NOAA Technical Memorandum NOS OMA 33

POTENTIAL TOXICANT EXPOSURE AMONG CONSUMERS OF RECREATIONALLY CAUGHT FISH FROM URBAN EMBAYMENTS OF PUGET SOUND: FINAL REPORT

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EXECUTIVE SUMMARY

The presence of organic and inorganic contaminants in fish and shellfish collected from urban embayments in Puget Sound, Washington, has resulted in growing public concern regarding the safety of consuming seafood caught in these areas. The present study was conducted in order to estimate the dosage of key contaminants that recreational anglers and their families might ingest through consumption of Puget Sound seafood. Exposure estimates were based on fish consumption rates and on contaminant levels in the edible portions of the most commonly caught species. Data on fish consumption patterns and rates were obtained through interviews with shoreside and boating anglers. Data on contaminant levels were obtained through chemical analysis of commonly caught species.

The study was conducted over a two-year period. During the first year, efforts were concentrated on collection of catch and consumption data, but a limited number of chemical analyses were also performed. A progress report summarizing the data collected during the first year has been published (Landolt et al., 1985). During the second year, efforts were concentrated on contaminant analysis; however, a limited amount of catch and consumption data was also collected. The results of the second year of the study are reported in this document.

Interviews of boating anglers revealed a population that consisted primarily of employed male Caucasians. Most had 12 or more years of education. Boating anglers fished mainly on weekends and during the summer. The most commonly caught species (based on weight) were chinook salmon, coho salmon, walleye pollock, Pacific cod, and lingcod. The vast majority of

fishermen planned to consume only fillets. The most common methods of preparation were frying and barbecuing.

Chemical analyses of seven trace metals revealed generally low levels. Concentrations of Hg, Cd, Pb and Se were similar among species. Concentrations of Cu and Zn were similar for all species except squid, where levels were elevated. Arsenic levels varied greatly among species and geographic sites. Arsenic levels were highest in squid and walleye pollock and were found in highest levels in specimens from Commencement Bay.

Chemical analyses of more than 20 trace organics revealed that only PCBs were present in all specimens. Other compounds that were frequently detected included p,p'-DDE, p,p'-DDD, hexachlorobenzene and p,p'-DDT. With the exception of a few specimens with high PCB levels, the concentrations of trace organics were low.

To examine the effect that cooking might have on contaminant levels, some specimens were analyzed raw and after frying. Cooking reduced the levels of PCBs and other organic contaminants by 50 - >90%, produced slight or no reductions in arsenic levels, slightly increased the concentrations of Cu, Cd, Hg, Se, and Zn, and markedly increased the concentrations of Ag and Pb.

Arsenic and PCBs were the only contaminants present in high enough concentrations to indicate a potential for excess cancer risk when tested by a conventional risk assessment model. These two contaminants were selected as model compounds for dose estimation. Arsenic concentrations at the 5th, 50th and 95th percentiles were calculated to be 0.6, 2.6 and 16.4 ppm, respectively. Based on an average fish consumption rate of 11 g/person/day, dose estimates at the same percentiles were 11, 33, and 220 ug/person-day. PCB concentrations at the 5th, 50th and 95th percentiles were calculated to be 24, 81 and 315 ppb, respectively. At the same consumption rate, the percentile dose estimates were 0.3, 0.9, and 3.5 ug/person-day. Consumption rates and dose estimates apply only to the period during which there is an active fishery for selected species.

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1. INTRODUCTION

High concentrations of organic and inorganic contaminants have been found in the sediments of some Puget Sound, Washington embayments, particularly those that are adjacent to urban areas (Malins et al., 1982 a and b). Investigators have also found accumulations of xenobiotic compounds or metabolites in the liver and bile of fish (Malins et al., 1980; Dexter et al., 1981), and in the lipids of marine mammals and birds (Riley et al., 1983; Calambokidis et al., 1984) collected from these areas. Although reports of this contamination have been widely publicized in local news media, the urban embayments of Puget Sound remain a popular fishing site for recreational anglers (Noviello, 1982).

In 1983 a study was initiated to determine the potential for recreational anglers to be exposed to contaminants through consumption of seafood caught near urban areas. The specific objectives of the study were (1) to identify the species most commonly caught by anglers in urban areas of Puget Sound; (2) to demographically characterize the anglers; (3) to characterize the fish consumption patterns of urban anglers (i.e. fishing frequency, amount of fish consumed, tissues eaten, method of preparation); (4) to assess the concentration of principal contaminants in the edible portions of commonly caught species; and (5) to estimate the quantity of selected chemicals consumed by anglers and their families. The study was not designed to assess risk or to set level-of-concern values for contaminants in fish. The study was designed as a two-year project. The first year focused on collection of demographic data and on analysis of catch and consumption patterns of shoreside anglers. In addition, a limited number of chemical analyses were conducted on tissue specimens. The results obtained in Year 1 have been published (Landolt et al., 1985) and will not be repeated in this report.

During the second year of the study, intensive chemical analyses were conducted on tissues collected during Year 1 as well as on additional tissue

samples collected in Year 2. The analyses were conducted in order to refine and update contaminant exposure estimates made in Year 1 (Landolt et al., 1985). Concentrations of seven trace metals (compared to only three in Year 1) and a variety of trace organics (compared to PCBs only in Year 1) were measured in samples of raw and cooked muscle tissue from 10 species of finfish. While resources were concentrated on chemical analyses, a limited number of interviews similar to those conducted with shoreside anglers were conducted with boating anglers.

2. METHODS

2.A. Interviews with Boating Anglers

2.A.1. Data collection

Boating anglers were interviewed over a nine-month period (February 1, 1985 to October 20, 1985) at two urban embayments in Puget Sound, Washington: (a) Commencement Bay (Tacoma); (b) Elliott Bay (Seattle). These sites (Figure 1) were near metropolitan areas, they have abundant demersal and anadromous fish populations, and they get fairly heavy fishing pressure. They also probably represent some of the most contaminated areas in the Sound in terms of sediments and biota. Two other sites, Sinclair Inlet (Bremerton) and Edmonds, which were studied in Year 1, were not included due to funding limitations. Interviewing effort was constant each month so we could assess temporal trends in fishing effort.

Boating anglers were interviewed on shore as they returned to boat ramps. It was not possible to determine accurately where the anglers fished because many refused to disclose their fishing site and others were vague as to their exact location.

Three veteran interviewers who participated in the shoreside angler survey conducted the boating angler interviews. Prior to employment they were tested on their ability to identify local marine fish species. In addition, three training sessions for the interviewers were conducted during the first eight months of the project.

Meetings with the interviewers were held at least monthly in order to provide continuous feedback to the field and data management coordinators on fishing conditions or activity which might influence the next month's field schedule. Survey and site description forms (Appendices A and B) were turned in every two to three weeks. These forms were checked for uniformity and completeness before coding and data entry both as a quality control for individual interviewers and as a means of obtaining current information on angling activity.

All interviews were conducted shoreside at public boat ramps. Elliott Bay anglers were interviewed at the Armeni Boat Ramp. Commencement Bay anglers were interviewed primarily at the Point Defiance Boat Ramp. Since most boaters were returning from completed trips, interviews reflected total catch, a fact which may help to explain the boaters' apparently greater fishing success, compared to the pier-based anglers who were often interviewed while still fishing. A small number of boaters were interviewed during a break in their trip, but in those cases they had been fishing for at least two hours. All interviews were completely voluntary and anonymous. Interviewers wore specially marked caps and carried University of Washington identification to avoid being mistaken for fisheries enforcement officials. Police, marina managers, and bait shop operators were informed of the aims of the study so that they might respond to questions from concerned anglers. Although some anglers proved uncooperative, interviewers were relatively well accepted by the fishing population. Boaters who were anxious to trailer their boats after a long wait at the ramp showed some irritation as the interview progressed.

A site description form (Appendix A) was completed at each location on each interview day. This form summarized weather and tidal conditions, the numbers and ethnic characteristics of groups of anglers, and the most commonly sought species. The field interview form used in this study is shown in Appendix B. The interviewer noted the age, sex and race of each angler, along with the type of fish sought. When anglers were fishing as a group, a single interview was conducted if the catch was being pooled; anglers were interviewed individually if they separated their catch into individual buckets. Anglers were asked how often they fished in the area, when they last had caught and eaten fish from that area, and what type(s) of fish was caught. City of residence, ethnic background, occupation, and years of education of the anglers also were elicited.

All specimens were identified to the species level using field guides by Hart (1973) and Somerton and Murray (1976). In some cases the species could not be identified because the fish had been beheaded, skinned, filleted, etc. Fork length was measured in centimeters and recorded on the survey form. Anglers were asked which species would be consumed and the mode of preparation for eating.

2.A.2. Data analysis

Angler interview data were entered into and analyzed on the PRIME computer of the Washington State Department of Social and Health Services, Epidemiology Laboratories, using SPSS Version 7.3 (Nie et al., 1975). Statistical tests used a two-tailed significance level of 0.05.

Questionaires were coded, entered, and analyzed by the same person (Hafer), using empirically-derived coding categories that omitted no data. Data entry utilized a screen entry program, such that an electronic facsimile of the interview form appeared on the computer screen; this procedure minimized data entry errors. Most of the coding categories appeared on the interview form itself. Individual species of fish were given a 3-digit identifier code. Occupations of the anglers were coded with the 3-digit categories used by Washington State in its Health Data Section for vital records. Prior to analysis, data were checked for improper or out-of-range values.

Data editing proceeded as follows. Printed output of raw data was verified against interview forms. Frequency distributions were constructed for all variables and reported to other members of the study team. Data then were broken down by study site after observing that boaters did not show much ethnic differentiation.

General data analysis -- Statistical analyses consisted of calculation of counts, percentages, means and medians. Because most of the distributions of values of variables tended to be skewed to the right, nonparametric estimates of location and species were used. In particular, to characterize such distributions, 5th, 50th and 95th percentile values were calculated. For a normal or bell-shaped distribution of values, the mean is equal to the median (50th percentile), and the 5th and 95th percentiles are approximately two standard deviations below and above the mean, respectively.

Consumption and dose estimation -- For each successful fishing trip the combined weight of each species was computed by applying weight-length regression coefficients (a = intercept; b = slope) for Puget Sound fish to the quantities (fishcount) and lengths (fishlength) recorded on the interview forms (Wildermuth, 1982). In cases where more than one fish per species was taken, the mean length was used to compute weight.

This total weight of fish caught was divided by the number of people reportedly eating fish in the angler's household (eaters), and by the number of days elapsed (days) since fish caught at the same site were last eaten. That value was then multiplied by a cleaning factor (cf: 0.49 for squid, crab; 0.3 for finfish) to obtain the mean daily grams of available edible portion (edfishwt) consumed per person. These calculations are depicted by the following expression:

$$\text{Edfishwt} = \frac{(\text{fishcount})\ (a)\ (\text{fishlength}^{b})\ (cf)}{(\text{eaters})\ (\text{days})}$$

Geometric means were calculated from the results obtained for each angler using the expression

$$\text{Geometric mean grams} = \sqrt[n]{\prod_{i} \text{Edfishwt}}$$

where n is the number of anglers who caught fish of the species in question. This value was multiplied by the means and by the lower and upper ranges of contaminant concentrations to provide an estimate of dose.

Dose (ug) = (Geometric mean grams) (contaminant concentration, ug/g)

2.B. General Methods for Chemical Analysis

2.B.1. Selection of samples

Year 1 activity included a limited survey of fish tissues for three trace metals and for total PCBs. The species analyzed were selected on the basis of preliminary angler survey data to reflect the most frequently caught fish.

Chemical analyses in Year 2 were intended to refine and update the exposure estimates made in Year 1. In order to select species for Year 2 chemical analysis, contamination data from previously published reports were examined to determine the amount and suitability of the data for purposes of dose estimation. The general requirements for these data were that the reported tissue levels be sufficiently specific to relate to consumption data from our survey. Under ideal circumstances, this degree of specificity would permit the existing tissue data to be classified as to location caught, fish species, age/size of fish, tissue type analyzed, season caught, and method of (food) preparation (if any). Without any consideration of the reliability of the chemical analysis, these requirements, if rigidly adhered to, would have excluded most of the existing data due to incomplete description of the samples, inconsistent units of expression of results, etc. Examples of the latter inconsistencies that make pooling of previous data difficult are: concentration in wet weight vs. dry weight; method of quantification for PCBs reported as Aroclor mixture or as per isomer group with increasing chlorine

number. In order to permit maximum use of historical data, the following decisions were made: (1) only salmon that permanently reside in Puget Sound would be considered; (2) salmon, cod and squid would be considered on a Sound-wide basis; (3) variances for tissue concentrations of toxicants would be expected to increase as data from different locations or species were pooled; (4) seasonality and age/size effects would also be expected to increase variation. If pooling data across these categories resulted in variability that was still adequate in terms of precision of dose estimate, and if probable high contamination conditions were characterized by existing data, then no further measurements needed to be made of those species. The test of adequacy of precision is difficult to apply in isolation from the end use of the data. The following general discussion defines the relationship between number of observations (i.e. sample measured) and the final precision of dose estimate for consumers.

The key statistical constraint on data quantity, assuming a desired 95% level of confidence, was recognition that the number of replicate samples required to achieve any target level of precision was controlled by the variability of the measurements within that category. Thus, examination of existing data had to include assessment of variance as well as of the levels found.

In order to assess the precision of intake estimation based on replication level and on variance of the contaminant measured, the following expression was used:

$$(1)\quad C.I./\,x = Z\,(s/\sqrt{N})\,/\,x$$

which is derived from the definition of confidence interval (C.I.). At the 95% confidence level,

$$(2)\quad C.I./\,x = (1.96/\sqrt{N})\,(s/x).$$

Plotting different values of s/x (the variability expressed as a proportion of the mean), N (replicates), and C.I./x (confidence interval expressed as a proportion of the mean) results in the nomograph shown in Appendix C. It should be noted that this treatment assumes that s/x remains constant for different subsets of x. From historical data and from other studies we could predict that s/x for truly replicate samples might reasonably be between 0.5 and 2.0. For three replicate samples, a small relative variance (0.5) produces a 95% confidence interval of 57% of the mean, so the highest value within that range is 157% of the mean; a large relative variance (2.0) produces a 95% confidence interval of 220% of the mean, so the largest value within that range is 320% of the mean.

Appendix C presents the data from previous studies that were available for PCBs in edible tissue of species taken by sport/subsistence anglers, according to the foregoing analysis. Based on these data, we could be 95% certain that any salmon caught would have 0-349 ppb total PCBs. Fifty-one additional measurements would be necessary to shrink the confidence interval by half. Similarly, 84 additional measurements would be needed to double the precision of the exposure estimate for "cod."

The historical data were also used to determine the number of replicates needed for underrepresented species. For resident species, values of s/x seen

in the study by Gahler et al. (1982), which was the only example of sufficient replication in single site/single resident species to permit the calculation, were universally below 1.0; addition of a second site raised s/x to 1.1 (Appendix C). Samples of migratory fish typically produced higher values of s/x (up to 1.6 for some sets of samples). Calculations based on these data showed that if the value of s/x were less than 1.0 and the desired precision of contaminant concentration for the species and location were within a factor of 2 of the mean (95% confidence), 4 replicates would be needed. If the relative variability were 1.5 then 5 additional replicates would be required to achieve the same precision of contaminant level estimate. For migratory species (estimated s/x = 1.6), 6 - 11 replicates were needed.

From these analyses of existing data we concluded that:

(1) Contaminant levels could be estimated within a factor of two for salmon and cod, on a Sound-wide basis, using existing data.

(2) Probable high concentration situations were not addressed by current data for any resident (localized) species, due to low numbers of samples from Elliott Bay, and might not be well described by pooled data from "migratory" species (note, for example, the differences between Sound-wide pollock PCB concentrations and Hylebos Waterway pollock concentrations).

(3) For Sound-wide salmon and previously-analyzed cod species (assuming that no bias exists in this data pooling), unfeasibly large numbers of additional samples would be required to double the dose estimation precision.

(4) For additional resident species, four to eight replicates per site/species would probably permit estimation of contaminant levels in tissue within a factor of two, while six to eleven replicates on a Sound-wide basis should provide equivalent precision for migratory species.

2.B.2. Sample collection

Fish were sampled near the sites where interviews were conducted (for exact locations, see Table 1). The fish were either caught with hook and line by the interviewers, were obtained from anglers, or were collected by trawling and beach seining. To prevent contamination of the samples, collectors avoided excess handling and unnecessary contact of the fish with plastic bags, buckets, rags, docks, or fishing piers.

When fish were caught by the interviewer, the catch was pulled from the water and placed in a glass jar, the line was cut leaving the hook in the fish, and the lid was put back on the jar. When fish were caught by an angler, the interviewers sampled only those fish caught in their presence. As soon as the fish was pulled out of the water, it was unhooked and placed in a glass container to avoid contact with the pier surface, or the angler's bag or bucket.

Some demersal fish were collected by a 7.3m otter trawl at 50 m depth on board the research vessel KITTIWAKE. Nearshore specimens were collected by sinking beach seine set 30 m from the shore, and floating beach seine set 60 m from the shore. Individual fish samples were hand-picked from the nets and

placed immediately in glass jars without touching either the ship's deck or the beach.

In the field, glass jars containing fish samples were kept cool on ice. Upon arrival in the laboratory, the jars were drained of excess water and placed in a freezer at 0°C until dissection and analysis.

All glass jars used as fish containers were precleaned in the laboratory with detergent and water, acid rinsed, rinsed with dichloromethane, and dried at 200°C. The lids of the jars were sealed with a Teflon lining.

2.B.3. Sample preparation

At the time of analysis, the samples were thawed in their original glass jars and then transferred to solvent-rinsed aluminum foil. After species confirmation, the weight in grams and total length in centimeters of the organism were recorded along with any other pertinent information (Table 1).

The fish skin was cut with a solvent-rinsed scalpel blade and pulled back with forceps to expose the muscle tissue. To avoid contamination, a new scalpel blade and forceps were used to remove approximately 30 g of muscle tissue. Since the species varied greatly in size and conformation, specific body sites were chosen to be dissected for each species (Figure 2). The skin was removed to avoid contamination from external sources. Approximately 10-30 g of muscle tissue were used for trace organic analysis, while two 7g subsamples were obtained for trace metal analysis and for calculating the wet/dry ratio. All samples and subsamples were stored frozen in solvent-cleaned vials and jars with Teflon-lined lids. In some cases the liver was dissected and stored frozen in solvent-cleaned aluminum foil. A schematic of sample preparation steps is shown in Figure 3.

2.B.4. Cooked samples

In order to obtain an evaluation of the effect of cooking on contaminant dose, a limited number of samples were subjected to a "standardized" cooking procedure. Based on interview results, pan-frying is the most common method of fish preparation used by Puget Sound anglers, so it was selected for study. In order to minimize variations in cooking, a teflon-coated electric fryer (wok) was used. This device had a thermostatic control and a curved bottom that allowed minimal volumes of oil to be used. Blank analyses were conducted on the cooking oil ("Wesson" - Trade mark), the fryer itself, and the utensils (Teflon-coated tweezers) used during cooking. Preweighed fish samples (15-24 g) were placed in 50 ml of oil preheated to 200+/- 10°C. The cooking proceeded for 3 to 5 minutes, and was halted when the appearance of the fish sample indicated complete cooking. The cooked fish was allowed to drain, and a cooked weight was then determined. Cooked samples were divided between organics analysis and metals assay; procedures for analysis were identical to those used for raw fish.

2.C. Trace Metal Analysis

2.C.1 General methods

For trace metal measurements, 0.3 to 0.5 g of dried tissue sample was accurately weighed and transferred into a 50 ml Teflon beaker. The sample was initially digested on a hotplate after adding 10 ml Ultrex HNO_3 and covering the beaker with a Teflon cover. This treatment was enough to decompose most of the organic matter. To assure complete digestion, 2 ml Ultrex HNO_3 and 1 ml $HClO_4$ were added to the sample and the digestion continued to near dryness. If a violent reaction was observed, the sample was cooled, an additional portion of HNO_3 was added, and the digestion was continued carefully.

The final sample was diluted with 0.5 M HNO_3 for instrumental analysis. The lipid content of the sample was not digested completely and showed as a drop of oil on the surface of the diluted sample, which was removed to avoid interference. Measurement of standard reference materials showed that the removal of this oil droplet did not cause any measureable change in concentration of trace metals. The instrumental analysis was carried out by flameless atomic absorption spectrophotometry (AA) for Ag, Cd, Cu, and Pb.

For Hg measurement, 1-2 g wet tissue was accurately weighed and placed in glass bottles with glass stoppers. After the bottles were chilled in ice water, 2 ml concentrated H_2SO_4 and 2 ml 6% $KMNO_4$ solution were added sequentially to the samples under continuous stirring (Toffaletti and Savory 1975). The bottles were then capped and allowed to stand overnight to complete the digestion. Mercury was reduced with $NaBH_4$ and measured as cold vapor on an atomic absorption spectrophotometer.

The neutron activation analysis (NAA) was conducted by standard comparison, in which samples of both known and unknown composition were irradiated together, and the elemental concentrations in the unknowns determined by comparison with National Bureau of Standards' standards.

2.C.2. Speciation

The objective of the speciation studies was to identify the chemical forms of trace elements present in fish tissues, since different species of the same metal often show different toxicity. For example, inorganic arsenic III compounds are considered to be more toxic than the other arsenic compounds. Identification of chemical species of As, Hg and Cd present in fish tissue was proposed as part of this study; however, the analytical results (Section 3.B) showed that the concentrations of total Hg and Cd in the samples were at or near the detection limits. For this reason, speciation was carried out for As only.

Inorganic arsenic (INA, As III and As V) and organic forms of arsenic, monomethylarsenic compounds (MMA) and dimethylarsenic compounds (DMA), can be identified and quantified using a combination of hydride generation, cryogenic chromatography, and atomic absorption spectroscopy. To avoid oxidation and changes in chemical forms of the arsenic species, special non-oxidative sample dissolution techniques should be used with the drawback that the arsenic is

not released quantitatively from the sample matrix into the solution. The approach taken for arsenic speciation was as follows:

Samples were digested with concentrated HCl for several days at room temperature and were then diluted with water prior to analysis. The As species were converted to hydride form using sodium borohydride, purged from the solution with helium gas, and trapped in a chromatography column at the temperature of liquid nitrogen. The trap was then slowly warmed and As species (INA, MMA, DMA) were sequentially volatilized and carried to the AA for quantification. The setup was calibrated using standard solutions with known ratios of INA, MMA, and DMA. National Bureau of Standards reference materials and EPA reference samples were digested and analyzed in the same way as the samples. Arsenic species heavier than DMA were not identified and were simply referred to as >DMA.

2.C.3. Quality control and quality assurance

Quality control and quality assurance of the analytical work were approached through a three-tiered program. The first tier included the use of multiple analyses, blanks, standards additions, and primary standards. The second tier included review of laboratory practices and the application of splits, blanks, blinds, and replicates to guarantee performance. The third tier included periodically introducing blinds from outside laboratories and participation in round-robin proficiency testing programs with other laboratories.

The instrumental analysis was preceded by daily calibration of instruments and measurement of NBS standards for metals. Blanks, standards, and duplicates were measured with each batch of samples. The quality assurance for each batch of 20 samples is summarized in the following:

1. At least one standard was measured every time the NAA was done.

2. A blank sample was measured with each batch.

3. A standard was measured after each 10 samples.

4. A sample preparation blank was prepared and measured with each set of samples.

5. One in every 20 samples was analyzed in duplicate.

6. One in every 20 samples was split in two fractions; one fraction was analyzed conventionally and the other fraction was analyzed by standard addition techniques.

Additional laboratory calibrations and quality controls were achieved by continuing our active participation in the IAEA International Calibration, EML-Interlab Calibration, and EPA Quality Assurance programs.

The quality control results for trace metals are summarized in Table 2. The detection limit is given in ug/g, so the value is dependent upon the weight of the sample. An average sample weight is used to compute this limit. Three times the standard deviation of all the blank measurements was divided

by the average weight of the sample to obtain the detection limits. The blank values are for digestion mixtures without tissue samples.

A known quantity of an element was added to a sample and the amount recovered was expressed as a percentage of the spike.

The precision value is obtained by analyzing a single sample five times and determining one standard deviation expressed in ug/g.

The standard tissue results are for EPA and NBS tissue samples with known amounts of the metals of interest.

2.D. Trace Organics Analysis

2.D.1. Overview

2.D.1.a. Approach. The analytical scheme utilized for characterization of tissue concentrations of organic contaminants represented a compromise between the most exhaustive and sensitive analysis necessary to achieve part-per-billion detection of a wide range of chemical agents (such as the diversity represented in the EPA "Priority Pollutant" list) and the need to characterize many catch-related variables. In order to allocate analytical effort efficiently, reliance was placed on previous studies conducted in Puget Sound to narrow the range of chemical agents to those most likely to be present at detectable levels. Some of the key studies that were considered in setting target detection limits are shown in Table 60 (cited later in text). From the existing data the following points were established: PCBs are the only organic contaminants universally reported in Puget Sound fish; target contaminants ranked according to apparent prevalence/concentration are: PCBs > DDE,DDD,DDT; hexachlorobenzene; hexachlorobutadiene (some locations) > PAH > other chlorinated organics such as chlorinated butadienes, styrenes, naphthalenes or PAH; other pesticides. The results from a subset of species that were screened for PCB content during Year 1 of this study confirmed the universality of PCBs and generally agreed with previous findings for distribution of PCBs, but supported the possibility that previously uncharacterized species might have significant PCB levels.

A two-tiered analytical scheme was used for trace organics analysis. Level 1 analyses were designed to provide comparable data for all of the key species and locations identified in the demographic survey for subset of probable contaminants most amenable to detection. From this pool of samples, the most contaminated fish from each species were selected for Level 2 analysis of additional agents, principally PAH, chlorinated compounds or pesticides. The procedures used are discussed in detail in the following sections. Figure 4 compares the two-tiered approach with that used in Year 1 and with that used by NOAA facilities. Table 3 presents the method performance summary.

2.D.1.b. General procedures. Reagent Purity: All solvents used in sample preparation or for cleaning chromatographic materials or apparati were distilled-in-glass grade (Burdick and Jackson, Baker, E.M. Merck) and were lot certified in the U.W. Trace Organics Center for freedom from interfering impurities. Chromatographic materials, sodium sulfate, boiling chips, glass

wool, extraction thimbles, and other materials contacting the sample were cleaned by continuous liquid extraction and verified by blank analysis.

Glassware Preparation: Chromatographic columns, beakers, sample vials, and other containers were cleaned with aqueous detergent, organic solvents, and pyrolyzed in a furnace at 500°C. Surface deactivation with dichlorodimethylsilane reagent was performed on all vials and other containers. Glassware was batch tested for freedom from contamination.

Concentration Techniques: Primary concentration was performed using Kuderna-Danish concentrator apparati with 3-ball Snyder columns. Concentration of extracts or chromatographic fractions in volumes smaller than 10 ml was performed at ambient temperature under a dry nitrogen stream.

Preservation and Storage of Analytical Samples: Amber sample vials were used throughout the study. Extractions and sample preparation other than HPLC were conducted in a laboratory equipped with gold-tone (UV filtered) lighting. Sample and extract storage was at -80°C for prolonged storage, and at -30°C for shorter intervals. Septum-topped containers were used for all transfers of concentrated extracts. No chemical preservatives were used for organics analysis samples.

Standards and Reference Materials: Pesticide and PCB standards were obtained from the following sources: Supelco Inc., (Bellefonte, PA), National Bureau of Standards (Chlorinated Pesticides SRM1583), and RFR (Mow Ultra Scientific, Hope, RI) and were verified against each other. Single isomerid PCB standards were obtained from Ultra Scientific and from the National Analytical Facility, NOAA. Reference PCB isomerid mixtures were obtained from Sweden from the International Council for the Exploration of the Sea (ICES), Marine Chemistry Working Group (twelve isomerids) and from the National Research Council of Canada, Marine Analytical Chemistry Standards Program (51 individually synthesized and certified components). Standards for PAH were obtained from the National Analytical Facility, NOAA, and verified against NBS SRM 1647 and Trace Organics Analysis Center standards from Aldrich and Analabs. Deuterated compounds were obtained from Stohler (Waltham, MA). Internal standards were obtained from PCR Inc., (Decafluorobenzophenone), and Ultra Scientific (Octachloronaphthalene). Additional reference materials used during this study were: PCBs and Pesticides in Fish, Water Pollution Quality Control Samples, U.S. EPA Environmental Monitoring and Support Laboratory, Cincinnati, OH.

2.D.2. Specific analytical procedures

2.D.2.a. Tissue sampling and extraction. Tissue samples were prepared as outlined in Section 2.B. Nominal sample weight was 10 g (for details see Appendix D). Preweighed samples were chopped and slurried with approximately 200 ml of methylene chloride. Soxhlet extracted/activated anhydrous granular sodium sulfate (50 g) was added and the mixture ground for approximately 5 minutes using a Brinkman Polytron sonicating tissue homogenizer with PT35K probe. After initial homogenization, each sample was spiked with 100 ul of o,p'-DDE, perdeuterated perylene. The sample was then homogenized further using the PT10 probe. Additional sodium sulfate was added until the sample was efficiently dehydrated as indicated by the persistence of free granular sodium sulfate. When homogenization/dehydration was complete, the slurry was

transferred to a fritted glass extraction thimble containing a bed of anhydrous sodium sulfate. The filled thimble was then transferred to a Soxhlet continuous extractor charged with 350-500 ml of methylene chloride and extracted for 24 hours. The extract was replaced with fresh solvent and the sample was reground and repacked in the thimble, with fresh sodium sulfate added as necessary, then extracted for an additional 24 hours. Careful Polytron cleaning, inspection and homogenation of blank solvent were used to ensure no cross-contamination between samples. The extracts were combined, concentrated to less than 10 ml, filtered through a 1 micron Gelman Acrodisc 0 and diluted to exactly 10 ml, and a 5% aliquot removed for extracted residue weight determination. The remaining extract was concentrated to 1 ml and diluted with 1 ml pentane prior to Size Exclusion preparative chromatography. Residue weights were determined by air drying to constant weight in a tared aluminum boat.

2.D.2.b. Sample preparation for Level 1 analysis. Size-exclusion chromatography (SEC): SEC columns (SX-2 Biobeads, Biorad, Inc.) were individually calibrated using a standard mixture containing all of the analytes in Table 3, plus several PCB isomerids and PAHs. They were eluted isocratically with 50% methylene chloride, 50% pentane solvent. Figure 5 depicts the elution of several target contaminants under this system. Initial elution of the priority compounds (indicated by hexachloro-1,3-butadiene) typically begins at 90-95 ml, with some non-target compounds (such as phthalates) and considerable biological background eluting in the 70-90 ml fraction. Three fractions were collected: 0-70 ml ("F1," discarded or archived), 70-90 ml ("F2," archived), and 90-350 ml ("F3," for further analysis). The elution behavior of each sample was verified by detection of fluorescent components (perdeuterated perylene plus endogenous PAH) with a UV handlight, in a 150-250 ml elution volume range.

Prepared extract concentrate (2ml) in 50/50 methylene chloride/pentane was loaded on the SX-23 column bed, and the collection of eluate (f1) was begun. Portions of elution solvent (2 ml) were used to transfer the sample quantitatively and to rinse down the walls of the column. The solvent reservoir of the column was then carefully filled without disturbing the chromatographic bed, and the elution continued to completion. Removal and replacement of the top 2 cm of column between samples if insoluble of non-elution sample components were observed could be accomplished without affecting the column calibration.

Normal-phase liquid chromatography: Florisil (magnesium silicate, 60/100 mesh, pesticide grade, Sigma Chemical) was cleaned, activated at 1250°C and stored at 100°C until use. The florisil column (5g slurry-packed in 50/50 methylene chloride/pentane) was direct-coupled to the SEC column and switched into the flow after the "F3" elution cut was reached at 90-95 mls. After elution of the F3 fraction through the florisil and collection, the florisil column was decoupled from the SEC column and further eluted with 50 ml of 10% diethylether in petroleum ether. This fraction ("F4") was concentrated and combined with F3 for GC/ECD; highly polar components were removed from the florisil column with methanol and archived ("F5").

