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 the rest of the world. There has been a concern that Persistent Organic Pollutants (POPs) have been identified across the globe including Arctic climates and may negatively impact the 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 in 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. 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 a general survey of selected marine and freshwater finfish species from around the state and testing these fishes for certain 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) and commercial and some Native fishermen, samples of salmon (all 5 species), halibut, Pollock, sablefish, Pacific cod, lingcod and rockfish were collected from primarily marine waters and at the mouth of rivers through out the state. Northern pike were caught from lakes and rivers in the Koyukuk, Kuskokwim, Yukon and Susitna River drainages and sheefish from rivers draining in to Kotzebue Sound. Sheefish were collected in the winter of 2001 while the majority of the remaining fish were collected during the 2002 fishing season (June through August).

All samplers were 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) and placed in wetlock boxes. The samples were immediately shipped on ice, or frozen and then shipped to the Environmental Health Laboratory (EHL) in Palmer, Alaska. Over 600 samples were collected during this initial collection period. The fish were processed at EHL lab and chemical analysis was performed on the homogenized skinless fillets of individual fish. All of the fish samples were tested for heavy metals at the EHL Lab (methyl mercury, cadmium, lead, nickel, chromium, arsenic and selenium). Results for the heavy metal analysis can be found on the State web page: http://www.state.ak.us/dec/eh/vet/fish.htm . These initial data support the Public Health Division's recommendation that all Alaskans, including pregnant women, women of childbearing age, and young children, continue unrestricted consumption of fish from Alaska waters http://www.epi.hss.state.ak.us/bulletins/docs/b2001_06.htm .

Due to the high cost for the analysis of organic contaminants only a subset of all the fish samples were analyzed for polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCCDs) , polychlorinated dibenzofurans (PCDFs) and organocholrine pesticides using approved USEPA Methods by AXYS Analytical Services Ltd. (AXYS) in British Columbia, Canada. Data results from AXYS were validated by an independent contractor using USEPA Region 10 Validation Methods. This subset of fish did not include all species collected during the study period. This report will present the data from 89 fish samples (18 chum, 17 Chinook, 24 sockeye, 11 halibut, 8 sheefish and 11 sablefish).

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

	Gulf of Alaska	**Bering Sea**	**Freshwater Drainage Kotzebue Sound**
Species (# of fish)			
Chum (18)	0	18	
Chinook (17)	9	8	
Sockeye (24)	12	12	
Halibut (11)	11		
Sablefish (11)	11		
Sheefish (8)			8

The fishes evaluated in this study occupy different positions in the Alaskan ecosystem. Salmon are anadromous fish, born in fresh water streams they migrate out to mature in the North Pacific and return to their birth stream to spawn. Chinook salmon, Alaska's State fish, is the largest and the most long-lived of the Pacific salmon species and is known for its high oil content. Sockeye are an important commercial species which, like the Chinook, contain a high oil content. Native fishermen harvest all species of salmon, which is the main protein source for traditional diet. Sheefish live in arctic rivers and annually migrate up stream to spawn. They are a favorite food for many Native communities and often pursued by recreational fishermen. Halibut are bottom fish found along the Pacific Coast from Washington State to the Bering Sea, as far north as Norton Sound. Like salmon, halibut are important to commercial, subsistence and recreational fisheries. Sablefish (also known as blackcod or butterfish) have a high oil content and range in the deep waters of the North Pacific from Western Canada to the Bering Sea. Generally, Sablefish are commercially harvested year-round from the Gulf of Alaska and Western Canada.

Table 2 Range, mean and standard deviation of the weight in kilograms (kg) of the fish collected

Weight (Kilograms)				
Species (# of fish)	**Mean**	**Std. Dev**	**Min**	**Max**
Chum (18)	3.47	0.82	2	5.4
Chinook (17)	5.6	2.64	2.3	13.8
Sockeye (24)	2.6	0.67	1.6	4
Halibut (11)	20.6	11.17	9.1	41.4
Sablefish (11)	1.3	0.35	0.8	1.7
Sheefish (8)	4.3	1.8	2.7	7.8

The oil or lipid concentrations vary considerably for different species of fish. The polyunsaturated fatty acids and omega 3 fatty acids contained in fish are responsible for many of the health benefits such as improved cardiovascular function and are essential for a healthy pregnancy and fetal neurodevelopment. Many of the organic contaminants are lipophilic and bioaccumulate in the fat component of the fish and it is important to know the relative lipid content of the different species when comparing the contaminant concentrations. As expected older and larger fish with higher percent lipid concentration would be expected to accumulate higher levels of organic contaminants. The percent lipid concentration of the fish analyzed is presented in Table 3.

Table 3 Lipid Concentration of Skinless Fillet tissue

% Lipid Concentration				
Species (# fish)	**Mean**	**Std Dev**	**Min**	**Max**
All Salmon (59)	7.29	4.24	1.98	23.6
Chum (18)	4.81	1.44	2.86	8.9
Chinook (17)	8.6	5.79	1.98	23.6
Sockeye (24)	8.22	3.67	2.17	16.1
Halibut (11)	0.46	0.25	0.15	0.9
Sablefish (11)	3.17	2.19	0.79	6.61
Sheefish (8)	1.47	0.74	0.22	2.89

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

Analytical Data results:

PCB Concentration-

The PCB concentration of the fish tissue (individual fish, homogenized skinless fillet) is reported as total PCBs ppb (parts per billion) or ng/g wet weight, which is the sum of 44 PCB congeners, eight of which were co-eluting congeners, are quantified. The list of congeners can be found in an attached Table 8 in the appendix to this report; 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. Table 4 lists the range of values, the mean and standard deviation of the PCB concentration for the three salmon species (chum, Chinook, sockeye) grouped together and then individually for each species.

Table 4 Total PCB concentrations in fish tissue sampled*

		Total PCB ppb (ng/gm)			
SPECIES	**# Fish**	**Mean**	**Std dev**	**Min**	**Max**
All SALMON	59	7.19	4.87	1.59	18.78
Chum	18	2.52	1.20	1.59	6.21
Chinook	17	8.17	4.58	4.11	18.02
Sockeye	24	10.00	4.26	3.00	18.78
Halibut	11	1.15	0.94	0.30	3.12
Sablefish	11	4.79	3.87	0.67	13.53
Sheefish	8	2.47	1.17	0.62	3.88

All samples below the detection limit are reported as zero for the calculations
Mean of the Sample Specific Detection Limit** for individual PCB congeners was 0.1958 pg/gm wet wt

* Total PCBs based on the sum of 44 Congeners listed in appendix
** [The sample specific detection limits are determined for each individual sample from the data during the chemical analysis using lab reagent blanks and adjusting for sample volume. This converts the signal of the instrument measuring the chemical to a numerical concentration by comparison to a known chemical standard.]

Dioxin Concentration-

The dioxin concentration in the fish tissue (individual fish, homogenized skinless fillet) is represented as Toxic Equivalent Quotients (TEQs) ppt (parts per trillion) or (pg/g wet weight). The calculation of the TEQ includes the concentration of dioxins, furans and dioxin-like PCBs using World Health Organization Toxic Equivalency Factors (Van den Berg et al. 1998). Table 5 illustrates the mean and standard deviation of the TEQ for the salmon species (chum, Chinook, sockeye) grouped together and then for each species separately.

