1F05

4040

ENVIRONMENTAL CONTAMINANTS IN BALD EAGLES NESTING IN HOOD CANAL, WASHINGTON, 1992 - 1997

Final Report

Study ID: 13410-1130-1F05

August 2001

ENVIRONMENTAL CONTAMINANTS IN BALD EAGLES NESTING IN HOOD CANAL, WASHINGTON, 1992 - 1997

STUDY ID: 13410-1130-1505

FINAL REPORT

By:

M.S. Mahaffy
U.S. Fish and Wildlife Service
Western Washington Fish and Wildlife Office
Lacey, Washington 98503

K.M. Ament and A.K. McMillan
Washington Department of Fish and Wildlife
Port Angeles Washington

D.E. Tillitt
U.S. Geological Survey, Biological Resources Division
Environmental Contaminant and Research Center
Columbia Missouri

August 2001

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The number of bald eagle nesting territories along Hood Canal in Washington State have increased from 3 known occupied territories in 1980 to 35 in 2000. Historically, the average productivity and success rate of eagles nesting in the Hood Canal territories was below the overall Washington State productivity and a success rate, and they fluctuated dramatically. The Hood Canal eagle territories have, however, achieved an average of 0.96 young per occupied territory and a success rate of 64.2 % over the past 5 years. These levels are close to the recovery objectives in the Pacific Bald Eagle Recovery Plan. A study was initiated in 1992 to evaluate if contaminants were a possible cause of the lower productivity. In 1992 and 1993, fresh eggs were collected from eight Hood Canal bald eagle territories. Nests with a history of the highest failure rates were selected for sampling. Between 1994 and 1997, only addled eggs were collected from the Hood Canal area nests. Addled eggs were also collected from 5 bald eagle nesting territories outside the Hood Canal area for comparison. Total PCB concentrations measured in the eggs collected from the Hood Canal territories exceeded threshold levels identified for normal bald eagle reproduction. The total dioxin-like activity measured in the eggs of bald eagles were above the threshold for adverse effects on reproduction. Overall, the eggs collected from Hood Canal territories during 1992 and 1993 had higher total PCB concentrations and total dioxin-like potency than eggs collected between 1994 and 1997 from Hood Canal and in eggs collected from outside the Hood Canal area. Non-*ortho* and mono-*ortho* planar PCBs measured in the bald eagle eggs accounted for the majority of the dioxin-like toxicity. Only two eggs collected during the study (one from Hood Canal and one from outside the Hood Canal area) exceeded the reproductive threshold limit for p,p'-DDE. Concentrations of mercury, selenium and arsenic were below levels of concern in the five eggs where they were analyzed. Detectable levels of PCBs and p,p'-DDE were present in blood samples. Concentrations of PCBs and dioxin-like compounds measured in the fish and sediment samples from Hood Canal were not great enough to account for the elevated amounts found in bald eagles from this area. Our sample sizes for the evaluation of the source of PCBs and other dioxin-like contaminants found in bald eagles and their eggs were extremely small and definite conclusions can not be made. However, our findings indicate that the contaminant pathway to the bald eagles in Hood Canal was likely from food items other than fish (ie. birds or marine mammals). At this time, additional contaminant studies on the Hood Canal bald eagles are not planned; however, productivity monitoring needs to be continued. If the productivity levels begin to fluctuate dramatically, or if they are consistently lower than statewide values, we recommend re-initiating a contaminants study. Since PCBs accounted for the greatest proportion of the total dioxin-like potency in the eggs of bald eagles from Hood Canal, we recommend that measurement of total PCBs would be sufficient to track the greatest chemical threat identified to the Hood Canal eagles if a contaminants monitoring effort were to resume.

INTRODUCTION

The bald eagle (*Haliaeetus leucocephalus*) is currently listed as a federally threatened species under the Endangered Species Act. In July 1999, the U.S. Fish and Wildlife Service published a proposal to remove the bald eagle from the List of Endangered and Threatened Wildlife (USDI 1999). At the time the species was listed, environmental contaminants were cited as the primary reason for its decline. Beginning in the 1940s, dichlorodiphenyltrichloroethane (DDT) and other organochlorine pesticides became widely used as insecticides. In the late 1960s and early 1970s, it was determined that dichlorophenyldichloroethylene (DDE), the principal breakdown product of DDT, accumulated in the fatty tissues of adult female bald eagles and caused eggshell thinning and reproductive failure (Wiemeyer *et al.* 1972, 1984; Grier 1982). Due to the bioaccumulative and persistent nature of DDT and the adverse reproductive effects elicited by DDT, particularly on birds, its use was banned in the United States in 1972. Restrictions on organochlorine pesticides, combined with concerted efforts to protect and manage habitat and to stop persecution, have resulted in recovery of bald eagle populations throughout most of the contiguous United States (USDI 1999).

As predators at the top of the food chain, bald eagles and other fish-eating birds are exposed to persistent environmental chemicals that accumulate in their prey. Productivity of bald eagles (Anthony *et al.* 1993, Buck *et al.* 1999) and double-crested cormorants (*Phalacrocorax auritus*, Buck and Sproul 1999) nesting near the Lower Columbia River continue to be impacted by dioxin-like compounds, including polychlorinated biphenlys (PCBs). Bald eagles (Colborn 1991, Kozie and Anderson 1991, Bowerman 1993, Best *et al.* 1994), Forster's terns (*Sterna forsteri*, Kubiak *et al.* 1989) and double-crested cormorants (Tillitt *et al.* 1992) from the Great Lakes were reported to be adversely impacted by organochlorine contaminants. Poor reproductive success of bald eagles in Maine were possibly linked to high PCB concentrations as well (Welsh 1994).

The number of known occupied bald eagle territories in Washington increased from 105 in 1980 to 664 in 1998. The estimated number of young produced increased by over 700% between 1980 and 1998 (WDFW, unpublished data). The bald eagle recovery plan for the Pacific Region established recovery goals of an average reproductive rate of 1.0 fledged young per occupied breeding area and an average success rate for occupied breeding areas of not less than 65% over a 5 year period (USFWS 1986). Although these goals largely have been met in Washington (USDI 1999), they have not been met in some areas of Washington, including Hood Canal. The Hood Canal area, however, came close to meeting the recovery goals for the first time in 2000 with a five year average of 0.96 fledged young per occupied breeding area and an average success rate of 64.2 % for occupied breeding areas.

In 1992, concern was raised because productivity of the Hood Canal nests remained significantly below Washington's (average) productivity average and fluctuated more dramatically than statewide values most years (Figure 1). The average success rate for occupied territories also tended to be lower for Hood Canal territories than the overall Washington State average

(Figure 2). A contaminants study was initiated in 1992 to evaluate if contaminants were a possible cause of the lower productivity. The primary study objectives were to: 1) evaluate productivity of the Hood Canal territories, 2) determine if elevated concentrations of dioxins, furans, PCBs, organochlorine pesticides, and metals were present in bald eagle eggs collected from nests near Hood Canal, and, 3) evaluate whether the contaminant levels present could be significantly contributing to the reproductive failures seen in the bald eagles from Hood Canal. An additional objective was to evaluate if resident bottom fish could be a source of contaminants.

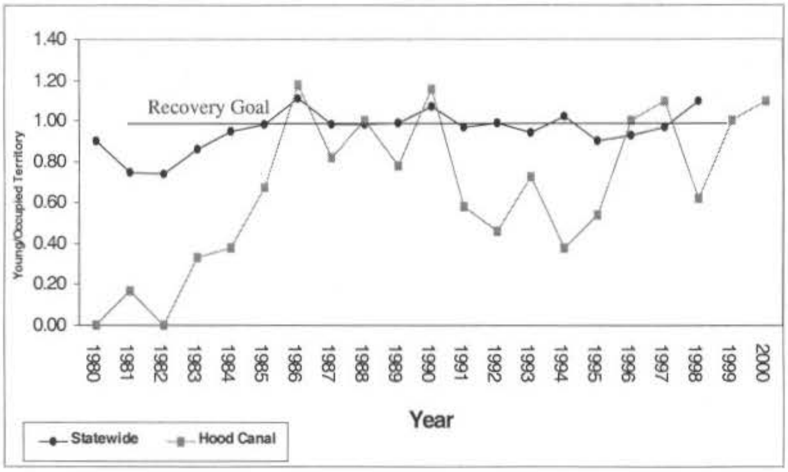

Figure 1: Annual bald eagle productivity (young/occupied territory with a known outcome) for the Hood Canal compared to the overall Washington State bald eagle productivity values.

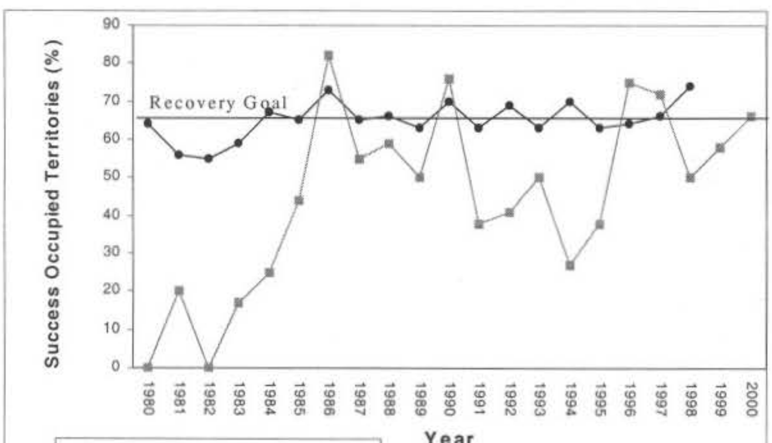

Figure 2: Estimated annual fledging success of occupied bald eagle territories for Hood Canal compared to the overall Washington State bald eagle success rate.

Study Area

Hood Canal is a 100-km, narrow deepwater fjord characterized by restricted water circulation and extreme water depths in west Puget Sound, Washington (Figure 3). Unique hydrogeologic characteristics make Hood Canal particularly sensitive to water pollution. Due to a shallow sill near the entrance of Hood Canal, water exchange is greatly reduced (Hood Canal Technical Work Group 1995). The three counties bordering Hood Canal are among the fastest growing counties in the state. A lumber mill at Port Gamble and the U.S. Naval Submarine Base at Bangor, both on the eastern shoreline of the northern reach of Hood Canal, are the two major industrial centers (Hood Canal Technical Work Group 1995).

Forested land accounts for over 86 % of the land area on the eastern side of Hood Canal and an even higher percentage on the western side (Rhine and Doane 1995). The upland forests, dominated by Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), and western redcedar (*Thuja plicata*), provide nest structures and perches for bald eagles (Leach 1996). Potential bald eagle prey species, including fish, seabirds, marine mammals and molluscs, are available throughout Hood Canal (Watson 1996, Leach 1996).

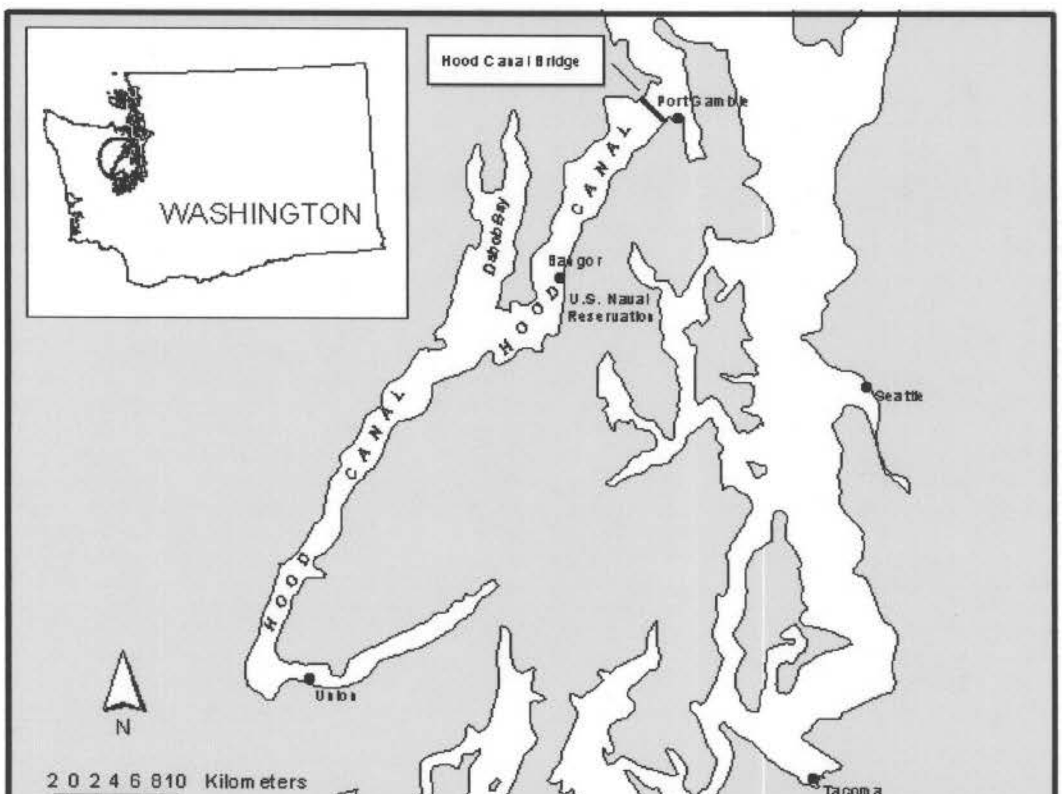

Figure 3: Study area for the Hood Canal, Washington bald eagle contaminants study, 1992-1997.

METHODS

Occupancy and Productivity Surveys

Occupancy and productivity surveys have been conducted by Washington Department of Fish and Wildlife (WDFW) on Hood Canal from 1980 to 2000. The Hood Canal bald eagle territories are defined as those associated with Hood Canal and Dabob Bay. Occupancy surveys of bald eagle territories were conducted using a fixed wing aircraft in early April. Territories were recorded as occupied if two adults were present, young or eggs were in the nest, or an adult was observed in incubation posture on the nest. Productivity surveys of the occupied nests were conducted by WDFW in early to mid-June using a helicopter. The number of young per nest were recorded and compared from year to year.

Site Selection for Contaminant Monitoring

Prior to the 1992 and 1993 nesting seasons, bald eagle territories with a repeated history of failure were selected for the contaminant study. Five territories were selected in 1992 and four in 1993 for the collection of fresh eggs (Appendix A). Aerial surveys of the Hood Canal territories were conducted the last week in March in addition to the early April aerial survey to determine the earliest evidence of egg laying and incubation. Beginning in 1994, only addled eggs were collected. Nests with addled eggs were identified during the mid-June productivity flights. When available, addled eggs also were collected from nests outside the Hood Canal territories in Western Washington for comparative purposes. Stations for sediment and fish collections were selected in the vicinity of the bald eagle nesting territories that were sampled.

Sample Collection and Processing

Eggs

In 1992, eggs were collected immediately after laying. One egg was collected from each selected nest between one to four days after the first evidence of laying or incubation. Nests were accessed by a professional tree climber. The eggs were wrapped in aluminum foil and placed in a cushioned can, then lowered by rope to an observer on the ground. A minimal amount of time was spent in each territory during egg collection.

In 1993, eggs were only collected from three of the four selected nests because it was not possible to safely climb one nest tree. One egg was collected from each of the three nest trees. Only one of the eggs was collected one day after first evidence of incubation. The other eggs were collected after incubation had occurred for a longer period of time (7 days at one nest tree and 16 days at the other) in an attempt to decrease the chance of nest desertion.

Between 1994 and 1997, a total of 5 addled eggs were collected from Hood Canal nests. One nest sampled in 1996 (Union) and one nest sampled in 1997 (Toandos East) were the same nests where eggs were collected in 1993 and 1994, respectively. Figure 4 shows the locations of the Hood Canal bald eagle territories where eggs were collected. Between 1992 and 1997, a total of five addled eggs were also collected from territories outside Hood Canal. Four were from the outer coast and one was from an inland Skagit River territory.

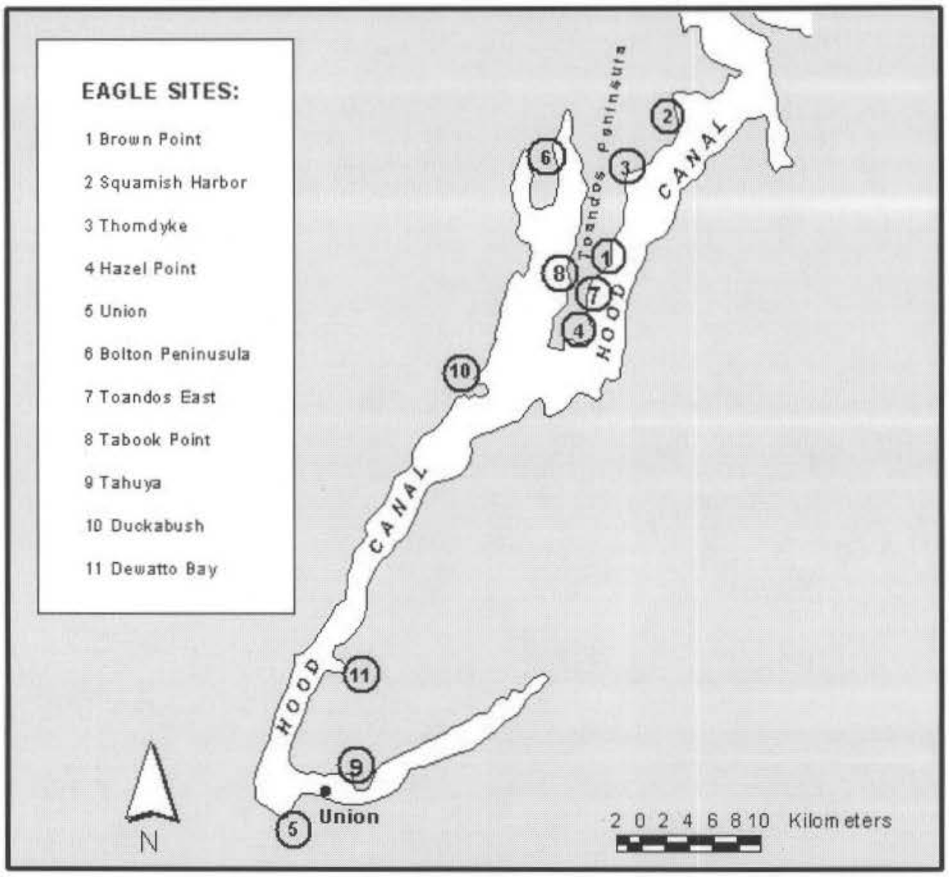

Figure 4: Locations of Hood Canal bald eagle territories where eggs were collected for contaminant analyses, 1992 - 1997.