2.D.2.c. Gas chromatography/electron capture detection (GC/ECD). Instrumental conditions: Level 1 extracts were solvent exchanged into hexane, spiked with 100 Ng/ml of decafluorobenzophenone (internal standard 1) and 165

ug/ml of octachloronaphthalene (internal standard 2), and subjected to capillary GC/ECD according to the instrumental conditions shown in Table 4.

Calibration and quantitation: Multi-level internal standard-based response curves for each component were established during calibration and verified daily during this analysis. Although these curves are substantially linear, a quadratic response equation was used to fit the calibration data and to quantitate sample components. A typical response curve is shown in Figure 6. A standard chromatogram labelled with the PCB isomerids quantitated in this study is shown in Figure 7.

To compensate for possible injection effects, quantitation for each compound was based on the two internal standards according to the following algorithm:

$$\text{amount} = \frac{(rt_i - rt_1)}{(rt_2 - rt_1)} amt_{i,1} + \frac{(rt_i - rt_2)}{(rt_2 - rt_1)} amt_{i,2}$$

where rti, rtl and rt2 are the retention times of the ith component of interest, internal standard 1 and internal standard 2, respectively; and amti,1 and amtl,2PV are the quantitated amounts of "i" based on internal standard 1 and 2, respectively. Compounds eluting before internal standard 1 or after internal standard 2 were based entirely on the closest single standard.

Data analysis: Raw chromatographic chart output and integrated response tables were manually inspected to verify proper peak integration, to identify merged components or other indications of interference, and to identify each component of interest, if present. Raw response areas for standard components and analytes were entered in an electronic spreadsheet program (Microsoft Excel run on a 512 K MacIntosh personal computer) for quantitation and reporting. Hand calculations were used to verify the accuracy of the final computations. Figure 8 shows the chromatogram of a typical Level 1 fish extract.

2.D.2.d. Selection of samples for Level 2 analysis. Samples for Level 2 analysis and for cooked replicate analysis were selected jointly with the Contracting Officer's Technical Representative, based on highest level concentrations per species. In some cases, alternative selections were used, due to limited amounts of sample remaining.

2.D.2.e. Sample preparation for Level 2 analysis. Final extracts (fractions F3 and F5 combined) were concentrated to 100 ul and fractionated by high performance liquid chromatography according to the instrumental conditions shown in Table 5. A semi-preparative scale (10 mm i.d. x 250mm, 5.0 um Amine-bonded normal phase, IBM Instruments, Inc.) column was used; injections were made from a 250 ul partially-filled loop. Detection was accomplished using tandem UV absorbance (254 nm, Waters Model 480) and fluorescence (265 nm excitation and 370 nm emission; Schoeffel Model FS970) spectrometers, each reporting to electronic integrators. Figure 9 shows a standard combined chromatogram. Instrument response to target PAH was calibrated prior to and following sample separations; analytical results from the preparative fractionations were computed using external standard response curves. Two fractions were collected for analysis: an early, low molecular weight PAH (FB) and chlorinated hydrocarbon fraction, and a late, high molecular weight PAH fraction (FD). These were concentrated to 10 and 50 ul, respectively, and

spiked with perdeuterated phenanthrene internal standard (110 and 150 ng/ul, respectively) for GC/MS analysis.

2.D.2.f. Gas Chromatography/Mass Spectrometry (GC/MS). Analysis by GC/MS was performed using a Finnigan 4023 system, containing a Hewlett Packard 5840B gas chromatograph equipped for capillary analysis with direct transfer of the column through the vacuum manifold into the ionizer of the MS. The instrumental conditions employed in the analyses are shown in Table 6; a standard reconstructed gas chromatogram is shown in Figure 10. All quantitation was based on internal standard; 1 ul injection volumes were used.

2.D.2.g. Gas Chromatography/Electron Capture Detection (GC/ECD). Samples of chlorinated hydrocarbon fractions (FB) were reanalyzed by GC/ECD using the prior conditions indicated in Table 4. The remaining sample was rediluted to 50 ul in methylene chloride and a 25 ul aliquot was then diluted to 200 ul in Hexane. An expanded standard containing additional pesticides was employed; this is depicted in Figure 11.

2.D.3. Quality assurance and quality control

2.D.3.a. Method validation. Method development/validation was conducted on 80 gram tissue samples from the following species: sablefish, squid, pacific cod, tom cod, rockfish, hake, starry flounder. With the exception of the last two species, tissue was pooled from several fish. Initial experiments compared mass extraction efficiency and spiked recovery compound extraction efficiency for several extraction methods using each of these species. Following the selection of the extraction protocol used throughout the remainder of the study (as specified in section 1.B.1), the tissue pools were carried through the stages of sample prefractionation individually, with evaluation of the recovery of target compounds and the degree of sample interference using GC/ECD. Spiked recoveries for the Level 1 target compounds for the sequence of sample preparation steps used for actual study samples is shown in Table 7.

2.D.3.b. Intralab QA/QC. Quality control for study samples consisted of: internal recovery compounds in each sample, instrumental quality control, and replicate analysis. The recovery compounds used represented the target classes of contaminants: pesticides, chlorinated hydrocarbons, PAH. Mean recoveries (standard error at 95% confidence) were: 2-chloronaphthalene, 80.3 (4.3%), o,p'DDE, 80.6 (1.8%). Instrumental quality control procedures consisted of: daily blanks and reference standards interspersed with study samples. Replicate analysis results are summarized in Table 8.

2.D.3.c. Interlab QA/QC. Aside from exchange of reference materials as described in section 2.A.2.e, interlab QC included participation in an international PCB interlaboratory comparison sponsored by ICES. These results have been published in NOAA's National Status and Trends Program/Quality Assurance Program for Marine Environmental Quality Measurements Newsletter, Winter, 1985 and are summarized in Table 15 of that report. In general, good comparability was seen between TOAC, NAF, and other NOAA contract laboratories. The laboratory also participated in the NOAA sponsored National Status and Trends Quality Assurance Program to measure PCB congeners in fish oil (Table 9). The laboratory number for TOAC was #3. The Trace Organics Analysis Center maintains accreditation in two programs requiring blind

performance samples: the National Institute for Occupational Safety and Health (NIOSH)/American Industrial Hygiene Association (AIHA) industrial hygiene analysis and the Centers for Disease Control (CDC) blood lead analysis. Concurrently with this study, the Trace Organics Center participated in an Environmental Protection Agency (EPA)/CDC Project under the Superfund program, which brought the TOAC under certain apsects of the EPA Contract Laboratory Program (CLP) quality assurance program (administered by EPA/Las Vegas) and included both blind performance samples and two on-site evaluations. The TOAC completed all of these programs in good standing, with superior performance records.

3. RESULTS

3.A. Interviews with Boating Anglers

From February through October 1985, 437 boating anglers were interviewed, with the majority of interviews (327, 75%) taking place at Commencement Bay and the remainder on Elliott Bay. The results of the interview data are summarized below.

3.A.1. Time, location and mode of activity

At both sites, fishing activity took place overwhelmingly on weekends (Table 10). Fishing activity peaked in the afternoons and evenings in the warmer summer months (Tables 11-13). By way of contrast, the shoreside anglers fished during similar hours of the day but became most active in the autumn, possibly because they were seeking squid, a species unreported by boating anglers.

3.A.2. Angler demographics

While the interviewees were nearly all males (Table 14), the many women who were observed fishing from boats with friends or relatives do not appear in our statistics unless they themselves were interviewed for their party, a relatively rare event. At both Elliott and Commencement Bays, boating anglers were clustered in the 19-39 year age groupings (Table 15). The boating anglers surveyed tended to be Caucasian, with small minority representation (Table 16).

About 90 percent of the boating anglers had 12 or more years of education (Table 17). Among boaters (Table 18) a large majority (69%) were employed. All of the boating anglers arrived by private auto. Most boaters fished close to home, with few (2%) coming from out of the state, and none from out of the country (Table 19).

All of the boating anglers were found to be fishing; none were clamming, crabbing or squidding. Few fished alone or with friends (Table 20); instead most fished in family groups of 2-4 people (Table 21). Fishing trips averaged 6.5 hours in duration (Table 22). Approximately 60% of the boaters fished successfully (Table 23). The boaters tended to be regular and frequent anglers (Tables 24 and 25), with most fishing weekly or more often. Boaters fished

predominantly for salmon, other species were much less frequently sought (Table 26).

3.A.3. Interview success

Negligible difficulties ensued due to language barriers or repeated interviews (Table 27). Among successful Elliott Bay boating anglers, about 11% would not allow inspection of the catch, compared to no refusals among Commencement Bay boaters (Table 28).

3.A.4. Fish caught

The boating anglers caught 1,379 animals or, expressed as mass, 1,246.2 kg of fish (Tables 29 and 30), for a grand mean of 4.7 kg or 5.2 individual fish per successful party. The catch was divided on average among four fisheaters per party (Table 31) and eaten approximately once every 14 days (Table 32). Over 90 percent ate only fillets (Table 33), and most fish were fried, barbecued, or baked (Table 34).

3.A.5. Ethnic differences

As mentioned earlier, ethnicity did not show important variation among any of the variables analyzed.

3.B. Trace Metals Analysis

3.B.1. Uncooked fish

The results of measurements of trace metal concentrations and wet/dry ratios in individual fish muscle samples together with the total weight and length of the fish are shown in Table 35. The values are grouped according to species and within each species they are arranged according to the site and location of the sample collection.

The results of Se, Ag, Pb, Cd, and Hg measurements (Table 35) show that the levels of these metals were almost comparable in all the samples analyzed. The concentration of Zn and Cu also showed comparable values among all the fish samples; however, the values of these two metals were much higher in squid than in the fish samples. The overall As concentration in some species was higher than the others. For example, rock sole, walleye pollock and Pacific cod showed generally higher As concentration than did starry flounder, rock fish, and sable fish. The highest As content was observed in two walleye pollock (#232, 11.4 mg/g and #231, 9.4 mg/g) caught off Brown's Point in Commencement Bay. However, a Pacific cod caught in Port Orchard (#260, 9.4 mg/g) also showed a high concentration of As. Overall, the data in Table 35 do not show any systematic pattern of high concentration of one or more metals in the samples collected from certain sites.

For comparison of the trace metal results in different species, the mean, range, and standard deviation of all the measurement are summarized in Table

36. For the purpose of mean calculation, the "less-than" values are considered as real values. For example, if the concentration of As was <0.001 mg/g, the value of 0.001 mg/g was used for the mean calculation. Also, the numerical values of "non-detectable" results were set to equal zero (ND=0) for the mean calculation.

The summary results in Table 36 show that mean concentration of Hg, Cd, Pb, and Se in all the groups fluctuated within a narrow range, and the mean values were almost comparable within the standard deviation of the measurements. The zinc and copper mean values of the different fish species also showed comparable values; however, squid showed clearly higher levels of Cu and Zn than did the fish samples. Rock sole showed almost twice as much arsenic as starry flounder, 3.3 +/- 0.7 mg/g and 1.5 +/- 0.7 mg/g, respectively. Pacific cod and walleye pollock, both migratory species, showed As values, 4.4 +/- 2.9 mg/g and 4.6 +/- 4.1 mg/g respectively, comparable with that of rock sole. The starry flounder caught at the mouth of the Puyallup River (Table 35) did not show higher As than did the Pacific cod or Pacific hake caught elsewhere.

3.B.2. Cooked fish

The concentrations of trace metals in fried fish (FF) and raw fish (RF) in nine samples are compared in Table 37. The concentration of trace metals in fried fish were normalized to the weight of raw fish, and then the ratios of metals in fried fish/raw fish were calculated. For the ratio calculations the less-than or more-than values were set to equal values and no ratio was calculated for ND values. The results show that the mean ratio of FF/RF for trace metals are: As = 0.8 ± 0.3; Se = 1.5 ± 0.8; Zn = 2.0 ± 0.9; Cu = 1.8 ± 0.86; Cd = 1.8 ± 1.8; Hg = 1.1 ± 0.95. This may be interpreted, regarding the standard deviation of the mean, to indicate that there was no substantial change in the concentration of these elements as a result of frying. The FF/RF ratio for As was 0.8 +/- 0.3 which shows "slight" decrease in the concentration of As as a result of frying. The lower values of some metals, such as As and Hg, in fried fish may have been due to the presence of volatile metal compounds (methylated forms of As and Hg) that were lost from the tissue during frying of the samples. On the other hand, the FF/RF mean ratios for Ag and Pb were 10.1 ± 6.8 and 17.4 ± 25.8, respectively. This indicates contamination of fish samples by Ag and Pb as a result of frying.

3.B.3. Speciation

The concentrations of inorganic (INA), monomethylated (MMA) and dimethylated (DMA) arsenic measured in the raw and fried fish samples together with corresponding values for reference materials are shown in Table 38. For comparison, the sum of concentrations of the three As species together with the total As measured in the same sample by NAA are also given in this table. The results show that only a small fraction of As (< 10%) can be measured by this technique in fish tissue, including that in the EPA reference fish sample. In the NBS standard (orchard leaves) about 52% of As is measured as INA. The only comparable values for total As versus the sum of the As species were found in the NBS standard "bovine liver." It should be noted, however, that the concentrations of some trace elements (including As) in the NBS "bovine liver" standard are not certified. This is due to the fact that the

measurements are based on the results of a non-reference method and are included for information only, or because they were not determined by two or more independent methods at the NBS. Since the concentration of As in this standard is not a certified value, no conclusion can be drawn from this measurement.

To determine whether the remaining As in the samples was present in the form of higher molecular weight compounds and/or whether it was present due to incomplete digestion of the samples, an oxidative digestion of the samples was made using a mixture of HNO3/HClO4 acids. The results of As species and the total As concentration measured by three different methods are shown in Table 39. These results show that a single HNO3/HClO4 digestion was sufficient to recover As completely (as quantified by NAA) from the orchard leaves standard. The recovery for the EPA fish sample was about 62% of that quantified by NAA and for the rest of the samples ranged from 18% to 78%. The results show that the As compounds in fish are in much more complex form than are those in the standard reference material and that they cannot be as readily recovered as those in the reference material. However, it should be noted that repeated digestion of the fish samples with HNO3/HClO4 will eventually lead to complete recovery of the As in the samples. Comparison of the sum of As species in fried and raw fish showed the value of all three As species to increase as a result of the frying process.

With one exception (fish #276), it seems that most of the As in fish tissue is in the form of naturally occurring high molecular weight organic compounds. This can be quantified as the difference between the total arsenic measured by NAA and the sum of arsenic species (high molecular weight organic compounds of arsenic = total arsenic measured by NAA - sum of species). By selective digestions and detailed separation methods it should be possible to identify and quantify these compounds.

3.C. Trace Organics Analysis

3.C.1. Sample preparation

Extracted residue weights and other sample characteristics for Level 1 fish are summarized in Appendix D. Because of limitations of field sampling, it was necessary to reduce the sample mass analyzed from the desired 20 grams to 10 grams (with a total mass analyzed being approximately 8 grams).

3.C.2. Level 1 results

Year 1 survey results are shown in Table 40. The Level 1 target compounds detected in Year 2 are presented in Table 41.

3.C.2.a. Hexachlorobutadiene

Spiked recovery of this compound in eight species averaged 140 +/- 35%. This result, plus the higher variability seen in replicate samples suggest that interference may have been significant in low level samples. The precision of instrumental analysis was 1.9% of the Relative Standard Deviation

(RSD = S/X x 100) across the calibrated range, with an R square value of 0.9999 (for quadratic response function).

This contaminant has been reported previously in Commencement Bay sediment and fish samples (Malins et al., 1982a and b). The Level 1 results detected hexachlorobutadiene in low levels (0.8 to 1.8 ppb) in five samples: hake, starry flounder and rockfish from Commencement Bay, and one hake and one rock sole each taken at Point Jefferson and Elliott Bay, respectively. The rock sole result was somewhat unexpected, since this is considered a localized species; however, the very low levels seen make this identification questionable. In the case of the hake sample cooked and reanalyzed, background interference with this compound was evident. In general, then, the results were consistent with previous reports and did not suggest that levels higher than 10 ppb are to be expected.

3.C.2.b. Hexachlorobenzene. Spiked recovery of this compound in eight species average 106 +/- 18%. In the five replicate raw fish analyses where HCB was detected, good agreement between analyses was seen in three instances, while in two cases (0.7 and 0.8 ppb) the replicate level was below detection limit. In actual fish samples, HCB was found above the detection limit in 21 of 67 samples, with a range and average concentration of 0.5 - 8.0, and 1.5 ppb, respectively. The levels seen are in general agreement with previous results.

3.C.2.c. p,p'-DDE. Spiked recovery for eight species averaged 93.4 +/- 18%. Replicate analysis of seven fish having detectable DDE showed good agreement in five cases, with two examples having less than detection limit results in one replicate. A closely related compound, o,p'-DDE was used as an intra-assay recovery standard, and showed average overall recovery of 80.6% with a standard error of 1.8%. DDE was detected in 59 of 67 fish samples, with a range and average amount of 0.93 - 15.6, and 3.6 ppb, respectively. This range of values corresponds reasonably well with previous studies.

3.C.2.d. o,p'-DDD (and o,p'DDT). These compounds are not expected to occur to any significant extent in environmental samples, as the commercial DDT used and introduced into the environment was largely the p,p' isomer. The o,p'-DDT isomer co-elutes under the GC conditions used with the p,p' isomer of DDT, so these agents are reported together. However, it is reasonable to infer that all of the detected pesticide is contributed from the p,p'-DDT. o,p'-DDD was detected in 10 of 67 samples, with a range and average amount of 0.75 - 5.7, and 1.8 ppb, respectively. None of these low level "hits" were confirmed in the GC/MS analysis. Given the method detection limit of approximately 0.7 - 1.0 ppb for o,p'-DDD, the few examples of its detection in these samples were probably analytical artifacts.

3.C.2.e. p,p'-DDD. Spiked recovery for eight species averaged 79.5% (85.2% with the exclusion of one questionable recovery result). Replicate analysis of seven fish samples having detectable p,p'-DDD showed good agreement in two cases and less than detectable results in replicate samples in five cases (all were within 3 ppb of the method detection limit for this compound). In actual samples, p,p'-DDD was detected in 35 of 67 cases, with a range and average amount of 1.7 - 7.8 and 2.8 ppb, respectively. These levels are consistent with previous results and with the levels of p,p'-DDE reported.

3.C.2.f. p,p'-DDT. Spiked recovery of this compound in eight species of fish averaged 112% recovery. Of the eight fish samples run in replicate, this compound was detected in only one (non-replicated) instance. In actual samples, p,p'-DDT was found in 17 of 67 examples, with a range and average amount of 1.8 - 7.5 and 2.9 ppb, respectively. These levels are close to the method detection limit, but are consistent with previous reports and with the levels of p,p'-DDE and p,p'-DDD seen in these samples.

3.C.2.g. PCBs. Spiked recovery of PCBs was evaluated using a mixture of seven isomerids (dichloro- through octachlorobiphenyl). This task was complicated by the significant background of environmental PCB compounds in the samples; correction for unspiked background yielded an average recovery for eight species of fish of 115%. Replicate fish analysis showed agreement that averaged 4.4% RSD. Analysis of actual samples gave detectable PCB compounds in 67 of 67 cases, with a range and average sum of 13 - 456, 84.3 ppb, respectively. Estimation of total Aroclor level based on these results gave a range and average of 19 - 684, 125 ppb, respectively. In general, these results are in agreement with previous reports. The specific method used for computing total PCB concentration from the detected amounts of specific isomerid components may be a key factor in the amount determined, however, and will be discussed in Appendix E.

3.C.3. The effect of cooking on contaminant levels

The raw fish versus cooked fish assay results are shown in Table 42. These results are presented in two ways: as raw levels and as levels corrected for recovery of the spiked o,p'-DDE. The cooked fish samples in several cases would not permit quantitation by the standard Level 1 protocol, due to sample or oil matrix interference with the second chromatography standard (octachloronaphthalene), so external standard response was used for these samples. Because of the possibly reduced comparability of these samples, the recovery-corrected table is provided. In general, for all of the compounds considered, reductions in tissue levels of 30% or more were seen after cooking. One consistent exception to this trend was the tomcod experiment, where apparent increases were seen. These increases were not large (a few ppb) and might be an effect of cooking on the fish matrix, or some analytical artifact. Without further replication, this result should be considered anomalous. The other samples display expected reductions as predicted by previous studies, and as would be expected for contaminants associated with lipid components of tissue that are rendered out of the fish during cooking. The overall conclusion from this experiment is that wet tissue analysis of contaminant loading represents highest level contamination, which would decrease upon frying.

No detectable levels of the analytes were found in blank cooking oil analyses; however, unresolved oil components did appear in the high temperature region of the chromatograms after the chlorinated biphenyl retention time.

3.C.4. Level 2 results

3.C.4.a. Polynuclear aromatic hydrocarbons. Polynuclear aromatic hydrocarbons were detected in two assays: HPLC/uv absorbance/fluorescence and

GC/MS. The results for both are presented in Table 43. In the present study, these methods should be viewed more as complementary than comparable, since fluorescence and absorbance methods provided more sensitive detection of the key 5-ring PAH compounds than did GC/MS, while the lighter PAH compounds were more sensitively detected by GC/MS. Given the greater specificity of the GC/MS analysis, the GC/MS result should be relied upon in such cases of disagreement. Recovery for PAH compounds was estimated by use of perdeuterated d12-perylene spiked into raw fish samples prior to extraction and quantitated in HPLC-fractionated fish using GC/MS. The average recovery seen was 70.7%. The levels of PAH seen ranged from trace levels (<1 ppb) to 32 ppb; but few of the levels seen could be confirmed by GC/MS. The very low levels of PAH seen in tissue are consistent with several previous studies of PAH metabolism in fish and with field studies of fish tissue taken in what is currently viewed as the most severe example of PAH contamination in Puget Sound, Eagle Harbor (Malins et al., 1985). Based on the results shown in Table 43 and in the previous studies cited, individual PAH carcinogens in edible tissue are clearly expected to fall below 10 ppb, regardless of sampling site.

3.C.4.b. Pesticides/PCBs. GC/MS analysis of Level 2 fish confirmed the presence of PCBs and chloronaphthalene (spiked QC compound), but failed to confirm the lower level analytes seen in Level 1 analysis. No other chlorinated xeno biotic agents were identified from these samples, with an estimated detection threshhold of 1-10 ppb. Re-analysis of the Level 2 samples by GC/ECD failed to detect any of the following pesticides (above an estimated detection limit of 1 ppb wet weight): [alpha, beta, gamma, delta]-BHC; aldrin, heptachlor epoxide, gamma-chlordane, dieldrin, endrin, beta-endosulfan, endrin aldehyde, endosulfan sulfate, methoxychlor and mirex. A chromatographic peak at the correct retention time for heptachlor was observed in several samples in amounts equivalent to 1.6 to 11.5 ppb. None of these results were confirmable by mass spectrometry, although the highest samples were above the nominal instrument detection limit. It is currently believed that this peak is an interferent.

3.D. Estimation of Contaminant Intake

Contaminant levels measured in Year 1 and Year 2 were quite low for most elements and compounds studied. For the purpose of this report, contaminant intake was estimated only for PCBs and for arsenic because they were the only compounds present in concentrations high enough to indicate the potential for excess cancer risk when tested with the risk assessment model developed for U.S. EPA Region 10 (Tetra Tech, Inc., 1986). Readers wishing to estimate dose values for the eight metals and the more than 20 organic compounds measured can do so from the data contained in this report.

3.D.1. Analysis of arsenic data

One hundred and forty fish specimens were analyzed for arsenic content. The species of fish were grouped into ten categories as detailed in Table 44. The species for which there were the most data included rock sole (28 samples) followed by English and flathead sole (22 samples). Other species for which there were substantial data were sablefish, rock fish and Pacific cod. There were fourteen squid samples. All of the samples came from nine locations

(Table 44). Sample sizes were largest at the Elliott Bay and Edmonds sites, with 38 and 36 samples, respectively. Few samples were available from Bremerton (2), Agate Pass (4), Port Orchard (5) or off Point Jefferson (5).

Table 45 lists the median arsenic levels by species and year of study. The median arsenic levels from Year 1 to Year 2 were comparable and similar. As determined by analysis of variance, there was significant variation in arsenic level among species, with the highest median level occurring in squid (median value of 5.00 ppm). The species with the next highest median levels were English/flathead sole and Pacific cod, 4.05 ppm and 3.60 ppm, respectively. The lowest level of arsenic was observed in tomcod with a median level of 1.10 ppm. This species was followed closely by sablefish with a level of 1.30 ppm. Figure 12 displays the individual arsenic levels by species. Single observations are represented by an asterisk; multiple observations are represented by the number of fish with that value. The graph indicates that relatively little variability in arsenic levels occurred among starry flounder with 8 values all less than 5 ppm. In contrast, English and flathead sole specimens exhibited considerable variability with 3 values exceeding 20 ppm and 12 values falling below 5 ppm. Rock sole specimens showed the same range of variability as did English and flathead sole.

In Table 46 median arsenic values are listed by site and by year of study regardless of species. During Year 1, the highest levels were associated with Commencement Bay and Sinclair Inlet with median values of 14.03 ppm and 5.90 ppm, respectively. The pattern during the second year differed, with the highest median value being 4.0 ppm at the Port Orchard site. It should be noted, however, that no specimens were obtained from this site during Year 1.

When the logarithms of the arsenic concentrations were analyzed by species, site, and year, the following conclusions were reached: there was significant variability in arsenic levels among species and among sites. As before, squid tended to have the highest arsenic levels, starry flounder the lowest. In terms of sites, Commencement Bay had the highest levels, followed closely by Sinclair Inlet. The lowest levels were found in Bremerton, but it should be noted that only two specimens were collected at this site. The Elliott Bay, Edmonds and Point Madison sites had the second lowest levels. Finally, after adjusting for species and site effects there was no significant difference in Year 1 and Year 2 levels.

Figure 13 displays arsenic concentration by site. The symbols are the same as in Figure 12. The graph illustrates that fish from Commencement Bay and Sinclair Inlet had the highest levels of arsenic as well as many low levels. The significance of the single high value in Edmonds is not known. Except for perhaps three or four extreme values at Port Orchard, Elliott Bay and Edmonds, the sites fall into two categories: Commencement Bay and Sinclair Inlet versus all other sites.

3.D.2. Analysis of PCB data.

One hundred and nine specimens were analyzed for PCBs. Table 44 lists the distribution of the samples by species and location. There was a reasonably equal distribution in the number of specimens by species. The samples were distributed relatively more heterogeneously among sites with 30 and 24 samples from Elliott Bay and Edmonds, respectively. Thus these two

sites contribute more than 50% of the samples for the analyses of PCBs.

In Table 47, median PCB values are listed by species and by year of study. The median PCB level in Year 1 was 46.5 ppb, the median level in Year 2 was 91.0 ppb. The overall median level (pooling Year 1 and Year 2 data) was 81.0 ppb.

Figure 14 presents PCB levels (ppb) by species. All but three values are below 400 ppb. Two of the high values (>400 ppb) are from samples of Pacific cod, one is from a sample of starry flounder. Table 48 lists the median PCB values by site and year of study. Figure 15 displays the PCB levels by site. The three specimens with PCB values above 400 ppb were collected at Sinclair Inlet, Port Orchard and Edmonds.

A multiple regression analysis of log (PCB) levels by species, site and year was carried out (Table 49). The sample of walleye pollock had significantly lower PCB levels when compared to other species. This is confirmed by the data from Table 47 indicating a median PCB level of 32.0 ppb in walleye pollock, compared to the overall median of 81.0 ppb for the entire sample. All other species, locations and years did not differ significantly.

Figure 16 displays a scattergram of PCB levels in fish specimens (ppb) versus fish length (cm). Single observations are represented by the symbol "P," multiple observations by the number of specimens with that value. The correlation between PCB levels and fish length was not statistically significant.

3.D.3. Estimates of Intake of Arsenic and PCBs

The estimated daily dose of arsenic and PCBs depends upon the estimate of the amount of fish eaten and the estimate of the concentrations of arsenic and PCBs in the fish. The estimate of the amount of recreationally caught fish that is consumed per person per day was subject to many sources of variability such as size of catch, number of people eating the catch, the amount of fish eaten per person and the number of days over which the fish is eaten (Tables 30-32). The intake of arsenic and PCBs from fish caught in this study was calculated as follows.

Estimated consumption rates for shoreside anglers were used (see Table 63 in Landolt et al., 1985). These consumption rates were higher than those estimated for boating anglers (Table 50), they showed less variability than did those for boating anglers and they included species such as squid that were not caught by boating anglers. The estimates of arsenic and PCB concentrations for Years 1 and 2 were pooled since there was no statistically significant difference between the values. Salmon were excluded since we did not actually analyze salmon tissue in this study.

Upper limits of percentiles were used in the estimation of intake. The fifth, fiftieth and ninety-fifth percentiles for arsenic tissue concentrations were assumed to be 1 ppm, 3 ppm and 20 ppm, respectively. Tables 51 and 52 indicate that these assumed values are somewhat higher than the estimates obtained from the data on site and species. However, the assumed ninety-fifth percentile (20 ppm) is approximately equal to the observed ninety-fifth percentiles for squid and English/flathead sole (Table 51) and the ninety-

fifth percentile of specimens from Commencement Bay (Table 52). By a similar argument, the fifth, fiftieth and ninety-fifth percentiles for PCBs were calculated to be 24 ppb, 81 ppb and 315 ppb, respectively.

Using the above ranges of values for arsenic concentration, the estimated arsenic intake for four species of fish was calculated (Table 53). The highest exposure was associated with squid (because it had the highest consumption rate). For squid the median dose was estimated to be 117 ug/day and the ninety-fifth percentile dose to be 780 ug/day.

For PCBs similar calculations for four species are summarized in Table 54. Differences among the species were again due to differences in consumption rates since the statistical analyses indicated little difference in PCB levels among species or sites. Thus, for squid the median PCB dose was estimated to be 3.2 ug/day (assuming 39 grams of consumption per person). The ninety-fifth percentile was 12.0 ug/day for squid. Values for other species were lower due to lower consumption rates. Dose estimates relate to the fishing period (season) for each species and should not be automatically extrapolated over the course of a year.

4. DISCUSSION

4.A. Comparison of Shoreside and Boating Anglers

The purpose of this two-year study was to gain insight into the fishing habits and demographic characteristics of urban anglers with the ultimate goal of estimating their potential for exposure to contaminants as a consequence of consuming recreationally caught fish from Puget Sound. The study did not attempt to assess risk, but rather to estimate catch of fish and consumption of fish and contaminants.

The average shoreside angler was an employed (57.2%) male (91.6%) with 12 or more years of education (76.6%). Most were Caucasian (68.7%); however, black (8.1%) and Asian (20.9%) fishermen were regularly encountered. The anglers ranged widely in age with a large percentage falling in the 17-34 year (50.1%) and 35-64 year (35.2%) age brackets. Shoreside anglers fished almost as frequently on weekdays (48.8%) as on weekends (51.2%), and were most active between the hours of 6:00 p.m. and midnight (56.2%). Although anglers fished year round, activity peaked in the Autumn (41.8%). More than half the anglers caught nothing (51.7%). Among those who did catch fish, most (70.7%) landed fewer than five per trip. The five most commonly caught species (based on numbers of organisms) were market squid (Loligo opalescens, 39% of catch), Pacific hake (Merluccius productus, 10% of catch), Pacific tomcod (Microgadus proximus, 5% of catch), walleye pollock (Theragra chalcogramma, 4.9% of catch), and Pacific cod (Gadus macrocephalus, 3.3% of catch). Overwhelmingly, the fishermen planned to consume only the fillet (93.2%). The most common modes of preparation were frying (53.2%), baking (16.8%) and boiling (11.1%).

The average boating angler was an employed (68.8%) male (95.9%) with 12 or more years of education (91.4%). Most were Caucasian (86.1%); however, black (3.8%) and Asian (8.3%) fishermen were encountered regularly. The anglers ranged widely in age, with a large percentage falling in the 19-39 year (59.9%) and 40-59 year (27.8%) age brackets. Boating anglers fished

predominantly on weekends (95.9%) and were most active between the hours of noon to 6:00 p.m. (66.8%). Although fishing activity occurred year-round, it peaked during the Summer (56.8%). Only 37.1% of the anglers caught no fish. Among those catching fish, most (72%) landed fewer than five per trip. The five most commonly caught species (based on numbers of organisms) were walleye pollock (29.8% of catch), Pacific cod (5.5% of catch), flatfish (mixed species, 12.7% of catch), rockfish (mixed species, 7.5% of catch), and coho salmon (Oncorhynchus kisutch, 7.0% of catch). Use of the term "mixed species" indicates that the fish had already been skinned and filleted at the time the interview was conducted, and that they could not be identified to species. The vast majority of fishermen (98.9%) planned to eat only the fillets. The most common methods of preparation were frying (41.5%), barbecuing (27.3%) and baking (18%).

