Alaska Department of Environmental Conservation
Fish Monitoring Program: Analysis of Organic Contaminants

The natural resources of the State provide a rich bounty of foods for Alaskan residents as well as for the rest of the world. There has been concern that Persistent Organic Pollutants (POPs) have been identified across the globe, including the Arctic, and may negatively impact the Alaskan environment. These pollutants can travel great distances in the atmosphere and in ocean currents from their source of origin. They resist chemical breakdown and bioaccumulate up the food chain. Limited sampling of Alaskan fishes for these contaminants has not found levels of concern, but questions about the safety of eating fish from the North Pacific still arise. The Alaska Department of Environmental Conservation (ADEC) developed the Fish Monitoring Program in order to conduct a more rigorous examination of contaminant levels in Alaskan fishes. The program involves collection of selected marine and freshwater finfish species from around the state and testing these fishes for a broad range of environmental contaminants.

In a collaborative effort with biologists from the Alaska Department of Fish and Game, the U.S. National Oceanic and Atmospheric Agency (NOAA), the International Pacific Halibut Commission (IPHC), the Department of the Interior US Fish and Wildlife Service (USFWS), the Alaska Department of Environmental Conservation, and commercial and native fishermen, fish tissue samples have been collected throughout the state. Fish were collected starting in 2001 and continue through the present.

All samplers have been trained to follow the standard protocol written in the Quality Assurance Project Plan to assure quality samples were submitted for analysis. Fish were caught, labeled, put in food grade plastic bags (fish sleeves or zip-lock type bags) and placed in lined wetlock boxes. The samples were either immediately shipped on ice, or frozen and then shipped when logistics allowed. Fish were shipped to the Environmental Health Laboratories (EH Lab) in Palmer or Anchorage, Alaska. Over 2300 samples have been collected as of fall 2006. The fish were processed at the EH Lab and chemical analysis was performed on the homogenized skinless fillets of individual fish. Tissue samples were tested for seven heavy metals at the EHL Lab: arsenic, cadmium, lead, nickel, chromium, selenium, and mercury. Results for the heavy metal and mercury analyses can be found on the State web page: http:www.state.ak.us/dec/eh/vet/fish.htm.

Two metals, inorganic arsenic and chromium^{+6} were measured in the same subset of samples as the organic analyses discussed below. All but one arsenic sample were below the detection limit, and the one sample was too low for reliable quantification, so no further mention will be made of these metals.

Due to the high cost of the analysis for organic contaminants, only a subset of fish samples were analyzed for organochlorine contaminants; polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs) (brominated fire retardants), polychlorinated dibenzo-p-dioxins (PCCDs) (dioxins), polychlorinated dibenzofurans (PCDFs) (furans), and organochlorine pesticides. USEPA analytical methods were followed by the contract laboratory (AXYS Analytical Services Ltd. (AXYS) in British Columbia, Canada) selected by the state for the analyses. Data results from AXYS were validated by independent third party contractors using USEPA Region 10 Validation Methods.

This report presents the organochlorine contaminant data from 157 fish samples. Included are Chinook (king) salmon (*Oncorhynchus tshawytscha*), chum (dog) salmon (*O. keta*), pink (humpback) salmon (*O. gorbuscha*), sockeye (red) salmon (*O. nerka*), Coho (silver) salmon (O. kisutch), Pacific halibut (*Hippoglossus stenolepis*), Walleye Pollock (*Theragra chalcogramma*), sablefish (*Anoplopoma fimbria*), and Sheefish (*Stenodus leucichthys*). This subset of fish did not include all species collected during the study period.

Table 1 Sample size by general area where the fish were collected.

Species (# of fish)	Southeast Alaska	Gulf of Alaska	Bering Sea	Freshwater (Kotzebue)
Chinook Salmon (35)	8	12	15	
Chum Salmon (18)			18	
Pink Salmon (17)	7	5		
Sockeye Salmon (24)		12	12	
Coho Salmon (14)	9	5		
Halibut (23)		23		
Pollock (11)			12	
Sablefish (12)		11		
Sheefish (8)				8

Figure 1. Map of Alaska, showing the general areas where the fish for this study were obtained.

The fishes evaluated in this study occupy different positions in Alaskan ecosystems. Salmon are anadromous. Born in fresh water streams, they migrate downstream to mature in the North Pacific, then return to their birth stream to spawn. They are found in all major waterways of Alaska, as well as the oceans and seas off Alaska's coastline. Native fishermen harvest all species of salmon, which is the main protein source in traditional diets across much of Alaska. Alaskan salmon are also important targets for sportsmen and commercial fishermen.

Chinook salmon, Alaska's State fish, is the largest and the most long-lived of the Pacific salmon species. It is prized for its high oil content, excellent flavor, and fighting ability when hooked. Sockeye salmon are an important commercial species which, like the Chinook, contain a high oil content. Chum salmon are also eaten in a subsistence diet, but in many parts of the state they are considered to be secondary to the more desirable species, such as Chinooks. Coho salmon are a favored sport fish, appreciated for their aerobatic skills, as well as their excellent flesh. Pink salmon are the smallest, shortest-lived (2 years), and are generally canned or processed for human consumption. Sheefish (inconnu) are residents of arctic rivers and typically overwinter in the estuaries of the larger Alaskan rivers where they annually migrate upstream to spawn. Sheefish are a favorite food for many Native communities and are often pursued by recreational fishermen. Halibut are bottom fish found along the coastline of the eastern Pacific from California to the southern Chukchi Sea and west to Russia and Japan. Like salmon, halibut are important to commercial, subsistence and recreational fisheries. Pollock is a ground fish with very high

commercial value, based on the tremendous population size in the Bering Sea off Alaska, and resiliency of the species. They are found in the North Pacific Ocean and the Bering Sea. Sablefish (blackcod or butterfish) have a high oil content and range in the deep waters of the North Pacific. Generally, Sablefish are commercially harvested in the Bering Sea, Gulf of Alaska and along the coast of western Canada.

Table 2 Weight (in pounds) of the fish analyzed for organic contaminants

Species (# of fish)	Mean	Std. Dev	Median	Min	Max
Chinook (35)	13.89	7.10	12.76	1.3	31.5
Chum (18)	7.64	1.84	7.37	4.4	11.9
Pink (17)	3.76	0.94	3.52	2.6	5.5
Sockeye (24)	5.66	1.47	5.50	3.5	8.8
Coho (14)	9.27	1.66	9.02	6.8	13.4
Halibut (23)	42.42	19.52	36.52	19.8	90.4
Sablefish (11)	2.84	0.78	3.08	1.8	3.7
Pollock (12)	2.64	1.10	2.64	1.3	5.5
Sheefish (8)	9.46	3.97	8.36	5.9	17.2

While the oil or lipid concentrations can vary considerably among individuals of a species, and among species, the omega 3 fatty acids they contain are responsible for many of the health benefits fish consumption provides. Benefits include improved cardiovascular function, and they are essential for a healthy pregnancy and fetal neurodevelopment.

Many of the organic contaminants are lipophilic and bioaccumulate in the fats of the fish. It is important to know the relative lipid content of the different species when comparing the contaminant concentrations. Older and larger fish, and fish with a higher percent lipid concentration, typically have accumulated higher levels of organic contaminants. In order to relate fat to contaminant concentration, percent lipid concentration of the fish analyzed is presented in Table 3.

Table 3 Lipid Concentration (% Lipid) of Skinless Fillet tissue

Species (# fish)	Mean	Std Dev	Median	Min	Max
Chinook (35)	9.68	5.14	7.93	2.0	23.6
Chum (18)	4.81	1.45	4.46	2.9	8.9
Pink (17)	3.46	0.76	3.52	1.8	4.6
Sockeye (24)	8.23	3.66	8.23	2.2	16.1
Coho (14)	2.91	1.89	2.91	1.1	6.3
Halibut (23)	1.69	1.68	1.26	0.2	6.5
Sablefish (11)	3.17	2.19	2.24	0.8	6.6
Pollock (12)	0.72	0.11	0.71	0.6	1.0
Sheefish (8)	1.47	0.74	1.40	0.2	2.9

Analytical Data results:

The average and standard deviation, median, minimum, and maximum concentrations reported in Tables 4, 5, and 8 are for homogenized skinless fillet tissue from individual fish. The Total PCB and PBDE concentrations reported are the sum of all congeners that could be quantified or measured in each fish tissue sample. Total dioxins reported are the sum of all tetra- through octa-dioxins and furans that could be quantified in each tissue sample. Generally the lower chlorinated compounds (mono-, di-, and tri- dioxins and furans, the lower chlorinated PCBs, the lower brominated PBDEs) are too volatile and cannot be measured reliably.

Compounds at concentrations below the Sample-Specific Detection Limits (SDL) were treated as zero in determining total concentrations of PCBs, PBDEs, and Dioxins/Furans. This has a minimal effect on the totals, as these compounds were at very low concentrations. They were much less than a part per trillion in most cases.

