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Data Report on a Reconnaissance-level Assessment for Avian Injury in Commencement Bay

Commencement Bay, Washington

Prepared for
The Commencement Bay Natural Resource Trustees

U.S. Fish and Wildlife Service
Western Washington Office
510 Desmond Drive SE, Suite 102
Lacey, WA 98503-1273

Data Report on a Reconnaissance-level Assessment for Avian Injury in Commencement Bay

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By

Jeffrey D. Krausmann, U.S. Fish and Wildlife Service

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Western Washington Office
510 Desmond Drive SE, Suite 102
Lacey, WA 98503-1263

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Jeff Krausmann
U.S. Fish and Wildlife Service
Western Washington Office
510 Desmond Drive, S.E. Suite 102
Lacey, Washington 98508-1263
(360) 753-6053/9440

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Executive Summary

In 1995, the U.S. Fish and Wildlife Service (FWS) initiated an investigation in association with an ongoing natural resource damage assessment (NRDA) to preliminarily assess the potential for injury to bird species exposed to contaminants in the Commencement Bay area. The purpose of this report is to provide the co-trustees of the damage assessment with a summary of the reconnaissance-level assessment and its major findings.

From June 1995 to May 1997, the FWS: (1) collected and analyzed eggs from four species of birds known to reside, feed, and nest in the Commencement Bay environment; (2) collected additional contaminant exposure information from surf scoters as they began and ended their wintering residence in Commencement Bay; and (3) observed the feeding behavior of great blue herons (i.e. forage site selection) at the Dumas Bay and Hylebos colonies.

The major findings of this preliminary assessment are:

1. Total TCDD Toxic Equivalency Quotients (TEQs) in the eggs of the Canada goose, glaucous-winged gull, great blue heron and mallard duck collected in Commencement Bay ranged from 6.57 ppt to 598 ppt. Mallard and heron eggs scored the highest TEQ values overall with polychlorinated biphenyls (PCBs) being the greatest contributor in the TEQ value for all species analyzed except Canada goose.

2. DDE and metal residues detected in the eggs of the four species analyzed were not above critical values associated with mortality or impaired reproductive success.

3. Mean concentrations of mercury (measured in liver and kidneys) and chromium (measured in liver) were significantly higher in surf scoters collected in the late winter sample group than the fall sample group.

4. Observations recording arrival and departure data from the Dumas Bay and Hylebos Waterway great blue heron colonies indicated that nearly one-half of the birds in each colony were selecting forage sites located in or near the industrial waterways of Commencement Bay.

5. Levels of productivity from the Dumas Bay great blue heron colony continue to be consistently below that which would be necessary for the colony to maintain itself.

Acknowledgments/Contributors

Avian Egg Collection and Analysis

Anne Hawthorne, Bill Sullivan, Tim Brown, Jeff Momot, Linda Ellingesen, Dave McEntee, John and Myrtice Thompson

Puyallup Tribe of Indians
Tacoma Kraft Company
Frontier Tree Service

Surf Scoter Collection and Analysis

Mary Mahaffy, David Nysewander, Camille Bennett, Wendy Parson, Jeff Foster, Doug Frederick, Rich Car/son, Cindy Shaffer, Shannon Dwyer, Jeff Momot, Chandra Madrona, Diane Howard, Constance Leonard, Briggs Hall, Tim Lawson, Darlene Deghetto, Brian Bogaczyk, Jeff Dillion, Craig Hansen, Don Krage, Kevin Maurice, John Grettenberger, Gene Stagner, Joy Evered, Ray Brunson, Jan White, Gary Shugart, Molly Hukari, Judy Lantor, Gwill Ging, Fred Seavy, Maggie Dutch, Mark Melancon, Jan White, Marty Wolfe, Peggy Krahn, Rich Comstock, Chris Patterson, Carol Langston, Tim Young, Joe Evenson, Vickie Richardson, John Armstrong, Kate Benkert, Scott Redmond, and Denise Baker

Progressive Animal Welfare Society
Pierce College Veterinary School
Point Defiance **Zoo**
Tacoma Parks Department
ASARCO
Vashon Island Landowners
Slater Museum of Puget Sound
U. S. Environmental Protection Agency

Great Blue Heron Colony Monitoring

Don Norman, Katina Kapantais, Brenda Senturias, David Shaw, Leslie Rose, David Adams, Nick Vulgaris, Liz Marshall, John and Myritice Thompson, Steve Speich, Caroline Curey, Kimberly Stewart, and Carol Langston

Chinook Marina
Puyallup Tribe of Indians
City of Federal Way Depattment of Community Development
Dumas Bay Landowners

Document Review

Denise Baker, Jay Davis, Lisa Williams, Roger Helm, and Don Steffeck

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List of Abbreviations

AHH	Aryl Hydrocarbon Hydroxylase
DO1	Department of the Interior
MFO	Mixed-Function Oxygenase
NPL	National Priorities List
NRDA	Natural Resource Damage Assessment
PCB	Polychlorinated Biphenyl
PSAMP	Puget Sound Ambient Monitoring Program
TCDD-Eq.	Tetrachlorodibenzodioxin Equivalent (=TEQ)
TEF	Toxic Equivalency Factor
TEQ	Toxic Equivalent (=TCDD-Eq.)

1.0 Introduction

1.1 Background

As part of an ongoing Natural Resource Damage Assessment (NRDA) in Commencement Bay, Washington, the U.S. Fish and Wildlife Service (FWS) was tasked with the responsibility to assess injury specific to avian species potentially exposed to contaminants present in the Commencement Bay area.

A Preliminary Natural Resource Survey performed by the FWS in March 1984 stated there was a high probability that waterfowl, shorebirds, fishes and a federally-classified threatened species (bald eagle) may be affected by releases in Commencement Bay (U.S. Department of the Interior 1984, U.S. Fish and Wildlife Service 1984). In 1991, the Commencement Bay Natural Resource Trustees' (Trustees) performed a Preassessment Screen which concluded that available data support the conclusion that contaminants have adversely affected natural resources in the Commencement Bay environment and a damage assessment may be undertaken at a reasonable cost (The Natural Resource Trustees 1991).

1.2 Location

Listed on the National Priority List (NPL) in 1981, the *Commencement Bay Nearshore/Tideflats Superfund Site* (Site), located near Tacoma, Pierce County, Washington, consists of approximately 15 square miles of estuarine habitat, industrial waterways, and uplands **(Figure 1).** Industrialized development in the estuary began in the 1920's and has included many activities including: shipping, pulp and paper production, oil and chemical production, railroad operations, and metal smelting. These activities have resulted in the acute and chronic release of numerous hazardous substances over time. Environmental contaminants released at the Site include chlorinated organic compounds, aromatic hydrocarbons, trace metals, dioxins, furans, and phenols. Concentrations 100 to 1,000 times reference conditions were measured for 28 contaminants or contaminant groups (Tetra Tech 1985).

1.3 Summary of Impacts

Documented adverse impacts from the contaminants include depressed or altered benthic organism populations, high mortality rates in benthic microfauna and macrofauna, tumors, growth and reproductive impacts in fish, elevated levels of contaminants in fish and shellfish resulting in human consumption advisories, and toxic sediment conditions as demonstrated in laboratory bioassays. Studies conducted on fish, crab, and shrimp in

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'U.S. Department of the Interior: Fish and Wildlife Service and Bureau of Indian Affairs; U.S. Department of Commerce: National Oceanic and Atmospheric Administration; State of Washington: Departments of Ecology, Fish and Wildlife, and Natural Resources; Muckleshoot Indian Tribe; and Puyallup Tribe of Indians.

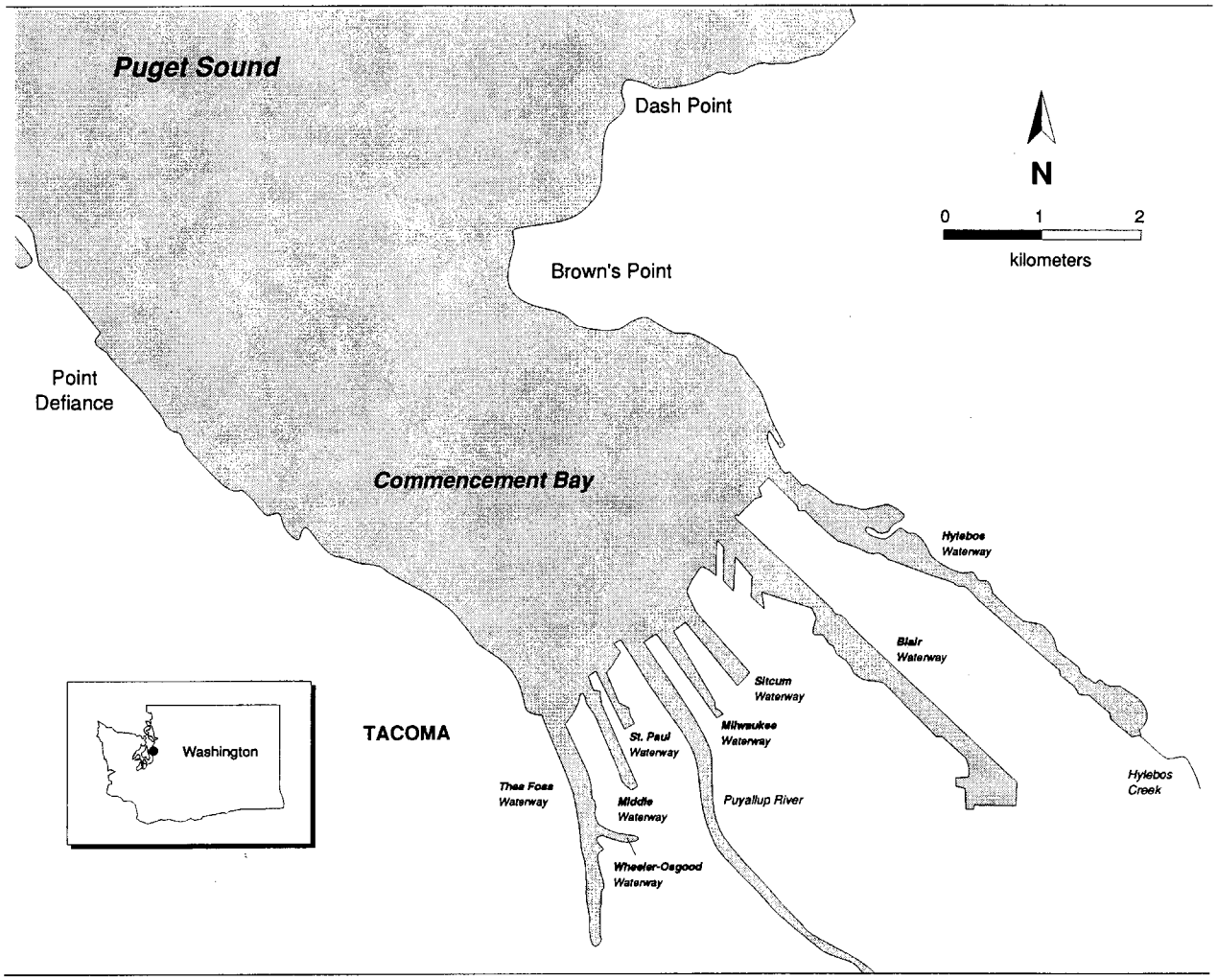

Figure 1. Map of the Commencement Bay Nearshore/Tideflats Superfund Site and surrounding area.

Commencement Bay have revealed elevated concentrations of organics and heavy metals in muscle tissues, elevated incidences of fin erosion and tumors, and abnormal tissue damage to internal organs (Malins *et al.* 1982, 1984; Tetra Tech 1985; McCain *et al.* 1990; Varanasi *et al.* 1993; Stein *et al.* 1992, 1995).

Information regarding contaminant exposure to higher trophic levels such as birds in the Commencement Bay area is generally limited, dated, or statistically inadequate. Eggs collected from a great blue heron (*Ardea herodias*) colony near Commencement Bay in 1984 and 1988 indicated that exposure to polychlorinated biphenyls (PCBs) had occurred and at concentration levels known to cause reproductive failure (e.g. egg lethality, embryonic deformities) in several waterfowl species (Speich et. al. 1992; Block 1992; Giesy et. al. 1994). The results of a productivity study funded and directed by the Trustees in 1994 suggested that this particular heron colony also exhibited lower productivity than other regionally

located colonies (EVS Environmental Consultants 1995).

Data collected from six glaucous-winged gull *(Lams glaucescens)* colonies in 1984 indicated incidences of histopathological impairment (e.g. liver disease), traumatic lesions, and egg-shell thinning in the Commencement Bay colony (Riley *et al.* 1983; Calambokidis et *al.* 1985; Speich et *al.* 1992). Analysis of western grebes (*Aechmophorus occidentalis*) and surf scoters (*Melanitta perspicillata*) in Commencement Bay indicated that significant amounts of PCBs, organochlorines and metals were being accumulated by the overwintering birds during 1985-1986 (Henny *et al.* 1990, 1991).

1.4 Study Objectives

To preliminarily assess injury to avian species residing in or utilizing the Commencement Bay area, the FWS designed and implemented a three-pronged reconnaissance assessment and approach designed to address and update our current knowledge of the extent, severity, and trend of contaminant exposure to birds from hazardous substances released into the Commencement Bay environment. The three components of the assessment are divided into separate overview sections in the report:

Avian Egg Collection and Analysis - Determine contaminant concentrations in the eggs of several different avian species known to reside, feed and nest in the Commencement Bay environment.

Surf Scoter Collection and Analysis - Utilize and expand upon an existing contaminant monitoring program (the Puget Sound Ambient Monitoring Program) and collect additional contaminant exposure information from surf scoters as they begin and end their wintering period in Commencement Bay.

Great Blue Heron Colony Monitoring - Observe feeding behavior of great blue herons at the Dumas Bay and Hylebos colonies in Commencement Bay.

This report presents the culmination of iterative steps taken between June 1995 and May 1997 investigating the potential for avian injury in Commencement Bay.

A2.0 Methods

To better understand the extent of chemical exposure, eggs were selected from birds with different feeding strategies and food preferences in Commencement Bay. Egg residues in general are a preferred medium to analyze for contaminants because of their high potential to biomagnify and accumulate specific chemicals known to cause injury.

A list of birds was generated from known observation data generated in part by Christmas Bird Count data and Appendix A from the Commencement Bay Programmatic Environmental Impact Statement Volume 1 (Commencement Bay Natural Resources Trustees 1997). Four species from this list were then selected based on: 1) whether or not the bird was known to nest in or near the Commencement Bay Site; 2) the likelihood of readily obtaining the egg samples; and 3) residence time and general abundance **(Table 1).** The four species selected were: Canada goose (*Branta canadensis);* glaucous-winged gull *(Lams glaucescens);* mallard duck (*Anas platyrhynchos*); and great blue heron (*Ardea herodias*).

A2.1 Collection

Collection took place during the Spring of 1995 and 1996. One egg was randomly collected from each nest of the four species. When possible, nests with three or more eggs visible were selected for collection. Four eggs were collected from the nests of Canada geese near the Hylebos and Blair Waterways and from glaucous-winged gull nests located on the roof of the Simpson Tacoma Kraft Mill in 1995. In 1996, five eggs were collected from nests of the great blue heron colony in Dumas Bay and 2 eggs were obtained from mallard nests located in between the Hylebos and Blair Waterways **(Figure 2).** The original intent of collecting five eggs from each species could only be accomplished for the great blue heron **(Table 2).** Searches for nesting duck species in the Commencement Bay area proved to be time-intensive and problematic.

A2.2 Processing

The contents of each egg collected in 1995 (goose and gull) were removed on site and placed (blown) into chemically clean I-CHEM® jars. Samples were placed in a cooler with cold packs and then frozen prior to shipment for analysis. Eggs collected in 1996 (heron and mallard) were collected and stored in paper cartons on cold packs until storage in a refrigerator. The eggs were then wrapped in nanograde acetone rinsed aluminum foil and transferred to another refrigerator prior to arrival to the lab facilities at the FWS Western Washington Office in Olympia. These eggs were then processed using procedures consistent with FWS Standard Operating Procedure (SOP) for avian egg harvesting and residue analysis (U.S. Fish and Wildlife Service 1990). Recorded information included: general condition, whole egg weight, length, width, volume, content weight, and shell

Species	Status	Food Habits	Observations (mean counts)
Western Grebe	Winter Resident	piscivore	6(235)
Mew Gull	Winter Resident	omnivore	6(207)
Northern Pintail	Winter Resident, Migrant	herbivore, benthivore	6(121)
> ***Glaucous-winged Gull***	***Resident, Breeding***	***piscivore, omnivore***	***5(83)***
Green-winged Teal	Winter Resident, Migrant	herbivore, benthivore	6(74)
Dunlin	Winter Resident, Migrant	insectivore, benthivore	4(69)
> ***Great Blue Heron***	***Resident, Breeding***	***piscivore, omnivore***	***6(64)***
American Coot	Resident	herbivore, omnivore	6(46)
> ***Mallard***	***Resident, Breeding***	***herbivore, benthivore***	***6(46)***
Barrows Goldeneye	Resident, Migrant	benthivore	6(29)
American Wigeon	Winter Resident, Migrant	herbivore, benthivore	6(27)
Greater Scaup	Winter Resident, Migrant	benthivore	5(26)
Western Sandpiper	Migrant	insectivore, benthivore	2(21)
Black Turnstone	Migrant	benthivore	5(11)
Red-breasted Merganser	Winter Resident, Migrant	piscivore, benthivore	6(9)
Double-crested Cormorant	Winter Resident	piscivore	4(9)
Northern Shoveler	Winter Resident	herbivore, benthivore	6(8)
> ***Canada Goose***	***Resident, Breeding***	***herbivore, benthivore***	***4(8)***
Killdeer	Resident, Breeding	insectivore, benthivore	2(6)
Least Sandpiper	Migrant	benthivore, insectivore	3(5)
Surf Scoter	Winter Resident, Migrant	benthivore	6(5)
Horned Grebe	Winter Resident	piscivore, benthivore	6(5)
Common Goldeneye	Winter Resident, Migrant	benthivore	6(5)

Table 1. Compiled bird list and selected species (>) for 1995 and 1996 egg collection in Commencement Bay using Hylebos Waterway Christmas Bird Count Data, 1977-1982.

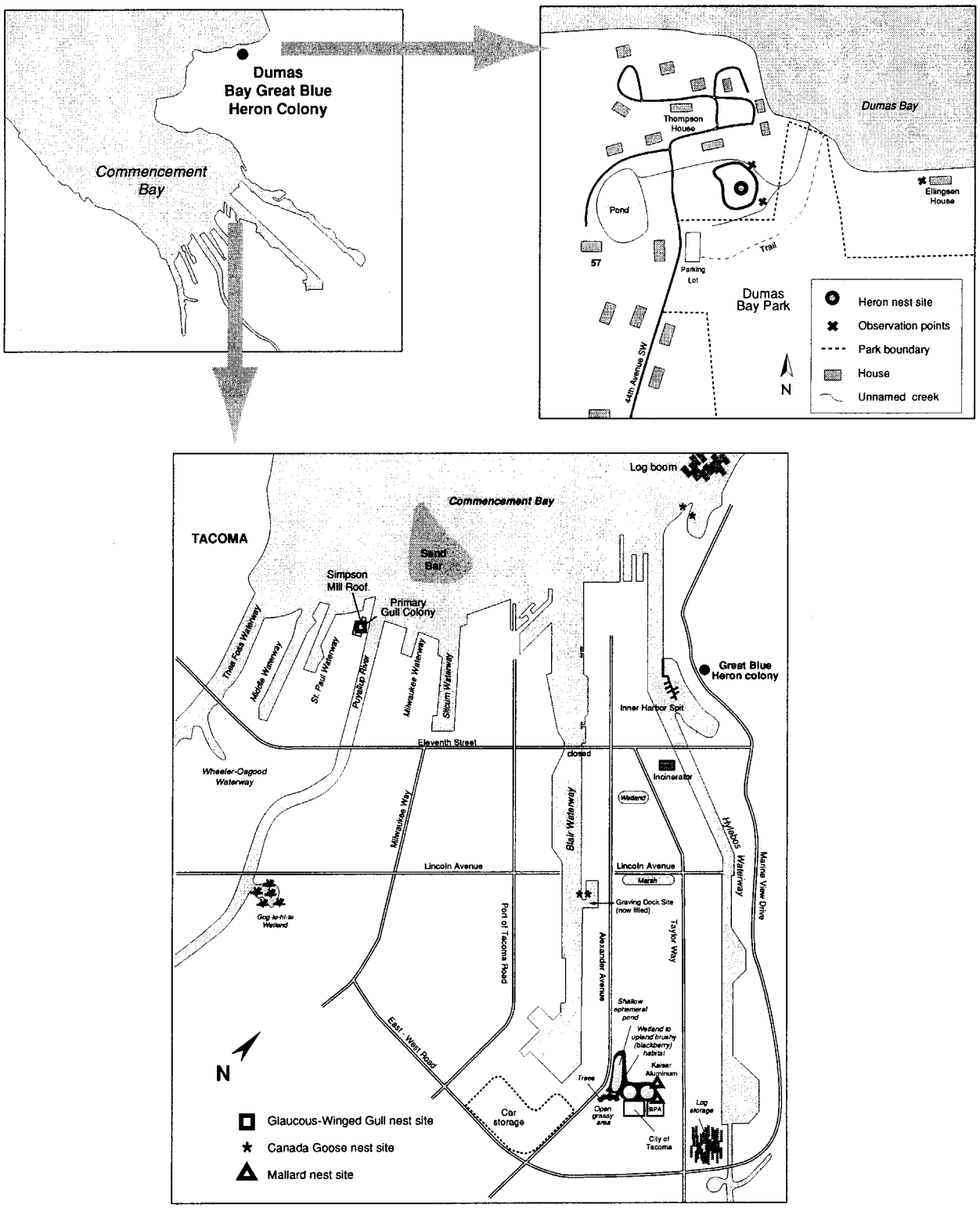

Figure 2. Map of egg collection locations in Commencement Bay in 1995 and 1996.

