5	13.1	199	79.5	45.8	10.5	108	63.1	31.3
CON168	0	0	0	0	0	0	0	0	0	0	0	0
CON169	0	0.700	0.0500	0.180	0	0	0	0	0	0	0	0

Table 8.5. Polychlorinated biphenyl (congeners 170-209) concentrations (ng/g wet weight) in eggs of Double-crested Cormorants collected at Gardiner's (n=15), Shooters (n=14), and Swinburne (n=13) Islands, 1999. Given are minimum, maximum, mean, and standard deviation.

	Gardiner's Island				Shooters Island				Swinburne Island			
Variable	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev
CON170	26.9	191	69.7	42.2	60.2	1110	402	255	55.4	347	208	95.8
CON171	3.55	29.6	11.0	6.52	10.3	267	87.1	62.7	9.28	72.2	42.8	21.8
CON172	4.39	35.3	11.9	7.63	9.77	167	61.9	38.5	9.55	53.6	32.3	14.1
CON173	0	0	0	0	0	0	0	0	0	0	0	0
CON174	0.210	0.800	0.520	0.170	1.08	23.1	8.40	7.58	0.530	3.20	1.53	0.750
CON175	0.340	4.34	1.38	0.930	0.820	31.6	9.73	7.47	1.23	8.92	4.73	2.54
CON176	0	0.0900	0.0500	0.0200	0.0800	2.16	0.820	0.670	0.0700	0.380	0.210	0.0900
CON177	5.53	61.0	19.9	13.4	14.5	261	107	68.4	14.0	125	59.6	30.7
CON178	9.15	59.6	24.6	13.6	9.19	258	92.9	58.8	19.1	117	65.2	29.4
CON179	0.0300	0.130	0.0800	0.0400	0.0800	3.71	1.01	1.11	0.0900	0.570	0.270	0.110
CON180	89.3	638	230	142	204	4150	1430	946	199	1090	713	315
CON181	0.0300	0.330	0.130	0.0700	0.150	5.83	1.68	1.41	0.100	1.08	0.620	0.350
CON182	0	0.560	0.120	0.160	0	4.07	0.880	1.04	0	0.65	0.200	0.280
CON183	0	99.8	35.3	26.3	32.3	885	288	207	32.7	262	148	72.6
CON184	0.0100	0.170	0.0500	0.0400	0	1.34	0.380	0.320	0.0700	0.420	0.180	0.100
CON185	0	0	0	0	0	0	0	0	0	0	0	0
CON186	0	0	0	0	0	0	0	0	0	0.0100	0	0
CON187	37.4	403	126	88.2	70.1	1520	579	350	102	607	355	161
CON188	0.0700	0.550	0.170	0.120	0	3.94	0.800	0.960	0.130	0.680	0.360	0.170
CON189	1.25	8.46	3.26	1.85	2.52	51.6	16.9	11.8	2.43	17.4	9.80	4.97
CON190	5.32	29.7	11.9	6.49	10.7	217	76.6	49.5	8.11	68.8	40.2	19.7
CON191	0.630	3.90	1.59	0.830	1.79	40.3	13.3	9.70	1.15	9.16	5.57	2.68
CON192	0	0	0	0	0	0.0400	0.0100	0.0100	0	0.0200	0	0.0100
CON193	0	0	0	0	0	0	0	0	0	0	0	0
CON194	14.4	96.3	40.1	22.7	32.5	635	213	144	36.3	196	114	55.5
CON195	4.23	22.1	10.3	5.26	9.14	182	64.7	42.5	6.78	48.6	29.8	14.7
CON196	4.88	36.8	15.0	8.60	10.1	390	98.6	92.3	15.7	68.3	42.1	18.3
CON197	1.16	8.89	3.78	2.09	0.870	35.1	12.2	8.06	3.07	15.9	8.44	3.97
CON198	22.5	187	69.6	45.6	33.6	975	293	221	65.5	274	155	69.1
CON199	0	0	0	0	0	0	0	0	0	0	0	0
CON200	0	0	0	0	0	0	0	0	0	0	0	0
CON201	1.86	18.8	7.32	4.49	1.68	144	33.3	33.9	6.51	33.6	19.6	8.80
CON202	2.24	18.3	7.48	4.19	0.850	262	48.9	64.7	9.76	48.1	26.4	11.5
CON203	11.2	68.4	31.8	17.9	20.2	773	199	181	34.6	197	101	49.0
CON204	0.0100	0.0800	0.0300	0.0200	0	0.420	0.130	0.100	0.0300	0.110	0.0600	0.0300
CON205	0.530	2.82	1.40	0.690	1.14	18.0	6.67	4.06	1.11	8.22	4.26	2.27
CON206	10.5	85.9	32.4	19.8	18.5	516	117	121	42.2	156	83.6	38.7
CON207	1.65	11.3	5.12	2.50	1.47	59.7	15.0	13.6	5.23	17.1	9.85	4.00
CON208	4.19	35.4	15.0	8.04	2.77	223	45.7	53.0	15.8	55.0	30.4	11.9
CON209	4.51	31.0	12.9	7.83	4.79	103	43.2	22.8	12.1	40.6	24.7	9.78

Table 8.6. Polychlorinated biphenyl (congeners 1-42) concentrations (ng/g wet weight) in plasma of Double-crested Cormorants collected at Gardiner's (n=11), Shooters (n=11), and Swinburne (n=13) Islands, 1999. Given are minimum, maximum, mean, and standard deviation.

	Gardiner's Island				Shooters Island				Swinburne Island			
Variable	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev
CON1	0	0.0300	0	0.0100	0	0	0	0	0	0.0100	0	0
CON2	0	0.0100	0	0	0	0	0	0	0	0	0	0
CON3	0	0.0500	0.0100	0.0200	0	0	0	0	0	0.0100	0	0
CON4	0	0.0700	0.0100	0.0200	0	0.0100	0.0100	0.0100	0	0.0400	0	0.0100
CON5	0	0	0	0	0	0	0	0	0	0	0	0
CON6	0	0.0100	0	0	0	0	0	0	0	0.0100	0	0
CON7	0	0.0700	0.0100	0.0200	0	0.110	0.0200	0.0300	0	0.0200	0.0100	0.0100
CON8	0	0.0300	0.0100	0.0100	0.0100	0.0300	0.0100	0.0100	0.0100	0.0200	0.0100	0
CON9	0	0.0100	0	0	0	0	0	0	0	0	0	0
CON10	0	0	0	0	0	0	0	0	0	0	0	0
CON11	0	0.0800	0.0100	0.0200	0.0100	0.0600	0.0200	0.0200	0.0100	0.0200	0.0100	0
CON12	0	0	0	0	0	0	0	0	0	0	0	0
CON13	0	0	0	0	0	0	0	0	0	0	0	0
CON14	0	0	0	0	0	0	0	0	0	0	0	0
CON15	0	0.0100	0	0	0	0.0100	0	0	0	0.0100	0	0
CON16	0	0.0100	0	0	0	0.0200	0	0.0100	0	0.0100	0	0
CON17	0	0.0200	0.0100	0.0100	0	0.0300	0.0100	0.0100	0	0.0100	0	0
CON18	0	0.0400	0.0100	0.0100	0.0200	0.150	0.0500	0.0400	0.0100	0.0200	0.0100	0
CON19	0	0.0100	0	0	0	0.0100	0	0.0100	0	0.0100	0	0
CON20	0.0700	0.240	0.140	0.0600	2.01	8.88	4.18	2.32	0.360	2.30	1.26	0.530
CON21	0	0.0200	0.0100	0.0100	0	0.0500	0.0200	0.0100	0	0.0100	0.0100	0.0100
CON22	0	0.0100	0	0.0100	0	0.0300	0.0100	0.0100	0	0.0100	0	0
CON23	0	0	0	0	0	0	0	0	0	0	0	0
CON24	0	0	0	0	0	0	0	0	0	0	0	0
CON25	0	0.0500	0	0.0200	0	0.0200	0.0100	0.0100	0	0	0	0
CON26	0	0.0200	0.0100	0.0100	0.0200	0.300	0.0900	0.0800	0.0200	0.0500	0.0300	0.0100
CON27	0	0	0	0	0	0.0300	0.0100	0.0100	0	0	0	0
CON28	0	0	0	0	0	0	0	0	0	0	0	0
CON29	0	0	0	0	0	0	0	0	0	0	0	0
CON30	0	0	0	0	0	0	0	0	0	0	0	0
CON31	0.0100	0.0400	0.0200	0.0100	0.0800	0.790	0.310	0.210	0.0500	0.100	0.0800	0.0200
CON32	0	0.0100	0	0	0	0.0300	0.0100	0.0100	0	0	0	0
CON33	0	0	0	0	0	0	0	0	0	0	0	0
CON34	0	0	0	0	0	0	0	0	0	0	0	0
CON35	0	0	0	0	0	0	0	0	0	0	0	0
CON36	0	0	0	0	0	0	0	0	0	0.0100	0	0
CON37	0	0.0300	0.0100	0.0100	0	0.0400	0.0100	0.0100	0	0.0100	0.0100	0.0100
CON38	0	0	0	0	0	0	0	0	0	0	0	0
CON39	0	0	0	0	0	0	0	0	0	0	0	0
CON40	0	0.0100	0.0100	0	0.0200	0.210	0.0700	0.0700	0	0.0100	0.0100	0
CON41	0	0	0	0	0	0	0	0	0	0	0	0
CON42	0	0.0100	0.0100	0.0100	0	0.0500	0.0200	0.0200	0	0	0	0

Table 8.7. Polychlorinated biphenyl (congeners 43-85) concentrations (ng/g wet weight) in plasma of Double-crested Cormorants collected at Gardiner's (n=11), Shooters (n=11), and Swinburne (n=13) Islands, 1999. Given are minimum, maximum, mean, and standard deviation.