Due to the limited sample numbers analyzed in this study and presented in this report, correlations of contaminant concentration with physical parameters (weight, sex, age) and location were not performed.

PCB Concentration-

Table 4 lists the mean and standard deviation, median, and minimum and maximum total PCB concentration found in salmon (Chinook chum, pink, sockeye, Coho), Pacific halibut, sablefish, Walleye Pollock, and Sheefish in this study to date. Total PCBs are reported in parts per billion, or ng/g, wet weight. PCB congener 153 was found at the highest concentration in 142 of the 157 fish tissue samples.

Table 4 Total PCB concentrations (parts per billion or ng/g wet weight) in fish tissue sampled*

SPECIES	Mean	Std dev	Median	Min	Max
Chinook (35)	10.83	5.53	9.04	2.3	22.7
Chum (18)	3.25	1.51	2.69	2.1	7.8
Pink (12)	1.27	0.39	1.19	0.9	2.4
Sockeye (24)	12.57	5.26	11.85	3.9	23.3
Coho (14)	1.96	0.47	2.08	1.2	2.6
Halibut (23)	3.95	4.77	2.69	0.4	22.4
Sablefish (11)	5.84	4.55	5.36	0.9	15.9
Pollock (12)	0.94	0.66	0.75	0.3	2.5
Sheefish (8)	3.01	1.41	3.17	0.8	4.7

Mean of the Sample Specific Detection Limit** for individual PCB congeners was 0.176 pg/g wet wt.
* Total PCBs are based on the sum of all congeners that could be quantified
** Sample-specific Detection Limits (SDLs) are determined for each individual congener in each sample during the chemical analysis. The SDL was calculated as 2.5 times the background (noise) level near the peak for that congener]

Appendix Table 10 lists PCB congeners of primary concern. These are included as a part of the total reported concentration, and are usually the majority of that total concentration. Co-eluting congeners are listed separated by a comma. These PCB congeners include the 12 designated by the World Health Organization to be the greatest of public interest, 14 being measured by the Arctic Monitoring and Assessment Program and the 26 congeners that the FDA considers important to assess in foods. The PCB congeners are listed using the International Union of Pure and Applied Chemistry (IUPAC) nomenclature.

Dioxin Concentration-

Table 5 presents total dioxin/furan concentrations in the fish tissue (individual fish, homogenized skinless fillet). Mean and standard deviation, median value, and minimum and maximum total concentrations of dioxins/furans are reported. Salmon (Chinook, chum, pink, sockeye, and Coho), Pacific halibut, sablefish, Walleye Pollock, and Sheefish were sampled in this study to date. Total dioxins/furans are reported in parts per trillion (pg/g) wet weight.

2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) is considered to be the most toxic of the dioxins/furans. It was detected at very low concentrations in only 25 of the 157 samples. All 25 of these samples were flagged as being too low to be reliable. All other samples had 2,3,7,8-TetraCDD concentrations below the Sample-specific Detection Level (non-detect).

Table 5 Total Dioxin/Furan concentrations (parts per trillion or pg/g wet weight) in fish tissue sampled*

SPECIES	Mean	Std dev	Median	Min	Max
Chinook (35)	2.14	1.41	1.72	0.31	5.56
Chum (18)	0.69	0.27	0.65	0.29	1.24
Pink (12)	0.20	0.09	0.20	0.09	0.43
Sockeye (24)	2.06	0.98	2.0	0.73	4.67
Coho (14)	0.28	0.12	0.28	0.12	0.49
Halibut (23)	0.44	0.40	0.27	.07	1.75
Sablefish (11)	0.45	0.32	0.34	0.15	1.05
Pollock (12)	0.35	0.30	0.28	0.08	1.20
Sheefish (8)	0.30	0.26	0.22	0.15	0.92

Mean of the Sample Specific Detection Limit** for individual Dioxin/Furan congeners was 0.05 pg/g wet wt.
* Total Dioxins/Furans is based on the sum of all congeners that could be quantified
** Sample-specific Detection Limits (SDLs) are determined for each individual congener in each sample during the chemical analysis. The SDL was calculated as 2.5 times the background (noise) level near the peak for that congener]

Dioxins are generally found as different mixtures of congeners in the fish tissue and environmental samples, and each congener has its own degree of toxicity. To express the overall toxicity of the mixture of congeners in a sample as a single number, the concept of "Toxic Equivalents" (TEQs) was developed. Dioxin toxicity of the mixture is represented in relation to the most toxic congener, 2,3,7,8-TCDD, and represented as a numeric value of TEQ in ppt (parts per trillion; pg/g wet weight). The calculation of the TEQ includes the concentration of dioxins, furans and dioxin-like PCBs using the 1998 World Health Organization (WHO) Toxic Equivalency Factors (Van den Berg et al. 1998). Table 6 illustrates the mean and standard deviation of the TEQ for the salmon species (Chinook, chum, pink, sockeye, and Coho), and for Pacific halibut, sablefish, Pollock, and Sheefish.

Table 6. TCDD Toxic Equivalent (TEQ) concentration (pg/g or parts per trillion, wet weight) based on the relative toxicity of the various PCDDs, PCDFs, and Dioxin-like (coplanar) PCBs *

SPECIES	Mean TECQ coplanar PCB	Std dev TEQ coplanar PCB	Mean TEQ Dioxin/Furan	Std dev TEQ Dioxin/Furan
Chinook (35)	0.272	0.189	0.197	0.136
Chum (18)	0.090	0.051	0.050	0.031
Pink (12)	0.027	0.026	0.005	0.012
Sockeye (24)	0.467	0.201	0.348	0.154
Coho (14)	0.048	0.018	0.017	0.014
Halibut (23)	0.124	0.161	0.034	0.040
Sablefish (11)	0.142	0.118	0.046	0.038
Pollock (12)	0.026	0.031	0.002	0.003
Sheefish (8)	0.092	0.046	0.010	0.011

* TEQ calculated using the 1998 WHO Toxic Equivalency Factors (Van den Berg 1998)

Table 7 Comparison of Contributions of Toxic Equivalent (TEQ) concentration from PCDDs, PCDFs, and Dioxin-like (coplanar) PCBs

SPECIES	%TEQ from coplanar PCBs	%TEQ from Dioxins/Furans
Chinook (35)	58.0%	42.0%
Chum (18)	64.1%	35.9%
Pink (12)	83.1%	16.9%
Sockeye (24)	57.3%	42.7%
Coho (14)	74.4%	25.6%
Halibut (23)	78.8%	21.2%
Sablefish (11)	75.6%	24.4%
Pollock (12)	91.9%	8.1%
Sheefish (8)	90.6%	9.4%

PBDE Concentration (Brominated Fire Retardants) -

The total PBDE concentration in the fish tissue (individual fish, homogenized skinless fillet) is presented as parts per billion (ng/g wet weight). Table 8 provides the mean and standard deviation of the total of all measurable PBDE congeners for salmon (Chinook, Chum, Pink, Sockeye, and Coho), Pacific

Halibut, Sablefish, Pollock, and Sheefish. One hundred forty-eight of the 157 samples chosen for organic analysis were analyzed for PBDEs.

Table 8 Total PBDE Concentration (in parts per billion or ng/g wet weight) *

SPECIES	Mean	Std dev	Median	Min	Max
Chinook (35)	0.53	0.67	0.28	0.08	2.77
Chum (18)	0.16	0.12	0.11	0.05	0.49
Pink (3)	0.22	0.10	0.28	0.11	0.29
Sockeye (24)	0.22	0.12	0.20	0.08	0.51
Coho (14)	0.19	0.07	0.18	0.08	0.34
Halibut (23)	0.28	0.15	0.27	0.09	0.64
Sablefish (11)	0.78	0.56	0.56	0.32	2.19
Pollock (12)	0.27	0.20	0.23	0.08	0.80
Sheefish (8)	0.39	0.13	0.43	0.10	0.53

Mean of the sample Specific Detection Limit** for individual PBDE congeners was 0.228 pg/g wet weight

* Total PBDEs based on the sum of all congeners that could be quantified

** Sample-specific Detection Limits (SDLs) are determined for each individual congener in each sample during the chemical analysis. The SDL was calculated as 3 times the background (noise) level near the peak for that congener]

Pesticide Concentration-

The fish tissue was analyzed for thirty-eight (38) different organocholrine pesticides. Due to the non-detectable concentrations of some of the compounds, data were obtained on only 34 pesticides for all 157 fish sampled. An additional three pesticides (1,4-Dichlorobenzene, 1,2-Dichlorobenzene, and 1,3-Dichlorobenzene) were reported for only 121 of the samples, with 100%, 50%, and 30%, respectfully having values above the SDL. One pesticide (4,4'-DDD) was detected in just 14 samples; of those 14 samples only 12 of had concentrations above the SDL.