4.B. Contamination by Trace Metals - Comparison of Year 1 and Year 2 Results

The levels of arsenic, cadmium and lead measured in Year 1 and Year 2 were comparable. Several samples that were analyzed in Year 1 were reanalyzed in Year 2 (Table 55). The data show generally good agreement.

4.C. Contamination by Trace Organics - Comparison of Year 1 and Year 2 Results

Only PCBs were measured in both years. In order to evaluate the analytical comparability of the Year 1 protocol and the Year 2 protocol, several Year 1 assays were repeated in Year 2. These are summarized in Table 56. Although the isomerid standards used in Year 2 were of an entirely different origin than those used in Year 1, the data were very similar. From these data, we conclude that no major method difference existed between Year 1 and Year 2 as far as sample preparation or detection/quantitation of PCB isomerids is concerned. There may be a small method difference in total PCB quantitation, due to differences in quantitation method between years, however, these differences were not consistent between years and suggest random variation rather than a method bias.

In Year 1, quantitation was based on a mixed Aroclor standard, containing Aroclor 1248, 1254, and 1260 in proportions 1:2:6 by mass. This mixture was felt to be the best approximation of isomerid distribution seen in actual samples. In Year 2, standards for 51 isomerids became available, and were used for quantitation. These standards represent the majority of the electron capture response for the Aroclor mixtures seen in these samples; for maximum comparability between years, the total isomerid results were scaled up to the weighted average of a 1:2:6 mixture of Aroclors as was assumed in Year 1. This represents an estimate of Aroclor content as 1.5 times the sum of the isomerids measured in each sample. Year 1 quantitation seems to have a lower ratio of isomerid to total Aroclor, perhaps resulting from different Aroclor standards. Alternative methods of estimating Aroclor concentration are presented in Appendix E. Based on both this chemical analysis comparison and statistical analysis of the Year 1 versus Year 2 data sets, we conclude that no major method-based differences are demonstrated in the data, and that data from both years may be pooled for the purpose of evaluation of trends in species, geography, and for dose evaluation.

4.D. Comparison of Contamination Data With Data From Previous Puget Sound Studies

Trace Metals -- In general, the concentrations of metals detected in this study closely resembled levels measured in fish during previous Puget Sound studies (Table 57). Mercury levels tended to be lower than those previously reported (Table 58); ranges in arsenic concentrations were found to be similar to those reported in earlier studies, with a tendency for the highest arsenic concentrations to be from fish caught in Commencement Bay (Table 59).

Trace Organics -- No major differences were noted between the results from this study and those reported previously in Puget Sound (Table 60). Previously unreported species/location contaminant levels appear from our results to be generally consistent with measurements taken elsewhere in Puget Sound, or in other species.

4.E. Comparison of Contaminant Data with Data From Other Geographic Regions

Trace Metals -- Table 61 shows the levels of arsenic found in other geographic areas. Fish muscle concentrations of lead, mercury, and cadmium in the tissues analyzed in this study were low and did not exceed the US FDA seafood tissue standards of 7.0 ppm, 0.5 ppm, and 1.0 ppm respectively (U.S.F.D.A., 1982). There are no FDA standards for arsenic.

Trace Organics -- Using PCBs as a marker one can see the level of trace organic contaminants that have been found in other regions of the United States (Table 62). The levels found in the present study are compatible with those found in other areas.

4.F. Contaminant Doses

With respect to two major pollutants, which we selected as markers (arsenic and PCB), the following conclusions and summary can be reached:

Arsenic - Arsenic levels varied significantly by species of fish and location of catch. Species with the highest levels of arsenic were squid, and English sole with median values at or near 5 ppm. Species with the lowest values were tomcod and sablefish. Locations appeared to fall into two categories: First, a high category consisting of Commencement Bay and Sinclair Inlet with median arsenic values around 6 ppm. Second, a low category consisting of all other locations with median arsenic values around 2 or 3 ppm. Conservative estimates (i.e., higher than is really the case) of the 5th, 50th and 95th percentile levels of arsenic concentration (across all species and sites) yielded values of 1 ppm, 3 ppm, and 20 ppm, respectively. Assuming a daily consumption rate of 11 grams of fish, this translated into doses of 11, 33 and 200 ug per day for the 5th, 50th and 95th percentile, respectively. These values may be compared with average daily intake estimates of the U.S. Food and Drug Administration for adult total diet samples (Table 63).

PCB - PCB levels were very homogeneous, demonstrating little variation in species or location of catch. In the total sample of specimens analyzed the 5th, 50th and 95th percentiles were 24 ppb, 81 ppb and 315 ppb, respectively. Assuming a consumption rate of 11 grams of fish, these concentrations are

equivalent to doses of 0.3 ug, 0.9 ug and 3.5 ug per day at the 5th, 50th and 95th percentile, respectively.

All of the fish analyzed in the present study contained PCB levels below the action limit set by the U.S. Food and Drug Adminstration (2000 ppb).

Since 1982, the FDA has measured PCB concentrations in specific commercial fish products that are consumed by people. The four fish food items used are: cod/haddock fillets, canned tuna, fish sticks, and fresh/frozen shrimp. Cod/haddock fillets had levels of 14 ppb. Tuna levels were reported to be 10 ppb. These levels are comparable to the 5th percentile (24 ppb) level measured in the present study.

Since 1984, there have been 7 market-basket surveys in which no food items contained detectable levels of PCBs.

4.G. Alternate Routes of Exposure to Contaminants in Puget Sound

While consumption of seafood is the primary means by which persons are likely to encounter the pollutants contained within Puget Sound, other routes are possible. One route is percutaneous adsorption through activities such as swimming, wading, digging for shellfish, or scuba diving. Another route is accidental ingestion of water or sediments which might accompany the aforementioned activities. Because of the low water temperatures in Puget Sound, swimming and wading are restricted to brief periods and are not likely to be a major source of exposure. Similarly, scuba diving is generally a recreational pursuit that is undertaken rather infrequently. In addition, because of the water temperature, only small portions of the diver's skin are exposed to the water or sediment. Another possible route of exposure might be through inhalation of contaminants that have been evaporated or aerosolized through wind or wave action. This pathway is unlikely to be a major source of contaminant exposure.

4.H. Routes of Exposure Unrelated to Puget Sound

The possible routes by which persons might be exposed to metals and organic compounds are as diverse as the number of elements and compounds measured. One might, for example, inhale lead from automobile exhaust, ingest benzo(a) pyrene through consumption of charcoal grilled meat, or imbibe pesticides in ground water. For the purpose of this section, we will limit our discussion to the two contaminants used as indicators in previous sections of this report: arsenic and PCBs.

Arsenic -- Arsenic can be found in various chemical forms, with each form having unique properties in the environment. The element is ubiquitous in water and is eaten or drunk by all animals. Plants can accumulate arsenic that is applied as fertilizer or deposited from smelter fallout (trivalent forms). Since the trivalent forms are more toxic than the pentavalent forms, these compounds are a major concern (Doull, 1980). High levels of arsenic have been reported in plants which have been grown in contaminated soils (NAS, 1977). FDA Market Basket surveys from 1985 indicate that arsenic (as arsenic trioxide) in the U.S. food diet ranged from 0 to 0.69 ppm with the meat, fish, and poultry group having the highest values. Of the 61.5 ppm average daily

intake of arsenic trioxide, 81% is contributed from the fish meat and poultry group. Fish and shellfish products contain the highest natural arsenic (pentavalent forms) concentrations of all organisms.

The extent of human exposure to man-made species of arsenic via air and water is strongly dependent on the proximity to contamination sources, i.e., smelters. A good example of this situation is the high arsenic concentrations found in the soils, particulates, and waters surrounding the ASARCO smelter in Tacoma, Washington (NAS, 1977). Since natural forms of arsenic are ubiquitous in soils and waters, potential for exposure to humans is almost unavoidable. Many forms of arsenic have been found to be associated with airborne particulates (NAS, 1977).

Any industry which purifies or uses arsenic stands the risk of exposing workers to arsenic. Arsenic compounds are prevalent in smelting operations, the ceramics and glass industries, herbicide formulations, and many other industrial chemicals.

PCBs -- The three major sources of PCB contamination in foodstuffs are fish, primarily those caught in lakes and streams, industrial accidents that leak PCBs directly on foodstuffs, and leakage of PCBs from packaging material. Since the 1977 ban on PCB use in open systems the chances of accidental exposure to extremely high concentrations has diminished.

From 1969 to 1975 PCBs were found in milk, eggs, cheese, animal feeds, processed fruits, and baby foods. Since 1975, PCB levels have declined significantly and have been detected in less than 1% of all food categories except fish (Cordle et al., 1978).

Extremely high concentrations of PCBs have been found in rice oils of Japan and Taiwan as a result of accidental PCB leakage into the oil.

Human exposure to PCBs through the air and water is believed to be nominal (Cordle et al., 1978). Since PCBs are not very soluble in water, high concentrations in water do not occur and thus do not pose a serious health hazard to humans. PCBs enter the atmosphere through various mechanisms and are capable of being transported globally. Ambient air concentrations of PCBs are relatively low and the levels accumulated through respiration are thought to be minimal.

Marine electricians, machinists, capacitor and transformer workers, laboratory workers and many workers in other occupations are exposed to PCB concentrations which are much higher than those encountered in other occupations (Table 64). Because use of PCBs has been banned, the number of people exposed has decreased.

4.I. Comparison of this Study with Other Catch and Consumption Studies

Two major studies of recreational angling in marine waters have been conducted outside of Puget Sound. One was conducted by Puffer et al. (1981) in Los Angeles Harbor, the other by Heatwole and West (1984) in the New York Bight.

In the Los Angeles study, 1,059 shoreside anglers were interviewed over a

one-year period. The average angler was an employed Caucasian male aged 18-40 years old. On average, the anglers fished once a week and most planned to consume their catch. The average consumption rate was 37 g/person/day (Table 65). Based upon previously recorded data, the median daily consumption rate for PCBs was below the permissable FDA guideline of 1 ug/kg/day.

In the New York Harbor study, 571 shoreside anglers were interviewed. The average angler was an employed, Caucasian male in the 21-40 year age class. Relatively few anglers (approximately 32%) kept their catch and even fewer (21%) planned to consume it. Consumption rates and contaminant levels were not calculated.

5. CONCLUSIONS (Years 1 and 2)

5.A. Catch and Consumption

The species most commonly consumed (g/person/day) by shoreside anglers were squid (39 g); sablefish (30 g); Pacific cod (27 g), Pacific hake (20 g); starry flounder (18 g); walleye pollock (16 g); tomcod and English sole (11 g). These rates apply only for the season during which each species is caught. The mean consumption rate for combined species was 11 grams/person/day.

The quantities of fish flesh consumed by shoreside anglers varied by embayment and species. The across-species mean consumption rates ranged from 14 g/person/day at Edmonds to 8 g/person/day at Commencement Bay. Consumption rates for individual species varied by embayment by a factor of two.

The preferred portion for consumption by shoreside anglers was either skinned or unskinned fillet, with >80% preference at all sites and for all ethnic subgroups. The skinned fillet was preferred to the unskinned fillet by approximately 4 to 1.

The preferred method of cooking used by shoreside anglers was frying, followed by baking and boiling. This ranking applied to all ethnic subgroups, but the proportion of each group that preferred frying varied from 72% (Black anglers) to 44% (Asian anglers).

Boating anglers were less cooperative than shoreside anglers. Only 83% consented to be interviewed, while more than 95% of the shoreside anglers participated in the study.

Boating anglers had higher average catch than did shoreside anglers. Salmon (coho and king) accounted for 62% of the total catch (by weight). Walleye pollock, Pacific cod and ling cod accounted for an additional 16%. No squid were reported as sought or taken by boating anglers.

Boating anglers preferred skinned fillet (>92%) and unskinned fillet (>4%) to other tissues, with preferred modes of preparation being frying, barbecuing and baking.

5.B. Contaminant Concentrations

Raw Fish -- Mean tissue concentrations of the elements Hg, Cd, Pb and Se were similar among species, nearly within the measurement uncertainty. The overall ranges for those elements were: Hg = 0.001-0.090; Cd = 0.001-0.120; Pb = 0.001-0.012; Se = 0-0.3 (all values in ppm wet wt).

The tissue concentrations of Cu and Zn were similar for all species, except squid (mean values for copper ranged from 0.25 to 0.40 ppm for all fish compared to 3.3 ppm for squid; mean zinc values for all fish ranged from 2.8 - 5.1 ppm while the zinc mean for squid was 13.4 ppm wwt).

Arsenic levels ranged between 0.5 and 15.9 ppm for individual fish, with species means varying as follows: squid (5.7 ppm); walleye pollock (4.6 ppm); Pacific cod (4.4 ppm); rock sole (3.3 ppm) and starry flounder, rockfish, sablefish, pacific hake and tomcod (all $\leq$ 2.0 ppm wet wt).

Among the organic contaminants sought, the frequency of detection and mean levels were: PCBs (100%; 84.3 ppb); pp'-DDE (88%; 3.5 ppb); p,p'-DDD (52%; 2.8 ppb); hexachlorobenzene (31%; 1.5 ppb); p,p'-DDT- (25%; 2.9 ppb); hexachloro-1,3-butadiene (8%; <1 ppb).

Examination of a subset of 10 samples having the highest levels of PCBs and DDE disclosed near or less than detection limit levels of: α, β, γ, and δ-BHC; aldrin; heptachlor epoxide; chlordane; dieldrin; endrin; β-endosulfan, endrin aldehyde, endosulfan sulfate; methoxychlor; mirex; fluorene (all not detected); naphthalene (<0.5ppb); methyl naphthalenes (<0.5ppb); dimethyl naphthalene (<0.5ppb); acenaphthalene (<0.5ppb); phenanthrene (<8ppb); anthracene (<0.5ppb); methylphenanthrene (<0.5ppb); fluoranthene (<32ppb); pyrene (<25ppb); benz(a)anthracene (<8ppb); chrysene (<1.3ppb); benzo(e)pyrene (<3.3ppb); benzo(a)pyrene (<12ppb); dibenz(a,b)anthracene (<13ppb).

Cooked Fish -- Cooking (frying in a teflon-coated pan) was found to reduce levels of PCBs and other organic contaminants by 50 - >90%, to produce slight or no reductions in arsenic level, to increase concentrations of copper, cadmium, mercury, zinc and selenium slightly (within a factor of two) and to increase the concentrations of silver and lead by about an order of magnitude.

The effects of cooking are attributed to volatile losses from the sample for those agents showing reductions, versus contamination from oil, atmosphere or utensils for agents showing increases.

5.C. Dose Estimation

Calculation of arsenic concentration by species and site at the 5th, 50th, and 95th percentile produced tissue concentrations of 0.6, 2.6, and 16.4 ppm, respectively.

Merging these concentrations with consumption rates by individual and combined species produced doses at the 5th, 50th, and 95th percentiles of 11, 33 and 220 ug/person-day, respectively.

Similar methods applied to PCB levels produced 5th, 50th and 95th percentile tissue concentrations (across species) of 24, 81, and 315 ppb, respectively.

For merged-species consumption rates, this produced 5th, 50th and 95th percentile dose estimates of 0.3, 0.9 and 3.5 ug/person-day, respectively.

6. RECOMMENDATIONS

Other dietary routes of exposure to Puget Sound contamination are possible. Bivalves (clams and mussels) and crab in particular may be contaminated by local environmental pollution. Studies currently underway involving chemical analyses of clams, kelp and salmon will provide needed additional information.

An independent assessment method for catch and consumption to verify the information provided by anglers is needed, since some of the consumption rates (30 or 40 g/person-day) seem to be high compared to those found in other studies (Versar Inc., 1985).

An ongoing assessment program for measuring PCBs in resident salmon would probably be useful to establish time trends clearly.

The nature of arsenic found in fish and squid needs further characterization. Because of the differences between human digestion and digestion methods used for laboratory analyses, the speciation analysis performed should be considered as suggestive rather than definitive.

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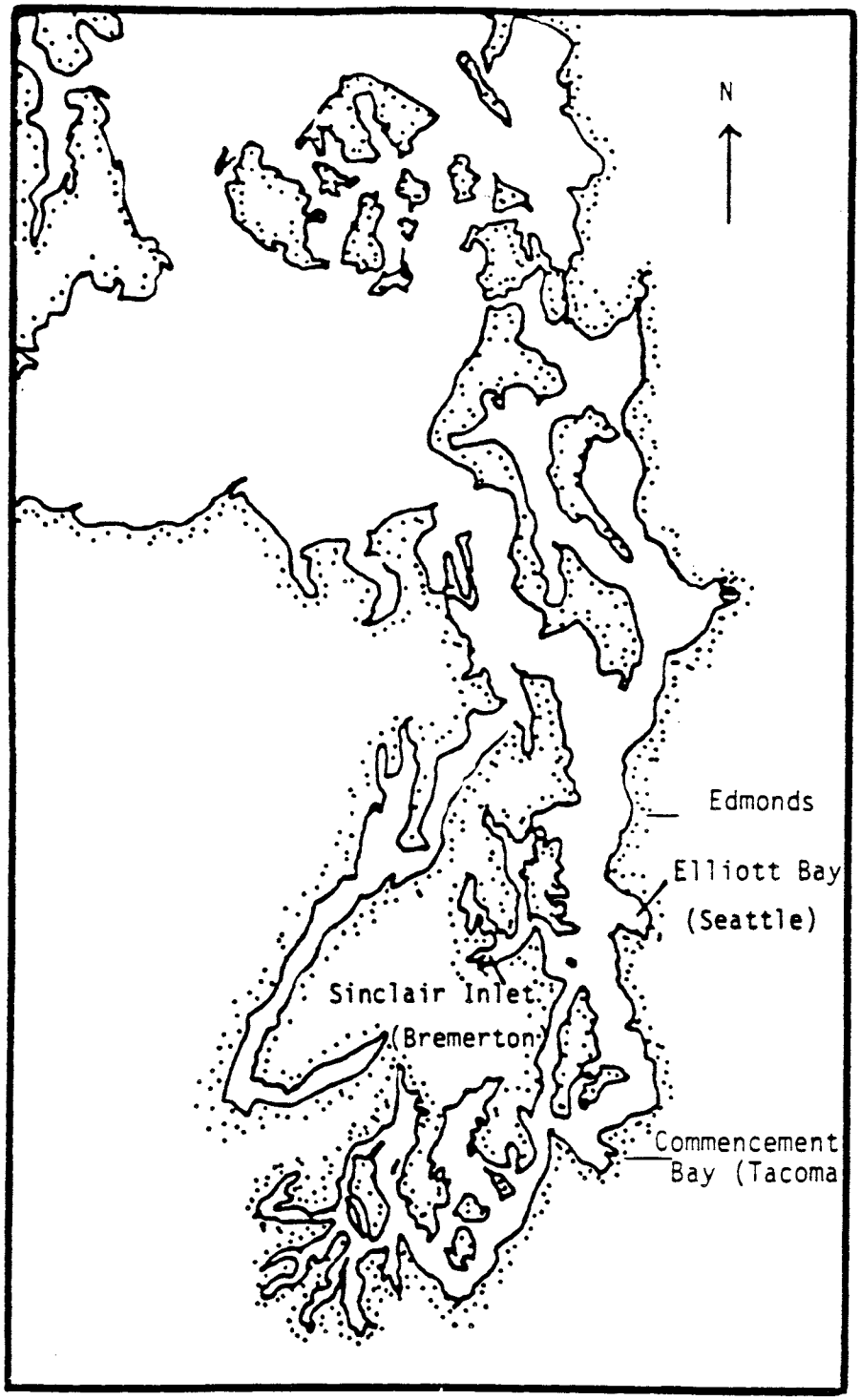


Figure 1. Location of study areas.

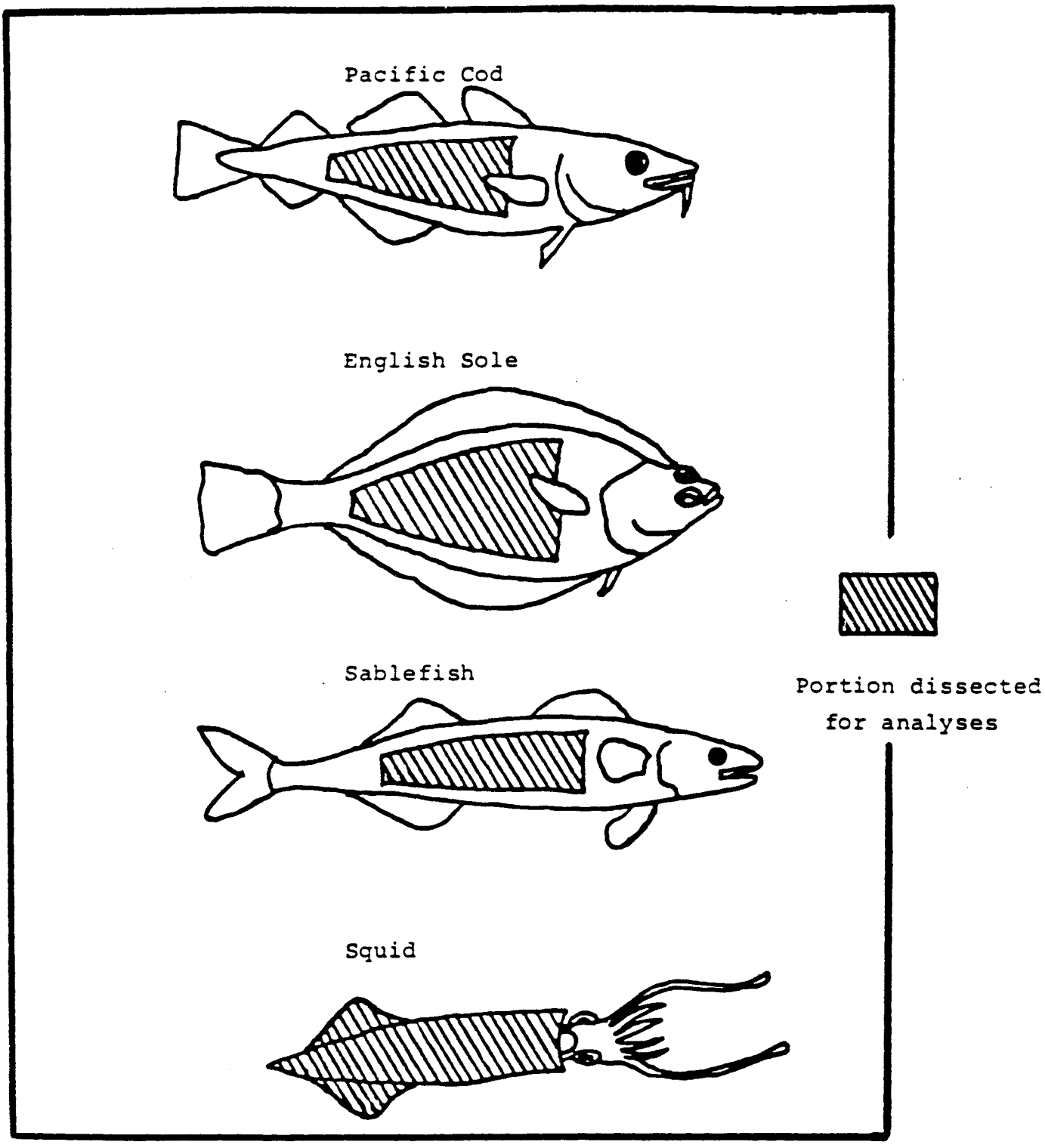


Figure 2. Specific parts of each species that were dissected for chemical analyses.

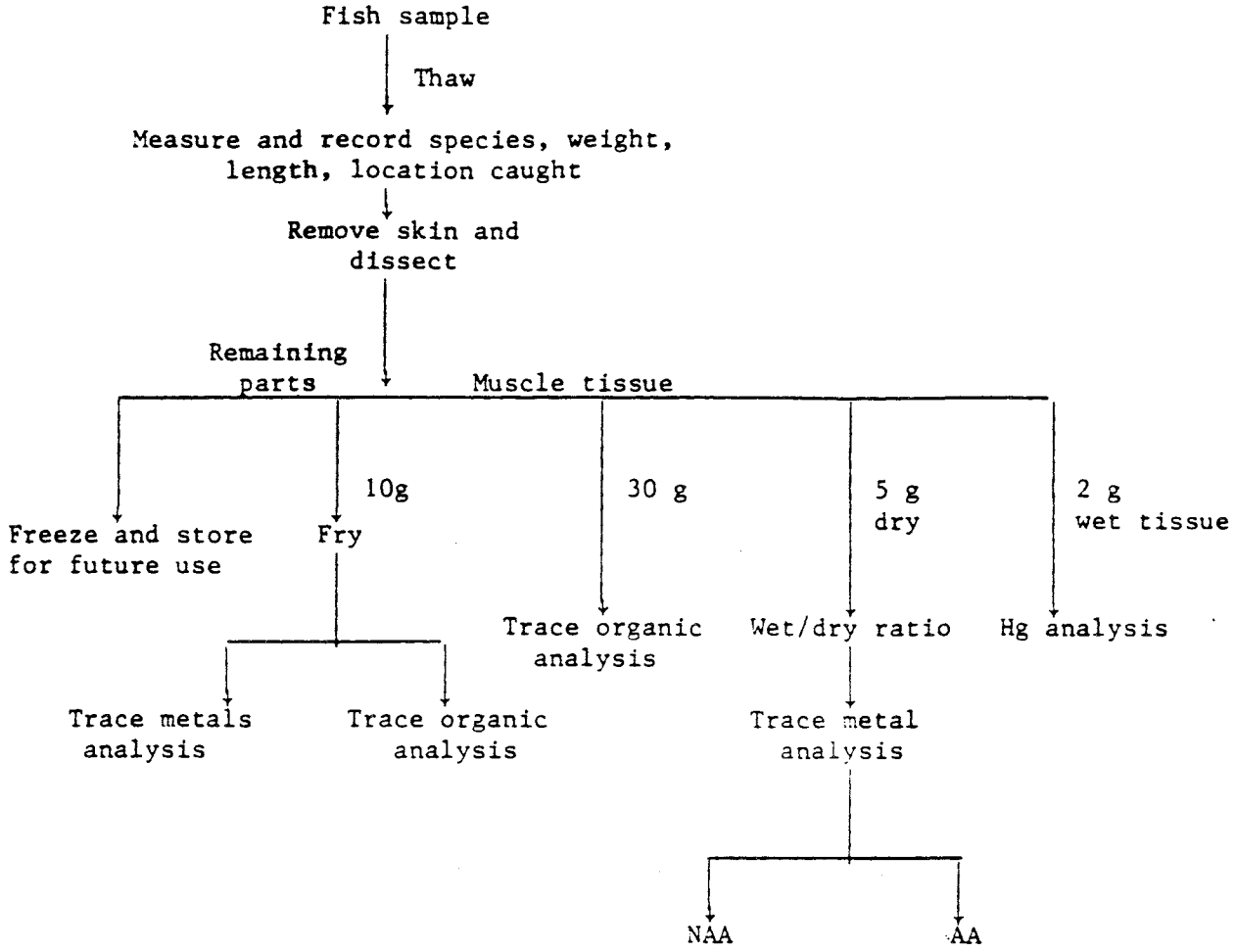


Figure 3. Schematic of sample preparation for chemical analysis.

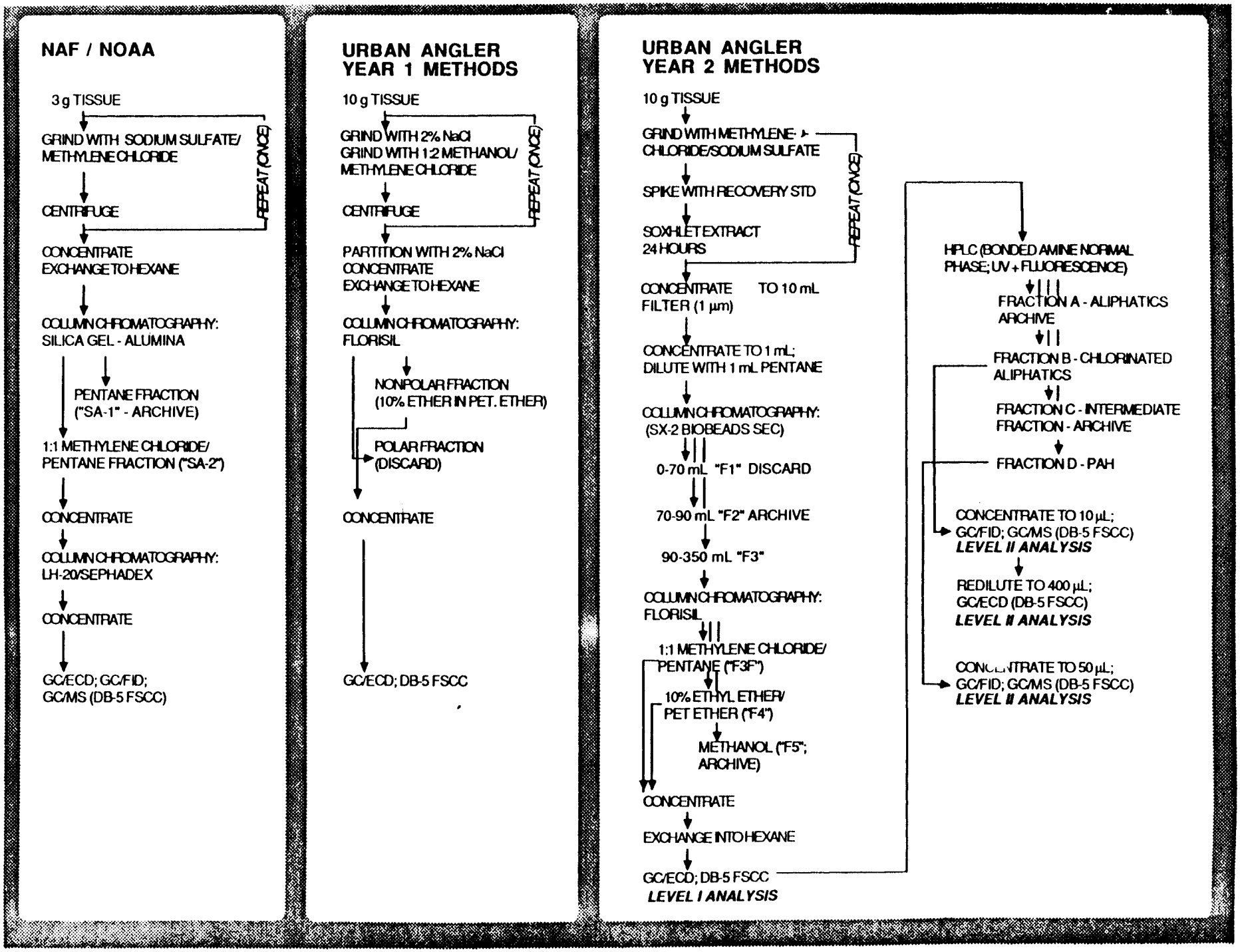


Figure 4. Comparison of methods used for organics analysis.