The eggs were stored in a refrigerator (4°C) until they were processed. Length, width and weight of the eggs were measured in the lab. Eggs were cut along the equator and contents placed in chemically-cleaned jars with teflon-lined lids and weighed. Eggshells were washed with water and air-dried for a minimum of 30 days. Using a dial micrometer, shell thickness (including membrane) was determined by averaging the measurements at five different locations on the approximate equator of the egg. Eggshell thinning was calculated as the percent difference between mean eggshell thickness of each egg and the mean eggshell thickness (0.6088 mm) of bald eagle eggs from the region prior to 1947, pre-DDT (Anderson and Hickey 1972).

Blood

Whole blood samples were collected from a total of four nestling bald eagles from different Hood Canal nests in 1995, 1996, and 1997. Whole blood samples were also taken from five adult bald eagles in the Hood Canal area and one adult bald eagle from an Indian Island nesting territory (five miles north of Hood Canal) in 1995 and 1996. Three of the eagles captured in the Hood Canal area were transients and two were from Hood Canal nesting territories. The adult birds were captured as part of a satellite telemetry study (Watson and Pierce 1998a).

Approximately 6cc of blood were taken from each eagle using a 12-ml disposable syringe and a 21-gauge needle. The blood was immediately transferred to heparinized glass vacutainers and stored on ice until they could be frozen upright. Blood samples were stored for more than four months prior to residue analysis. A loss of DDE occurs within two weeks after freezing (Wiemeyer *et al.* 1984) so the reported blood DDE concentrations are minimum values.

Carcasses

Tissue samples were collected from 1 immature and 2 adult bald eagles found in the study area in 1993 and 1994. The immature eagle was found dead on Indian Island and one adult eagle was found dead near East Bremerton. The causes of death were unknown. The second adult eagle, died of injuries following what appeared to be a territorial battle near Quilcene Bay. It was not known if the birds were transients or resident birds.

Fish

In May 1994, composites of five starry flounder (*Platichthys stellatus*) were collected from five locations in the Hood Canal/Dabob area (Fig. 5). Starry flounder were selected to be sampled because bald eagles have been documented to feed on these fish in Hood Canal (Jim Watson pers. comm 1993, Watson *et al.* 1996). One additional composite of five great sculpin (*Myoxocephalus polyacanthocephalus*) was collected at a shallower location at one of the five sites. A commercial trawler was used to collect the fish. Mixed age composites of 5 fish were collected at each sample location. Fish lengths and weights were measured, composites labeled, and samples frozen while still on the trawler.

Sediments

Sediment samples were collected using a ponar dredge at each fish collection site in 1994 (Figure 5). Samples were taken from a depth of approximately 10 to 18 meters. Each sample was obtained by mixing four subsamples representing approximately the top 10 centimeters of sediment at each site. The subsamples were homogenized in a decontaminated stainless steel bowl and placed in chemically clean jars. Sampling equipment was decontaminated between stations. One additional sediment sample was collected using a van Veen grab sample from a 192 meter deep site in Dabob Bay in April 1994 as a comparison. The top 2 centimeters of sediment were collected from several grab subsamples and homogenized in a decontaminated stainless steel bowl.

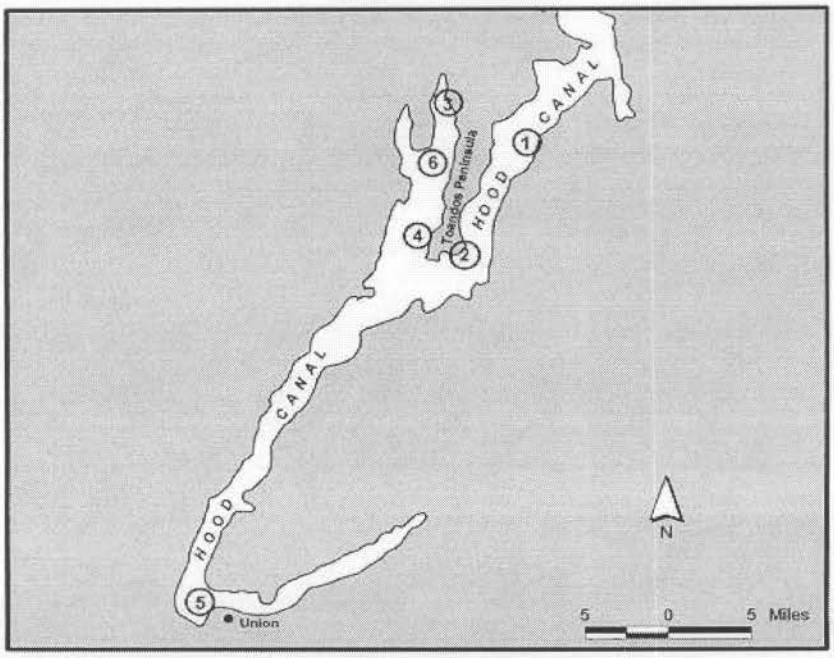

Figure 5: Sample locations for fish samples (Sites 1-5) and sediment samples (Sites 1-6) collected as part of the Hood Canal bald eagle contaminant study in 1994.

All Samples

Following sample processing in the laboratory, all of the samples (egg, fish, sediment, blood and tissue) were stored frozen at -20° until they were submitted for contaminant analyses. Samples were shipped overnight on dry ice to the U.S. Geological Survey, Biological Resources Division, Columbia Environmental Research Center (CERC) in Columbia, Missouri for analyses.

Contaminant Analyses

Samples were submitted to CERC for homogenizing and chemical analyses. All of the bald eagle egg, fish and sediment samples were analyzed for dioxin-like compounds including seven polychlorinated dibenzo-*p*-dioxins (PCDDs), ten dibenzofurans (PCDFs) and four non- and eight mono-*ortho*-chloro substituted PCB congeners (Table 1). Congener-specific analyses of PCB residues were conducted for the egg, eagle tissue, fish and sediment samples. The PCB congener identification numbers used in this paper follow that of the International Union of Pure Applied Chemistry (IUPAC).

A screen for p,p'-DDE (a principle metabolite of DDT) was also conducted for all the samples. Prior to conducting the screen for p,p'-DDE and the congener-specific PCB analyses, a scan was conducted for total PCBs. The scan for total PCBs was based upon a combined Aroclor standard (1242:1248:1254:1260 in a 1:1:1:1 ratio). These standards were quantified based upon the total peak area. Because environmental samples have many other detectable peaks and interferences (such as OC pesticides and phthalates) and are changed by weathering and through the trophic chain, such samples can be up to 20% higher than the concentration as determined by a sum of individually determined congeners. The scan for total PCBs was not conducted on the last set of five eggs analyzed. Only the 1992 eggs had metal analyses (arsenic, selenium, and mercury) and a complete organochlorine pesticide scan.

Table 1: Samples analyzed for the Hood Canal bald eagle study, 1992-1997

Samples	Year	Total PCB Scan	Congener Specific PCBs	Dioxins/ Furans	DDE Scan	OC Pesticide Scan	Arsenic, Mercury, Selenium
Hood Canal Eggs							
5 eggs (fresh)	1992	x	x	x	x	x	x
3 eggs (fresh)	1993	x	x	x	x		
1 egg (addled)	1994	x	x	x	x		
1 egg (addled)	1995	x	x	x	x		
1 egg (addled)	1996		x	x	x		
2 eggs (addled)	1997		x	x	x		
Outside Hood Canal Eggs							
1 egg (addled)	1992	x	x	x	x		
2 eggs (addled)	1995	x	x	x	x		
1 egg (addled)	1996		x	x	x		
1 egg (addled)	1997		x	x	x		
Eagle Blood Samples							
7 samples	1995	x			x		
3 samples	1996				x		
1 samples	1997				x		
Eagle Carcasses							
1 bird	1993	x			x		
2 birds	1994	x			x		
Fish Samples							
6 samples	1994		x	x	x		
Sediment Samples							
6 samples	1994		x	x	x		

All samples were thawed at room temperature. Sediment samples were air dried. Egg samples were homogenized in a blender, and tissue and sediment samples were ground. The samples were aliquoted for analysis (except the blood samples, in which the entire sample was used) and dehydrated with three-to-four times their weight of anhydrous sodium sulfate. The samples were extracted using methylene chloride as the solvent. The resultant extract was concentrated by rotoevaporation. The extracts were treated by a two stage reactive column clean-up; employing first a sulfuric acid silica gel/potassium silicate column and then, a column of sulfuric acid silica gel/potassium silicate/silica gel. The extracts were further purified with high performance gel permeation chromatography according to Meadows (1991). Extracts were analyzed for DDE and total PCBs at this point. The samples were then fractionated on an automated C-18/PX-21 carbon column system according to Feltz (1994), isolating four fractions: 1) bulk and di-*ortho* PCB congeners, 2) mono-*ortho* PCB congeners, 3) non-*ortho* PCB congeners, and, 4) PCDDs/PCDFs.

PCDD/PCDF fractions were eluted through basic alumina for removal of potential co-contaminants such as chlorinated diphenyl ethers and residual polychlorinated naphthalenes and PCBs. A total of 1 ng of the instrumental internal standard, ^{13}C-labeled 1,2,3,4-PCDD, was added to each semiconical autosampler vial prior to final transfer. The alumina fractions were transferred under a steam of nitrogen.

PCDD/PCDF fractions were determined by gas chromatography/high resolution mass spectrometry (GC/HRMS) by monitoring five sequential mass windows of selected ions during the chromatographic separation (Kuehl *et al.* 1991). The non-*ortho* PCB congeners also were determined by GC/HRMS, by monitoring two sequential mass windows of selected ions during the chromatographic separation (Peterman 1994).

The bulk and di-*ortho* PCB congeners and the mono-*ortho* PCB congeners were determined by capillary gas chromatography/electron capture detection (CGC/ECD). Analysis of bulk and di-*ortho* PCB congeners followed the methods of Schwartz and Stalling (1991) for congener-specific analysis. Analysis of mono-*ortho* PCBs followed the methods of Meadows (1992) for samples collected in 1992 and Swartz *et al.* (1993) for and those collected in later years. Method limits of detection target concentrations were 1.0 pg/g for dioxins and furans and <1 ng/g for the PCB congeners.

Aliquots of enriched sample extracts from the 1992 Hood Canal territory eggs were analyzed by CGC/ECD to measure residues of 25 organochlorine contaminants. The CGC/ECD analyses were similar to those described in Schmitt *et al.* (1990).

Arsenic and selenium sample preparation included subjecting an aliquot of each to a combination nitric/hydrochloric acid wet digestion followed by dry ashing with magnesium nitrate. Prepared digestates were analyzed by hydride generation atomic absorption spectroscopy. For mercury, samples were digested by a microwave oven procedure employing both nitric acid and hydrogen peroxide. Digestates were analyzed for mercury using cold vapor atomic absorption spectroscopy.

Quality Assurance/Quality Control (QA/QC) procedures included analyses of spiked samples with appropriate standards, analysis of replicates, analysis of procedural and matrix blanks, and the demonstration of correct chemical identifications. Matrix samples (blanks and spikes) prepared from chicken eggs, clean bluegill tissue, and samples of CERC's standard positive control tissue (common carp from Saginaw Bay, MI), and procedural blanks were processed concurrently with the actual samples as quality control.

Recoveries of the ^{13}C-labeled PCDFs and PCDDs were within the QC range of 25% to 125%, except OCDD in two of the flounder samples and one of the flounder replicate samples where recoveries were slightly below 25 %. TCDD and TCDF recoveries in all the samples ranged from 40% to 100%. Recoveries of the ^{13}C-labeled non-*ortho* PCBs ranged from 42% to 95%. Recoveries of the congener-specific analysis of PCB residues averaged 62% to 210% (see Appendix G for corrections). Recoveries of the organochlorine pesticide and total PCB analyses exceeded 80% for all compounds except: HCB (55%), PCA (69%), heptachlor (56%), delta-BHC (52%), oxychlordane (66%), *trans*-nonachlor (69%), p,p'-DDT (64%), and mirex (66%). Recoveries of the metals ranged from 96% to 98%.

The H4IIE Bioassay

The H4IIE rat hepatoma cell bioassay provided an estimate of the relative potency of complex planar hydrogenated hydrocarbons (PHHs) mixtures in extracts of the bald eagle egg, fish and sediment samples. The H4IIE rat hepatoma cell bioassay procedures were a modification of the standard methods reported by Tillitt *et al.* (1991). The modifications were to miniaturize and automate the procedures into a 96-well microtitre plate configuration. The samples were calibrated against *2,3,7,8*-tetrachlorodibenzo-*p*-dioxin (TCDD) for the determination of TCDD-equivalents (TCDD-EQ) in the samples. The doses of each sample (g-equivalents /mg cellular protein) or TCDD standards (pg TCDD/mg cellular protein) were plotted against ethoxyresorufin *O*-deethylase (EROD) activity (pmol/min/mg cellular protein) to develop dose-response curves. The linear portions of these curves were used to compare the relative potencies of the samples with that of the standard, TCDD.

Data Analysis

All residues in eggs were corrected for moisture loss and are reported as fresh weight. Egg fresh weight corrections were determined using egg dimensions to calculate volume, assuming a density of 1 (Stickel *et al.* 1973). Egg volume was calculated using the formula: $(\text{width})^2$ (length) (0.51). Concentrations were adjusted by multiplying each analyte concentration, originally determined based on the eggs analytical wet weight, by the egg mass/egg volume. Tissue (fish and carcasses) concentrations are reported as wet weight. Sediment samples are reported in pg/g, dry weight and were not normalized to organic carbon because of the low total organic carbon values, particularly at one site. Low total organic carbon values may artificially increase organic contaminant concentrations above sediment quality standards if normalization is conducted (Michelsen 1992). The reported contaminant concentrations were not corrected for procedural internal standard losses. Contaminant concentrations below detection limits were assigned a value of one-half the detection limits for data analysis purposes.

The total dioxin-like potency of planar chlorinated compounds in the bald eagle eggs were summarized as TCDD toxic equivalents (TEQs). The TEQs were estimated using standard avian-based toxic equivalent factors (TEFs) for PCDDs, PCDFs, mono-*ortho* and non-*ortho* PCBs as suggested by the World Health Organization (WHO, Van den Berg *et al*. 1998). The concentration of each planar chlorinated hydrocarbon in an egg sample was multiplied by its corresponding TEF value (Table 2).

Table 2: World Health Organization's toxic equivalency factors (TEFs) used to estimate avian-based toxic equivalents (TEQs)[a].

	TEF		TEF
Chlorinated dibenzodioxins		**Non-*ortho* chlorinated**	
2,3,7,8-Tetra	1	3,4,4',5-Tetra (81)	0.1
1,2,3,7,8-Penta	1	3,3',4,4'-Tetra (77)	0.05
1,2,3,4,7,8-Hexa	0.05	3,3',4,4',5-Penta (126)	0.1
1,2,3,6,7,8-Hexa	0.01	3,3',4,4',5,5'-Hexa (169)	0.001
1,2,3,7,8,9-Hexa	0.1	**Mono-*ortho* chlorinated**	
1,2,3,4,6,7,8-Hepta	<0.001	2,3,3',4,4'-Penta (105)	0.0001
Octa	0.0001	2,3,4,4',5-Penta (114)	0.0001
Chlorinated dibenzofurans		2,3',4,4',5-Penta (118)	0.00001
2,3,7,8-Tetra	1	2',3,4,4',5-Penta (123)	0.00001
1,2,3,7,8-Penta	0.1	2,3,3',4,4',5-Hexa (156)	0.0001
2,3,4,7,8-Penta	1	2,3,3',4,4',5'-Hexa (157)	0.0001
1,2,3,4,7,8-Hexa	0.1	2,3'4,4',5,5'-Hexa (167)	0.00001
1,2,3,6,7,8-Hexa	0.1		
1,2,3,7,8,9-Hexa	0.1		
2,3,4,6,7,8-Hexa	0.1		
1,2,3,4,6,7,8-Hepta	0.01		
1,2,3,4,7,8,9-Hepta	0.01		
OCDF	0.0001		

[a]TEFs from van den Berg *et al.* (1998) used to calculate toxic equivalents (TEQs) for bald eagle eggs from Washington, 1992-1997.