Several pesticides were reported in only a small number of the fish samples collected. Table 9 lists the 12 pesticides that were detected in fewer than 25 % of the samples. The mean SDL and maximum concentration that was detected in the eliminated samples is also presented. The data for these pesticides are not presented in any of the summary tables.

Table 9. Pesticides for which Fewer than 25% of all Samples were Above the Sample Detection Limit

Max concentration found is included for each of these pesticides				
Pesticide	**Mean Sample Specific Detection Limit (ppb)**	**#Detected**	**# of Samples**	**Max (ppb)**
beta-Endosulfan	0.0540	1	157	0.026
Methoxychlor	0.1669	3	157	0.036
alpha-Endosulfan	0.0413	4	157	0.065
1,3,5-Trichlorobenzene	0.0549	8	157	0.096
Hexachlorobutadiene	0.0166	10	157	0.069
1,2,3-Trichlorobenzene	0.0572	10	157	0.120
Endrin Aldehyde	0.1606	13	157	0.019
Endrin Ketone	0.0613	15	157	0.026
Endosulfan Sulfate	0.0650	21	157	0.068
Heptachlor	0.1392	22	157	0.451
Aldrin	0.0629	22	157	0.042
delta-HCH (delta-hexachlorocyclohexane)	0.0798	27	157	0.858

Appendix tables 11-A through 11-I list the mean, standard deviation, SDL, and range for each pesticide concentration detected by species for Chinook, chum, pink, sockeye, and Coho salmon, and for Pacific halibut, sablefish, Pollock and Sheefish. Pesticide concentrations are reported as ppb (parts per billion, ng/g) wet weight. Data are calculated for all fish samples. All sample results below the SDL are treated as one half the SDL value for that compound in that sample and are included in the calculations.

Discussion

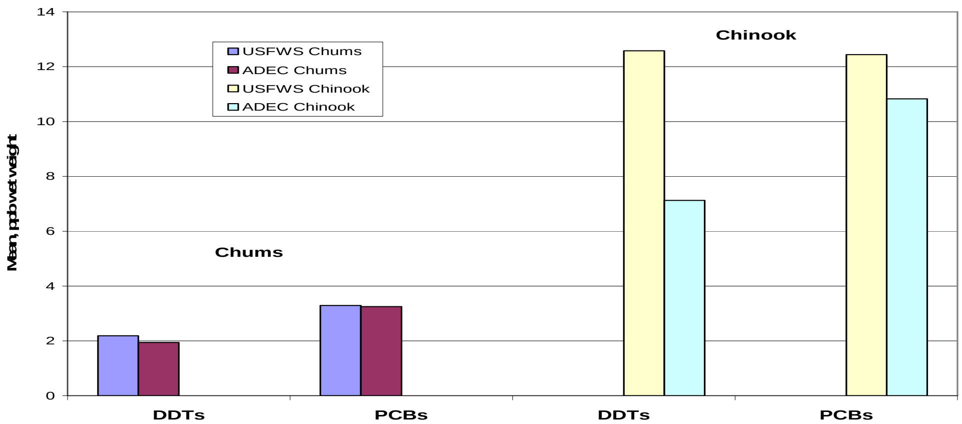
The environmental contaminants evaluated in this study:

1) resist chemical degradation and persist in the environment,
2) can travel great distances from their source of production,
3) can bioaccumulate in the food chain.

Recent studies (USFWS, 2001; Hites et al., 2004; Krummel et al., 2003; Ewald et al., 1996) show similar findings of low concentrations of contaminants in wild salmon similar to those reported in this study. Since there are no major industrial areas located in Alaska and most areas of the Arctic where these environmental pollutants have been found, it is generally agreed that low level concentrations of these chemicals represent a global presence of these pollutants. In 2001, the U.S. Fish and Wildlife Service (USFWS) conducted a study of contaminant concentrations in Chinook and chum salmon from the Yukon and Kuskokwim Rivers. When contaminant concentrations for Chinook and chum salmon from the USFWS study, representing fish exclusively from the Yukon and Kuskokwim

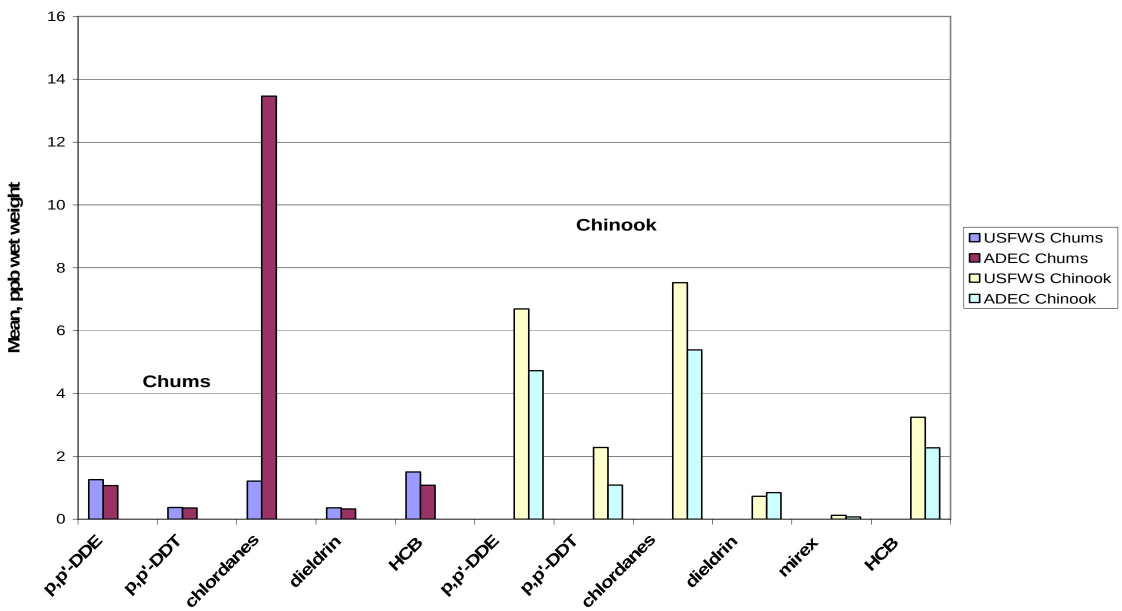
River basins (Y-K), are compared with our fish monitoring study, which covers a much broader geographic range, the results are similar (Figures 2 and 3).

Figure 2. Total PCBs and Sum DDTs in Chum and Chinook Salmon from Alaska. A Comparison of ADEC data with USFWS data from the Y-K Region



* [1] U.S. Fish and Wildlife Service, unpublished data
Results are mean values, ng/g (ppb) wet weight

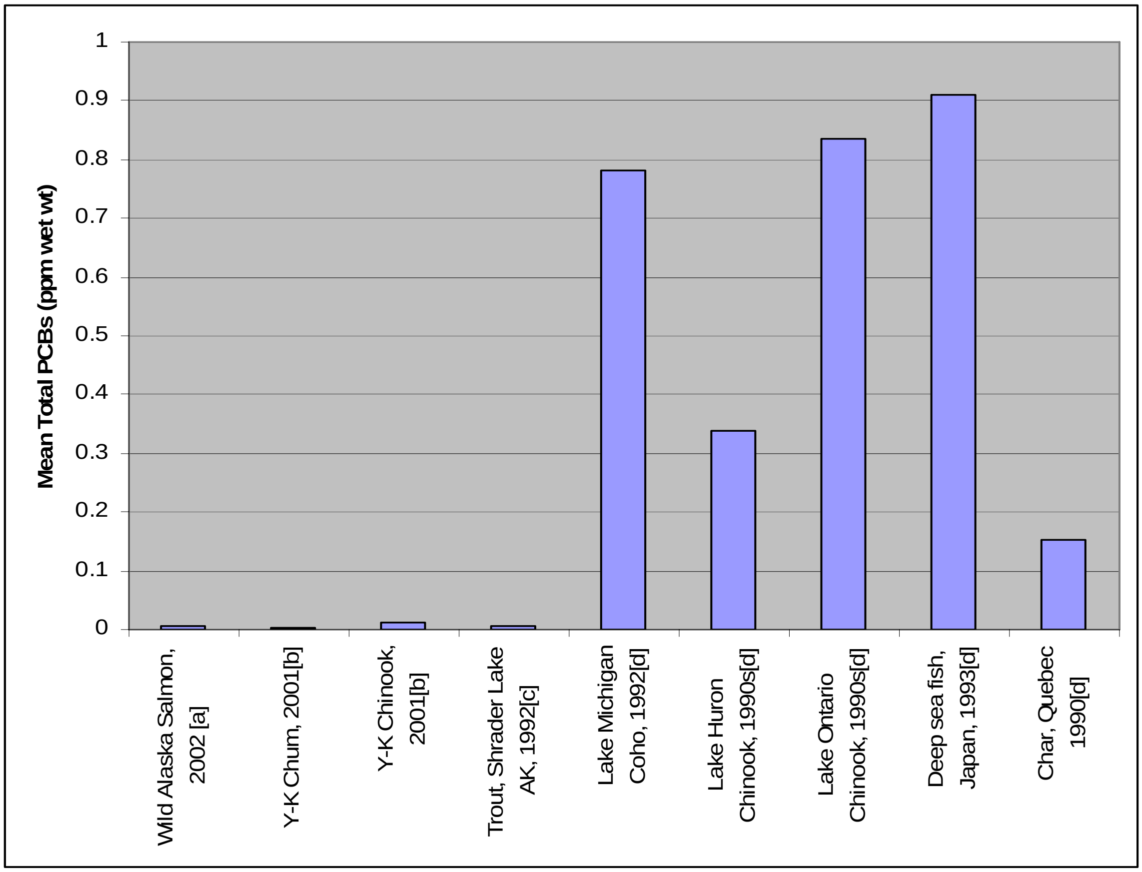
Figure 3. Organochlorine Pesticides in Chum and Chinook Salmon from Alaska: Comparison of ADEC Data with USFWS Data from the Y-K Region