	Gardiner's Island				Shooters Island				Swinburne Island			
Variable	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev
CON43	0	0	0	0	0	0.0100	0	0	0	0	0	0
CON44	0.0700	0.390	0.170	0.100	2.36	9.43	4.16	2.19	0.210	2.06	1.05	0.460
CON45	0	0.0500	0.0100	0.0200	0.0200	0.0800	0.0400	0.0200	0	0.0200	0.0100	0.0100
CON46	0	0	0	0	0	0	0	0	0	0	0	0
CON47	0	0	0	0	0	0	0	0	0	0	0	0
CON48	0	0.0100	0	0	0	0.0200	0.0100	0.0100	0	0	0	0
CON49	0.0200	0.0900	0.0500	0.0300	0.520	2.99	1.31	0.870	0.120	0.400	0.270	0.0900
CON50	0	0.0100	0	0	0.0100	0.100	0.0500	0.0400	0	0.0100	0.0100	0.0100
CON51	0	0	0	0	0	0	0	0	0	0	0	0
CON52	0.0200	0.160	0.0700	0.0400	0.360	4.13	1.92	1.48	0.160	0.730	0.400	0.190
CON53	0	0	0	0	0	0	0	0	0	0	0	0
CON54	0	0	0	0	0	0.0100	0	0	0	0	0	0
CON55	0	0	0	0	0	0	0	0	0	0	0	0
CON56	0	0.0200	0.0	0.0100	0	0.0400	0.0100	0.0100	0	0.0100	0	0
CON57	0	0	0	0	0	0	0	0	0	0	0	0
CON58	0	0	0	0	0	0	0	0	0	0	0	0
CON59	0	0.0300	0.0100	0.0100	0.130	0.560	0.260	0.130	0.0100	0.140	0.0700	0.0300
CON60	0.0300	0.140	0.0600	0.0300	0.530	2.55	1.28	0.630	0.100	0.550	0.320	0.130
CON61	0.150	0.800	0.340	0.190	2.24	9.07	5.01	2.33	0.550	2.93	1.85	0.670
CON62	0	0	0	0	0	0	0	0	0	0	0	0
CON63	0.0100	0.0500	0.0300	0.0100	0.130	0.350	0.210	0.0700	0.0400	0.210	0.130	0.0500
CON64	0	0.0200	0.0100	0	0.0700	0.820	0.300	0.270	0.0100	0.0400	0.0300	0.0100
CON65	0	0	0	0	0	0	0	0	0	0	0	0
CON66	0	0.790	0.350	0.210	2.86	14.4	6.45	3.68	0.470	3.23	2.01	0.760
CON67	0	0	0	0	0	0.0100	0	0.0100	0	0	0	0
CON68	0.0100	0.0300	0.0200	0.0100	0.0200	0.0800	0.0500	0.0200	0.0100	0.0600	0.0400	0.0100
CON69	0	0	0	0	0	0	0	0	0	0	0	0
CON70	0	0	0	0	0	0	0	0	0	0	0	0
CON71	0	0	0	0	0	0	0	0	0	0	0	0
CON72	0.0100	0.0400	0.0200	0.0100	0.0300	0.130	0.0700	0.0300	0.0300	0.100	0.0700	0.0200
CON73	0	0	0	0	0	0.0500	0.0100	0.0200	0	0	0	0
CON74	0	0	0	0	0	0	0	0	0	0	0	0
CON75	0	0	0	0	0	0	0	0	0	0	0	0
CON76	0	0	0	0	0	0	0	0	0	0	0	0
CON77	0.0100	0.0300	0.0100	0.0100	0.0100	0.0400	0.0200	0.0100	0.0100	0.0600	0.0300	0.0100
CON78	0	0	0	0	0	0	0	0	0	0	0	0
CON79	0	0.0100	0	0	0	0.0100	0	0	0	0	0	0
CON80	0	0	0	0	0	0	0	0	0	0	0	0
CON81	0	0.0100	0	0	0	0.0400	0.0200	0.0100	0	0.0100	0.0100	0
CON82	0	0.0100	0	0	0	0.0400	0.0200	0.0100	0	0.0100	0	0
CON83	0.640	2.70	1.53	0.650	4.05	17.4	10.2	4.15	1.39	5.54	3.94	1.06
CON84	0	0.0100	0.0100	0.0100	0.0100	0.230	0.0800	0.0800	0.0100	0.0100	0.0100	0
CON85	0.0500	0.240	0.130	0.0600	0.940	3.19	1.79	0.720	0.180	0.760	0.470	0.160

Table 8.8. Polychlorinated biphenyl (congeners 86-127) concentrations (ng/g wet weight) in plasma of Double-crested Cormorants collected at Gardiner's (n=11), Shooters (n=11), and Swinburne (n=13) Islands, 1999. Given are minimum, maximum, mean, and standard deviation.

	Gardiner's Island				Shooters Island				Swinburne Island			
Variable	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev
CON86	0.0400	0.160	0.100	0.0400	0.600	2.83	1.38	0.800	0.150	0.370	0.280	0.060
CON87	0	0	0	0	0	0	0	0	0	0	0	0
CON88	0	0.0200	0.0100	0.0100	0.0200	0.390	0.150	0.130	0.0100	0.0400	0.0300	0.0100
CON89	0	0	0	0	0	0	0	0	0	0	0	0
CON90	0.0800	0.710	0.250	0.180	1.02	7.15	3.25	2.25	0.420	1.45	0.840	0.330
CON91	0	0	0	0	0	0	0	0	0	0	0	0
CON92	0.0300	0.320	0.110	0.0800	0.610	2.33	1.28	0.610	0.280	0.630	0.460	0.120
CON93	0.0200	0.110	0.0500	0.0300	0.210	2.11	0.900	0.750	0.0800	0.280	0.150	0.0500
CON94	0	0	0	0	0	0.0100	0	0	0	0	0	0
CON95	0	0	0	0	0	0	0	0	0	0	0	0
CON96	0	0	0	0	0	0.0100	0	0	0	0	0	0
CON97	0	0	0	0	0	0	0	0	0	0	0	0
CON98	0	0	0	0	0	0	0	0	0	0	0	0
CON99	0	0	0	0	0	0	0	0	0	0	0	0
CON100	0	0	0	0	0	0	0	0	0	0	0	0
CON101	0	0	0	0	0	0	0	0	0	0	0	0
CON102	0	0	0	0	0	0	0	0	0	0	0	0
CON103	0	0.0100	0	0	0	0.0400	0.0200	0.0100	0	0.0100	0	0.0100
CON104	0	0	0	0	0	0	0	0	0	0	0	0
CON105	0.200	1.03	0.520	0.250	2.39	9.31	5.76	2.30	0.770	3.50	2.18	0.730
CON106	0	0	0	0	0	0	0	0	0	0	0	0
CON107	0	0.0100	0.0100	0.0100	0.0100	0.0600	0.0300	0.0200	0.0100	0.0500	0.0200	0.0100
CON108	0	0	0	0	0	0	0	0	0	0	0	0
CON109	0.0800	0.350	0.210	0.0900	0.240	0.720	0.450	0.120	0.170	0.620	0.430	0.140
CON110	0.0200	0.120	0.0600	0.0300	0.490	3.47	1.42	1.09	0.0900	0.240	0.180	0.0400
CON111	0.0100	0.0200	0.0100	0.0100	0	0.0400	0.0200	0.0100	0.0100	0.0300	0.0200	0.0100
CON112	0	0	0	0	0	0	0	0	0	0	0	0
CON113	0	0	0	0	0	0	0	0	0	0	0	0
CON114	0.0100	0.0600	0.0300	0.0200	0.180	0.750	0.470	0.200	0.0500	0.260	0.160	0.0600
CON115	0	0	0	0	0	0	0	0	0	0	0	0
CON116	0	0	0	0	0	0	0	0	0	0	0	0
CON117	0	0	0	0	0	0	0	0	0	0	0	0
CON118	0.930	4.54	2.48	1.14	7.65	27.1	17.3	6.54	2.75	12.4	7.98	2.57
CON119	0	0	0	0	0	0	0	0	0	0	0	0
CON120	0.0100	0.0700	0.0300	0.0200	0.0200	0.0500	0.0300	0.0100	0.0200	0.0500	0.0400	0.0100
CON121	0	0.0100	0	0	0	0.0200	0.0100	0.0100	0	0.0100	0.0100	0.0100
CON122	0	0	0	0	0	0	0	0	0	0	0	0
CON123	0.0100	0.0600	0.0300	0.0200	0.160	0.740	0.400	0.180	0.0600	0.230	0.150	0.0500
CON124	0	0	0	0	0	0	0	0	0	0	0	0
CON125	0	0	0	0	0	0	0	0	0	0	0	0
CON126	0.0100	0.0300	0.0100	0.0100	0.0200	0.0700	0.0400	0.0200	0.0100	0.0400	0.0300	0.0100
CON127	0	0.0500	0	0.0200	0.0100	0.0500	0.0300	0.0100	0	0.0100	0.0100	0

Table 8.9. Polychlorinated biphenyl (congeners 128-169) concentrations (ng/g wet weight) in plasma of Double-crested Cormorants collected at Gardiner's (n=11), Shooters (n=11), and Swinburne (n=13) Islands, 1999. Given are minimum, maximum, mean, and standard deviation.

	Gardiner's Island				Shooters Island				Swinburne Island			
Variable	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev
CON128	0.210	0.730	0.480	0.190	1.49	4.47	2.95	1.06	0.400	1.93	1.27	0.420
CON129	1.59	6.12	3.81	1.56	11.5	38.6	24.8	9.12	3.71	14.1	9.5	3.05
CON130	0.0300	0.170	0.0900	0.0500	0.370	1.13	0.650	0.240	0.130	0.450	0.260	0.0800
CON131	0	0	0	0	0	0.0200	0.0100	0.0100	0	0	0	0
CON132	0.0100	0.0300	0.0200	0.0100	0.0500	0.710	0.240	0.220	0.0200	0.0700	0.0400	0.0100
CON133	0.0600	0.160	0.110	0.0400	0.210	0.640	0.420	0.140	0.0800	0.310	0.220	0.0600
CON134	0	0.0100	0	0	0	0.110	0.0400	0.0400	0	0.0100	0.0100	0
CON135	0.0800	0.270	0.170	0.0700	0.450	3.41	1.31	0.920	0.220	0.500	0.340	0.0700
CON136	0	0.0100	0.0100	0	0.0100	0.280	0.0800	0.0800	0.0100	0.0300	0.0100	0.0100
CON137	0.0300	0.150	0.0800	0.0400	0.410	1.29	0.810	0.270	0.0900	0.390	0.270	0.0800
CON138	0	0	0	0	0	0	0	0	0	0	0	0
CON139	0.0100	0.0300	0.0200	0.0100	0.100	0.350	0.200	0.0800	0.0200	0.0700	0.0500	0.0100
CON140	0	0	0	0	0	0	0	0	0	0	0	0
CON141	0	0.130	0.0400	0.0400	0.480	3.92	1.25	1.00	0.0800	0.260	0.170	0.0500
CON142	0	0	0	0	0	0	0	0	0	0	0	0
CON143	0	0	0	0	0	0	0	0	0	0	0	0
CON144	0.0100	0.0300	0.0100	0.0100	0.0600	0.510	0.180	0.140	0.0200	0.0700	0.0400	0.0100
CON145	0	0	0	0	0	0	0	0	0	0	0	0
CON146	0.450	1.89	1.07	0.460	2.32	7.93	4.60	1.79	0.950	3.24	2.12	0.700
CON147	0.0400	0.170	0.110	0.0500	0.380	5.00	1.67	1.48	0.170	0.580	0.310	0.120
CON148	0	0.0200	0.0100	0.0100	0.0100	0.0500	0.0300	0.0100	0.0100	0.0200	0.0100	0
CON149	0	0	0	0	0	0	0	0	0	0	0	0
CON150	0	0.100	0.0200	0.0400	0	0.0100	0	0.0100	0	0	0	0
CON151	0	0	0	0	0	0	0	0	0	0	0	0
CON152	0	0	0	0	0	0	0	0	0	0	0	0
CON153	2.42	9.68	5.98	2.39	12.7	49.8	32.8	13.3	4.68	20.5	13.6	4.63
CON154	0	0	0	0	0	0	0	0	0	0	0	0
CON155	0	0.0200	0.0100	0	0.0100	0.0800	0.0400	0.0300	0.0100	0.0200	0.0100	0
CON156	0.130	0.600	0.310	0.150	1.21	4.16	2.56	0.940	0.390	1.62	1.10	0.360
CON157	0	0	0	0	0	0	0	0	0	0	0	0
CON158	0.0700	0.310	0.170	0.0800	0.940	3.31	2.09	0.810	0.200	0.880	0.580	0.200
CON159	0	0.100	0.0100	0.0300	0	0.140	0.0300	0.0400	0	0.0100	0	0
CON160	0	0	0	0	0	0	0	0	0	0	0	0
CON161	0	0	0	0	0	0	0	0	0	0	0	0
CON162	0.0100	0.0400	0.0200	0.0100	0.0300	0.0800	0.0500	0.0100	0.0200	0.0500	0.0400	0.0100
CON163	0	0	0	0	0	0	0	0	0	0	0	0
CON164	0	0.0200	0.0100	0.0100	0	1.34	0.370	0.400	0	0.0500	0.0300	0.0200
CON165	0.0100	0.0400	0.0200	0.0100	0.0100	0.0300	0.0200	0.0100	0.0100	0.0300	0.0200	0
CON166	0	0	0	0	0	0	0	0	0	0	0	0
CON167	0.0900	0.340	0.180	0.0800	0.550	1.78	1.16	0.420	0.200	0.830	0.540	0.170
CON168	0	0	0	0	0	0	0	0	0	0	0	0
CON169	0	0.0100	0	0.0100	0	0	0	0	0	0	0	0

Table 8.10. Polychlorinated biphenyl (congeners 170-209) concentrations (ng/g wet weight) in plasma of Double-crested Cormorants collected at Gardiner's (n=11), Shooters (n=11), and Swinburne (n=13) Islands, 1999. Given are minimum, maximum, mean, and standard deviation.