Sample ID	# in Nest	Species	Date Collected	Location	Method
HBS-1	1 of 7	Canada Goose	07apr95	Inner Hylebos Spit	Blown
HBS-2	1 of 5	Canada Goose	07apr95	Inner Hylebos Spit	Blown
BGD-1	1 of 6	Canada Goose	07apr95	Blair Graving Dock	Blown
BGD-2	1 of 5	Canada Goose	07apr95	Blair Graving Dock	Blown
SIM-1	1 of 3	Glaucous-winged Gull	05may95	Simpson Mill Roof	Blown
SIM-2	1 of 2	Glaucous-winged Gull	05may95	Simpson Mill Roof	Blown
SIM-3	1 of 1	Glaucous-winged Gull	05may95	Simpson Mill Roof	Blown
SIM-4	1 of 1	Glaucous-winged Gull	05may95	Simpson Mill Roof	Blown
GBH96-1	1of 2	Great Blue Heron	08apr96	Dumas Bay	USFWS SOP
GBH96-2	1 of 5	Great Blue Heron	08apr96	Dumas Bay	USFWS SOP
GBH96-3	1 of 1	Great Blue Heron	08apr96	Dumas Bay	USFWS SOP
GBH96-4	1 of 3	Great Blue Heron	08apr96	Dumas Bay	USFWS SOP
GBH96-5	1 of 5	Great Blue Heron	08apr96	Dumas Bay	USFWS SOP
MAL96-1	1 of 8	Mallard	01may96	Kaiser/BPA	USFWS SOP
MAL96-2	1 of 9	Mallard	06may96	Kaiser/BPA	USFWS SOP

Table 2. Summary information on eggs collected in 1995 and 1996 in Commencement Bay.

weight (**Appendix A**). Egg contents were then placed in chemically clean I-CHEM® jars and frozen prior to shipment for analysis. All standard chain-of-custody procedures were followed for both sets of samples.

A2.3 Lab Methodology and Analysis

Analysis of egg residues was conducted by Alta Analytical Laboratory Inc. of El Dorado Hills, California. Samples were analyzed using EPA Method 8290 for tetra- to octa-chlorinated dioxins/dibenzofurans and modified EPA Method 680 for polychlorinated biphenyls (PCBs). Additional analysis for organics and inorganics was carried out by ToxScan, Inc. of Watsonville, California. **Table 3** lists the compounds or elements analyzed and the analytical methodology followed for each.

Analyte	Methodology	Lab
Dioxins/Furans	EPA Method 8290	Alta Analytical
PCBs	EPA modified Method 680	Alta Analytical
Antimony	EPA Method 7041	ToxScan
Arsenic	EPA Method 7060	ToxScan
Cadmium	EPA Method 7131	ToxScan
Chromium	EPA Method 7191	ToxScan
Copper	EPA Method 7211	ToxScan
Lead	EPA Method 7421	ToxScan
Mercury	EPA Method 7470	ToxScan
Nickel	EPA Method 7521	ToxScan
Selenium	EPA Method 7741	ToxScan
Silver	EPA Method 7761	ToxScan
Chlorinated pesticides	EPA Method 8080	ToxScan
Chlorinated herbicides	EPA Method 8150	ToxScan
Semivolatile organic compounds	EPA Method 8270	ToxScan
Butyltins	Gas Chromatograph with Flame Photometric Detector	ToxScan

Table 3. Methodologies used by contracted labs for analyzing constituents in avian eggs collected in Commencement Bay in 1995 and 1996.

To determine the overall dioxin-like potency of planar chlorinated compounds in the egg tissue, congener-specific analysis was requested for dibenzodioxins, dibenzofurans and biphenyl compounds (McFarland *et al.* 1989). Dioxin toxic equivalents (TEQs) in each of the samples were calculated by normalizing concentrations of individual dioxin-like compounds relative to the potency of TCDD using toxic equivalency factors (TEFs) as proposed by Safe (1990) and Ahlborg *et al.* (1992, 1994) with modifications by Van den Berg *et al.* (1998). Specifically, the Van den Berg derivation of TEFs specific to avian species follows a tiered approach that gives higher weight to overt toxicity *in vivo* studies than to biochemical effects such as enzyme induction *in vitro* (Van Leeuwen 1997). These TEF values were recently applied by the FWS in evaluating productivity and contaminant levels in bald eagles of the lower Columbia River (Buck 1998). Comparisons were made between I-TEF values (based on mammalian endpoints), H4IIE - TEF values (bioassay endpoints) and TEF values proposed for birds (aka. C-TEFs or WHO avian TEFs). For the purposes of this assessment, all TEQ calculations were derived from using these avian specific TEFs (**Table 4**).

Dibenzodioxin	TEF	Dibenzofuran	TEF	Biphenyl (IUPAC #)	TEF
2,3,7,8-TCDD	1	2,3,7,8-TCDF	1	3,3',4,4'-TeCB (77)	0.05
1,2,3,7,8-PeCDD	1	1,2,3,7,8-PeCDF	0.1	3,4,4',5-TeCB (81)	0.1
1,2,3,4,7,8-HxCDD	0.05	2,3,4,7,8-PeCDF	1	2,3,3',4,4'-PeCB (105)	0.0001
1,2,3,6,7,8-HxCDD	0.01	1,2,3,4,7,8-HxCDF	0.1	2,3,4,4',5-PeCB (114)	0.0001
1,2,3,7,8,9-HxCDD	0.1	1,2,3,6,7,8-HxCDF	0.1	2,3',4,4',5-PeCB (118)	0.00001
1,2,3,4,6,7,8-HpCDD	0.001	2,3,4,6,7,8-HxCDF	0.1	2',3,4,4',5-PeCB (123)	0.00001
		1,2,3,7,8,9-HxCDF	0.1	3,3',4,4',5-PeCB (126)	0.1
		1,2,3,4,6,7,8-HpCDF	0.01	2,3,3',4,4',5-HxCB (156)	0.0001
		1,2,3,4,7,8,9-HpCDF	0.01	2,3,3',4,4',5'-HxCB (157)	0.0001
		OCDF	0.0001	2,3',4,4',5,5'-HxCB (167)	0.0001
				3,3',4,4',5,5'-HxCB (169)	0.001
				2,3,3',4,4',5,5'-HpCB (189)	0.00001

Table 4. Avian toxic equivalency factors (TEFs) used to calculate TCDD-equivalents in avian egg tissues collected in Commencement Bay in 1995 and 1996.

Each sample concentration for planar chlorinated compounds was multiplied by its corresponding TEF value and then summed. The resulting TEQ value represents a single value for determining dioxin-like potency. Percent contribution from dibenzodioxin, dibenzofuran, and biphenyl compounds were then determined for each sample.

Residue values for each egg were not adjusted for moisture loss and lipid content and therefore all values are reported as wet weight. All trace metal and butyltin values are reported in dry weight. Heron and mallard egg samples collected in 1996 were measured for volume by means of whole egg displacement with egg content calculated from length and width measurements (Stickel *et al.* 1973). Field measurements were unavailable for goose or gull egg samples collected in 1995. Lab generated percent moisture values were unavailable for heron and mallard samples. Correction factors for conversion to fresh weight are presented in **Table 11**. Since these values were not all available for each species, no attempt was made to adjust analytical results accordingly. This was decided due to the screening nature of the analysis and to maintain a species-to-species comparability for all analytes tested.

EcoChem, Inc. of Seattle, Washington reviewed the data packages provided by the analytical laboratories and provided a validation report to the FWS (**Appendix B**). Upon their recommendations, unqualified data was treated as not detected and reported as half the detection value for computational purposes. Non-detect values are calculated as half the detection limit for TEQ computational purposes only. This approach was applied to all dibenzodioxin, dibenzofuran, and biphenyl data. For the remaining contaminants, not-detected values are reported as the detection limit for that constituent. In addition, limited sample volumes in the egg samples collected in 1996 (heron and mallard) resulted in the contract lab setting higher detection limits for trace metals, butyltins, and pesticides.

A3.0 Results

A3.1 Dibenzodioxin, Dibenzofuran, and Biphenyls

Total PCB data is summarized per species in **Table 5**. Congener-specific values and their corresponding TEF value for dibenzodioxin, dibenzofuran, and non ortho- and mono ortho-chlorinated biphenyls (PCBs) are reported in **Table 6** and **Table 7**. With the exception of PCB 118[2], no mono ortho-chlorinated biphenyl data were reported for eggs collected in 1995 (goose and gull). Since total TEQs were determined by summing the individual TEQs from all three groups of planar chlorinated compounds, including the non ortho- and mono ortho-chlorinated biphenyls, reported total TEQ values for goose and gull may be underestimated.

Avian Species (n)	*Geometric Mean (Range) ng/g wet weight*
Canada Goose (4)	32.80 (21.63 - 80.10)
Glaucous-winged Gull (4)	760.45 (452.65 - 1575.38)
Great Blue Heron (5)	1971.65 (509.74 - 6462.65)
Mallard Duck (2)	399.10 (397.82 - 400.39)

Table 5. Total PCBs in ng/g (ppb) wet weight in avian egg tissues collected in Commencement Bay in 1995 and 1996.

Tables 6 and **7** present congener specific values in pg/g (ppt) wet weight and their corresponding TCDD-Eq. value for each species. Because of the small sample sizes, means were calculated geometrically with the range of values. In an attempt to tease out forage preference and/or congener assimilation differences between species, values were plotted graphically for each congener for dibenzodioxins, dibenzofurans, and biphenyls. Congeners with corresponding tissue levels and TEF/TEQ values are illustrated in **Figures 3 - 6**. Other congener data (congeners not currently assigned a TEF) are available but not included for the purposes of this report.

Looking solely at dibenzodioxin congener concentrations most species compared relatively equal (**Figure 3**). One exception appeared to be with OCDD and gulls. However, because of blank contamination problems with OCDD in the lab analysis and a lack of data on avian toxicity related to this congener, no further investigation was pursued. Comparing dibenzofuran congener concentrations between species appears to show mallard eggs containing the higher levels of most of the dibenzofuran congeners (**Figure 4**). One exception may be with 2,3,4,7,8 -PeCDF in heron, where at least one heron egg scored

[2]Union of Pure and Applied Chemists congener number (Ballschmiter and Zell 1980).

Contaminant	Avian TEF	Canada Goose n=4		Glaucous-winged Gull n=4	
		Geo. Mean (Range) *pg/g wet weight*	*TEQ Mean (Range)* *pg/g wet weight*	*Geo. Mean (Range)* *pg/g wet weight*	*TEQ Mean (Range)* *pg/g wet weight*
Dibenzodioxins					
2,3,7,8-TCDD	1	0.29 (0.12 - 0.50)[1]	0.29 (0.12 - 0.50)[1]	0.58 (0.18 - 1.40)[1]	0.58 (0.18 - 1.40)[1]
1,2,3,7,8-PeCDD	1	1.96 (1.40 - 3.10)	1.96 (1.40 - 3.10)	1.17 (0.53 - 2.30)[3]	1.17 (0.53 - 2.30)[3]
1,2,3,4,7,8-HxCDD	0.05	1.53 (0.90 - 2.20)	0.08 (0.05 - 0.11)	0.24 (0.20 - 0.32)[1]	0.01 (<0.01 - 0.01)[1]
1,2,3,6,7,8-HxCDD	0.01	5.33 (3.20 - 7.20)	0.05 (0.03 - 0.07)	5.52 (2.20 - 14.00)	0.06 (0.02 - 0.14)
1,2,3,7,8,9-HxCDD	0.1	1.42 (0.78 - 1.90)	0.14 (0.08 - 0.19)	0.45 (0.16 - 1.30)[1,3]	0.04 (0.01 - 0.13)[1,3]
1,2,3,4,6,7,8-HpCDD	<0.001	7.83 (5.20 - 14.00)	<0.01 (<0.01 - <0.01)	5.48 (2.30 - 22.00)	<0.01 (<0.01 - 0.02)
OCDD	N/A	9.43 (2.20 - 36.00)[2]	N/A	8.08 (2.25 - 78.00)[2]	N/A
Dibenzofurans					
2,3,7,8-TCDF	1	1.36 (0.90 - 2.80)	1.36 (0.90 - 2.80)	0.13 (0.10 - 0.26)[1]	0.13 (0.10 - 0.26)[1]
1,2,3,7,8-PeCDF	0.1	0.90 (0.52 - 1.50)[3]	0.09 (0.05 - 0.15)[3]	0.12 (0.08 - 0.21)[1]	0.01 (<0.01 - 0.02)[1]
2,3,4,7,8-PeCDF	1	1.10 (0.58 - 2.60)[3]	1.10 (0.58 - 2.60)[3]	0.59 (0.20 - 1.10)[1,3]	0.59 (0.20 - 1.10)[1,3]
1,2,3,4,7,8-HxCDF	0.1	1.03 (0.50 - 1.80)[3]	0.10 (0.05 - 0.18)[3]	0.52 (0.27 - 1.30)[1,3]	0.05 (0.03 - 0.13)[1,3]
1,2,3,6,7,8-HxCDF	0.1	0.47 (0.22 - 0.76)[3]	0.05 (0.02 - 0.08)[3]	1.12 (0.70 - 1.70)[1,4]	0.11 (0.07 - 0.17)[1,4]
2,3,4,6,7,8-HxCDF	0.1	0.60 (0.38 - 0.72)[3]	0.06 (0.04 - 0.07)[3]	0.38 (0.28 - 0.71)[1,3]	0.04 (0.02 - 0.07)[1,3]
1,2,3,7,8,9-HxCDF	0.1	0.05 (0.02 - 0.09)[1]	<0.01 (<0.01 - <0.01)[1]	0.09 (0.04 - 0.30)[1]	<0.01 (<0.01 - 0.03)[1]
1,2,3,4,6,7,8-HpCDF	0.01	0.80 (0.34 - 1.10)[3]	<0.01 (<0.01 - <0.01)[3]	0.43 (0.20 - 1.80)[1]	<0.01 (<0.01 - 0.01)[1]
1,2,3,4,7,8,9-HpCDF	0.01	0.07 (0.02 - 0.14)[1,3,4]	<0.01 (<0.01 - <0.01)[1,3,4]	0.12 (0.07 - 0.26)[1]	<0.01 (<0.01 - <0.01)[1]
OCDF	0.0001	0.39 (0.32 - 0.49)[1,2,3,4]	<0.01 (<0.01 - <0.01)[1,2,3,4]	0.42 (0.38 - 0.55)[2]	<0.01 (<0.01 - <0.01)[2]
Non ortho-chlorinated Biphenyls					
3,4,4',5-TeCB (81)	0.1	2.66 (1.70 - 3.50)[1]	<0.01 (<0.01 - <0.01)[1]	112.28 (58.00 - 210.00)	11.23 (5.80 - 21.00)
3,3',4,4'-TeCB (77)	0.05	52.71 (38.00 - 82.00)	2.64 (1.90 - 4.10)	32.09 (4.95 - 170.00)[1]	1.61 (0.25 - 8.50)[1]
3,3',4,4',5-PeCB (126)	0.1	7.52 (3.00 - 33.00)[1]	<0.01 (<0.01 - 3.30)[1]	88.32 (39.00 - 160.00)	8.83 (3.90 - 16.00)
3,3',4,4',5,5'-HxCB (169)	0.001	6.61 (5.00 - 8.50)[1]	<0.01 (<0.01 - <0.01)[1]	12.60 (8.50 - 19.50)[1]	0.01 (0.01 - 0.02)[1]
Mono ortho-chlorinated Biphenyls					
2,3,3',4,4'-PeCB (105)	0.0001	N/A	N/A	N/A	N/A
2,3,4,4',5-PeCB (114)	0.0001	N/A	N/A	N/A	N/A
2,3',4,4',5-PeCB (118)	0.00001	1101.60 (120.00 - 5900.00)	0.01 (0.001 - 0.059)	21519.07 (11000.00 - 38000.00)	0.22 (0.11 - 0.38)
2',3,4,4',5-PeCB (123)	0.00001	N/A	N/A	N/A	N/A
2,3,3',4,4',5-HxCB (156)	0.0001	N/A	N/A	N/A	N/A
2,3,3',4,4',5'-HxCB (157)	0.0001	N/A	N/A	N/A	N/A
2,3',4,4',5,5'-HxCB (167)	0.0001	N/A	N/A	N/A	N/A
2,3,3',4,4',5,5'-HpCB (189)	0.00001	N/A	N/A	N/A	N/A

Table 6. Congener specific mean and range values in pg/g (ppt) wet weight and corresponding TEF/TEQ values for Canada goose and glaucous-winged gull eggs collected in Commencement Bay in 1995.

[1]Detection Limit for some or all of the values. Value reported as ½ detection limit.

[2]Compound detected in the blank for some or all of the values. Value reported as ½ detection limit

[3]The amount detected is below the method calibration limit for some or all of the values.

[4]The amount reported is the maximum possible concentration for some or all of the values.