* [1] U.S. Fish and Wildlife Service, unpublished data.
Results are mean values, ng/g (ppb) wet weight

These data also appear to be similar to graphed organic contaminant concentrations in wild Alaska salmon from another recent scientific study (Hites et al. 2004). Levels of PCBs measured in Alaska fish are far below those measured in fish from other parts of the world (Fig. 4). Note that Figure 4 represents a relative comparison of data only, and definitive conclusions cannot be drawn from this comparison since each study may have used different analytical methodology, tissue used for analysis etc.

Figure 4. Comparison of PCB Levels in Fish from Alaska vs. Other Parts of the World



[a] Three salmon species combined, this study
[b] USFWS, unpublished data
[c] EPA Cook Inlet Study 1998
[d] Wilson et al., 1995
[e] EPA Columbia River Study, 2002
[f] ATSDR, 2000

Small differences in mean chemical concentrations in a particular fish species among Alaska studies (i.e. studies a, b, c and d listed above) may be due in part to differences in analytic methodology or other technical aspects of the studies. Due to their chemical properties, organochlorine concentrations in fish are influenced by many factors such as age, season, condition, and amount of fat

stores. Any variations in chemical concentrations within a fish species among Alaska studies are probably due to both differences in analytical methods and differences in biological factors, and are not indicative of geographic differences or localized sources of contamination.

It should be noted that some of these Persistent Organic Pollutants (POPs), such as PCBs and DDTs, have been banned from industrial production in the U.S. for many years. So even though these compounds were detected in small amounts in the fish tissue collected in this project, as well as in fish in other studies, it is expected that their concentrations will decrease over time. This general trend has been noted in the most recent report of the Arctic Monitoring and Assessment Program (AMAP) (2002, AMAP Report).

Oxychlordane levels were elevated in some individual salmon, but not in others. The maximum levels of oxychlordane in Chinook, chum, and sockeye salmon were 13.9 ppb, 106 ppb, and 109 ppb, respectively. Approximately 37% of sockeye, 16% of chum, and 11% of Chinook individuals had elevated oxychlordane levels, and those fish were not all collected from the same area of Alaska. In contrast, pink and Coho salmon were unaffected, as no fish of these species had detectable oxychlordane levels (mean sample detection limit was 0.07 ppb for pink salmon, and 0.19 ppb for Coho salmon). The significance of these elevated oxychlordane levels in these particular species of fish is unknown, and this is an important topic for further investigation.

The AMAP report emphasized that not all POPs are decreasing. There are some chemicals for which the decline is minimal and unfortunately some areas where POP levels may actually be increasing, indicating a need for continued monitoring, which the State of Alaska in undertaking. An important example is polybrominated diphenyl ethers (PBDEs), a class of common flame retardant that is rapidly increasing worldwide in the environment. There are few existing data regarding the PBDE levels in fish from Alaska, so the data in this report begin to define a baseline against which future data can be compared to assess trends over time.

Public Health Interpretation

The Alaska Division of Public Health, Section of Epidemiology has reviewed the contaminant data from this fish biomonitoring project. The overall conclusion is that organic contaminant concentrations in fish from Alaska waters are low, and are not of public health concern. We do not recommend any consumption restrictions of fish from Alaska waters as a result of any organic contaminant levels detailed in this report.

Some organochlorines such as polychlorinated biphenyls (PCBs) were found at trace levels in this study. They were only detectable because of recent, sophisticated advances in analytical methodology. In past decades such trace levels would have been beyond our technical capabilities of measurement, and the concentrations would not have been detectable. With our ability to detect tiny concentrations of chemicals comes the challenge of interpreting the health significance of small chemical exposures.

Several U.S. government agencies provide guidelines for assessing the safety of consuming fish or other food products that contain trace levels of contaminants. The U.S. Food and Drug Administration (FDA) has established legal tolerances for the maximum levels of contaminants allowed in foods sold in commerce in the U.S. All contaminant concentrations found in fish from this study were well below those legal tolerances.

The U.S. Environmental Protection Agency has established guidelines to assist states in evaluating contaminant levels in sport-caught and subsistence fish, and utilizing that information to develop fish consumption advice. These guidelines consist of four stages: sampling and analysis, risk assessment, risk management, and risk communication. EPA's risk assessment guidelines offer conservative guidelines for screening contaminant concentrations for potential health risks. If screening values are exceeded, local risk management is an important next step. In the risk management phase, local information and circumstances, such as the health benefits of fish consumption, the social, cultural and economic importance of fish, and the health risks of alternative replacement foods, must be considered to develop the best overall public health advice.

We have compared the fish contaminant data from this study to the EPA's screening criteria for recommended levels of fish consumption. For many chemicals, the EPA offers two sets of screening guidelines based on two different health endpoints: chronic health effects and cancer. Both sets of guidelines were considered when available, but the Alaska Division of Public Health places more weight on the chronic health effect guidelines for a number of scientific reasons. EPA cancer guidelines are designed to be very conservative, and are likely to overestimate actual risk. Also, they do not take into account the growing body of research showing that fish consumption actually protects against some forms of cancer (Terry et al., 2003). We are concerned that populations who decrease their level of fish consumption might actually experience an increased incidence of cancer.

EPA's chronic health guidelines consider possible reproductive and developmental effects during the most sensitive life-stage for many of these chemicals: the developing fetus. They are conservative numbers that employ large safety factors. For example, reference doses (the maximum dose of a chemical that EPA deems safe to intake every day for a lifetime of 70 years) are

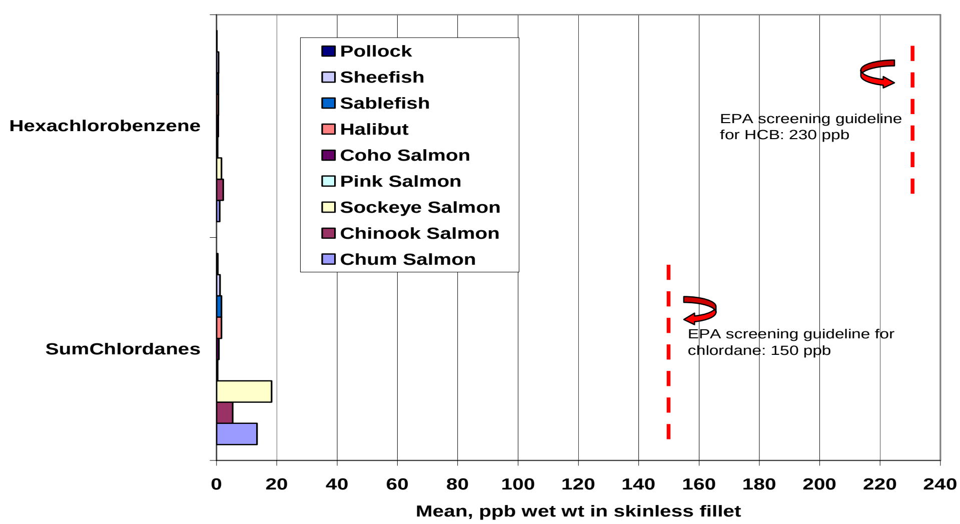
often 100- to 1000-fold below the concentrations that have produced observable health effects in laboratory animals.

Results

Average organochlorine concentrations in skinless fillets are presented for each fish species tested in Tables 4,5, 8 and 11-A through 11-I. Federal risk assessment guidance was not available for all chemicals tested. Results with sufficient risk assessment information available are discussed in the section that follows.