Statistical analyses were not conducted on the sample results because the methods for egg collections were not consistent throughout the study and the sample sizes were small and spread out over a 6 year period. Fresh eggs were collected the first two years from the Hood Canal territories and addled eggs were collected the remaining four years from the Hood Canal territories and from all the nests outside the Hood Canal area. In 1992, eagle territories in the Hood Canal area with the worst history for producing young were selected for egg collections. In 1993, Hood Canal bald eagle territories again were selected for egg collections based on their history of failure; however, their history of failure was not as extreme as the nests selected for 1992. After 1993, only addled eggs were collected and a territory's history of failure was not a consideration. The only factors affecting addled egg collections were egg availability and feasibility of climbing the nest trees.

RESULTS

Productivity

The number of known occupied territories increased in the Hood Canal area from 3 in 1980 to 35 in 2000 (Table 3). The number of young per occupied territory has met the recovery goal of 1.0 the last 4 out of 5 years. In 1994, 1995, and 1998, however, the number of young produced per occupied territory was nearly half that of the other four years (Table 3). The average success rate for the past five years has been close to the recovery goal of 65% and has been reasonably constant (Table 3).

Table 3: Comparisons of the estimated number of Washington statewide and Hood Canal bald eagle occupied territories, productivity and percent fledging success.

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Statewide Data																					
No. occupied territories	105	126	138	168	206	231	250	268	308	369	403	445	469	493	547	558	594	582	664	-	-
No. young/occupied territory.[a]	0.9	0.75	0.74	0.86	0.95	0.98	1.11	0.98	0.98	0.99	1.07	0.97	0.99	0.94	1.02	0.90	0.93	0.97	1.10	-	-
Occupied territories successful (%)[a]	64	56	55	59	67	65	73	65	66	63	70	63	69	63	70	63	64	66	74	-	-
Hood Canal Data																					
No. occupied territories	3	5	4	6	8	9	11	11	16	18	23	26	25	24	21	21	29	27	32	31	35
No. young/occupied territory	0	0.2	0	0.3	0.4	0.7	1.2	0.8	1	0.8	1.2	0.6	0.6[b]	0.9[c]	0.4	0.5	1.0	1.1	0.6	1.0	1.1
Occupied territories successful (%)	0	20	0	17	25	44	82	55	59	50	76	38	41	50	27	38	75	72	50	58	66

[a]Estimated young were projected based on the average number of young produced by pairs with known outcome. Most surveys had nests known to be productive but without young counted.
[b]Eggs were removed from 5 territories and those territories were not included in the calculations.
[c]Eggs were removed from 3 territoires and those territories were not included in the calculations.

In 1992, only one of the five nesting territories where fresh eggs were collected was successful at fledging an eaglet. Three of the nests had two eggs in them prior to collection and two of the nests only had one egg. Of the five nests, three of the nests were abandoned shortly after the eggs were collected, one nest failed even though the adults resumed incubation, and in the fifth nest, a second egg was laid after the first egg was collected and one young successfully fledged. No live young were produced in the nest sites where fresh eggs were collected in 1993.

Contaminants in Eggs

Eggshell thickness

Eggshell thickness of all the eggs collected for this study ranged from 15.7% thinner to 14.0% thicker than the mean eggshell thickness of bald eagle eggs collected pre-DDT (Table 4). Twelve of the thirteen bald eagle eggs collected from the Hood Canal territories exhibited eggshell thinning, with a mean difference of 6.1% thinner. In contrast, 4 of the 5 eggs collected from outside the Hood Canal territories, were thicker than the pre-DDT average with a mean difference of 0.4% thicker (Table 4, Appendix A).

Organochlorines pesticides and total PCBs

All of the bald eagle eggs analyzed contained PCBs and p,p'-DDE. The scan for total PCBs was not conducted on the eggs collected in 1996 and 1997 (3 eggs from Hood Canal and 2 from outside the Hood Canal area.). The geometric mean of total PCB concentrations in the eggs from Hood Canal territories was 13,300 ng/g when they were analyzed using an organochlorine scan. In comparison, when the total PCB concentrations were determined by adding the concentrations of mono-*ortho*-substituted PCBs and the congener specific PCBs, the geometric mean of total PCBs for the same 10 eggs collected between 1992 and 1995 was 7,340. The geometric mean for total PCB concentrations determined by adding the mono-*ortho* PCBs and the congener specific PCBs was 6,490 ng/g when including all 13 Hood Canal eagle eggs (Table 4, Appendix A). Concentrations of total PCBs in the 3 eggs collected from outside the Hood Canal territories in 1992 and 1995 had a geometric mean of 4,130 ng/g using the scan and 2,510 ng/g when determined by adding the concentrations of mono-*ortho*-substituted PCBs and the congener specific PCBs. (Table 4, Appendix A). Geometric means of p, p'-DDE concentrations were 1,920 ng/g and 1,940 ng/g for the bald eagle eggs sampled from Hood Canal nests and from nests outside the Hood Canal area, respectively (Table 4, Appendix A). Individual egg sample concentrations of the congener specific PCBs are presented in Appendix B. The total number of individual and/or coeluding congener specific PCBs analyzed varied between 90 and 104 over the 6 years of the study.

Concentrations of organochlorine pesticides and their metabolites in the five eggs collected from Hood Canal territories in 1992 are presented in Table 5 and Appendix C. Concentrations of p,p'-DDE were detected at higher levels than other organochlorine pesticides. The following organochlorines were below detectable limits: pentachloroanisole, alpha-BHC, Lindane (gamma-BHC), heptachlor, delta-BHC, Dacthal, o,p'-DDE, o,p'-DDD, and Endrin.

Table 4: Eggshell measurements and concentrations (ng/g, fresh weight) of p,p'-DDE and total PCBs in bald eagle eggs collected from Hood Canal territories and from nests outside the Hood Canal area in Washington, 1992 - 1997.

	Hood Canal			Outside Hood Canal		
	Mean[a]	**Range**	**n**	**Mean[a]**	**Range**	**n**
Eggshell Parameters						
Eggshell Thickness (mm)	0.572	0.513 - 0.694	12	0.607	0.529 - 0.658	5
Percent Change	-6.1	-15.7 - +14.0	12	+0.4	-13.1 - +8.1	5
Chemicals (ng/g fresh wt.)						
p,p'-DDE	1,920	936 - 4,330	13	1,940	367 - 5,680	5
Total PCBs (Scan)[b]	13,300	5,020 - 23,300	10	4,130	3,330- 5,970	3
Total PCBs (Congeners)[c]	6,490	3,660 - 13,100	13	2,680	1,130 - 5,400	5

[a]Arithmetic mean for eggshell parameters and geometric mean for chemical concentrations.
[b]Total PCBs determined using a scan prior to determining PCB congeners.
[c]Total PCBs determined by adding the concentrations of mono-*ortho*-chloro PCBs and congener specific PCBs.

Table 5: Concentrations of organochlorine pesticides and their metabolites (ng/g, fresh weight) in five bald eagle eggs collected from different Hood Canal territories in 1992.

Organochlorine Pesticides	Geometric mean	Range
hexachlorobenzene	9	6 - 20
beta-BHC	33	13 - 51
oxychlordane	49	32-63
heptachlor epoxide	22	14-27
trans-chlordane	3	ND[a]- 5
cis-chlordane	6	ND - 16
dieldrin	23	ND - 44
p,p'-DDE	2,690	1,770 - 3,270
trans-nonachlor	191	124 - 313
cis-nonachlor	77	55 - 118
o,p'-DDT	18	8 - 27
p,p'-DDD	147	102 - 221
p,p'-DDT	8	ND - 14
mirex	20	12 - 33
toxaphene	441	281 - 783

[a]ND: Not detected at specified detection limit

Dioxins, Furans and Planar PCBs

All of the eggs contained concentrations of dioxins, furans, and planar PCBs. The following dioxins were present at the most elevated concentrations in the eggs: 1,2,3,7,8-PentaCDD, 1,2,3,6,7,8-HexaCDD, and 2,3,7,8-TetraCDD (Table 6, Appendix D). In general, concentrations of dioxins in eggs from nests outside the Hood Canal area were present at lower levels than those detected in eggs from Hood Canal nests. Similar patterns were observed with furans. The most elevated furans were 2,3,7,8-TetraCDF and 2,3,4,7,8-PentaCDF, with highest concentrations present in the eggs from Hood Canal (Table 6, Appendix E).

All of the eggs contained dioxin-like planar PCBs. Of the non-*ortho*-substituted PCBs, congeners 126 and 77 were present at the most elevated levels. Congeners 118 and 105 were present at the highest levels of the mono-*ortho*-substituted PCBs (Table 6, Appendices F and G).

The geometric means for the TEQs were higher in eggs collected from Hood Canal nests than in eggs collected from nests outside the Hood Canal area (Table 7). A geometric mean of 258 pg/g was derived when using the TEQ values for all the Hood Canal eggs. Since the collection methods were different for the 1992 and 1993 eggs than for the eggs collected between 1994 and 1999, we also calculated geometric means for the two different sets of eggs. The 8 fresh eggs collected in 1992 and 1993 had a geometric TEQ value of 351 pg/g, compared to a geometric mean of 158 pg/g for the addled eggs collected between 1994 and 1999. The TEQ values for individual egg samples are presented in Appendix H.

The non-*ortho* PCBs contributed the most dioxin-like toxicity to the TEQ values (Figure 6). PCB 126 comprised the greatest percentage of the total dioxin-like toxicity, with average percentages of 48.6% in the eggs from the Hood Canal nests and 45.5% in the eggs collected from nests outside the Hood Canal area (Table 8). PCB 77 contributed the second highest percentage of the total dioxin-like toxicity for the TEQ values with average percentages of 19.7% and 21.2% in the Hood Canal eggs and in those from outside the Hood Canal area, respectively.

TCDD-EQs as derived from the H4IIE extract bioassay were detected in all eggs collected in 1992 to 1994 (Appendix H). The overall mean for the samples from Hood Canal was 52.3 pg/g, with a range of 6 pg/g to 228 pg/g. The values were the highest for the 1992 eggs with a range of 95 pg/g to 228 pg/g. The H4IIE extract bioassay was conducted on only one sample from outside the Hood Canal territories and resulted in a concentration of 5.4 pg/g.

Table 6: Concentrations (pg/g, fresh weight) of PCDDs, PCDFs, and planar PCBs in bald eagle eggs collected from territories within and outside the Hood Canal area in Washington, 1992 - 1997.

	Hood Canal			Outside Hood Canal		
Chemical	**n**	**Geo Mean**	**Range**	**n**	**Geo Mean**	**Range**
Chlorinated dibenzodioxins						
2,3,7,8-Tetra	13	9.0	2.7 - 20.7	5	4.7	2.3 - 14.4
1,2,3,7,8-Penta	13	13.8	4.1 - 32.0	5	5.0	2.8 - 7.3
1,2,3,4,7,8-Hexa	13	1.2	0.4 - 2.3	5	0.4	0.2 NQ[a] - 0.4
1,2,3,6,7,8-Hexa	13	11.4	4.7 - 27.3	5	5.6	2.6 - 9.6
1,2,3,7,8,9-Hexa	13	0.6	0.2 NQ - 0.9	5	0.1	< 0.1 - 0.6
1,2,3,4,6,7,8-Hepta	13	0.9	0.4 - 16.7	5	0.3	< 0.1 - 1.3
OCDD	13	6.0	2.5 - 56.5	5	3.6	1.1 - 8.7
Chlorinated dibenzofurans						
2,3,7,8-Tetra	13	11.2	3.5 - 33.8	5	5.2	3.2 - 9.5
1,2,3,7,8-Penta	13	1.0	0.4 - 2.3	5	0.5	0.3 NQ - 1.1 NQ
2,3,4,7,8-Penta	13	7.9	2.0 - 18.8	5	2.7	1.5 - 6.1
1,2,3,4,7,8-Hexa	13	0.6	0.1 - 1.1	5	0.3	0.1 NQ - 0.3
1,2,3,6,7,8-Hexa	13	0.8	0.2 NQ - 3.0	5	0.5	0.2 - 0.6
1,2,3,7,8,9-Hexa	13	0.1	<0.1 - 0.3	5	0.1	<0.1 - 0.2 NQ
2,3,4,6,7,8-Hexa	13	0.8	<0.1 - 5.3	5	0.4	<0.1 - 2.9
1,2,3,4,6,7,8-Hepta	13	1.1	0.2 NQ - 6.8	5	0.6	0.3 - 1.7
1,2,3,4,7,8,9-Hepta	13	0.6	0.1 - 3.2	5	0.3	0.2 - 0.7 NQ
OCDF	13	2.3	0.5 - 10.0	5	3.1	2.3 - 5.5
Non-*ortho* chlorinated						
3,4,4',5-Tetra (81)	13	114	54 - 222	5	53	35 - 63
3,3',4,4'-Tetra (77)	13	990	367 - 1,880	5	440	220 - 818
3,3',4,4',5-Penta (126)	13	1,250	442 - 2,820	5	476	328 - 782
3,3',4,4',5,5'-Hexa (169)	13	243	96 - 1,540	5	113	58 - 169
Mono-*ortho* chlorinated						
2,3,3',4,4'-Penta (105)	13	136,000	49,900 - 277,000	5	45,000	28,600 - 68,700
2,3,4,4',5-Penta (114)	13	3 ,800	<100 - 24,100	5	900	<100 - 18,200
2,3',4,4',5-Penta (118)	13	442,300	158,000 - 1,010,000	5	127,000	99,200 - 158,000
2',3,4,4',5-Penta (123)	4	5,000	3,200 - 6,400	1	1,200	1,200
2,3,3',4,4',5-Hexa (156)	13	76,100	40,700 - 145,000	5	24,500	10,900 - 57,500
2,3,3',4,4',5'-Hexa (157)	7	16,200	14,400 - 24,000	3	8,000	2,900 - 13,400
2,3'4,4',5,5'-Hexa (167)	13	43,500	14,100 -120,000	5	17,700	9,200 - 31,900
2,3,3',4,4',5,5'-Hepta (189)	13	6,200	2,000 - 15,300	5	2,900	1,400 - 6,700

[a] NQ: Not Quantitated at specified average concentration due to inaccurate ion ratio

Table 7: Geometric means (pg/g, range in parenthesis) of the toxic equivalents (TEQs) in bald eagle eggs collected from within and outside the Hood Canal area in Washington,1992 - 1997.

	TEQ (pg/g)	
Chemical	**Hood Canal**	**Outside Hood Canal**
sample size (n)	13	5
PCDD/F[a]	42	19
	(13 -106)	(10 -29)
PCDD/F + nPCBs[b]	231	96
	(93 - 499)	(73 - 155)
PCDD/F + nPCBs + mPCBs[c]	258	106
	(106 - 549)	(81 - 167)

[a]TEQs calculated with polychlorinated dioxin and furan congeners only
[b]TEQs calculated with polychlorinated dioxin and furan congeners and non-*ortho* PCBs
[C]TEQs calculated with polychlorinated dioxin and furan congeners, non- and mono-*ortho* PCBs

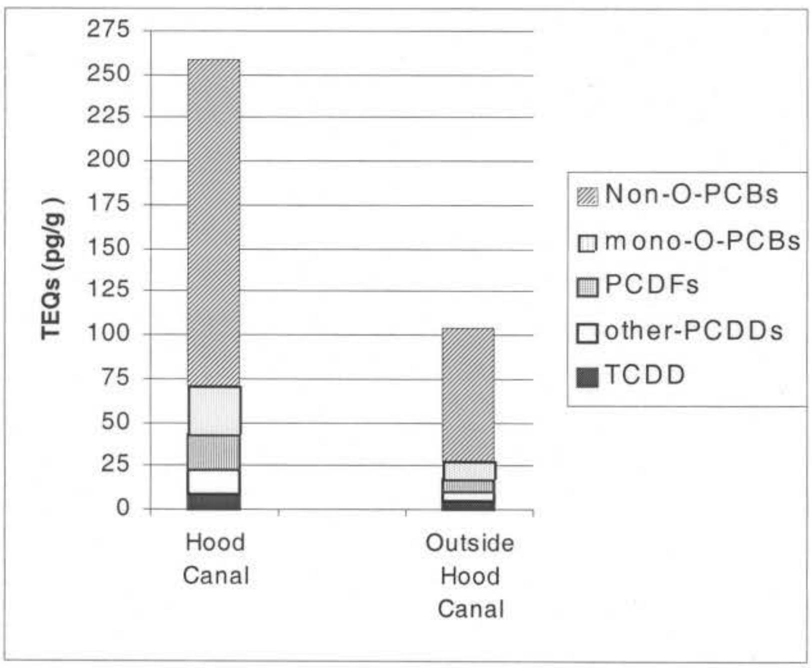

Figure 6: Geometric means of TEQ values for compounds with dioxin-like activity in bald eagle eggs collected from territories within and outside Hood Canal in Washington,1992-1997.

Table 8: The average percentages of the primary congeners that comprised the total dioxin-like toxicity (TEQs) in bald eagle eggs collected from within and outside the Hood Canal area in Washington, 1992 - 1997.