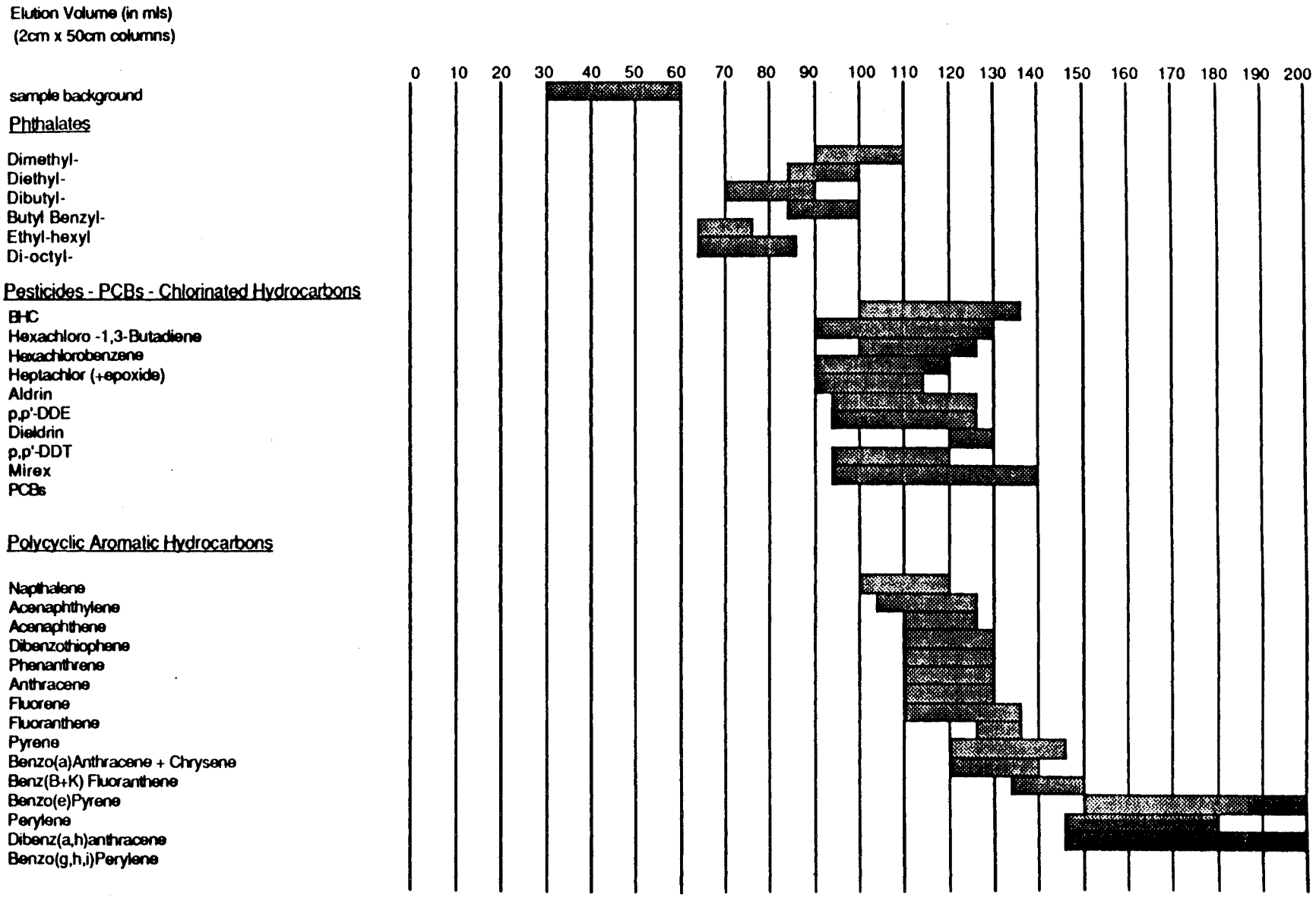


Figure 5. Compound elution with SX-2 Biobeads.

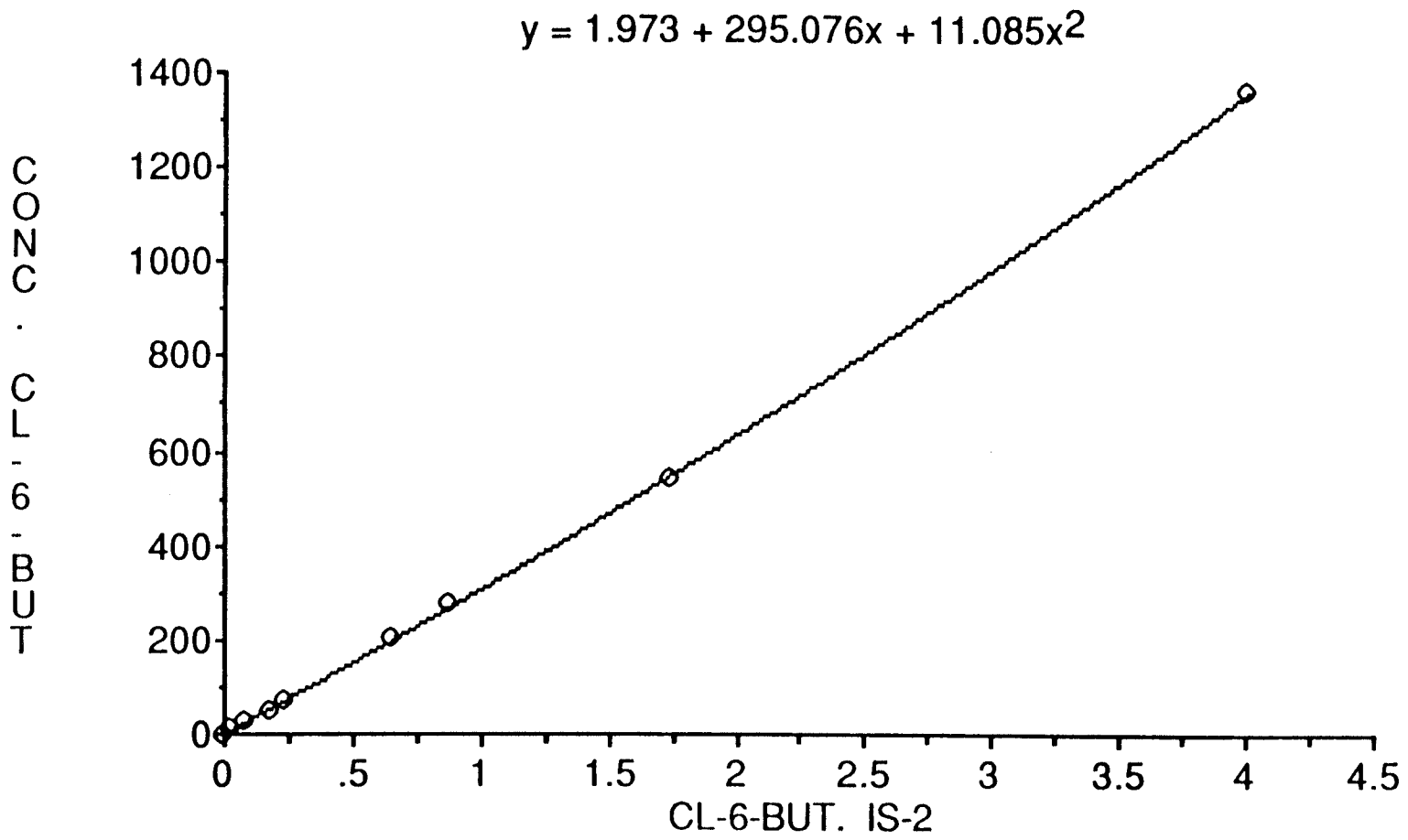


Figure 6. Typical multi-level response curve (hexachlorobutadiene).

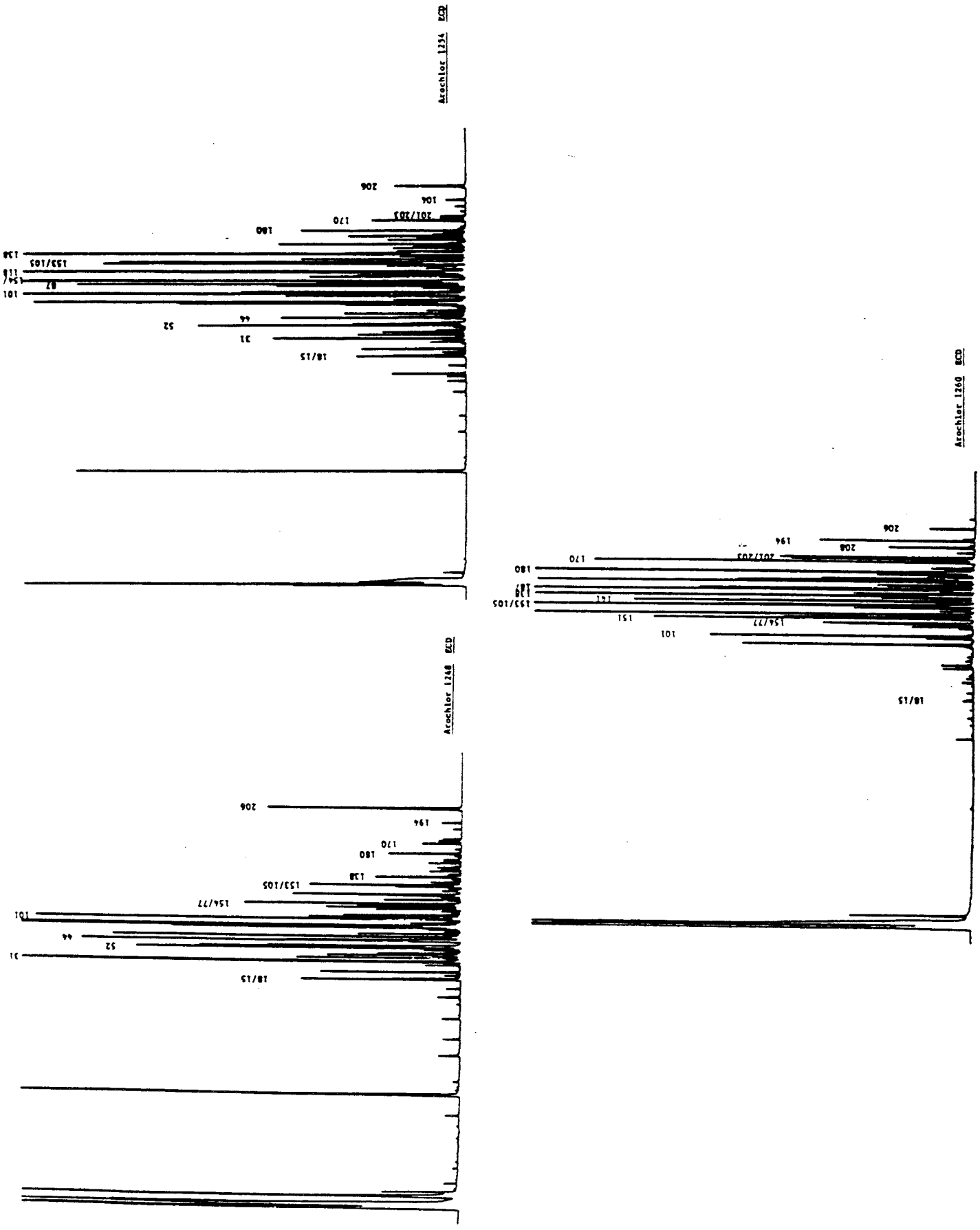


Figure 7. GC/ECD analysis of Aroclor mixtures.

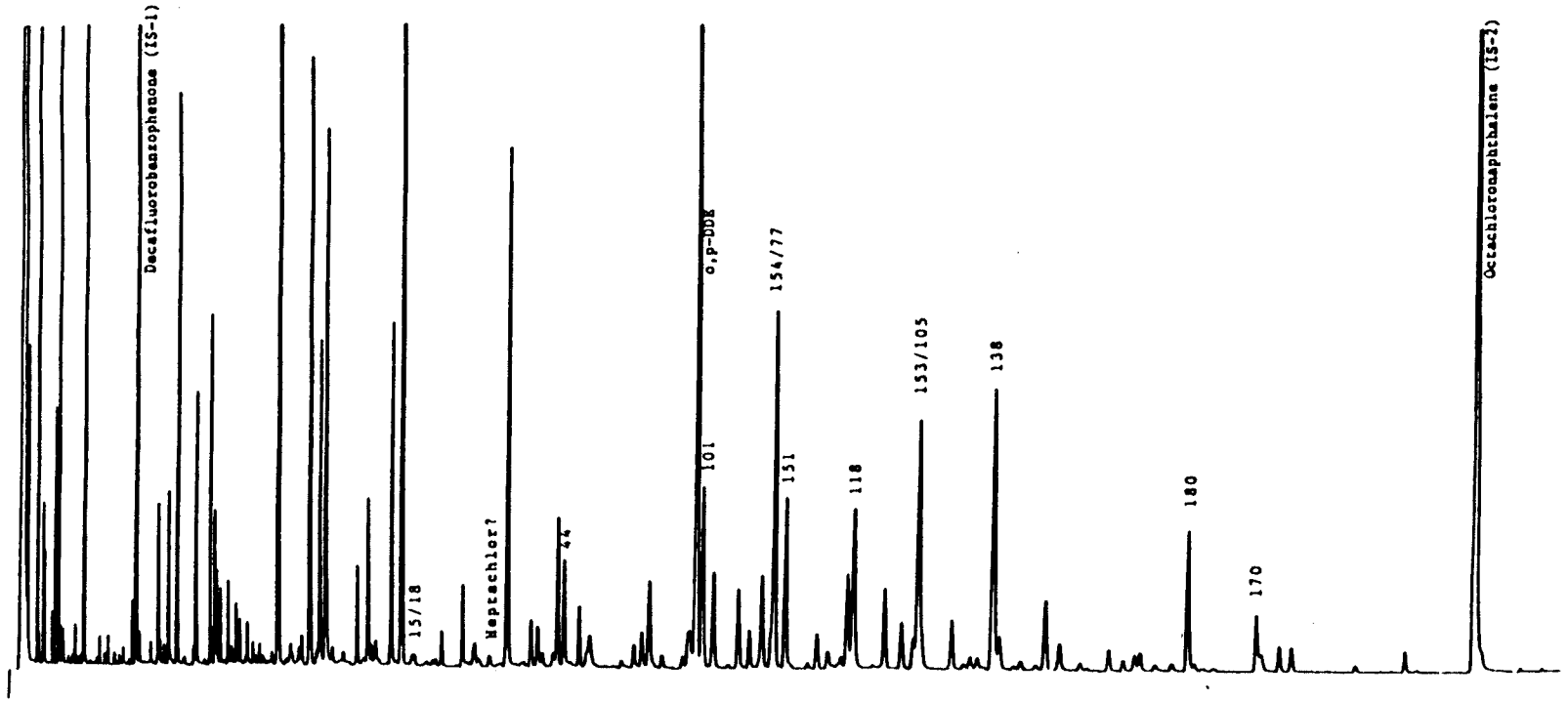
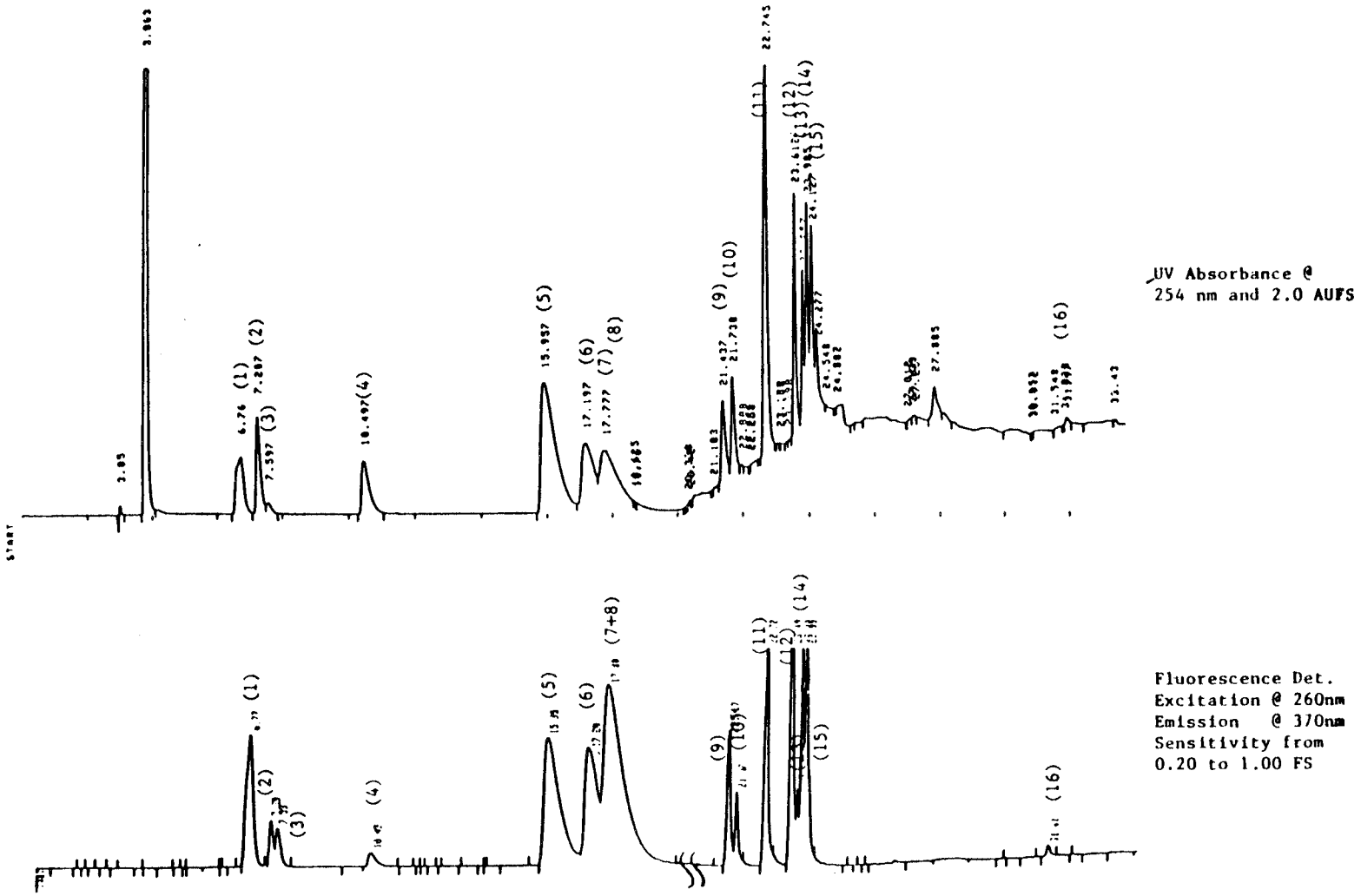


Figure 8. Target compounds detected in actual fish sample fractions. Numbers refer to IUPAC isomerid numbers for Aroclor components.



Compound Identities:
(1) Naphthalene + Naphthalene-D8 (2) Methyl Naphthalenes (3) Dimethyl Naphthalene (4) Acenaphthene (5) Fluorene
(6) Anthracene (7) Phenanthrene (8) Methyl Phenanthrene (9) Fluoranthene (10) Pyrene (11) Benz(a)anthracene + Chrysene
(12) Benzo(e)pyrene (13) Benzo(a)pyrene (14) Perylene-D12 (15) Perylene (16) Dibenz(a,h)anthracene

Sensitivity change from 0.20 F.S. to 1.00 F.S.

Figure 9. Simultaneous fluorescence and UV absorbance chromatograms for polynuclear aromatic hydrocarbon analysis.

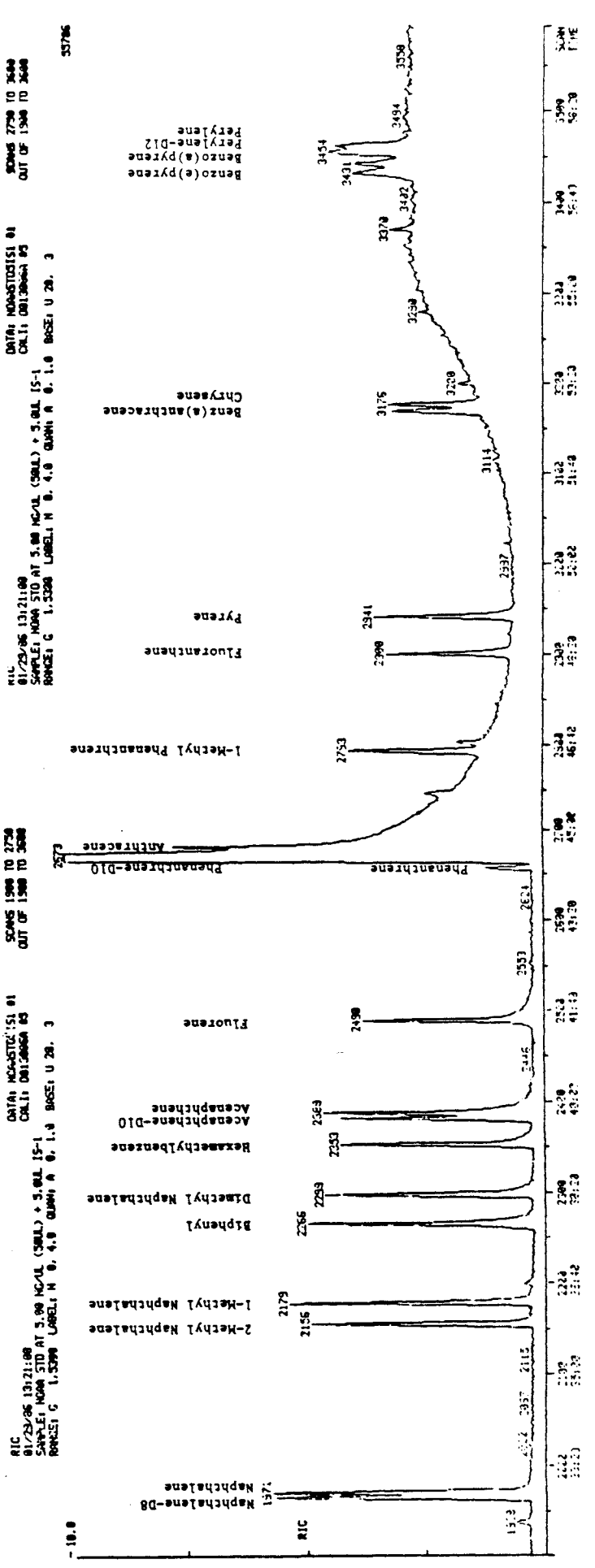


Figure 10. GC/MS detection of polynuclear aromatic hydrocarbons.

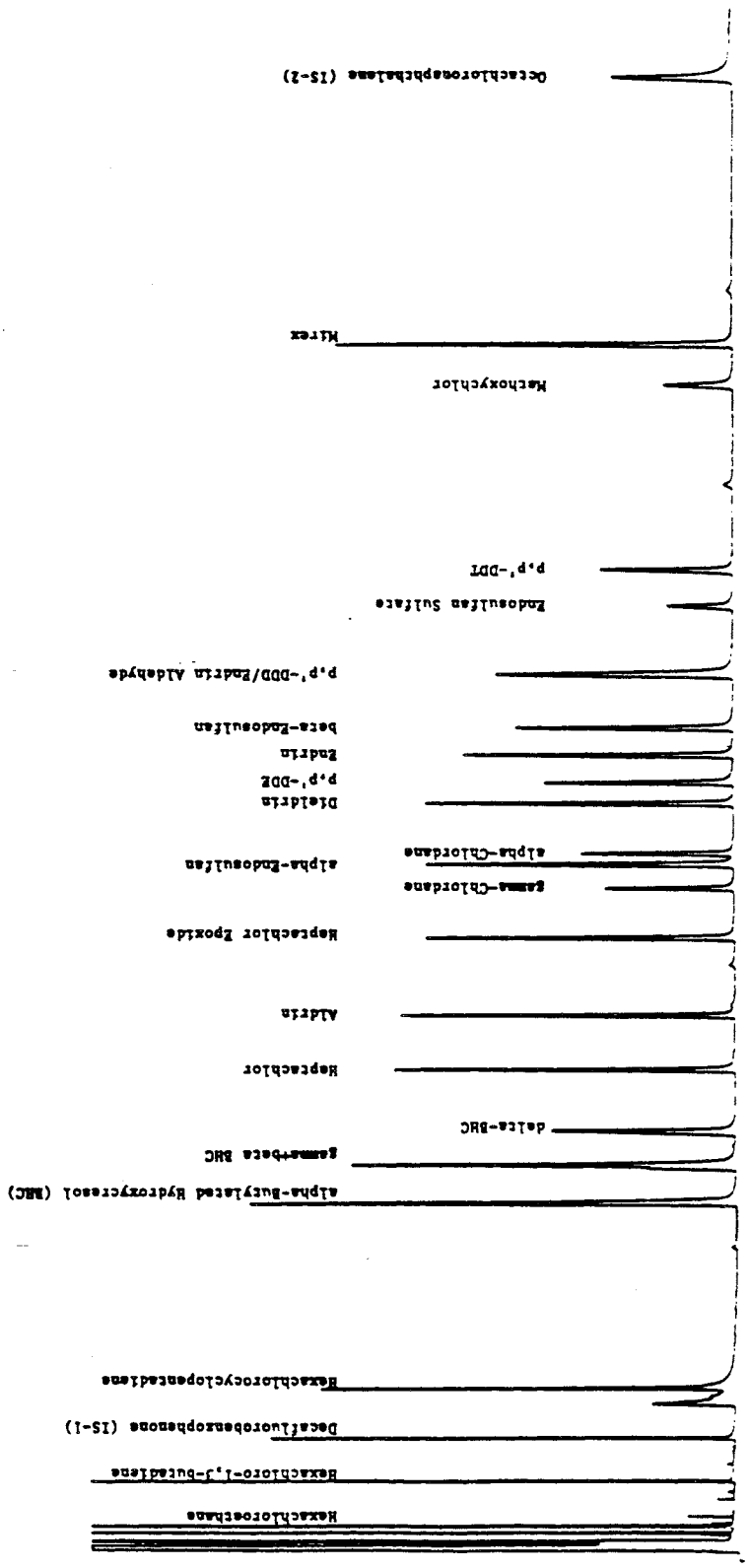


Figure 11. Expanded (Level 2) pesticide standard, GC/ECD.

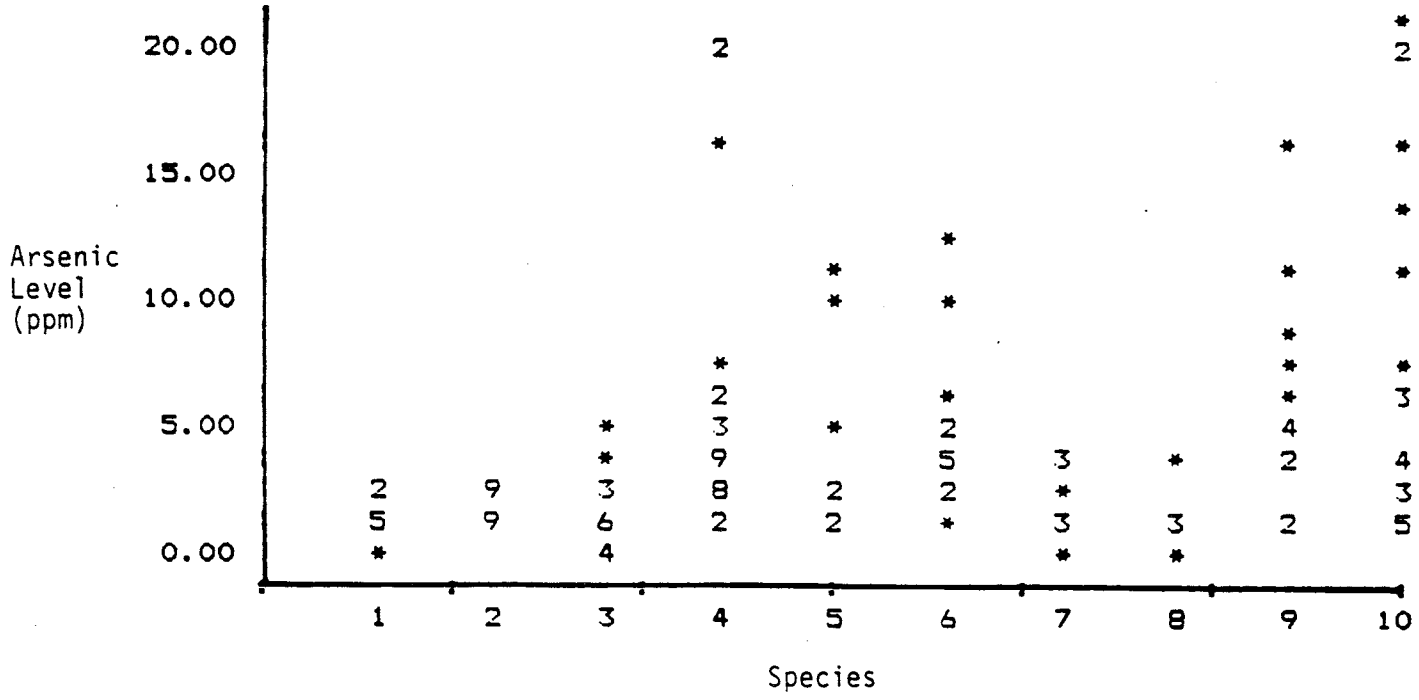


Figure 12. Arsenic level in raw fish tissue. Single observations are represented by asterisks; multiple observations by the number o fish with that value. Species codes are 1 = starry flounder, 2 = rockfish, 3 = sablefish, 4 = rock sole, 5 = walleye pollock, 6 = pacific cod, 7 = hake, 8 = tomcod, 9 = squid, 10 = English/flathead sole.

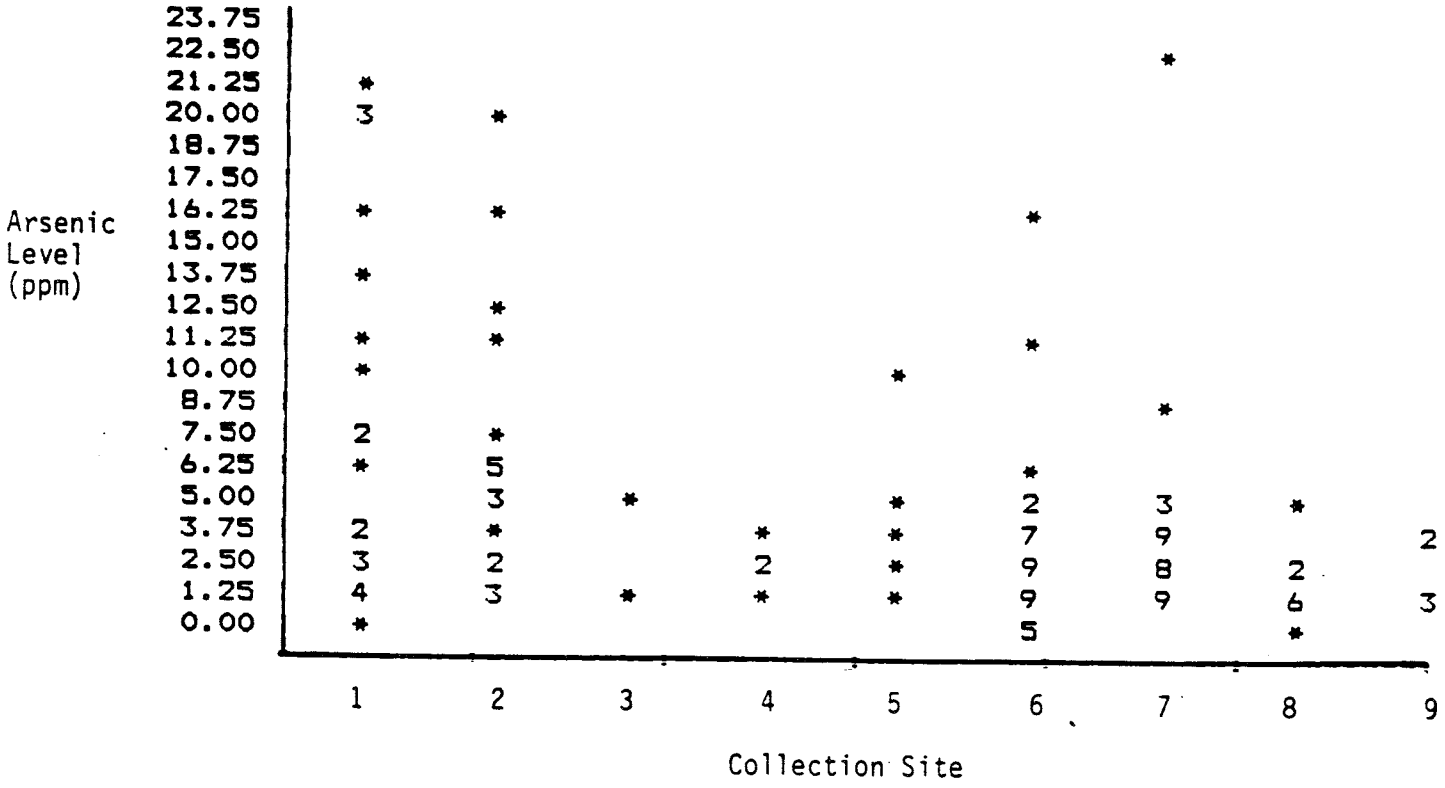


Figure 13. Arsenic levels in raw fish tissues compared by collection site. Single observations are represented by asterisks; multiple observations by the number of fish with that value. Site codes are 1 = Commencement Bay, 2 = Sinclair Inlet; 3 = Bremerton, 4 = Agate Pass, 5 = Port Orchard, 6 = Elliott Bay, 7 = Edmonds, 8 = Port Madison, 9 = Point Jefferson.