Table 5 Toxic Equivalency Quotient (TEQ) concentration based on PCDDs, PCDFs, and Dioxin-like PCBs *

<u>TEQ ppt (pg/gm wet weight)</u>

SPECIES	# Fish	Mean	Std dev	
ALL SALMON	59	0.4411	0.368	
Chum	18	0.1062	0.0901	
Chinook	17	0.3971	0.2685	
Sockeye	24	0.7234	0.3362	
				The fraction of TEQ attributed to co-planer PCB for salmon averages 65%
Halibut	11	0.0198	0.0224	
				The fraction of TEQ attributed to co-planer PCB for halibut averages 94%
Sablefish	11	0.139	0.1237	
				The fraction of TEQ attributed to co-planer PCB for sablefish averages 90%
Sheefish	8	0.0872	0.0528	
				The fraction of TEQ attributed to co-planer PCB for sheefish averages 97%

All samples below the detection limit are reported as zero for the calculations

Mean Sample Specific Detection Limit for individual PCB congeners = 0.1958 pg/gm wet wt

Mean Sample Specific Detection Limit for individual Dioxin and Furan congeners = 0.0487 pg/gm wet wt

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

Pesticide Concentration-

Forty (40) pesticides were measured in each tissue sample. Several pesticides that were not detected in a majority of the fish samples collected. Table 6 lists the 13 pesticides that were not detected in over 75 % of the fish samples of all fish species. The mean sample specific detection limit and maximum concentration that was detected in the few samples is also illustrated. The data for these pesticides will not be illustrated in any of the summary tables. There were additional pesticide compounds that were not detected in over 75% of the fish samples in an individual species. These pesticide compounds will be listed separately at the bottom of the species table.

Table 6

Non-Detects found in > 75% of samples of all species
Max Concentrations for each pesticide listed

Pesticide	Mean Sample Specific Detection Limit (ppb)	#Detected	Max
1,2-Dichlorobenzene	0.1000	2	1.3900
1,2,3-Trichlorobenzene	0.0525	1	0.1200
1,3,5-Trichlorobenzene	0.0502	0	ND
Aldrin	0.0787	0	ND
alpha-Endosulphan	0.0604	3	0.0649
beta-Endosulphan	0.0784	0	ND
Endrin Aldehyde	0.2405	0	ND
Endrin Ketone	0.0941	0	ND
HCH, delta	0.1196	3	0.8580
Heptachlor	0.1592	1	0.1130
Hexachlorobutadiene	0.0236	0	ND
Methoxychlor	0.2601	0	ND
Oxychlordane	0.3661	3	0.2350

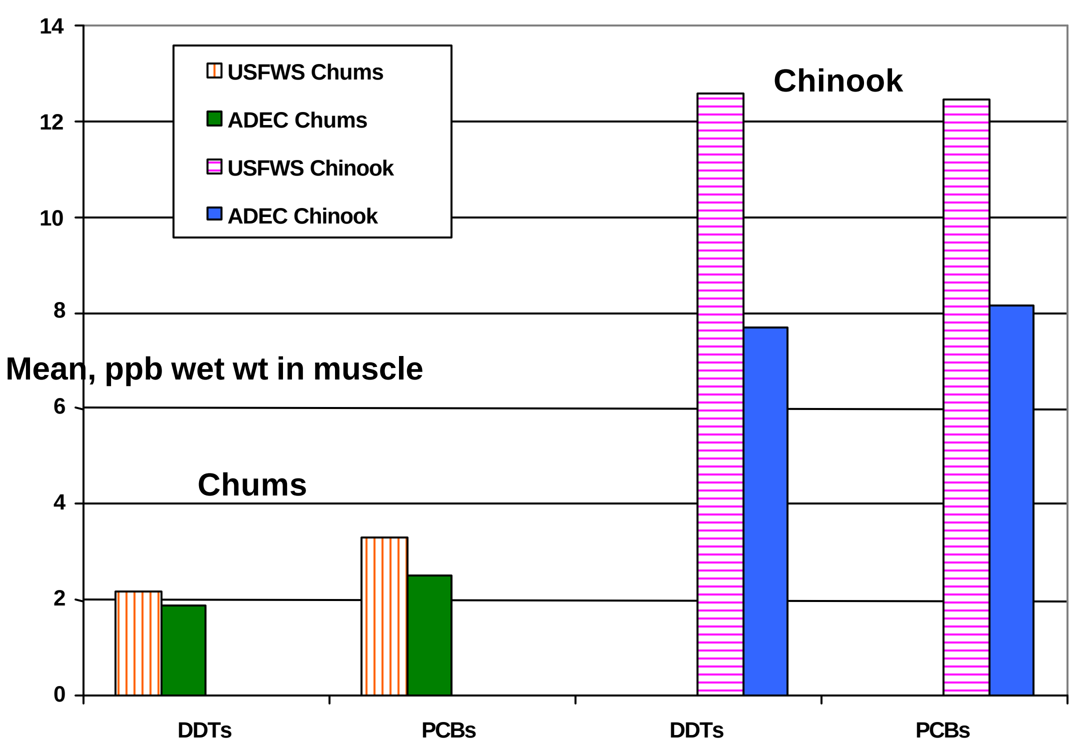
*ND=not detected

Appendix tables 7 A-G list the mean, standard deviation and range for each pesticide concentration detected by species and for chum, Chinook and sockeye salmon combined. Pesticide concentrations are reported as ppb (parts per billion) ng/gm wet weight. Data are calculated only for individual fish samples with a reportable concentration above the detection limit (all non-detects are treated as a zero value and are not included in the calculation. A footnote for each table will list the specific pesticides that were not detected in over 75% of all the tissue samples for that particular species.

Discussion

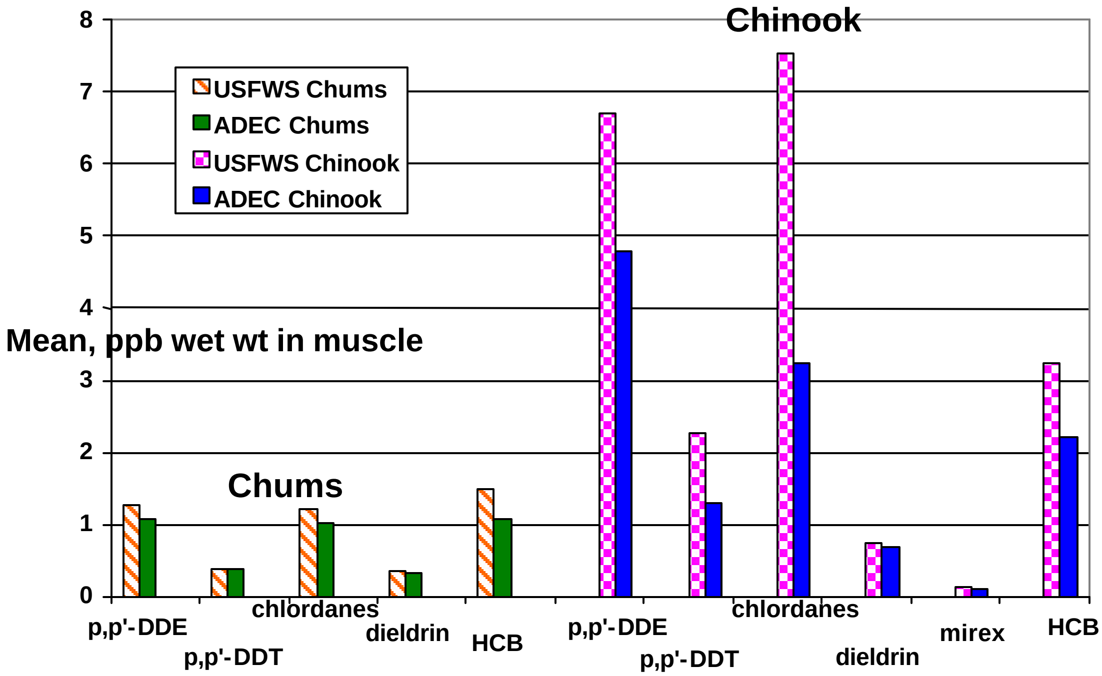
The environmental contaminants evaluated in this study: 1) resist chemical degradation, 2) travel great distances from their source of production and 3) bioaccumulate in the food chain. Recent studies (USFW, 2001; Hites et al., 2004; Krummel et al., 2003; Ewald et al., 1996) show similar findings of low concentrations of contaminants in wild salmon such as 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 the global presence of these pollutants. In 2001, the U.S. Fish and Wildlife Service (USFWS) conducted a study of contaminant concentrations in king and chum salmon from the Yukon and Kuskokwim Rivers. When contaminant concentrations for each species are compared between the USFWS study, representing fish exclusively from the Yukon and Kuskokwim River basins, and our fish monitoring study, which covers a much broader geographic range, the results are similar (Figures 1 and 2).