	Gardiner's Island				Shooters Island				Swinburne Island			
Variable	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev	Minimum	Maximum	Mean	Std Dev
CON170	0.250	0.910	0.520	0.230	2.61	11.2	5.20	2.47	0.510	2.60	1.56	0.510
CON171	0.0600	0.230	0.140	0.0600	0.720	2.77	1.39	0.610	0.200	0.660	0.430	0.130
CON172	0.0500	0.190	0.110	0.0500	0.440	1.98	0.920	0.430	0.110	0.440	0.270	0.0800
CON173	0	0	0	0	0	0	0	0	0	0	0	0
CON174	0.0100	0.0500	0.0300	0.0100	0.100	2.42	0.590	0.680	0.0300	0.100	0.0600	0.0200
CON175	0.0100	0.0500	0.0300	0.0100	0.100	0.400	0.200	0.0900	0.0400	0.130	0.0800	0.0300
CON176	0	0.0100	0	0	0.0100	0.150	0.0500	0.0400	0	0.0200	0.0100	0
CON177	0.110	0.410	0.250	0.100	1.01	5.15	2.01	1.16	0.450	1.14	0.760	0.220
CON178	0.150	0.470	0.290	0.110	0.730	2.23	1.27	0.490	0.290	0.900	0.630	0.160
CON179	0	0.0100	0.0100	0	0.0100	0.220	0.0500	0.0600	0.0100	0.0400	0.0200	0.0100
CON180	0.870	3.10	1.78	0.790	8.76	35.7	17.5	7.94	1.96	9.55	5.70	1.91
CON181	0	0	0	0	0.0200	0.0500	0.0300	0.0100	0	0.0100	0.0100	0
CON182	0	0.0100	0	0	0.0200	0.0400	0.0300	0.0100	0.0100	0.0100	0.0100	0
CON183	0	0.800	0.360	0.290	2.12	8.00	4.12	1.76	0	2.09	1.17	0.650
CON184	0	0.0100	0	0	0	0.0200	0.0100	0.0100	0	0.0100	0	0.0100
CON185	0	0	0	0	0	0	0	0	0	0	0	0
CON186	0	0	0	0	0	0	0	0	0	0	0	0
CON187	0.690	2.51	1.40	0.610	4.29	16.3	8.55	3.62	1.96	6.39	3.80	1.32
CON188	0	0.0200	0.0100	0.0100	0.0100	0.0300	0.0100	0.0100	0.0100	0.0200	0.0100	0
CON189	0.0200	0.0500	0.0300	0.0100	0.130	0.450	0.240	0.100	0.0300	0.160	0.0900	0.0300
CON190	0.0500	0.170	0.100	0.0400	0.590	2.51	1.28	0.540	0.140	0.770	0.430	0.170
CON191	0.0100	0.0400	0.0200	0.0100	0.130	0.570	0.270	0.130	0.0300	0.110	0.0700	0.0200
CON192	0	0	0	0	0	0	0	0	0	0	0	0
CON193	0	0	0	0	0	0	0	0	0	0	0	0
CON194	0.200	0.610	0.350	0.150	1.31	5.18	2.66	1.18	0.360	1.72	0.940	0.330
CON195	0.0500	0.140	0.0900	0.0300	0.360	1.87	0.840	0.430	0.0900	0.460	0.240	0.0900
CON196	0.100	0.470	0.200	0.110	0.640	3.06	1.41	0.730	0.160	0.670	0.410	0.130
CON197	0.030	0.110	0.060	0.030	0.0800	0.400	0.190	0.100	0.0400	0.110	0.0700	0.0200
CON198	0.290	1.14	0.600	0.270	1.67	6.50	3.35	1.50	0.500	2.35	1.33	0.480
CON199	0	0	0	0	0	0	0	0	0	0	0	0
CON200	0	0	0	0	0	0	0	0	0	0	0	0
CON201	0.0500	0.220	0.110	0.0500	0.190	0.660	0.400	0.180	0.110	0.320	0.210	0.0700
CON202	0.0900	0.450	0.230	0.100	0.410	1.32	0.790	0.330	0.300	0.800	0.540	0.140
CON203	0.140	0.630	0.290	0.140	1.11	3.88	2.32	0.990	0.330	1.45	0.870	0.290
CON204	0	0.100	0.0100	0.0300	0	0.0100	0	0	0	0	0	0
CON205	0.0100	0.0200	0.0100	0.0100	0.0500	0.200	0.110	0.0500	0.0200	0.0800	0.0400	0.0200
CON206	0.140	0.600	0.400	0.140	0.860	3.07	1.75	0.800	0.57	1.63	0.930	0.290
CON207	0.0400	0.150	0.0800	0.0300	0.110	0.390	0.240	0.110	0.0700	0.210	0.120	0.0400
CON208	0.0900	0.320	0.210	0.0700	0.350	1.14	0.600	0.300	0.220	0.780	0.370	0.150
CON209	0.110	0.550	0.360	0.130	0.520	2.31	1.06	0.560	0.440	1.07	0.640	0.160

Table 8.11. Percent detections of PCB congeners in eggs of Double-crested Cormorants collected at Gardiner's (n=15), Shooters (n=14) and Swinburne (n=13) Islands, 1999.

Con	GA	SH	SW	Con	GA	SH	SW	Con	GA	SH	SW	Con	GA	SH	SW
1	0	57	15	**53**	0	0	0	**105**	100	100	100	**157**	0	0	0
2	0	0	0	**54**	0	79	8	**106**	0	0	0	**158**	100	100	100
3	13	64	15	**55**	0	0	0	**107**	33	50	46	**159**	80	71	46
4	0	14	0	**56**	0	50	0	**108**	0	0	0	**160**	0	0	0
5	0	0	0	**57**	0	0	0	**109**	100	100	100	**161**	0	0	0
6	0	7	0	**58**	0	36	8	**110**	100	100	100	**162**	100	100	100
7	0	0	0	**59**	100	100	100	**111**	100	100	100	**163**	0	0	0
8	0	43	0	**60**	100	100	100	**112**	0	0	0	**164**	40	64	31
9	0	0	0	**61**	100	100	100	**113**	0	0	0	**165**	100	100	100
10	0	0	0	**62**	0	0	0	**114**	100	100	100	**166**	0	0	0
11	0	14	8	**63**	100	100	100	**115**	0	0	0	**167**	100	100	100
12	0	0	0	**64**	100	100	100	**116**	0	0	0	**168**	0	0	0
13	0	0	0	**65**	0	0	0	**117**	0	0	0	**169**	7	0	0
14	0	0	0	**66**	100	100	100	**118**	100	100	100	**170**	100	100	100
15	7	0	0	**67**	0	36	0	**119**	0	0	0	**171**	100	100	100
16	13	86	8	**68**	100	100	100	**120**	100	100	100	**172**	100	100	100
17	53	93	62	**69**	0	0	0	**121**	100	93	100	**173**	0	0	0
18	53	100	100	**70**	0	0	0	**122**	7	7	0	**174**	100	100	100
19	0	86	62	**71**	0	0	0	**123**	100	100	100	**175**	100	100	100
20	100	100	100	**72**	100	86	100	**124**	0	0	0	**176**	93	100	100
21	67	0	8	**73**	0	7	8	**125**	0	0	0	**177**	100	100	100
22	53	64	62	**74**	0	0	0	**126**	100	100	92	**178**	100	100	100
23	0	0	8	**75**	0	0	0	**127**	27	93	54	**179**	100	100	100
24	0	29	0	**76**	0	0	0	**128**	100	100	100	**180**	100	100	100
25	33	93	85	**77**	100	100	92	**129**	100	100	100	**181**	100	100	100
26	93	100	100	**78**	0	0	0	**130**	100	100	100	**182**	53	71	38
27	0	86	62	**79**	7	64	8	**131**	0	21	0	**183**	87	100	100
28	0	0	0	**80**	0	0	0	**132**	100	100	100	**184**	100	100	100
29	0	0	0	**81**	67	64	92	**133**	100	100	100	**185**	0	0	0
30	0	0	0	**82**	27	79	31	**134**	40	93	77	**186**	0	0	8
31	100	100	100	**83**	100	100	100	**135**	100	100	100	**187**	100	100	100
32	13	93	85	**84**	80	100	100	**136**	100	100	100	**188**	100	93	100
33	0	0	0	**85**	100	100	100	**137**	100	100	100	**189**	100	100	100
34	0	29	0	**86**	100	100	100	**138**	0	0	0	**190**	100	100	100
35	0	7	0	**87**	0	0	0	**139**	100	100	100	**191**	100	100	100
36	0	0	8	**88**	100	100	100	**140**	0	0	0	**192**	0	29	8
37	40	93	85	**89**	0	21	0	**141**	60	100	100	**193**	0	0	0
38	0	86	62	**90**	100	100	100	**142**	0	0	0	**194**	100	100	100
39	0	0	0	**91**	0	0	0	**143**	0	0	0	**195**	100	100	100
40	73	100	100	**92**	100	100	100	**144**	100	100	100	**196**	100	100	100
41	0	0	0	**93**	100	100	100	**145**	0	0	0	**197**	100	100	100
42	67	93	69	**94**	0	29	0	**146**	100	100	100	**198**	100	100	100
43	7	36	31	**95**	0	0	0	**147**	100	100	100	**199**	0	0	0
44	100	100	100	**96**	0	86	15	**148**	100	100	100	**200**	0	0	0
45	7	93	77	**97**	0	0	0	**149**	0	0	0	**201**	100	100	100
46	0	71	8	**98**	0	0	0	**150**	80	93	92	**202**	100	100	100
47	0	0	0	**99**	0	0	0	**151**	0	0	0	**203**	100	100	100
48	73	93	69	**100**	0	0	0	**152**	0	36	8	**204**	100	100	100
49	100	100	100	**101**	0	0	0	**153**	100	100	100	**205**	100	100	100
50	47	93	100	**102**	0	0	0	**154**	0	0	0	**206**	100	100	100
51	0	0	0	**103**	73	93	100	**155**	100	93	100	**207**	100	100	100
52	100	100	100	**104**	0	57	0	**156**	100	100	100	**208**	100	100	100
												209	100	100	100

Table 8.12. Percent detections of PCB congeners in plasma of Double-crested Cormorants collected at Gardiner's (n=11), Shooters (n=11) and Swinburne (n=13) Islands, 1999.