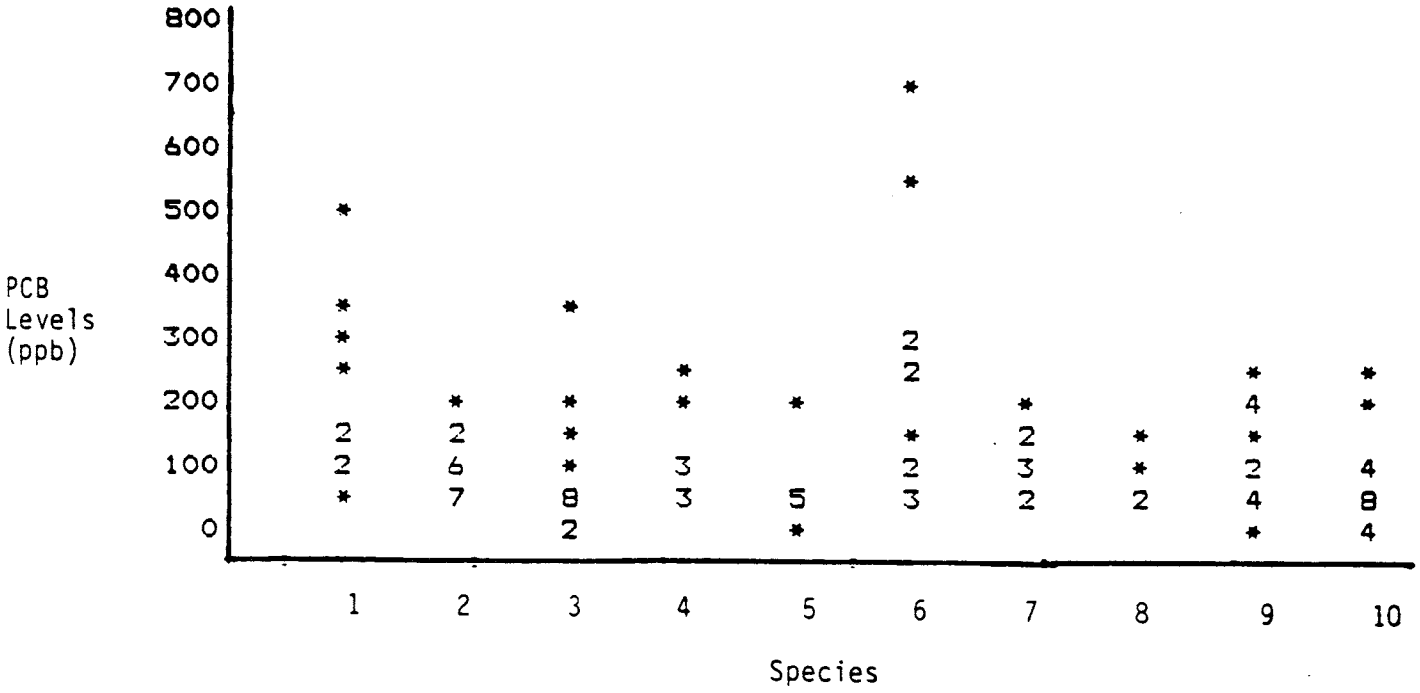


Figure 14. PCB levels in raw fish tissue samples. Single observations are represented by asterisks; multiple observations by the number of fish with that value. Species codes are 1 = starry flounder, 2 = rockfish, 3 = sablefish, 4 = rock sole, 5 = walleye pollock, 6 = pacific cod, 7 = hake, 8 = tomcod, 9 = squid, 10 = English/flathead sole.

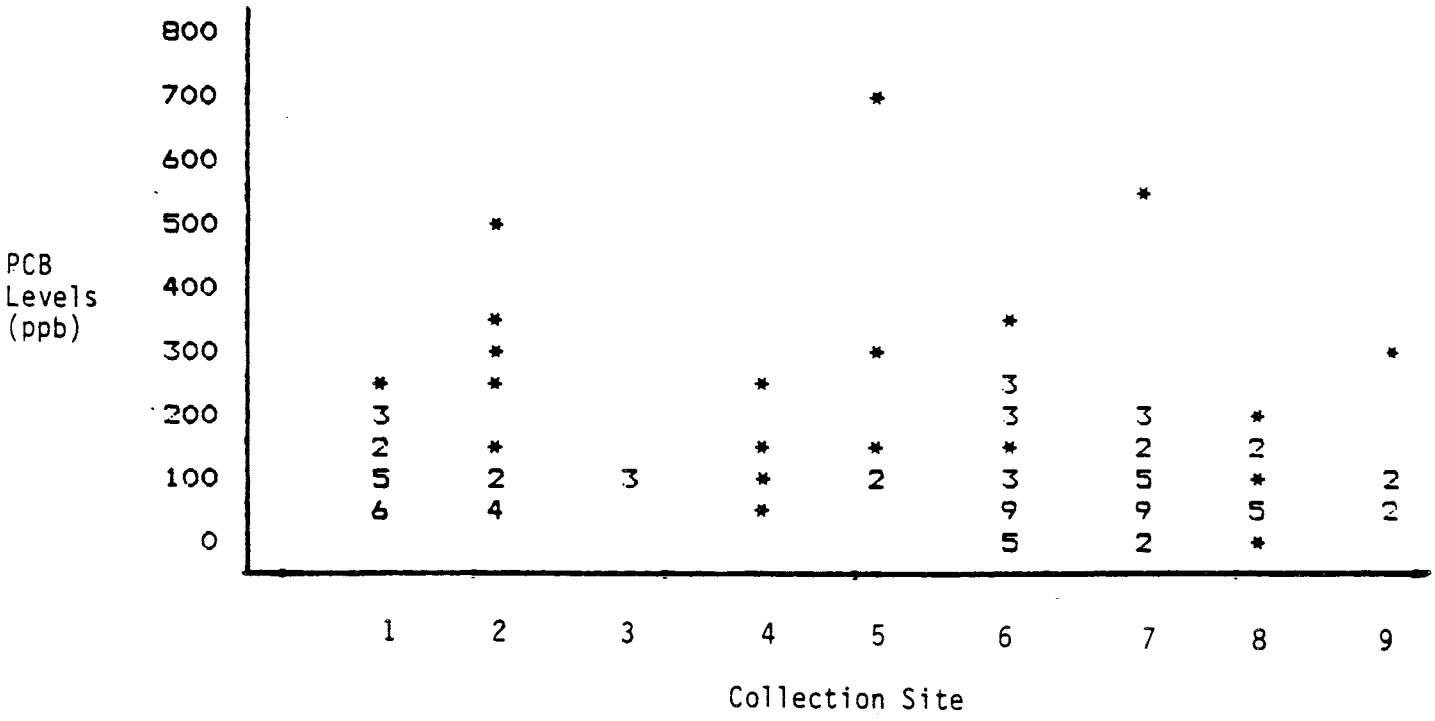


Figure 15. PCB levels in raw fish tissues compared by collection site. Single observations are represented by asterisks; multiple observations by the number of fish with that value. Collection site codes are 1 = Commencement Bay, 2 = Sinclair Inlet; 3 = Bremerton, 4 = Agate Pass, 5 = Port Orchard, 6 = Elliott Bay, 7 = Edmonds, 8 = Port Madison, 9 = Point Jefferson.

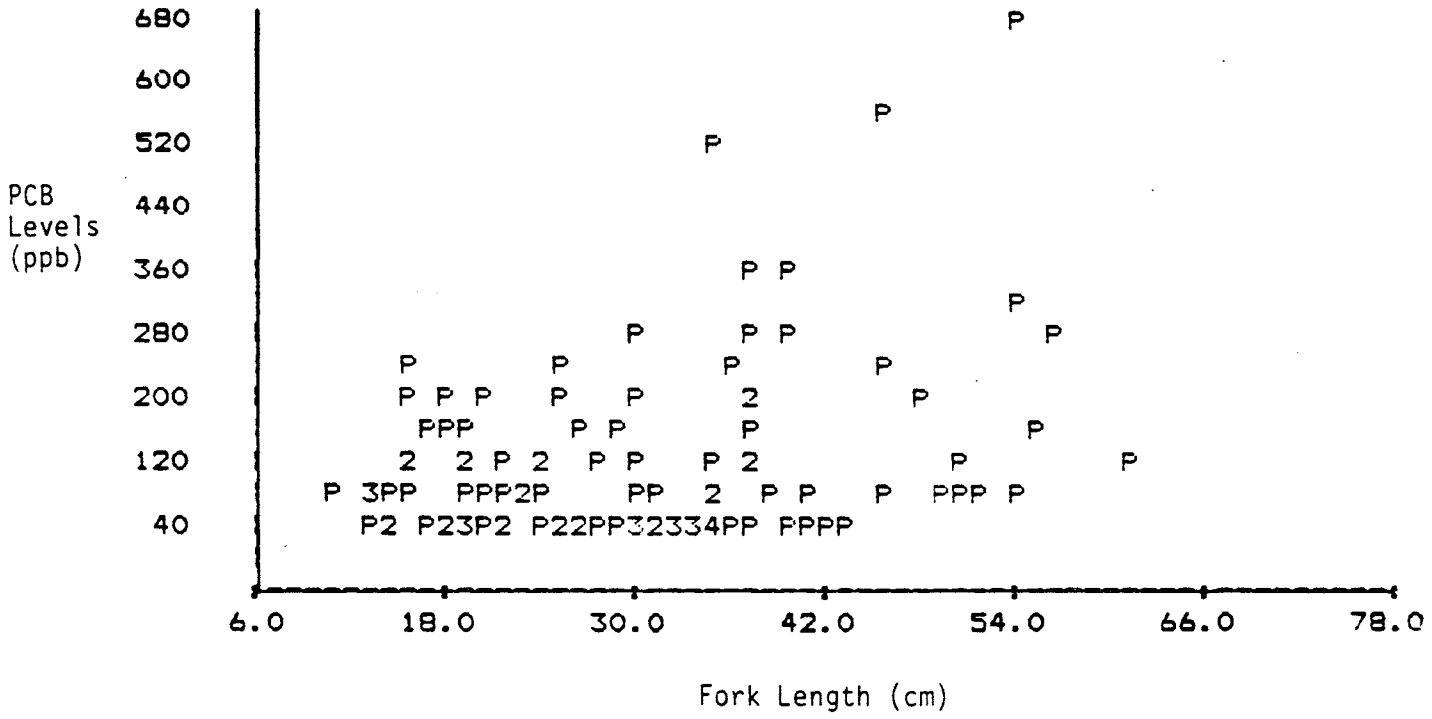


Figure 16. Relationship between PCB levels in raw fish and fork length. Single observations are represented by the symbol "P"; multiple observations by the number of fish with that value.

Table 1. Collection site and size of fish used in chemical analyses.

Sample No. and species	Date	Site and location	Length (cm)	Weight (g)
Starry Flounder				
195	3/14/85	Comm. Bay, Puyallup R.	28.7	236.7
200	3/14/85	Comm. Bay, Puyallup R.	30.6	300.5
199	3/14/85	Comm. Bay, Puyallup R.	31.0	350.6
198	3/14/85	Comm. Bay, Puyallup R.	29.9	277.5
96	6/14/84	Bremerton, Sinclair Inlet	37.0	602.9
111	6/14/84	Bremerton, Sinclair Inlet	35.0	597.9
105	6/14/84	Bremerton, Sinclair Inlet	37.7	604.9
116	6/14/84	Bremerton, Sinclair Inlet	37.7	680.7
Rockfish				
261	3/1/85	Port Orchard, Agate Pass	31.5	608.1
217	3/1/85	Port Orchard, Agate Pass	39.0	1380.0
218	3/1/85	Port Orchard, Agate Pass	37.2	1000.0
262	4/30/85	Port [illegible]ard, Manchester	46.0	2060.0
206	3/14/85	Comm. [illegible], Brown's Pt.	22.4	260.1
207	3/14/85	Comm. Bay, Brown's Pt.	21.6	171.2
204	3/14/85	Comm. Bay, Brown's Pt.	22.0	231.8
203	3/14/85	Comm. Bay, Brown's Pt.	22.3	226.0
233	3/14/85	Elliott Bay, Denny St. Out.	14.2	48.3
234	3/14/85	Elliott Bay, Denny St. Out.	30.3	474.6
32	3/28/84	Elliott Bay, Pier 86	20.0	156.7
280	5/31/85	Edmonds Public Fishing Pier	13.3	51.8
276	5/31/85	Edmonds Public Fishing Pier[2]	26.2	346.6
277	5/31/85	Edmonds Public Fishing Pier[2]	18.8	121.0
279	5/31/85	Edmonds Public Fishing Pier[2]	15.2	118.7
278	5/31/85	Edmonds Public Fishing Pier[2]	16.8	110.0
Sablefish				
264	5/19/85	Point Madison	35.0	428.0
263	5/19/85	Point Madison	48.3	889.0
Rock Sole				
158	6/30/84	Edmonds Public Fishing Pier	29.5	365.0
159	6/30/84	Edmonds Public Fishing Pier	24.1	190.0
182	6/30/84	Edmonds Public Fishing Pier	34.8	504.5
157	6/30/84	Edmonds Public Fishing Pier	33.0	509.5
125	6/15/85	Elliott Bay, Pier 91	25.2	187.8
126	6/15/84	Elliott Bay, Pier 91	21.2	114.7
124	6/15/84	Elliott Bay, Pier 91	25.2	187.8
123	6/15/84	Elliott Bay, Pier 91	24.2	165.6
Walleye Pollock				
270	5/19/85	Point Madison	31.4	277.0
266	5/19/85	Point Madison	30.5	332.0
267	5/19/85	Point Madison	33.0	309.9
269	5/19/85	Point Madison	26.3	146.7
268	5/19/85	Point Madison	26.6	210.1
232	3/14/85	Comm. Bay, Brown's Pt.	37.3	465.3
231	3/14/85	Comm. Bay, Brown's Pt.	28.0	191.7
Pacific Cod				
258	4/3/85	Port Orchard, Manchester	54.4	1440.0
259	4/3/85	Port Orchard, Manchester	54.8	1660.0
260	4/3/85	Port Orchard, Manchester	54.1	1480.0
257	4/3/85	Port Orchard, Manchester	61.2	2050.0
256	4/3/85	Port Orchard, Agate Pass	45.6	860.0
255	4/3/85	Point Jefferson	57.0	1560.0

Table 1. Continued

Sample No. and species	Date	Site and location	Length (cm)	Weight (g)
Pacific Hake				
202	3/14/85	Comm. Bay, Brown's Pt.	18.7	185.4
DSHS-15	10/15/85	Elliott Bay, Pier 57	37.0	348.1
DSHS-16	10/15/85	Elliott Bay, Pier 57	37.0	348.1
281	7/15/85	Point Jefferson[3]	54.5	880.0
282	7/15/85	Point Jefferson[3]	51.2	1020.0
283	7/15/85	Point Jefferson[3]	50.9	860.0
284	7/15/85	Point Jefferson[3]	50.3	1000.0
Tomcod				
274	5/19/85	Point Madison	20.3	89.6
273	5/19/85	Point Madison	18.7	60.7
275	5/19/85	Point Madison	27.1	143.4
Squid[4]				
239	11/16/84	Bremerton, 1st St. Dock	13.3	46.2
240	11/16/84	Bremerton, 1st St. Dock	11.1	47.1
249	11/16/84	Elliott Bay, Pier 70	13.2	53.8
245	11/16/84	Elliott Bay, Pier 86	16.1	93.0
243	11/16/84	Elliott Bay, Pier 86	15.3	72.5
24	11/12/84	Edmonds Public Fishing Pier	13.0	65.4
28	11/12/84	Edmonds Public Fishing Pier	13.8	82.6

[2]Fish bought from anglers.

[3]Fish obtained from charterboat.

[4]Mantle length in centimeters was used for length measurement.

Table 2. Quality control and quality assurance results for metals.

	Zn	Cu	Pb	Cd	Ag	Hg
Sample ID (duplicates; µg/g dry)						
281	18.3	1.69	0.022	0.029	0.006	
281-D	19.2	1.82	0.025	0.025	0.004	
282	17.0	1.21	0.017	0.105	<0.003	
282-D	14.9	1.31	0.019	0.116	<0.003	
283	16.8	1.07	0.015	0.086	0.018	
283-D	15.2	0.99	0.017	0.064	0.013	
284	21.4	1.83	0.032	0.025	0.004	
284-D	21.4	2.00	0.035	0.023	0.007	
Detection Limits (µg/g)	0.20	0.40	0.008	0.008	0.003	
Blanks (µg/L)	<10	<25	1.6	<0.5	<0.20	
Spike Recovery (%)	115	109	91	102	93	
Precision (µg/g)	0.67	0.15	0.004	0.002	0.002	
EPA Fish:						
Found 1	46.0	1.93	0.26	0.14	--	
Contains 2	43.6	2.21	0.26	0.16	--	2.52
NBS Bovine Liver:						
Found 1	134	190	0.36	0.25	0.066	
Contains 2	130	193	0.34	0.27	0.060	0.016

Table 3. Analytical performance, Level 1 target compounds.

ANALYTE	UNITS	hexachloro-butadiene	hexachloro-benzene	o,p'-DDE	p,p'-DDE	o,p'-DDD	p,p'-DDD	o,p'-DDT	p,p'-DDT
detection limit*	ng/g wet wt	0.5	0.5	0.5	0.5	0.7	0.7	1	0.8
calibration range	ng/mL	14-2730	14-2830	6-1140	8-1560	6-1160	4-780	8-1640	11-2280
response parameters:									
a (x^2)		1.58E-09	1.61E-08	-1.1E-08	-2.82E-09	-1.53E-08	-2.24E-09	-2.24E-09	-1.86E-09
b (x)		0.00709	0.0107	0.00876	0.00467	0.00839	0.00581	0.00581	0.00508
c (intercept)		-0.62	-3.62	4.13	10.2	7.31	19.5	19.5	17.4
RSD		0.059	0.01	0.07	0.07	0.08	0.09	0.09	0.07

ANALYTE (PCB Isomerid)		15 (Cl2)	33 (Cl3)	52 (Cl4)	101 (Cl5)	153 (Cl6)	183 (Cl7)	196 (Cl8)	207 (Cl9)
detection limit*	ng/g wet wt	1.3	0.4	1.2	0.3	1.3	1	0.9	4
calibration range	ng/mL	56-1120	30-6000	11-2200	26-5200	6-1120	6-1200	6-1280	5-960
response parameters:									
a (x^2)		0.00000183	0.000000039	1.29E-07	5.6E-10	3.14E-09	-5.8E-09	4.53E-09	2.17E-10
b (x)		0.105	0.0286	0.0301	0.00836	0.0175	0.00735	0.00889	0.00249
c (intercept)		68.2	-9.14	-6.5	5.15	-0.5	2.61	-1.39	-3.02
RSD		0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063

* detection limit is expressed in concentration units for original sample (assuming 8 grams of fish tissue per sample); response parameters and calibration range refer to instrument-ready concentrations.

Table 4. Instrumental conditions for gas chromatography/electron capture detection (GC/ECD).

Instrument	-	HP-5880 Capillary GC; ^{63}Nickel Detector
Column	-	30 M x 0.25mm I.D. Fused Silica Capillary Column, DB-5 (J & W Scie[illegible]); equipped with a 1 meter retention gap.
Mobile Phase	-	Hydrogen, 46 cm/sec mean linear velocity (@100°C)
Injection	-	2.0 ul splitless, at 50°C
Zone Temperatures	-	Injector - 290°C Detector - 320°C
Oven Program	-	50°C isothermal for 1 minute +4°C/min to 170°C +1°C/min to 200°C +2°C/min to 240°C +15°C/min to 300°C Post Value - 320°C for 8 minutes

Table 5. Instrumental conditions for high performance liquid chromatography.

Instrument	-	IBM LC 9533 HPLC
Detectors	-	Waters Model 480 UV Absorbance Detector (254nm)
	-	Schoeffel Model FS970 Fluorescence Detector (265nm Excitation; 370nm Emission)
Column	-	IBM Bonded Amine (10mm X 250mm) Semi-prep column
Mobile Phase	-	1) 100% Pentane; isocratic for 15 minutes
		2) Gradient to 20% Pentane: 80% $MeCl_2$ over 15 minutes
		3) Isocratic at 20% Pentane for 10 minutes
		4) Gradient to 100% $MeCl_2$ over 5 minutes
		5) Isocratic at 100% $MeCl_2$ for 15 minutes
		6) Equilibrate back to 100% Pentane in 5 minutes
Flow Rate	-	5.0 ml per minute
Injection	-	100ul in a 250ul loop (partial loop inj.)
Analysis Temp.	-	Ambient

Table 6. Instrumental conditions for gas chromatography/mass spectrometry.

Instrument	-	Finnegan 4023 GC/MS/DS with a H/P 5840 GC and direct coupling interface
Column	-	30 M x 0.25mm I.D. Fused Silica Capillary Column, DB-5 (J & W Scientific)
Mobile Phase	-	Helium, 30.5 cm/sec mean linear velocity
Injection	-	1.0ul splitless, at 30°C
Zone Temperatures	-	Injector - 290°C Transfer Oven - 260°C Ionizer Temp. - 320°C
Oven Program	-	30°C isothermal for 10 minutes +3°C/min to 90°C +8°C/min to 295°C Post Value - 295°C for 35 minutes
MS Conditions	-	Electron Impact Ionization Mode; 70 ev electron energy Mass Range - 34 - 534 amu Cycle Time - 1.0 second
Data System	-	Incos 2000 , Release 3.0 for Finnegan Mass Spectrometers

Table 7. Quality control results for spiked fish samples. Percent recovery based upon spiked level-background level.

SPECIES TYPE	% RECOVERY 2-Cl-Naphthalene	% RECOVERY o,p-DDE	% RECOVERY Cl-6-Butadiene	% RECOVERY Cl-6-Benzene	% RECOVERY p,p'-DDE	% RECOVERY o,p-DDD	% RECOVERY p,p'-DDD/o,p-DDT	% RECOVERY p,p'-DDT	% RECOVERY PCB's	N
Tom Cod	91.2	72.7	132.3	83.4	76.1	92.5	69.9	89.4	81.8	3
Black Cod (Sablefish)	70.2	62.5	197.0 *	112.6	117.6	138.2	103.8	132.2	122.2	2
Rock Fish	74.4	63.4	118.6	107.1	92.6	116.7	85.0	113.1	102.5	1
Hake **	156.9	109.9	162.3	109.2	96.9	121.5	89.3	115.6	107.4	1
Squid **	79.2	68.7	170.2	140.0	115.6	155.0	104.3	138.4	137.3	2
Starry Flounder	82.2	48.1	101.5	106.0	71.9	98.3	39.7 *	77.4	92.7	2
Pacific Cod	85.8	66.2	102.5	109.6	100.1	122.3	90.2	109.3	113.2	3
PC-21	82.0	73.4	119.7	83.0	76.2	120.1	53.9	121.8	166.6	1

* Outlier in data
** ESTD Quan. only

Table 8. Replicate analyses of raw fish samples. Results are in ng/g (ppb wet weight.

Sample #	Wet Weight Analyzed	% Recovery 2-Cl-Naph.	% Recovery o,p-DDE	Hexachloro-Butadine	Hexachloro-Benzene	p,p-DDE	o,p-DDE	p,p-DDD/ o,p-DDT	p,p-DDT	PCB's
123	8.08	120.9	79.5	-	-	2.2	-	-	-	79.0
123	8.08	80.6	92.5	-	-	3.0	-	-	-	78.0
Average	8.08	100.8	86.0			2.6				78.5
Std. Dev.	0.00	28.5	9.2			0.6				0.7
193	18.00	140.0	95.9	-	0.7	-	-	2.6	-	114.0
193	18.00	125.7	66.4	-	-	2.3	-	2.4	-	106.5
Average	18.00	132.9	81.2		0.7	2.3		2.5		110.3
Std. Dev.	0.00	10.1	20.9					0.2		5.3
203	8.08	108.5	86.1	-	-	1.2	-	1.9	-	48.7
203	8.08	99.3	74.0	-	0.8	1.0	-	-	-	40.9
Average	8.08	103.9	80.1		0.8	1.1		1.9		44.8
Std. Dev.	0.00	6.5	8.6			0.2				5.5
262	8.09	*	*	0.8	0.6	3.9	0.7	-	-	64.5
262	8.08	83.4	54.0	-	0.6	3.3	-	3.3	-	55.2
Average	8.09	83.4	54.0	0.8	0.6	3.6	0.7	3.3		59.9
Std. Dev.	0.01				0.0	0.4				6.6
245	8.08	89.2	87.9	-	1.5	1.1	-	-	-	41.0
245	8.08	106.8	66.5	-	0.8	-	-	3.2	3.0	42.4
Average	8.08	98.0	77.2		1.1	1.1		3.2	3.0	41.7
Std. Dev.	0.00	12.4	15.1		0.5					1.0
16+43	18.00	87.3	32.6	3.5	1.2	-	-	2.1	-	25.2
16+43	9.00	236.0	79.0	-	3.0	-	-	*	-	35.2
Average	13.50	161.7	55.8	3.5	2.1			2.1		30.2
Std. Dev.	6.36	105.1	32.8		1.3					7.1
267	8.08	75.8	92.1	-	-	3.3	-	1.9	-	22.0
267	8.08	84.9	87.3	-	-	3.8	-	1.8	-	30.0
Average	8.08	80.4	89.7			3.5		1.8		26.0
Std. Dev.	0.00	6.4	3.4			0.3		0.1		5.7
266	7.66	*	*	-	-	1.0	-	1.9	-	16.0
266	8.08	16.8	77.8	-	-	0.9	-	-	-	21.0
Average	7.87	16.8	77.8			1.0		1.9		18.5
Std. Dev.	0.30					0.1				3.5

* *No spike on one replicate*

** *Iupac Isomerid #15 excluded due to merged peak in replicate sample*

Table 9. Concentration (ng/g) of PCB Congeners in Fish Oil

IUPAC isomer no.	Responding laboratory							All data			All data except lab 1		
	1	2	3	4	5	6	7	Mean	S.D.	C.V.	Mean	S.D.	C.V.
52	1294	213	275	298	60	230	290	380	411	108	228	89	39
44	786	139	164	510	NA	125	131	309	277	90	214	166	78
95	1427	490	502	617	346.5	440	603	632	363	57	500	102	20
101	1401	756	721	660	306.9	430	587	695	350	50	577	176	30
110	1176	661	578	489	279.1	360	562	586	291	50	488	144	29
118	802	122	NA	319	205.7	305	484	373	243	65	287	136	47
153	1184	636	738	660	795.7	850	994	837	195	23	779	133	17
138	1169	865	853	872	925.8	720	889	899	135	15	854	70	8
128	374	308	254	128	170.7	250	159	235	88	38	212	69	33
180	415	324	365	255	48	215	250	267	120	45	243	110	45
170	248	141	155	135	NA	115	99.6	149	52	35	129	22	17
194	264	19.6	48	NA	90.3	20	20.5	77	96	124	40	31	78

Table 2. Concentration (ng/ml) of PCB Congeners in an Aroclor 1254 Solution

52	24.5	33.5	50.4	-	53.9	69	59.5	48	17	34	53	13	25
44	9.05	19.1	30.1	-	7.2	30	25.8	20	10	50	22	10	43
95	44.8	62.1	83.9	-	103.2	86	83.1	77	21	27	84	15	17
101	46.1	98.9	110.3	-	118.8	95	86.3	93	25	28	102	13	13
110	45.9	98.1	102.6	-	120.5	100	90.9	93	25	27	102	11	11
118	53.4	70.7	NA	-	143.5	83	75.4	85	34	40	93	34	36
153	24.2	45.7	47	-	63.5	51	57.5	48	14	28	53	7	14
138	36.7	123	87.4	-	103.5	81	70.1	84	30	35	93	21	22
128	10.8	31	19.5	-	10.3	20	17.1	18	8	42	20	7	38
180	4.2	13.4	9.4	-	1.4	11	8.45	8	4	56	9	5	52
170	3.8	11.3	8	-	NA	8.9	7.26	8	3	35	9	2	20
194	ND	<2.1	2.6	-	NA	.4	tr						

Table 3. Normalized Concentrations of PCB congeners in Fish Oil

52	3.12	.66	.75	1.17	1.25	1.07	1.16	1	1	63	1	0	24
44	1.89	.43	.45	2.00	NA	.58	.52	1	1	93	1	1	103
95	3.44	1.51	1.38	2.42	7.22	2.05	2.41	3	2	69	3	2	78
101	3.38	2.33	1.98	2.59	6.39	2.00	2.35	3	2	52	3	2	68
110	2.83	2.04	1.58	1.92	5.81	1.67	2.25	3	1	57	3	2	64
118	1.93	.38	NA	1.25	4.29	1.42	1.94	2	1	87	2	2	98
153	2.85	1.96	2.02	2.59	16.58	3.95	3.98	5	5	108	5	6	109
138	2.82	2.67	2.34	3.42	19.29	3.35	3.56	5	6	115	6	7	115
128	.90	.95	.70	.50	3.56	1.16	.64	1	1	88	1	1	92
180	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1	0	0	1	0	0
170	.60	.44	.42	.53	NA	.53	.40	0	0	47	0	0	51
194	.64	.06	.13	NA	1.88	.09	.08	0	1	166	0	1	197

Table 4. Normalized Concentrations of PCB Congeners in an Aroclor 1254 Solution

52	5.83	2.50	5.36	-	38.50	6.27	7.04	11	14	125	12	15	125
44	2.15	1.43	3.20	-	5.14	2.73	3.05	3	1	43	3	1	43
95	10.67	4.63	8.93	-	73.71	7.82	9.83	19	27	139	21	30	141
101	10.98	7.38	11.73	-	84.86	8.64	10.21	22	31	138	25	34	137
110	10.93	7.32	10.91	-	86.07	9.09	10.76	23	31	138	25	34	138
118	12.71	5.28	NA	-	102.50	7.55	8.92	23	39	172	25	44	175
153	5.76	3.41	5.00	-	45.36	4.64	6.80	12	16	139	13	18	139
138	8.74	9.18	9.30	-	73.93	7.36	8.30	19	27	137	22	29	135
128	2.57	2.31	2.07	-	7.36	1.82	2.02	3	2	71	3	2	76
180	1.00	1.00	1.00	-	1.00	1.00	1.00	1	0	0	1	0	0
170	.90	.84	.85	-	NA	.81	.86	1	0	49	1	0	56
194	-	-	.28	-	NA	.04							

S.D. - Standard deviation; C.V. - Coefficient of variation; tr - Trace; NA - Not available; ND - Not detectable

Table 10. Percentage of boating anglers fishing weekends versus weekdays, n=437.

Location	Weekend (5p.m. Fri-6p.m. Sun)	Weekday
Commencement Bay	95.1	4.9
Elliott Bay	98.2	1.8
Total	95.9	4.1

Table 11. Boating angler interviews by location and hour of day, n = 437. Values expressed in percent.

Location	00:00 -5:59	06:00 -11:59	noon -17:59	18:00 -midnight
Commencement Bay	0.6	7.3	69.1	22.9
Elliott Bay	0.0	14.5	64.5	20.9

Table 12. Boating angler interviews by month of year, 1986. Values expressed in percent.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Commencement Bay	0.0	4.6	3.7	5.8	7.0	0.0	39.1	18.0	11.3	10.4	0.0	0.0
Elliott Bay	0.0	0.0	5.5	0.0	10.9	11.8	16.4	28.2	24.5	2.7	0.0	0.0

Table 13. Seasonal boat fishing activity at the two sites. Values expressed as percent of interviews.

Location	Spring Mar-May	Summer Jun-Aug	Autumn Sep-Nov	Winter Dec-Feb
Commencement Bay	16.5	57.2	21.7	4.6
Elliott Bay	16.4	56.4	27.3	0.0

Table 14. Sex of boating anglers at the two sites. Values expressed in percent; n = 437.