Figure 1. Total PCBs and Sum DDTs in Chum Salmon and Chinook Salmon from Alaska: A comparison of ADEC data with USFWS data from the Y-K region [1]



* [1] U.S. Fish and Wildlife Service, unpublished data

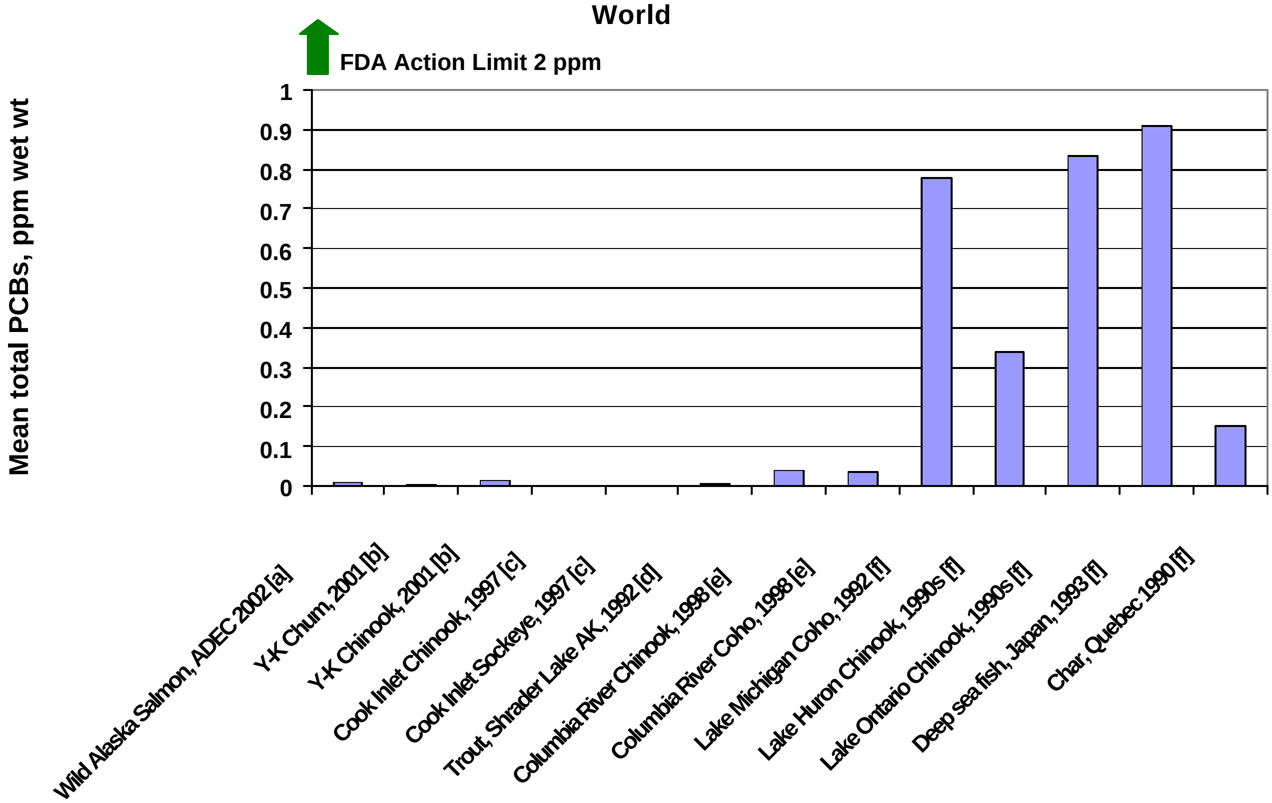
Figure 2. Organochlorine Pesticides in Chum Salmon and Chinook Salmon from Alaska: A Comparison of ADEC data with USFWS data from the Y-K Region [1]



* [1] U.S. Fish and Wildlife Service, unpublished data

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. 3). Note that Figure 3 represents a relative comparison of data only and definitive conclusions cannot be drawn from this comparison since each study could have used different analytical methodology, tissue used for analysis etc.

Figure 3. 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 slight differences in chemical concentrations in a fish species among Alaska studies are probably due to both differences analytical methods and differences in biological factors, and are not indicative of 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 fish in other studies it is expected that their concentrations will continue to decrease.

This general trend has been noted in the most recent report of the Arctic Monitoring and Assessment Program (AMAP) (2002, AMAP Report). However, it was emphasized that the decrease was not noted for all POPs. There are some instances for which the decline is minimal and unfortunately areas where the levels may actually be increasing, indicating a need for continued monitoring which the State of Alaska in undertaking.

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 contaminant concentrations in fish from Alaska waters are low, and are not of public health concern. We continue to recommend the unrestricted consumption of fish from Alaska waters.

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 concentration 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 levels of contaminants found in fish from this study were more than 100-fold lower than 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 (USEPA, 2000a), risk assessment (USEPA, 2000b), risk management (USEPA, 1996), and risk communication (USEPA, 1995). 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 4,5,7 A-G. 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, aldrin, endosulphans, hexachlorobutadiene, methoxychlor, heptachlor, hexachlorobenzene, lindane and mirex (Figures 4 and 5).