Con	GA	SH	SW	Con	GA	SH	SW	Con	GA	SH	SW	Con	GA	SH	SW
1	9	0	8	**53**	0	0	0	**105**	100	100	100	**157**	0	0	0
2	9	0	0	**54**	0	9	0	**106**	0	0	0	**158**	100	100	100
3	18	0	8	**55**	0	0	0	**107**	64	100	100	**159**	9	82	23
4	9	64	23	**56**	36	64	23	**108**	0	0	0	**160**	0	0	0
5	0	0	0	**57**	0	0	0	**109**	100	100	100	**161**	0	0	0
6	9	0	8	**58**	0	0	0	**110**	100	100	100	**162**	100	100	100
7	27	64	77	**59**	82	100	100	**111**	100	91	100	**163**	0	0	0
8	27	100	100	**60**	100	100	100	**112**	0	0	0	**164**	55	82	85
9	9	0	0	**61**	100	100	100	**113**	0	0	0	**165**	100	100	100
10	0	0	0	**62**	0	0	0	**114**	100	100	100	**166**	0	0	0
11	27	100	100	**63**	100	100	100	**115**	0	0	0	**167**	100	100	100
12	0	0	0	**64**	91	100	100	**116**	0	0	0	**168**	0	0	0
13	0	0	0	**65**	0	0	0	**117**	0	0	0	**169**	36	0	0
14	0	0	0	**66**	91	100	100	**118**	100	100	100	**170**	100	100	100
15	9	9	8	**67**	0	36	0	**119**	0	0	0	**171**	100	100	100
16	18	18	8	**68**	100	100	100	**120**	100	100	100	**172**	100	100	100
17	45	82	15	**69**	0	0	0	**121**	27	91	54	**173**	0	0	0
18	82	100	100	**70**	0	0	0	**122**	0	0	0	**174**	100	100	100
19	18	36	8	**71**	0	0	0	**123**	100	100	100	**175**	100	100	100
20	100	100	100	**72**	100	100	100	**124**	0	0	0	**176**	18	100	92
21	82	82	62	**73**	0	45	0	**125**	0	0	0	**177**	100	100	100
22	45	73	8	**74**	0	0	0	**126**	100	100	100	**178**	100	100	100
23	0	0	0	**75**	0	0	0	**127**	9	100	77	**179**	82	100	100
24	0	0	0	**76**	0	0	0	**128**	100	100	100	**180**	100	100	100
25	9	45	0	**77**	100	100	100	**129**	100	100	100	**181**	0	100	92
26	64	100	100	**78**	0	0	0	**130**	100	100	100	**182**	27	100	100
27	0	45	0	**79**	9	27	0	**131**	0	55	0	**183**	91	100	85
28	0	0	0	**80**	0	0	0	**132**	100	100	100	**184**	9	8200	38
29	0	0	0	**81**	27	91	62	**133**	100	100	100	**185**	0	0	0
30	0	0	0	**82**	9	91	8	**134**	9	91	69	**186**	0	0	0
31	100	100	100	**83**	100	100	100	**135**	100	100	100	**187**	100	100	100
32	18	82	0	**84**	45	100	100	**136**	73	100	100	**188**	73	100	100
33	0	0	0	**85**	100	100	100	**137**	100	100	100	**189**	100	100	100
34	0	0	0	**86**	100	100	100	**138**	0	0	0	**190**	100	100	100
35	0	0	0	**87**	0	0	0	**139**	100	100	100	**191**	100	100	100
36	0	0	8	**88**	55	100	100	**140**	0	0	0	**192**	0	0	0
37	36	64	54	**89**	0	0	0	**141**	82	100	100	**193**	0	0	0
38	0	0	0	**90**	100	100	100	**142**	0	0	0	**194**	100	100	100
39	0	0	0	**91**	0	0	0	**143**	0	0	0	**195**	100	100	100
40	82	100	85	**92**	100	100	100	**144**	100	100	100	**196**	100	100	100
41	0	0	0	**93**	100	100	100	**145**	0	0	0	**197**	100	100	100
42	55	82	0	**94**	0	18	0	**146**	100	100	100	**198**	100	100	100
43	0	9	0	**95**	0	0	0	**147**	100	100	100	**199**	0	0	0
44	100	100	100	**96**	0	9	0	**148**	73	100	100	**200**	0	0	0
45	27	100	77	**97**	0	0	0	**149**	0	0	0	**201**	100	100	100
46	0	0	0	**98**	0	0	0	**150**	18	45	0	**202**	100	100	100
47	0	0	0	**99**	0	0	0	**151**	0	0	0	**203**	100	100	100
48	18	45	0	**100**	0	0	0	**152**	0	0	0	**204**	9	9	0
49	100	100	100	**101**	0	0	0	**153**	100	100	100	**205**	100	100	100
50	27	100	62	**102**	0	0	0	**154**	0	0	0	**206**	100	100	100
51	0	0	0	**103**	9	82	38	**155**	91	100	100	**207**	100	100	100
52	100	100	100	**104**	0	0	0	**156**	100	100	100	**208**	100	100	100
												209	100	100	100

Table 8.13. Total polychlorinated biphenyl (congener) concentrations (ng/g wet weight) in eggs and plasma of Double-crested Cormorants collected at Gardiner's, Shooters, and Swinburne Islands, 1999. Given are n samples, minimum, maximum, median, mean, and standard deviation (s). Normality of sample population was tested with Shapiro-Wilk's test (S-W; probability P).

	n	minimum	maximum	median	mean	s	S-W	P
Eggs								
GA	15	935	6770	2220	2490	1490	0.84	0.013
SH	14	1980	40400	12500	13900	9170	0.821	0.009
SW	13	1930	13200	8760	8000	3600	0.947	0.551
Plasma								
GA	11	12.3	44.4	26.8	27.8	10.8	0.946	0.594
SH	11	105	331	192	209	77.7	0.939	0.505
SW	13	30.3	108	78.6	77.5	22.2	0.951	0.616

Table 8.14. Predicted toxic equivalents of *Ah* receptor-active PCB congeners (77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, 189) in eggs and plasma of Double-crested Cormorants, coastal New York 1999. Given are mean ± standard error (n samples) concentration (ng/g wet weight) based on WHO avian toxic equivalent factors (Van den Berg et al. 1998).

Colony	Eggs	Plasma
Gardiner's Island	0.104 ± 0.0154 (15)	0.00239 ± 0.000277 (11)
Swinburne Island	0.249 ± 0.0341 (13)	0.00539 ± 0.000499 (13)
Shooters Island	0.322 ± 0.0629 (14)	0.00848 ± 0.000964 (11)

Table 8.15. Total homologue PCB concentrations in eggs and plasma of Double-crested Cormorants collected at colonies in coastal New York, 1999. Given are mean + standard deviation (ng/g wet weight).

Homologue Group Eggs	Gardiner's Island (n=15)	Swinburne Island (n=13)	Shooters Island (n=14)
1-mono	0.00333 + 0.00900	0.00538 + 0.00967	0.0229 + 0.0164
2-dichloro	0.00200 + 0.00775	0.00538 + 0.0194	0.0650 + 0.105
3-trichloro	10.1 + 6.36	89.3 + 53.5	182 + 141
4-tetrachloro	59.8 + 31.4	443 + 248	1040 + 820
5-pentachloro	440 + 248	1680 + 788	2880 + 2030
6-hexachloro	1170 + 736	3460 + 1550	5480 + 3350
7-heptachloro	548 + 346	1690 + 749	3180 + 2060
8-octachloro	187 + 111	501 + 220	969 + 782
9-nonochloro	52.6 + 30.1	124 + 51.0	177 + 187
10-decachloro	12.9 + 7.83	24.7 + 9.78	43.2 + 22.8
Plasma	**Gardiner's Island (n=11)**	**Swinburne Island (n=13)**	**Shooters Island (n=11)**
1-mono	0.00909 + 0.0202	0.00154 + 0.00555	0 + 0
2-dichloro	0.0345 + 0.0552	0.0377 + 0.0188	0.0527 + 0.0502
3-trichloro	0.215 + 0.0792	1.40 + 0.529	4.71 + 2.39
4-tetrachloro	1.17 + 0.463	6.31 + 2.23	21.3 + 9.54
5-pentachloro	5.58 + 2.44	17.4 + 5.03	45.0 + 15.9
6-hexachloro	12.8 + 5.06	30.6 + 9.83	78.4 + 29.7
7-heptachloro	5.07 + 2.25	15.1 + 4.60	43.7 + 19.6
8-octachloro	1.96 + 0.859	4.65 + 1.43	12.1 + 5.27
9-nonochloro	0.694 + 0.233	1.42 + 0.457	2.59 + 1.20
10-decachloro	0.361 + 0.132	0.642 + 0.161	1.06 + 0.558

Table 8.16. Results of correlation analysis of reproductive endpoints and total PCB congener concentrations in tissues of Double-crested Cormorants collected in coastal New York, 1999. Given are n samples, Spearman correlation coefficient (r), and probability (P).

		n	r	P
Egg	Egg Laid	42	0.116	0.466
	Max Young	34	0.142	0.424
	Max Chick Days	28	-0.111	0.575
Plasma	Egg Laid	35	-0.139	0.427
	Max Young	34	-0.230	0.191
	Max Chick Days	34	-0.307	0.077

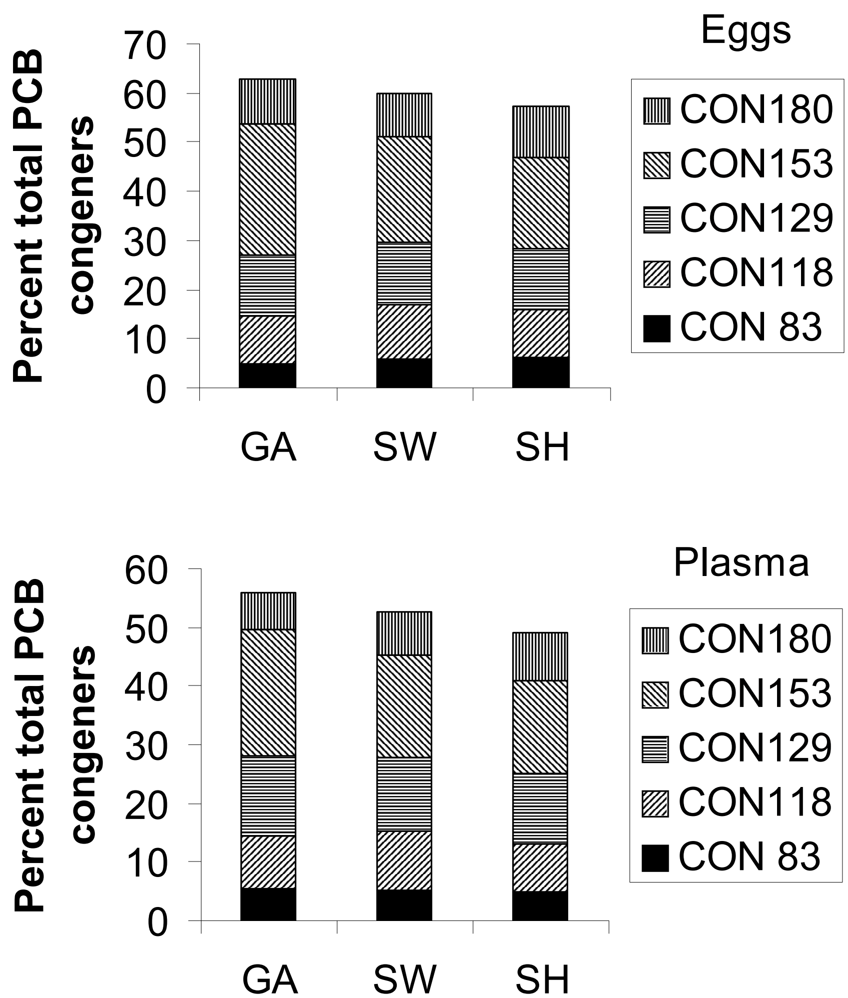

Figure 8.1. Comparison of PCB congeners in eggs and plasma of Double-crested Cormorant from different colonies in coastal New York, 1999. Shown are the percent contributions of individual congeners to total PCB concentrations.