Location	Male	Female	Unknown
Commencement Bay	98.2	1.2	0.6
Elliott Bay	92.7	6.4	0.9

Table 15. Age of boating anglers at the two sites, n = 437. Values expressed in percent.

Location	5-18	19-29	30-39	40-49	50-59	60-69	70+	mean	median	mode
Commencement Bay	2.5	21.7	41.3	16.8	11.5	5.9	0.3	37.1	34.5	35.0
Elliott Bay	9.2	24.8	32.1	16.5	11.0	6.4	0.0	35.3	32.3	30.0

Table 16. Ethnic origin of boating anglers at the two sites, n = 437. Values express in percent.

Location	No Answer	Caucasian	Black	Asian	Am. Indian
Commencement Bay	2.4	85.9	4.9	6.7	0.0
Elliott Bay	0.0	86.4	2.7	10.0	0.9

Table 17. Educational background of boating anglers at the two sites, n = 141. Values expressed in percent.

Location	1-8	9-11	12	13-15	16	17+	mean	median	mode
Commencement Bay	0.0	5.5	44.6	20.3	18.9	10.9	13.8	12.5	12.0
Elliott Bay	3.0	9.0	29.9	34.4	17.9	6.0	13.3	13.5	12.0

Table 18. Employment status of boating anglers at the two sites, n = 437. Values expressed in percent.

Location	No Answer	Employed	Unemployed
Commencement Bay	16.5	71.3	12.2
Elliott Bay	13.6	66.4	20.0

Table 19. City of residence of boating anglers at the two sites, n = 437. Values expressed in percent.

City	Commencement Bay	Elliott Bay
No Answer	2.4	4.5
Seattle	5.5	74.5
Everett	0.0	0.9
Tacoma	51.7	0.0
King County, WA	13.1	16.4
Pierce County, WA	22.6	0.0
Other Washington Counties	3.1	0.9
Other U.S. States	1.5	2.7
Other Countries	0.0	0.0

Table 20. Types of boat fishing groups at the two sites, n=436. Values expressed in percent.

Location	Alone	Family	Friends	Family & Friends	No Answer
Commencement Bay	6.4	25.8	56.1	7.7	4.0
Elliott Bay	10.0	30.0	50.9	7.3	1.8

Table 21. Fishing group size at the two sites, n=424. Values expressed as percent of boating anglers reporting.

Location	Number People per Group >1					(Including 28 solo anglers)			
	2	3	4	5	6+	mean	median	mode	s.e.
Commencement Bay	57.1	26.9	12.4	1.7	2.0	2.55	2.32	2.0	0.054
Elliott Bay	54.1	34.7	8.2	3.1	0.0	2.47	2.34	2.0	0.083

Table 22. Number of hours boating angler spent fishing during current trip, n=416. Values expressed in percent of anglers reporting.

Location	Number of hours (to nearest hour)											
	1	2	3	4	5	6	7	8+	mean	median	mode	se
Commencement Bay	.3	2.9	6.7	9.3	13.1	17.6	12.8	37.0	6.9	6.5	6.0	.16
Elliott Bay	1.0	2.9	12.5	6.7	14.4	18.3	9.6	34.7	6.5	6.2	6.0	.30

Table 23. Number of fish per successful angler during current boat fishing trip. Values expressed as percent of anglers reporting, n=437.

Location	Number of fish caught this trip											
	0	1	2	3	4	5	6	7	8+	mn	med	mode	se
Commencement Bay	33.6	22.6	11.6	7.3	4.0	2.4	3.1	2.1	12.9	3.7	1.2	0	.48
Elliott Bay	45.5	22.7	10.9	5.5	2.7	2.7	1.8	2.7	5.4	1.8	0.7	0	.28

Table 24. Frequency (trips/period) with which boating anglers fish the two sites. Values expressed as percent of anglers reporting, n=424.

Frequency	Commencement Bay	Elliott Bay
1st Time	15.0	21.2
2nd Time	2.2	2.9
3rd Time	0.3	1.0
4th-7th Time	0.0	0.0
1/Week	23.4	24.0
2/Week	5.6	3.8
3/Week	2.8	2.9
4/Week	0.6	1.0
5/Week	0.0	1.9
6/Week	0.0	0.0
7/Week	0.0	0.0
1/Month	13.1	10.6
2/Month	13.4	16.3
3/Month	3.1	1.9
4/Month	2.2	0.0
5/Month	0.6	0.0
1/Year	2.5	1.9
2/Year	2.8	2.9
3/Year	2.5	2.9
4/Year	0.0	0.0
5/Year	2.8	2.9
6/Year	0.9	0.0
7/Year	4.4	1.9
8/Year	0.3	0.0
9+/Year	0.6	0.0

Table 25. Time elapsed (days) since boating angler last fished site of present interview, n=344. Values expressed as percent of anglers reporting.

Number of days	Commencement Bay	Elliott Bay
1	4.5	6.6
2	1.1	3.9
3	2.2	3.9
4	1.5	0.0
5	2.6	0.0
6	0.0	1.3
7	32.1	38.2
8	0.4	0.0
9	0.7	0.0
10	1.9	0.0
14	12.3	13.2
15-20	0.4	1.3
21	6.3	3.9
22-29	0.0	1.3
30	10.8	9.2
31-364	15.4	11.7
365+	7.8	5.3
mean	58.8 days	41.3
median	13.7	7.4
mode	7.0	7.0
s.e.	7.8	10.0

Table 26. Species sought by boating anglers at the two sites. V ues expressed in percent of anglers reporting, n=437.

Species sought	Commencement Bay	Elliott Bay
No response	1.5	0.0
Bottomfish, "any"	25.7	26.4
Cod	3.1	0.0
Perch	0.0	1.8
Rockfish	0.6	0.0
Flounder	0.3	0.0
Salmon today only	7.0	2.7
Salmon	60.6	69.1
Ling Cod	1.2	0.0

Table 27. Interview status of boating anglers at the two sites, n=437. Values expressed in percent; more than one response is possible.

Location	Agreed to be Interviewed	Refused to be Interviewed	Language Barrier	Previously Interviewed
Commencement Bay	85.6	1.8	0.9	11.0
Elliott Bay	80.9	6.3	0.0	14.5

Table 28. Willingness of successful anglers at the two sites to have their catch examined. Values expressed in percent of responses to question; more than one response is possible. n=437.

Location	Nothing Caught	Agreed to Inspection	Refused Inspection	Catch Not Available	No Answer
Commencement Bay	32.1	66.4	0.0	0.6	0.9
Elliott Bay	42.2	35.8	4.6	16.5	0.9

Table 29. The 20 species most commonly taken at both sites (as numbers of fish) by urban boating anglers, 1985. Total catch = 1379 animals.

Species	Number Caught	% of Total Catch
1. Walleye pollock	411	29.8
2. Pacific cod	213	15.5
3. Unidentified flatfish	175	12.7
4. Unidentified rockfish	104	7.5
5. Coho salmon	96	7.0
6. King salmon	92	6.7
7. Rock sole	72	5.2
8. Copper rockfish	52	3.8
9. Pacific hake	29	2.1
10. Quillback rockfish	27	2.0
11. Ling cod	18	1.3
12. Brown rockfish	17	1.2
13. Dogfish shark	15	1.1
14. Pacific sanddab	14	1.0
15. Sablefish	11	0.8
16. Unidentified sculpin	7	0.5
17. Pacific staghorn sculpin	5	0.4
18. Black rockfish	5	0.4
19. Unidentified perch	5	0.4
20. All other species	11	0.8

Table 30. The 20 species most commonly taken at both sites (as kilograms), by urban boating anglers. Total catch = 1246.2 kg.

Species	Number kilograms	% Kilograms
1. King salmon	519.5	41.7
2. Coho salmon	247.5	19.9
3. Walleye pollock	129.7	10.4
4. Pacific cod	114.8	9.2
5. Lingcod	46.4	3.7
6. Unidentified flatfish	38.5	3.1
7. Unidentified rockfish	37.3	3.0
8. Copper rockfish	19.4	1.6
9. Dogfish shark	19.4	1.6
10. Rock sole	16.9	1.4
11. Pacific hake	9.6	0.8
12. Sablefish	8.4	0.7
13. Quillback rockfish	8.1	0.7
14. Brown rockfish	7.5	0.6
15. Black rockfish	7.3	0.6
16. Unidentified sculpins	3.3	0.3
17. Pacific sanddab	3.0	0.2
18. Unidentified perch	2.5	0.2
19. Unidentified salmon	2.5	0.2
20. All other species	4.6	0.4

Table 31. Number of people eating fish caught at the two sites, n=328. Values expressed in percent of boating anglers reporting.

No. of Consumers	Commencement Bay	Elliott Bay
1	4.1	5.7
2	20.7	19.5
3	24.1	26.4
4	23.7	14.9
5	12.9	12.6
6-9	11.2	16.0
10+	3.5	4.5
mean	3.96	4.05
median	3.54	3.44
mode	3.00	3.00
s.e.	0.16	0.25

Table 32. Time elapsed (days) since boating angler last ate fish caught at site of present interview. Values expressed as percent of anglers reporting, n=287.

No. Days.	Commencement Bay	Elliott Bay
1	4.0	1.6
2	1.3	4.8
3	2.2	0.0
4	1.8	0.0
5	1.8	0.0
6	0.0	3.2
7	31.1	29.0
8	0.4	0.0
9	0.9	0.0
10	1.3	0.0
11-13	0.0	1.6
14	12.9	14.5
15-20	0.4	1.6
21	4.9	3.2
22-29	0.8	1.6
30	9.8	9.7
31-364	15.3	14.5
365+	10.6	14.5
mean	69.5 days	84.0
median	13.9	14.2
mode	7.0	7.0
s.e.	9.2	19.0

Table 33. Parts of fish eaten by boating anglers at the two sites. Values expressed in percents of anglers responding, n=241. More than one response is possible.

Parts Eaten	Commencement Bay	Elliott Bay
Skinned fillet	96.4	91.8
Unskinned fillet	3.6	6.1
Broth	0.0	2.0
Head	0.0	0.0
Whole	0.0	0.0
Other	0.0	0.0

Table 34. Mode of preparation of fish for eating by boating anglers at the two sites. Values expressed as percent of anglers responding, n = 292. More than one response is possible.

Mode of Preparation	Commencement Bay	Elliott Bay
Raw	1.4	0.0
Boiled	1.9	1.9
Baked	22.9	13.2
Fried	50.9	32.1
Smoked	7.9	1.9
Barbequed	20.6	34.0
Steamed	1.4	3.8
Broiled	6.5	5.7
Pickled	0.5	0.0

Table 35. Concentration of trace metals in Puget Sound fish muscle. Values are in ug/g (ppm) of wet tissue.

Sample No. and species	Date	Site and location	Length (cm)	Weight (g)	Dry/wet ratio	As (NAA)	Se (NAA)	Zn (AA)	Ag (AA)	Cu (AA)	Pb (AA)	Cd (AA)	Hg[1] (AA)
Starry Flounder													
195	3/14/85	Comm. Bay, Puyallup R.	28.7	236.7	0.14	2.6	ND	4.3	<0.0004	0.24	<0.001	0.002	<0.002
200	3/14/85	Comm. Bay, Puyallup R.	30.6	300.5	0.15	1.0	0.1	4.2	<0.0004	0.36	<0.001	0.005	0.156
199	3/14/85	Comm. Bay, Puyallup R.	31.0	350.6	0.17	0.5	0.2	4.1	<0.0005	0.29	0.002	0.003	<0.002
198	3/14/85	Comm. Bay, Puyallup R.	29.9	277.5	0.19	0.8	0.1	6.0	<0.0006	0.23	0.001	0.003	<0.002
96	6/14/84	Bremerton, Sinclair Inlet	37.0	602.9	0.17	1.7	ND	4.5	<0.0005	0.27	0.002	0.010	0.011
111	6/14/84	Bremerton, Sinclair Inlet	35.0	597.9	0.17	2.2	0.2	6.6	<0.0005	0.40	0.002	0.004	0.014
105	6/14/84	Bremerton, Sinclair Inlet	37.7	604.9	0.17	1.8	0.3	5.2	0.001	0.24	0.002	0.003	0.017
116	6/14/84	Bremerton, Sinclair Inlet	37.7	680.7	0.17	1.2	0.1	3.9	0.0005	0.22	0.002	0.007	<0.002
Rockfish													
261	3/1/85	Port Orchard, Agate Pass	31.5	608.1	0.20	2.4	0.1	2.6	0.0006	0.20	0.004	0.02	<0.003
217	3/1/85	Port Orchard, Agate Pass	39.0	1380.0	0.21	2.1	0.1	3.3	<0.0006	0.17	0.007	0.007	0.017
218	3/1/85	Port Orchard, Agate Pass	37.2	1000.0	0.22	1.1	0.1	3.4	<0.0007	0.24	0.004	0.004	0.016
262	4/30/85	Port Orchard, Manchester	46.0	2060.0	0.22	2.9	0.1	5.7	<0.0007	0.34	<0.002	0.009	0.015
206	3/14/85	Comm. Bay, Brown's Pt.	22.4	260.1	0.19	1.9	0.2	2.9	<0.0006	0.25	0.003	0.004	<0.003
207	3/14/85	Comm. Bay, Brown's Pt.	21.6	171.2	0.19	0.8	0.1	3.8	<0.0006	0.39	0.01	0.010	0.009
204	3/14/85	Comm. Bay, Brown's Pt.	22.0	231.8	0.20	2.8	0.1	3.8	<0.0006	0.34	0.003	0.004	<0.002
203	3/14/85	Comm. Bay, Brown's Pt.	22.3	226.0	0.19	--	--	4.5	<0.0006	0.27	0.008	0.002	0.079
233	3/14/85	Elliott Bay, Denny Way Out.	14.2	48.3	0.20	2.0	0.2	3.8	0.002	0.32	0.023	0.012	<0.003
234	3/14/85	Elliott Bay, Denny Way Out.	30.3	474.6	0.20	1.2	0.1	3.7	<0.0006	0.36	<0.002	0.004	0.015
32	3/28/84	Elliott Bay, Pier 86	20.0	156.7	0.22	1.3	--	4.2	<0.0007	0.59	0.004	0.010	0.003
280	5/31/85	Edmonds Public Fishing Pier	13.3	51.8	0.20	0.8	0.2	5.1	0.002	0.50	0.006	0.016	0.008
276	5/31/85	Edmonds Public Fishing Pier[2]	26.2	346.6	0.21	2.3	0.2	4.1	<0.0006	0.35	<0.002	0.020	0.028
277	5/31/85	Edmonds Public Fishing Pier[2]	18.8	121.0	0.20	2.2	ND	3.7	<0.0006	0.29	0.002	0.007	0.007
279	5/31/85	Edmonds Public Fishing Pier[2]	15.2	118.7	0.19	1.7	0.1	4.4	0.001	0.26	0.002	0.013	0.055
278	5/31/85	Edmonds Public Fishing Pier[2]	16.8	110.0	0.20	1.5	ND	4.4	0.001	0.30	<0.001	0.006	0.005
Sablefish													
264	5/19/85	Point Madison	35.0	428.0	0.17	0.8	0.1	2.6	0.002	0.26	<0.001	0.023	0.003
263	5/19/85	Point Madison	48.3	889.0	0.22	1.7	0.1	3.1	0.0007	0.30	<0.002	0.015	0.022

- Not measured

Table 35. Continued.

Sample No. and species	Date	Site and location	Length (cm)	Weight (g)	Dry/wet ratio	As (NAA)	Se (NAA)	Zn (AA)	Ag (AA)	Cu (AA)	Pb (AA)	Cd (AA)	Hg[1] (AA)
Rock Sole													
158	6/30/84	Edmonds Public Fishing Pier	29.5	365.0	0.24	3.8	--	4.8	<0.0007	0.19	<0.002	0.003	0.002
159	6/30/84	Edmonds Public Fishing Pier	24.1	190.0	0.21	3.2	ND	5.2	<0.0006	0.11	<0.002	0.004	0.002
182	6/30/84	Edmonds Public Fishing Pier	34.8	504.5	0.22	3.7	0.1	5.5	<0.0007	0.25	0.007	0.011	0.003
157	6/30/84	Edmonds Public Fishing Pier	33.0	509.5	0.25	2.2	0.2	5.7	<0.0008	0.26	0.008	0.004	<0.002
125	6/15/85	Elliott Bay, Pier 91	25.2	187.8	0.24	2.4	0.2	5.3	<0.0007	0.32	0.002	0.002	0.003
126	6/15/84	Elliott Bay, Pier 91	21.2	114.7	0.21	3.3	ND	4.1	<0.0006	0.24	0.003	0.002	0.004
124	6/15/84	Elliott Bay, Pier 91	25.2	187.8	0.24	4.3	0.2	6.1	<0.0007	0.45	0.006	0.006	0.009
123	6/15/84	Elliott Bay, Pier 91	24.2	165.6	0.21	3.5	0.2	4.4	<0.0006	0.26	<0.002	0.020	<0.002
Walleye Pollock													
270	5/19/85	Point Madison	31.4	277.0	0.18	1.4	ND	4.8	0.003	0.46	<0.001	0.002	0.073
266	5/19/85	Point Madison	30.5	332.0	0.16	1.1	0.1	3.5	0.001	0.31	<0.001	0.004	0.008
267	5/19/85	Point Madison	33.0	309.9	0.16	4.4	0.1	4.0	0.008	0.25	<0.001	0.006	0.003
269	5/19/85	Point Madison	26.3	146.7	0.18	2.5	0.1	3.6	0.002	0.37	<0.001	0.003	0.006
268	5/19/85	Point Madison	26.6	210.1	0.19	2.3	0.1	3.6	0.001	0.33	0.003	0.003	<0.001
232	3/14/85	Comm. Bay, Brown's Pt.	37.3	465.3	0.17	11.4	0.1	3.9	0.002	0.28	0.004	0.004	--
231	3/14/85	Comm. Bay, Brown's Pt.	28.0	191.7	0.18	9.4	ND	3.6	0.001	0.80	0.012	0.005	0.006
Pacific Cod													
258	4/3/85	Port Orchard, Manchester	54.4	1440.0	0.16	5.4	ND	3.9	0.0006	0.59	0.002	0.008	0.007
259	4/3/85	Port Orchard, Manchester	54.8	1660.0	0.17	4.0	0.1	4.3	0.0007	0.37	0.001	0.005	0.090
260	4/3/85	Port Orchard, Manchester	54.1	1480.0	0.17	9.4	--	3.0	<0.0005	0.21	0.002	0.015	0.003
257	4/3/85	Port Orchard, Manchester	61.2	2050.0	0.17	0.7	ND	11.2	<0.0005	0.17	0.005	0.010	0.013
256	4/3/85	Port Orchard, Agate Pass	45.6	860.0	0.15	3.5	0.2	3.6	0.008	0.21	0.001	0.001	0.013
255	4/3/85	Point Jefferson	57.0	1560.0	0.15	3.4	--	3.2	0.001	0.23	0.003	0.002	0.026
Pacific Hake													
202	3/14/85	Comm. Bay, Brown's Pt.	18.7	185.4	0.18	3.2	0.3	2.4	0.0005	0.28	0.002	0.003	0.004
DSHS-15	10/15/85	Elliott Bay, Pier 57	37.0	348.1	0.17	2.5	0.1	2.1	<0.0006	0.22	0.006	0.020	0.003
DSHS-16	10/15/85	Elliott Bay, Pier 57	37.0	348.1	0.17	0.5	0.2	2.1	<0.0006	0.23	0.004	0.011	0.003
281	7/15/85	Point Jefferson[3]	54.5	880.0	0.17	1.0	0.2	3.1	0.001	0.29	0.004	0.005	0.005
282	7/15/85	Point Jefferson[3]	51.2	1020.0	0.18	1.4	0.2	3.1	<0.0005	0.22	0.003	0.020	0.003
283	7/15/85	Point Jefferson[3]	50.9	860.0	0.17	3.5	0.2	2.9	0.003	0.18	0.003	0.015	0.005
284	7/15/85	Point Jefferson[3]	50.3	1000.0	0.17	1.8	0.1	3.6	0.0007	0.31	0.005	0.004	0.009

Table 35. Continued.

Sample No. and species	Date	Site and location	Length (cm)	Weight (g)	Dry/wet ratio	As (NAA)	Se (NAA)	Zn (AA)	Ag (AA)	Cu (AA)	Pb (AA)	Cd (AA)	Hg[1] (AA)
Tomcod													
274	5/19/85	Point Madison	20.3	89.6	0.18	1.1	0.1	4.2	<0.0005	0.31	<0.001	0.002	0.005
273	5/19/85	Point Madison	18.7	60.7	0.18	1.4	ND	4.2	<0.0005	0.28	<0.001	0.012	0.003
275	5/19/85	Point Madison	27.1	143.4	0.16	0.5	0.1	3.1	<0.0005	0.42	<0.001	0.004	0.008
Squid[4]													
239	11/16/84	Bremerton, 1st St. Dock	13.3	46.2	0.21	1.3	0.1	13.7	0.057	0.53	<0.002	0.017	--
240	11/16/84	Bremerton, 1st St. Dock	11.1	47.1	0.21	4.4	ND	11.5	0.057	4.41	<0.002	0.026	0.022
249	11/16/84	Elliott Bay, Pier 70	13.2	53.8	0.21	11.8	0.3	13.6	0.053	4.80	<0.002	0.039	0.016
245	11/16/84	Elliott Bay, Pier 86	16.1	93.0	0.22	15.9	ND	14.3	0.091	5.83	<0.002	0.041	0.008
243	11/16/84	Elliott Bay, Pier 86	15.3	72.5	0.21	1 [illegible]	ND	12.8	0.011	2.31	0.002	0.032	0.005
24	11/12/84	Edmonds Public Fishing Pier	13.0	65.4	0.22	3.6	ND	13.8	0.007	2.90	0.008	0.120	0.006
28	11/12/84	Edmonds Public Fishing Pier	13.8	82.6	0.22		ND	14.3	0.003	2.40	<0.002	0.008	0.003

[1]Cold vapor.

[2]Fish bought from anglers.

[3]Fish obtained from charterboat.

[4]Mantle length in centimeters was used for length measurement.

Table 36. Mean concentration of trace metals in Puget Sound fish muscle. Values are in ug/g (ppm) of wet tissue. In calculating the mean values the numbers in Table 35 were set to equal values and ND values were set to zero.

Species	Length (cm)	Weight (g)	Dry/wet ratio	As	Se	Zn	Ag	Cu	Pb	Cd	Hg
Starry flounder											
Range	28.7-37.7	236.7-680.7	0.14-0.19	0.5-2.6	0-0.3	3.9-6.6	0.0004-0.001	0.22-0.40	0.001-0.002	0.002-0.01	0.002-0.017
n	8	8	8	8	8	8	8	8	8	8	8
$\bar{x}$	33.5	456.5	0.17	1.5	0.13	4.9	0.0006	0.28	0.002	0.005	0.02
σ	3.8	181	0.02	0.7	0.10	1.0	0.0002	0.07	0.0005	0.003	0.05
Rockfish											
Range	13.3-46.0	48.3-2,060	0.19-0.22	0.8-2.9	0-0.2	2.6-5.7	0.0006-0.002	0.17-0.59	0.001-0.01	0.002-0.02	0.002-0.028
n	16	16	16	15	14	16	16	16	16	16	16
$\bar{x}$	24.8	460.3	0.2	1.8	0.11	4.0	0.0008	0.32	0.005	0.009	0.02
σ	9.6	562.5	0.01	0.7	0.07	0.8	0.0005	0.11	0.005	0.006	0.02
Sablefish											
Range	35.0-48.3	428.0-889.0	0.17-0.22	0.8-1.7	0.1-0.1	2.6-3.1	0.0007-0.002	0.26-0.3	0.001-0.002	0.015-0.023	0.003-0.022
n	2	2	2	2	2	2	2	2	2	2	2
$\bar{x}$	41.7	658.5	0.2	1.3	0.1	2.9	0.001	0.28	0.002	0.02	0.013
σ	9.4	326	0.04	0.6	0	0.4	0.0009	0.03	0.0007	0.006	0.013
Rock sole											
Range	21.2-34.8	165.6-509.5	0.21-0.25	2.2-4.3	0-0.2	4.1-6.1	0.0006-0.0007	0.11-0.45	0.002-0.008	0.002-0.02	0.002-0.009
n	8	8	8	8	7	8	8	8	8	8	8
$\bar{x}$	27.2	278.1	0.23	3.3	0.13	5.1	0.0007	0.26	0.004	0.007	0.003
σ	4.8	158.5	0.02	0.7	0.1	0.7	0.0001	0.1	0.003	0.006	0.002
Walleye pollock											
Range	26.3-37.3	146.7-465.3	0.16-0.19	1.1-11.4	0-0.1	3.5-4.8	0.001-0.008	0.25-0.28	0.001-0.012	0.002-0.006	0.001-0.073
n	7	7	7	7	7	7	7	7	7	7	6
$\bar{x}$	30.4	276	0.17	4.6	0.07	3.9	0.003	0.4	0.003	0.004	0.016
σ	3.9	107	0.01	4.1	0.05	0.5	0.003	0.2	0.004	0.001	0.03

Table 36. Continued

Species	Length (cm)	Weight (g)	Dry/wet ratio	As	Se	Zn	Ag	Cu	Pb	Cd	Hg
Pacific cod											
Range	45.6-61.2	860.0-2,050	0.15-0.17	0.7-9.4	0-0.2	3.0-11.2	0.0005-0.001	0.17-0.59	0.001-0.005	0.001-0.010	0.003-0.090
n	6	6	6	6	4	6	6	6	6	6	6
$\bar{x}$	54.5	1,508	0.16	4.4	0.08	4.9	0.002	0.3	0.002	0.007	0.03
σ	5.1	386	0.01	2.9	0.1	3.1	0.001	0.16	0.002	0.009	0.01
Pacific hake											
Range	18.7-54.5	185.4-1,020	0.17-0.18	0.5-3.5	0.1-0.3	2.1-3.6	0.0005-0.001	0.18-0.31	0.002-0.006	0.003-0.020	0.003-0.009
n	7	7	7	7	7	7	7	7	7	7	7
$\bar{x}$	42.8	663	0.17	2.0	0.2	2.8	0.001	0.25	0.004	0.011	0.005
σ	12.8	354	0.005	1.1	0.07	0.6	0.0009	0.05	0.001	0.007	0.002
Tomcod											
Range	18.7-27.1	60.7-143.4	0.16-0.18	0.5-1.4	0-0.1	3.1-4.2	0.0005-0.0005	0.28-0.42	0.001-0.001	0.002-0.004	0.003-0.008
n	3	3	3	3	3	3	3	3	3	3	3
$\bar{x}$	22.0	97.9	0.17	1.0	0.07	3.8	0.0005	0.34	0.001	0.006	0.005
σ	4.5	42.0	0.01	0.5	0.06	0.6	0	0.07	0	0.005	0.003
Squid											
Range	11.1-16.1	46.2-93.0	0.21-0.22	1.3-15.9	0-0.3	11.5-14.3	0.003-0.091	0.53-5.83	0.002-0.008	0.008-0.120	0.003-0.022
n	7	7	7	4	7	7	7	7	7	7	5
$\bar{x}$	13.7	65.8	0.21	5.7	0.06	13.4	0.04	3.3	0.003	0.04	0.01
σ	1.6	18	0.005	6.9	0.11	1.0	0.03	1.8	0.002	0.04	0.007

Table 37. Concentration of trace metals in samples of fried fish that were analyzed raw (RF) and following frying (FF). Values are in ug/g (ppm) of wet tissue; ND = not detected, for mean calculation set equal to zero.

Sample Type	Sample No.	Fried Wt. / Wet Wt.	% Water Loss (Wt. %)	As			Se			Zn		
				FF	RF	FF/RF	FF	RF	FF/RF	FF	RF	FF/RF
Rock sole	125	0.34	66.0	1.7	2.4	0.7	0.2	0.2	1.0	16.6	5.3	3.1
Tomcod	275	0.25	75.3	0.75	0.5	1.5	0.1	0.1	1.0	7.4	3.1	2.4
Rockfish	276	0.38	62.5	1.9	2.3	0.8	0.34	0.2	1.7	5.4	4.1	1.3
Pacific cod	260	0.32	67.6	5.6	9.4	0.6	0.22	-	-	5.3	3.0	1.8
Sablefish	263	0.34	65.6	0.9	1.7	0.5	0.31	0.1	3.1	5.2	3.1	1.7
Squid	243	0.41	56.7	1.1	1.3	0.8	0.25	ND	-	13.2	12.8	1.0
Starry flounder	116	0.33	66.6	1.0	1.2	0.8	0.13	0.1	1.3	12.7	3.9	3.5
Walleye pollock	231	0.28	72.0	3.8	9.4	0.4	0.22	ND	-	2.7	3.6	0.8
Pacific hake	202	0.40	60.5	2.4	3.2	0.8	0.4	0.3	1.1	5.3	2.4	2.2
$\bar{x}$	-	0.34	66.0	2.1	3.5	0.8	0.24	0.13	1.5	8.2	4.6	2.0
S.D.	-	0.05	5.6	1.6	3.4	0.3	0.1	0.10	0.8	4.8	3.2	0.9
Wesson oil before frying [b]	500	-	-	0.1	-	-	<0.03	-	-	0.6	-	-
Wesson oil after frying [b]	501	-	-	<0.1	-	-	<0.04	-	-	0.6	-	-

[a] < Values or > values set to = values for the mean calculation.

[b] The values are for unheated oil.

Table 37. Continued.

Ag			Cu			Pb			Cd			Hg		
FF	RF	FF/RF	FF	RF	FF/RF	FF	RF	FF/RF	FF	RF	FF/RF	FF	RF	FF/RF
0.016	<0.0007[a]	≥22.8[a]	0.35	0.32	1.1	0.026	0.002	13.0	0.012	0.002	6.0	<0.002	0.003	≤0.6
0.009	<0.0005	≥18.0	0.65	0.42	1.6	0.085	0.001	85.0	0.011	0.004	2.8	<0.002	0.008	≤0.2
0.008	<0.0006	≥13.3	0.46	0.35	1.3	0.015	<0.002	≥7.5	0.008	0.020	0.4	0.023	0.028	0.82
0.004	<0.0005	≥ 8.0	0.40	0.21	1.9	0.033	0.002	16.5	0.008	0.015	0.5	-	0.033	-
0.004	0.0007	5.7	0.63	0.30	2.1	0.013	<0.002	≥6.5	0.013	0.015	0.9	0.055	0.022	2.5
0.011	0.011	1.0	2.20	2.31	1.0	0.011	0.002	5.5	0.012	0.032	0.4	<0.002	0.005	≤0.4
0.005	0.0005	10.0	0.69	0.22	3.1	0.011	0.002	5.5	0.007	0.007	1.0	-	<0.002	-
0.006	0.001	6.0	0.66	0.80	0.8	0.020	0.012	1.7	0.006	0.005	1.2	0.013	0.006	2.1
0.003	0.0005	6.0	0.88	0.28	3.1	0.030	0.002	15.5	0.008	0.003	2.7	-	0.004	-
0.007	0.0002	10.1	0.77	0.58	1.8	0.030	0.003	17.4	0.009	0.011	1.8	0.016	0.01	1.1
0.004	0.0003	6.8	0.56	0.67	0.86	0.020	0.003	25.8	0.003	0.010	1.8	0.021	0.01	0.95
<0.003	-	-	0.03	-	-	<0.020	-	-	<0.01	-	-	-	-	-
<0.003	-	-	0.02	-	-	<0.020	-	-	<0.01	-	-	-	-	-

Table 38. Comparison of As species in Fish and Reference samples with the total As measured by neutron activation values in mg/g of wet weight tissue of fish and mg/g of dry weight of reference materials. INA = inorganic arsenic; MMA = monomethyl arsenic; DMA = dimethyl arsenic; NAA = neutron activation analysis.