Figure 4. Endrin, Toxaphene, Lindane and Mirex in Chinook and Sockeye Salmon from Alaska - Comparison with EPA Guidelines (chronic) for Unlimited Consumption

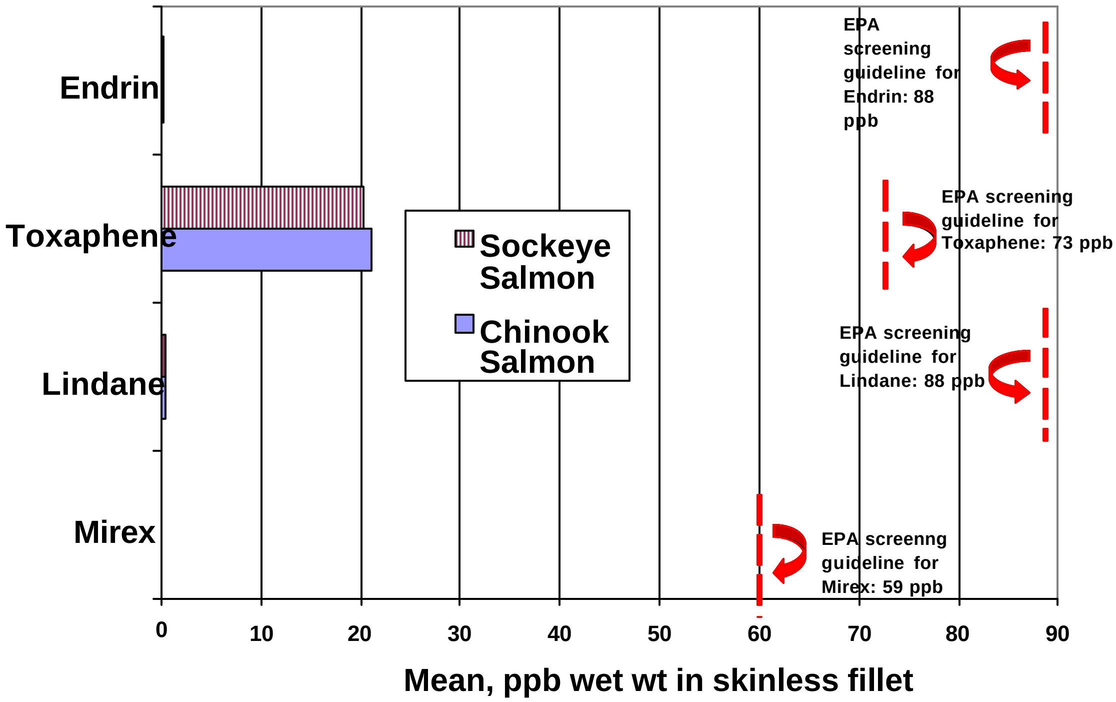
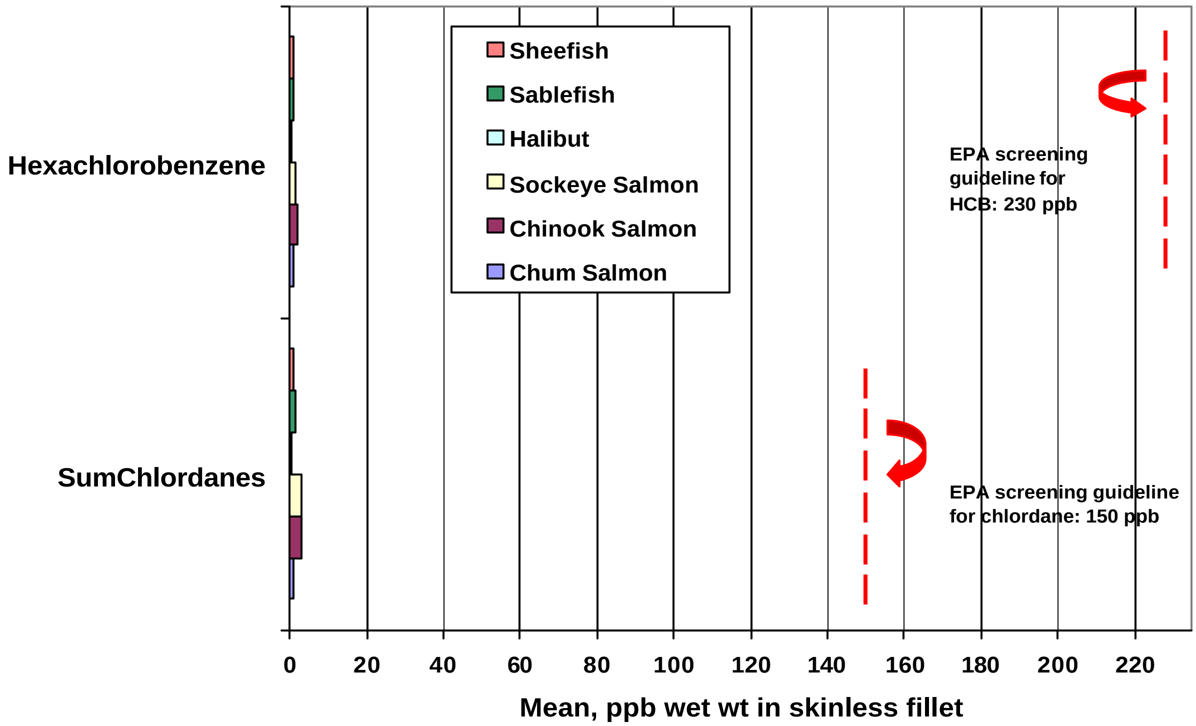
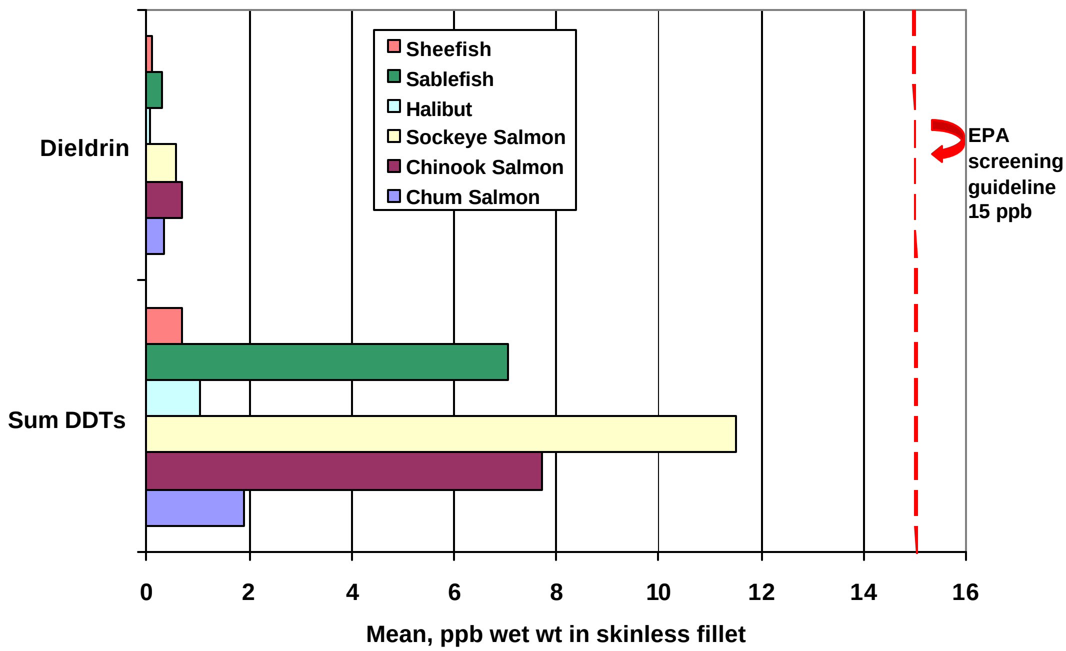


Figure 5. Hexachlorobenzene and SumChlordanes in Alaska Fish - Comparison with EPA Guidelines (chronic) for Unlimited Consumption