N/A = not available

Contaminant	Avian TEF	Great Blue Heron n=5		Mallard Duck n=2	
		Geo. Mean (Range) pg/g wet weight	*TEQ Mean (Range)* pg/g wet weight	*Geo. Mean (Range)* pg/g wet weight	*TEQ Mean (Range)* pg/g wet weight
Dibenzodioxins					
2,3,7,8-TCDD	1	3.54 (2.40 - 4.60)	3.54 (2.40 - 4.60)	3.00 (3.00 - 3.00)	3.00 (3.00 - 3.00)
1,2,3,7,8-PeCDD	1	12.02 (5.40 - 17.00)	12.02 (5.40 - 17.00)	9.00 (8.80 - 9.20)	9.00 (8.80 - 9.20)
1,2,3,4,7,8-HxCDD	0.05	1.79 (1.40 - 2.60)	0.09 (0.07 - 0.13)	3.79 (3.60 - 4.00)	0.19 (0.18 - 0.20)
1,2,3,6,7,8-HxCDD	0.01	9.41 (5.10 - 13.00)	0.09 (0.05 - 0.13)	12.96 (12.00 - 14.00)	0.13 (0.12 - 0.14)
1,2,3,7,8,9-HxCDD	0.1	0.77 (0.28 - 1.50)[1]	0.08 (0.02 - 0.15)[1]	1.94 (1.50 - 2.50)	0.19 (0.15 - 0.25)
1,2,3,4,6,7,8-HpCDD	<0.001	6.34 (4.70 - 7.60)	<0.01 (<0.01 - <0.01)	19.60 (16.00 - 24.00)	0.02 (0.02 - 0.02)
OCDD	N/A	13.46 (5.50 - 27.00)[2]	N/A	21.49 (21.00 - 22.00)[2]	N/A
Dibenzofurans					
2,3,7,8-TCDF	1	0.70 (0.33 - 1.30)	0.70 (0.33 - 1.30)	82.58 (62.00 - 110.00)	82.58 (62.00 - 110.00)
1,2,3,7,8-PeCDF	0.1	1.20 (0.48 - 1.80)[3]	0.12 (0.04 - 0.18)[3]	31.08 (23.00 - 42.00)	3.11 (2.30 - 4.20)
2,3,4,7,8-PeCDF	1	17.59 (4.20 - 80.00)	17.59 (4.20 - 80.00)	36.52 (29.00 - 46.00)	36.52 (29.00 - 46.00)
1,2,3,4,7,8-HxCDF	0.1	2.79 (0.72 - 12.00)[3]	0.28 (0.07 - 1.20)[3]	12.30 (8.90 - 17.00)	1.23 (0.89 - 1.70)
1,2,3,6,7,8-HxCDF	0.1	4.74 (2.60 - 12.00)[4]	0.47 (0.26 - 1.20)[4]	4.41 (3.60 - 5.40)	0.44 (0.36 - 0.54)
2,3,4,6,7,8-HxCDF	0.1	0.83 (0.71 - 0.98)[3]	0.08 (0.07 - 0.09)[3]	2.25 (2.20 - 2.30)	0.22 (0.22 - 0.23)
1,2,3,7,8,9-HxCDF	0.1	0.13 (0.11 - 0.18)[1]	0.01 (0.01 - 0.02)[1]	0.53 (0.29 - 1.00)[1,3]	0.05 (0.02 - 0.10)[1,3]
1,2,3,4,6,7,8-HpCDF	0.01	1.65 (1.00 - 3.00)[3,4]	0.02 (0.01 - 0.03)[3,4]	3.33 (3.00 - 3.70)	0.03 (0.03 - 0.04)
1,2,3,4,7,8,9-HpCDF	0.01	0.29 (0.22 - 0.35)[1]	<0.01 (<0.01 - <0.01)[1]	0.30 (0.24 - 0.37)[1]	<0.01 (<0.01 - <0.01)[1]
OCDF	0.0001	0.62 (0.32 - 4.30)[1]	<0.01 (<0.01 - <0.01)[1]	7.25 (2.50 - 21.00)	<0.01 (<0.01 - <0.01)
Non ortho-chlorinated Biphenyls					
3,4,4',5-TeCB (81)	0.1	125.85 (31.00 - 970.00)[1]	12.59 (3.10 - 97.00)[1]	285.66 (240.00 - 340.00)	28.57 (24.00 - 34.00)
3,3',4,4'-TeCB (77)	0.05	174.82 (60.00 - 310.00)	8.74 (3.00 - 15.50)	5509.99 (4600.00 - 6600.00)	275.50 (230.00 - 330.00)
3,3',4,4',5-PeCB (126)	0.1	540.61 (220.00 - 1700.00)	54.06 (22.00 - 170.00)	418.21 (330.00 - 530.00)	41.82 (33.00 - 53.00)
3,3',4,4',5,5'-HxCB (169)	0.001	<1.25 (<1.25 - <1.25)[1]	<0.01 (<0.01 - <0.01)[1]	<1.25 (<1.25 - <1.25)[1]	<0.01 (<0.01 - <0.01)[1]
Mono ortho-chlorinated Biphenyls					
2,3,3',4,4'-PeCB (105)	0.0001	75,750.67 (17,000.00 - 390,000.00)	7.58 (1.70 - 39.00)	23,366.64 (21,000.00 - 26,000.00)	2.34 (2.10 - 2.60)
2,3,4,4',5-PeCB (114)	0.0001	8294.76 (1200.00 - 83,000.00)	0.83 (0.12 - 8.30)	1349.07 (1300.00 - 1400.00)	0.13 (0.13 - 0.14)
2,3',4,4',5-PeCB (118)	0.00001	364,083.71 (75,000.00 - 1,700,000.00)	3.64 (0.75 - 17.00)	78,364.53 (69,000.00 - 89,000.00)	0.78 (0.69 - 0.89)
2',3,4,4',5-PeCB (123)	0.00001	6967.64 (1200.00 - 65,000.00)	0.07 (0.01 - 0.65)	1691.15 (1300.00 - 2200.00)	0.02 (0.01 - 0.02)
2,3,3',4,4',5-HxCB (156)	0.0001	35,597.51 (9500.00 - 130,000.00)	3.56 (0.95 - 13.00)	7097.18 (6900.00 - 7300.00)	0.71 (0.69 - 0.73)
2,3,3',4,4',5'-HxCB (157)	0.0001	7822.65 (1500.00 - 38,000.00)	0.78 (0.15 - 3.80)	1843.91 (1700.00 - 2000.00)	0.18 (0.17 - 0.20)
2,3',4,4',5,5'-HxCB (167)	0.0001	54,112.78 (16,000.00 - 250,000.00)	5.41 (1.60 - 25.00)	12,000.00 (12,000.00 - 12,000.00)	1.20 (1.20 - 1.20)
2,3,3',4,4',5,5'-HpCB (189)	0.00001	2481.62 (860.00 - 6000.00)	0.02 (0.01 - 0.06)	449.00 (320.00 - 630.00)	<0.01 (<0.01 - <0.01)

Table 7. Congener specific mean and range values in pg/g (ppt) wet weight and corresponding TEF/TEQ values for great blue heron and mallard duck eggs collected in Commencement Bay in 1996.

[1]Detection Limit for some or all of the values. Value reported as ½ detection limit.

[2]Compound detected in the blank for some or all of the values. Value reported as ½ detection limit

[3]The amount detected is below the method calibration limit for some or all of the values.

[4]The amount reported is the maximum possible concentration for some or all of the values.

N/A = not available

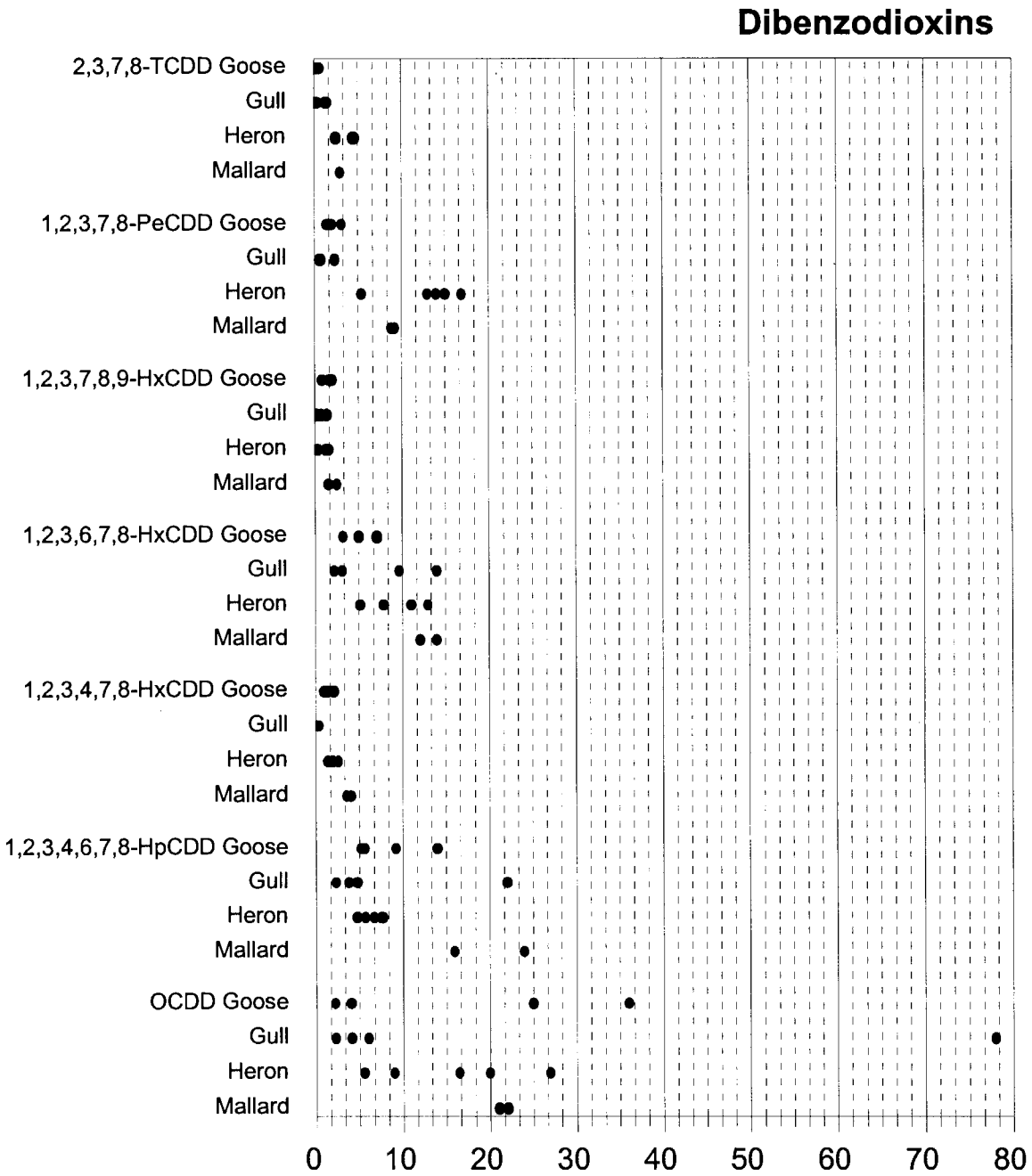

Figure 3. Congener-specific comparison between avian species for dibenzodioxins in pg/g (ppt) wet weight in egg tissues collected in Commencement Bay in 1995 and 1996.

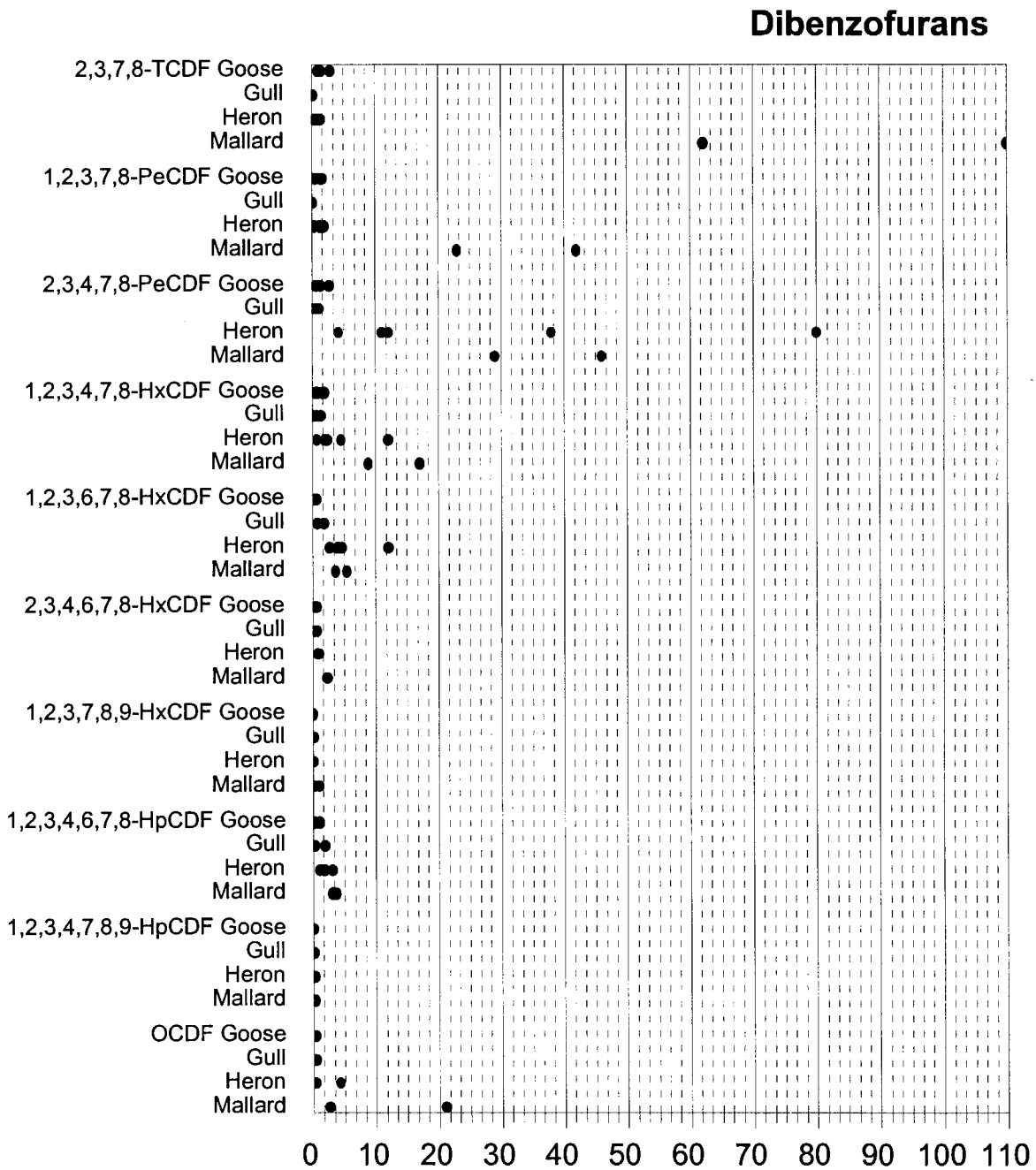

Figure 4. Congener-specific comparison between avian species for dibenzofurans in pg/g (ppt) wet weight in egg tissues collected in Commencement Bay in 1995 and 1996.

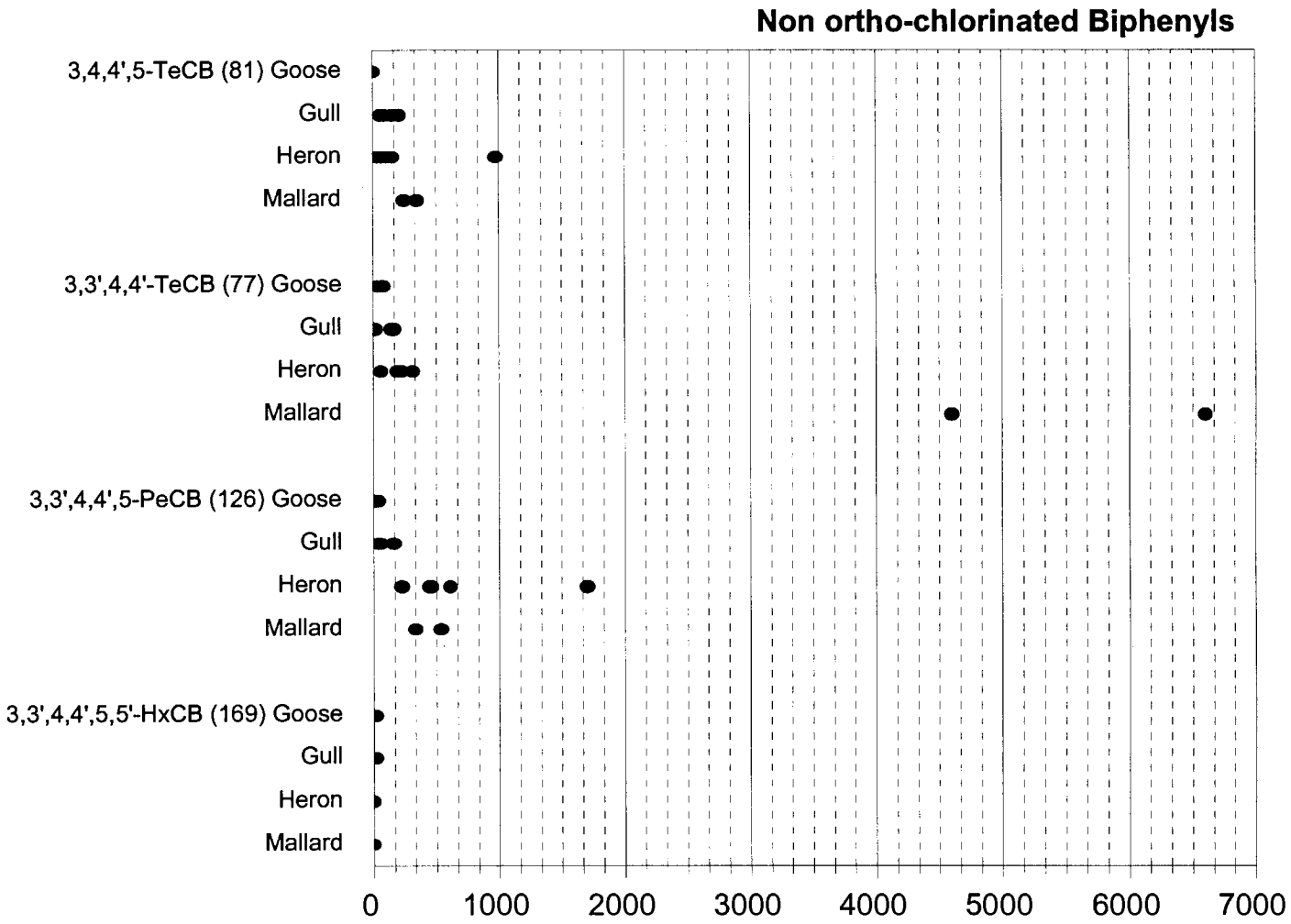

Figure 5. Congener-specific comparison between avian species for non ortho-chlorinated biphenyls in pg/g (ppt) wet weight in egg tissues collected in Commencement Bay in 1995 and 1996.

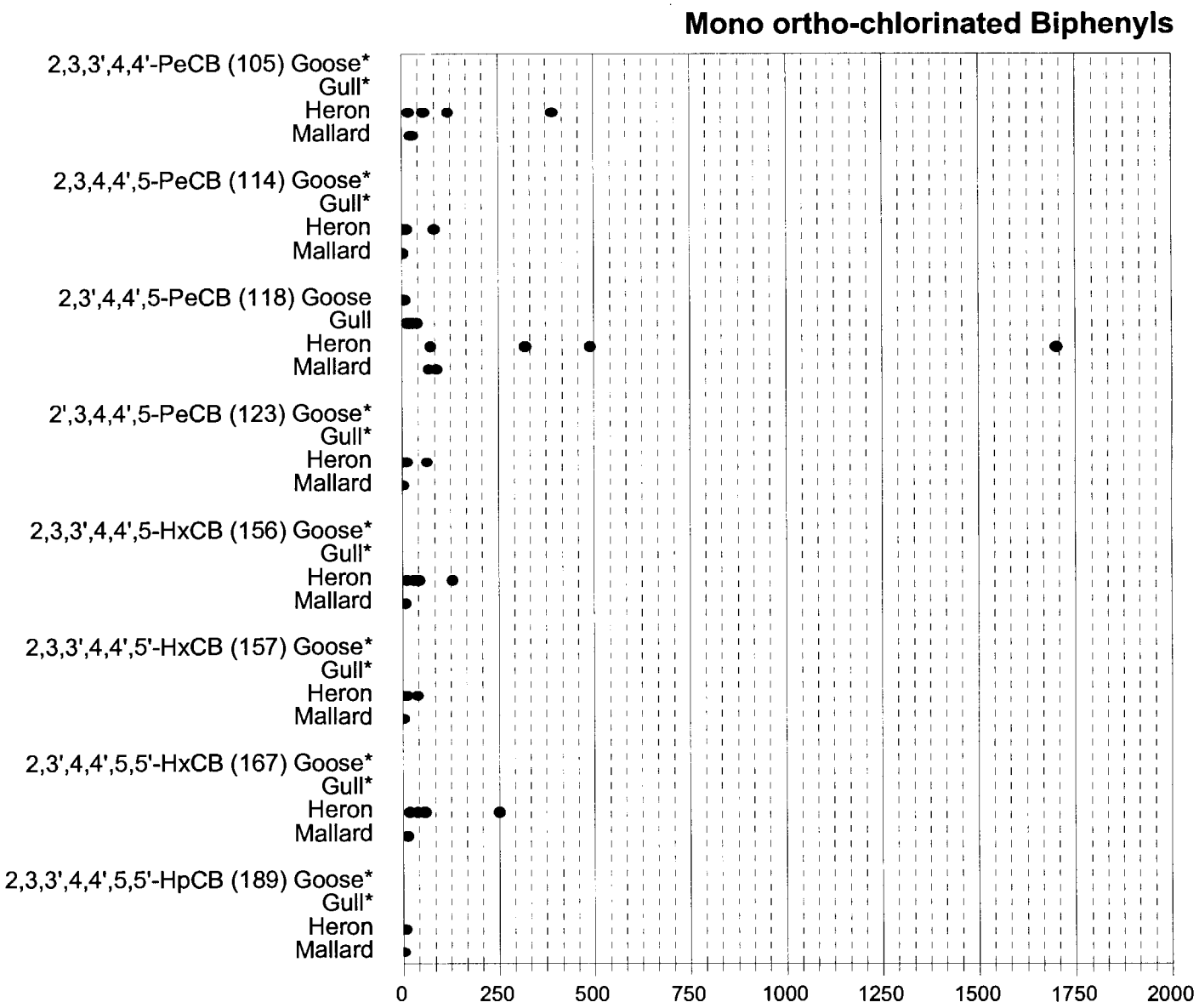

Figure 6. Congener-specific comparison between avian species for mono ortho-chlorinated biphenyls in ng/g (ppb) wet weight in egg tissues collected in Commencement Bay in 1995 and 1996.