	Hood Canal (n=13)		Outside Hood Canal (n=5)	
Congener	**Avg. %**	**Range**	**Avg. %**	**Range**
Non-*ortho* chlorinated Biphenyls				
PCB 126	48.6	41.0 - 55.3	45.5	34.3 - 58.2
PCB 77	19.7	9.5 - 25.5	21.2	13.6 - 25.6
PCB 81	4.5	2.9 - 6.4	5.2	3.7 - 6.6
Mono-*ortho* chlorinated Biphenyls				
PCB 105	5.5	3.6 - 9.0	4.3	3.0 - 5.3
PCB 156	2.7	1.6 - 4.2	2.9	1.1 - 6.1
PCB 118	1.8	1.1 - 2.9	1.2	0.9 - 1.7
Chlorinated dibenzodioxins				
1,2,3,7,8 PECDD	5.4	3.9 - 7.1	4.9	3.0 - 7.6
2,3,7,8 TCDD	3.5	2.5 - 5.2	5.7	2.9 - 15.0
Chlorinated dibenzofurans				
2,3,7,8 TCDF	4.7	1.9 - 9.3	5.2	3.3 - 8.3
2,3,4,7,8 PECDF	3.1	1.9 - 4.1	2.6	1.6 - 3.7

Metals

Arsenic, mercury and selenium were analyzed in bald eagle eggs collected from Hood Canal in 1992 only. Mercury and selenium were present in all 5 eggs and arsenic was detected in 1 out of 5 eggs at a concentration of 38 ng/g. Geometric means for the concentrations of mercury and selenium were 298 ng/g and 553 ng/g, respectively (Table 9).

Table 9: Concentrations (ng/g, fresh wet weight) of arsenic, mercury, and selenium in five bald eagle eggs collected from Hood Canal territories in 1992.

Territory	Arsenic	Mercury	Selenium
Brown Point	38	380	524
Squamish Harbor	ND[a]	297	551
Thorndyke	ND	456	682
Hazel Point	ND	322	704
Union	ND	142	372
Geometric Mean	**NC[b]**	**298**	**553**

[a] Not detected
[b] Not calculated

Contaminants in Blood

All of the eagle blood samples contained PCBs. The geometric means of the PCB concentrations in the nestling and adult blood samples were 50.4 ng/g and 209 ng/g, respectively. All of the adult blood samples and two of the five nestling blood samples contained detectable levels of p,p'-DDE (Table 10). The geometric mean of the concentrations of p,p'DDE in the adult blood samples was 44.9 ng/g. The geometric mean of the concentrations of p,p'DDE in the nestling blood samples was 10.2 ng/g. The concentration determined for the Toandos East nestling sample was likely low as indicated by the 32 % recovery of the spiked sample of PCB congener 204.

Table 10: Concentrations of total PCBs and p,p'-DDE (ng/g) in adult and juvenile bald eagle blood samples from Hood Canal, 1995 - 1997.

Location	Year	Age	Status	Total PCBs	p,p'-DDE
Duckabush	1995	Nestling		56.7	<6.7
Dosewallips	1995	Nestling		47.6	<6.7
Waketickeh Cr.	1995	Nestling		47.3	<6.7
Union	1996	Nestling		NC[a]	74
Toandos East	1997	Nestling		NC	39
Red Bluff	1995	Adult	male, breeder	193	19.2
Pt. Whitney	1995	Adult	male, non-breeder	348	50.7
Indian Island	1995	Adult	female breeder	197	38.5
Broad Spit	1995	Adult	female non-breeder	145	32.7
Pt. Whitney	1996	Adult	male, non-breeder	NC	61.7
Bolton Peninsula	1996	Adult	male, breeder	NC	89.8

[a]NC: Scan of total PCBs not conducted

Contaminants in Eagle Carcasses

Concentrations of total PCBs and p,p'DDE detected in three eagle carcasses are reported in Table 11. The eagle collected near Quilcene had the highest PCB concentration, 22,6 00 ng/g, in muscle. Concentrations of DDE in the 2 brain samples were low at 1,180 ng/g and 1,220 ng/g.

Table 11: Concentrations of total PCBs and p,p'-DDE (ng/g, wet weight) measured in three bald eagles found dead in the Hood Canal area.

Location/ Tissue sampled	% Lipid	Total PCBs	p,p'-DDE
Indian Island (Immature)			
Muscle	1.5	6,950	2,440
Liver	2.8	6,910	2,150
Kidney	1.9	5,020	1,450
Brain	5.1	3,400	1,220
Quilcene Bay (Adult)			
Muscle	4.9	22,600	8,620
Liver	2.0	9,380	1,890
Kidney	0.9	6,490	1,330
Brain	5.3	6,720	1,180
Bremerton (Adult)			
Muscle	4.3	9,780	2,530
Liver	4.9	9,450	2,120
Kidney	2.3	5,580	936

Contaminants in Fish

PCBs and p,p'-DDE were present in all 6 composite fish samples. The geometric means of the total PCBs and p,p'-DDE were 109 ng/g and 1.6 ng/g, respectively (Table 12). The only dioxin and furan congeners detected in all 6 fish samples were 2,3,7,8-TCDF and OCDF, with geometric means of 0.6 pg/g and 3.2 pg/g, respectively (Table 13). Concentrations of OCDD were detected in 4 of the 6 fish samples and 2,3,7,8 TCDD, 1,2,3,7,8 PCDD, and 2,3,4,7,8 PCDD were near the detection limit (Table 13). Concentrations of other dioxins and furans were not detected at 0.1 pg/g.

Of all the dioxin-like congeners, the mono-*ortho* PCB congeners 118 and 105 were present at the highest concentrations with geometric means of 1,840 pg/g and 525 pg/g, respectively. Congeners 167 and 156 were the only other mono-*ortho* PCBs present in most of the fish samples (Table 14). The other mono-*ortho* PCB congeners (123, 114, 157, and 189) were below detection limits in all samples except the Tarboo fish sample which had a concentration of 150 pg/g of congener 157. Congeners 77 and 126 were the only non-*ortho* PCBs detected in all the fish samples (Table 14). Congener 81 was not detected or near quantification limits in all of the fish samples and congener 169 was not detected in any of the fish samples except for the Tongue/Dabob and Thorndyke samples where concentrations were 2 pg/g.

The fish samples contained only small amounts of dioxin-like activity as measured by the H4IIE bioassay. The geometric mean of the TCDD-EQ for the 6 fish samples was 1.8 pg/g with a range of 0.1 to 7.1 pg/g (Table 12). The Thorndyke fish sample (from site number 1) was the only sample with a TCDD-EQ above 1.4 pg/g. A significant induction occurred in 2 of the 3 extracts tested from the Thorndyke sample; however, there was a large amount of variability associated with the overall sample mean which had a standard deviation of 8.0.

Table 12: Fish tissue concentrations (ng/g, wet weight) of total PCBs and p,p'-DDE.

Location	Site No.	Species	% Lipid	Total PCBs	p,p'-DDE	TCDD-EQ[b] (pg/g)
Thorndyke[a]	1	Starry Flounder	2.0	157	3.5	7.1
Hazel Point	2	Starry Flounder	1.1	81	0.8	0.7
Tarboo	3	Starry Flounder	2.5	124	1.5	0.2
Tongue/Dabob	4	Starry Flounder	2.8	155	4.4	1.4
Union	5	Starry Flounder	2.3	74	0.9	0.8
Hazel Point	2	Greater Sculpin	1.7	92	1.0	0.3
Geometric Mean				109	1.6	1.8

[a]Average of replicates
[b]As determined by H4IIE Bioassay

Table 13: Fish tissue concentrations (pg/g wet weight) of dioxins and furans.

Location	Fish[a]	2,3,7,8-TCDD	1,2,3,7,8-PCDD	OCDD[c]	2,3,7,8-TCDF	2,3,4,7,8-PCDF	OCDF
Thorndyke[b]	F	0.1	0.2	ND[c]	1.1	0.2	3.5
Hazel Point	F	0.1 NQ[d]	0.1 NQ	0.6 NQ	0.2	0.1 NQ	2.9
Tarboo	F	ND	0.1 NQ	1.0	0.6	ND	2.8
Tongue/Dabob	F	0.1	0.1	0.8	0.7	0.1 NQ	3.5
Union	F	ND	ND	ND	0.3	ND	2.9 NQ
Hazel Point	S	0.1	0.1	0.1 NQ	1.0	0.1	3.6
Geometric Mean		**0.1**	**0.1**	**0.4**	**0.6**	**0.1**	**3.2**

[a] Fish species were starry flounder (F) and great sculpin (S)
[b] Average of replicates
[c]ND: Not detected at specified detection limit
[d]NQ: Not quantitated at specified average concentration due to inaccurate ion ratio

Table 14: Fish tissue concentrations (pg/g wet weight) of non-*ortho* PCBs, and mono-*ortho* PCBs.

Location	**Fish**[a]	**77**	**126**	**118**	**105**	**167**	**156**
Thorndyke[b]	F	16	10	2,190	570	200	190
Hazel Point	F	8	3	670	220	<110	<60
Tarboo	F	18	13	5,530	1,430	410	490
Tongue/Dabob	F	23	10	4,150	1,010	310	320
Union	F	9	3	580	180	<110	<60
Hazel Point	S	11	7	1,990	640	120	140
Geometric Mean		**13**	**7**	**1,840**	**525**	**145**	**125**

[a] Fish species were starry flounder (F) and great sculpin (S)
[b] Average of replicates

Contaminants in Sediments

Overall, concentrations of the organochlorine compounds were low in the sediment samples. All of the sediment samples contained PCB congeners; however, concentrations of most of the congeners were below the detection limit level of 0.3 ng/g, dry weight. The geometric mean of the concentrations of total PCBs (determined by adding the mono-*ortho* PCBs and the congener specific PCBs) in the sediment samples was 16.9 ng/g (Table 15). PCB congeners 118 and 167 were the only mono-*ortho* PCB congeners detected in the sediment samples (Table 15). All of the other mono-*ortho* PCB congeners (123, 114, 105, 156, 157, and 189) were below detection limits. All of the sediment samples, except one of the triplicate samples from Union, had DDE concentrations below the quantifiable levels of 1.4 to 1.7 ng/g. The geometric mean for the Union sample was 2.0 ng/g. Contaminant concentrations listed in the tables have not been normalized, however; percent total organic carbon for each sample is presented in Table 15.

Concentrations of dioxins and furans were below detection limits for most of the compounds in all the sediment samples. Concentrations of 2,3,7,8-TCDF were near the detection limit in all the samples, except the Union sample which contained an average concentration of 2.5 pg/g. Similarly, concentrations of 1,2,3,4,6,7,8-HCDD were not detected, or were slightly above detection limits at all the sites, except Union which contained an average concentration of 27.5 pg/g.

Table 15: Concentrations of PCBs (ng/g, dry weight), OCDD and OCDF (pg/g, dry weight), and percent total organic carbon in sediment samples collected from Hood Canal, 1994.

Location	Site No.	% TOC	PCB 118	PCB 167	Total PCBs[a]	OCDD	OCDF
Hazel Pt.	2	0.12	<0.35	<0.35	13.6	6.4	7.6
Tongue/Dabob	4	0.15	0.52	<0.35	17.0	6 NQ[b]	4 NQ
Tarboo	3	0.41	0.42	<0.35	17.2	15	6.5
Union[c]	5	0.89	0.69	0.66	25.7	194	16
Thorndyke	1	0.08	0.39	1.00	19.7	3 NQ	6 NQ
Dabob Bay[d]	6	2.08	<0.35	<0.35	11.5	42	9 NQ

[a]Total PCBs are derived by adding the mono-*ortho* chlorinated PCBs and the congener specific PCBs.
[b]NQ: Not quantitated at specified average average concentration due to inaccurate ion ratio.
[c]Average of replicates
[d]Sediment sample from the one deep water site

DISCUSSION

Contaminants in Bald Eagle Eggs and Effects on Productivity

As was mentioned in the methods section, the methodology for the collection of bald eagle eggs changed during the study. In 1992 and 1993, when fresh eggs were collected, it was possible to target the bald eagle nests with the highest failure rates. If environmental contaminants were the cause of the nest failures, we assumed that the nests with the highest failure rates would also be the nests containing eggs with the highest contaminant concentrations. With the exception of the Union territory, eggs collected in 1992 and 1993 from Hood Canal territories contained higher concentrations of PCBs than other eggs collected for this study. Also, all of the Hood Canal eggs collected in 1992 and 1993 had higher TEQ values than any of the other eggs collected for this study, except for the addled egg collected in 1994 from the Tahuya territory.

Wiemeyer *et al.* (1993) reported that concentrations of $\leq$4.0 µg/g total PCBs (fresh wet weight) were correlated with normal reproduction for bald eagles. Kubiak and Best (1991) estimated a threshold concentrations of <6.0 µg/g (fresh wet weight) total PCBs for a healthy subpopulation of bald eagles ($\geq$ 1.0 young/occupied breeding area) in the Great Lakes region. These studies, and others in past literature, reported concentrations of total PCBs that were estimated using a scan. Total PCBs can be quantitated by comparing selected peak areas in a scan or by analyzing individual PCB congeners and summing their total concentrations. Analyzing individual PCB congeners is a newer, more refined technique that removes confounding factors and interferences caused by co-eluding compounds. Total PCB concentrations measured using a scan are only available for 13 of the 18 eggs sampled for this study.

All 13 of the Hood Canal eggs, except possibly 1 which had a total PCB concentration of 3.7 µg/g based on summing the individual PCB congeners, exceeded the 4.0 µg/g total PCB level estimated by Wiemeyer *et al.* (1993) for normal reproduction of bald eagles. The 9 Hood Canal eggs collected between 1992 and 1994 exceeded the 6.0 µg/g (fresh wet weight) total PCB concentration level described for a healthy subpopulation of bald eagles in the Great Lakes region (Kubiak and Best 1991). For the eggs from outside the Hood Canal area, only 1 of the 3 eggs with total PCB concentrations estimated using a scan exceeded the 4.0 µg/g total PCB level. Based on these results, PCBs likely were negatively impacting productivity in the Hood Canal territories. Concentrations of total PCBs in the eggs from Hood Canal were higher than four out of the five eggs collected for this study outside the Hood Canal area in Western Washington. The PCB concentrations in eggs from the Hood Canal study are comparable to those found in bald eagle eggs from the Columbia River territories. (Anthony *et al.* 1993, Buck *et al.* 1999). These territories were also experiencing depressed reproduction.

Eggshell-thinning data have shown improvement since the ban of DDT in 1972 for most bald eagle populations (Buehler 2000). Bald eagle populations have generally experienced reproductive problems when eggshell thinning is 15-20% (Anderson and Hickey 1972). Mean eggshell thinning for the Hood Canal eagles was less than this value with only 6.1% thinning. Additionally, Wiemeyer *et al.* (1993) reported that mean bald eagle production increased when shell thinning was less than approximately 10%.

Although bald eagles appear to be less sensitive to DDE-induced shell thinning than a number of other raptor species (Wiemeyer *et al.*1988), they are nevertheless adversely affected by DDE. Wiemeyer *et al.* (1993) determined that bald eagle productivity was normal when eggs contained <3.6 µg/g DDE (wet weight), was nearly halved between 3.6 to 6.3 µg/g, and halved again when concentrations exceeded 6.3 µg/g. Because PCBs, p,p'DDE and dieldrin in addled eggs are inversely correlated to productivity, their individual effects are difficult to separate (Nisbet 1989, Bowerman *et al.* 1994). Only two eggs in this study exceeded the 3.6 µg/g level. The addled egg collected from the Union territory in Hood Canal contained 4.3 µg/g and one egg from the outer coast (Browns Point) contained 5.7 µg/g. One young fledged from the Union nest the same year that the addled egg was collected. The remainder of the bald eagle eggs collected for this study contained DDE concentrations less than the 3.6 µg/g threshold level. The tree climbers did not find crushed or cracked eggs, which would have been possible evidence of egg shell thinning, in the nests where eggs were collected. Results from this study indicated that for almost all of the Hood Canal nests, concentrations of DDE were less than those considered to have an impact on bald eagle productivity.

As a comparison on a regional basis, the mean concentration of p,p'-DDE measured in eggs collected from the lower Columbia River was higher, with 5.63 µg/g (fresh weight) compared to 1.92 µg/g (fresh weight) in the Hood Canal eggs. Mean DDE concentrations, 3.86 µg/g wet weight, in two eagle eggs collected within the Fraser delta, an area of intensive farming, were also higher than the mean concentration in this study's eggs. Concentrations of DDE in the Hood Canal eggs were similar to those measured in four eggs collected upstream of the main agricultural areas on the British Columbia coast, which had a mean concentration of 1.63 µg/g wet weight (Elliott et al. 1996a).

PCDDs and PCDFs are highly lipophilic, chemically stable environmental contaminants with low volatility. They bioaccumulate in fish and wildlife and biomagnify through food chains (Eisler 1986). Several PCDDs and PCDFs, as well as a few dioxin-like PCBs, have been shown to exert a number of common toxic responses similar to those observed for 2,3,7,8-TCDD, including reproductive deficits, dermal toxicity, immunotoxicity, teratogenicity, endocrine toxicity and carcinogenicity/tumor promotion (Ahlborg *et al.* 1994). The evidence of a common mechanism of action that causes similar effects in mammals and birds and for additivity of effects from exposure to PCDD, PCDF and PCB mixtures has led to the development of TEQs (Elliott *et al.* 1996b).