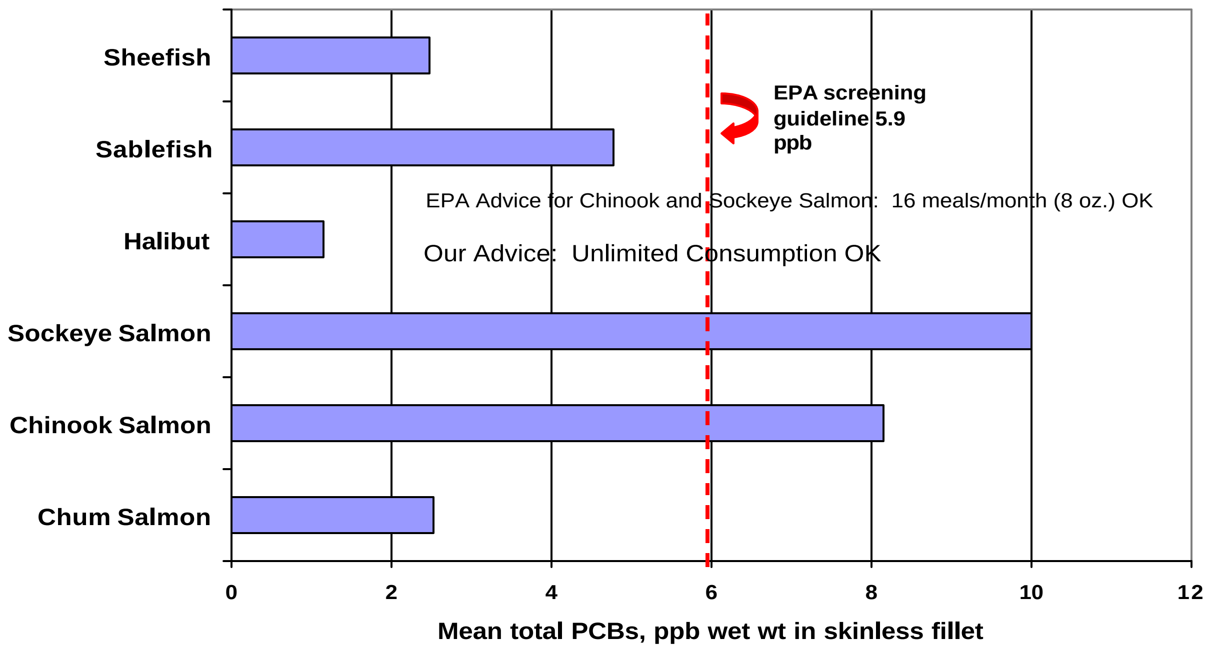
Several pesticides were detected in many of the fish tested, in small amounts below the EPA screening guidelines for unrestricted consumption using a chronic health endpoint. These pesticides include sum-DDTs, dieldrin, toxaphene, and several hexachlorocyclohexane isomers (Figures 4 and 6).

Figure 6. Dieldrin and SumDDTs in Fish from Alaska - Comparison with the EPA Guideline (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. Comparison of PCB Levels in Salmon with the EPA Guideline for Unrestricted Consumption (chronic) - ADEC Fish Monitoring Project



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 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 can be safely consumed. Given EPA's safety factor and considering the many health benefits of fish consumption (illustrated in the next section), the Alaska Division of Public Health continues to recommend the unrestricted consumption of fish caught from Alaska waters, including Chinook and sockeye salmon.

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 (Receveur et al., 1997). 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 chronic disease prevalence, including an increase in hypertension, glucose intolerance, and diabetes (Murphy et al., 1997; Risica et al., 2000a; Risica et al., 2000b). 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 (State of Alaska Dept.of Health & Social Services, 2003).

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 (Alaska Division of Public Health, 2003).

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 continues to recommend the unrestricted consumption of fish from Alaska waters.
- 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.

Acknowledgement: Many thanks to Angela Matz and Keith Mueller from the Fairbanks field office of the U.S. Fish and Wildlife Service, for generously providing information on contaminant concentrations in salmon from the Yukon and Kuskokwim rivers.

Reference List

Alaska Division of Public Health . Alaska Mercury Biomonitoring. 21. 7-30-2003. Anchorage, AK, State of Alaska Section of Epidemiology.
Ref Type: Report

AMAP (2002) *Arctic Pollution 2002.* Arctic Monitoring and Assessment Programme, Oslo.

ATSDR (2000) *Toxicological profile for polychlorinated biphenyls (PCBs)*. Agency for Toxic Substances and Disease Registry, Public Health Service, U.S. Department of Health and Human Services.

Ewald,G., Larson,P., Linge,H., Okla,L., and Szarzi,N (1998) Biotransport of Organic Pollutants to an Inland Alaska Lake by Migrating Sockeye Salmon. *Arctic* **51:** 40-47.

Hites,R.A., Foran,J.A., Carpenter,D.O., Hamilton,M.C., Knuth,B.A., and Schwager,S.J. (2004) Global assessment of organic contaminants in farmed salmon. *Science* **303:** 226-229.

Krummel,E.M., Mcdonald,R.W. Kimpe,L.E., Gregory-Eaves,I., Demers,M.J., Smol,J.P., Finney,B., Blais,J.M. (2002) Delivery of Pollutants by Spawning Salmon. *Nature* 425:225.

Murphy,N.J., Schraer,C.D., Theile,M.C., Boyko,E.J., Bulkow,L.R., Doty,B.J., and Lanier,A.P. (1997) Hypertension in Alaska Natives: association with overweight, glucose intolerance, diet and mechanized activity. *Ethnicity & Health* **2:** 267-275.

Receveur,O., Boulay,M., and Kuhnlein,H.V. (1997) Decreasing Traditional Food Use Affects Diet Quality for Adult Dene/Métis in 16 Communities of the Canadian Northwest Territories. *J Nutr* **127:** 2179-2186.

Risica,P.M., Ebbesson,S.O.E., Schraer,C.D., Nobmann,E.D., and Caballero,B.H. (2000a) Body fat distribution in Alaskan Eskimos of the Bering Straits region: the Alaskan Siberia Project. *International Journal of Obesity Relat Metab Disord* **24:** 171-179.

Risica,P.M., Schraer,C., Ebbesson,S.O.E., Nobmann,E.D., and Caballero,B. (2000b) Overweight and obesity among Alaskan Eskimos of the Bering Straits Region: the Alaska Siberia project. *Int J Obes Relat Metab Disord* **24:** 939-944.

State of Alaska Dept.of Health & Social Services . The burden of overweight & obesity in Alaska. 2003. Anchorage, AK, Alaska Division of Public Health, Section of Epidemiology.
Ref Type: Report

Terry,P.D., Rohan,T.E., and Wolk,A. (2003) Intakes of fish and marine fatty acids and the risks of cancers of the breast and prostate and of other hormone-related cancers: a review of the epidemiologic evidence. *Am J Clin Nutr* **77:** 532-543.

USEPA. A Survey of Chemical Contaminants in Fish, Invertebrates and in Plants Collected in the Vicinity of Tyonek, Seldovia, Port Graham and Nanwalek - Cook Inlet, AK. Dec 2003.

U.S. EPA, 2002. Columbia River Basin Fish Contaminants Survey 1996-1998. EPA, Region 10 Report EPA910/R-02-006.