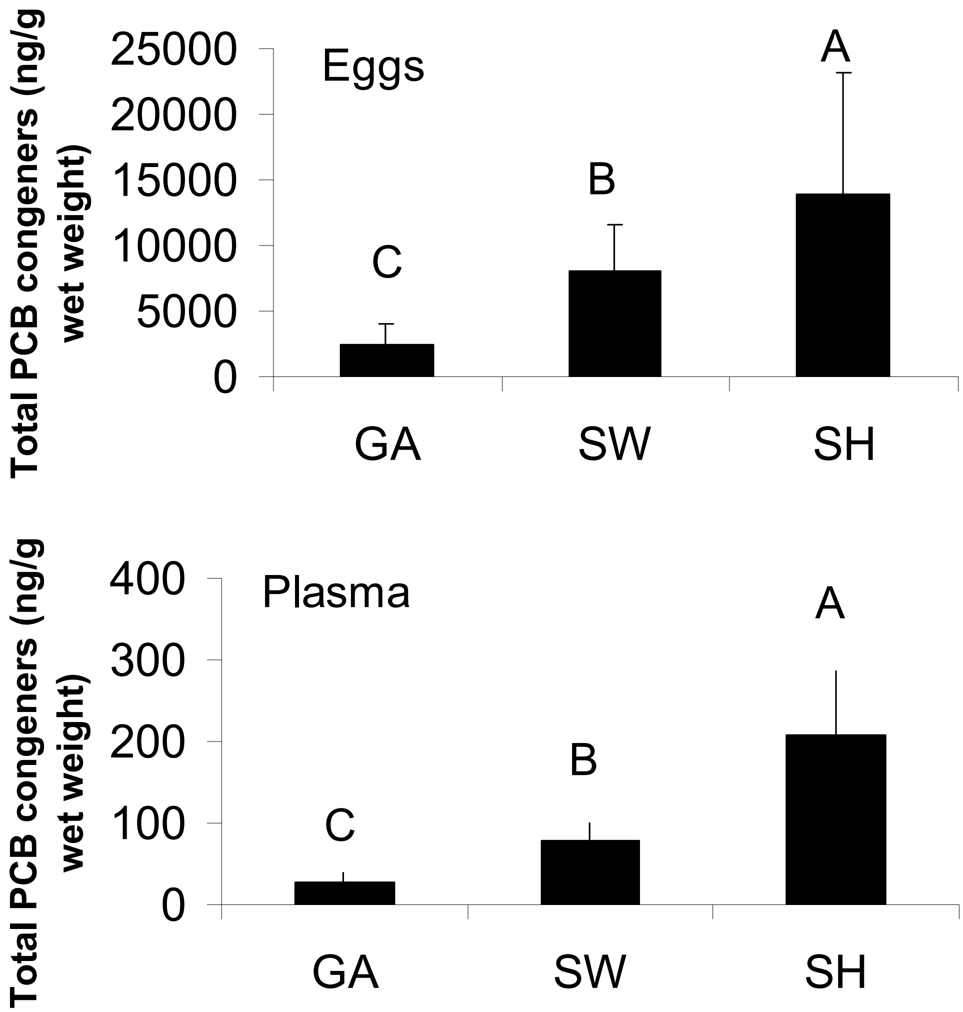

Figure 8.2. Comparison of total PCB congeners in eggs and plasma of Double-crested Cormorant from different colonies in coastal New York, 1999. Shown are mean + standard deviation concentration (ng/g wet weight) total PCB congeners (see text) detected in eggs and plasma from Gardiner's Island (GA), Shooters Island (SH), and Swinburne Island (SW). Unlike letters indicate colony differences.

DIOXINS AND FURANS

RESULTS

Double-crested Cormorant egg and plasma tissues were analyzed for seven dioxins and ten furans including 1,2,3,4,6,7,8-HpCDD; 1,2,3,4,6,7,8-HpCDF; 1,2,3,4,7,8,9-HpCDF; 1,2,3,4,7,8-HxCDD; 1,2,3,4,7,8-HxCDF; 1,2,3,6,7,8-HxCDD; 1,2,3,6,7,8-HxCDF; 1,2,3,7,8,9-HxCDD; 1,2,3,7,8,9-HxCDF; 1,2,3,7,8-PeCDD; 1,2,3,7,8-PeCDF; 2,3,4,6,7,8-HxCDF; 2,3,4,7,8-PeCDF; 2,3,7,8-TCDD; 2,3,7,8-TCDF; OCDD; OCDF. In addition, homologue groups HPCDD, HPCDF, HXCDD, HXCDF, PECDD, PECDF, TCDD and TCDF were analyzed for both tissue types. Results are reported as non-lipid adjusted pg/g wet weight for both egg and plasma. Detection limits ranged from 0 to 210 pg/g in eggs and 0.000422 to 13.7 pg/g in plasma (see Appendix 1—Quality Assurance). Non-detects were adjusted to zero.

Descriptive statistics of dioxin and furan analytes and homologue groups are provided in Tables 9.1-9.8. All dioxin and furan analytes were detected in at least one egg sample from all three colonies (Tables 9.1-9.3). All dioxin and furan analytes were detected in at least one plasma sample from Swinburne Island (Table 9.7), but 1,2,3,7,8-PeCDF was not detected in any plasma samples from Shooters or Gardiner's Islands and an additional six analytes (1,2,3,4,7,8,9-HpCDF; 1,2,3,4,7,8-HxCDD; 1,2,3,6,7,8-HxCDD; 1,2,3,7,8,9-HxCDD; 1,2,3,7,8-PeCDF; 2,3,7,8-TCDF) were not detected in any plasma samples from Gardiner's Island.

Total analyte (summed dioxin and furan analyte concentrations) and homologue (summed dioxin and furan homologue concentrations) variables were used to examine spatial patterns in tissue concentrations. Transformations of total variables in eggs failed to stabilize variance (Levene's test; $P < 0.05$), so data were ranked. A Tukey mean separation procedure was used to identify colony differences in significant models (ANOVA).

Plasma analyte (total) data were homogeneous (Levene's test; $P > 0.05$), so unranked ANOVA and Tukey mean separation procedures were used to assess differences between colonies. Plasma homologue (total) data were log-transformed after examining residuals. The Pearson correlation coefficient was generated to examine the relationship between nestling size and plasma dioxins and furans. Unless otherwise noted, $\alpha=0.05$.

Cormorant nestlings selected for plasma sampling were not of uniform size across colony sites (see Table 4.4). Tissue samples were taken from nestlings significantly smaller on Shooters Island compared to Swinburne Island. Nevertheless, no correlations were detected between nestling size and total dioxin and furan concentrations (analyte and homologue) at any island ($P > 0.05$).

The relative contribution of different analytes to total dioxins and furans in eggs was similar at Shooters and Swinburne Islands, but eggs at Gardiner's Island had relatively more 1,2,3,6,7,8-HxCDD and 1,2,3,7,8-PeCDD and less 2,3,7,8-TCDD. Similarly, eggs from Gardiner's Island had relatively more of the HXCDD homologue group and less of TCDD than the other two sites (Figure 9.1).

Plasma concentrations of dioxin and furan analytes were dominated by OCDD with relatively little 2,3,7,8-TCDD at Gardiner's Island compared to Swinburne and Shooters Islands (Figure 9.2). Plasma homologues were dominated by TCDD at Shooters Island; detection of all homologues was very low at Gardiner's Island (Table

9.8). Although HxCDF dominated plasma homologues at Gardiner's Island, it was present in only 27% of all samples.

Toxic equivalents were highest in eggs (mean=92.0 pg/g) and plasma (mean=3.99 pg/g) collected at Shooters Island, and were nearly 100% greater than samples from Swinburne Island and 3-10 times greater than samples from Gardiner's Island (Table 9.9). Cormorant eggs from Shooters and Swinburne Islands had greater concentrations of total dioxins and furans (analytes and homologues) than eggs from Gardiner's Island (Figure 9.3). Similarly, nestling plasma collected at Shooters and Swinburne Islands had greater concentrations of homologue dioxins and furans than samples from Gardiner's Island, although analyte concentrations did not differ between sites (Figure 9.4).

No relationships between total dioxin/furan concentrations and reproductive endpoints, including a measure of egg production (Eggs Laid), hatching success (Maximum Young Observed) and chick survival (Maximum Chick Days), were detected (Table 9.10).

Discussion

Most dioxins and furans were detected in a majority of eggs collected from all three coastal New York sites. The level of detection of these contaminants in plasma was lower, especially at Gardiner's Island. However, the highly toxic 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) was detected in all eggs and all plasma samples from the two New York Harbor sites (Shooters and Swinburne Islands). TCDD was detected in all eggs from Gardiner's Island, but in only 27% of plasma samples.

TCDD and octochlorodibenzo-p-dioxin (OCDD) contributed 40-50% of total dioxins and furans in eggs from Shooters and Swinburne Islands, but less than 30% in eggs from Gardiner's Island. Mean concentrations of TCDD in eggs ranged from 6-60 pg/g wet weight in the present study which is comparable to levels detected in cormorant eggs in the Great Lakes in the late 1990s (16-62 pg/g wet weight; Kannan et al. 2001), but somewhat higher than a study conducted in the Great Lakes in the early 1990s (9-20 pg/g wet weight; Ryckman et al. 1998). TCDD levels in eight cormorant eggs collected from Shooters Island in 1993 averaged 82.8 pg/g wet weight (range 46.5-161; Karwowski and Parsons, unpublished data). Mean TCDD concentrations in eggs of Neotropic Cormorant (*Phalacrocorax brasilianus*) collected in Texas in 1996 ranged from 10-106 pg/g wet weight (Frank et al. 2001).

Other dioxin isomers detected in cormorant eggs from Shooters and Swinburne Islands were comparable to levels detected in the Great Lakes with the exception of OCDD which was higher in coastal New York (Ryckman et al. 1998). Dioxins and furans were not detected in cormorant eggs collected from colonies in the Canadian maritime region in the early 1970s (Zitko et al. 1972).

Mean concentrations of 2,3,7,8-tetrachlorodibenzofuran (TCDF) in eggs were approximately 0.2-0.4 pg/g wet weight in the present study. Great Lakes studies of TCDF found ND-2 pg/g concentrations in the early 1990s (Ryckman et al. 1998) and 27-48 pg/g concentrations in the late 1990s (Kannan et al. 2001). In general, furan concentrations in cormorant eggs in the Great Lakes were greater than levels detected in coastal New York. TCDF was not detected in cormorant eggs in Texas (Frank et al. 2001).

Little information is available to aid in interpretation of plasma concentrations of dioxins and furans in the present study. Nestling carcass concentrations of TCDD, total dioxins, TCDF and total furans were 4, 25, 2, and 10 pg/g wet weight, respectively, in a study of Michigan cormorants (Stalling et al. 1985). With the exception of TCDD in plasma from Shooters Island, these levels are greater than levels detected in the present study.