Since laboratory dose-response studies of bald eagle eggs have not been conducted, no-observable-adverse-effect-levels (NOAELs) for bald eagles have been based on numerous laboratory studies of other birds and field studies. Giesy *et al.* (1995) estimated a no- or lowest-observable-adverse-effect-level (NOEL/LOAEL) of 7 pg/g for TEQs based on concentrations of 2,3,7,8-TCDD in bald eagle eggs. Elliott *et al.* (1996a) reported that bald eagle eggs collected at a reference location in British Columbia with little industrial activity, other than lumber yarding, contained 15 pg/g 2,3,7,8-TCDD. Ellliott *et al.* (1996b) suggested using a no-observed-effect-level (NOEL) when $TEQs_{WHO}$ (which included planar PCBs) were 100 pg/g and a lowest-observable-effect-level (LOEL) when TEQs were about 210 pg/g on a whole egg (wet weight) for bald eagle chicks.

The geometric mean of 2,3,7,8-TCDD for the Hood Canal bald eagles was 9.0 pg/g. This concentration is slightly above the NOEL/LOAEL of 7 pg/g estimated by Giesy *et al.* (1995) and lower than the 15 pg/g measured at the reference location in British Columbia (Elliott *et al.* 1996a). The geometric mean of 2,3,7,8-TCDD was higher in Lower Columbia River eagle eggs with 22 pg/g (Buck *et al.* 1999) than in the Hood Canal eggs. Similarly, the geometric means of 2,3,7,8-TCDD were higher in eagle eggs from nests from four sites in British Columbia that receive industrial wastes (44 pg/g to 84 pg/g, Elliott *et al.* 1996a). Results from this study indicated that concentrations of 2,3,7,8-TCDD in the Hood Canal eggs were comparable to concentrations in eggs from areas that were not adversely impacted by 2,3,7,8-TCDD. The TEQ with planar PCBs calculated for the Hood Canal eagles showed that the TCDDs/TCDFs contributed less than 17% to the overall dioxin-like toxicity of the sample.

The overall geometric mean TEQ value (including the planar PCBs) of 258 pg/g, calculated for all 13 of the Hood Canal eggs, was higher than the 210 pg/g LOEL suggested by Elliott *et al.* (1996b). The mean TEQ values for the eggs collected during 1992 and 1993 from Hood Canal was 351 pg/g, which is above the LOEL. In comparison, the mean TEQ value for the eggs collected during 1994 to1997 was below the LOEL with 158 pg/g. The geometric mean TEQ value, 106 pg/g, calculated for the eggs collected outside Hood Canal was close to, although slightly above, the NOEL of 100 pg/g. The TEQs with planar PCBs calculated for the Lower Columbia River eggs and eggs from three of the British Columbia sites also exceeded the 210 pg/g threshold value (Buck *et al.* 1999, Elliott *et al.* 1996a).

Non-*ortho* and mono-*ortho* planar PCBs accounted for 78.2% to 87.7% of the total dioxin-like toxicity found in the Hood Canal bald eagle eggs and 70.6% to 89.1% in the eggs collected outside the Hood Canal area for this study. PCB 126 contributed the majority of the dioxin-like activity (average 49.3% in the Hood Canal eggs and 48.3% in the eggs from outside Hood Canal.) PCB 77 contributed the second greatest dioxin-like toxicity in the eggs. The greatest proportion of the TCDD-EQ in birds of the Great Lakes is contributed by the planar PCBs (Giesy *et al.* 1994). PCB 126 contributed the majority of the dioxin-like activity towards calculations of the TEQs in the Lower Columbia River (Buck *et al.* 1999). Two congeners, PCB 105 and PCB 126, accounted for more than 90% of the median estimated TCDD equivalents in Forster's tern eggs from Green Bay, Lake Michigan and Lake Poygan, Wisconsin (Kubiak *et al.* 1989). Elliott *et al.* (1996b) found concentrations of the toxic non-*ortho* PCBs 126>77>169>81>37 in bald eagle yolk sacs from British Columbia with the PCB congeners being the major contributors to TCDD-like toxicity. Results of their study compared to the pattern of contribution in common terns from the Netherlands where the PCB congeners 126 and 118 were the major contributors to TCDD-like toxicity (Bosveld *et al.* 1994 in Elliott *et al.*1996b).

Hoffman *et al.* (1998) found that hatching success in American kestrels was affected at dose levels of PCB 126 that were 40- to 50-fold higher than in chickens. The approximate 50% lethal dose (LD50) for PCB 126 in chickens was 0.4 ng/g, 65 ng/g in kestrels, and 104 ng/g in terns. Hoffman *et al.* (1988) stated that high concentrations of PCB 126 found in bald eagle eggs are within the range of the LD50 (65 ng/g) in their study for American kestrels, but are nearly 20-fold higher than the lowest concentration tested in kestrels that caused significant edema and teratogenesis. Concentrations of PCB 126 measured as part of this study were well below the LD50 concentration of 65 ng/g), with a range of 0.44 ng/g to 2.82 ng/g of PCB 126 in eagle eggs from Hood Canal territories, and lower concentrations in the eggs from nests outside Hood Canal.

Bald eagles and other bird species can bioaccumulate mercury to elevated concentrations that cause toxic effects (Wiemeyer *et al.* 1984, Wood *et al.* 1996, Wolfe *et al.* 1998). Wiemeyer *et al.* (1993) reported that adverse effects of mercury on bald eagle reproduction might be expected when eggs contain more that 0.5 μg/g (wet weight) mercury. Thompson (1996) reported that values of 0.5 to 2.0 μg/g (wet weight) mercury were sufficient to cause adverse effects on birds. Concentrations of mercury in all the eggs from Hood Canal were well below these levels with 142 ng/g to 456 ng/g. Concentrations of selenium in the Hood Canal eggs were also well below levels known to cause biological impacts to birds (Skorupa and Ohlendorf 1991).

Contaminants in Bald Eagle Blood Samples

Nestling bald eagles are appropriate biosentinels of the general contamination of their immediate environment (Bowermann *et al.* 1994). Concentrations of PCBs and organochlorine pesticides in blood plasma from nestling bald eagles has been correlated with concentrations in the eagles' prey base within approximately 8 km of the nest site for the first 6 to 9 weeks post-hatch (Bowerman *et al.* 1990 in Bowerman *et al.* 1994). Hood Canal nestlings are exposed to PCBs. Whole blood samples were collected for this study and for the Lower Columbia River study (Anthony *et al.* 1993). The arithmetic mean concentration of PCBs (51 ng/g) measured in Hood Canal nestling blood was higher than the arithmetic mean concentration of 40 ng/g in nestling blood samples from the Lower Columbia River (Anthony *et al.* 1993). However, the Hood Canal sample size was small with only 3 samples, compared to a sample size of 15 for the Lower Columbia River study.

Geometric means of total PCBs in blood plasma of bald eagle nestlings from 8 locations on the coast of British Columbia ranged from 6.8 ng/g at Clayoquot Sound to 56 ng/g at Powell River (Elliott and Norstrom 1998). When comparing differences in organochlorine residue concentrations between plasma and whole blood, plasma should contain about twice the concentration as whole blood (Wiemeyer *et al.* 1989). Therefore, the mean total PCB concentrations measured in the Hood Canal nestlings was also higher, with a geometric mean of 50 ng/g, than the samples from British Columbia.

Bowerman *et al.* 1994 also analyzed nestling bald eagle blood plasma samples. Nestling eagles from interior areas of Michigan, Minnesota, Ohio, Ontario, and Wisconsin had an arithmetic mean concentration of 24 ng/g total PCBs, while nestlings from the Great Lakes shoreline nests had a mean PCB concentration of 183 ng/g with an arithmetic mean concentration of 51 ng/g total PCB. The 3 Hood Canal nestling blood samples had higher concentrations than the interior area nests and lower concentration than the Great Lakes shoreline nests (Bowerman *et al.* 1994).

The mean concentration of DDE residues in nestling blood from this study (24.6 ng/g) was comparable to the levels measured by Bowerman *et al.*(1994) from the interior nests. It was lower than DDE residues measured in blood plasma from the Great Lakes nestlings (61 ng/g, Bowerman *et al.* 1994) and in whole blood in nestlings from the Lower Columbia River (50 ng/g, Anthony *et al.* 1993). The geometric mean of DDE residues in whole blood from nestling bald eagles from this study (10.2 ng/g) was comparable with geometric mean concentrations of DDE residues in blood plasma of eagle nestlings from the 8 locations on the coast of British Columbia (6.6 ng/g to 22.3 ng/g, Elliott and Norstrom 1998).

Contaminants in Bald Eagle Carcasses

It is unknown whether or not the eagles carcasses collected in the Hood Canal area were from resident or transient birds. For this reason, correlations cannot be made between contaminant burdens in the carcasses and potential sources of contamination in Hood Canal. Frenzel and Anthony (1989) collected 10 eagle carcasses in the vicinity of the Klamath Basin wintering area, Oregon and California. Concentrations of organochlorines in brains of the eagles necropsied for their study were far below those associated with death. The highest concentration of DDE and PCBs that they observed in the brains were 24.0 and 35.0 ppm (wet weight), respectively. Concentrations of DDE and PCBs in the one brain sample for this study were lower. Frenzel and Anthony (1989) noted that the mean concentration of DDE in the whole carcass tissues was 2.61 ppm (wet weight) and mean concentration of PCBs was 2.23 ppm (wet weight). Concentrations of DDE in two eagles from this study were at comparable levels to the Klamath Basin eagles, but the PCB levels in all three eagle carcasses from this study were higher.

Evaluation of Contaminant Exposure

Bald eagles are migratory birds and forage in different areas which complicates identifying areas of contaminant exposures. Watson and Pierce (1998a) monitored the movements of 6 adult bald eagles captured in the Hood Canal area via satellite telemetry. Between May and August, eagles migrated northward along coastal and interior British Columbia, as far as southeast Alaska. Evidence suggested that the migration was in response to summer and fall spawning runs of coastal salmon. The two breeding adult eagles monitored returned to breeding territories following a migration northward. Other than 5 short (<75 km) and brief (≤4 days) excursions from breeding territories just before and after migration, they remained on their territories the rest of the year. The use of coastal British Columbia and southeast Alaska by migrant eagles in the fall appears to be the consistent with other breeding populations from Western Washington (Watson and Pierce 1998a). Therefore, bald eagles from throughout western Washington are potentially exposed to contaminants in Alaska and British Columbia. However, if this was the source of contaminants for Hood Canal bald eagles, it would be expected that elevated levels of contaminants would be observed throughout western Washington, not just in Hood Canal (Watson and Pierce 1998b).

Hood Canal bald eagles are exposed to environmental contaminants in their prey. Because of the bald eagle's position as an upper trophic level predator, it bioaccumulates persistent chemicals from a diverse prey base. Watson *et al.* (1996) conducted a bald eagle foraging study in 1993 in the Hood Canal area. They identified 308 prey items to taxonomic class, with fish accounting for 85% and birds for 15% of the prey items. Only 16 fish were identified to species, with 11 of those being starry flounder. Starry flounder were sampled for this study based on the findings from the Watson study that the Hood Canal eagles ate starry flounder.

In a separate study on Hood Canal, fish comprised 91% and birds 7% of prey captured by eagles, with the most abundant prey species being flounder (family Pleuronectidae), plainfin midshipman (*Porichthys notatus*), dogfish shark (*Squalus acanthias*), sculpin (family Cottidae), unidentified bivalves, and unidentified gulls (*Larus* spp.,Watson and Pierce 1998a). Fish accounted for 90% of prey captured by eagles and 71% of the prey remains found in nests in the Columbia River Estuary (Watson *et al.* 1991), indicating that the eagles primarily fed fish to their nestlings.

Prey remains collected from territories on the San Juan Islands, Olympic Peninsula and along Puget Sound, were comprised of 53% birds (49 species, n=439 individual items), 34% fish (15 species, n=337 items), 9% mammals (8 species, n= 99 items), and 4% invertebrates (14 species, n=36 items); however, based on direct observation, 92% of prey items delivered to nestlings (n=47) were fish (Knight *et al.* 1990). Western grebes (*Aechmophorus occidentalis*) and common murres (*Uria aalge*) were the most common bird species collected and rockfish (*Sebastes* spp.) and lingcod (*Ophiodon elongatus*) were the most common fish species collected (Knight *et al.* 1990). Knight *et al.* (1996) also determined that glaucous-winged gulls (*Larus glaucescens*), another observed prey species, contained detectable levels of PCBs and DDE. Kozie and Anderson (1991) noted that fish-eating birds, such as waterfowl, gulls and other colonial waterbirds, appeared to be the major source of elevated contaminant levels in bald eagles nesting near Lake Superior, even though fish contained low concentrations of organochlorine and PCB residues.

The contaminant concentrations in fish composites collected for this study were low. In a study being conducted for the Puget Sound Ambient Monitoring Program (PSAMP), WDFW confirmed that English sole and rockfish in the Hood Canal area have low PCB concentrations based on analysis of Aroclors 1248, 1254 and 1260. Average concentrations of the sum of the Aroclors in English sole muscle tissue collected from three sites in Hood Canal between 1991 and 1996 ranged from 6.0 to 9.2 ng/g, with an overall average of 7.3 ng/g (WDFW unpubl. data 1999). PSAMP was designed to monitor the average or "ambient" conditions in Puget Sound. English sole and rockfish sampled in the non-urban bays (which included Hood Canal) accumulated lower concentrations of PCBs than fish from the near-urban and urban bays (PSWQAT 1998). Exposure to PCB-contaminated sediment was believed to be the main factor associated with PCB accumulation in English Sole (PSWQAT 2000).

The methods utilized between WDFW's study and this study were different since congener specific PCBs were analyzed for this study. If any of the congeners were not detected, one-half of the detection limit was added in to the total concentration. During analysis, several of the congeners co-eluted and a single concentration value was reported for 18 groups of 2 to 3 congeners. Of the total 87 concentrations reported, which included individual congener concentrations and concentrations for the co-eluted congeners, 52 were detected in 2 or more of the 5 fish samples, 10 were detected in only one fish sample, and 25 were not detected in any of the fish samples.

Chemicals that are relatively insoluble in water, including PCBs, PCDDs and PCDFs, accumulate through the food chain beginning with the uptake from sediments. Based on the low concentrations of PCBs and compounds with dioxin-like activity in the six sediment samples collected for this study, an obvious pathway of contaminants from the sediments to fish was not identified. The Effects Range Low (ER-L) value of 22.7 ng/g is intended to represent concentrations of total PCBs toward the low end of the effects range, below which adverse biological effects are rarely observed (Long *et al.* 1995). Total PCB concentrations measured in sediment samples from all the sites, except Union with an average of 25.7 ng/g, were below the ER-L value. This ER-L value relates to the health of aquatic invertebrate organisms. The total PCB values reported in Table 15 were not corrected for background concentrations as measured by procedural blanks. The blanks had an average concentration of 13 ng/g for total PCBs. This value was almost half the value reported for the Union sediment sample so it is possible that the Union sample is reported at a concentration slightly higher than its true value. Concentrations of PCBs were not detected in sediment samples collected in Hood Canal as part of the Puget Sound Ambient Monitoring Program (Llanso *et al.* 1998). A study of sediment conditions in Lynch Cove Estuary at the tip of Hood Canal in the south found that all levels of contaminants analyzed for, including PCBs and a number of metals, were below state standards, with many being undetectable (Clifford 1996).

SUMMARY AND RESEARCH IMPLICATIONS

Concentrations of PCB compounds with dioxin-like activity were elevated at levels of concern in the eggs from the Hood Canal nests. Total PCB concentrations measured in the eggs collected from the Hood Canal territories exceeded threshold levels identified for normal bald eagle reproduction. Concentrations of PCBs and the total dioxin-like activity in bald eagle eggs from Hood Canal declined from 1992 to 1997. The overall mean total dioxin-like activity measured in the eggs of bald eagles from Hood Canal was above the threshold for adverse effects on reproduction. The mean TEQ value for the eggs collected in 1992 and 1993 was above the LOEL of 210 pg/g (Elliott *et al.* 1996a), whereas the mean TEQ value for the eggs collected between 1994 and 1997 was below the LOEL. Concentrations of DDE, other organochlorine pesticides, mercury, selenium and arsenic measured in the eggs were less than those considered to have an impact on bald eagle productivity. Concentrations of PCBs and total dioxin-like activity were higher in the 13 eggs collected from the Hood Canal area than in 4 of the 5 eggs collected from outside Hood Canal.

As older birds with substantial contaminant burdens are replaced by younger birds, we expect to see a decrease in the persistent environmental contaminants present in eggs if a constant or new source of the environmental contaminants is not available to the eagles. Eggs from two nests were sampled during two different years, and lower concentrations in contaminants were measured the second year; however, it is not possible to compare the results from the two years and conclude that conditions are improving for individual birds. The adult eagles were not color marked so it was not possible to tell if the eggs were from the same birds both years. Both of the nests had a year of inactivity between the first and second sampling times.

Monitoring productivity and nesting success of the Hood Canal nests should be continued to evaluate if the Hood Canal area is meeting recovery goals. If dramatic fluctuations in the average number of young produced per occupied territory or in the nest success rates occur, or if productivity and success rates are consistently lower than the statewide values, we recommend re-initiating a contaminants study of the Hood Canal bald eagles. Additional egg and blood samples should be collected and analyzed to compare with this study's results to evaluate if the levels of the contaminants present in Hood Canal eagles are changing. PCBs account for the greatest proportion of the total dioxin-like potency in the eggs of bald eagles from Hood Canal. Therefore, if a contaminants monitoring effort were to resume, we recommend that measurement of total PCBs would be sufficient to track the greatest chemical threat identified in this study to the Hood Canal eagles. Other environmental contaminants that could be potentially adversely affecting the Hood Canal eagles, but were not included in this study, possibly could also be considered if a contaminants study is reinitiated.