*Not analyzed in Canada goose and glaucous-winged gull.

higher than all the other species including mallard.

Herons appeared to assimilate higher amounts of the non ortho-chlorinated biphenyl congeners (**Figure 5**). The one notable exception was with PCB 77 in mallards where concentration levels in both samples were clearly more elevated than the other species. Herons also appeared to have higher concentration levels of the mono ortho-chlorinated biphenyl congeners than the mallard (**Figure 6**). This comparison was limited to PCB 118 for all species, and between mallard and heron for the remaining mono ortho-chlorinated congeners that have assigned TEF values. **Table 8** describes lowest observable adverse effect levels (LOAELs) associated with total PCBs in bird eggs from the Great Lakes region.

Species	*Adverse Effect*	*PCBs-LOAEL*	*Reference*
Bald Eagle	egg lethality	**4.0 mg/kg**	Weimeyer *et al.* 1984
Herring Gull	embryonic deformities egg lethality	**5.0 mg/kg**	Weseloh *et al.* 1991
Caspian Tern	21% embryonic deformities egg lethality	**4.2 mg/kg**	Yamashita *et al.* 1993
Double-crested Cormorant	egg lethality (twice as great as control)	**3.5 mg/kg**	Yamashita *et al.* 1993 Tillitt *et al.* 1992

Table 8. Lowest observable adverse effect levels in mg/kg or μg/g (ppm) wet weight of total polychlorinated biphenyls (PCBs) in bird eggs from the Great Lakes region (modified and adapted from FWS December 2, 1996 letter to EPA).

A3.2 TCDD Equivalents (or TEQs)

To more accurately assess the true toxicity and potential for avian injury from the dioxin-like compounds, TEQs were calculated for each sample. This approach assumes an additive model for toxicity and that the chemistry-derived TCDD equivalents are a function of the specific toxic equivalency factors used (**Table 4**). Total TEQ values derived from eggs collected in Commencement Bay ranged from approximately 6.6 pg/g (Canada goose) to 598 pg/g (mallard duck)(**Table 9**).

For each species, all dioxin-like compounds were evaluated for percent contribution to a total TEQ value calculated from TEFs and tissue values. Although a complete picture of toxic contributors for goose and gull is limited due to the lack of data for most of the mono ortho-chlorinated biphenyls, some general comparisons can be made among the more toxic

congeners. **Figure 7a** illustrates a fairly even contribution between 1,2,3,7,8 -PeCDD; 2,3,7,8 -TCDF; 2,3,4,7,8 - PeCDF; and PCB 77 for Canada goose. These four congeners are roughly within a fifteen to thirty percent range for percent contribution to the total TEQ value. Glaucous-winged gull data (**Figure 7b**) appears to be leaning primarily towards PCB contributors with PCB 81 and PCB 126 contribution roughly forty to forty-five percent of the total TEQ value. Some gull samples showed a sizable contribution from PCB 77 as well.

Great blue heron data indicated that PCB 126 contributed roughly thirty-five to forty-one percent of the total TEQ value (**Figure 7c**). Remaining contributors appeared to be evenly distributed between 1,2,3,7,8 -PeCDD; 2,3,4,7,8 - PeCDF; and PCB 81. In addition, a fairly even contribution at around the four percent level from a majority of the mono ortho-chlorinated biphenyl congeners was evident in the heron egg samples. Mallard eggs (**Figure 7d**) were over fifty-five percent PCB 77 with 2,3,7,8 - TCDF contributing at the fifteen to eighteen percent level. 2,3,4,7,8 PeCDF; PCB 81; and PCB 126 were next highest contributing approximately five to eight percent to the total TEQ.

When comparing total TEQ values between species, mallard egg TEQs were eight to twelve times higher than the highest gull sample and approximately thirty times higher than goose (**Table 9**). Heron egg samples had the second highest TEQ values overall with one sample exceeding a mallard sample TEQ.

Canada Goose

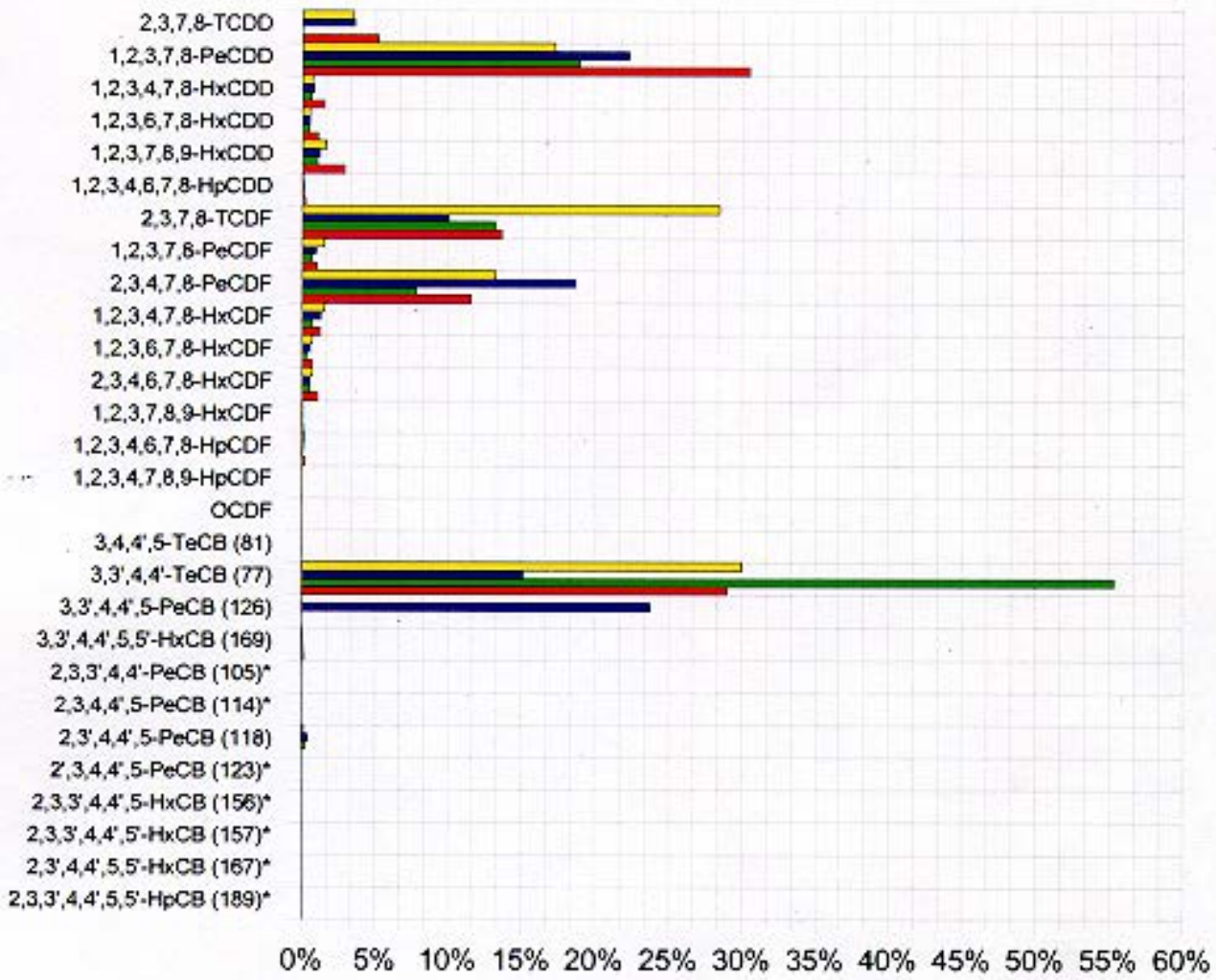

Figure 7a. Percent fraction of total TCDD-equivalents in Canada goose eggs (n=4) collected in Commencement Bay in 1995.

*Not analyzed in Canada goose and glaucous-winged gull.

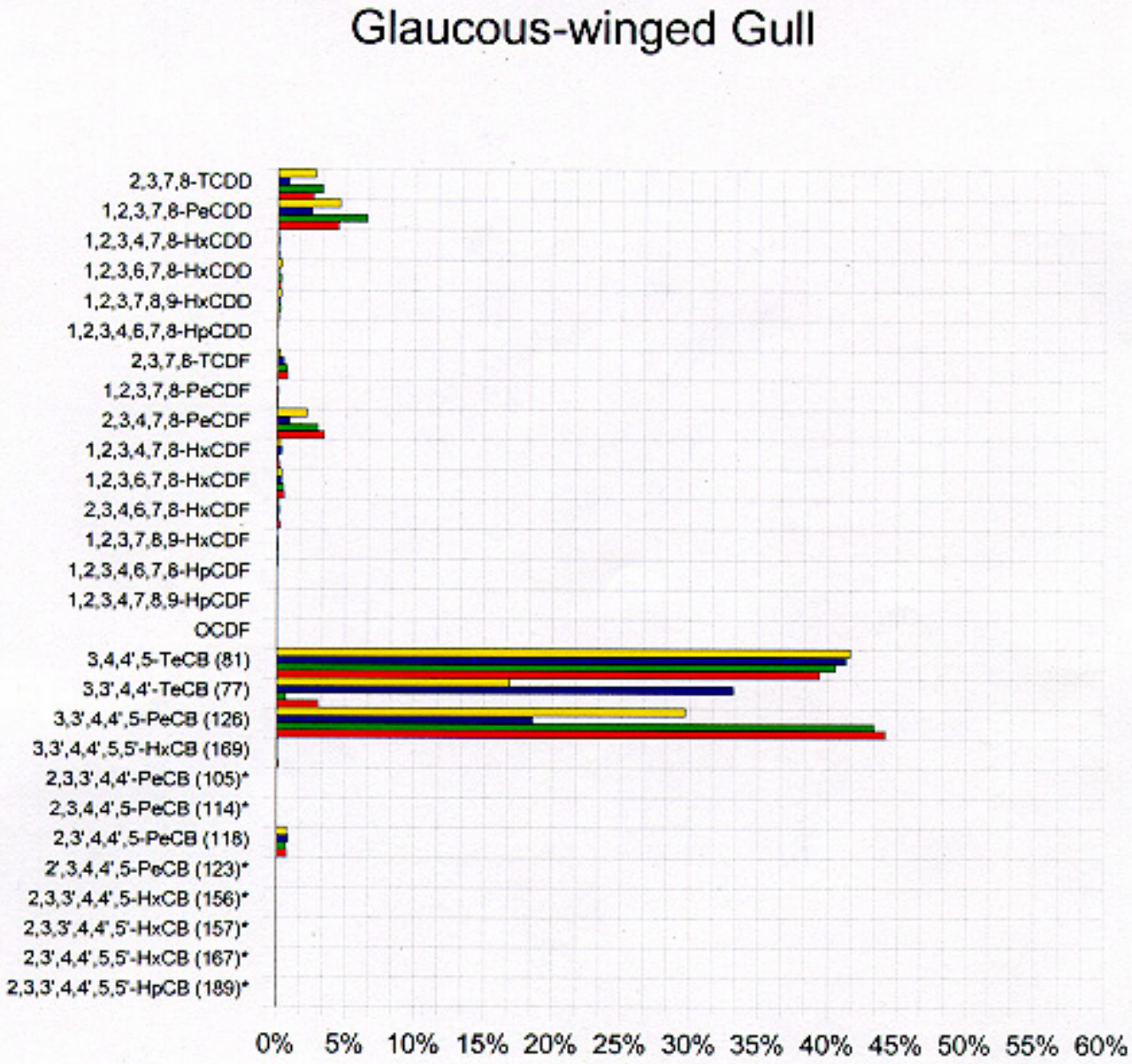

Figure 7b. Percent fraction of total TCDD-equivalents in glaucous-winged gull eggs (N=4) collected in Commencement Bay in 1995.

*Not analyzed in Canada goose and glaucous-winged gull.

Great Blue Heron

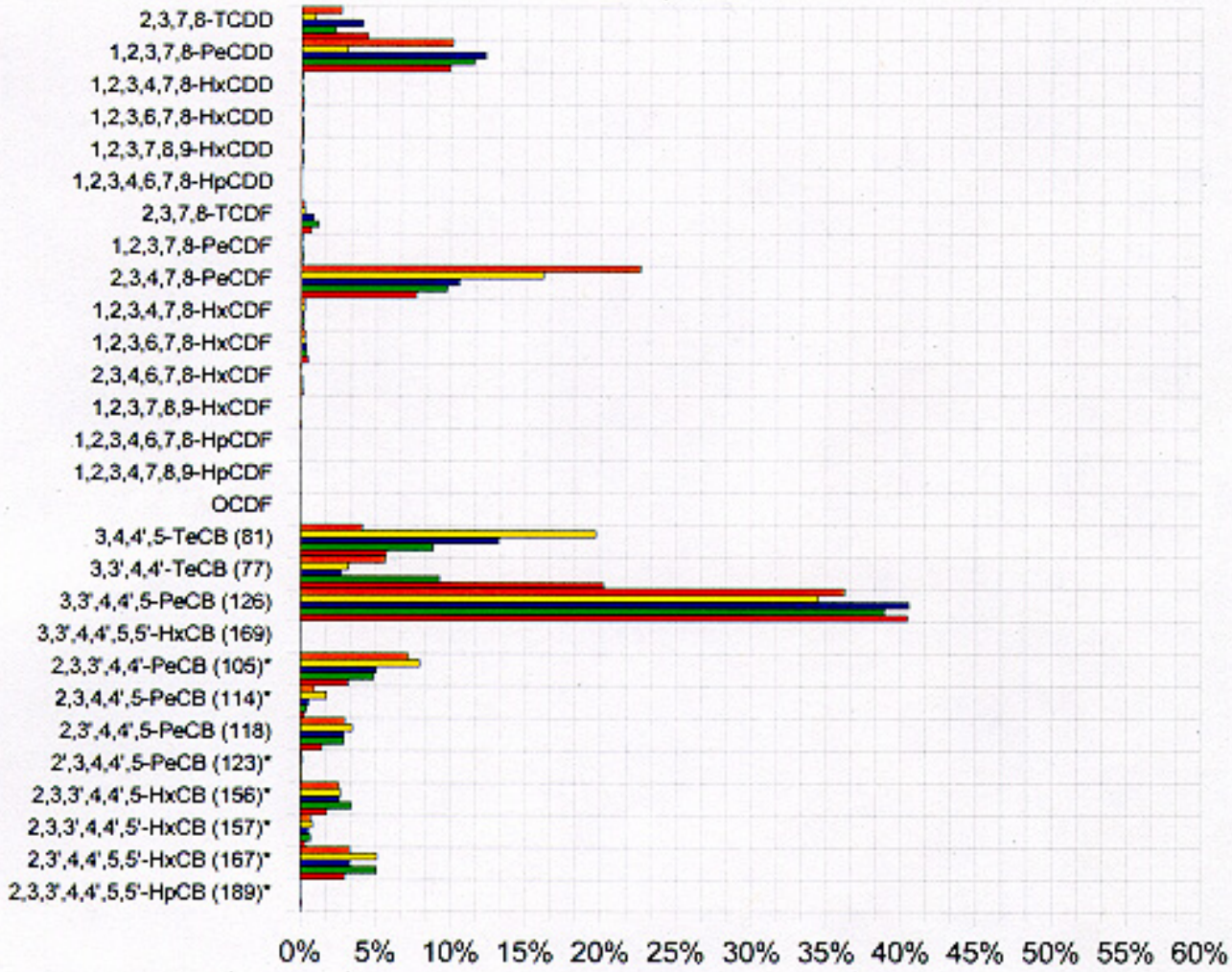

Figure 7c. Percent fraction of total TCDD-equivalents in great blue heron eggs (N=5) collected in Commencement Bay in 1996.

*Not analyzed in Canada goose and glaucous-winged gull.

Mallard

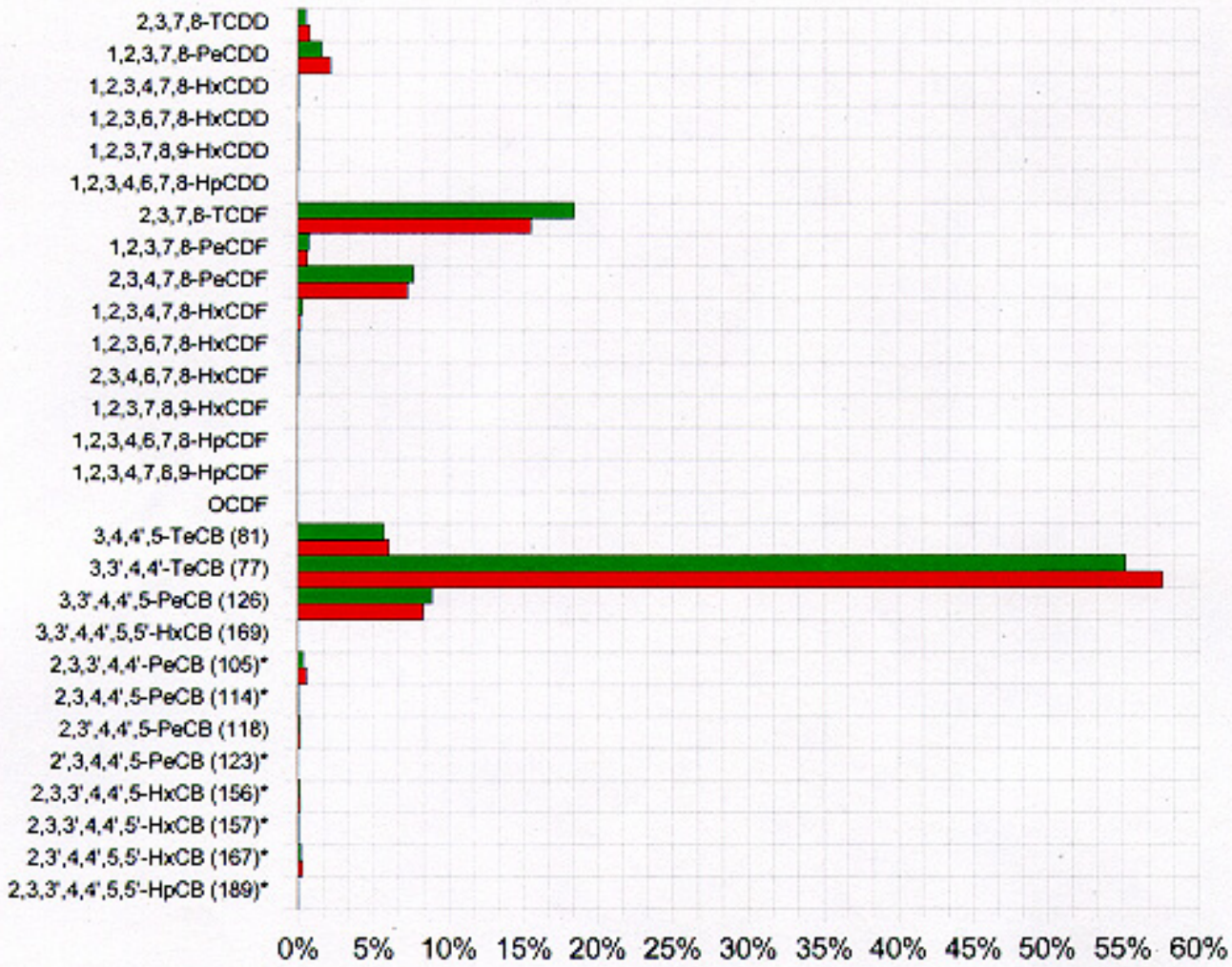

Figure 7d. Percent fraction of total TCDD-equivalents in mallard eggs (N=2) collected in Commencement Bay in 1996.

*Not analyzed in Canada goose and glaucous-winged gull.