Dioxins and furans exert acute and chronic toxicological effects in sensitive bird species at or below ng/g levels of concentration. TCDD, in particular, is highly embryotoxic and teratogenic. Concentrations in cormorant eggs from 5.3 to 22 pg/g may result in embryo mortality and a number of deformities (summarized in Hoffman et al. 1996). All eggs sampled at the New York Harbor sites and most eggs from Gardiner's Island showed TCDD concentrations within this range. The LD50 concentration of TCDD in bird eggs in general has been estimated at 147 pg/g (reviewed in Hoffman et al. 1996).

Potential toxic effects from all dioxins and furans may also be estimated using toxic equivalency factors (TEFs) which generate a TCDD-equivalent concentration. Standard factors are often used to calculate TCDD-equivalents, or species-specific factors may be derived from bioassays of detoxifying enzyme activity (e.g., Frank et al. 2001). Toxic equivalents from directly measured factors are generally up to 30% lower than those produced by standard TEFs (Hoffman et al. 1996, Frank et al. 2001). Toxic equivalents from dioxins and furans detected in coastal New York cormorants ranged from 25 to 92 pg/g wet weight. Comparable values from the Great Lakes ranged from 9.4 to 20.8 pg/g wet weight (Kannan et al. 2001). Toxic equivalents (bioassayed; TCDD only) associated with adverse effects in cormorant eggs range from 85 to 413 pg/g (summarized in Hoffman et al. 1996).

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Table 9.1. Dioxin and furan concentrations (pg/g wet weight) in eggs (n=15) of Double-crested Cormorants collected at Gardiner's Island, 1999. Given are percent detection, minimum, maximum, range, mean, and standard deviation.

Analyte	% Detection	Minimum	Maximum	Range	Mean	Std Dev
2,3,7,8-TCDD	100	2.69	12.5	9.81	5.98	2.97
1,2,3,7,8-PeCDD	100	4.55	20.1	15.6	10.9	4.35
1,2,3,4,7,8-HxCDD	100	0.847	4.60	3.75	1.86	0.912
1,2,3,6,7,8-HxCDD	100	6.87	30.2	23.3	13.7	6.72
1,2,3,7,8,9-HxCDD	100	1.22	9.22	8.00	3.97	2.15
1,2,3,4,6,7,8-HpCDD	100	1.83	29.9	28.1	7.98	6.86
OCDD	100	6.23	66.5	60.3	15.2	14.8
TOTAL DIOXINS		29.7	172	142	59.6	34.7
2,3,7,8-TCDF	100	0.113	0.423	0.310	0.234	0.0868
1,2,3,4,6,7,8-HpCDF	100	0.158	1.54	1.38	0.615	0.488
1,2,3,4,7,8,9-HpCDF	13	0	0.264	0.264		
1,2,3,7,8-PeCDF	73	0	0.469	0.469	0.185	0.149
2,3,4,7,8-PeCDF	100	3.34	15.3	12.0	6.77	3.24
1,2,3,4,7,8-HxCDF	100	0.347	1.64	1.29	0.914	0.303
1,2,3,6,7,8-HxCDF	100	0.33	1.58	1.25	0.887	0.381
2,3,4,6,7,8-HxCDF	100	0.369	1.40	1.03	0.806	0.314
1,2,3,7,8,9-HxCDF	33	0	0.213	0.213		
OCDF	53	0	0.716	0.716	0.209	0.243
TOTAL FURANS		5.94	20.2	14.2	10.7	4.07
TOTAL		37.5	188	150	70.3	36.7

Table 9.2. Dioxin and furan concentrations (pg/g wet weight) in eggs (n=14) of Double-crested Cormorants collected at Shooters Island, 1999. Given are percent detection, minimum, maximum, range, mean, and standard deviation.

Analyte	% Detection	Minimum	Maximum	Range	Mean	Std Dev
2,3,7,8-TCDD	100	8.59	201	192	59.8	52.8
1,2,3,7,8-PeCDD	100	2.48	33.0	30.5	15.3	10.0
1,2,3,4,7,8-HxCDD	100	0.416	6.81	6.39	2.65	2.15
1,2,3,6,7,8-HxCDD	100	2.97	52.3	49.3	23.4	17.8
1,2,3,7,8,9-HxCDD	100	0.911	17.3	16.4	6.85	5.51
1,2,3,4,6,7,8-HpCDD	100	2.15	39.6	37.5	14.3	12.0
OCDD	100	12.9	70.2	57.3	34.5	18.1
TOTAL DIOXINS		38.3	353	314	157	105
2,3,7,8-TCDF	93	0	1.08	1.08	0.382	0.253
1,2,3,4,6,7,8-HpCDF	100	0.510	4.51	4.00	1.97	1.23
1,2,3,4,7,8,9-HpCDF	36	0	0.416	0.416		
1,2,3,7,8-PeCDF	86	0	0.419	0.419	0.211	0.137
2,3,4,7,8-PeCDF	100	1.49	36.6	35.1	13.7	10.6
1,2,3,4,7,8-HxCDF	100	1.04	45.0	44.0	11.1	12.7
1,2,3,6,7,8-HxCDF	100	0.670	10.2	9.53	3.51	3.12
2,3,4,6,7,8-HxCDF	100	0.454	6.15	5.70	1.99	1.60
1,2,3,7,8,9-HxCDF	57	0	0.832	0.832	0.170	0.237
OCDF	100	0.471	2.65	2.18	1.08	0.631
TOTAL FURANS		5.91	91.5	85.5	34.1	28.2
TOTAL		44.2	440	396	191	131

Table 9.3. Dioxin and furan concentrations (pg/g wet weight) in eggs (n=13) of Double-crested Cormorants collected at Swinburne Island, 1999. Given are percent detection, minimum, maximum, range, mean, and standard deviation.

Analyte	% Detection	Minimum	Maximum	Range	Mean	Std Dev
2,3,7,8-TCDD	100	7.76	48.1	40.3	28.2	13.6
1,2,3,7,8-PeCDD	100	9.87	22.8	12.9	15.0	4.30
1,2,3,4,7,8-HxCDD	100	0.777	3.93	3.15	2.09	0.918
1,2,3,6,7,8-HxCDD	100	9.18	32.5	23.3	18.6	6.31
1,2,3,7,8,9-HxCDD	100	2.18	7.82	5.64	4.60	1.88
1,2,3,4,6,7,8-HpCDD	100	3.64	16.1	12.5	9.42	4.68
OCDD	100	9.88	45.9	36.0	24.4	11.7
TOTAL DIOXINS		62.4	151	88.2	102	29.2
2,3,7,8-TCDF	100	0.252	0.599	0.347	0.405	0.129
1,2,3,4,6,7,8-HpCDF	100	0.154	2.15	2.00	0.943	0.656
1,2,3,4,7,8,9-HpCDF	8	0	0.378	0.378		
1,2,3,7,8-PeCDF	92	0	0.682	0.682	0.263	0.165
2,3,4,7,8-PeCDF	100	5.28	20.0	14.7	10.9	4.55
1,2,3,4,7,8-HxCDF	100	0.867	5.08	4.21	2.40	1.25
1,2,3,6,7,8-HxCDF	100	0.732	3.69	2.96	1.62	0.863
2,3,4,6,7,8-HxCDF	100	0.520	2.59	2.07	1.22	0.592
1,2,3,7,8,9-HxCDF	69	0	0.253	0.253	0.0957	0.0878
OCDF	92	0	2.19	2.19	0.690	0.630
TOTAL FURANS		8.35	35.4	27.1	18.6	8.05
TOTAL		70.7	186	115	121	35.4

Table 9.4. Total homologue dioxin and furan concentrations (pg/g wet weight) in eggs of Double-crested Cormorants collected at Gardiner's (n=15), Shooters (n=14) and Swinburne (n=13) Islands, 1999. Given are percent detection, minimum, maximum, range, mean, and standard deviation.

Homologue	% Detection	Minimum	Maximum	Range	Mean	Std Dev
Gardiner's Island						
TCDD	100	2.69	12.5	9.81	5.98	2.97
PECDD	100	4.55	20.1	15.6	10.9	4.35
HXCDD	100	8.90	44.1	35.2	19.1	9.90
HPCDD	100	0.789	33.0	32.2	8.74	7.56
TOTAL DIOXINS		20.0	109	88.6	44.8	22.6
TCDF	53	0	0.718	0.718	0.182	0.212
PECDF	93	0	15.6	15.6	6.45	3.69
HXCDF	100	0.797	3.88	3.08	2.45	0.999
HPCDF	20	0	0.421	0.421		
TOTAL FURANS		1.60	20.0	18.3	9.15	4.46
TOTAL		25.1	121	95.4	53.9	24.7
Shooters Island						
TCDD	100	8.59	201	192	59.9	52.8
PECDD	100	2.48	33.0	30.5	15.3	10.0
HXCDD	100	0.970	72.1	71.1	32.2	25.9
HPCDD	100	2.93	42.2	39.3	16.6	12.8
TOTAL DIOXINS		17.7	313	295	124	93.1
TCDF	86	0	0.777	0.777	0.273	0.199
PECDF	100	1.13	37.9	36.8	13.4	11.3
HXCDF	100	2.51	56.4	53.9	16.7	16.9
HPCDF	29	0	3.77	3.77		
TOTAL FURANS		4.72	91.1	86.4	31.2	27.9
TOTAL		23	393	370	155	119
Swinburne Island						
TCDD	100	7.76	48.1	40.3	28.2	13.6
PECDD	100	9.87	22.8	12.9	15.0	4.31
HXCDD	100	12.8	39.0	26.2	25.4	8.28
HPCDD	100	5.61	19.3	13.7	11.2	5.31
TOTAL DIOXINS		39.0	111	72.0	79.8	23.5
TCDF	85	0	0.694	0.694	0.398	0.220
PECDF	100	5.28	20.4	15.1	11.2	4.63
HXCDF	100	2.26	11.5	9.24	5.01	2.76
HPCDF	62	0	1.80	1.80	0.526	0.590
TOTAL FURANS		7.92	33.6	25.7	17.1	7.50
TOTAL		47.1	143	95.5	96.9	29.9

Table 9.5. Dioxin and furan concentrations (pg/g wet weight) in plasma (n=11) of Double-crested Cormorants collected at Gardiner's Island, 1999. Given are percent detection, minimum, maximum, range, mean, and standard deviation.

Analyte	% Detection	Minimum	Maximum	Range	Mean	Std Dev
2,3,7,8-TCDD	27	0	0.623	0.623		
1,2,3,7,8-PeCDD	9	0	0.755	0.755		
1,2,3,4,7,8-HxCDD	0					
1,2,3,6,7,8-HxCDD	0					
1,2,3,7,8,9-HxCDD	0					
1,2,3,4,6,7,8-HpCDD	64	0	1.61	1.61	0.703	0.634
OCDD	100	2.03	32.8	30.8	6.53	8.75
TOTAL DIOXINS		2.03	33.6	31.5	7.43	8.75
2,3,7,8-TCDF	0					
1,2,3,4,6,7,8-HpCDF	27	0	1.53	1.53		
1,2,3,4,7,8,9-HpCDF	0					
1,2,3,7,8-PeCDF	0					
2,3,4,7,8-PeCDF	18	0	0.759	0.759		
1,2,3,4,7,8-HxCDF	64	0	0.782	0.782	0.387	0.319
1,2,3,6,7,8-HxCDF	9	0	0.485	0.485		
2,3,4,6,7,8-HxCDF	9	0	1.04	1.04		
1,2,3,7,8,9-HxCDF	18	0	0.727	0.727		
OCDF	0					
TOTAL FURANS		0	3.44	3.44	1.01	1.11
TOTAL		2.03	37.0	35.0	8.44	9.63

Table 9.6. Dioxin and furan concentrations (pg/g wet weight) in plasma (n=11) of Double-crested Cormorants collected at Shooters Island, 1999. Given are percent detection, minimum, maximum, range, mean, and standard deviation.