Evaluations of total PCBs should be coupled with a more refined effort to understand the source(s) of PCBs in the eagle's diets. Our sample sizes for the evaluation of sources were extremely small. Therefore, definite conclusions cannot be made about the source(s) of PCBs and other dioxin-like contaminants to the bald eagles. Fish are a major component of the diets of bald eagles in Hood Canal, but the concentrations of PCBs, PCDDs, and PCDFs measured in fish collected from Hood Canal were not great enough to account for the elevated amounts found in bald eagles from this area. Sediments from the area also did not appear to be elevated in concentrations of PCBs, PCDDs, and PCDFs. Therefore our findings indicate that the contaminant pathway to the bald eagles in Hood Canal was likely from food items other than fish. If a contaminant study is reinitiated, we recommend that marine mammals and fish-eating birds be sampled to better understand these potential pathways of contaminant movement.

ACKNOWLEDGMENTS

We appreciate the cooperation and assistance of numerous individuals who participated in this project. The authors would like to thank everyone who helped collect and process samples including: Tom James, of the U.S. Navy; James Watson, Tim Brown, Matt Nixon, Alan Geise, and James Beam of WDFW; Joseph Stewart; Clark Peterson; Jeff Momot of the USFWS; Kurt Dobazinsky; and Ken Dzinbal of WDOE. We would like to thank John Medows, Kevin Feltz, George Tegerdine, Paul Peterman, Robert Gale, and Kathy Echols of the CERC for sample preparation and chemical analysis. We would also like to thank Kathy Echols, Margaret Dutch of WDOE, and Greg Lippert of WDFW for their help with data interpretation and assistance with interpretation of techniques. Special thanks to Andrea LaTier, Jay Davis, John Grettenberger, and Alisa Ralph for review of the draft document; Janis Orton, Kevin Aitkin, and Steve Dilley for assistance with figures and to Pam Kosonen for her many hours working on tables, figures and formatting the document, all of the USFWS. In addition to funding by the U.S. Fish and Wildlife Service, partial funding was provided by the U.S. Navy. We wish to thank Tom James and Kent Livezey for assisting with obtaining and transferring the Navy funding.

LITERATURE CITED

Ahlborg, U.G., G.C. Beckling, L.S. Birnbaum, A. Brouwer, H.J. Derks, M. Feeley, G. Golor, A. Hanberg, J.C. Larsen, A.K.D. Liem, S.H. Safe, C. Schlatter, F. Waern, M. Younes, and E. Yruanheikki. 1994. Toxic equivalency factors for dioxin-like PCBs. Chemosphere 28: 1049-1067.

Anderson, D.W., and J.J. Hickey. 1972. Eggshell changes in certain North American birds. Proc. Int. Ornithol. Congr. 15:514-540.

Anthony, R.G., M.G. Garrett, and C.A.Schuler. 1993. Environmental contaminants in bald eagles in the Columbia River estuary. J. Wildl. Manage. 57(1):10-19.

Best, D.A., W.W. Bowerman IV, T.J. Kubiak, S.R., Winterstein, S. Postupalsky, M.C. Shieldcastle, and J.P. Giesy, Jr. 1994. Reproductive impairment of bald eagles *(Haliaeetus leucocephalus*) along the Great Lakes Shorelines of Michigan and Ohio. Pages 697-702 *in* B.U. Meyburg and R.D. Chancellor, eds. Raptor Conservation Today. World Working Group on Birds of Prey and The Pica Press. East Sussex, U.K.

Bowerman IV, W. W. 1993. Regulation of bald eagle (*Haliaeetus leucocephalus*) productivity in the great lakes basin: An ecological and toxicological approach. PhD Dissertation, Michigan State University, Lansing, Michigan. 291 pp.

Bowerman IV, W.W. D.A. Best, E.D. Evans, S. Potupalsky, M.S. Martell, K.D. Kozie, R.L. Welsh, R.H. Scheel, K.F. Durling, J.C. Rogers, T.J. Kubiak, D.E. Tillitt, T.R. Schwartz, P.D. Jones, and J.P. Giesy. 1990. PCB concentrations in plasma of nestling bald eagles from the Great Lakes Basin, North America. Pages 212-216 *in* H.Fielder and O. Hutzinger, eds. 10th Intl. Conf. on organohalogen compounds, Bayreuth, Germany, Vol. IV.

Bowerman IV, WW., D.A. Best, J.P. Giesy, Jr., T.J. Kubiak, and J.G. Sikarskie. 1994. The influence of environmental contaminants on bald eagle *Haliaeetus leucocephalus* populations in the Laurentian Great Lakes, North America. Pages 703-791 *in* B.U. Meyburg and R.D. Chancellor, eds. Raptor Conservation Today. World Working Group on Birds of Prey and The Pica Press. East Sussex, U.K.

Bosveld, A.T.C., J. Gradener, A.J. Murk, A. Brouwer, M. Van Kampen, E.H.G. Evers and M. Van den Berg. 1994. Effects of PCDDs, PCDFs, and PCBs in common tern (*Sterna hirundo*) breeding in estuarine and coastal colonies in the Netherlands and Belgium. Environ. Toxicol. Chem. 14:99-115.

Buck, J. and E. Sproul. 1999. Organochlorine contaminants in double-crested cormorants from Lewis and Clark National Wildlife Refuge in the Columbia River Estuary. Final Report, U.S. Fish and Wildlife. Service, Portland, Oregon. 41 pp.

Buck, J., R.G. Anthony, and F.B. Isaacs. 1999. Changes in productivity and environmental contaminants in bald eagles nesting along the lower Columbia River. Final Report, U.S. Fish and Wildlife Service, Portland, Oregon. 59 pp.

Buehler, D.A. 200. Bald eagle (*Haliaeetus leucocephalus*). 40 pp. *In*: A. Poole and F. Gill, eds. The Birds of North America, No. 506. The Birds of North America, Inc. Philadelphia, PA.

Clifford W. 1996. A review of sediment conditions in the Lynch Cove Estuary: Hood Canal, Mason County, Washington. Unpubl. report, Mason County Dept. of Health Services, Shelton, Washington. 11 pages, plus appendices.

Colborn T. !991. Epidemiology of Great Lakes bald eagles. J. Toxicol. Environ. Health 33:395-454.

Eisler, R. 1986. Dioxin hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife. Service Biol. Rep. 85(1.8). 37 pp.

Elliott, J.E. and R.J. Norstrom. 1998. Chlorinated hydrocarbon contaminants and productivity of bald eagle populations on the Pacific Coast of Canada. Environ Tox, and Chem. 17(6): 1142-1153.

Elliott, J.E., R.J. Norstrom, G.E.J. Smith. 1996a. Patterns, trends, and toxicological significance of chlorinated hydrocarbon and mercury contaminants in bald eagle eggs from the Pacific Coast of Canada, 1990-1994. Arch. Environ. Contam. Toxicol. 31:354-367.

Ellliott, J.E. R.J. Ross, J. Norstrom, A. Lorenzen,, L.E. Haart, H. Philibert, S.W. Kennedy, J.J. Stegeman, G.D. Bellward and K.M. Cheng. 1996b. Biological effects of polychlorinated dibenzo-*p*-dioxins, dibenzofurans, and biphenyls in bald eagle (Haliaeetus leucocephalus) chicks. Environ. Toxicol.. Chem. 15(5):782-793.

Feltz, K. 1994. NFCRC SOP: C5.202. Procedure for use of automated apparatus employing carbon dispersed by C_{18} volumes to produce three PCB fractions and a PCDD/PCDF fraction. Environmental Contaminant and Research Center, Columbia, MO.

Frenzel, R. W. and R.G. Anthony. 1989. Relationship of diets and environmental contaminants in wintering bald eagles. J. Wildlife Manage. 53(3):792-802.

Giesy, J.P., W.W. Bowerman, M.A. Mora, D.A. Verbrugge, R.A. Othoudt, J.L. Newsted, C.L. Summer, R.J. Aulerich, S.J. Bursian, J.P. Ludwig, G.A. Dawson, T.J. Kubiak, D.A. Best, and D.E. Tillitt. 1995. Contaminants in fishes from the Great Lakes-influenced sections and above dams of three Michigan rivers: III. Implications for health of bald eagles. Arch. Enviton. Contam. Toxicol. 29:309-321.

Giesy, J.P., J.P. Ludwig, and D.E. Tillitt. 1994. Dioxins, dibenzofurans, PCBs and colonial, fish-eating waterbirds. Pages 249-307 *in* A. Schecter, ed. Dioxins and health. Plenum Press, New York.

Grier, J.W. 1982. Ban of DDT and subsequent recovery of reproduction in bald eagles. Science 218:1232-1235.

Hoffman, D.J. , M. J. Melancon, P.N. Klein, J.D. Eisemann, and J.W. Spann. 1998. Comparative developmental toxicity of planar polychlorinated biphenyl congeners in chickens, American kestrels, and common terns. Environ. Toxicol. Chem. 17:747-756.

Hood Canal Technical Work Group. 1995. Shellfish and finfish resources at risk in the Hood Canal Watershed. Unpublished Hood Canal Coordinating Council report. 149 pp.

Knight, R.L., P.J. Randolph, G.T. Allen, L.S. Young and R.J. Wigen. 1990. Diets of nesting bald eagles, *Haliaeetus leucocephalus*, in Western Washington. Can. Field Nat. 104:545-551.

Kozie, K.D. and R.K. Anderson. 1991. Productivity, diet, and environmental contaminants in bald eagles nesting near the Wisconsin shoreline of Lake Superior. Arch. Environ. Contam. Toxicol. 20:41-48.

Kubiak, T.J. and D.A. Best. 1991. Wildlife risks associated with passage of contaminated, anadromous fish at Federal Energy Regulatory Commission-licensed dams in Michigan. Unpubl. Report, U.S. Fish and Wildl. Serv., Div. Ecol. Serv., East Lansing, MI. 24 pp., plus appendices.

Kubiak T.J., H.J. Harris, L.M. Smith, T.R. Schwartz, D.L. Stalling, J.A. Trick, L. Sileo, D.E. Docherty, and T.C. Erdman. 1989. Microcontaminants and reproductive impairment of the Forester's Tern on Green Bay, Lake Michigan-1983. Arch. Environ. Contam. Toxicol. 18:706-727.

Kuehl, D.W., B.C. Butterworth, J. Libal, and P. Marquis. 1991. An isotope dilution high resolution gas chromatographic-high resolution mass spectrometric method for the determination of coplaner polychlorinated biphenlys: application to fish and marine mammals. Chemosphere 22:849-858.

Leach, C.L. 1996. An analysis of habitat characteristics and diet in relation to productivity of the Hood Canal bald eagle population. Senior Thesis, University of Washington, Seattle, Washington.

Llanso, R.J., S. Asen, and K. Welch. 1998. Marine sediment monitoring program I. Chemistry and toxicity testing 1989-1995. Publication No. 98-323, Washington State Department of Ecology, Olympia, Washington. 101 pp. plus appendices.

Long, E.R., D.D. Macdonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environ. Manag. 19:81-97.

Meadows, J. 1991. NFCRC SOP:C5.144. Sediment analyses for PCBs and low-level PHHs. Environmental Contaminant and Research Center, Columbia, MO.

Meadows, J. 1992. NFCRC SOP: C5.143, Extraction of PCBs, PCDDs, and PCDFs from tissue samples, and cleanup of the extracts in preparation for GC/ECD analysis for PCBs, then fractionation of the extracts on dispersed carbon. Revision 1/23/92. Environmental Contaminant and Research Center, Columbia, MO. 6 pp.

Michelsen, T.C. 1992. Organic carbon normalization of sediment data. Washington State Dept. of Ecology, Sediment Management Unit, Olympia, WA.

Nisbet, I.C.T. 1989. Organochlorines, reproductive impairment, and declines in bald eagle *Haliaeetus leucocephalus* populations: Mechanisms and dose-response relationships. Pages 483-489 *in* B.U. Meyburg & R.D. Chancellor, eds, Raptors in the Modern World. World Working Group on Birds of Prey and Owls. Berlin, London, and Paris. 611 pp.

Peterman, P.H. 1994. High resolution gas chromatography/high resolution mass spectrometry for the determination of selected non-o-chloro-substituted polychlorinated biphenyls. MSC SOPC 5.181. Environmental Contaminant and Research Center, Columbia, MO.

Puget Sound Water Quality Action Team. 1998. 1998 Puget Sound update, sixth report of the Puget Sound Ambient Monitoring Program. Puget Sound Water Quality Action Team, Olympia, Washington. 96 pp.

Puget Sound Water Quality Action Team. 2000. 2000 Puget Sound update, seventh report of the Puget Sound Ambient Monitoring Program. Puget Sound Water Quality Action Team, Olympia, Washington. 127 pp.

Rhine, R. and R. Doane. 1995. The Hood Canal watershed: A demographic and economic profile. Hood Canal Coordinating Council unpublished report.

Schmitt, C.J., J.L. Zajicek, and P.H. Peterman. 1990. National Contaminant Biomonitoring Program: Residues of organochlorine chemicals in freshwater fish, 1976-1984. Arch. Environ. Contam. Toxicol. 19:748-781.

Schwartz, T.R. and D.L. Stalling. 1991.Chemometric comparison of polychlorobiphenyl residues and toxicologically active polychlorobiphenyl congeners in the eggs of Forster's terns (Sterns fosteri). Arch. Environ. Contam. and Toxicol. 20:183-199.

Schwartz, T.R., D.E. Tillit, K.P. Feltz, and P.H. Peterman. 1993. Determination of mono-and non-o,o'-chlorine substituted polychlorinated biphenyls in aroclors and environmental samples. Chemosphere 26(8):1443-1460.

Skorupa, J.P. and H.M. Ohlendorf. 1991. Contaminants in drainage water and avian risk thresholds. pp. 345-368 *in* A. Dinar and D. Zilberman eds. The economics and management of water and drainage in agriculture. Klewer Academic Publish.

Stickel, L.F., S.N. Wiemeyer, and L.J. Blus. 1973. Pesticide residues in eggs of wild birds: adjustment for loss of moisture and lipid. Bull. Environ. Contam. and Toxicol. 9:193-196.

Thompson 1996. Mercury in birds and terrestrial mammals. Pp. 341-356. *In:* W.N. Beyer, G.H. Heinz, A.W. Redmon-Norwood, (Eds.). Environmental contaminants in wildlife - interpreting tissue concentrations. SETAC Special Publications Series, Lewis Publishers, New York, NY. 494 pp.

Tillitt D.E., J.P. Giesy, and G.T. Ankley. 1991. Characterization of the H4IIE rat hepatoma cell bioassay as a tool for assessing toxic potency of planar halogenated hydrocarbons (PHHs) in environmental samples. Environ. Sci. Tech. 25:87-92.

Tillitt D.E., G.T. Ankley, J.P. Giesy, J.P. Ludwig, H. Kurita-Matsuba, D.V. Weseloh, P.S. Ross, C.A. Bishop, L. Sileo, K.L. Stromberg, J. Larson, and T.J. Kubiak. 1992. Polychlorinated biphenyl residues and egg mortality in double-crested cormorants from the Great Lakes. Environ. Toxic. and Chem. 11:1281-1288.

U.S. Department of Interior. 1999. Endangered and threatened wildlife and plants; proposed rule to remove the bald eagle in the lower 48 states from the list of endangered and threatened wildlife. Fed. Reg. Vol. 64, No. 128, pp. 36464-36454.

U.S. Fish and Wildlife Service. 1986. Recovery plan for the Pacific bald eagle. U.S. Fish and Wildl. Serv., Portland, OR. 160 pp.

Van den Berg, M., L. Birnbaum, A. T.C. Bosveld, B. Brunstrom, P. Cook, M. Feeley, J.P. Giesy, A. Hanberg, R. Hasegawa, S.W. Kennedy, T. Kubiak, J.C. Larsen, F.X. Rolaf van Leeuwen, A.K. D. Liem, C. Nolt, R.E. Peterson, L. Poellinger, S. Safe, D. Schrenk, D. Tillit, M. Tyklind, M. Younes, F. Waern, and T. Zacharewski. 1998, Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. Environ. Health Perspectives. Vol. 106 (12).

Watson, J.W. 1993. Personal communication. Washington Department of Fish and Wildlife, Olympia, Washington.

Watson, J.W., M.G. Garrett, and R.G. Anthony. 1991. Foraging ecology of bald eagles in the Columbia River Estuary. J. Wildl. Manage. 55(3):492-499.

Watson, J.W., D. Mundy, J.S. Begley, and D.J. Pierce. 1996. Responses of nesting bald eagles to the harvest of geoduck clams (*Panopea abrupta*). Final Report. Wash. Dept. Fish and Wildlife, Olympia. 23 pp.

Watson, J.W. and D.J. Pierce. 1998a. Migration, diets, and home ranges of bald eagles breeding along Hood Canal and at Indian Island, Washington. Final Report. Wash. Dept. Fish and Wildlife, Olympia, Washington. 28 pp. plus appendices.

Watson, J.W. and D.J. Pierce. 1998b. Ecology of bald eagles in western Washington with an emphasis of the effect of human activity. Final Report. Wash. Dept. Fish and Wildlife, Olympia, Washington.

Welch, L.J. 1994. Contaminant burdens and reproductive rates of bald eagles breeding in Maine. M.S. Thesis, Univ. Maine, Orono. 86 pp.