Species	Dioxins/Furans		PCBs		Total	Mean
	TEQ	% Fraction	TEQ	% Fraction		
Canada Goose	6.88	69.87%	2.96	30.13%	9.84	
Canada Goose	8.44	60.72%	5.46	39.28%	13.90	
Canada Goose	3.29	44.42%	4.12	55.58%	7.41	**9.43**
Canada Goose	4.67	71.05%	1.90	28.95%	6.57	
Glaucous-winged Gull	5.61	11.10%	44.89	88.90%	50.50	
Glaucous-winged Gull	1.28	6.06%	19.80	93.94%	21.08	
Glaucous-winged Gull	5.42	14.67%	31.54	85.33%	36.96	**30.82**
Glaucous-winged Gull	1.85	12.58%	12.88	87.42%	14.73	
Great Blue Heron	61.35	36.50%	106.74	63.50%	168.09	
Great Blue Heron	103.59	21.02%	389.31	78.98%	492.90	
Great Blue Heron	32.60	28.73%	80.86	71.27%	113.46	**118.39**
Great Blue Heron	29.15	25.78%	83.93	74.22%	113.08	
Great Blue Heron	13.03	23.94%	41.39	76.06%	54.42	
Mallard	175.48	29.33%	422.78	70.67%	598.26	
Mallard	107.24	26.86%	292.01	73.14%	399.25	**498.76**

Table 9. Total TEQs in pg/g (ppt) wet weight and percent fraction between Dioxins/Furans and PCBs in avian egg tissues collected in Commencement Bay in 1995 and 1996.

Figure 8 further illustrates the relationship between total TEQ values, the four avian species, and the three groups of dioxin-like compounds. With the exception of goose, TEQ contribution appears primarily attributable to PCBs for all samples. Dibenzofurans were a more prominent contributor in mallards and some of the heron and goose samples than dibenzodioxin. However, dibenzodioxins appeared to be a more prominent contributor in the remaining heron samples and a distant second over PCBs in gulls. **Table 10** summarizes adverse effects associated with avian egg TEQ values from field studies on five different bird species.

Species	Adverse Effect(s)	TCDD-Eq.[1]	2,3,7,8 -TCDD	Reference
Forster's tern	Embryo mortality Impaired reproductive success Subcutaneous edema of head and neck AHH[2] induction Hard tissue deformities	**618 - 7,366 ppt**	14 - 105 ppt	Kubiak *et al.* 1989 Hoffman *et al.*1987 Tillitt *et al.* 1993
Caspian tern	Multiple deformities Edema Embryo mortality Impaired reproductive success	**1,300 - 2,800 ppt**	8 - 22 ppt	Ludwig *et al.* 1993 Yamashita *et al.* 1993 Tillitt *et al.* 1991
Double-crested cormorant	Embryonic mortality Beak deformities Club foot	**350 - 1,300 ppt**	5.3 - 22 ppt	Fox *et al.* 1991a,b,c Tillitt *et al.* 1991 Yamashita *et al.* 1993
Wood duck	General reproductive impairment Beak deformities Subcutaneous edema of head and neck	**3 - 611 (52)[3] ppt**	2 - 482 (36)[3] ppt	White *et al.* 1994 White *et al.* 1995
Great blue heron	Altered embryonic growth Shortened beak Scarcity of down follicles Subcutaneous edema MFO[4] induction Intercerebral asymmetry	**227 ± 36 ppt**	211 ± 34 ppt	Hart *et al.* 1991 Bellward *et al.* 1990 Henshel *et al.* 1995

Table 10. Field studies measuring exposure in eggs and effects in TCDD-equivalents and 2,3,7,8 -TCDD values (ppt) for selected species (modified and adapted from Hoffman et al. 1996).

[1]calculated from congener chemistry

[2]aryl hydrocarbon hydroxylase

[3]geometric mean

[4]mixed-function oxygenase

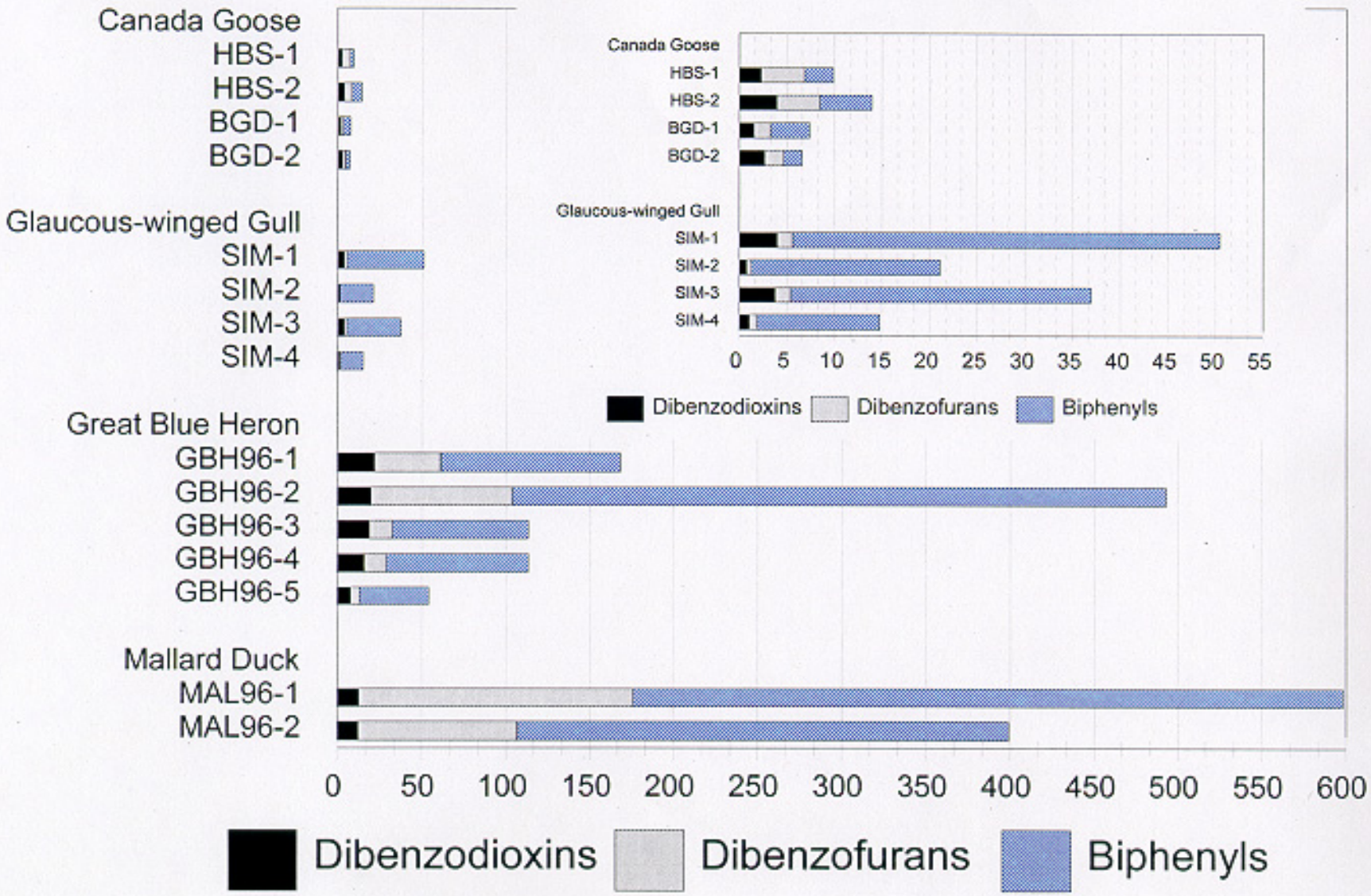

Figure 8. Comparison of TCDD-equivalent contributions in pg/g (ppt) in eggs collected in Commencement Bay in 1995 and 1996 between avian species and between dibenzodioxins, dibenzofurans, and biphenyls.

A3.3 Metals

Antimony, arsenic, cadmium and silver were not detected in the eggs of all four avian species analyzed (**Table 11**). One Canada goose egg sample contained 330 μg/g (ppm dry weight) chromium, while all remaining samples were below the 1996 non-detect level of 0.50 μg/g dry weight. The same goose egg sample contained 170 μg/g dry weight nickel while all other samples were at or below the non-detect level. Copper values generally ranged from 2.30 - 4.00 μg/g dry weight for all species. However, two heron egg samples contained copper values as high as 5.4 and 7.0 μg/g dry weight (**Figure 9**). Lead levels appeared relatively equal among the four species and was at or below the 1996 non-detect levels of about 0.50 μg/g dry weight. Mercury values appeared to be highest in heron eggs with values ranging between 0.77 and 1.50 μg/g dry weight. Selenium generally ranged from not detected to 0.45 μg/g dry weight for all species except heron. Selenium values in heron eggs ranged from 1.1 to 2.7 μg/g dry weight. Zinc was detected relatively equal among species with all values below approximately 86 μg/g dry weight. Overall, metal residues detected were below concentrations associated with adverse effects such as mortality or reproductive impairment (Elliot *et al.* 1989; Blus *et al.* 1985; Block 1992; Fimreite *et al.* 1971; Eisler 1985,1987; Lemly 1993; Thomas 1997).

Contaminant	Canada Goose n=4	Glaucous-winged Gull n=4	Great Blue Heron n=5	Mallard Duck n=2
	Geo. Mean (Range)	*Geo. Mean (Range)*	*Geo. Mean (Range)*	*Geo. Mean (Range)*
Metals	*µg/g dry weight*	*µg/g dry weight*	*µg/g dry weight*	*µg/g dry weight*
Antimony	<0.05 (<0.05 - <0.05)[1]	<0.05 (<0.05 - <0.05)[1]	<0.10 (<0.10 - <0.10)[1]	<0.10 (<0.10 - <0.10)[1]
Arsenic	<0.05 (<0.05 - <0.05)[1]	<0.05 (<0.05 - <0.05)[1]	<0.50 (<0.50 - <0.50)[1]	<0.50 (<0.50 - <0.50)[1]
Cadmium	<0.05 (<0.05 - <0.05)[1]	<0.05 (<0.05 - <0.05)[1]	<0.50 (<0.50 - <0.50)[1]	<0.50 (<0.50 - <0.50)[1]
Chromium	0.61 (<0.05 - 330.00)[1]	0.08 (<0.05 - 0.27)[1]	<0.50 (<0.50 - <0.50)[1]	<0.50 (<0.50 - <0.50)[1]
Copper	2.91 (2.30 - 4.00)	3.24 (2.70 - 4.00)	4.02 (2.60 - 7.00)	3.29 (2.70 - 4.00)
Lead	0.30 (0.20 - 0.53)	0.26 (0.22 - 0.34)	<0.50 (<0.50 - <0.50)[1]	<0.50 (<0.50 - <0.50)[1]
Mercury	<0.01 (<0.01 - <0.01)[1]	0.07 (<0.01 - 0.16)[1]	1.06 (0.77 - 1.50)	0.13 (0.12 - 0.14)
Nickel	0.65 (<0.05 - 170.00)[1]	0.08 (<0.05 - 0.40)[1]	<0.50 (<0.50 - <0.50)[1]	<0.50 (<0.50 - <0.50)[1]
Selenium	0.23 (0.16 - 0.35)	0.18 (<0.05 - 0.37)[1]	2.08 (1.10 - 2.70)	0.21 (0.10 - 0.45)
Silver	<0.05 (<0.05 - <0.05)[1]	<0.05 (<0.05 - <0.05)[1]	<0.20 (<0.20 - <0.20)[1]	<0.20 (<0.20 - <0.20)[1]
Zinc	67.29 (56.00 - 85.00)	62.26 (48.00 - 86.00)	44.98 (37.00 - 56.00)	50.28 (32.00 - 79.00)
Butyltins	*µg/kg dry weight*	*µg/kg dry weight*	*µg/kg dry weight*	*µg/kg dry weight*
Monobutyltin	1.40 (<1.00 - 3.80)[1]	1.91 (<2.00 - 6.60)[1]	2.05 (<2.00 - 9.00)[1]	<4.00 (<4.00 - <4.00)[1]
Dibutyltin	<1.00 (<1.00 - <1.00)[1]	3.03 (<2.00 - 42.00)[1]	3.14 (<2.00 - 19.00)[1]	<4.00 (<4.00 - <4.00)[1]
Tributyltin	<1.00 (<1.00 - <1.00)[1]	4.47 (<2.00 - 200.00)[1]	<2.00 (<2.00 - <2.00)[1]	<4.00 (<4.00 - <4.00)[1]
Tetrabutyltin	<1.00 (<1.00 - <1.00)[1]	<2.00 (<2.00 - <2.00)[1]	<2.00 (<2.00 - <2.00)[1]	<4.00 (<4.00 - <4.00)[1]
Phthalates, Phenols and PAHs	*µg/kg wet weight*	*µg/kg wet weight*	*µg/kg wet weight*	*µg/kg wet weight*
4-Chloro-3-methylphenol	<400.00 (<400.00 - <400.00)[1]	<800.00 (<800.00 - <800.00)[1]	<56.00 (<56.00 - <56.00)[1]	66.63 (37.00 - 120.00)
Hexachlorobenzene	<400.00 (<400.00 - <400.00)[1]	<800.00 (<800.00 - <800.00)[1]	<56.00 (<56.00 - <56.00)[1]	34.21 (<18.00 - 65.00)[1]
Dimethylphthalate	<200.00 (<200.00 - <200.00)[1]	<400.00 (<400.00 - <400.00)[1]	<56.00 (<56.00 - <56.00)[1]	<56.00 (<56.00 - <56.00)[1]
Diethylphthalate	<200.00 (<200.00 - <200.00)[1]	<400.00 (<400.00 - <400.00)[1]	<56.00 (<56.00 - <56.00)[1]	59.87 (<56.00 - 64.00)[1]
Di-n-butylphthalate	<200.00 (<200.00 - <200.00)[1]	<400.00 (<400.00 - <400.00)[1]	100.72 (42.00 - 280.00)	583.95 (310.00 - 1100.00)
Bis (2-ethylhexyl) phthalate	<200.00 (<200.00 - <200.00)[1]	363.68 (<400.00 - 520.00)[1]	123.90 (<38.00 - 480.00)[1]	1214.91 (180.00 - 8200.00)
Percent Lipid	2.2% (1.3% - 8.8%)	8.2% (5.1% - 11.0%)	5.8% (4.3% - 7.2%)	13.0% (12.5% - 13.5%)
Percent Moisture	69.5% (66.0% - 71.0%)	77.5% (74.0% - 81.0%)	N/A	N/A
Correction Factor (WW)	N/A	N/A	1.0 (0.99 - 1.05)	0.92 (0.92 - 0.92)

Table 11. Mean and range values for trace metals in µg/g (ppm) dry weight; butyltins in µg/kg (ppb) dry weight; phthalates, phenols, and PAHs in µg/kg (ppb) wet weight; and percent lipid, percent moisture, and wet weight conversion factors in avian egg tissues collected in Commencement Bay in 1995 and 1996.

[1]Detection Limit for some or all of the values.

N/A = not available

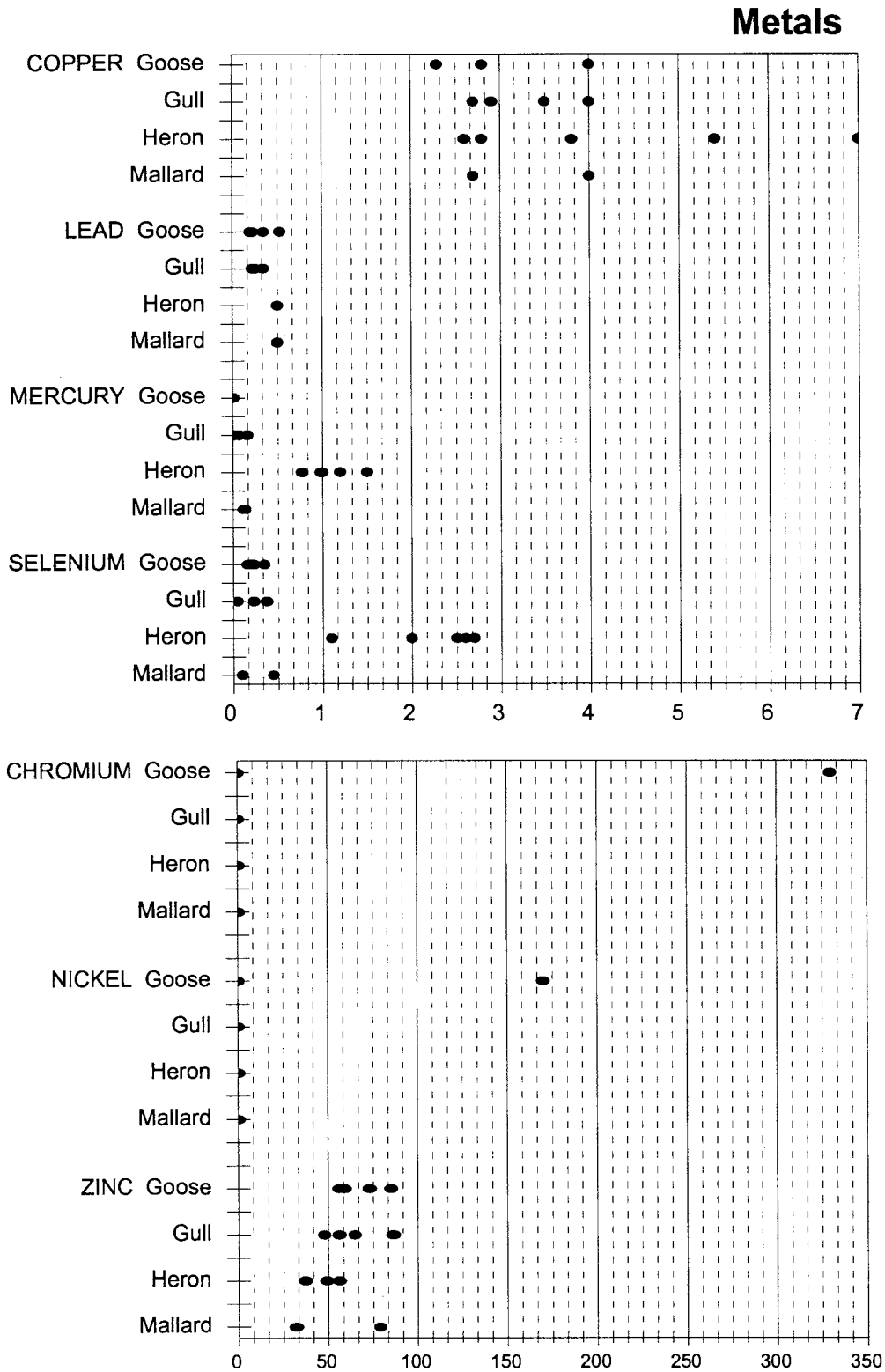

Figure 9. Comparison of trace metal values in µg/g (ppm) dry weight between avian species egg tissues collected in Commencement Bay in 1995 and 1996.

A3.4 Pesticides, Butyltins, and other analytes

Most conventional pesticides were at or below the detection limit in the avian egg tissues analyzed (**Table 12**). However, residues for the organochlorine pesticide DDT were high enough to compare across species (**Figure 10**). Values for 4,4' -DDT, -DDD, and -DDE appeared highest in heron eggs with one sample for DDE detected at approximately 1300 μg/kg (ppb) wet weight. The level of DDE detected were not above critical values associated with impaired reproductive success (Block 1992; Noble *et al.* 1986; Blus 1982, 1984; Henny *et al.* 1984, 1985; Fitzner *et al.* 1988). As with some of the trace metals and butyltins analyzed in 1996, limited sample volumes resulted in higher pesticide detection levels for heron and mallard.

Levels and ranges for butyltins are found in **Table 11**. One gull sample tested highest overall with a tributyltin value of 200 μg/kg (ppb) dry weight (**Figure 10**). The majority of samples were at or below the non-detect level of about 1.0-2.0 μg/kg dry weight. The one exception was one heron egg that was detected with 9.0 and 8.0 μg/kg dry weight for monobutyltin and dibutyltin, respectively.

Certain phthalates, phenols and PAHs were also analyzed in avian egg tissue (**Table 11**). However, high detection level limits reported in the 1995 samples for these analytes made cross-species comparisons infeasible.