Analyte	% Detection	Minimum	Maximum	Range	Mean	Std Dev
2,3,7,8-TCDD	100	1.13	10.1	8.97	3.14	2.70
1,2,3,7,8-PeCDD	45	0	0.463	0.463		
1,2,3,4,7,8-HxCDD	9	0	0.205	0.205		
1,2,3,6,7,8-HxCDD	55	0	0.534	0.534	0.222	0.219
1,2,3,7,8,9-HxCDD	9	0	0.2	0.2		
1,2,3,4,6,7,8-HpCDD	91	0	1.81	1.81	0.833	0.493
OCDD	100	1.41	7.7	6.29	3.89	2.03
TOTAL DIOXINS		3.64	14.6	11.0	8.31	3.65
2,3,7,8-TCDF	18	0	0.636	0.636		
1,2,3,4,6,7,8-HpCDF	82	0	2.76	2.76	0.781	0.731
1,2,3,4,7,8,9-HpCDF	18	0	0.291	0.291		
1,2,3,7,8-PeCDF	0					
2,3,4,7,8-PeCDF	82	0	0.722	0.722	0.444	0.237
1,2,3,4,7,8-HxCDF	100	0.569	1.33	0.761	0.849	0.279
1,2,3,6,7,8-HxCDF	18	0	0.34	0.34		
2,3,4,6,7,8-HxCDF	55	0	0.626	0.626	0.261	0.277
1,2,3,7,8,9-HxCDF	9	0	0.216	0.216		
OCDF	55	0	0.801	0.801	0.354	0.354
TOTAL FURANS		1.08	5.27	4.19	2.88	1.18
TOTAL		6.23	18.0	11.7	11.2	4.57

Table 9.7. Dioxin and furan concentrations (pg/g wet weight) in plasma (n=13) of Double-crested Cormorants collected at Swinburne Island, 1999. Given are percent detection, minimum, maximum, range, mean, and standard deviation.

Analyte	% Detection	Minimum	Maximum	Range	Mean	Std Dev
2,3,7,8-TCDD	100	0.581	1.63	1.05	1.03	0.345659
1,2,3,7,8-PeCDD	38	0	0.492	0.492		
1,2,3,4,7,8-HxCDD	31	0	0.452	0.452		
1,2,3,6,7,8-HxCDD	69	0	0.633	0.633	0.289	0.238
1,2,3,7,8,9-HxCDD	31	0	0.488	0.488		
1,2,3,4,6,7,8-HpCDD	100	0.388	2.73	2.34	0.814	0.592
OCDD	100	1.69	41.8	40.1	6.09	11.0
TOTAL DIOXINS		2.95	47.7	44.8	8.56	12.0
2,3,7,8-TCDF	31	0	0.448	0.448		
1,2,3,4,6,7,8-HpCDF	100	0.533	1.07	0.537	0.690	0.158
1,2,3,4,7,8,9-HpCDF	85	0	0.652	0.652	0.260	0.170
1,2,3,7,8-PeCDF	8	0	0.582	0.582		
2,3,4,7,8-PeCDF	92	0	0.885	0.885	0.519	0.215
1,2,3,4,7,8-HxCDF	100	0.593	1.42	0.827	0.783	0.208
1,2,3,6,7,8-HxCDF	77	0	0.479	0.479	0.188	0.136
2,3,4,6,7,8-HxCDF	85	0	0.575	0.575	0.266	0.154
1,2,3,7,8,9-HxCDF	92	0	0.839	0.839	0.301	0.194
OCDF	62	0	4.09	4.09	0.685	1.09
TOTAL FURANS		1.59	10.9	9.32	3.84	2.24
TOTAL		6.46	58.6	52.2	12.4	14.1

Table 9.8. Total homologue dioxin and furan concentrations (pg/g wet weight) in plasma of Double-crested Cormorants collected at Gardiner's (n=11), Shooters (n=11) and Swinburne (n=13) Islands, 1999. Given are percent detection, minimum, maximum, range, mean, and standard deviation.

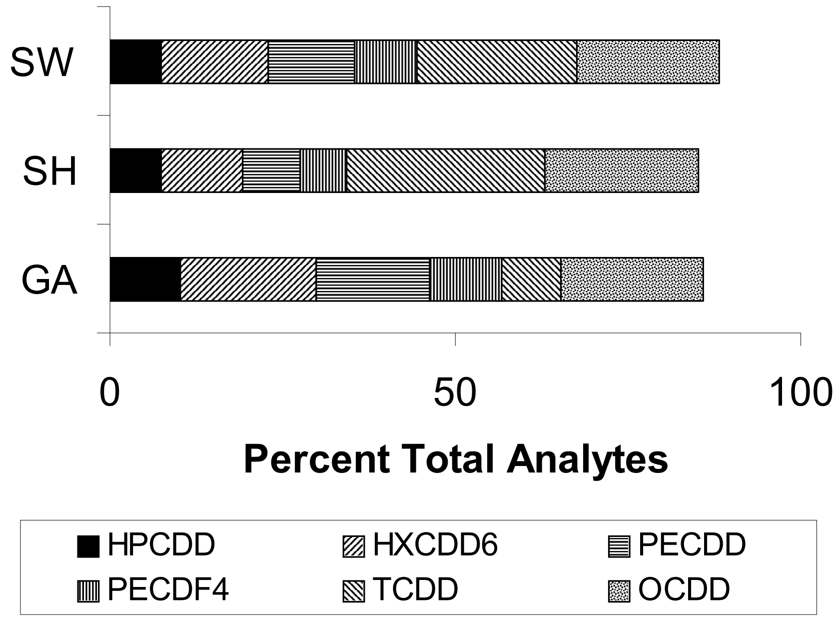
Homologue	% Detection	Minimum	Maximum	Range	Mean	Std Dev
Gardiner's Island						
TCDD	0	0	0	0		
PECDD	0	0	0	0		
HXCDD	0	0	0	0		
HPCDD	9	0	1.13	1.13		
TOTAL DIOXINS		0	1.13	1.13		
TCDF	0	0	0	0		
PECDF	9	0	0.563	0.563		
HXCDF	27	0	0.782	0.782		
HPCDF	0	0	0	0		
TOTAL FURANS		0	1.35	1.35		
TOTAL	27	0	2.48	2.48		
Shooters Island						
TCDD	73	0	10.1	10.1	2.60	3.04
PECDD	18	0	0.463	0.463		
HXCDD	18	0	0.143	0.143		
HPCDD	55	0	1.63	1.63	0.571	0.613
TOTAL DIOXINS		0	10.1	10.1	3.28	2.97
TCDF	18	0	0.754	0.754		
PECDF	0	0	0	0		
HXCDF	55	0	2.14	2.14	0.562	0.705
HPCDF	0	0	0	0		
TOTAL FURANS		0	2.14	2.14	0.655	0.750
TOTAL	91	0	10.1	10.1	3.93	3.26
Swinburne Island						
TCDD	23	0	1.63	1.63		
PECDD	0	0	0	0		
HXCDD	31	0	0.557	0.557		
HPCDD	69	0	4.44	4.44	0.893	1.17
TOTAL DIOXINS		0	6.52	6.52	1.29	1.75
TCDF	38	0	0.432	0.432		
PECDF	46	0	0.885	0.885		
HXCDF	92	0	3.31	3.31	1.08	0.780
HPCDF	38	0	0.660	0.660		
TOTAL FURANS		0	4.20	4.20	1.65	1.04
TOTAL	100	0.852	10.7	9.87	2.94	2.51

Table 9.9. Predicted toxic equivalents of *Ah* receptor-active dioxins and furans in eggs and plasma of Double-crested Cormorants, coastal New York 1999. Given are mean ± standard error (n) concentration based on WHO avian toxic equivalent factors (Van den Berg 1998).

Colony	Eggs pg/g wet weight	Plasma pg/g wet weight
Gardiner's Island	24.9 + 2.20 (15)	0.387 + 0.161 (11)
Swinburne Island	55.8 + 5.50 (13)	2.00 + 0.172 (13)
Shooters Island	92.0 + 2.00 (14)	3.99 + 0.891 (11)

Table 9.10. Results of correlation analysis of reproductive endpoints and total dioxin/furan analytes and homologues within tissues of Double-crested Cormorants collected in coastal New York, 1999. Given are n samples, Spearman correlation coefficient, and probability (P). Alpha'=0.017 (Sidak's method).

Tissue	Reproductive Endpoints	n samples	Spearman correlation coefficient	P
Egg--Analytes	Eggs Laid	42	0.138	0.385
	Max Young Observed	34	0.124	0.483
	Max Chick Days	28	-0.046	0.818
Egg--Homologues	Eggs Laid	42	0.075	0.639
	Max Young Observed	34	0.021	0.906
	Max Chick Days	28	-0.032	0.871
Plasma--Analytes	Eggs Laid	35	-0.08	0.649
	Max Young Observed	34	-0.135	0.447
	Max Chick Days	34	-0.23	0.192
Plasma--Homologues	Eggs Laid	35	-0.062	0.724
	Max Young Observed	34	-0.177	0.318
	Max Chick Days	34	-0.264	0.132



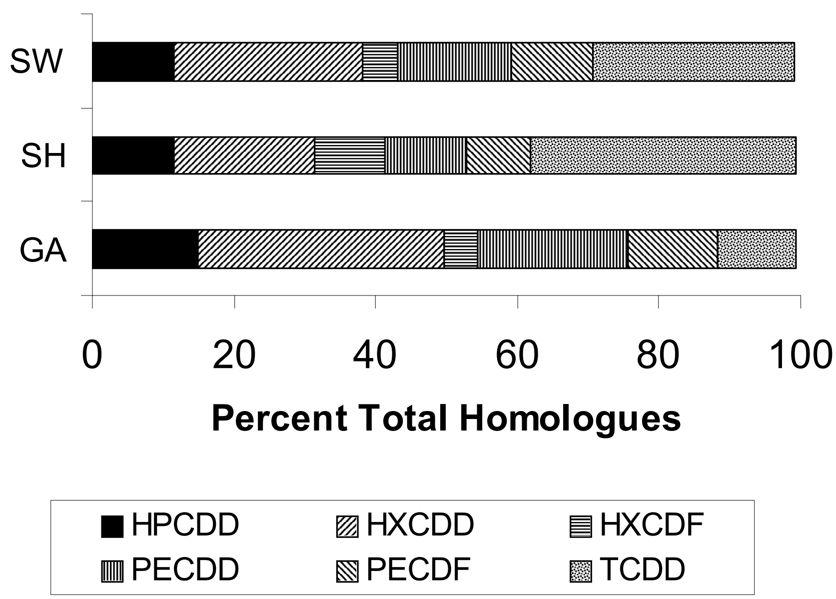
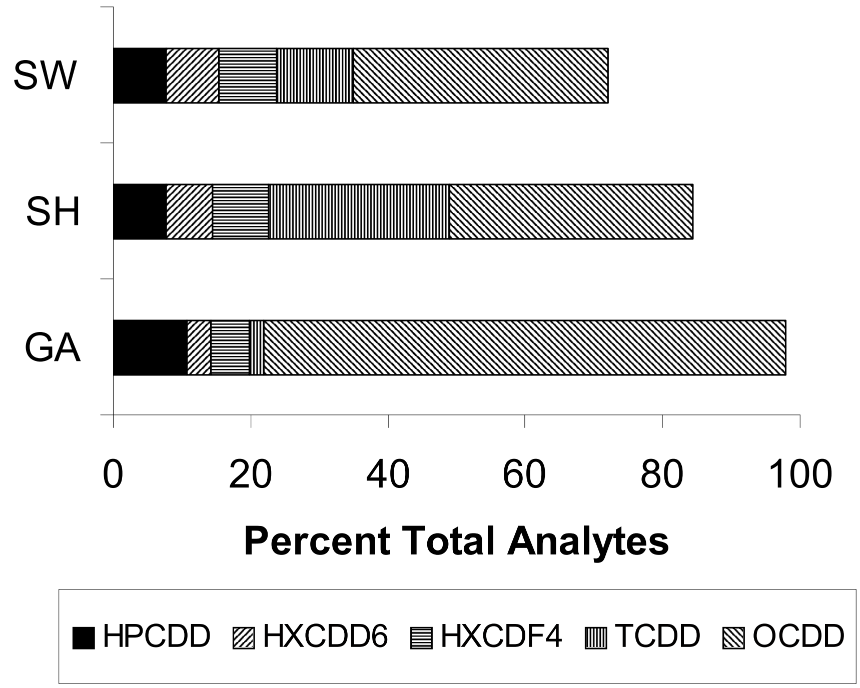