Wiemeyer S.N., B.M Mulhern., F.J. Ligas, R.J. Hensel, J.E. Mathisen, F.C. Robards, and S. Postupalsky. 1972. Residues of organochlorine pesticides, polychlorinated biphenyls, and mercury in bald eagle eggs and changes in shell thickness - 1969 and 1970. Pestic. Monit. J. 6:50-55.

Wiemeyer, S.N., T.G. Lamont, C.M. Bunck, C.R, Sindelar, F.J. Gramlich, J.D. Fraser, and M.A. Byrd. 1984. Organochlorine pesticide, polychlorobiphenyl, and mercury residues in bald eagles eggs–1969-79–and their relationships to shell thinning and reproduction. Arch. Environ. Contam. Toxicol. 13:529-549.

Wiemeyer, S.N., C.M. Bunck, and A.J. Krynitsky. 1988. Organochlorine pesticide, Polychlorinated Biphenyls, and mercury residues in osprey eggs–1970-79–and their relationships to shell thinning and reproduction. Arch. Environ. Contam. Toxicol.17:767-787.

Wiemeyer, S.N., R.W. Frenzel, R.G.Anthony, B.R. McClelland, and R.L. Knight. 1989. Environmental contaminants in blood of Western bald eagles. J. Raptor Res. 23(4):140-146.

Wiemeyer, S.N., C.M. Bunck, C.J. Stafford. 1993. Environmental contaminants in bald eagle eggs–1980-84–and further interpretations of relationships to productivity and shell thickness. Arch. Environ. Contam. Toxicol. 24:213-227.

Wolfe, M.F., S. Schwarzbach, R.A. Sulaiman. 1998. Effects of mercury on wildlife: a comprehensive review. Environ. Toxicol. and Chem. 17(2):146-160.

Wood, P.B., J.H. White, A. Steffer, J.M. Wood, C.F. Facemire, H.F. Percival. 1996. Mercury concentrations in tissue of Florida bald eagles. J. Wildl. Manage. 60(1):178-185.

APPENDICES

Appendix A: Nest productivity and concentrations (ng/g, freshweight) of total PCB's and p,p'DDE in individual bald eagle samples from territories in Hood Canal and outside Hood Canal, Washington, 1992-1997.

Location	Year	Egg Status	Nest Productivity	Total PCBs[a] (Scan, ppm)	Total PCBs[b] (Congeners)	p,p'-DDE	Avg. egg-shell thick.	Percent Change	Failure Rate[c]
Hood Canal Territories									
Brown Point	1992	Fresh	Failed	21,300	12,300	2,700	0.513	-15.7	8/11
Squamish Harbor	1992	Fresh	1 fledged	23,300	11,300	2,600	0.548	-10.0	5/8
Thorndyke[d]	1992	Fresh	Failed	21,300	10,500	3,110	0.573	-5.9	6/6
Hazel Point	1992	Fresh	Failed	17,600	13,900	3,270	0.559	-8.2	5/7
Union	1992	Fresh	Failed	7,390	4,360	1,770	0.525	-13.8	3/5
Bolton Peninsula	1993	Fresh	Failed	10,100	5,230	936	0.546	-10.3	2/3
Toandos East	1993	Fresh	Failed	14,900	7,870	1,140	0.590	-3.1	2/4
Tabook Pt.[d]	1993	Fresh	Failed	12,600	5,550	1,270	0.530	-12.9	8/9
Tahuya	1994	Addled	Failed	13,000	4,930	1,380	0.570	-6.4	new nest
Duckabush[d]	1995	Addled	1 fledged	5,020	4,830	1,910	NA[e]	NA	new nest
Union	1996	Addled	1 fledged	NC[f]	3,660	4,330	0.605	-0.6	5/7
Toandos East	1997	Addled	1 fledged	NC	4,590	1,390	0.694	+14.0	3/6
Dewatto Bay[d]	1997	Addled	Failed	NC	4,730	1,790	0.605	-0.6	0/2
Outside Hood Canal									
Skagit (Utopia Road)	1992	Addled	Failed	3,330	1,130	367	0.529	-13.1	New nest
Kydikabbit Pt.	1995	Addled	Failed	3,550	2,580	3,520	0.610	+0.2	0/1
Browns Point	1995	Addled	Failed	5,970	5,400	5,680	0.623	+2.3	0/1
Bahobohosh Point	1996	Addled	Failed	NC	3,410	1,930	0.658	+8.1	6/10
Saddle Rock	1997	Addled	Failed	NC	2,560	3,190	0.637	+4.6	3/8

[a] Total PCB's were determined using an Organochlorine Scan
[b] Total PCBs were determined by adding congener specific PCBs
[c] Failure rate of the nests (years fail/active with known outcome) prior to year eggs were collected, not including years eggs were sampled before.
[d] Average of replicates
[e] NA: Not available
[f] NC: Analysis was not conducted on this sample

Appendix B: Polychlorinated biphenyl congeners (ng/g fresh weight) in individual egg samples from bald eagles nesting in the Hood Canal area and in territories outside Hood Canal in Western Washington, 1992 - 1997.

	Hood Canal Territories													Outside Hood Canal Territories				
IUPAC	Union	Brown Point	Hazel Point	Squamish Harbor	Thorn.[a]	Bolton Pen.	Toandos East	Tabook Point[a]	Tahuy[a]	Duck.[a]	Union	Toandos East	Dewatto Bay[a]	Skagit	Kydik. Point	Browns Point	Bahob	Saddle Rock
Congener no.	1992	1992	1992	1992	1992	1993	1993	1993	1994	1995	1996	1997	1997	1992	1995	1995	1996	1997
% lipid	5.7	4.5	4.0	4.9	4.8	6.1	5.0	4.7	3.6	2.7	5.5	6.1	6.3	7.3	4.5	4.7	1.8	6.4
030% rec[b]											60.0	58	61.0				59.0	52.0
204% rec[c]											70.0	68	69.0				65.0	59.0
004, 010	<0.2	<0.2	<0.2	<0.2	<0.2	<0.02	<0.02	<0.02	<0.02	<0.3	<1.9	<1.9	<1.9	<0.02	<0.2	<0.2	<1.9	<1.9
007, 009	<0.2	<0.2	<0.2	<0.2	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.7	<0.7	<0.7	<0.02	<0.2	<0.2	<0.7	<0.7
006	<0.2	<0.2	<0.2	<0.2	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<1.0	<1.0	<1.0	<0.02	<0.2	<0.2	<1.0	<1.0
005, 008	<0.2	<0.2	<0.2	<0.2	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	0.4	<0.3	0.2	<0.02	<0.2	<0.2	0.2	<0.3
019	<0.2	<0.2	<0.2	<0.2	<0.2	<0.02	<0.02	<0.02	<0.02	0.4	<0.6	<0.6	0.3	<0.02	0.4	0.3	<0.6	<0.6
018	<0.2	<0.2	<0.2	<0.2	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.4	<0.4	<0.4	0.1	<0.2	<0.2	<0.4	<0.4
017, 015	<0.2	<0.2	<0.2	<0.2	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.3	0.3	0.2	0.2	<0.2	<0.2	<0.3	<0.3
024, 027	<0.2	<0.2	<0.2	<0.2	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.3	0.2	<0.3	<0.02	<0.2	<0.2	<0.3	<0.3
016, 032	<0.2	<0.2	0.4	<0.2	<0.2	0.1	<0.02	<0.02	<0.02	<0.2	0.2	0.2	0.3	0.1	<0.2	<0.2	0.2	0.1
029	<0.2	<0.2	<0.2	<0.2	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	0.2	<0.1	0.1	<0.02	<0.2	0.3	0.1	<0.1
026	<0.2	0.4	0.3	<0.2	<0.2	4.1	5.8	<0.02	5.6	3.5	3.0	0.2	0.2	1.4	1.6	2.7	1.0	<0.1
025	1.4	0.6	2.2	1.8	1.0	<0.02	<0.02	<0.02	<0.02	0.9	<0.2	<0.2	<0.2	<0.05	0.8	1.4	<0.2	<0.2
031	0.6	<0.2	<0.2	<0.2	<0.2	0.4	<0.02	0.8	1.2	0.4	0.6	0.9	1.1	0.8	<0.3	0.5	0.6	0.5
028	<0.2	<0.2	0.7	<0.2	0.5	3.3	3.8	5.0	7.0	2.2	3.2	3.2	3.9	2.0	1.6	3.9	2.7	2.5
020,033	<0.2	<0.2	<0.2	<0.2	<0.2					<0.2	0.2	<0.3	<0.3		<0.3	<0.2	<0.3	<0.3
053	<0.2	<0.2	<0.2	<0.2	<0.2					<0.2	0.1	0.1	0.1		<0.2	<0.3	0.1	0.1
020, 033, 053						0.3	0.3	0.4	0.3					0.3				
051	<0.2	<0.2	<0.2	<0.2	<0.2	<0.02	<0.05	0.1	0.1	<0.2	0.1	0.1	0.1	<0.05	<0.2	<0.2	<0.1	<0.1
022	<0.2	<0.2	<0.2	<0.2	<0.2	<0.02	0.2	0.3	0.6	<0.2	0.4	0.3	0.3	0.3	<0.2	<0.2	0.2	0.2
045	<0.2	<0.2	<0.2	<0.2	<0.2	<0.02	<0.02	<0.02	0.3	<0.2	0.4	0.1	0.2	0.1	<0.3	0.4	0.1	0.1
046	<0.2	<0.2	<0.2	<0.2	<0.2	<0.02	<0.02	<0.02	<0.02	<0.2	<0.1	<0.1	<0.1	<0.02	0.9	0.4	<0.1	<0.1
052	6.5	15.5	23.5	10.4	13.7	7.2	9.0	13.6	11.8	19.7	5.7	8.6	12.2	3.4	5.9	9.6	4.0	5.5
043										18.8	0.3	0.2	0.3		<0.2	0.7	0.2	0.4
049										16.3	8.6	10.5	12.9		5.6	12.4	6.6	7.5
049, 043	11.3	20.8	29.8	21.6	23.8	11.1	14.1	21.0	32.9					5.8				
047						17.5	25.2	24.8	21.7	22.9	18.7	13.7	20.3	5.9	9.9	8.1	1.5	10.9

Appendix B: continued

IUPAC	Hood Canal Territories													Outside Hood Canal Territories				
IUPAC	Union	Brown Point	Hazel Point	Squamish Harbor	Thorn.[a]	Bolton Pen.	Toandos East	Tabook Point[a]	Tahuya	Duck.[a]	Union	Toandos East	Dewatto Bay[a]	Skagit	Kydik. Point	Browns Point	Bahob	Saddle Rock
Congener no.	1992	1992	1992	1992	1992	1993	1993	1993	1994	1995	1996	1997	1997	1992	1995	1995	1996	1997
048						<0.02	<0.02	<0.02	<0.02	1.3	0.7	0.5	0.9	<0.02	0.4	25.8	13.0	0.5
047, 048	17.4	43.7	47.7	33.7	44.6													
044	1.9	2.7	3.8	3.1	3.1	2.0	2.5	2.5	3.1	1.5	1.4	1.3	1.4	1.8	1.8	2.5	1.1	0.7
042	1.1	1.4	4.1	2.3	2.4	1.6	1.2	3.2	2.9	1.6	1.2	1.6	1.8	1.6	1.3	1.2	0.9	0.9
041	4.4	2.6	8.9	9.5	4.9	<0.02	<0.02	<0.02	<0.02	0.7	<0.1	1.0	0.4	<0.02	0.5	<0.3	<0.1	0.1
064	3.0	7.3	11.4	7.3	8.4	4.1	<0.02	8.2	17.5	2.9	2.7	4.1	3.4	3.2	2.5	3.3	1.8	2.7
040	2.0	3.0	4.4	3.3	3.2	0.4	0.5	0.6	<0.02	1.3	0.7	0.4	0.6	0.5	0.8	1.5	0.5	0.3
067	3.3	7.1	7.7	7.4	7.3	2.5	3.5	3.5	2.7	1.8	2.5	1.8	2.0	1.3	0.8	3.3	1.4	1.4
063	77.3	126	120	130	147	<0.02	<0.02	<0.02	<0.02	1.8	1.7	1.7	1.9	<0.02	1.1	22.2	1.4	1.4
074	0.2	0.6	1.4	<0.2	<0.2	5.3	9.7	7.5	8.9	20.1	16.7	153	17.8	0.7	11.4	24.2	12.6	11.4
070, 076	<0.2	<0.2	<0.2	<0.2	<0.2	4.6	5.5	6.4	5.6	3.8	3.6	6.1	5.8	0.9	2.9	3.5	3.5	2.8
066										16.4	1.0	1.0	0.9		14.1	24.2	0.7	0.8
095										20.9	8.5	9.5	12.4		9.7	6.2	5.3	3.9
066, 095, 088	13.7	25.8	42.6	25.7	31.1	19.5	26.2	31.6	29.3					10.2				
091	14.4	24.6	34.7	27.7	28.4	15.5	18.3	24.2	28.6	18.7	13.9	10.7	15.2	9.9	11.5	8.6	8.1	6.9
056, 060	0.3					0.4	0.4	0.5	1.0	1.9	2.6	2.9	2.4	<0.02	1.9	2.8	1.7	2.1
092	39.5	39.5	54.6	40.8	51.4	11.8	13.5	14.9	9.1	4.4	8.8	8.5	12.9	5.2	4.6	91.7	4.6	3.2
084	30.6	38.9	61.8	54.0	40.6	<0.02	<0.02	<0.02	<0.02	17.6	0.8	0.5	0.6	<0.02	0.7	35.6	<0.3	<0.3
101										141	83.3	126	133		47.1	93.0	78.0	64.9
101, 090	107	270	281	231	263	142	209	222	185					36.1				
099	137	392	331	309	441	247	294	277	204	253	180	140	190	57.1	98.4	195	107	81.4
119	10.2	29.6	29.7	26.6	25.5	11.9	19.0	10.4	13.7	8.7	7.4	8.8	8.2	4.4	6.0	8.2	5.3	4.7
083	148	328	538	426	378	2.2	<0.02	<0.02	1.8	136	1.5	1.4	1.2	1.5	176.5	90.0	<0.1	0.9
097	4.2	9.3	9.3	7.6	8.5	6.3	7.4	12.8	3.7	6.3	3.1	4.4	5.0	4.5	4.2	2.4	2.3	1.1
081										9.2					4.7	8.5		
087	23.9	55.3	64.9	55.0	56.5	34.2	44.3	47.4	42.8	29.7	21.2	24.0	25.5	13.2	14.5	17.7	15.5	15.7
136	<0.2	<0.2	<0.2	34.2	<0.2	<0.02	<0.02	<0.02	<0.02	5.6	7.1	2.9	4.2	<0.02	8.5	4.9	3.2	3.7
110	24.4	86.5	92.3	66.8	121.5	32.4	53.0	53.0	45.1	24.9	18.0	34.2	25.1	9.3	12.1	11.2	13.1	20.9
082						<0.02	<0.02	<0.02	15.2	22.1	9.9	15.9	20.4	<0.02	46.3	26.1	10.3	12.4
151						17.5	17.5	30.2	21.1	26.0	23.3	2.0	26.6	11.2	13.6	15.2	9.4	7.8
082, 151	<0.2	<0.2	<0.2	<0.2	<0.2													
135, 144, 124	12.9	25.9	36.8	25.3	25.5	22.1	19.0	33.5	19.1	24.7	16.5	17.8	19.9	5.2	10.8	21.5	10.3	10.3