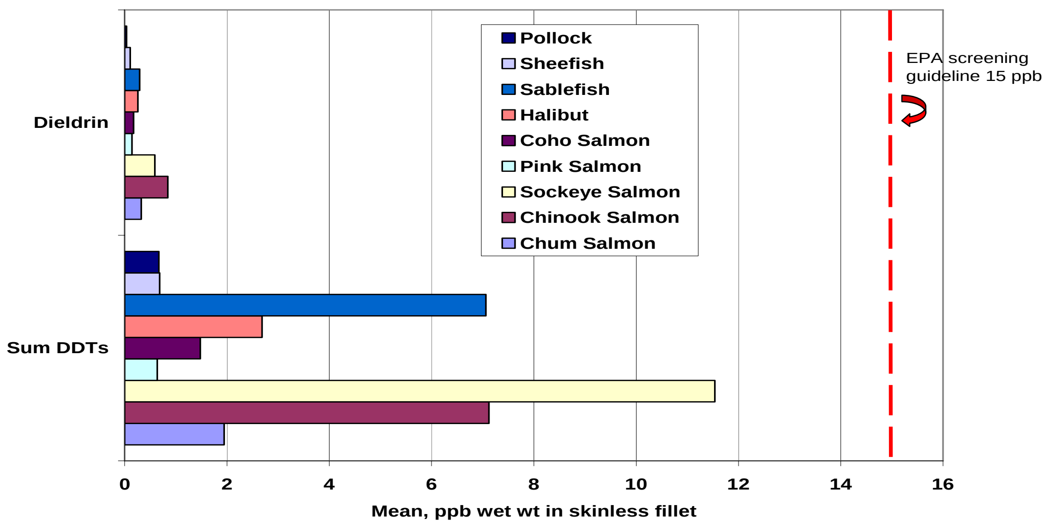
Many pesticides tested were present in fish at low levels or were not detected, and were far below EPA guidelines for unrestricted consumption (defined by EPA as more than 16 8-ounce meals per month). These pesticides included chlordanes, endrin, endosulphans, hexachlorobenzene, lindane and mirex (Figure 5).

Figure 5. Hexachlorobenzene and Sum Chlordanes in Alaskan Fish: Comparison with EPA Guidelines (chronic) for Unlimited Consumption



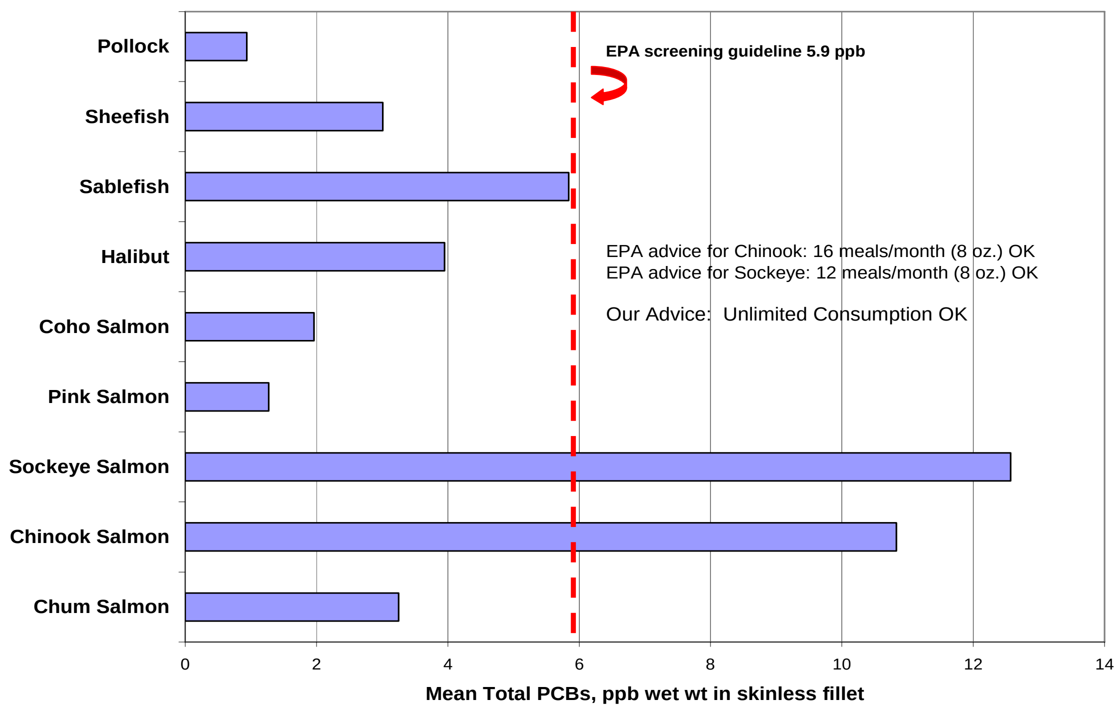
Several pesticides were detected in many of the fish tested, in small amounts below the EPA screening guidelines for unrestricted consumption using a chronic health endpoint. These pesticides include sum-DDTs, dieldrin and toxaphene. (Figure 6).

Figure 6. Dieldrin and Sum DDTs in Fish from Alaska: Comparison with the EPA Guidelines (chronic) for Unrestricted Consumption



Small amounts of polychlorinated biphenyls (PCBs) were also measured in most fish. Average "total PCB" levels for most fish species tested below EPA screening guidelines for unrestricted consumption using a chronic health endpoint (Fig. 7).

Figure 7. PCB Concentrations in Salmon from Alaska: Comparison with the EPA Guidelines (chronic) for Unrestricted Consumption



Average PCB levels for Chinook and sockeye salmon exceeded the screening guideline. Without the benefit of local risk management, the EPA screening guidelines would recommend that an adult eat no more than 16 meals per month of Chinook or 12 meals a month of sockeye salmon based on a chronic health endpoint. However, the EPA guideline is only a screening tool used as part of a balanced benefit/risk analysis. The EPA reference dose for PCBs, upon which that calculation was based, incorporates a 300-fold safety factor below the lowest dose at which subtle health effects have been seen in the offspring of laboratory monkeys fed PCBs. In addition, Health Canada's daily intake guideline for PCB's is 50x greater (1ug/kg-body weight/day) than EPA's (0.02 ug/kg-body weight/day) suggesting much more than 16 meals per month of either species can be safely consumed.

The EPA has not yet established screening guidelines for safe levels of PBDEs in fish. Since PBDEs are an emerging concern, there have not been a large number of health or toxicity studies conducted on PBDEs yet. Scientists are

finding that PBDEs have a similar mechanism of action and toxicity as PCBs, but that they are considerably less potent (Darnerud et al 2001). The levels of PBDEs found in Alaska fish in this project are extremely low, and not of health concern.

Given EPA's safety factors and considering the many health benefits of fish consumption (illustrated in the next section), the Alaska Division of Public Health does not recommend any consumption restrictions of fish from Alaska waters as a result of organic contaminant levels detailed in this report. Wild Alaska Chinook and sockeye salmon are safe to eat in unlimited quantities.

The Health Benefits of Fish Consumption

In developing public health advice about the dietary intake of fish, it is crucial to consider both the benefits and the risks of fish consumption. Fish are a very nutritious protein source that is low in saturated fat, providing essential fatty acids, antioxidants and vitamins. Alaska salmon and other fatty fish are excellent sources of omega-3 fatty acids, which provide many health benefits including protection from diabetes and cardiovascular disease, and improved maternal nutrition and neonatal/infant brain development.

When evaluating the health implications of reduced fish consumption, it is also necessary to consider the health risks of alternative replacement foods. The market foods that often replace locally harvested fish are high in saturated fat, vegetable oils, and carbohydrates and often lower in nutrient value. Diets high in saturated fat and carbohydrates are strong risk factors for a number of chronic diseases such as heart disease, diabetes, and cancer. Increasing non-traditional food use and sedentary lifestyles among Alaska Natives have been associated with an increasing prevalence of chronic disease, including an increase in hypertension, glucose intolerance, and diabetes. This increased incidence in chronic disease is related to a dramatic increase in obesity prevalence in Alaska: from 48% in 1991-1993 to 61% in 1999-2001.

Recommendations and Conclusions

This initial data from the Fish Monitoring Program is an important contribution to our understanding of contaminant concentrations in Alaska seafood. No single monitoring study would be sufficient on its own to derive comprehensive public health dietary guidelines. In this study, the sample size was relatively small, only a few fish species were analyzed, and the fish were of a size range that may or may not be representative of the fish most commonly consumed. However, the results of this study add to a significant body of evidence that already exists, and that is rapidly expanding, regarding contaminant levels in the Alaskan environment and its people.

The data from this study are consistent with other recent fish monitoring studies, which lends considerable weight to the results. Recent, ongoing human monitoring projects also provide important exposure information to optimize and validate our consumption advice, including the Alaska Native Tribal Health Consortium's maternal-infant cord blood study and our maternal hair mercury biomonitoring program.

Taken together, the growing body of information about contaminant levels in food and humans, disease incidence and trends in Alaska, and health benefits of fish and other wild foods, provide a foundation upon which to base our public health dietary advice. The Alaska Division of Public Health and the Alaska Department of Environmental Conservation provide the following conclusions and recommendations:

- Fish is a very nutritious protein source that is low in saturated fat, providing essential fatty acids, antioxidants and vitamins. It is far more healthful than many alternative replacement foods.
- Organochlorine contaminant concentrations in Alaska fish are low, and are not expected to cause adverse health effects in even the most frequent fish consumers.
- The Alaska Division of Public Health does not recommend any consumption restrictions of fish from Alaska waters as a result of any organic contaminant levels detailed in this report.
- Ongoing monitoring is needed to better understand the factors influencing contaminant concentrations in Alaska fish and wildlife, actual exposure levels in humans who consume wild foods, and trends in contaminant concentrations over time.