USEPA. Guidance for assessing chemical contaminant data for use in fish advisories. Vol. IV: Risk Communication. EPA 823-R-95-001. 1995. Washington, D.C., Office of Water [4305].
Ref Type: Report

USEPA. Guidance for assessing chemical contaminant data for use in fish advisories. Vol. 3: Overview of risk management. EPA 823-B-96-006. 1996. Washington, D.C., Office of Water [4305].
Ref Type: Report

USEPA. Guidance for assessing chemical contaminant data for use in fish advisories. Vol. 1: Fish sampling and analysis, Third Edition. EPA 823-B-00-007. 2000a. Washington, D.C., Office of Water [4305].
Ref Type: Report

USEPA. Guidance for assessing chemical contaminant data for use in fish advisories. Volume 2: Risk assessment and fish consumption limits, Third Edition. EPA 823-B-00-008. 2000b. Office of Water (4305).
Ref Type: Report

Van den Berg, Birnbaum,L., Bosveld,A.T.C., Bronstrom,B., Cook,P., Feeley,M., Giesy,J.P., Hanberg,A., Hasegawa,R., Kennedy,S.W., Kubiak,T., Larsen,J.C., van Leeuwen,F.X.R., Djien Leim,A.K., Nolt,C., Peterson,R.E.,Maged Younes,L., Waern,F., and Zacharewski,T. (1998) Toxic Equivalency Factors (TEFs) for PCBs, PCCDs, PCDFs for Humans and Wildlife, Environmental Health Perspectives 106(12):775-792.

Wilson,R., Allen-Gil,S., Griffin,D., and Landers,D. (1995) Organochlorine contaminants in fish from an Arctic lake in Alaska, USA. *Science of the Total Environment* **160/161:** 511-519.

Appendix:

Table 8   Congener List

PCB Congeners used to calculate Total PCB *

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 7, A

Pesticide Concentration ppb (ng/gm wet wt)

Species (# collected) — All SALMON Grouped (59)

PESTICIDE COMPOUND	Mean Detection Limit ppb	#Detect	Mean	Std dev	Min	Max
1,2,3,4-Tetrachlorobenzene	0.0238	34	0.0529	0.0353	0.0128	0.182
1,3-Dichlorobenzene	0.0879	15	0.2317	0.1729	0.0456	0.553
1,4-Dichlorobenzene	0.1128	30	3.6165	2.66	0.641	11.1
cis-Chlordane	0.0263	59	0.86	0.5522	0.215	2.42
cis-Nonachlor	0.0291	59	0.2815	0.1745	0.074	0.803
Dieldrin	0.0791	59	0.5396	0.3159	0.1385	1.89
Endrin	0.1158	33	0.1897	0.1102	0.0482	0.561
HCH, alpha	0.1155	59	0.8102	0.62	0.116	3.38
HCH, beta	0.1329	52	0.5045	0.3261	0.125	1.63
HCH, gamma (Lindane)	0.1437	19	0.3134	0.2666	0.104	0.927
Heptachlor Epoxide	0.1077	49	0.3145	0.1498	0.1325	0.858
Hexachlorobenzene	0.0271	59	1.6432	0.9455	0.696	5.19
Mirex	0.0480	33	0.0948	0.0396	0.0424	0.198
o,p'-DDD	0.0273	58	0.3199	0.2076	0.07	0.912
o,p'-DDE	0.0258	53	0.3075	0.2375	0.202	0.943
o,p'-DDT	0.0370	58	1.2213	0.9615	0.163	3.77
p,p'-DDE	0.3500	59	4.0521	2.9231	0.583	11.1
p,p'-DDT	0.0408	58	1.6788	1.5103	0.119	5.74
Pentachlorobenzene	0.0287	56	0.1162	0.066	0.0434	0.401
Total Toxaphene	5.7754	36	18.8075	12.2677	2.74	52.4
trans-Chlordane	0.0229	56	0.3099	0.1903	0.843	0.844
trans-Nonachlor	0.0256	59	1.1078	0.7257	0.273	3.24
Sum Chlordane	Sum: NonDetect =0	59	2.552	1.633	0.69	7.28
Sum DDT	Sum: NonDetect =0	59	7.4936	5.7207	0.67	22.08

Table lists # of samples with a Detectable Concentration (removes all non-detects from calculations)

Detection limit listed as mean value for each pesticide analyzed

The following pesticides were not detected in over 75% of all the Salmon samples: 1,2,4-Trichlorobenzene, 1235/1245-Tetrachlorobenzene, Endosulphan Sulphate.

PESTICIDE COMPOUND	Mean Detection Limit ppb	#Detect	Max	Mean
1,2,4-Trichlorobenzene	0.0401	9	0.2150	0.1231
1235/1245-Tetrachlorobenzene	0.0138	7	0.0571	0.0282
Endosulphan Sulphate	0.0068	6	0.0680	0.0500

Table 7, B

Pesticide Concentration ppb (ng/gm wet wt)

Species (# collected) Chum (18)

PESTICIDE COMPOUND	Mean Detection Limit ppb	#Detect	Mean	Std dev	Min	Max
1,2,3,4-Tetrachlorobenzene	0.0238	5	0.0298	0.0108	0.0192	0.046
1,4-Dichlorobenzene	0.1128	9	1.5028	1.033	0.641	3.69
cis-Chlordane	0.0263	18	0.3849	0.1414	0.215	0.7130
cis-Nonachlor	0.0291	18	0.116	0.0394	0.074	0.194
Dieldrin	0.0791	18	0.3255	0.13	0.15	0.664
Endrin	0.1158	7	0.0349	0.0495	ND	0.1470
Endosulphan Sulphate	0.0992	6	0.05	0.0143	0.028	0.068
HCH, alpha	0.1155	18	0.4337	0.1293	0.197	0.7435
HCH, beta	0.1329	17	0.2691	0.0952	0.125	0.518
Heptachlor Epoxide	0.1077	9	0.2527	0.0853	0.149	0.402
Hexachlorobenzene	0.0271	18	1.078	0.2875	0.696	1.82
o,p'-DDD	0.0273	17	0.1249	0.0509	0.07	0.256
o,p'-DDE	0.0258	13	0.0539	0.036	0.0202	0.156
o,p'-DDT	0.0370	17	0.356	0.2722	0.163	1.31
p,p'-DDE	0.3500	18	1.069	0.6677	0.583	3.32
p,p'-DDT	0.0408	17	0.3716	0.4079	0.1199	1.84
Pentachlorobenzene	0.0287	17	0.776	0.0272	0.0481	0.139
trans-Chlordane	0.0229	16	0.1328	0.0429	0.0843	0.215
trans-Nonachlor	0.0256	18	0.4121	0.1583	0.273	0.816
Sum Chlordane	Sum: NonDetect =0	18	1.031	0.378	0.69	1.79
Sum DDT	Sum: NonDetect =0	18	1.9132	1.4225	0.67	6.89

Table lists # of samples with a Detectable Concentration (removes all non-detects from calculations)
Detection limit listed as mean value for each pesticide analyzed
The following pesticides were not detected in over 75% of Chum samples: 1,2,4-Trichlorobenzene, 1235/1245-Tetrachlorobenzene, 1,3-Dichlorobenzene, gamma HCH (Lindane), Mirex, Total Toxaphene.