Contaminant	Canada Goose n=4	Glaucous-winged Gull n=4	Great Blue Heron n=5	Mallard Duck n=2
	Geo. Mean (Range) *µg/kg wet weight*	*Geo. Mean (Range)* *µg/kg wet weight*	*Geo. Mean (Range)* *µg/kg wet weight*	*Geo. Mean (Range)* *µg/kg wet weight*
Pesticides				
Aldrin	<1.50 (<1.50 - <1.50)[1]	4.04 (<3.00 - 6.70)[1]	<8.00 (<8.00 - <8.00)[1]	<8.00 (<8.00 - <8.00)[1]
alpha-BHC	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	<8.00 (<8.00 - <8.00)[1]	<8.00 (<8.00 - <8.00)[1]
beta-BHC	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	8.37 (<8.00 - 10.00)[1]	<8.00 (<8.00 - <8.00)[1]
delta-BHC	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	<8.00 (<8.00 - <8.00)[1]	<8.00 (<8.00 - <8.00)[1]
gamma-BHC	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	<8.00 (<8.00 - <8.00)[1]	<8.00 (<8.00 - <8.00)[1]
alpha-Chlordane	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	<8.00 (<8.00 - <8.00)[1]	<8.00 (<8.00 - <8.00)[1]
gamma-Chlordane	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	<8.00 (<8.00 - <8.00)[1]	<8.00 (<8.00 - <8.00)[1]
4,4' -DDD	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	21.53 (12.00 - 72.00)	<8.00 (<8.00 - <8.00)[1]
4,4' -DDE	3.63 (<1.50 - 8.70)[1]	74.02 (29.00 - 140.00)	390.36 (320.00 - 710.00)	338.23 (88.00 - 1300.00)
4,4' -DDT	<3.00 (<3.00 - <3.00)[1]	<6.00 (<6.00 - <6.00)[1]	15.12 (<8.00 - 63.00)[1]	<8.00 (<8.00 - <8.00)[1]
Dieldrin	2.20 (<1.50 - 3.60)[1]	<3.00 (<3.00 - <3.00)[1]	<16.00 (<16.00 - <16.00)[1]	<16.00 (<16.00 - <16.00)[1]
Endosulfan I	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	<16.00 (<16.00 - <16.00)[1]	<16.00 (<16.00 - <16.00)[1]
Endosulfan II	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	<16.00 (<16.00 - <16.00)[1]	<16.00 (<16.00 - <16.00)[1]
Endosulfan Sulfate	<4.50 (<4.50 - <4.50)[1]	<9.00 (<9.00 - <9.00)[1]	<16.00 (<16.00 - <16.00)[1]	<16.00 (<16.00 - <16.00)[1]
Endrin	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	<16.00 (<16.00 - <16.00)[1]	<16.00 (<16.00 - <16.00)[1]
Endrin Aldehyde	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	<16.00 (<16.00 - <16.00)[1]	<16.00 (<16.00 - <16.00)[1]
Endrin Ketone	<3.00 (<3.00 - <3.00)[1]	<6.00 (<6.00 - <6.00)[1]	<16.00 (<16.00 - <16.00)[1]	<16.00 (<16.00 - <16.00)[1]
Heptachlor	<4.50 (<4.50 - <4.50)[1]	<9.00 (<9.00 - <9.00)[1]	<8.00 (<8.00 - <8.00)[1]	<8.00 (<8.00 - <8.00)[1]
Heptachlor Epoxide	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	12.50 (<8.00 - 20.00)[1]	<8.00 (<8.00 - <8.00)[1]
Methoxychlor	<7.50 (<7.50 - <7.50)[1]	<15.00 (<15.00 - <15.00)[1]	<80.00 (<80.00 - <80.00)[1]	<80.00 (<80.00 - <80.00)[1]
Toxaphene	<40.00 (<40.00 - <40.00)[1]	<80.00 (<80.00 - <80.00)[1]	<160.00 (<160.00 - <160.00)[1]	<160.00 (<160.00 - <160.00)[1]
2,4' -DDD	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	<8.00 (<8.00 - <8.00)[1]	<8.00 (<8.00 - <8.00)[1]
2,4' -DDE	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	32.06 (16.00 - 56.00)	8.49 (<8.00 - 9.00)[1]
2,4' -DDT	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	<8.00 (<8.00 - <8.00)[1]	<8.00 (<8.00 - <8.00)[1]
trans-Nonachlor	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	57.34 (29.00 - 110.00)	<8.00 (<8.00 - <8.00)[1]
cis-Nonachlor	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	<8.00 (<8.00 - <8.00)[1]	<8.00 (<8.00 - <8.00)[1]
Mirex	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	<8.00 (<8.00 - <8.00)[1]	<8.00 (<8.00 - <8.00)[1]
Oxychlordane	<1.50 (<1.50 - <1.50)[1]	<3.00 (<3.00 - <3.00)[1]	<8.00 (<8.00 - <8.00)[1]	<8.00 (<8.00 - <8.00)[1]

Table 12. Mean and range values for pesticides in µg/kg (ppb) dry weight in avian egg tissues collected in Commencement Bay in 1995 and 1996.

[1]Detection Limit for some or all of the values.

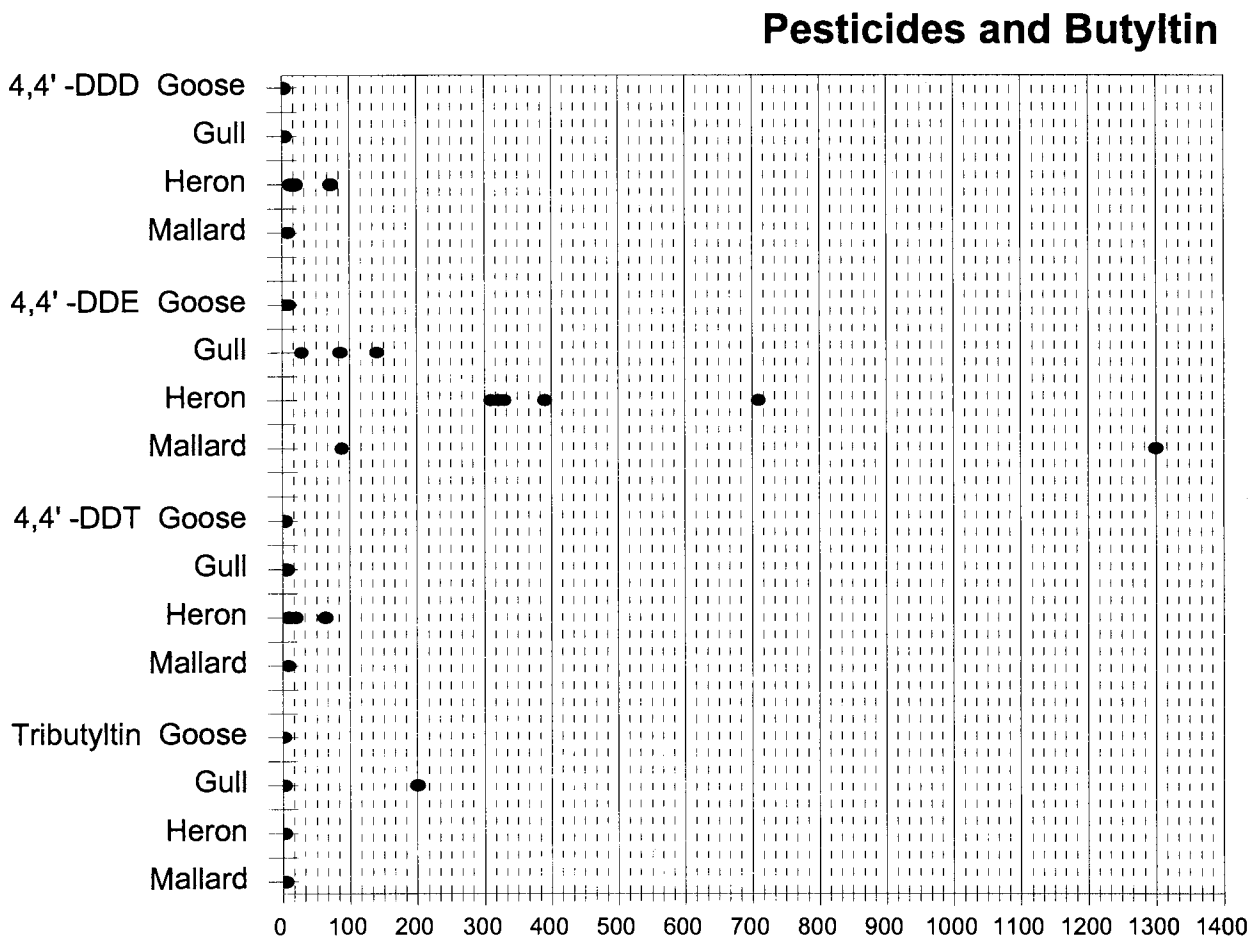

Figure 10. Comparison of 4,4' -DDT, -DDD, -DDE residue values in µg/kg (ppb) wet weight and tributyltin residue values in µg/kg (ppb) dry weight between avian species egg tissues collected in Commencement Bay in 1995 and 1996.

B2.0 Methods

The Fish and Wildlife Service is an implementing agency under the Puget Sound Ambient Monitoring Program (PSAMP) and is responsible for monitoring marine birds to characterize spatial and seasonal patterns of distribution. PSAMP is a multi-agency, long-term monitoring program designed to measure environmental conditions in Puget Sound (PSWQA 1988). As part of this effort, the FWS provided additional funding through the Natural Resource Damage Assessment and Restoration Fund to specifically expand upon the monitoring of surf scoters in the Commencement Bay area. Completed in November 1997 (Mahaffy *et al.*), this report and its findings relevant to this assessment are discussed in this section.

B2.1 Objectives

The surf scoter (*Melanitta perspicillata*) was the species selected to monitor because: (1) they are abundant in Puget Sound; (2) they forage in the marine system; and (3) they spend a substantial portion of their lives in Puget Sound either as year-round or winter residents. The primary objective in monitoring the surf scoter was to measure the occurrence and concentration of selected trace elements and organics in their tissues and document any changes in contaminant concentrations between the October (fall) and February (late winter) sampling periods.

Under this additional funding effort, the FWS: (1) helped expand the list of contaminants to be analyzed to include low and high molecular weight polynuclear aromatic hydrocarbons (LPAHs and HPAHs); (2) analyzed liver samples for cytochrome P450-associated microsomal monooxygenase activity; and (3) conducted a hematology screen for various parameters in blood samples in order to accomplish a more complete health assessment of the surf scoters wintering in Commencement Bay. Telemetry conducted over a two-year period prior to collection indicated that the surf scoters in Commencement Bay were very predictable in their movements. Twenty out of twenty-three radio-tagged birds exhibited strong site fidelity (87%) and were found within 11 km from their capture sites.

B2.2 Collection and Processing

Twenty adult male surf scoters were collected in the study area during the two sampling periods of fall and late winter (October 30 - November 1, 1995 and February 26 - 27, 1996). **Figure 11** identifies the locations of the collection efforts during 1995-1996. **Figure 11** also identifies the radiotelemetry site and the previous collection site used by Henny *et al.* (1991) in 1984-1985.

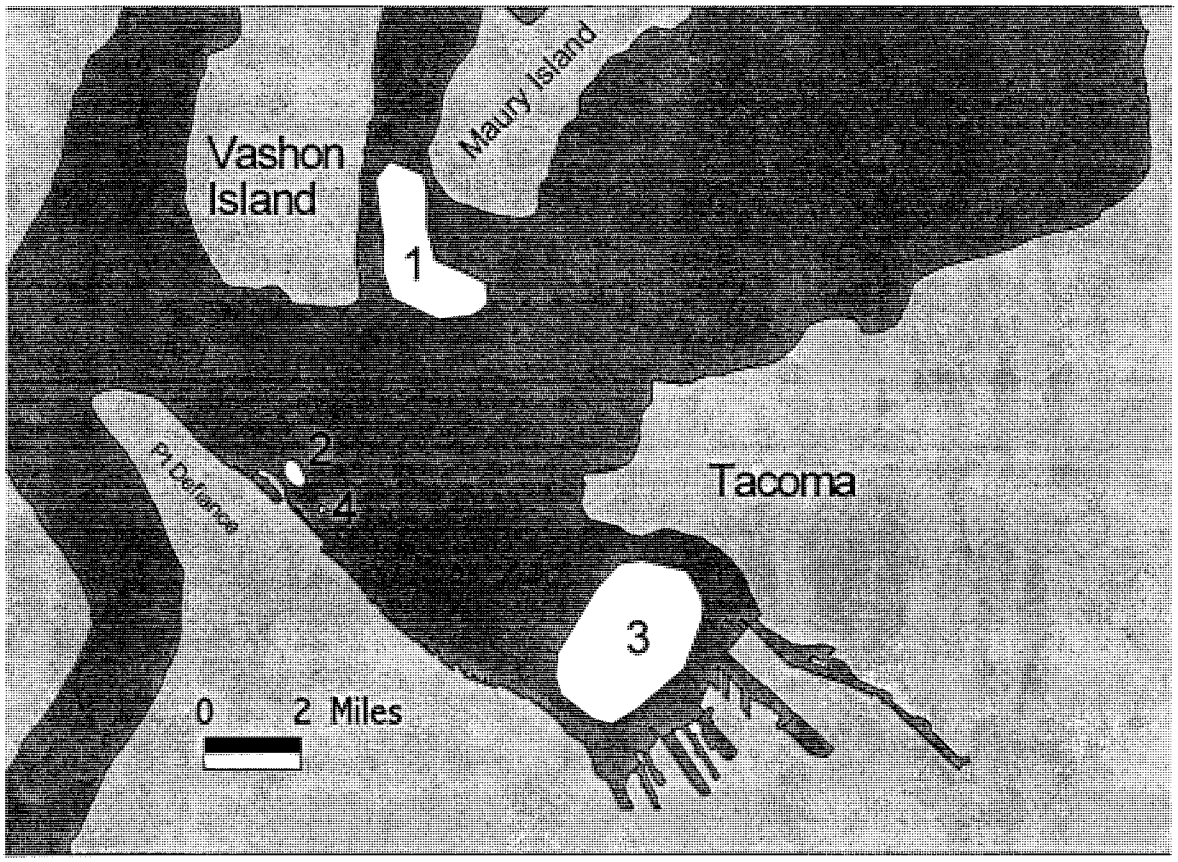

Figure 11. Surf scoter collection (1 and 2) and telemetry locations (4) in 1995/1996, and collection site (3) utilized in 1984-1985 by Henny et al. (1991) in Commencement Bay.

Blood samples were taken immediately after collection, chilled, and submitted to Consolidated Veterinary Diagnostics, Inc./ITEH Wildlife Health Center at the University of California -Davis for hematology. Information such as body weight and length, stomach contents, subcutaneous fat indexing and other field data on the carcasses was recorded for each bird collected. Livers and kidneys were removed, frozen, and submitted to Hazleton Laboratories America, Inc. in Madison, Wisconsin for trace metal and/or organochlorine analysis. Bile was collected from the gall bladder, frozen, and sent to the Northwest Fisheries Science Center of the National Marine Fisheries Service in Seattle, Washington for fluorescent aromatic compound (FACs) analysis. Liver samples were also analyzed for cytochrome P450-associated monooxygenase activities at the Patuxent Environmental Science Center in Laurel, Maryland. Histology on the carcasses was performed by Wildlife Pathology International of Fort Collins, Colorado.

B2.3 Statistical Analysis

Inorganic and organic analytical results were evaluated using the non-parametric Wilcoxon' Rank-Sum Test (Mann-Whitney Two-Sample method) due to numerous outliers and high standard deviations. Unless stated otherwise, the probability level used to determine statistical significance was $P<0.05$.

B3.0 Results

B3.1 Tissue and Bile Chemistry

Mean concentrations of mercury in the livers and kidneys were significantly higher ($P<0.001$) in the late winter birds collected than in the fall set (**Table 13**). Chromium in liver tissue was also significantly higher ($P<0.001$) in the late winter bird set. Mean concentrations of cadmium, copper, iron, molybdenum, and zinc were significantly lower in the livers of the late winter birds when compared to the fall set[3]. A significant decrease in cadmium was also recorded in the kidneys between the two sampling periods.

The only organic compounds detected were p,p'-DDE and total PCBs. DDE was detected in a greater number of the late winter birds than from the fall set. Similarly, PCBs were measured in a greater number of birds in the late winter than in the fall (**Table 13**). However, the differences between the fall and late winter mean concentrations of total PCBs was not significant.

Analyte	*Fall Sample (n=20)*	*Late Winter Sample (n=20)*
p,p'-DDE	Detected in 55% of birds	Detected in 95% of birds
PCBs	Detected in 65% of birds	Detected in 85% of birds
Mercury	Kidney = 1.11 mg/kg Liver = 2.10 mg/kg	Kidney = 1.84 mg/kg Liver = 2.59 mg/kg
Chromium	Liver = 0.55 mg/kg	Liver = 0.58 mg/kg

Table 13. Comparisons between selected analytes and surf scoter sampling sets collected from Commencement Bay in 1995 and 1996 (Mercury and Chromium values are mean concentrations in ppm).

Bile samples analyzed for biliary FACs (mean concentrations) measured at the phenanthrene, benzo(a)pyrene, and naphthalene wavelengths were not significantly different between the fall and in the late winter samples suggesting no appreciable uptake of PAHs by surf scoters had occurred during their residency in Commencement Bay.

[3]Text in the final report (Mahaffy *et al.* 1997) incorrectly includes chromium in this statement on page 11.

B3.2 Cytochrome P450, Blood and Histology

Both Ethoxyresorufin-0-dealkylase (EROD) and methoxyresorufin-0-dealkylase (MROD) activity were measured and normalized for the fall and late winter liver samples. No clearcut difference could be detected between the two sets of samples. However, within each set of samples, there were a great range of values suggesting that there were both relatively uninduced and induced birds in both the fall and late winter birds.

The mean white blood cell (mononuclear WBC/lymphocytes) count estimates were not significantly different between the fall and late winter samples. However, there was a significant decrease in heterophils (polymorphonuclear WBCs) in the late winter samples. The occurrence of blood parasites appeared to be limited to only one bird out of each of the sampling sets.

Histological examination of the carcasses from both sampling periods revealed the presence of lesions similar in both sets. Overall, the lesions found were extremely minimal and fairly common to sea birds. The most common lesion identified was a mild inflammation of the collecting ducts of the kidneys. This type of lesion was determined to be most likely caused by a trematode parasite.

C2.0 Methods

In Section A of this report, contaminant data was presented from five great blue heron eggs collected in 1996 from the Dumas Bay heron colony located near Commencement Bay **(Figure 2).** Chemical analysis revealed that some of these eggs contained elevated levels of organochlorine contaminants similar to those levels found during the 1984 and 1988 sampling events. This information and the reports of low productivity of the colony when compared to other nearby heron colonies (EVS 1995) prompted the next approach in the reconnaissance effort to assess the potential for avian injury in the Commencement Bay area. In this section, an overview of the great blue heron field studies is provided.

C2.1 Objectives

The primary objective of the great blue heron field studies conducted in 1997 was to determine if a link could be established and quantified between low productivity in a heron colony (Dumas Bay) located near Commencement Bay and forage site selection. In an attempt to determine this linkage, three primary tasks were pursued: (1) Establish where herons nesting in the colony were feeding; (2) determine how much time the Dumas Bay birds were spending in potentially contaminated feeding areas; and (3) link individual heron productivity outcomes with actual feeding site preferences.

C2.2 Tasks

Monitoring studies of the Dumas Bay colony conducted in 1996 suggested that the bimodal distribution of chick production and wide ranges of contaminant values in heron eggs were correlated. This suggested that herons were using both contaminated and uncontaminated foraging areas. In order to establish a link between lowered productivity and feeding site preferences, a study was designed to determine nesting success per nest and compare the amount of time individual birds spent feeding in areas of Commencement Bay known to be contaminated. Observation data would be collected and linked to specific foraging locations inside Commencement Bay and then regressed against productivity data for individual nests in the colony.

To establish where the Dumas Bay herons were feeding and for how long, observers were placed in strategic vantage points and records of flight direction (arrivals and departures), numbers of birds, and time of day data was collected. These time intensive observations were designed to delineate the major roosting and foraging territories used by the colony. For comparison purposes, numbers of active nests, failed nests, and all colony disturbances were recorded from the Dumas Bay colony as well as from two other nearby heron colonies: the Peasley Canyon heronry in Auburn, and the Nisqually National Wildlife Refuge heronry near Olympia **(Figure 12).**

An attempt was made to divide arrival and departure observation data into three nesting phase time periods: (1) a "pre-clutch completion" period when the egg is being formed; (2) a "small chick present" period (incubation and one adult foraging away from nest); and (3) a "large chick present" period (both adults foraging away from nest). The transition from pre-clutch completion phase to beginning incubation and small chick present phase was determined by adding 7 days to the first confirmed incubation since herons typically lay one egg every other day and begin incubation after the first egg is laid. This division of observation data was designed to allow for a greater level of discernment as to when the greatest potential for contaminant exposure, uptake, and injury may exist for the colony.