Figure 9.1. Comparison of dioxin and furan analytes and homologue groups in eggs of Double-crested Cormorant from different colonies in coastal New York, 1999. Shown are the percent contributions of individual analytes and homologues to total dioxins and furans. Analytes HPCDD=1,2,3,4,6,7,8-HpCDD; HXCDD6=1,2,3,6,7,8-HxCDD; PECDD=1,2,3,7,8-PeCDD; PECDF4=2,3,4,7,8-PeCDF; TCDD=2,3,7,8-TCDD; OCDD=OCDD.



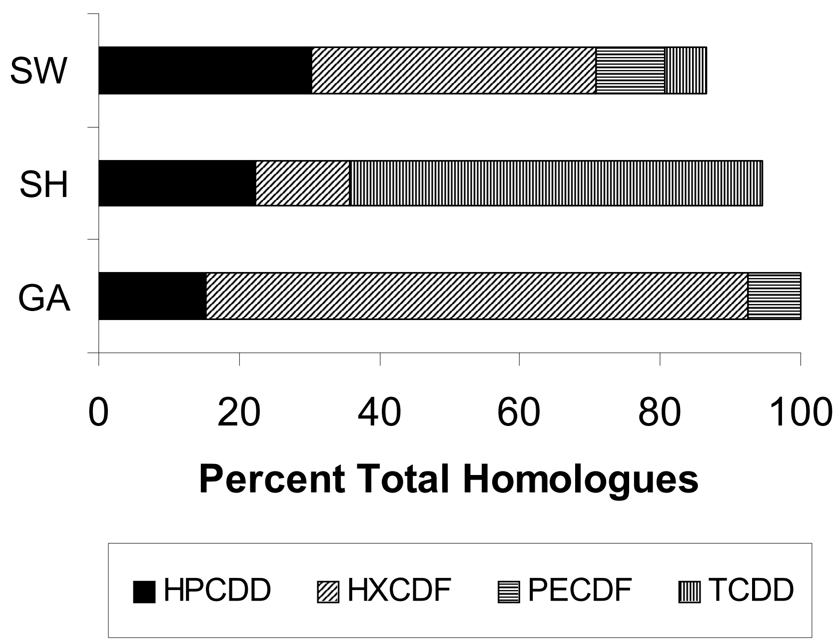


Figure 9.2. Comparison of dioxin and furan analytes and homologue groups in plasma of Double-crested Cormorant from different colonies in coastal New York, 1999. Shown are the percent contributions of individual analytes and homologues to total dioxins and furans. Analytes HPCDD=1,2,3,4,6,7,8-HpCDD; HXCDD6=1,2,3,6,7,8-HxCDD; HXCDF4=2,3,4,6,7,8-HxCDF; TCDD=2,3,7,8-TCDD; OCDD=OCDD.

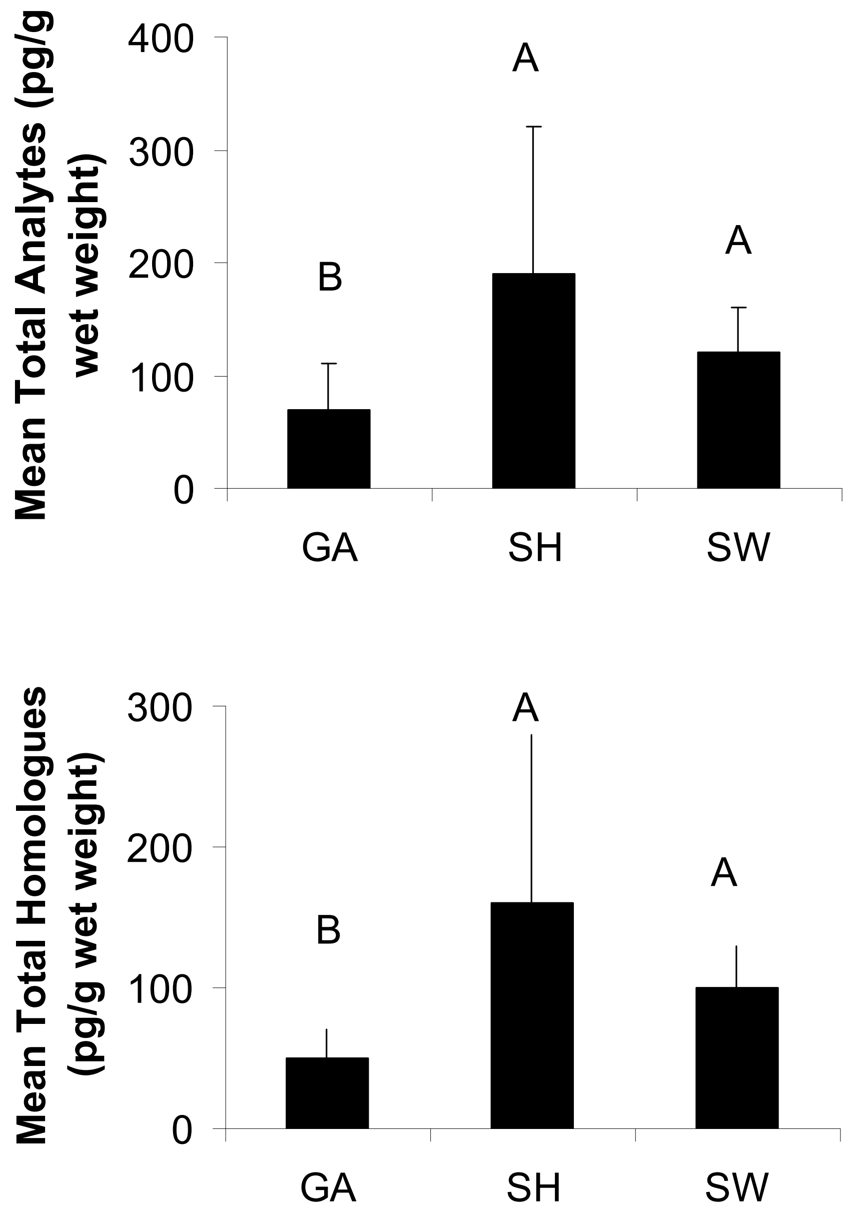


Figure 9.3. Comparison of total dioxin and furan analytes and homologue groups in eggs of Double-crested Cormorant from different colonies in coastal New York, 1999. Shown are mean + standard deviation concentration (ng/g wet weight) total analytes and homologues detected in eggs from Gardiner's Island (GA), Shooters Island (SH), and Swinburne Island (SW). Unlike letters indicate colony differences.

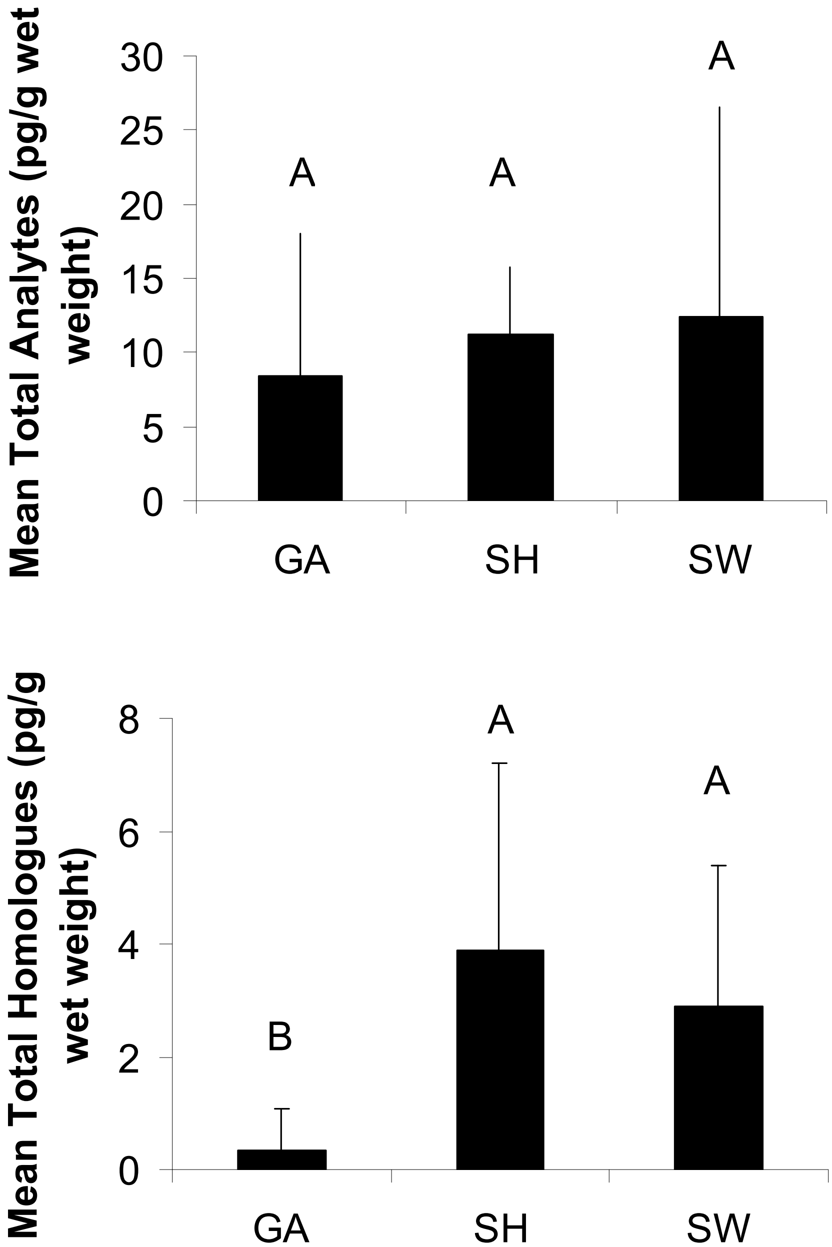


Figure 9.4. Comparison of total dioxin and furan analytes and homologue groups in plasma of Double-crested Cormorant from different colonies in coastal New York, 1999. Shown are mean + standard deviation concentration (ng/g wet weight) total analytes and homologues detected in plasma from Gardiner's Island (GA), Shooters Island (SH), and Swinburne Island (SW). Unlike letters indicate colony differences.