Appendix B: Continued

IUPAC	Hood Canal Territories													Outside Hood Canal Territories				
	Union	Brown Point	Hazel Point	Squamish Harbor	Thorn.[a]	Bolton Pen.	Toandos East	Tabook Point[a]	Tahuya	Duck.[a]	Union	Toandos East	Dewatto Bay[a]	Skagit	Kydik. Point	Browns Point	Bahob	Saddle Rock
Congener no.	1992	1992	1992	1992	1992	1993	1993	1993	1994	1995	1996	1997	1997	1992	1995	1995	1996	1997
147										15.2	19.1	26.2	29.6		13.4	7.8	15.3	14.2
107	1.3	21.8	3.7	79.9	83.5	5.9	8.1	5.7	8.3	17.9	7.8	17.3	12.4	<0.02	6.5	15.6	10.9	12.4
123, 149	62.4	194	207	143	174	121	190	171	120	95.7	80.5	113	105	28.7	41.5	66.0	54.6	42.4
118	<0.2	9.8	<0.2	<0.2	<0.2	4.3	3.0	4.3	4.9	158	164	195	177	0.8	99.2	158.1	141.1	93.8
134	179	47.7	<0.2	<0.2	<0.2	<0.02	<0.02	<0.02	<0.02	0.7	1.5	0.8	0.9	<0.02	1.7	<0.3	<0.1	0.6
114										17.2	<0.1	<0.1	<0.1		5.6	18.2	<0.1	<0.1
131, 122										1.0	1.1	1.2	1.4		4.9	0.6	<0.1	0.9
146	183	481	472	488	416	202	262	181	166	185	123	126	148	35.2	75.3	147.4	107.9	74.9
153	634	1760	1630	1660	1550	611	852	557	492	699	466	522	618	119	343	753	525	284
132	26.5	109	91.7	61.7	69.4	168	176	252	87.2	37.8	18.1	9.3	18.7	15.8	23.3	12.2	10.2	8.7
105	12.6	22.0	23.7	38.3	28.6	<0.02	<0.02	<0.02	<0.02	49.9	95.9	114.9	93.8	<0.02	32.0	50.3	63.8	49.1
141	20.3	61.3	72.6	60.0	47.6	28.3	46.4	33.2	36.7	26.7	14.6	25.2	22.9	8.2	10.5	17.3	14.6	12.3
179	<0.2	<0.2	<0.2	<0.2	0.6	0.7	1.3	<0.02	0.7	1.2	1.4	1.4	1.0	<0.02	3.4	2.2	0.7	0.4
137	2.3	8.1	5.8	7.4	6.7	49.4	67.9	47.4	35.8	33.8	30.5	32.2	34.7	11.5	18.5	38.6	14.7	15.8
176	<0.2	<0.2	<0.2	<0.2	<0.2	2.8	3.5	4.9	2.3	23.5	1.9	2.0	1.7	6.4	23.7	1.6	1.0	0.9
130	37.9	101	131	105	97.3	45.8	64.6	46.5	46.9	23.1	26.7	31.1	34.5	8.8	9.1	36.7	18.1	17.2
138	476	1660	1550	1410	1440	835	1100	756	637	680	462	551	649	149	309	602	413	280
158	50.6	179	218	152	133	71.8	111	58.7	56.5	49.2	37.8	47.4	44.6	11.3	25.1	56.2	26.4	21.7
129						1.1	2.0	3.2	1.2	2.2	1.5	0.9	1.4	1.9	0.8	<0.2	0.7	0.4
178						51.2	77.8	52.7	50.3	46.3	36.3	41.3	45.9	10.7	14.9	58.2	22.6	24.2
129, 178	33.8	130	143	130	113													
182, 187	283	978	1151	1083	758	386	588	384	359	347	211	294	303	79.5	160	428	227	181
183	144	421	477	427	315	157	274	158	149	130	111	135	139	25.7	74.4	191	133	85.0
128	102	392	361	284	327	137	172	115	103	126	99.4	112	126	19.9	48.6	115	62.3	52.6
167	<0.2	<0.2	<0.2	<0.2	<0.2	<0.02	<0.02	<0.02	<0.02	18.5	14.1	25.8	19.1	<0.02	14.0	31.9	22.9	14.6
185	2.0	4.8	7.1	3.7	4.7	1.8	2.9	3.8	3.5	2.8	2.2	2.2	2.5	0.5	1.3	2.0	1.3	1.4
174	9.0	24.0	35.2	24.1	22.7	19.4	30.9	29.1	22.1	17.9	15.3	18.7	17.2	5.9	8.1	9.5	9.8	7.9
177	41.1	150	185	164	123	80.2	132	88.0	89.4	66.8	54.7	67.8	62.4	15.1	24.5	69.9	35.7	36.8
171, 202										40.1	39.6	40.5	42.3		15.6	49.6	27.6	24.2
156										44.8	39.6	55.2	47.4		23.4	57.5	29.5	23.6
202, 171, 156	62.1	197	224	220	153	74.1	135	85.5	79.2					13.9				
173										2.1	0.2	0.2	0.3		1.3	<0.3	0.0	0.1

Appendix B: continued						Hood Canal Territories								Outside Hood Canal Territories				
IUPAC	Union	Brown Point	Hazel Point	Squamish Harbor	Thorn.[a]	Bolton Pen.	Toandos East	Tabook Point[a]	Tahuya	Duck.[a]	Union	Toandos East	Dewatto Bay[a]	Skagit	Kydik. Point	Browns Point	Bahob	Saddle Rock
Congener no.	1992	1992	1992	1992	1992	1993	1993	1993	1994	1995	1996	1997	1997	1992	1995	1995	1996	1997
201											13.4	26.7	24.8				15.8	11.5
157											16.7	16.5	12.2				12.4	11.3
157, 201	11.8	26.5	41.1	40.4	19.7	11.7	25.6	15.9	18.2	20.2				2.8	12.4	27.4		
172	19.1	61.0	86.0	67.5	40.1	21.8	38.7	21.3	22.3	20.0	15.8	19.4	18.4	4.1	13.0	33.9	14.2	13.9
197										1.7	2.0	2.4	2.1		1.3	3.3	2.0	1.5
180	348	1090	1370	1157	713	496	839	536	579	309	355	508	540	94.2	214	596	459	351
193	39.1	132	187	136	113	27.8	44.1	29.8	28.1	23.6	18.2	21.8	22.9	5.4	11.3	125	15.8	14.9
191	18.8	51.8	67.0	56.6	37.9	12.8	20.0	14.9	14.3	11.3	8.3	11.9	11.2	3.3	3.5	24.5	9.2	6.1
200	3.3	6.7	11.8	9.7	6.4	0.2	0.4	1.2	0.5	0.4	0.6	0.5	0.5	0.3	0.5	<0.2	0.3	0.1
170, 190	84.1	332	382	339	245	138	237	136	129	106	68.9	97.2	112.4	29.0	65.7	150	75.4	76.1
198										1.9	2.9	2.9	3.2		1.3	4.6	2.3	2.5
199	67.3	192	247	247	139	69.6	126	71.0	74.1	69.5	55.2	69.4	67.4	14.5	26.2	100	54.0	48.8
196, 203	63.2	176	196	212	131	60.6	126	64.2	63.6	51.8	51.5	57.2	58.8	13.2	31.5	89.4	45.9	39.8
189										3.3	2.0	3.7	3.2	3.4	2.2	6.7	3.4	2.5
208, 195	14.2	40.5	37.7	45.4	32.2	13.9	26.7	17.1	15.7	12.7	13.5	14.0	15.6	13.5	6.6	23.7	10.2	11.0
207										2.4	2.0	2.0	2.2		1.4	2.7	1.7	1.7
194	60.2	151	194	187	92.0	48.9	91.7	47.8	51.2	36.2	45.7	52.2	50.8		26.3	80.6	49.1	41.9
205										7.2	4.2	6.3	6.5		3.5	10.6	7.1	5.0
206										11.4	12.3	14.3	15.9		5.6	<0.2	13.5	10.9
209										3.6	3.3	4.4	4.9		1.5	4.4	3.8	3.1

[a] Average of replicates
[b] PCB 030 recoveries should be used to correct for recovery of congeners 004, 010 up through 022
[c] PCB 204 recoveries should be used to correct for recovery for the remaining congeners

Appendix C: Concentrations of organochlorine pesticides (ng/g, fresh weight) detected in bald eagle eggs collected in 1992 from Hood Canal territories

Analyte	Union	Brown Point	Squamish Harbor	Thorndyke[a]	Hazel Point
hexachlorobenzene	6	6	8	10	20
beta-BHC	13	32	49	41	51
oxychlordane	32	50	47	63	63
heptachlor epoxide	14	18	24	27	28
trans-chlordane	ND[b]	4	ND	5	5
cis-chlordane	ND	9	ND	15	16
dieldrin	ND	40	44	43	39
p,p'-DDE	1,770	2,700	2,600	3,110	3,270
trans-nonaachlor	124	178	151	246	313
cis-nonaachlor	55	64	85	79	118
o,p'-DDT	8	17	23	20	27
p,p'-DDD	136	102	126	177	221
p,p'-DDT	10	13	ND	14	7
mirex	12	18	24	19	33
Toxaphene	281	390	350	556	783

[a] Average of replicates

[b] ND: Not detected at specified detection limit

Appendix D: Concentrations of polychlorinated dibenzo-p-dioxins (pg/g, fresh weight) in individual bald eagle eggs from Hood Canal territories and outside Hood Canal, Washington, 1992 - 1997.

Territory	Year	Location	% Lipid	2,3,7,8 TCDD	1,2,3,7,8 PECDD	1,2,3,4,7,8 HXCDD	1,2,3,6,7,8 HXCDD	1,2,3,7,8,9 HXCDD	1,2,3,4,6,7,8 HPCDD	OCDD
Hood Canal										
Brown Point	1992	North	4.5	13	18	1.2	14	0.5	1.4	3.1
Squamish Harbor	1992	North	4.9	17	25	2.0	23	0.8	0.6	3.0
Thorndyke [a]	1992	North	4.8	16	22	1.2	16	0.8	0.9	2.5
Hazel Point	1992	North	4.0	21	32	2.3	27	0.8	0.6	2.7
Union	1992	South	5.7	9.0	11	1.7	11	0.6	1.1	4.7
Bolton Peninsula	1993	North	6.1	8.2	15	1.3	12	0.9	16.7	57
Toandos East	1993	North	5.0	8.4	16	0.8	8.9	0.5 NQ[b]	0.4	6.1
Tabook Pt.[a]	1993	North	4.7	10	15	1.2	13	0.6	0.5	6.8
Tahuyaa	1994	South	3.6	12	20	1.8	14	1.0	1.1	2.9
Duckabush[a]	1995	North	2.7	2.7	4.1	0.4	4.7	0.2 NQ	0.5 NQ	3.3
Union	1996	South	5.5	5.5	7.5	0.5 NQ	7.3	0.3	1.0 NQ	34
Toandos East	1997	North	6.1	5.8	8.9	0.9 NQ	5.8	0.4	0.5 NQ	5.9
Dewatto Bay[a]	1997	South	6.3	5.3	9.6	1.5	9.2	0.5 NQ	0.8	9.3
Outside Hood Canal										
Skagit	1992	Inland	7.3	14	7.3	0.4	8	0.1 ND	1.3	1.1
Kydikabbit Pt.	1995	Outer Coast	4.5	2.3	3.2	0.2 NQ	5.5	0.1 ND	0.2 NQ	4.7
Browns Point	1995	Outer Coast	4.7	2.7	2.8	0.2 NQ	2.6	0.1 ND	0.1 ND	1.7
Bahobohosh	1996	Outer Coast	1.8	4.9	8.2	1.1 NQ	9.6	0.6	1.1 NQ	8.1
Saddle Rock	1997	Outer Coast	6.4	5.2	5.8	0.9	5.1	0.2	0.3	8.7

[a] Average of replicates

[b] NQ: Not quantitated at specified average concentration due to inaccurate ion ratio

Appendix E: Concentrations of polychlorinated dibenzofurans (pg/g, fresh weight) in individual bald eagle eggs from Hood Canal territories and outside Hood Canal, Washington, 1992 - 1997.

Territory	2,3,7,8 TCDF	1,2,3,7,8 PECDF	2,3,4,7,8 PECDF	1,2,3,4,7,8 HXCDF	1,2,3,6,7,8 HXCDF	1,2,3,7,8,9 HXCDF	2,3,4,6,7,8 HXCDF	1,2,3,4,6,7,8 HPCDF	1,2,3,4,7,8,9 HPCDF	OCDF
Hood Canal										
Brown Point	12	0.8	10	0.5	0.5	<0.3 NQ[b]	<1 NQ	0.9	<0.4 NQ	0.8
Squamish Harbor	13	1.1	13	0.7	0.6	<0.03 ND[c]	<0.7 NQ	0.6	0.5	0.5
Thorndyke[a]	17	1.3	13	0.6	0.7	<0.3 ND	<0.6 NQ	0.6	0.6	<0.5 NQ
Hazel Point	34	2.3	19	0.8	0.9	<0.1 ND	<1 NQ	1.0	<0.4 NQ	0.8
Union	12	0.7	6.1	0.5	0.4	<0.1 ND	<0.4 NQ	0.4	<0.2 NQ	0.5
Bolton Peninsula	5.6	0.9	8.0	0.8	1.7	0.2	2.3	4.1	2.1	6.7
Toandos East	14	1.4	9.0	1.1	3.0	0.3	5.3	6.8	3.2	9.0
Tabook Pt.[a]	28	1.7	11	0.8	2.2	0.2	4.5	6.1	2.1	10
Tahuya	11	1.4	12	1.5	2.6	0.3	5.0	6.2	2.4	8.4
Duckabush[a]	4.0	0.4	2.0	0.1	0.8	0.1 ND	0.1 ND	0.5	0.1	2.6
Union	3.5	0.6 NQ	3.5	0.5 NQ	0.2 NQ	0.1 NQ	0.2 NQ	0.2 NQ	0.3 NQ	4.0
Toandos East	10	1.0	6.3	0.3	0.3 NQ	0.1 NQ	0.3 NQ	0.3	0.3	3.0
Dewatto Bay[a]	11	1.1	5.6	0.6	0.3	0.1 NQ	0.3 NQ	0.5	0.3 NQ	4.0
Outside Hood Canal										
Skagit	3.2	0.4	2.9	0.3	0.5	0.1 ND	0.9	1.7	0.7 NQ	3.7
Kydikabbit Pt.	4.1	0.3 NQ	1.7	0.2 NQ	0.6	0.2 NQ	2.9	0.6 NQ	0.2 NQ	2.3
Browns Point	3.2	0.3 NQ	1.5	0.1 NQ	0.6	0.1 NQ	0.1 ND	0.3 NQ	0.3 NQ	2.3
Bahobohosh	9.5	1.1 NQ	6.1	0.8	0.6 NQ	0.2 NQ	0.5 NQ	0.8 NQ	0.4 NQ	5.5
Saddle Rock	9.3	0.7	3.1	0.2 NQ	0.2	0.1 NQ	0.1 NQ	0.3	0.2	2.6

[a] Average of replicates
[b] NQ: Not quantitated at specified average concentration due to inaccurate ion ratio
[c] ND: Not detected at specified detection limit

Appendix F: Concentrations of non-ortho chlorinated biphenlys (pg/g fresh weight) in bald eagle eggs from Washington, 1992 - 1997.

Territory	Year	Location	3,3',4,4'-TeCB (77)	3,4,4',5-TeCB (81)	3,3',4,4',5-PeCB (126)	3,3'4,4'5,5'-HxCB (169)
Hood Canal						
Brown Point	1992	North	662	138	1930	313
Squamish Harbor	1992	North	1500	160	2210	470
Thorndyke[a]	1992	North	1360	150	1880	296
Hazel Point	1992	North	1880	160	2820	508
Union	1992	South	1210	85	1120	223
Bolton Peninsula	1993	North	1340	134	1530	163
Toandos East	1993	North	1320	176	1700	245
Tabook Pt[a]	1993	North	1460	151	1230	1540
Tahuya	1994	South	1620	222	1580	242
Duckabush[a]	1995	North	367	63	550	100
Union	1996	South	456	54	442	96
Toandos East	1997	North	612	70	758	123
Dewatto Bay[a]	1997	South	665	63	772	122
Outside Hood Canal						
Skagit	1992	Inland	456	63	328	58
Kydikabbit Pt.	1995	Outer Coast	220	35	470	140
Browns Point	1995	Outer Coast	350	60	460	130
Bahobohosh	1996	Outer Coast	818	61	782	169
Saddle Rock	1997	Outer Coast	574	54	442	105

[a] Average of replicates

Appendix G: Concentrations (ng/g fresh weight) of monoortho-substituted polychlorinated biphenyls in individual bald eagle egg samples collected in Washington, 1992 - 1997.

Territory	Year	Location	% Lipid	105	114	118	123	156	157	167	189
Hood Canal											
Brown Point	1992	North	4.5	277	24.1	1010	10.7 [b] (14.8)	137.8	37.1 [c] (17.7)	103	14.2
Squamish Harbor	1992	North	4.9	215	18.6	863	8.7[b] (12.0)	124.9	32.5 [c] (15.5)	102	14.4
Thorndyke [a]	1992	North	4.8	237	22	907	9.7[b] (13.4)	104.1	33.9 [c] (16.1)	68.9	11.5
Hazel Point	1992	North	4	238	19.2	897	9.2[b] (12.7)	144.8	36.6 [c] (17.4)	120	15.3
Union	1992	South	5.7	85.8	6.3	392	3.6[b] (5.0)	40.7	13.0 [c] (6.2)	41.9	6
Bolton Peninsula [a]	1993	North	6.1	113	8.4	423	3.2	50	14.8	34.9	3.9
Toandos East	1993	North	5	189	15	785	6.4	93.6	24	70.5	9.2
Tabook Pt[a]	1993	North	4.7	118	10.4	473	4	47.1	14.4	33	4.7
Tahuya	1994	South	3.6	141	10.5	609	4.9	62.3	16.1	50.5	6.3
Duckabush [a]	1995	North	2.7	49.9	17.2	158	NA[d]	44.8	NA	18.5	3.3
Union	1996	South	5.54	95.9	<0.1	164	NA	20.5	16.7	14.1	2
Toandos East	1997	North	6.1	118	<0.1	201	NA	56.8	16.9	26.6	3.9
Dewatto Bay [a]	1997	North	6.28	94.7	<0.1	179	NA	48	12.4	19.3	3.2
Outside Hood Canal											
Skagit	1992	Inland	7.3	28.6	2.8	126	1.2	10.9	2.9	9.2	1.4
Kydikabbit Pt.	1995	Outer Coast	4.5	32	5.6	99.2	NA	23.4	NA	14	2.2
Browns Point	1995	Outer Coast	4.7	50.3	18.2	158	NA	57.5	NA	31.9	6.7
Bahobohosh	1996	Outer Coast	1.8	68.7	<0.1	152	NA	31.8	13.3	24.7	3.6
Saddle Rock	1997	Outer Coast	6.4	58.2	<0.1	111	NA	28	13.4	17.3	3

[a] Average of replicates
[b] Recoveries in an eagle egg matrix spike were low with 62.1% recovered, values in parentheses were adjusted to 100% recovery and were included in calculations
[c] Recoveries in an eagle egg matrix spike were high with 210% recovered, values in parentheses were adjusted to 100% recovery and were included in calculations
[d] NA: Not Available