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Appendix:

Table 10-A, PCB Congeners of Primary Concern

18	86	135,151	178
20,28	90,101	137	180
37	93,95	146	183
44	105	147,149	187
49	110	153	189
52	114	156	194
61	118	167	195
66	123	169	196
77,74	126	170	201
81	128	172	206
83,99	129,138	177	209

* PCB congeners listed are based on IUPAC nomenclature. Congeners listed together co-elute.

Table 10-B, Dioxin/Furan Congeners of Primary Concern

Dioxins	Furans
2,3,7,8-TetraCDD	2,3,7,8-TetraCDF
1,2,3,7,8-PentaCDD	1,2,3,7,8-PentaCDF
1,2,3,4,7,8-HexaCDD	2,3,4,7,8-PentaCDF
1,2,3,6,7,8-HexaCDD	1,2,3,4,7,8-HexaCDF
1,2,3,7,8,9-HexaCDD	1,2,3,6,7,8-HexaCDF
1,2,3,4,6,7,8-HeptaCDD	1,2,3,7,8,9-HexaCDF
	2,3,4,6,7,8-HexaCDF
	1,2,3,4,6,7,8-HeptaCDF
	1,2,3,4,7,8,9-HeptaCDF

Table 11

11-A, Pesticide Concentration ppb (ng/g wet wt)							
Species (# collected)	**Chinook Salmon (35)**						
Pesticide Compound	**Mean Conc.**	**St. Dev.**	**Mean SDL.**	**N**	**# Detects.**	**Min**	**Max**
1,2-Dichlorobenzene	0.1651	0.0815	0.1528	30	17	0.049	0.424
1,2,3,4-Tetrachlorobenzene	0.0642	0.0505	0.0216	35	28	0.011	0.184
1,2,4-Trichlorobenzene	0.1033	0.0650	0.0902	35	17	0.034	0.265
1,3-Dichlorobenzene	0.1504	0.1192	0.1370	30	13	0.040	0.553
1,4-Dichlorobenzene	1.641	1.475	0.1592	30	30	0.410	5.17
cis-Chlordane	1.147	0.6125	0.0238	35	35	0.309	2.60
Trans-Chlordane	0.3542	0.2082	0.0205	35	35	0.114	0.861
cis-Nonachlor	0.4156	0.1949	0.0222	35	35	0.096	0.841
trans-Nonachlor	1.501	0.7454	0.0195	35	35	0.381	3.24
Oxy-Chlordane	1.955	3.684	0.4700	35	22	0.079	13.9
Dieldrin	0.8425	0.4193	0.0707	35	34	0.034	1.97
Endrin	0.2362	0.1311	0.1013	35	26	0.041	0.624
HCH, alpha	1.148	0.8245	0.0933	35	35	0.199	3.38
HCH, beta	0.6770	0.4507	0.1464	35	31	0.067	1.63
HCH, gamma (Lindane)	0.2288	0.1877	0.1066	35	25	0.033	0.881
Heptachlor Epoxide	0.3895	0.1559	0.0890	35	34	0.157	0.858
Hexachlorobenzene	2.271	1.046	0.0227	35	35	0.898	5.19
Mirex	0.0729	0.0411	0.0338	35	32	0.013	0.174
o,p'-DDD	0.2461	0.1436	0.0235	35	35	0.050	0.551
o,p'-DDE	0.2372	0.1812	0.0261	35	35	0.035	0.802
o,p'-DDT	0.8176	0.6999	0.0319	35	35	0.055	2.79
p,p'-DDE	4.728	2.486	0.0341	35	35	0.803	10.7
p,p'-DDT	1.087	1.031	0.0354	35	35	0.108	4.03
Pentachlorobenzene	0.1547	0.0811	0.0262	35	34	0.035	0.401
Total Toxaphene	28.31	24.80	5.498	35	30	2.89	120
Sum Chlordanes	5.388	4.354		35		1.029	18.41
Sum DDT	7.119	4.271		35		1.206	18.87
SDL: Sample detection Limit							
ND: Below SDL							
One half the SDL is used as the value for all NDs when calculating mean and standard deviation							

11-B, Pesticide Concentration ppb (ng/g wet wt)							
Species (# collected)	**Chum Salmon (18)**						
Pesticide Compound	**Mean Conc.**	**St. Dev.**	**Mean SDL**	**N**	**# Detects.**	**Min**	**Max**
1,2-Dichlorobenzene	0.1494	0.0688	0.1195	18	13	ND	0.267
1,2,3,4-Tetrachlorobenzene	ND	ND	0.0254	18	6	ND	0.046
1,2,4-Trichlorobenzene	0.1027	0.0588	0.0431	18	13	ND	0.215
1,3-Dichlorobenzene	ND	ND	0.1054	18	3	ND	.369
1,4-Dichlorobenzene	1.161	0.8204	0.1299	18	18	0.525	3.69
cis-Chlordane	0.3847	0.1415	0.0272	18	18	0.215	0.713
Trans-Chlordane	0.1327	0.0403	0.0237	18	18	0.084	0.215
cis-Nonachlor	0.1159	0.0395	0.0216	18	18	0.074	0.194
trans-Nonachlor	0.4117	0.1585	0.0188	18	18	0.273	0.816
Oxy-Chlordane	12.42	30.35	0.2387	18	8	ND	106
Dieldrin	0.3249	0.1298	0.0762	18	18	0.150	0.664
Endrin	ND	ND	0.1123	18	7	ND	0.147
HCH, alpha	0.4328	0.1272	0.0810	18	18	0.197	0.728
HCH, beta	0.2685	0.0955	0.0987	18	18	0.125	0.518
HCH, gamma (Lindane)	0.1097	0.1276	0.1000	18	8	ND	0.602
Heptachlor Epoxide	0.1734	0.1033	0.1172	18	9	ND	0.402
Hexachlorobenzene	1.0783	0.2877	0.0325	18	18	0.696	1.82
Mirex	ND	ND	0.0392	18	3	ND	0.063
o,p’-DDD	0.1236	0.0503	0.0325	18	17	ND	0.265
o,p’-DDE	0.0476	0.0326	0.0246	18	16	ND	0.156
o,p’-DDT	0.3433	0.2696	0.0443	18	17	ND	1.31
p,p’-DDE	1.069	0.6676	0.0323	18	18	0.583	3.32
p,p’-DDT	0.3590	0.3993	0.0493	18	17	ND	1.84
Pentachlorobenzene	0.0763	0.0266	0.0293	18	18	0.048	0.139
Total Toxaphene	ND	ND	5.272	18	4	ND	7.16
Sum Chlordanes	13.46	30.61		18	18	0.821	107
Sum DDT	1.943	1.402		18	18	0.957	6.89
SDL: Sample detection Limit							
ND: Below SDL							
One half the SDL is used as the value for all NDs when calculating mean and standard deviation							

11-C, Pesticide Concentration ppb (ng/g wet wt)							
Species (# collected)	**Pink Salmon (12)**						
Pesticide Compound	**Mean Conc.**	**St. Dev.**	**Mean SDL**	**N**	**# Detects.**	**Min**	**Max**
1,2-Dichlorobenzene	ND	ND	0.1058	12	0	ND	ND
1,2,3,4-Tetrachlorobenzene	0.0171	0.0079	0.0138	12	7	ND	0.028
1,2,4-Trichlorobenzene	0.0341	0.0228	0.0237	12	7	ND	0.063
1,3-Dichlorobenzene	0.1002	0.1095	0.0945	4	1	ND	0.264
1,4-Dichlorobenzene	1.365	0.6415	0.1104	4	4	0.611	1.97
cis-Chlordane	0.1148	0.0381	0.0105	12	12	0.059	0.215
Trans-Chlordane	0.0574	0.0124	0.0090	12	12	0.046	0.091
cis-Nonachlor	0.0452	0.0130	0.0094	12	12	0.030	0.082
trans-Nonachlor	0.1545	0.0451	0.0081	12	12	0.109	0.278
Oxy-Chlordane	ND	ND	0.0692	12	0	ND	ND
Dieldrin	0.1438	0.0296	0.0174	12	12	0.106	0.206
Endrin	ND	ND	0.0325	12	0	ND	ND
HCH, alpha	0.4789	0.1191	0.0293	12	12	0.169	0.615
HCH, beta	0.2335	0.0673	0.0394	12	12	0.059	0.318
HCH, gamma (Lindane)	0.1132	0.0305	0.0307	12	12	0.047	0.158
Heptachlor Epoxide	0.0535	0.0379	0.0488	12	4	ND	0.134
Hexachlorobenzene	0.3877	0.0777	0.0125	12	12	0.228	0.522
Mirex	ND	ND	0.0133	12	3	ND	0.019
o,p'-DDD	0.0273	0.0100	0.0076	12	11	ND	0.053
o,p'-DDE	0.0143	0.0066	0.0100	12	9	ND	0.030
o,p'-DDT	0.0754	0.0278	0.0135	12	12	0.046	0.135
p,p'-DDE	0.4333	0.0859	0.0130	12	12	0.313	0.625
p,p'-DDT	0.0863	0.0247	0.0155	12	12	0.063	0.138
Pentachlorobenzene	0.0413	0.0090	0.0131	12	12	0.025	0.057
Total Toxaphene	ND	ND	1.923	12	1	ND	3.61
Sum Chlordanes	0.4065	0.1067		12	12	0.274	0.699
Sum DDT	0.6365	0.1356		12	12	0.490	0.980
SDL: Sample detection Limit							
ND: Below SDL							
One half the SDL is used as the value for all NDs when calculating mean and standard deviation							