	Speciation of As				Total As
Sample #	INA	MMA	DMA	Sum of Species	NAA
255	0.012	-[a]	-	0.012	3.4
263	0.008	0.041	-	0.049	1.7
116	0.006	-	-	0.006	1.2
276	-	-	0.041	0.041	2.3
273	0.103	-	-	0.103	1.4
202	0.005	-	-	0.005	3.2
240	0.032	0.004	0.048	0.084	4.4
34	0.013	-	-	0.013	1.7
95	0.003	-	-	0.003	11.1
DSHS-35	0.016	0.004	0.055	0.075	5.3
DSHS-28	0.015	-	0.020	0.035	5.8
188	0.001	-	-	0.001	4.2
145	0.005	-	-	0.005	2.9
276F[c]	0.020	-	0.074	0.094	1.9
116F	0.021	0.042	0.037	0.100	1.0
255F	0.045	0.012	0.076	0.133	--[i]
Orchard[d] Leaves	7.353	-	-	7.353	14 ± 2[f]
Bovine[d] Liver	0.025	0.017	-	0.042	(0.055)[g]
Metals[e] in Fish	0.099	0.008	-	0.017	2.43 ± 0.79[h]

a - Not detected
b - Sample lost
c - Fried fish
d - NBS - standard
e - EPA reference sample
f - NBS value
g - Uncertified NBS value
h - EPA value
i - Not measured

Table 39. Comparison of As concentrations using a method with mild $HNO_3/HClO_4$ digestion with those derived with a method using HCl digestion and a method using NAA. Concentrations are in mg/g of wet fish samples and mg/g of dry Reference samples. INA = inorganic arsenic; MMA = monomethyl arsenic; DMA = dimethyl arsenic; NAA = neutron activation analysis.

Sample #	INA	MMA	DMA	>DMA	TOTAL $HNO_3/HClO_4$	TOTAL HCl	TOTAL NAA
255	0.055	-[a]	0.64	-	0.695	0.012	3.8
263	0.233	-	0.31	-	0.543	0.049	1.7
116	0.103	-	0.286	-	0.389	0.006	1.2
276	1.339	-	0.451	-	1.79	0.041	2.3
276F[c]	0.087	-	0.228	-	0.315	0.094	1.9
116F	0.044	-	0.20	0.272	0.516	0.100	1.0
255F	0.782	-	0.622	2.66	4.064	0.133	--[b]
Orchard[d] Leaves	15.6	-	-	-	15.6	7.353	14 ± 2f
Metals[e] in Fish	1.309	-	0.206	-	1.515	0.017	2.43 ± 0.79g

a - Not detected
b - Not measured
c - Fried fish
d - NBS standard
e - EPA Reference sample
f - NBS value
g - EPA value

Table 40. Range, mean and standard deviation (SD) of trace metal and PCB values detected during Year 1. Values are expressed in ug/g of wet tissue. This table is reprinted from Landolt et al., 1985.

Species	Location	As (ppm) n	As Range	As Mean	As SD(s)	Cd (ppm) n	Cd Range	Cd Mean	Cd SD(s)	Pb (ppm) n	Pb Range	Pb Mean	Pb SD(s)	PCB (ppm) n	PCB Range	PCB Mean	PCB SD(s)
Sablefish	B	13	0.5-5.3	1.831	1.494	12	0.001-0.008	0.002	0.002	12	0.008-0.02	0.012	0.003	12	0.023-0.36	0.066	0.094
Hake	A	1	4.05	4.05	N.A.	1	0.001	0.001	N.A.	1	0.013	0.013	N.A.	0	--	--	--
Tomcod	C	2	0.82-4.02	2.42	2.263	2	0.004-0.005	0.0045	0.0007	2	0.028-0.03	0.029	0.0014	0	--	--	--
Striped perch	A	2	0.4-0.6	0.5	0.141	2	0.001-0.006	0.0035	0.0035	2	0.01-0.18	0.095	0.12	0	--	--	--
Rock sole	A	7	1.2-3.6	2.63	1.014	6	0.001	0.001	0	6	0.01-0.058	0.02	0.019	0	--	--	--
Rock sole	C	2	7.7-20.6	14.15	9.122	2	0.0006-0.001	0.0008	0.0003	2	0.006-0.1	0.053	0.067	0	--	--	--
Rock sole	D	6	5.0-16.3	8.473	4.206	5	0.0006-0.001	0.00092	0.00018	5	0.006-0.083	0.0252	0.0326	0	--	--	--
Rock sole	B	6	2.1-4.4	2.84	0.929	5	0.001	0.001	0	5	0.01-0.017	0.0114	0.00313	0	--	--	--
Rockfish	B	1	1.2	1.2	N.A.	1	0.003	0.003	N.A.	1	0.012	0.012	N.A.	0	--	--	--
Rockfish	A	4	1.1-2.4	1.76	0.534	3	0.001-0.018	0.007	0.0095	3	0.01-0.03	0.0187	0.01	0	--	--	--
Squid	A	5	4.4-22.1	9.04	7.503	5	0.002-0.25	0.0612	0.1064	5	0.002-0.012	0.0088	0.0039	5	0.024-0.215	0.1486	0.076
Squid	C	2	6.4-6.9	6.65	0.354	2	0.004-0.063	0.0335	0.0417	2	0.01	0.01	0	1	0.177	0.177	N.A.
English sole	A	6	1.0-3.9	1.883	1.042	5	0.0008-0.002	0.001	0.0005	5	0.006-0.01	0.008	0.0014	5	0.021-0.081	0.0422	0.0238
English sole	C	4	14.03-20.4	17.793	3.089	3	0.001-0.003	0.002	0.001	3	0.022-0.048	0.0357	0.013	4	0.068-0.19	0.12	0.051
English sole	D	5	2.1-11.1	6.38	3.233	5	0.0008-0.001	0.00096	0.00009	5	0.01-0.032	0.0204	0.01	4	0.039-0.259	0.113	0.1022
English sole	B	6	1.8-6.5	3.787	1.563	5	0.001-0.002	0.0012	0.000454		0.01-0.045	0.0195	0.017	5	0.02-0.047	0.0276	0.011
Pacific cod	B	1	2.0	2.0	N.A.	1	0.066	0.066	N.A.	1	0.015	0.015	N.A.	1	0.271	0.271	N.A.
Pacific cod	A	3	2.0-3.6	2.6	0.872	3	0.0008-0.001	0.00086	0.00012	3	0.01-0.2	0.076	0.1075	3	0.03-0.548	0.218	0.287
Pacific cod	E	4	3.6-12.6	6.85	3.951	4	0.001-0.002	0.0013	0.0005	4	0.008-0.01	0.0095	0.001	3	0.03-0.091	0.0563	0.0313
Pacific sanddab	C	1	20.7	20.7	N.A.	1	0.002	0.002	N.A.	1	0.047	0.047	N.A.	0	--	--	--
Buffalo sculpin	C	1	1.0	1.0	N.A.	1	0.002	0.002	N.A.	1	0.018	0.018	N.A.	0	--	--	--

Legend: Location =
A = Edmonds
B = Elliott Bay
C = Commencement Bay
D = Bremerton
E = Sinclair Inlet

Table 41. Results of Level 1 trace organics analysis. All results are in ng/g (ppb) wet weight.

SAMPLE ID	LOCATION CAUGHT	GRAM WET WEIGHT	% REC 2-Cl-Naph	%REC o,p-DDE	HEXACHLORO BUTADIENE	HEXACHLORO BENZENE	p,p'-DDE	o,p-DDD	p,p'-DDD/ o,p-DDT	p,p'-DDT	PCBs - SUM OF ISOMERIDS	ESTIMATED TOTAL
STARRY FLOUNDER												
195	CB	8 08	56 59	76 19	<DL	<DL	2 67	<DL	<DL	<DL	113	170
200	CB	8 08	0 00	77 09	<DL	<DL	3 21	<DL	1 78	<DL	69	104
199	CB	8 08	37 18	68 61	<DL	<DL	1 10	<DL	<DL	<DL	23	35
198	CB	8 08	81 12	95 58	0 80	1 02	6 42	1 06	<DL	2 21	175	263
96	SI	8 13	66 66	104 00	<DL	<DL	8 00	<DL	3 76	2 05	108	162
111	SI	8 08	87 67	98 49	<DL	<DL	2 81	0 77	<DL	<DL	345	518
105	SI	8 09	50 66	77 61	<DL	<DL	6 23	<DL	3 53	2 06	227	340
116	SI	7 51	83 39	92 33	<DL	<DL	15 60	1 19	<DL	2 05	196	295
112	BREM	18 00	31 53	18 23	<DL	<DL	2 36	<DL	1 72	<DL	64	96
ROCKFISH												
261	AGT	8 10	89 80	81 81	<DL	0 52	<DL	<DL	<DL	<DL	46	68
217	AGT	8 10	61 04	76 82	<DL	<DL	4 91	<DL	1 85	2 02	54	81
218	AGT	8 08	139 35	85 50	<DL	<DL	3 32	<DL	2 17	<DL	86	129
262	PO	8 08	83 41	54 00	<DL	0 61	3 27	<DL	3 27	<DL	56	83
206	CB	8 08	54 29	68 02	<DL	0 84	2 22	<DL	<DL	<DL	49	73
207	CB	8 08	123 60	81 50	0 82	7 68	<DL	<DL	<DL	1 97	60	91
204	CB	8 08	128 20	84 90	<DL	0 86	2 25	<DL	<DL	<DL	72	108
203	CB	8 08	108 50	86 09	<DL	<DL	1 21	<DL	1 85	<DL	48	73
233	EBDS	6 70	72 68	87 45	<DL	<DL	<DL	<DL	<DL	<DL	39	59
234	EBDS	8 08	87 51	77 30	<DL	<DL	<DL	<DL	<DL	<DL	132	199
32	EB#86	8 08	91 93	72 65	<DL	<DL	2 15	0 79	<DL	<DL	60	90
280	EDM	7 54	89 72	77 09	<DL	<DL	3 49	<DL	<DL	<DL	49	74
276	EDM	8 08	102 80	75 18	<DL	1 09	3 87	<DL	<DL	1 86	95	142
277	EDM	7 23	61 69	50 48	<DL	<DL	2 31	<DL	<DL	<DL	25	38
279	EDM	8 08	85 89	83 36	<DL	<DL	2 50	<DL	<DL	<DL	80	120
278	EDM	8 08	95 24	80 37	<DL	<DL	2 35	<DL	<DL	<DL	36	53
BLACK COD												
264	Pt Md	7 60	38 83	61 80	<DL	1 84	8 04	<DL	1 97	3 14	85	127
263	Pt Md	8 56	68 06	82 57	<DL	<DL	9 71	0 88	1 87	3 46	120	180
ROCK SOLE												
158	EDM	8 08	110 40	90 64	<DL	0 76	2 40	<DL	<DL	<DL	54	81
159	EDM	8 08	88 34	86 58	<DL	<DL	1 07	<DL	<DL	<DL	30	45
182	EDM	8 08	80 46	77 20	<DL	<DL	2 64	<DL	<DL	<DL	58	88
157	EDM	8 15	36 68	50 00	<DL	<DL	<DL	<DL	3 14	<DL	22	33
125	EB #91	8 08	89 33	76 80	1 14	0 89	5 38	<DL	5 36	<DL	166	249
126	EB #91	8 08	38 48	46 76	<DL	<DL	1 04	<DL	<DL	<DL	32	49
124	EB #91	6 70	65 91	69 01	<DL	<DL	2 88	<DL	<DL	<DL	138	208
123	EB #91	8 08	80 60	92 51	<DL	<DL	2 99	<DL	<DL	<DL	78	116
WALLEYE POLLOCK												
270	Pt Md	8 08	68 39	75 73	<DL	<DL	2 41	<DL	1 91	<DL	32	49
266	Pt Md	8 08	16 81	77 82	<DL	<DL	0 94	<DL	<DL	<DL	16	24
267	Pt Md	8 08	75 80	92 06	<DL	<DL	3 32	<DL	1 85	<DL	22	32
269	Pt Md	8 08	62 51	87 23	<DL	<DL	1 07	<DL	1 88	<DL	17	25
268	Pt Md	8 08	82 78	85 30	<DL	<DL	0 93	<DL	<DL	<DL	18	27
232	CB	8 40	78 81	64 27	<DL	1 95	<DL	<DL	<DL	<DL	13	19
231	CB	8 08	90 78	87 55	<DL	0 86	2 37	<DL	<DL	<DL	30	46
PACIFIC COD												
258	PO	6 19	106 70	102 60	<DL	<DL	10 60	<DL	<DL	<DL	209	314
259	PO	8 12	99 36	97 90	<DL	<DL	6 03	1 99	1 94	1 83	114	171
260	PO	6 00	27 40	55 50	<DL	<DL	4 90	5 70	7 80	<DL	456	684
257	PO	5 98	66 58	94 17	<DL	<DL	6 12	<DL	2 52	<DL	75	112
256	AGT	8 11	103 30	89 98	<DL	<DL	8 56	2 43	3 96	3 89	163	245
255	Pt Jf	8 09	52 55	93 04	<DL	<DL	8 32	2 39	4 70	4 42	189	283

Table 41. Continued.

SAMPLE ID	LOCATION CAUGHT	GRAM WET WEIGHT	% REC 2-Cl-Naph	%REC o,p-DDE	HEXACHLORO BUTADIENE	HEXACHLORO BENZENE	p,p'-DDE	o,p-DDD	p,p'-DDD/ o,p-DDT	p,p'-DDT	PCBs - SUM OF ISOMERIDS	ESTIMATED TOTAL
HAKE												
202	CB	8 08	63 72	73 38	0 83	1 61	5 06	<DL	1 83	7 47	95	143
DSHS 15	EB#57	8 11	85 39	81 95	<DL	<DL	3 69	0 75	1 99	3 45	120	180
DSHS 16	EB#57	8 08	165 90	80 08	<DL	1 53	3 54	<DL	3 40	1 86	90	135
281	Pt JI	8 08	8 13	70 51	<DL	<DL	2 31	<DL	1 78	<DL	41	62
282	Pt JI	8 08	94 12	91 29	1 79	0 66	1 02	<DL	1 81	1 91	50	75
283	Pt JI	8 08	50 81	90 22	<DL	<DL	1 03	<DL	1 87	<DL	45	68
284	Pt JI	8 08	102 70	94 60	<DL	1 23	2 76	<DL	<DL	<DL	72	108
193	EDM	18 00	140 00	95 89	<DL	0 68	<DL	<DL	2 64	<DL	74	111
TOMCOD												
274	Pt Md	8 14	59 07	64 62	<DL	<DL	2 54	<DL	3 52	<DL	33	49
273	Pt Md	8 14	84 31	85 54	<DL	<DL	1 06	<DL	<DL	<DL	57	86
275	Pt Md	8 13	101 80	83 16	<DL	<DL	3 88	<DL	4 18	3 17	88	132
16+43	CB	9.00	236 00	79 12	<DL	2 97	<DL	<DL	*	<DL	36	54
SQUID												
239	BREM	8 08	45 55	89 36	<DL	<DL	2 81	<DL	1 90	<DL	62	93
240	BREM	8 08	56 55	84 37	<DL	<DL	0 94	<DL	1 91	<DL	55	82
249	EB#70	8 08	86 51	93 39	<DL	0 96	1 22	<DL	1 89	<DL	48	72
245	EB#86	8 08	89 20	87 92	<DL	1 50	1 10	<DL	<DL	<DL	41	61
243	EB#86	8 16	71 15	96 29	<DL	1 64	3 49	<DL	7 44	<DL	153	230
24	EDM	8 14	46 34	88 40	<DL	<DL	2 31	<DL	1 77	<DL	38	57
28	EDM	8 08	114 10	103 20	<DL	<DL	1 02	<DL	1 83	<DL	50	74

SAMPLE ID	SPECIES	LOCATION CAUGHT

LOCATION CODE KEY:
"CB" = COMMENCEMENT BAY
"BREM" = BREM 1ST ST DOCK
"EB#--" = ELLIOTT BAY PIER #
"Pt Md" = POINT MADISON
"EDM"=EDMONDS FISH PIER
"Pt JI" = POINT JEFFERSON
"P O" = PORT ORCHARD
"AGT" = AGATE PASS BRIDGE
"EB DS"= ELLIOTT BAY, OFF DENNY WAY CSO
"SI"= SINCLAIR INLET

*merged with o,p DDT Spike

Table 42. Organic toxicant levels in samples of fish analyzed raw and after cooking (frying). All results are in ng/g (ppb) wet weight.

	Sample Number	%RECOVERY 2-CL-NAPH	%RECOVERY o,p-DDE	NG/G WET WEIGHT: hexachloro butadiene	hexachloro benzene	p,p'-DDE	o,p-DDD	p,p-DDD + o,p-DDT	p,p'-DDT	individual PCB isomerids: Cl-3-Ø2	Cl-4-Ø2	Cl-5-Ø2	Cl-6-Ø2	Cl-7-Ø2	Cl-8-Ø2	Cl-9-Ø2	Cl-10-Ø2
INTERNAL STANDARD QUANTITATION:																	
STARRY FLOUNDER																	
Uncooked	116	83.39	92.33	<DL	<DL	15.60	1.19	<DL	2.05	<DL	8.20	<DL	208.28	14.95	10.97	7.30	<DL
Cooked	116-C	104.40	94.07	<DL	<DL	5.27	<DL	2.39	<DL	<DL	<DL	<DL	41.59	3.64	<DL	3.78	1.53
ROCKFISH																	
Uncooked	276	102.80	75.18	<DL	1.09	3.87	<DL	<DL	1.86	1.05	2.08	<DL	19.42	1.49	<DL	<DL	<DL
Cooked	276-C	62.76	48.56	<DL	<DL	0.94	<DL	<DL	<DL	<QL	0.52	<DL	2.59	<DL	<DL	0.46	<QL
PACIFIC COD																	
Uncooked	260	27.40	55.50	<DL	<DL	4.90	5.70	7.80	<DL	<DL	3.10	2.90	15.90	1.62	1.98	<DL	<DL
Cooked	260-C	65.46	77.19	<DL	<QL	1.56	<DL	1.89	<DL	<QL	0.98	<DL	6.42	<DL	<DL	0.96	0.31
WALLEYE POLLOCK																	
Uncooked	231	90.78	87.55	<DL	0.86	2.37	<DL	<DL	<DL	<DL	3.25	<DL	7.30	0.66	0.94	<DL	<DL
Cooked	231-C	83.20	67.96	0.85	<DL	<DL	<DL	<DL	<DL	<DL	0.65	<DL	1.80	<DL	<DL	4.28	1.42
TOMCOD																	
Uncooked	275	101.80	83.16	<DL	<DL	1.07	<DL	1.88	<DL	1.68	3.26	<DL	9.33	0.69	<DL	<DL	<DL
Cooked	275-C	66.25	61.97	<DL	<DL	2.04	<DL	6.79	3.26	0.99	3.71	<DL	11.00	<DL	2.21	<DL	8.55
ROCKSOLE																	
Uncooked	125	89.33	76.80	1.14	0.89	5.38	0.00	5.36	0.00	0.65	4.78	0.00	33.17	2.07	1.47	<DL	25.67
Cooked	125-C	111.98	88.80	<DL	<DL	1.75	<DL	2.05	<DL	<QL	1.52	<DL	8.91	0.73	<DL	<DL	1.36
BLACKCOD																	
Uncooked	263	68.06	82.57	<DL	<DL	9.71	0.88	1.87	3.46	0.55	9.17	<DL	30.64	2.26	1.28	<DL	<DL
Cooked	263-C	102.09	74.43	<DL	<QL	2.82	<DL	1.93	<DL	<QL	1.91	<DL	6.38	<DL	<DL	<DL	0.40
SQUID																	
Uncooked	243	71.15	96.29	<DL	1.64	3.49	<DL	7.44	<DL	1.85	43.06	<DL	26.70	1.95	0.99	<DL	<DL
Cooked	243-C	57.51	89.17	<DL	<DL	1.23	<DL	<DL	<DL	<QL	1.34	<DL	7.15	<DL	<DL	<DL	<DL
HAKE																	
Uncooked	202	63.72	73.38	0.83	1.61	5.06	<DL	1.83	7.47	2.47	7.14	<DL	18.45	<DL	<DL	<DL	<DL
Cooked	202-C	61.26	43.42	25.05	0.30	1.26	<DL	<DL	<DL	<QL	0.95	<DL	3.01	<DL	<DL	<DL	1.10
CORRECTION TO 100% RECOVERY:																	
STARRY FLOUNDER																	
Uncooked	116			<DL	<DL	16.90	1.29	<DL	2.22	<DL	8.88	<DL	225.58	16.19	11.88	7.91	<DL
Cooked	116-C			<DL	<DL	5.60	<DL	2.54	<DL	<DL	<DL	<DL	44.21	3.87	<DL	4.02	1.63
ROCKFISH																	
Uncooked	276			<DL	1.06	5.15	<DL	<DL	2.47	1.40	2.77	<DL	25.83	1.98	<DL	<DL	<DL
Cooked	276-C			<DL	<DL	1.94	<DL	<DL	<DL	<DL	1.07	<DL	5.34	<DL	<DL	0.94	<DL
PACIFIC COD																	
Uncooked	260			<DL	<DL	8.83	10.27	14.05	<DL	<DL	5.59	5.23	28.65	2.92	3.57	<DL	<DL
Cooked	260-C			<DL	<DL	2.02	<DL	2.45	<DL	<DL	1.28	<DL	8.32	<DL	<DL	1.24	0.41
WALLEYE POLLOCK																	
Uncooked	231			<DL	0.95	2.71	<DL	<DL	<DL	<DL	3.71	<DL	8.34	0.75	1.07	<DL	<DL
Cooked	231-C			1.02	<DL	<DL	<DL	<DL	<DL	<DL	0.96	<DL	2.65	<DL	<DL	6.30	2.09
TOMCOD																	
Uncooked	275			<DL	<DL	1.29	<DL	2.26	<DL	2.02	3.92	<DL	11.22	0.83	<DL	<DL	<DL
Cooked	275-C			<DL	<DL	3.29	<DL	10.96	5.26	1.60	5.99	<DL	17.75	<DL	3.56	<DL	13.79
ROCKSOLE																	
Uncooked	125			1.28	1.00	7.01	0.00	6.98	0.00	0.85	6.22	0.00	43.19	2.70	1.91	<DL	33.42
Cooked	125-C			<DL	<DL	1.98	<DL	2.31	<DL	<DL	1.72	<DL	10.04	0.82	<DL	<DL	1.53
BLACKCOD																	
Uncooked	263			<DL	<DL	11.76	1.07	2.26	4.19	0.67	11.11	<DL	37.11	2.74	1.55	<DL	<DL
Cooked	263-C			<DL	<DL	3.78	<DL	2.60	<DL	<DL	2.56	<DL	8.58	<DL	<DL	<DL	0.54
SQUID																	
Uncooked	243			<DL	2.30	3.62	<DL	7.73	<DL	1.92	44.72	<DL	27.73	2.03	1.03	<DL	<DL
Cooked	243-C			<DL	<DL	1.38	<DL	<DL	<DL	<DL	1.51	<DL	8.02	<DL	<DL	<DL	<DL
HAKE																	
Uncooked	202			1.30	2.53	6.90	<DL	2.49	10.18	3.37	9.73	<DL	25.14	<DL	<DL	<DL	<DL
Cooked	202-C			40.89	0.48	2.90	<DL	<DL	<DL	<DL	2.19	<DL	6.92	<DL	<DL	<DL	2.53

Table 43. Level 2 polynucleararomatic hydrocarbon analysis results. All results are in ng/g (ppb) wet weight.

SAMPLE:	ROCK SOLE		BLACK COD		STARRY FLOUNDER		HAKE		PACIFIC COD		PACIFIC COD		ROCK FISH		SQUID		TOM COD		POLLOCK	
	GC/MS	HPLC	GC/MS	HPLC	GC/MS	HPLC	GC/MS	HPLC	GC/MS	HPLC	GC/MS	HPLC	GC/MS	HPLC	GC/MS	HPLC	GC/MS	HPLC	GC/MS	HPLC
SAMPLE WEIGHT, g	4.84		5.13		3.76		4.84		6.19		1.04		8.08		8.16		8.13		8.08	
SPIKE RECOVERY (%)	93.6	88	117.1	67	25.2	48	79.3	75	45.7	57	30.7	58	*	67	52.1	33	50.6	34	96.4	75
DETECTION LIMIT, ppb	0.5		0.5		0.7		0.5		0.4		2.4		0.3		0.3		0.3		0.3	
QUANTITATION LIMIT, ppb	5.2		4.9		6.6		5.2		4		24		3.1		3.1		3.1		3.1	
NAPHTHALENE	<DL				<DL						<DL		<DL							
2-METHYL NAPHTHALENE	<DL				<DL								<DL						<DL	
1-METHYL NAPHTHALENE							<DL						<DL						<DL	
2,6-DIMETHYL NAPHTHALENE																				
ACENAPHTHENE							<DL													
FLUORENE																				
PHENANTHRENE					8.3		7.5		4.3	3.1	<DL		5.6		6.4		3.1			
ANTHRACENE															<DL					
1-METHYL PHENANTHRENE													<DL		<DL		<DL			
FLUORANTHENE	<DL	18.7	<DL		<DL		<DL		<DL	23.5		31.5	<DL		12.5	0.5	<DL		<DL	
PYRENE	<DL	0.1	<DL		<DL		<DL		<DL	25.1			<DL		10.2	3.8	<DL		<DL	
BENZ[a]ANTHRACENE		3.4	<DL	3		2.7		2.5				4		8.5		2.9		2.3	<DL	1.6
CHRYSENE				0.5		0.2						0.5		0.6		1.3		0.3	<DL	0.1
BENZO[e]PYRENE		0.6				0.6				1				3.3		2.1		0.8		
BENZO[a]PYRENE		*		12.3		1.7		4.1						2.8		*		*		*
PERYLENE		*		*		*		*		*		*		*		*		*		*
DIBENZ[a,h]ANTHRACENE		*						*						12.9		1.4				

BLANK VALUES ARE < DL
* INDICATES MERGED PEAKS

Table 44. Samples available for analysis.

Species	Number of Samples Available for Analysis As	PCB
Starry flounder	8	9
Rockfish	20	16
Sablefish	15	14
Rock sole	28	8
Walleye pollock	7	7
Pacific cod	13	12
Hake	8	8
Tomcod	5	4
Squid	14	13
English sole, Flathead sole	22	18
Total	140	109

Site	As	PCB
Commencement Bay	21	17
Sinclair Inlet	19	11
Bremerton	2	3
Agate Pass	4	4
Port Orchard	5	5
Elliott Bay	38	30
Edmonds	36	24
Pt. Madison	10	10
Pt. Jefferson	5	5
Total	140	109

Table 45. Median arsenic levels by species and year of study. Median arsenic levels (ppm).

Species	Year 1 Median	Year 1 n	Year 2 Median	Year 2 n	Overall Median	Overall n
Starry Flounder	--	--	1.45	8	1.45	8
Rockfish	1.7	5	1.90	15	1.77	20
Sablefish	1.3	13	1.25	2	1.30	15
Rock sole	3.5	20	3.40	8	3.45	28
Walleye pollock	--	--	2.50	7	2.50	7
Pacific cod	3.6	7	3.75	6	3.60	13
Hake	4.05	1	1.80	7	2.15	8
Tomcod	2.42	2	1.10	3	1.10	5
Squid	6.40	7	3.60	7	5.00	14
English/flathead sole	4.05	22	--	--	4.05	22
Overall	3.60	77	2.20	63	2.60	140

Table 46. Median arsenic levels by site and year of study.

Site	Median Arsenic Levels (ppm) Year 1 Median	n	Year 2 Median	n	Overall Median	n
Commencement Bay	14.03	11	2.25	10	6.40	21
Sinclair Inlet	5.90	15	1.75	4	5.70	19
Bremerton	--	--	2.85	2	2.85	2
Agate Pass	--	--	2.25	4	2.25	4
Port Orchard	--	--	4.00	5	4.00	5
Elliott Bay	2.25	26	2.45	12	2.35	38
Edmonds	2.70	25	2.30	11	2.55	36
Port Madison	--	--	1.40	10	1.40	10
Point Jefferson	--	--	1.80	5	1.80	5

Table 47. Median PCB levels by species and year of study.

Species	Median PCB Level (ppb) Year 1 Median	n	Year 2 Median	n	Overall Median	n
Starry Flounder	--	--	170.0	9	170.0	9
Rockfish	--	--	82.0	16	82.0	16
Sablefish	41.5	12	153.5	2	42.0	15
Rock sole	--	--	84.5	8	84.5	8
Walleye pollock	--	--	32.0	7	32.0	7
Pacific cod	69.5	6	264.0	6	208.0	12
Hake	--	--	109.5	8	109.5	8
Tomcod	--	--	70.0	4	70.0	4
Squid	176.0	6	74.0	7	93.0	13
English/flathead sole	47.0	18	--	--	47.0	18
Overall	46.5	42	91.0	67	81.0	107

Table 48. Median PCB levels by site and year of study.

Site	Median PCB Level (ppb) Year 1 Median	n	Year 2 Median	n	Overall Median	n
Commencement Bay	115.0	5	97.5	12	106.0	17
Sinclair Inlet	48.0	7	317.5	4	100.0	11
Bremerton	--	--	93.0	3	93.0	3
Agate Pass	--	--	105.0	4	105.0	4
Port Orchard	--	--	171.0	5	171.0	5
Elliott Bay	35.5	18	150.5	12	48.0	30
Edmonds	64.5	12	74.0	12	74.0	24
Port Madison	--	--	49.0	10	49.0	10
Point Jefferson	--	--	75.0	5	75.0	5

Table 49. Multiple regression analysis of log (PCB) concentration on site, species and year. See text for explanation of analysis.

Variable	Regression Estimate	Standard Error
Intercept	4.82	.44
Sinclair Inlet	- .05	.31
Bremerton	- .79	.49
Agate Pass	- .14	.44
Port Orchard	.03	.47
Elliott Bay	- .42	.27
Edmonds	- .49	.27
Port Madison	- .17	.41
Point Jefferson	- .55	.47
Rockfish	- .55	.35
Sablefish	- .53	.49
Rock sole	- .34	.41
Walleye pollock	-1.40	.49**
Pacific cod	.17	.43
Hake	- .17	.45
Tomcod	- .82	.55
Squid	.06	.39
English/flathead sole	- .61	.44
Year (2)	.44	.32

** Significant at $p<0.01$ level. All other slopes not significant.

Table 50. Daily fish consumption rates for boating anglers, expressed as geometric mean gm/person/day. Rates apply only to the fishing season.

Species	Commencement Bay	Elliott Bay	Combined
Pacific Cod	18.9	7.4	16.6
Pacific Hake	6.7	2.9	6.0
Walleye Pollock	1.3	--	1.3
Unidentified Cod	4.6	--	4.6
Striped Perch	--	3.6	3.6
Unidentified Perch	--	35.7	35.7
Rock Sole	5.9	3.8	5.4
Dover Sole	4.3	--	4.3
Pacific Sanddab	2.9	--	2.9
Unidentified Flatfish	20.1	16.9	19.0
Copper Rockfish	5.9	7.9	6.8
Brown Rockfish	9.9	--	9.9
Quillback Rockfish	8.6	--	8.6
Black Rockfish	10.7	NA	10.7
Redstripe Rockfish	--	10.1	10.1
Unidentified Rockfish	14.3	7.3	12.1
Pacific Staghorn Sculpin	3.7	--	3.7
Unidentified Sculpins	5.0	--	5.0
Kelp Greenling	12.7	--	12.7
Lingcod	119.0	26.0	47.8
Sablefish	17.2	29.7	20.7
Dogfish Shark	60.7	52.1	55.4
Coho Salmon	18.1	31.0	21.6
King Salmon	38.5	53.9	51.7
Unidentified Salmon	17.9	--	17.9
Steelhead Trout	14.9	--	14.9

Table 51. Estimated 5th, 50th and 95th percentile tissue concentrations (ppm) of arsenic by species.

Species	Percentile level of As (ppm) 5th	50th	95th
Starry Flounder	.5	1.4	2.6
Rockfish	.8	1.8	2.8
Sablefish	.5	1.3	5.0
Rock Sole	1.2	3.4	19.7
Walleye Pollock	1.1	2.5	11.0
Pacific Cod	.89	3.6	12.1
Hake	.5	2.2	4.0
Tomcod	.5	1.1	4.0
Squid	1.3	5.0	20.9
English/flathead Sole	1.0	4.0	20.5
Overall	.6	2.6	16.4

Table 52. Estimated 5th, 50th and 95th percentile tissue concentrations (ppm) of arsenic by site.