Along with temporal considerations, all arrival and departure data was qualified and assigned a code as to the "quality" of the observation. Birds observed with a clearly known origin or destination into or out of a foraging site location were given a "high confidence" data qualifier. If the arrival or departure was clearly seen along with flight direction, but no determination could be made whether the bird came directly from or landed in a specific foraging site location, the observation was given a separate qualifier. A third designation or qualifier was assigned if the bird observation was not recorded or observed by one of the two observers and flight direction could not be established.

Seasonal changes in foraging locations in female herons was also recognized as a concern when determining potential contaminant sources by measuring chemical burdens in egg tissue. Therefore, attempts were made to sex the birds during the observational periods. All SOPs used and developed for this study are from Norman (1998).

C3.0 Results

Several unanticipated events during the 1997 field season significantly altered the original study design and time line, as well as the anticipated results. In early March, a new heron colony began to establish itself on the hillside above the Chinook Marina in the Hylebos Waterway. This colony (referenced as "the Hylebos colony") was subsequently added to the list of colonies to be observed and monitored. In mid-May, the focus colony in Dumas Bay failed and was abandoned. As a result, the ability to catagorize observation data by nesting phase was limited. Similarly, one of the control colonies (Peasley Canyon in Auburn) failed and was abandoned at the end of May.

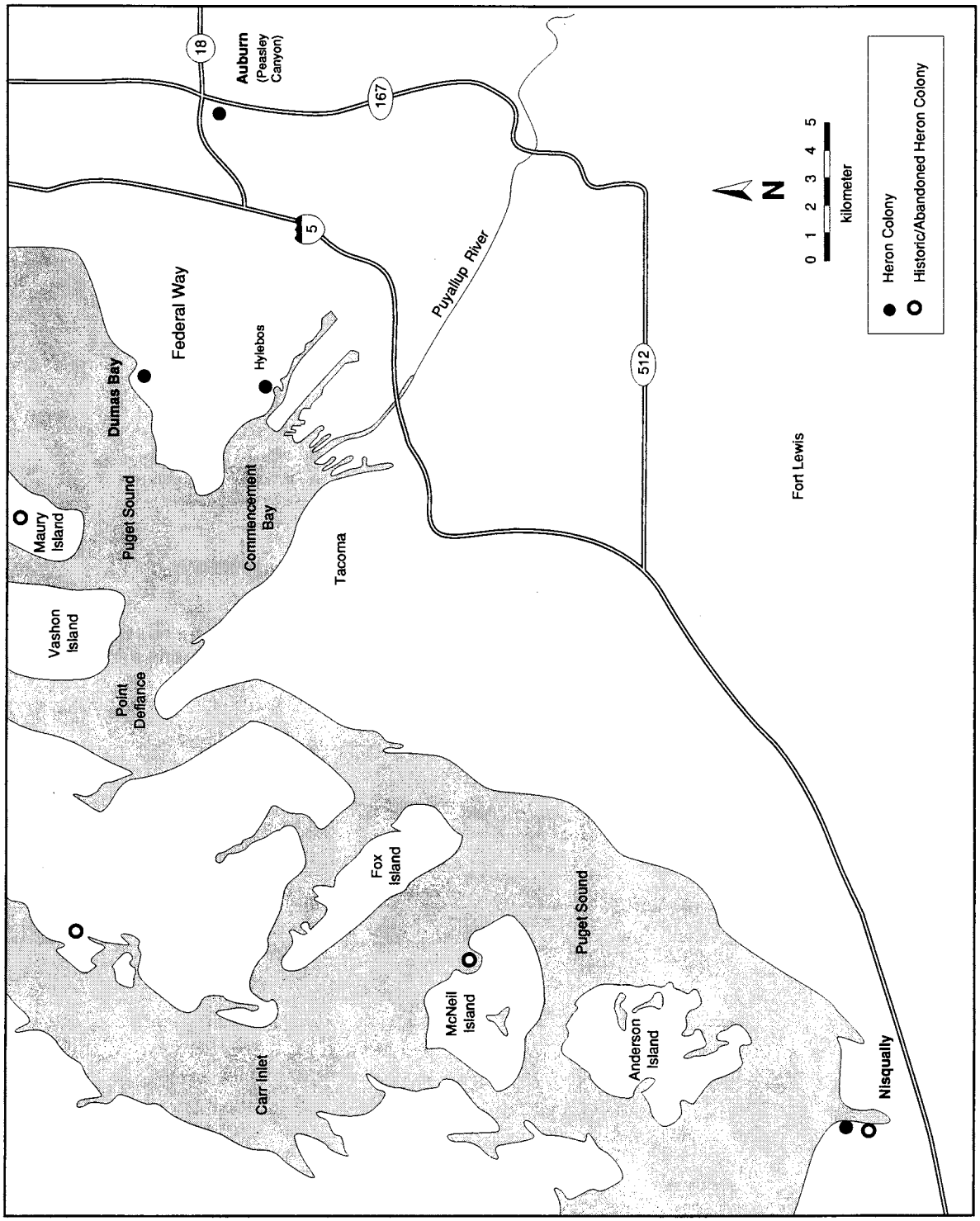

Figure 12. Great blue heron colony locations in and near Commencement Bay in 1997 and historically.

The ability to sex individual herons could not be accomplished since the optical scale for measuring beak size (radicule) could not be secured in time for the study. However, information gathered from Bennett (1993) and Butler (1993, 1995) regarding caloric intake requirements to begin egg production in female herons, links the association of nest initiation with the available number of hours of low tides in the Spring. This would indicate that the majority of contaminant loading potential would likely be related to marine forage sites instead of the inland locations utilized early in the season by female herons. Therefore, the inability to sex the birds in this reconnaissance study component was not considered to be problematic.

Gathering time allocation data became overly burdensome due to the enormous amount of observation hours required to record time intervals when herons returned to the nest during the morning hours. However, data obtained from this monitoring study yielded results that were deemed useful in the overall effort to preliminarily assess avian injury in Commencement Bay. A significant number of great blue herons (at least half from the Dumas Bay and Hylebos heron colonies) were observed using forage sites in Commencement Bay and therefore had the potential to be exposed to elevated levels of contaminants associated with the industrial waterways **(Figure 13).**

C3.1 Dumas Bay Colony - Productivity and Forage Site Selection

Monitoring at the Dumas Bay colony revealed late incubation (when compared to previous years), poor synchronization, and continuous harassment by bald eagles. Observations between early February and late May noted eagles in or near the colony on almost every occasion, and likely the most probable cause for the colony's ultimate failure and abandonment in 1997. By late May, only one nest remained active, fledging two chicks from a total of **16** once-active nests. A similar result occurred in 1995[4] when casual observations of the colony (Norman unpublished data) recorded only a few chicks present with fledging occurring late into the season **(Figure 14).**

Productivity trends observed from 1984-1997 (Norman, unpublished data) indicate that herons from the Dumas Bay colony have had consistently lower productivity rates than other nearby heron colonies **(Figure 15).** Levels of productivity measured at the colony continue to be consistently below that which would be necessary for the colony to maintain itself (1.7 young per active nest from Henny 1972 and 1.9 young per active nest from Butler *et al.* 1995).

Observations between March 8, 1997 and May 1, 1997 at the Dumas Bay colony recorded 250 arrivals and departures of which 47% were confirmed as using forage sites in Commencement Bay **(Figure 16).** Because of the colony failure, no other information was collected.

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[4]Data other than "casual observations" are not available for the Dumas Bay Colony in 1995, and therefore not included in the figure.

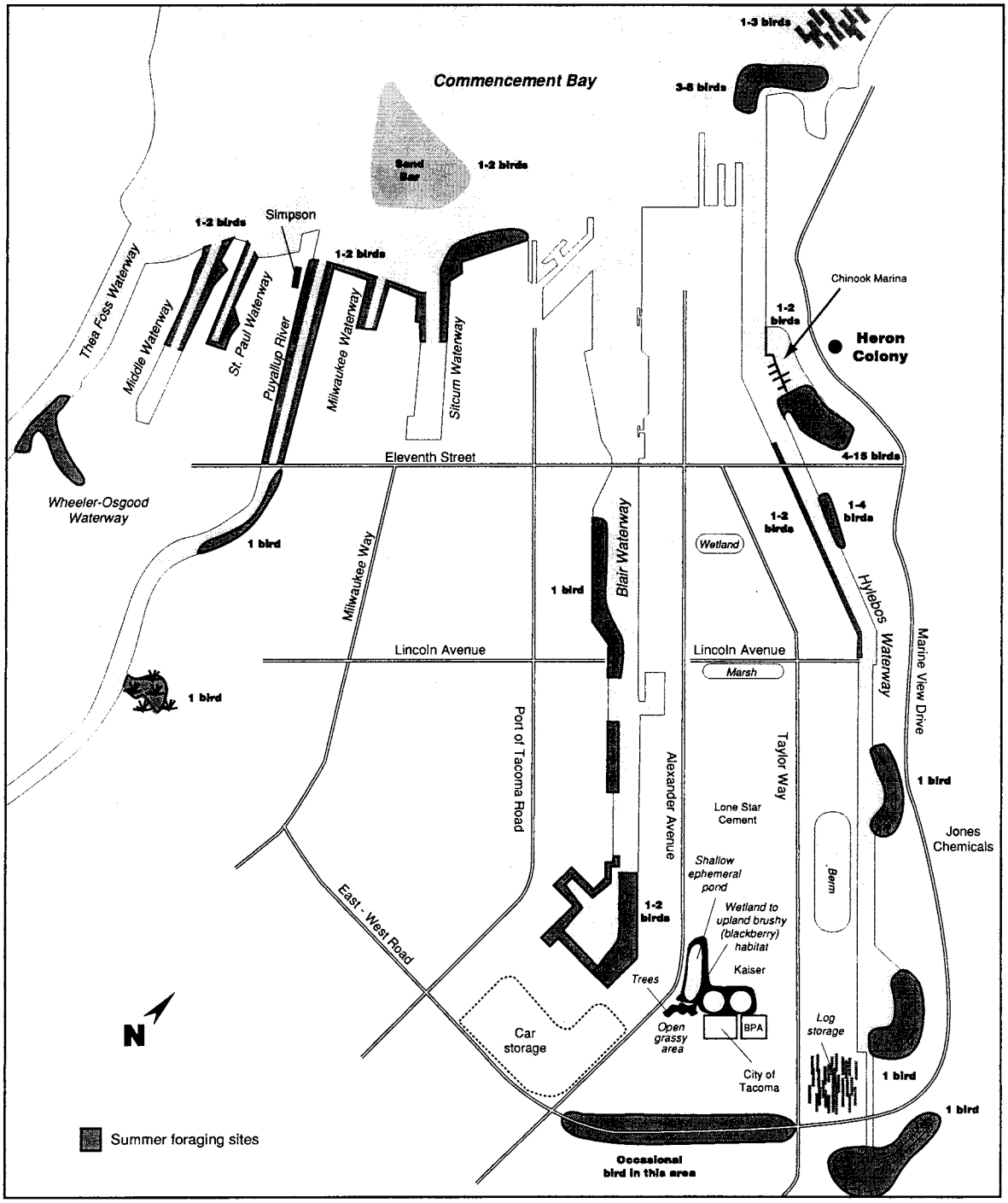


Figure 13. Primary summer foraging sites utilized by great blue herons observed in Commencement Bay in 1997.

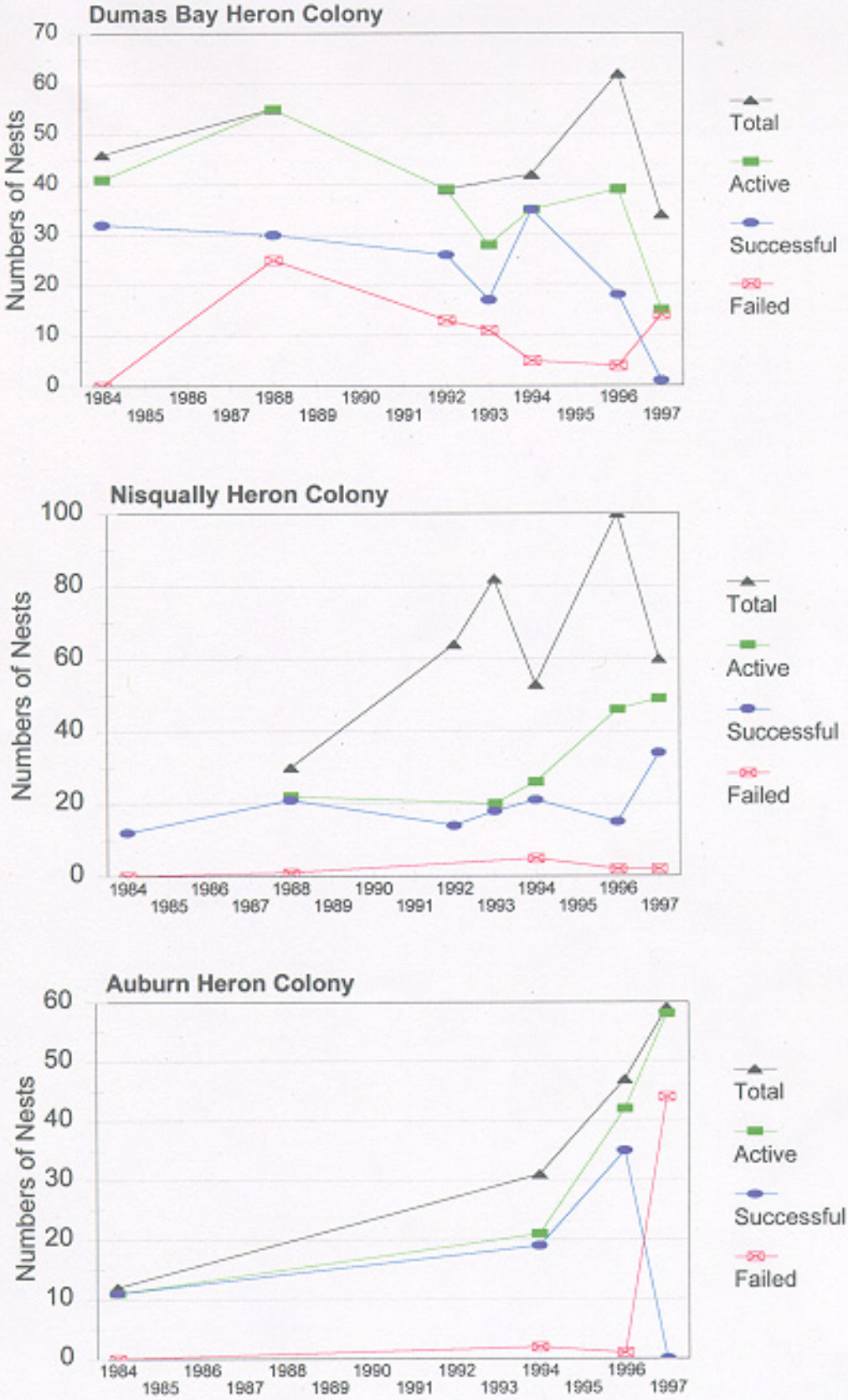
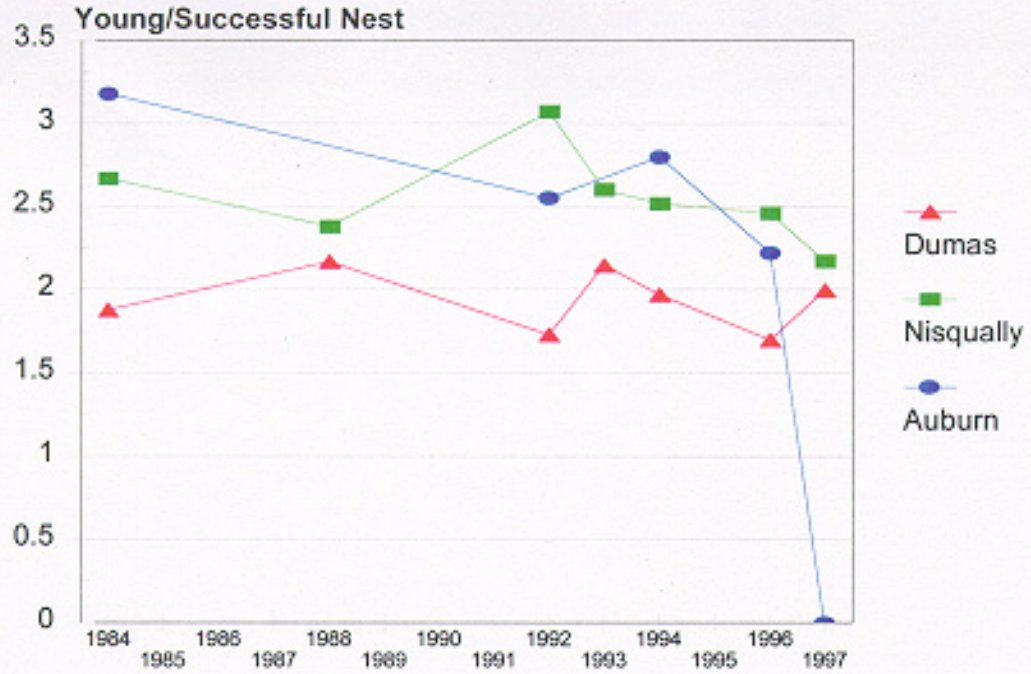


Figure 14. Nesting observations from the Dumas Bay, Nisqually, and Auburn great blue heron colonies,1984-1997.



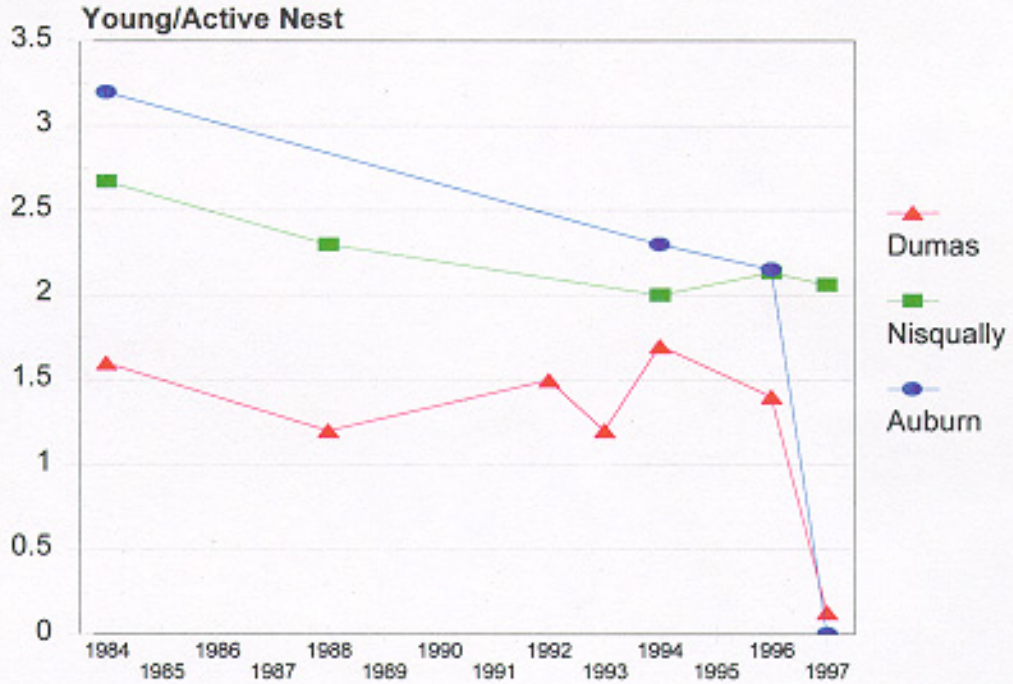


Figure 15. Productivity of the Dumas Bay, Nisqually, and Auburn great blue heron colonies by numbers of young per successful nest and numbers of young per active nest, 1984-1997.

C3.2 Hylebos Colony - Productivity and Forage Site Selection

Confirmation of the new heron colony above the Chinook Marina on the Hylebos Waterway was established in early March 1997. Twenty-one nests were located and eggshell fragments found beneath the nests confirmed that the colony had nested at this location in the previous year. Herons began occupancy late in the nesting season, with 11 birds established in the colony by early April. A large increase in birds nesting in the colony was noted about the time when the Dumas Bay colony became abandoned. Of 30 nests observed, 26 were active and 25 were successful (able to produce young). The mean productivity for the colony was 2.26 young per active nest. Eagles were observed nearby but harassment or incursion into the colony was not observed.