PESTICIDE COMPOUND	Mean Detection Limit ppb	#Detect	Max	Mean
1,2,4-Trichlorobenzene	0.0325	1	0.2150	NA
1235/1245-Tetrachlorobenzene	0.0232	0	ND	NA
1,3-Dichlorobenzene	0.0631	3	0.3690	0.1565
gamma HCH (Lindane)	0.1437	3	0.1565	0.1301
Mirex	0.0360	1	0.0630	NA
Total Toxaphene	3.3325	4	7.1600	4.3350

*ND= not detected, NA= Not apply

Table 7, C

Pesticide Concentration ppb (ng/gm wet wt)

Species (# collected) Chinook (17)

PESTICIDE COMPOUND	Mean Detection Limit ppb	#Detect	Mean	Std dev	Min	Max
1,2,3,4-Tetrachlorobenzene	0.0238	11	0.0659	0.0537	0.0248	0.182
1,2,4-Trichlorobenzene	0.0510	5	0.1007	0.0299	0.0814	0.151
1,3-Dichlorobenzene	0.0879	6	0.2563	0.1695	0.0575	0.553
1,4-Dichlorobenzene	0.1128	9	3.5222	1.1823	1.96	5.17
cis-Chlordane	0.0263	17	1.073	0.6349	0.448	2.42
cis-Nonachlor	0.0291	17	0.3836	0.1915	0.207	0.803
Dieldrin	0.0791	17	0.6944	0.4155	0.1385	1.89
Endrin	0.1158	10	0.2525	0.1294	0.132	0.561
HCH, alpha	0.1155	17	0.9961	0.7841	0.205	3.38
HCH, beta	0.1329	14	0.6367	0.3847	0.156	1.63
HCH, gamma (Lindane)	0.1437	8	0.3153	0.254	0.144	0.881
Heptachlor Epoxide	0.1077	17	0.03618	0.178	0.157	0.858
Hexachlorobenzene	0.0271	17	2.2029	1.2724	0.898	5.19
Mirex	0.0480	14	0.0887	0.0297	0.0424	0.145
o,p'-DDD	0.0273	17	0.3042	0.1453	0.113	0.551
o,p'-DDE	0.0258	16	0.3082	0.2039	0.106	0.802
o,p'-DDT	0.0370	17	1.0352	0.7645	0.292	2.79
p,p'-DDE	0.3500	17	4.7953	2.661	2.12	10.7
p,p'-DDT	0.0408	17	1.2891	1.1531	0.287	4.03
Pentachlorobenzene	0.0287	15	0.1493	0.0949	0.0451	0.401
Total Toxaphene	5.7754	13	21.1373	14.7876	3.685	52.4
trans-Chlordane	0.0229	17	0.3699	0.2072	0.183	0.844
trans-Nonachlor	0.0256	17	1.4104	0.78	0.73	3.24
Sum Chlordane	Sum: NonDetect =0	17	3.2448	1.8064	1.57	7.28
Sum DDT	Sum: NonDetect =0	17	7.714	4.7459	3.13	18.87

Table lists # of samples with a Detectable Concentration (removes all non-detects from calculations)
Detection limit listed as mean value for each pesticide analyzed
The following pesticides were not detected in over 75% of Chinook samples: 1235/1245-Tetrachlorobenzene, Endosulphan Sulphate.

PESTICIDE COMPOUND	Mean Detection Limit ppb	#Detect	Max	Mean
1235/1245-Tetrachlorobenzene	0.0268	4	0.0571	0.0272
Endosulphan Sulphate	0.0992	0	ND	NA

*ND= not detected, NA= Not apply

Table 7, D

Pesticide Concentration ppb (ng/gm wet wt)

Species (# collected) Sockeye (24)

PESTICIDE COMPOUND	Mean Detection Limit ppb	#Detect	Mean	Std dev	Min	Max
1,2,3,4-Tetrachlorobenzene	0.0238	18	0.0513	0.0207	0.0128	0.0937
1,3-Dichlorobenzene	0.0879	6	0.2448	0.1926	0.0456	0.533
1,4-Dichlorobenzene	0.1128	12	5.2725	3.1948	1.55	11.1
cis-Chlordane	0.0263	24	1.065	0.4688	0.445	2.36
cis-Nonachlor	0.0291	24	0.3333	0.1349	0.0926	0.621
Dieldrin	0.0791	24	0.5906	0.2505	0.297	1.29
Endrin	0.1158	16	0.1942	0.09	0.0482	0.39
HCH, alpha	0.1155	24	0.961	0.6072	0.116	2.74
HCH, beta	0.1329	21	0.611	0.3042	0.152	1.38
HCH, gamma (Lindane)	0.1437	8	0.3801	0.3139	0.159	0.927
Heptachlor Epoxide	0.1077	23	0.3038	0.1408	0.1325	0.603
Hexachlorobenzene	0.0271	24	1.6706	0.7646	0.705	3.71
Mirex	0.0480	18	0.1012	0.0463	0.0492	0.198
o,p'-DDD	0.0273	24	0.4692	0.197	0.192	0.912
o,p'-DDE	0.0258	24	0.4443	0.2096	0.131	0.943
o,p'-DDT	0.0370	24	1.9659	0.822	0.528	3.77
p,p'-DDE	0.3500	24	5.7629	2.5101	1.65	11.1
p,p'-DDT	0.0408	24	2.8805	1.3013	0.664	5.74
Pentachlorobenzene	0.0287	24	0.12294	0.0507	0.0434	0.231
Total Toxaphene	5.7754	19	20.2603	9.67	7.13	39.1
trans-Chlordane	0.0229	23	0.3889	0.1612	0.158	0.818
trans-Nonachlor	0.0256	24	1.415	0.584	0.477	2.64
Sum Chlordane	Sum: NonDetect =0	24	3.202	1.32	1.17	6.43
Sum DDT	Sum: NonDetect =0	24	11.5229	4.9003	3.17	22.08

Table lists # of samples with a Detectable Concentration (removes all non-detects from calculations)
Detection limit listed as mean value for each pesticide analyzed
The following pesticides were not detected in over 75% of all the Sockeye samples: 1,2,4-Trichlorobenzene, 1235/1245-Tetrachlorobenzene, Endosulphan Sulphate.

PESTICIDE COMPOUND	Mean Detection Limit ppb	#Detect	Max	Mean
1,2,4-Trichlorobenzene	0.0510	3	0.1410	0.1297
1235/1245-Tetrachlorobenzene	0.0268	3	0.0376	0.0296
Endosulphan Sulphate	0.0992	0	ND	NA

*ND= not detected, NA= Not apply

Table 7, E

Pesticide Concentration ppb (ng/gm wet wt)

Species (# collected) Halibut (11)

PESTICIDE COMPOUND	Mean Detection Limit ppb	#Detect	Mean	Std dev	Min	Max
1,4-Dichlorobenzene	0.1128	8	0.852	1.031	0.287	3.17
cis-Chlordane	0.0263	11	0.1175	0.0613	0.0448	0.208
cis-Nonachlor	0.0291	10	0.0782	0.0422	0.0247	0.132
Dieldrin	0.0791	5	0.0613	0.0142	0.0475	0.0765
Hexachlorobenzene	0.0271	11	0.2094	0.0705	0.13	0.32
o,p'-DDT	0.0370	7	0.0667	0.0377	0.0275	0.122
p,p'-DDE	0.3500	11	0.9134	1.1001	0.114	3.12
p,p'-DDT	0.0408	7	0.115	0.1119	0.0318	0.299
trans-Nonachlor	0.0256	11	0.2696	0.1813	0.0695	0.593
Sum Chlordane	Sum: NonDetect =0	11	0.469	0.289	0.17	0.93
Sum DDT	Sum: NonDetect =0	11	1.0308	1.2392	0.11	3.5

Table lists # of samples with a Detectable Concentration (removes all non-detects from calculations)
Detection limit listed as mean value for each pesticide analyzed
The following pesticides were not detected in over 75% of all the Halibut samples: 1,2,3,4-Tetrachlorobenzene, 1,2,4-Trichlorobenzene, 1,3-Dichlorobenzene, 1235/1245-Tetrachlorobenzene, Endosulphan Sulphate, Endrin, Alpha, beta, gamma HCH (Lindane), Heptachlor Epoxide, Mirex, o,p'-DDD, o,p'-DDE, Pentachlorobenzene, Total Toxaphene, trans-Chlordane.