11-D, Pesticide Concentration ppb (ng/g wet wt)							
Species (# collected)	**Sockeye Salmon (24)**						
Pesticide Compound	**Mean Conc.**	**St. Dev.**	**Mean SDL**	**N**	**# Detects.**	**Min**	**Max**
1,2-Dichlorobenzene	0.2175	0.2697	0.1009	24	18	ND	1.33
1,2,3,4-Tetrachlorobenzene	0.0423	0.0241	0.0237	24	18	ND	0.094
1,2,4-Trichlorobenzene	0.1336	0.1068	0.0510	24	17	ND	0.466
1,3-Dichlorobenzene	0.1331	0.1374	0.0899	24	10	ND	0.533
1,4-Dichlorobenzene	3.306	3.025	0.1084	24	24	0.495	11.1
cis-Chlordane	1.066	0.4697	0.0243	24	24	0.445	2.36
Trans-Chlordane	0.3918	0.1579	0.0209	24	24	0.158	0.818
cis-Nonachlor	0.3332	0.1352	0.0380	24	24	0.093	0.621
trans-Nonachlor	1.418	0.5853	0.0334	24	24	0.477	2.64
Oxy-Chlordane	15.07	31.08	0.4931	24	14	ND	109
Dieldrin	0.5893	0.2514	0.0866	24	24	0.297	1.29
Endrin	0.1628	0.0902	0.1337	24	16	ND	0.390
HCH, alpha	0.9598	0.6072	0.1100	24	24	0.116	2.74
HCH, beta	0.5649	0.3157	0.1363	24	23	ND	1.38
HCH, gamma (Lindane)	0.2852	0.3343	0.1363	24	13	ND	1.11
Heptachlor Epoxide	0.2957	0.1429	0.1189	24	22	ND	0.603
Hexachlorobenzene	1.670	0.7656	0.0243	24	24	0.705	3.71
Mirex	0.0862	0.0506	0.0450	24	19	ND	0.198
o,p'-DDD	0.4721	0.0243	0.0301	24	24	0.178	0.912
o,p'-DDE	0.4451	0.2105	0.0286	24	24	0.131	0.943
o,p'-DDT	1.967	0.8277	0.0400	24	24	0.528	3.77
p,p'-DDE	5.766	2.514	0.0377	24	24	1.65	11.1
p,p'-DDT	2.886	1.304	0.0436	24	24	0.664	5.74
Pentachlorobenzene	0.1227	0.0509	0.0240	24	24	0.043	0.231
Total Toxaphene	16.98	10.59	7.114	24	19	ND	39.1
Sum Chlordanes	18.28	31.25		24	24	1.27	113
Sum DDT	11.54	4.918		24	24	3.16	22.1
SDL: Sample detection Limit							
ND: Below SDL							
One half the SDL is used as the value for all NDs when calculating mean and standard deviation							

11-E, Pesticide Concentration ppb (ng/g wet wt)

Species (# collected)	Coho Salmon (14)						
Pesticide Compound	**Mean Conc.**	**St. Dev.**	**Mean SDL**	**N**	**# Detects.**	**Min**	**Max**
1,2-Dichlorobenzene	ND	ND	0.2454	11	0	ND	ND
1,2,3,4-Tetrachlorobenzene	0.0183	0.0077	0.0154	14	11	ND	0.036
1,2,4-Trichlorobenzene	ND	ND	0.0641	14	1	ND	0.102
1,3-Dichlorobenzene	ND	ND	0.2118	11	0	ND	ND
1,4-Dichlorobenzene	0.5782	0.1523	0.2532	11	11	0.450	0.890
cis-Chlordane	0.2364	0.0905	0.0226	14	14	0.125	0.408
Trans-Chlordane	0.0903	0.0266	0.0199	14	14	0.060	0.144
cis-Nonachlor	0.0869	0.0254	0.0172	14	14	0.050	0.131
trans-Nonachlor	0.2956	0.0821	0.0150	14	14	0.165	0.430
Oxy-Chlordane	ND	ND	0.1899	14	0	ND	ND
Dieldrin	0.1756	0.0865	0.0168	14	14	0.071	0.347
Endrin	0.0380	0.0254	0.0210	14	12	ND	0.099
HCH, alpha	0.4416	0.3043	0.0681	14	14	0.138	1.05
HCH, beta	0.2066	0.1433	0.0932	14	12	ND	0.478
HCH, gamma (Lindane)	0.1136	0.0652	0.0732	14	10	ND	0.251
Heptachlor Epoxide	0.0689	0.0326	0.0136	14	14	0.026	0.132
Hexachlorobenzene	0.5855	0.1940	0.0150	14	14	0.273	0.915
Mirex	ND	ND	0.0289	14	2	ND	0.029
o,p'-DDD	0.0408	0.0224	0.0262	14	12	ND	0.095
o,p'-DDE	ND	ND	0.0215	14	5	ND	0.081
o,p'-DDT	0.1439	0.0840	0.0696	14	13	ND	0.401
p,p'-DDD	0.1848	0.0565	0.0590	14	12	ND	0.280
p,p'-DDE	0.9507	0.2128	0.0276	14	14	0.532	1.34
p,p'-DDT	0.1346	0.0496	0.0829	14	12	ND	0.217
Pentachlorobenzene	0.0383	0.0255	0.0188	14	11	ND	0.088
Total Toxaphene	ND	ND	3.737	14	5	ND	6.53
Sum Chlordanes	0.8042	0.2188		14	14	0.536	1.20
Sum DDT	1.476	1.484		14	14	0.847	1.90
SDL: Sample detection Limit							
ND: Below SDL							
One half the SDL is used as the value for all NDs when calculating mean and standard deviation							

11-F, Pesticide Concentration ppb (ng/g wet wt)							
Species (# collected)	Pacific Halibut (23)						
Pesticide Compound	Mean Conc.	St. Dev.	Mean SDL	N	# Detects.	Min	Max
1,2-Dichlorobenzene	0.1608	0.3415	0.0938	15	6	ND	1.39
1,2,3,4-Tetrachlorobenzene	0.0265	0.0351	0.0199	23	9	ND	0.171
1,2,4-Trichlorobenzene	0.1255	0.1778	0.0463	23	13	ND	0.852
1,3-Dichlorobenzene	0.0859	0.0832	0.0793	15	5	ND	0.355
1,4-Dichlorobenzene	0.9289	0.8780	0.1035	15	15	0.287	3.17
cis-Chlordane	0.3880	0.4168	0.0156	23	23	0.045	1.69
Trans-Chlordane	0.0676	0.0378	0.0137	23	22	ND	0.170
cis-Nonachlor	0.2238	0.2673	0.0214	23	22	ND	1.21
trans-Nonachlor	0.7918	0.9401	0.0185	23	23	0.070	4.27
Oxy-Chlordane	0.1827	0.1773	0.1522	23	9	ND	0.784
Dieldrin	0.2584	0.3290	0.0334	23	17	ND	1.27
Endrin	ND	ND	0.0536	23	1	ND	0.124
HCH, alpha	0.2798	0.2915	0.0814	23	15	ND	1.11
HCH, beta	0.1724	0.1766	0.0691	23	13	ND	0.720
HCH, gamma (Lindane)	0.1611	0.1491	0.1018	23	15	ND	0.593
Heptachlor Epoxide	0.0618	0.0708	0.0490	23	5	ND	0.283
Hexachlorobenzene	0.6885	0.7924	0.0195	23	23	0.130	3.40
Mirex	0.0534	0.0562	0.0313	23	13	ND	0.256
o,p'-DDD	0.0349	0.0391	0.0116	23	13	ND	0.165
o,p'-DDE	0.0417	0.0530	0.0129	23	13	ND	0.221
o,p'-DDT	0.1615	0.2168	0.0175	23	20	ND	1.03
p,p'-DDE	2.229	2.683	0.0169	23	23	0.114	12.7
p,p'-DDT	0.2198	0.2659	0.0193	23	19	ND	1.24
Pentachlorobenzene	0.0379	0.0363	0.0230	23	12	ND	0.159
Total Toxaphene	8.179	11.32	2.584	23	12	ND	51.2
Sum Chlordanes	1.654	1.812		23	23	0.290	8.08
Sum DDT	2.687	3.245		23	23	0.150	15.4
SDL: Sample detection Limit							
ND: Below SDL							
One half the SDL is used as the value for all NDs when calculating mean and standard deviation							