By mid-April, it was determined that the newly-formed Hylebos colony was going to be viable and incubation was taking place in large enough numbers to commence forage site selection observations by nest (i.e. recording arrivals and departures). Asynchronous nesting in the colony made the determination of pre-clutch completion difficult. By estimating and using the seven day rule, the range for clutch completion for a majority of the birds in the colony was determined to be between April 21, 1997 and May 27, 1997. After reviewing mean and mode values from the range, May 1, 1997 was selected to represent the end of the pre-clutch completion phase for the Hylebos colony.

Observations of arrivals and departures was reported by colony and by nest. No significant differences were noted between the two data sets, and since most nests were successful in producing young, no correlation could be drawn between failed nests and forage site selection. Over 140 observations were recorded between April 2, 1997 and May 1, 1997 during the pre-clutch phase. Approximately 76 of these recorded arrival and departure observations received the high confidence data qualifier (birds were observed with a clearly known origin or destination into or out of a foraging site location). Of these observations, 44.7% could be linked to forage sites within Commencement Bay.

From May 1, 1997 to July 19, 1997, arrival and departure observations were recorded 627 times during the incubation and chick present stage. Of these observations, 323 were designated with the high confidence data qualifier and 71.2% were linked with forage sites within Commencement Bay. Due to data collection complications resulting from the failed Dumas Bay colony and the asynchronous nesting exhibited in the Hylebos colony, no attempt was made to further separate the observation data into other nesting time periods (i.e. 1 chick present at nest versus 2 or more). **Figure 16** illustrates the patterns of arrival and departure observations during the pre-clutch completion and incubation/chick present nesting phases for the Hylebos colony. Numbers and percentages depicted in **Figure 16** represent an approximation of what was observed using both the high confidence qualified data and data qualified as being a lower confidence level quality[5]. Correlation of nest

[5]Arrivals or departures were clearly seen along with flight direction, but no determination could be made whether the bird came directly from or landed in a specific foraging site location.

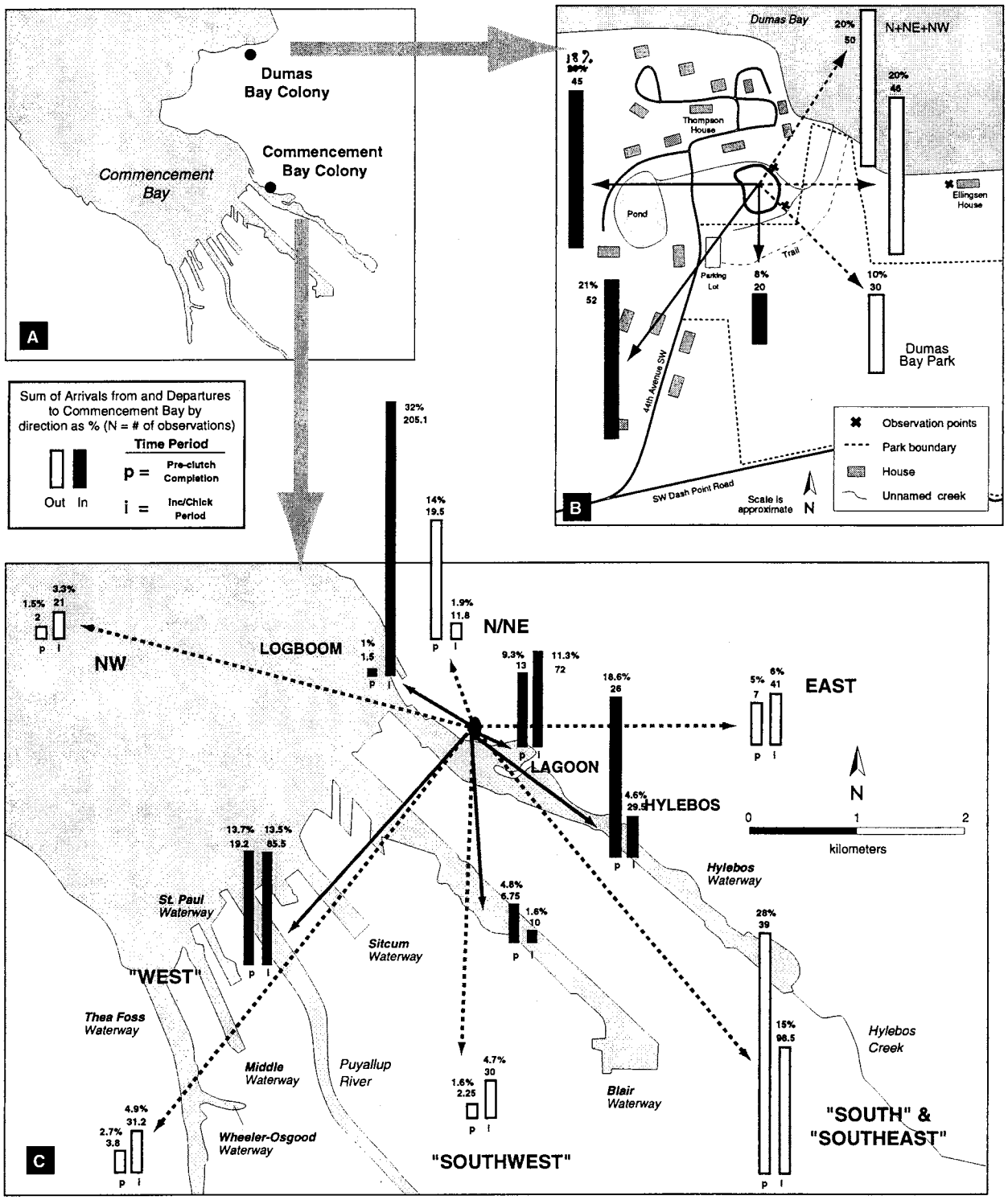


Figure 16. Arrival and departure data results from the Dumas Bay (B) and Hylebos (C) great blue heron great blue heron colony in 1997.

failure and the selection of foraging locations inside Commencement Bay was not meaningful since very few nests failed at the Hylebos colony and most birds were found to be foraging in Commencement Bay.

C3.3 Comparison Colonies at Auburn and Nisqually

The Peasley Canyon colony at Auburn had nearly 60 nests before being abandoned at the end of May 1997. Continuous bald eagle harassment and incursions similar to what was observed at the Dumas Bay colony most likely contributed in the colony's failure. The Nisqually colony was also subjected to eagle incursions but continued to be successful with approximately 68 nests fledging young at rates within a normal distribution. Nesting also appeared to be synchronous.

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Appendix A

Morphological measurements of eggs collected in Commencement Bay, WA

Table A-1 Morphological measurements of eggs collected in 1996 from Commencement Bay, WA

Date	*Species*	*Sample ID*	*General Condition*	*Float Stage/ Approx. Age (days)*	*Whole Egg Weight (gms)*	*Length (mm)*	*Width (mm)*
11apr96	Great Blue Heron	GBH96-1	fresh/good	0/1-5	71.12	64.34	45.20
11apr96	Great Blue Heron	GBH96-2	fresh/hairline crack	--/11-12	70.91	66.10	46.10*
11apr96	Great Blue Heron	GBH96-3	fresh/good	0/1-5	66.22	61.32	45.26
11apr96	Great Blue Heron	GBH96-4	fresh/good	5/14-15	63.88	62.74	45.62
11apr96	Great Blue Heron	GBH96-5	fresh/good	5/17-20	64.22	60.16	46.58
05jun96	Mallard	MAL96-1	fresh/good	3/10-11	26.84	46.38	33.65
05jun96	Mallard	MAL96-2	fresh/good	2/7-8	24.25	45.30	31.92

Date	*Species*	*Sample ID*	*Volume (Mean of 3 reps.) (ml)*	*Jar Weight (gms)*	*Jar/egg contents Weight (gms)*	*Egg Contents Weight (gms)*	*Shell Weight (fresh/dry) (gms)*
11apr96	Great Blue Heron	GBH96-1	68.15	201.21	264.50	63.29	7.74/6.22
11apr96	Great Blue Heron	GBH96-2	--	201.29	265.20	63.91	6.91/5.67
11apr96	Great Blue Heron	GBH96-3	62.99	201.88	259.20	57.32	8.75/5.94
11apr96	Great Blue Heron	GBH96-4	65.80	200.38	258.13	57.75	6.07/6.15
11apr96	Great Blue Heron	GBH96-5	65.99	201.29	259.19	57.90	6.12/5.95
05jun96	Mallard	MAL96-1	29.23	110.85	135.42	24.57	2.22/ --
05jun96	Mallard	MAL96-2	26.37	110.59	132.59	22.00	2.18/ --

** Approximated value. Volume calculated by formula (USFWS 1990).*

Appendix B

Data validation report - Avian tissue analysis 1995 and 1996

EcoChem, Inc.

Environmental Science and Chemistry

DATA VALIDATION REPORT
AVIAN TISSUE ANALYSIS 1995 and 1996

Prepared for:

U.S. Fish and Wildlife Service
Division of Environmental Contaminants
North Pacific Coast Ecoregion
Western Washington Field Office
Olympia, Washington

Prepared by:

EcoChem, Inc.
100 South King Street, Suite 405
Seattle, Washington 98104-2885

September 16, 1998

100 South King Street • Suite 405 • Seattle, WA 98104-2885 • (206) 233-9332 • Fax (206) 233-0114

DATA VALIDATION REPORT
EGG RESIDUE ANALYSIS 1995 AND 1996

Introduction

This report summarizes results from a review of analytical data for 8 avian eggs collected in 1995 and 7 avian eggs collected in 1996 by the U.S. Fish and Wildlife Service. Analyses for polychlorinated biphenyls (PCBs), polychlorinated dibenzodioxins/furans (PCDDs/PCDFs) and percent lipids were performed by Alta Analytical Laboratory (El Dorado Hills, CA). Analyses for pesticides, semivolatile organics, butyltins, and metals were performed by ToxScan, Inc. (Watsonville, CA). A list of samples reviewed is provided in **Table 1.**

Basis for Data Review

Data packages were received from the laboratories for each year of samples submitted. The package consisted of sample results with a summary of associated quality control (QC) information. Data packages did not include sample preparation information, instrument calibration data, run logs, or instrument printouts. Thus, only summary information could be assessed, and calculation checks could not be performed.

Data were reviewed by EcoChem, Inc. using criteria as specified in the method referenced in the laboratory report or the laboratory method (if provided), and general guidelines as presented in US EPA Functional Guidelines (US EPA, 1994). Qualified data are summarized in **Table 2.**

Completeness

The laboratory did not provide a case narrative which describes the analyses and any anomalies found during analysis. A chain of custody (COC) form was not included by Alta Analytical with the 1995 data, but the laboratory's check-in form noted that a COC accompanied the samples. The requested analytical results were provided by both laboratories for all samples.

The 1995 PCB analyses did not include results for several individual PCB congeners, which were provided with the 1996 PCB results (congeners 105, 114, 123, **156, 157, 167, 189).** The 1995 total PCB results included these congeners, but the individual congener results were not recorded by the laboratory.

Overall Assessment

Quality control (QC) information which was reported indicated good analytical recovery and precision. Some results for octachlorodibenzodioxin (OCDD) and octachlorodibenzofuran (OCDF) are recommended to be qualified as not detected (U) because the laboratory blank results indicated possible cross contamination. Method criteria for the butyltin analyses were not provided and no QC information was provided with the trace metals report. Thus no assessment of the precision or accuracy of the butyltin or metals data could be made. Because the data quality could not be assessed, these data are recommended to be estimated. However, the

information on methods, and the results reviewed, indicate that the metals and tributyltin data would be appropriate for screening purposes.

The laboratory reported different detection limits for some analytes for the 1995 samples than for the 1996 samples. The trace metal detection limits were higher in 1996 than in **1995,** which could affect the comparability of the metal results within 5 times the detection limit. The detection limits for the semivolatile organic analyses were significantly higher in 1995 than in 1996. Because of these higher detection limits, less semivolatile compounds were detected in the eggs collected in 1995 than 1996.

The specific technical items assessed for each laboratory report, and data qualifications are summarized in the following sections.

I. DATA REVIEW OF PCB RESULTS

The tissue samples were analyzed for PCBs by gas chromatography/high resolution mass spectrometry/selective ion monitoring (GC/HRMS/SIM) using a combination of features from EPA Method 680 to measure PCB homologues, and Method 1668 to extract, cleanup sample extracts, and measure specific PCB congeners. The laboratory modified their PCB method between the 1995 and 1996 sample analyses, thus different internal standards and PCB congeners were reported for each of the years.

The quality control (QC) requirements that were reviewed are listed below.

- Blanks (Method)
- In tern al Standards
- * Laboratory Control Sample
- * Matrix Spikes
- * Laboratory Duplicates
- Reported Detection Limits

Those items marked with an asterisk (*) may not meet all specified QC criteria and are discussed below. QC items not marked with an asterisk meet all QC criteria.

Laboratory Control Sample

Recovery results from a Laboratory Control Sample (LCS) and a duplicate LCS analysis were reported indicating good recovery for individual PCB congeners. The concentration of the analytes in the LCS were not stated, thus it is not possible to evaluate how comparable these recoveries may be to the recovery of PCBs in the actual samples.

Matrix Spikes

No matrix spike results were provided. As the analysis was performed by isotope dilution, the samples were spiked with similar compounds, which provides excellent recovery information for each sample extracted. The isotopic recovery results indicated good recovery was obtained.

Duplicates

No sample duplicate results were reported. Thus, precision of the overall subsampling and the analytical method could not be evaluated.

II. DATA REVIEW OF PCDD AND PCDF RESULTS

The 1995 and 1996 tissue samples were analyzed for PCDDs and PCDFs by GC/HRMS/SIM using EPA Method 8290. The 1995 data summary lists the sample matrix as "fish" rather than "egg" for some of the samples and associated quality control.

The quality control (QC) requirements that were reviewed are listed below.

* Blanks (Method)
  internal Standards
* Laboratory Control Sample
* Matrix Spikes
* Laboratory Duplicates
  Reported Detection Limits

Those items marked with an asterisk (*) may not meet all specified QC criteria and are discussed below. QC items not marked with an asterisk meet all QC criteria.

Blanks

OCDD (1.3 pg/g) and OCDF (3.6 pg/g) were detected in the 1995 method blank, and OCDD (5.4 pg/g) only in the 1996 method blank. Validation guidelines recommend that data within ten times a reported OCDD blank result and five times a reported OCDF blank result should be qualified as "non-detected" **(U).**

Laboratory Control Sample

Recovery results from a Laboratory Control Sample (LCS) and a duplicate LCS analysis were reported indicating good recovery for PCDD and PCDF. The concentration of the analytes in the LCS were not stated, thus it is not possible to evaluate how comparable these recoveries may be to the recovery of these compounds in the actual samples.

Matrix Spikes

No matrix spike results were provided. As the analysis was performed by isotope dilution, the samples were spiked with similar compounds, which provides excellent recovery information for each sample extracted. The isotopic recovery results indicated good recovery was obtained.

Duplicates

No sample duplicate results were reported. Thus, precision of the overall subsampling and the analytical method could not be evaluated.

III. DATA REVIEW OF PESTICIDE AND HERBICIDE RESULTS

The 1995 and 1996 tissue samples were analyzed for chlorinated pesticides by EPA Method 8080 and chlorinated herbicides by EPA Method 8150. Both methods are using gas chromatography with a electron capture detector (GC-ECD).

The quality control (QC) requirements that were reviewed are listed below.

- Blanks (Method)
- Surrogate Recovery
- * Laboratory Control Sample
- * Matrix Spikes
- * Laboratory Duplicates
- Reported Detection Limits

Those items marked with an asterisk (*) may not meet all specified QC criteria and are discussed below. QC items not marked with an asterisk meet all QC criteria.

Laboratory Control Sample

Recovery results from a Laboratory Control Sample (LCS) were reported indicating good recovery for pesticides and herbicides. The concentration of the analytes in the LCS were not stated, thus it is not possible to evaluate how comparable these recoveries may be to the recovery of the compounds in the actual samples.

Matrix Spikes

No matrix spike results were provided. Thus, it is not possible to assess if sample interferences may cause problems in achieving analytical accuracy.

Duplicates

No sample duplicate results were reported. Thus, precision of the overall subsampling and the analytical method could not be evaluated.

IV. DATA REVIEW OF SEMIVOLATILE ORGANIC RESULTS

The 1995 and 1996 tissue samples were analyzed for semivolatile organics by EPA Method 8270 using gas chromatogrtiphy with mass spectroscopy (GC/MS).

The quality control (QC) requirements that were reviewed are listed below.

- Blanks (Method)
- Surrogate Recovery
- * Laboratory Control Sample
- * Matrix Spikes
- * Laboratory Duplicates
- * Reported Detection Limits

Those items marked with an asterisk (*) may not meet all specified QC criteria and are discussed below. QC items not marked with an asterisk meet all QC criteria.

Laboratory Control Sample

Recovery results from a Laboratory Control Sample (LCS) were reported indicating good recovery for a subset of semivolatile compounds. The concentration of the analytes in the LCS were not stated, thus it is not possible to evaluate how comparable these recoveries may be to the recovery of the compounds in the actual samples.

Matrix Spikes

No matrix spike results were provided. Thus, it is not possible to assess if sample interferences may cause problems in achieving analytical accuracy.

Duplicates

No sample duplicate results were reported. Thus, precision of the overall subsampling and the analytical method could not be evaluated.

Reported Detection Limits

The sample detection limits are high for the results reported in 1995. In the 1995 data summary, only one positive result was reported in a single sample. Thus, the high detection limits resulted in limited positive results. Commonly, detection limits in tissue can be obtained which are an order of magnitude lower than those reported. In 1996 better detection limits were obtained, and more positive results were obtained.

REFERENCE

US Environmental Protection Agency. 1994. *National Functional Guidelines for Organic Data Review.* EPA-540/R94/0 12. Washington, D.C.

Table 1 Avian Egg Sample Results Reviewed

Field ID	Date Collected
HBS-1	4/7/95
HBS-2	4/7/95
BGD-1	4/7/95
BGD-2	4/7/95
SIM-1	5/5/95
SIM-2	5/5/95
SIM-3	5/5/95
SIM-4	5/5/95
GBH96-1	4/8/96
GBH96-2	4/8/96
GBH96-3	4/8/96
GBH96-4	4/8/96
GBH96-5	4/8/96
MAL96-1	5/1/96
MAL96-2	5/6/96

Table 2 Summary of Qualified Data

Field ID	Lab ID	Analysis	Analyte	Qualifier	Reason
HBS-1	1826-0001-SA	Dioxin	OCDD	U	Blank contamination
HBS-2	1826-0002-SA	Dioxin	OCDF	U	Blank contamination
BGD-1	1826-0003-SA	Dioxin	OCDD	U	Blank contamination
BGD-2	1826-0004-SA	Dioxin	OCDF	U	Blank contamination
SIM-1	1826-0005-SA	Dioxin	OCDF	U	Blank contamination
SIM -2	1826-0006-SA	Dioxin	OCDD	U	Blank contamination
SIM-2	1826-0006-SA	Dioxin	OCDF	U	Blank contamination
SIM-3	1826-0007-SA	Dioxin	OCDD	U	Blank contamination
SIM-3	1826-0007-SA	Dioxin	OCDF	U	Blank contamination
SIM-4	1826-0008-SA	Dioxin	OCDD	U	Blank contamination
SIM-4	1826-0008-SA	Dioxin	OCDF	U	Blank contamination
GBH96-1	2629-0001-SA	Dioxin	OCDD	U	Blank contamination
GBH96-2	2629-0002-SA	Dioxin	OCDD	U	Blank contamination
GBH96-3	2629-0003-SA	Dioxin	OCDD	U	Blank contamination
GBH96-4	2629-0004-SA	Dioxin	OCDD	U	Blank contamination
GBH96-5	2629-0005-SA	Dioxin	OCDD	U	Blank contamination
MAL96-1	2629-0006-SA	Dioxin	OCDD	U	Blank contamination
MAL96-2	2629-0007-SA	Dioxin	OCDD	U	Blank contamination
All Samples	Tox Scan T-12800; Tox Scan T-13734	Trace Metals	Antimony, Arsenic, Cadmium, Copper, Lead, Mercury, Nickel, Selenium, Silver, Zinc	J	QC results not provided
All Samples	Tox Scan T-12800; Tox Scan T-13734	Tributyltin	Monobutyltin, Dibutyltin, Tributyltin, Tetrabutyltin	J	Method criteria unspecified