PESTICIDE COMPOUND	Mean Detection Limit ppb	#Detect	Max	Mean
1,2,3,4-Tetrachlorobenzene	0.0238	1	0.1710	NA
1,2,4-Trichlorobenzene	0.0510	2	0.8520	0.5005
1,3-Dichlorobenzene	0.0879	0	ND	NA
1235/1245-Tetrachlorobenzene	0.0268	1	0.1830	NA
Endosulphan Sulphate	0.0992	0	ND	NA
Endrin	0.1158	0	ND	NA
Alpha HCH	0.1155	3	0.1330	0.1093
beta HCH	0.1329	1	0.0742	NA
gamma HCH (Lindane)	0.1437	1	0.0773	NA
Heptachlor Epoxide	0.1077	0	ND	NA
Mirex	0.0480	1	0.0759	NA
o,p'-DDD	0.0273	1	0.0197	NA
o,p'-DDE	0.0258	0	ND	NA
Pentachlorobenzene	0.0287	1	0.0512	NA
Total Toxaphene	5.7754	0	ND	NA
trans-Chlordane	0.0229	3	0.0533	0.0412

*ND= not detected, NA= Not apply

Table 7, F

Pesticide Concentration ppb (ng/gm wet wt)

Species (# collected) — Sablefish (11)

PESTICIDE COMPOUND	Mean Detection Limit ppb	#Detect	Mean	Std dev	Min	Max
1,2,3,4-Tetrachlorobenzene	0.0238	5	0.093	0.0147	0.0836	0.119
1,2,4-Trichlorobenzene	0.051	4	0.4368	0.1309	0.292	0.552
1,4-Dichlorobenzene	0.1128	8	3.4183	3.9588	0.545	10.4
1235/1245-Tetrachlorobenzene	0.0268	5	0.036	0.0079	0.0311	0.0497
cis-Chlordane	0.0263	11	0.416	0.3136	0.0864	0.934
cis-Nonachlor	0.0291	10	0.2369	0.1707	0.0629	0.537
Dieldrin	0.0791	11	0.2917	0.224	0.0719	0.807
HCH, alpha	0.1155	8	0.6027	0.3488	0.162	1.03
HCH, beta	0.1329	5	0.3722	0.139	0.169	0.505
Heptachlor Epoxide	0.1077	6	0.1575	0.0606	0.1	0.26
Hexachlorobenzene	0.0271	11	0.662	0.4156	0.212	1.37
o,p'-DDD	0.0273	6	0.0672	0.0296	0.0264	0.1
o,p'-DDE	0.0258	7	0.1479	0.1212	0.0235	0.396
o,p'-DDT	0.037	10	0.2661	0.2334	0.0407	0.893
p,p'-DDE	0.35	11	6.2731	6.6238	0.478	21.7
p,p'-DDT	0.0408	10	0.4424	0.3637	0.0658	1.13
Pentachlorobenzene	0.0287	6	0.0772	0.0262	0.0345	0.116
Total Toxaphene	5.7754	3	12.8767	5.3738	7.03	17.6
trans-Chlordane	0.0229	6	0.1245	0.0303	0.0677	0.149
trans-Nonachlor	0.0256	11	0.7561	0.6462	0.136	2.11
Sum Chlordane	Sum: NonDetect =0	11	1.4554	1.1792	0.22	3.7
Sum DDT	Sum: NonDetect =0	11	7.0479	7.1317	0.52	23.22

Table lists # of samples with a Detectable Concentration (removes all non-detects from calculations)
Detection limit listed as mean value for each pesticide analyzed
The following pesticides were not detected in over 75% of all the Sablefish samples: 1,3-Dichlorobenzene, Endosulphan Sulphate, Endrin, gamma HCH (Lindane), Mirex.

PESTICIDE COMPOUND	Mean Detection Limit ppb	#Detect	Max	Mean
1,3-Dichlorobenzene	0.0879	1	0.4620	NA
Endosulphan Sulphate	0.0992	0	ND	NA
Endrin	0.1158	0	ND	NA
gamma HCH (Lindane)	0.1437	2	0.3010	0.2600
Mirex	0.0480	0	ND	NA

*ND= not detected, NA= Not apply

Table 7, G

Pesticide Concentration ppb (ng/gm wet wt)

Species (# collected) Sheefish (8)

PESTICIDE COMPOUND	Mean Detection Limit ppb	#Detect	Mean	Std dev	Min	Max
1,4-Dichlorobenzene	0.1128	4	1.215	0.4655	0.864	1.89
cis-Chlordane	0.0263	8	0.2776	0.1727	0.0218	0.508
cis-Nonachlor	0.0291	7	0.2088	0.0845	0.0807	0.327
Dieldrin	0.0791	7	0.1177	0.0717	0.0733	0.278
HCH, alpha	0.1155	7	0.112	0.0311	0.0865	0.176
Hexachlorobenzene	0.0271	8	0.7309	0.4121	0.106	1.55
p,p'-DDE	0.35	8	0.5896	0.2959	0.122	0.959
p,p'-DDT	0.0408	7	0.0789	0.0354	0.0166	0.117
trans-Nonachlor	0.0256	7	0.6426	0.25	0.243	0.941
Sum Chlordane	Sum: NonDetect =0	8	1.023	0.601	0.02	1.78
Sum DDT	Sum: NonDetect =0	8	0.6667	0.3473	0.14	1.1

Table lists # of samples with a Detectable Concentration (removes all non-detects from calculations)
Detection limit listed as mean value for each pesticide analyzed
The following pesticides were not detected in over 75% of all the Sheefish samples: 1,2,3,4-Tetrachlorobenzene, 1,2,4-Trichlorobenzene, 1,3-Dichlorobenzene, 1235/1245-Tetrachlorobenzene, Endosulphan Sulphate, Endrin, Beta and gamma HCH (Lindane), Heptachlor Epoxide, Mirex, o,p'-DDD, o,p'-DDE, o,p'-DDT, Pentachlorobenzene, Total Toxaphene, trans-Chlordane.

PESTICIDE COMPOUND	Mean Detection Limit ppb	#Detect	Max	Mean
1,2,3,4-Tetrachlorobenzene	0.0238	2	0.0153	0.1445
1,2,4-Trichlorobenzene	0.0510	1	01170	NA
1,3-Dichlorobenzene	0.0879	1	0.1210	NA
1235/1245-Tetrachlorobenzene	0.0268	0	ND	NA
Endosulphan Sulphate	0.0992	0	ND	NA
Endrin	0.1158	0	ND	NA
beta HCH	0.1329	0	ND	NA
gamma HCH (Lindane)	0.1437	0	ND	NA
Heptachlor Epoxide	0.1077	1	0.1360	NA
Mirex	0.0480	2	0.0603	0.0583
o,p'-DDD	0.0273	1	0.0195	NA
o,p'-DDE	0.0258	0	ND	NA
o,p'-DDT	0.0370	1	0.0453	NA
Pentachlorobenzene	0.0287	1	0.0287	NA
Total Toxaphene	5.7754	0	ND	NA
trans-Chlordane	0.0229	0	ND	NA

*ND= not detected, NA= Not apply