11-G, Pesticide Concentration ppb (ng/g wet wt)							
Species (# collected)	**Walleye Pollock (12)**						
Pesticide Compound	**Mean Conc.**	**St. Dev.**	**Mean SDL**	**N**	**# Detects.**	**Min**	**Max**
1,2-Dichlorobenzene	NA	NA	NA	NA	NA	NA	NA
1,2,3,4-Tetrachlorobenzene	ND	ND	0.0090	12	1	ND	0.010
1,2,4-Trichlorobenzene	ND	ND	0.0209	12	3	ND	0.044
1,3-Dichlorobenzene	NA	NA	NA	NA	NA	NA	NA
1,4-Dichlorobenzene	NA	NA	NA	NA	NA	NA	NA
cis-Chlordane	0.0947	0.0895	0.0105	12	12	0.022	0.339
Trans-Chlordane	0.0506	0.0215	0.0089	12	12	0.034	0.101
cis-Nonachlor	0.0300	0.0298	0.0078	12	11	ND	0.113
trans-Nonachlor	0.1135	0.1343	0.0067	12	12	0.022	0.489
Oxy-Chlordane	ND	ND	0.3502	12	0	ND	ND
Dieldrin	0.0367	0.0093	0.0121	12	12	0.023	0.059
Endrin	ND	ND	0.0152	12	0	ND	ND
HCH, alpha	0.0682	0.0166	0.0334	12	11	ND	0.097
HCH, beta	ND	ND	0.0376	12	1	ND	0.030
HCH, gamma (Lindane)	ND	ND	0.0339	12	0	ND	ND
Heptachlor Epoxide	ND	ND	0.0129	12	0	ND	ND
Hexachlorobenzene	0.1575	0.0553	0.0068	12	12	0.093	0.249
Mirex	ND	ND	0.0118	12	2	ND	0.027
o,p'-DDD	0.0140	0.0097	0.0072	12	9	ND	0.033
o,p'-DDE	ND	ND	0.0048	12	0	ND	ND
o,p'-DDT	0.0624	0.0566	0.0109	12	10	ND	0.186
p,p'-DDE	0.4492	0.4658	0.0062	12	12	0.056	1.68
p,p'-DDT	0.1270	0.1357	0.0130	12	10	ND	0.431
Pentachlorobenzene	ND	ND	0.0113	12	1	ND	0.012
Total Toxaphene	ND	ND	1.868	12	1	ND	5.64
Sum Chlordanes	0.4826	0.4156		12	12	0.119	1.27
Sum DDT	0.6686	0.6595		12	12	0.079	2.26
SDL: Sample Detection Limit							
ND: Below SDL							
NA: Data Not Reported							
HCH, beta-; Maximum concentration was below the average SDL. But above the SDL for that fish							
One half the SDL is used as the value for all NDs when calculating mean and standard deviation							

11-H, Pesticide Concentration ppb (ng/g wet wt)							
Species (# collected)	**Sablefish (11)**						
Pesticide Compound	**Mean Conc.**	**St. Dev.**	**Mean SDL**	**N**	**# Detects.**	**Min**	**Max**
1,2-Dichlorobenzene	ND	ND	0.1068	11	0	ND	ND
1,2,3,4-Tetrachlorobenzene	0.0535	0.0395	0.0288	11	6	ND	0.119
1,2,4-Trichlorobenzene	0.2048	0.2086	0.0696	11	5	ND	0.552
1,3-Dichlorobenzene	0.1426	0.1778	0.0956	11	3	ND	0.493
1,4-Dichlorobenzene	2.684	3.544	0.1351	11	11	0.545	10.4
cis-Chlordane	0.4160	0.3136	0.0297	11	11	0.086	0.934
Trans-Chlordane	0.0842	0.0521	0.0258	11	9	ND	0.149
cis-Nonachlor	0.2183	0.1733	0.0252	11	11	0.032	0.537
trans-Nonachlor	0.7561	0.6462	0.0221	11	11	0.136	2.11
Oxy-Chlordane	ND	ND	0.3155	11	1	ND	0.276
Dieldrin	0.2917	0.2240	0.0513	11	11	0.072	0.807
Endrin	ND	ND	0.0719	11	0	ND	ND
HCH, alpha	0.4940	0.3527	0.2355	11	8	ND	1.03
HCH, beta	0.2396	0.1698	0.1454	11	7	ND	0.505
HCH, gamma (Lindane)	0.3398	0.2532	0.2985	11	7	ND	0.952
Heptachlor Epoxide	0.0998	0.0790	0.0679	11	6	ND	0.260
Hexachlorobenzene	0.6620	0.4156	0.0276	11	11	0.212	1.37
Mirex	ND	ND	0.0799	11	1	ND	0.074
o,p'-DDD	0.0436	0.0343	0.0286	11	6	ND	0.100
o,p'-DDE	0.0983	0.1164	0.0207	11	7	ND	0.396
o,p'-DDT	0.2443	0.2601	0.0390	11	10	ND	0.893
p,p'-DDE	6.273	6.624	0.0354	11	11	0.478	21.7
p,p'-DDT	0.4039	0.3679	0.0422	11	10	ND	1.13
Pentachlorobenzene	0.0510	0.0356	0.0355	11	6	ND	0.116
Total Toxaphene	ND	ND	6.402	11	3	ND	17.6
Sum Chlordanes	1.647	1.191		11	11	0.433	3.93
Sum DDT	7.063	7.119		11	11	0.561	23.2
SDL: Sample Detection Limit							
ND: Below SDL							
Mirex; Maximum concentration was below the average SDL. But above the SDL for that fish							
One half the SDL is used as the value for all NDs when calculating mean and standard deviation							

11-I, Pesticide Concentration ppb (ng/g wet wt)							
Species (# collected)	**Sheefish (8)**						
Pesticide Compound	**Mean Conc.**	**St. Dev.**	**Mean SDL**	**N**	**# Detects.**	**Min**	**Max**
1,2-Dichlorobenzene	0.0988	0.0133	0.0783	8	7	ND	0.199
1,2,3,4-Tetrachlorobenzene	ND	ND	0.0169	8	2	ND	0.015
1,2,4-Trichlorobenzene	0.1235	0.0524	0.0360	8	7	ND	0.200
1,3-Dichlorobenzene	ND	ND	0.0639	8	1	ND	0.121
1,4-Dichlorobenzene	0.8696	0.4913	0.0842	8	8	0.339	1.89
cis-Chlordane	0.2776	0.1727	0.0186	8	8	0.022	0.508
Trans-Chlordane	0.0460	0.0144	0.0167	8	8	0.030	0.072
cis-Nonachlor	0.1855	0.1022	0.0301	8	8	0.023	0.327
trans-Nonachlor	0.5687	0.3117	0.0265	8	8	0.052	0.941
Oxy-Chlordane	ND	ND	0.2269	8	2	ND	0.197
Dieldrin	0.1056	0.0746	0.0490	8	7	ND	0.278
Endrin	ND	ND	0.0608	8	0	ND	ND
HCH, alpha	0.1007	0.0430	0.0545	8	7	ND	0.176
HCH, beta	ND	ND	0.0849	8	0	ND	ND
HCH, gamma (Lindane)	ND	ND	0.0679	8	0	ND	ND
Heptachlor Epoxide	ND	ND	0.0654	8	1	ND	0.136
Hexachlorobenzene	0.7309	0.4121	0.0159	8	8	0.106	1.55
Mirex	ND	ND	0.0473	8	2	ND	0.060
o,p'-DDD	ND	ND	0.0143	8	2	ND	0.026
o,p'-DDE	ND	ND	0.0190	8	0	ND	ND
o,p'-DDT	0.0228	0.0146	0.0193	8	4	ND	0.045
p,p'-DDE	0.5896	0.2959	0.0249	8	8	0.122	0.959
p,p'-DDT	0.0706	0.0403	0.0216	8	7	ND	0.117
Pentachlorobenzene	0.0233	0.0143	0.0218	8	5	ND	0.055
Total Toxaphene	ND	ND	3.7938	8	0	ND	ND
Sum Chlordanes	1.219	1.286		8	8	0.178	1.95
Sum DDT							
SDL: Sample Detection Limit							
ND: Below SDL							
1,2,3,4-Tetreachlorobenzene, cis-Nonachlor; Maximum concentration was below the average SDL. But above the SDL for that fish							
One half the SDL is used as the value for all NDs when calculating mean and standard deviation							