Site	Percentile level of As (ppm) 5th	50th	95th
Commencement Bay	.7	6.4	20.6
Sinclair Inlet	1.4	5.7	18.1
Bremerton	1.3	2.8	4.4
Agate Pass	1.1	2.2	3.5
Port Orchard	.7	4.0	9.4
Elliott Bay	.5	2.4	9.7
Edmonds	1.0	2.6	7.7
Port Madison	.5	1.4	4.4
Point Jefferson	1.0	1.8	3.5
Overall	.6	2.6	16.4

Table 53. Estimated range of arsenic doses (ug) per person per day of consumption. Values are based on observed mean catch and upon As values from tissue analysis. Differences among species are due to different rates of consumption of fish. Fish consumption rates from Table 63 on Year 1 report.

Species	Assumed Fish Consumption rates gms/person/day	Estimated aresenic dose (ug) Percentile bound 5th	Median	95th
Sable fish	30	30	90	600
Pacific cod	27	27	81	540
Squid	39	39	117	780
English sole	11	11	33	220
Overall mean for nine species in Table 35	11	11	33	220

Table 54. Estimated range of PCB doses (ug) per person per day. Values are based on observed mean catch and upon PCB values/m tissue analysis. Difference among species are due to different rates of consumption of fish. Fish comsumption rates are from Table 63 of Year 1 report.

Species	Assumed Consumption rate: gms/person/day	Estimated PCB Dose (ug) Percentile Bound 5th	Median	95th
Sable fish	30	.7	2.4	9.4
Pacific cod	27	.6	2.2	8.5
Squid	39	.9	3.2	12.0
English sole	11	.3	.9	3.5
Overall mean for nine species in Table 41	11	.3	.9	3.5

Table 55. Results of trace metal analyses of eight samples performed in Year 1 and again in Year 2. Values are in ppm (ug/g) wet weight.

Sample #	As Yr1	As Yr2	Cd Yr1	Cd Yr2	Pb Yr1	Pb Yr2
32	1.2	1.3	0.003	0.01	<0.012	0.004
123	2.1	3.5	<0.001	0.02	<0.01	<0.002
124	4.4	4.3	<0.001	0.006	0.017	0.006
125	2.6	2.4	<0.001	0.002	<0.01	0.002
126	2.2	3.3	<0.001	0.002	<0.01	0.003
157	1.2	2.2	<0.001	0.004	0.015	0.008
158	3.6	3.8	<0.001	0.003	<0.01	<0.002
159	3.1	3.2	<0.001	0.004	<0.058	<0.002

Table 56. Results of PCB analyses performed in Year 1 and repeated in Year 2. Values are in ppb (ng/g) wet weight.

SPECIES	SAMPLE ID	YEAR	IUPAC ISOMERID NUMBER: (ppb) 101	118	128	138	153	170	180	183	194	SUM OF ISOMERIDS	TOTAL PCBs
Pacific Cod	59	1	18.3	53.8	13.5	104.1	90.2	24.7	66.7	9.8	5.5	386.6	271.0
	"	2	19.2	24.7	5.1	83.4	116.2	16.7	53.3	10.5	2.3	389.9	584.7
	DSHS-2	1	1.9	5.5	1.3	5.1	5.6	1.1	1.9	0.6	0.7	23.6	30.0
	"	2	1.0	1.5	-	2.3	6.1	1.1	1.5	-	1.0	18.2	27.3
Black Cod	DSHS-31	1	18.0	22.7	7.2	21.9	28.3	6.8	14.6	3.1	3.8	126.4	360.0
	"	2	16.0	10.0	-	16.6	33.6	7.1	8.4	2.2	1.7	130.2	208.8
	DSHS-36	1	1.2	2.2	0.7	2.1	2.3	0.6	1.1	0.2	0.6	10.9	23.0
	"	2	2.2	-	-	-	6.2(m)	-	-	-	-	11.4	17.1
Squid	42	1	22.3	31.7	3.2	32.2	32.5	3.5	9.7	2.7	1.3	139.1	215.0
	"	2	15.6	12.9	1.5	18.5	37.8	11.3	5.6	2.9	-	145.2	217.8
	45	1	2.4	3.5	1.2	3.0	3.6	0.4	1.3	0.3	0.3	16.0	24.0
	"	2	3.2	1.8	-	1.8	13.4(m)	-	-	-	-	20.2	30.3

(m) indicates merged GC/ECD peak

Table 57. Selected element concentrations (ppm, wet weight) from previous studies on Puget Sound fish muscle tissues.

Element		As	Se	Zn	Ag	Cu	Pb	Cd	Hg	Reference
Species	Site									
Rock sole	CB	11.6	0.17	8.0	-	.4	0.52	.008	-	Gahler, 1982
Rock sole	EB	2.0	0.38	8.1	-	.3	0.05	.004	-	Stober, 1984
Sole	EB	6.1	0.49	5.0	.003	.57	0.02	-	.120	Romberg, 1984
Sole	EB-CSO	4.4	0.41	5.1	.002	.52	0.02	.003	.068	Romberg, 1984
Cod	EB	2.3	0.45	3.8	.005	.89	0.03	.006	.180	Romberg, 1984
Cod	EB-CSO	0.9	0.40	4.2	.002	.64	0.02	-	.170	Romberg, 1984
Eng.sole	CB-PD	<6.3	-	3.9	<.002	.10	0.16	<.01	<.053	Tetra Tech, 1985
Eng.sole	CB-CW	3.0	-	3.6	.009	.14	0.35	<.03	<.045	Tetra Tech, 1985
FDA Marketbasket avg. conc for fish,poultry,meat		0.20	0.20	31.1	-	-	0.04	.008	.012	Gartrell, 1985
Acceptable Daily Intake(mcg/day)		-	50-200	15000	-	-	429	57-72	43	Gartrell, 1985
USFDA Seafood Tissue Standard		-	-	-	-	-	7.0	0.5	1.0	Gartrell, 1985

CB=Commencement Bay EB=Elliott Bay CSO=Combined Sewage Overflow Site
PD=Point Defiance CW=City Waterway

Table 58. Mercury concentrations (ppm, wet weight) in edible fish tissues from previous studies in Puget Sound.

Species	Site	n	Mean	Range	Ref.
English sole	Comm. Bay	74	0.059		Tetra Tech, 1985
English sole	Carr Inlet	10	<0.055		Tetra Tech, 1985
Rockfish	Comm. Bay	1	0.030		Gahler, 1982
Tomcod	Comm. Bay	3	0.030		Gahler, 1982
Tomcod	Discovery Bay	1	0.040		Gahler, 1982
Pacific hake	Comm. Bay	10	0.040	0.01-0.07	Gahler, 1982
Starry flounder	Comm. Bay	1	0.040		Gahler, 1982
Walleye pollock	Comm. Bay	10	0.060	0.040-0.08	Gahler, 1982
Walleye pollock	Discovery bay	5	0.080		Gahler, 1982
Rock sole	Comm. Bay	5	0.040	0.020-0.05	Gahler, 1982
Pacific cod	Comm. Bay	3	0.060	0.04-0.12	Gahler, 1982

able 59. Arsenic concentrations (ppm, wet weight) in edible fish muscle tissues from previous Puget Sound studies.

Species	Site	n	Mean	Range	Reference
English sole	Comm. Bay	74	3.3	<1.5-6.7	Tetra Tech, 1985
English sole	Discovery Bay	5	3.2		Gahler, 1982
English sole	Carr Inlet	10	7.9		Tetra Tech, 1985
Rockfish	Comm. Bay	1	0.55		Gahler, 1982
Tomcod	Comm. Bay	3	0.70		Gahler, 1982
Tomcod	Discovery Bay	1	3.4		Gahler, 1982
Pacific hake	Comm. Bay	10	0.59		Gahler, 1982
Starry flounder	Comm. Bay	1	2.1		Gahler, 1982
Starry flounder	Discovery Bay	1	0.7		Gahler, 1982
Walleye pollock	Comm. Bay	15	1.35	0.77-1.9	Gahler, 1982
Walleye pollock	Discovery Bay	5	1.7		Gahler, 1982
Rock sole	Comm. Bay	5	11.6	4.6-16.2	Gahler, 1982
Pacific cod	Comm. Bay	4	2.5	1.8-3.1	Malins, 1982

Table 60. Summary of trace organics results from previously conducted studies.

YEAR SAMPLED	LOCATION SAMPLED	SPECIES SAMPLED	RESULTS: (PPB wet weight) NUMBER	HEXACHLOROBUTADIENE	HEXACHLOROBENZENE	DDT + DDE + DDD	PCBs	REFERENCE
1979	COMMENCEMENT BAY	ENGLISH SOLE	3	2 - 42	6 - 28		608 - 644	MALINS, et.al., 1980
		CRAB	2	<0.1	2 - 11		12 - 84	
1978-81	COMMENCEMENT BAY	ENGLISH SOLE	5				160 - 850	MALINS, et.al., 1982
		SALMON	COMPOSITE				22 - 57	
		COD	COMPOSITE				14 - 46	
	ELLIOTT BAY	ENGLISH SOLE	5				270 -2100	
		SALMON	5				140 - 150	
		COD	3				14 - 38	
	"REFERENCE AREAS"	SALMON	5				29 - 130	
		COD	3				7 - 14	
1981-82	COMMENCEMENT BAY (4 SITES)	BOTTOM FISH (5 SPECIES)	31	<1	<1 - 15	<1 - 49	54 -1030	GAHLER,et.al., 1982
	DISCOVERY BAY	MIXED FISH (4 SPECIES)	18	<1	<1 - 15	<1 - 16	10 -1120	
		OFF-BOTTOM FISH (4 SPECIES)	37	<1	<1		10 - 530	
1983-84	ELLIOTT BAY "CENTRAL BASIN"	SOLE	6			1.6(m) - 7	32(m)-290	GALVIN,et.al, 1984
		COD	2			2 - 6	179 - 300	
		SALMON	5			8(m) - 13	146(m)-1350	

(m) indicates mean values from several assays

Table 61. Arsenic concentrations (ppm, wet weight) of edible muscle tissues from fishes and squid from Europe.

Species	concentration	Ref. (NAS, 1982)
Squid	6.5	
Cod	2.2	
Squid(raw)	0.8-7.5	
Squid(cooked)	0.4-3.3	
Cod	0.4-0.8	
Sole	5.2	
Flounder	<1.0	

Table 62. Total PCB concentrations (ppm, wet weight) of edible muscle tissues from fishes in various marine waterways of the United States (Gadbois, 1983).

Species	Site	n	Mean	Range
Red hake	New York Bight	8	0.10	0.03-0.34
Atlantic tomcod	Hudson river, NY	1	0.10	
Silver hake	San Luis Pass, TX	1	0.03	
Striped bass	Hudson River, NY	5	1.5	1.1-2.1
Striped bass	Coos River, OR	28	0.27	0.04-1.86
Weakfish	Sandy Hook, NJ	6	0.23	0.02-0.12
White perch	Hudson River, NY	5	10.2	1.9-22.0
Bluefish	SandyHook, NJ	1	1.2	
Winter flounder	New York Bight	13	0.23	0.060-0.56
Windowpane flounder	NY Bight	10	0.21	0.040-0.63
Spanish mackeral	East Bay, Fl	2	0.90	0.89-0.92
Pacific sanddab	Catalina, Ca	2	0.02	0.02-0.02
Summer flounder	Cape May,NJ	2	0.02	0.02-0.02
Striped mullet	Mobile Bay, Ala	5	0.34	0.04-0.85
Gulf menhaden	Galveston, TX	4	0.49	0.43-0.54

Table 63. Average daily intake (micrograms/day) of selected elements determined by the U.S. FDA Total Diet Study (Gartell et al., 1985).

Element	Acceptable intake limit	1977	1978	1979	1980
Arsenic	---	72	59	62	63
Cadmium	57-72	37	31	32	28
Lead	429	79	95	82	83
Mercury	43	6	3	5	5
Selenium	50-200	110	156	152	141
Zinc	15000	18000	17000	18000	18000

Table 64. Comparative concentrations of PCBs in human tissues (From Cordle, 1978).

SUBJECTS	PCBs in blood, (fat basis) mg/kg	
	Average	Range
Workers in capacitor factory	313	100-700
Persons handling PCBs in analytical labs	53	33-71
Persons without any special exposure to PCBs	5	3.6-9.9

Table 65. Comparative fish consumption rates. Average seafood consumption rates in the U.S. may vary from about 6 to 100 g/day depending on the region and the local population studied. A summary of consumption rates from various studies is listed below.

Study	Group	Average Consumption Rates (grams/person/day)	Location
Puffer et al.	Los Angeles Anglers		
" "	Age <17	27.2	Los Angeles, CA
" "	Ages 18-40	32.5	" "
" "	Ages 41-65	39.0	" "
" "	Age >65	113.0	" "
" "	Average of all ages	36.9	" "
Humphrey	Lake Michigan Anglers	48.6	Lake Michigan
FAO-UN	General Population	84.0	Japan
NMFS	General Population	18.7	United States
USEPA	Estimated	6.5	United States
Landolt et al.	Puget Sound Anglers	11-40	Puget Sound, WA

Appendix A

FISHING SITE DESCRIPTION

Site _____ Location _____

Interviewer _____ Interview nos. _____ - _____

Date ___/___/___ Time _____A.M./P.M. Day of week _____

Tide: High/Low Time _____A.M./P.M. Peak high/low _____ (ft.)

Weather: Temperature (°F) _____ Rain/Snow/Wind/Fog/Clear/Partly cloudy/Overcast

Comments _____

****

No. of anglers _____ % regulars _____

Predominant group type (families, friends, alone, etc.) _____

Predominant race _____ Predominant age _____

What are most people fishing for? _____

Fishing preference:

Tide _____

Time of day _____

Day of week _____

Season/Species _____

Weather _____

Other _____

Comments:

APPENDIX B

FIELD SURVEY FORM

Date: ___/___/___ Day . . . . . Time: ___:___ am/pm Interview # _____

Site: . . . . . Location: . . . . . Surveyor: . . . . . .

Mode: 1. Dock 2. Beach 3. Bridge 4. Boat 5. . . . . (_)

Race: . . . . . Sex: Male/Female Age: (____)

Previous interview? Yes/No Interview status: 1. Agree 2. Disagree 3. Language barrier

Group type: 1. Alone 2. Family 3. Friends 4. Both 2&3 (_) Group size (___) Person # ___

What are you trying for? . . . . . (_____)

May I examine your catch? 1. Nothing caught 2. Yes 3. No 4. Not available (_)

****

WEIGH FISH ONLY IF GREATER THAN 99 cm.

Species	No.	Length (cm) or Weight (kg)	Will eat?	Parts consumed*	Preparation method**
. . . . .	(___)	_____	. . .(_)	. . . . . (_)	. . . . . .(_)
. . . . .	(___)	_____	. . .(_)	. . . . . (_)	. . . . . .(_)
. . . . .	(___)	_____	. . .(_)	. . . . . (_)	. . . . . .(_)
. . . . .	(___)	_____	. . .(_)	. . . . . (_)	. . . . . .(_)
. . . . .	(___)	_____	. . .(_)	. . . . . (_)	. . . . . .(_)
. . . . .	(___)	_____	. . .(_)	. . . . . (_)	. . . . . .(_)
. . . . .	(___)	_____	. . .(_)	. . . . . (_)	. . . . . .(_)

* 1. Entire 2. Muscle 3. Skin 4. Entrails 5. Broth 6. Other

** 1. Raw 2. Boil 3. Bake 4. Fry 5. Smoke 6. BBQ 7. Steam 8. Broil 0. Stir-fry

****

How often do you fish here? (___1st) (___2nd) (___per week) (___per month) (___per year)

When did you last use this area? (___days) How long were you out? (___hrs,___min)

When did you last catch and eat something from this area? (___days)

	Species	No.	Species	No.	Species	No.
What did you get?	. . . . .	(__)	. . . . .	(__)	. . . . .	(__)

How many people will eat these fish? (_____)

City of residence: . . . . . .(____) Zip code: (_____)

Country of origin: . . . . . (_____)

How did you get here? 1. Car 2. City bus 3. Walked 4. Bicycle 5. . . . . (__)

What time did you arrive? ___:___am/pm When will you leave? ___:___am/pm

Occupation: (_____) Currently employed? Yes/No Years of schooling (____)

APPENDIX C

Evaluation Criteria For Additional Chemical Analyses

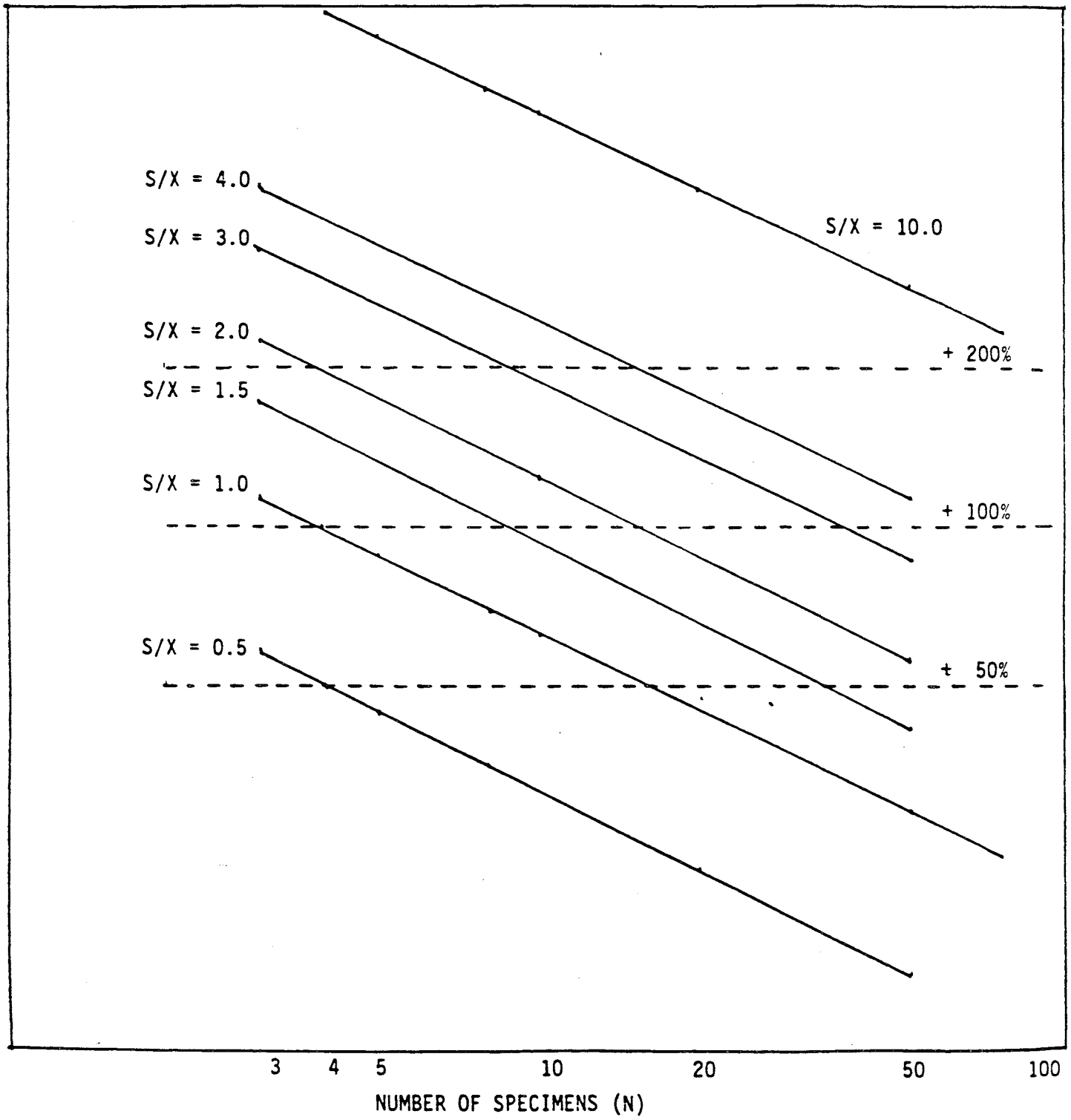


Figure C-1 Precision of dose as a function of sample size and variability of contaminant level.

Table C-1: PCB Concentrations - Statistical Summary (Selected Species)

Species	Location	N	$\bar{x}$	s	$\bar{s}/x$	$\%CI/\bar{x}$	"worst case" $\bar{x}$ + CI
Salmon	Soundwide	17	193	328	1.7	81	339 ppb
Cod (all species)	Soundwide	28	68.5	94.8	1.4	56	107 ppb
Pollock	Soundwide	20	80	126	1.6	69	135 ppb
Pollock	Commencement Bay	15	84	134	1.6	81	152 ppb
Pollock	Hylebos WW	5	170	214	1.3	110	357 ppb
English sole	Soundwide	29	278	298	1.1	39.1	386 ppb
	Commencement Bay	19	377	308	0.82	36.7	515 ppb
	Hylebos WW	5	552	391	0.71	62	894.2 ppb

APPENDIX D
Fish sample data for Year 2.

SAMPLE #	FISH SPECIES	COLLECTION DATE	SITE & LOCATION	EXTRACTED WT. (GRAMS)	RESIDUE WEIGHT (GRAMS)	DILUTION FACTOR	WEIGHT % EXTRACTED	LENGTH (CM)	WEIGHT GRAMS	DRY/WET RATIO
24	SQUID	11/12/84	EFP	10.08	0.0129	20	2.56	13.0	65.4	0.2*
28	SQUID	11/12/84	EFP	10.00	0.0162	20	3.24	13.8	82.6	0.22
239	SQUID	11/16/84	BREM	10.00	0.0166	20	3.32	13.3	46.2	0.21
243	SQUID	11/16/84	EBP 86	10.10	0.0232	20	4.59	15.3	72.5	0.21
249	SQUID	11/16/84	EBP 70	10.00	0.0160	20	3.19	13.2	53.8	0.21
245	SQUID	11/16/84	EBP 86	10.00	0.0170	20	3.40	16.1	93.0	0.22
240	SQUID	11/16/84	BREM	10.00	0.0120	20	2.40	11.1	47.1	0.21
203	ROCKFISH	3/14/85	OB	10.00	0.0074	20	1.49	22.3	226.0	0.19
204	ROCKFISH	3/14/85	OB	10.00	0.0074	20	1.47	22.0	231.8	0.20
206	ROCKFISH	3/14/85	OB	10.00	0.0084	20	1.68	22.4	260.1	0.19
207	ROCKFISH	3/14/85	OB	10.00	0.0077	20	1.53	21.6	171.2	0.19
217	ROCKFISH	3/1/85	APB	10.03	0.0086	20	1.71	39.0	1380.0	0.21
218	ROCKFISH	3/1/85	APB	10.01	0.0112	20	2.24	37.2	1000.0	0.22
233	ROCKFISH	3/14/85	EBDS	8.30	0.0048	20	1.16	14.2	48.3	0.20
234	ROCKFISH	3/14/85	EBDS	10.01	0.0096	20	1.92	30.3	474.6	0.20
261	ROCKFISH	4/3/85	APB	10.03	0.0097	20	1.93	31.5	608.1	0.20
262	ROCKFISH	4/30/85	PO	10.02	0.0114	20	2.28	46.0	2060.0	0.22
279	ROCKFISH	5/31/85	EBPFP	10.00	0.0073	20	1.47	15.2	118.7	0.19
32	ROCKFISH	3/28/84	EB 86	10.00	0.0067	20	1.34	20.0	156.7	0.22
276	ROCKFISH	5/31/85	EDM	10.00	0.0104	20	2.09	26.2	346.6	0.21
277	ROCKFISH	5/31/85	EDM	10.01	0.0167	20	3.34	18.8	121.0	0.20
278	ROCKFISH	5/31/85	EDM	10.00	0.0078	20	1.56	16.8	110.0	0.20
280	ROCKFISH	5/31/85	EDM	9.85	0.0196	10	1.99	13.3	51.8	0.20
112	STARRY FLOUNDER	6/14/84	BREM	20.00	0.0212	10	1.06	?	?	?
195	STARRY FLOUNDER	3/14/85	OB	10.00	0.0072	20	1.44	28.7	236.7	0.14
198	STARRY FLOUNDER	3/14/85	OB	10.00	0.0087	20	1.73	29.9	277.5	0.19
199	STARRY FLOUNDER	3/14/85	OB	10.00	0.0078	20	1.57	31.0	350.6	0.17
200	STARRY FLOUNDER	3/14/85	OB	10.00	0.0075	20	1.51	30.6	300.5	0.15
96	STARRY FLOUNDER	6/14/84	BREM	10.04	0.0141	10	1.40	37.0	602.9	0.17
105	STARRY FLOUNDER	6/14/84	BREM	10.02	0.0069	20	1.38	37.7	604.9	0.17
111	STARRY FLOUNDER	6/14/84	BREM	10.00	0.0052	20	1.04	35.0	597.9	0.17
116	STARRY FLOUNDER	6/14/85	BREM	9.30	0.0023	20	0.50	37.7	680.7	0.17
193	HAKE	6/21/84	EDM	20.00	0.0170	10	0.86	?	?	?
DSHS 15	HAKE	10/15/83	EBP 57	10.04	0.0083	20	1.65	37.0	348.1	0.17
DSHS 16	HAKE	10/15/83	EBP 57	10.00	0.0159	20	3.18	37.0	348.1	0.17
202	HAKE	3/14/85	OB	10.00	0.0091	20	1.82	18.7	185.4	0.18
281	HAKE	7/15/85	PT. JEF.	10.00	0.0063	20	1.27	54.5	880.0	0.17
282	HAKE	7/15/85	PT JEF.	10.00	0.0044	20	0.88	51.2	1020.0	0.18
283	HAKE	7/15/85	PT. JEF.	10.00	0.0074	20	1.48	50.9	860.0	0.17
284	HAKE	7/15/85	PT. JEF	10.00	0.0058	20	1.16	50.3	1000.0	0.17
255	PACIFIC COD	4/3/85	PT JEF	10.02	0.0076	20	1.52	57.0	1560.0	0.15
256	PACIFIC COD	4/3/85	P.O.	10.04	0.0072	20	1.43	45.6	860.0	0.15
257	PACIFIC COD	4/3/85	P.O.	7.41	0.0057	20	1.54	61.2	2050.0	0.17
258	PACIFIC COD	4/3/85	P.O.	7.67	0.0049	20	1.28	54.4	1440.0	0.16
259	PACIFIC COD	4/3/85	P.O.	10.06	0.0081	20	1.61	54.8	1660.0	0.17
260	PACIFIC COD	4/3/85	P.O.	6.00	0.0034	20	1.13	54.1	1480.0	0.17
16+43	TOMCOD	2/7/84	OB	20.00	0.0248	10	1.24	?	?	?
273	TOMCOD	5/19/85	PT. MD	10.08	0.0078	20	1.55	18.7	60.7	0.18
274	TOMCOD	5/19/85	PT. MD	10.08	0.0058	20	1.15	20.3	89.6	0.18
275	TOMCOD	5/19/85	PT. MD	10.07	0.0044	20	0.87	27.1	143.4	0.16
263	SABLEFISH	5/19/85	PT. MD	10.60	0.0075	20	1.42	48.3	889.0	0.22
264	SABLEFISH	5/19/85	PT. MD	10.00	0.0427	20	8.54	35.0	428.0	0.17
182	ROCKSOLE	6/30/84	EDM	10.00	0.0048	20	0.95	34.8	504.5	0.22
158	ROCKSOLE	6/30/84	EDM	10.00	0.0074	20	1.48	29.5	365.0	0.24
157	ROCKSOLE	6/30/84	EDM	10.09	0.0044	20	0.87	33.0	509.5	0.25
159	ROCKSOLE	6/30/84	EDM	10.00	0.0058	20	1.16	24.1	190.0	0.21
123	ROCKSOLE	6/15/84	EBP 91	10.00	0.0043	20	0.87	24.2	165.6	0.21
124	ROCKSOLE	6/15/84	EBP 91	8.30	0.0062	20	1.49	25.2	187.8	0.24
125	ROCKSOLE	6/15/84	EBP 91	10.00	0.0051	20	1.01	25.2	187.8	0.24
126	ROCKSOLE	6/15/84	EBP 91	10.00	**	20	**	21.2	114.7	0.21
269	WALLEYE POLLOCK	5/19/85	PT. MD	10.00	0.0073	20	1.46	26.3	146.7	0.18
232	WALLEYE POLLOCK	3/14/85	OB	10.40	0.0123	10	1.19	37.3	465.3	0.17
267	WALLEYE POLLOCK	5/19/85	PT. MD	10.00	0.0049	20	0.98	33.0	309.9	0.16
268	WALLEYE POLLOCK	5/19/85	PT. MD	10.00	0.0047	20	0.94	26.6	210.1	0.19
270	WALLEYE POLLOCK	5/19/85	PT. MD	10.00	0.0055	20	1.11	31.4	277.0	0.18
266	WALLEYE POLLOCK	5/19/85	PT. MD	10.01	0.0063	20	1.26	30.5	332.0	0.16
231	WALLEYE POLLOCK	3/14/85	OB	10.00	0.0063	20	1.26	28.0	191.7	0.18

APPENDIX E

Quantitation of PCB in tissue extracts by GC/ECD

The aim of this appendix is to provide an explicit basis for quantitation of PCBs that will permit duplication of results by other labs and will produce comparable data, while recognizing the fact that "PCBs" are not chemical entities and that the composition of Aroclor mixtures are perturbed by environmental processes, by biochemical transformations, and by the analytical process itself. Interlab comparison exercises conducted by ICES, and our own experience in comparing results from the Year 1 methods with the Year 2 results of this study, support the conclusion that quatitation of individual isomerid components among labs is far more reproducible than is the process of using marker-compound methods to estimate "total PCB." Within the literature comprising the historical data for PCBs in Puget Sound fish tissue, for example, considerable variation in approach and assumptions is seen. Gahler, et al. (1982) reported that only Aroclor 1254 was detected in tissue samples taken from Elliott Bay, Commencement Bay, and reference areas. The NOAA/NMFS National Analytical Facility reports contain reference to PCB content based on level of chlorination only, with no reference to Aroclor mixtures, while EPA-directed investigations invariably report PCB results by Aroclor mixture. It is not the scope or intention of this report to evaluate these approaches, but to leave a clear trail for the reader to apply our quantitation method.

The method used was made possible by the recent availability of a reliable standard containing 51 individual isomerids of polychlorinated biphenyl, that include most of the mass (and ECD response) for the common Aroclor mixtures. The application of this standard is as follows:

(1) The ECD response function for each compound is established

(2) The sample is assayed for as many of the isomerids as can be detected

(3) The isomerid concentrations are computed on a ppb wet weight of tissue basis

(4) Proportions among isomerid levels are compared to the proportions seen for Aroclor 1248, 1254 and 1260 standards, to identify any single isomerids that are probably merged with interfering background components to such an extent that a major effect on the sum of all isomerids quantitated would result. The only isomerid that consistently showed such interference was IUPAC #15.

(5) After elimination of background artifacts, the quantified amount of isomerids for the 51 components included in the calibration mixture is summed. This total is reported as "total isomerids."

Based on evaluation of Aroclor standards, the relationship of the 51-compound subset to the 209-component mixture of key Aroclors is as follows: 75.6% of the EC response in Aroclor 1260 is contained in the 51-isomerid standard; 58.6% of the EC response in Aroclor 1254 and 47.6% of the EC response in Aroclor 1248. For the purposes of generating an estimate that is consistent

with Year 1 assumptions, an average of these proportions of 1:2:6 1248:1254:1260 is 68.7%. Assuming average EC response for the 51 isomerid mixture is not very different from average response in the Aroclor mixtures, this would result in an estimate of total 1:2:6 Aroclor as being 1.5 times the "total isomerid" measured. This is the second PCB result reported in Table 41. It should be emphasized that this and all other reports of "total PCBs" are estimates, as opposed to the "total isomerid" values reported, which are measured quantities.

An alternative to the above method (which is valid only if the 1:2:6 hypothesis is correct) is the fitting of proportions among the isomerids to individual Aroclor mixtures. This has been done in a limited way for this study, as follows:

(1) - (3) same as previous method

(4) Each isomerid concentration is scaled up to the equivalent amount of Aroclor 1248, assuming no other Aroclor mixtures are present.

(5) This procedure is repeated assuming that only Aroclor 1254 is present; then likewise for Aroclor 1260.

(6) The isomerids are ranked for each Aroclor mixture, according to their relative contribution to the Aroclor mixture, based on ECD response. The target isomerids used were: (for 1248) #31, 60, 77; (for 1254) #77, 138, 118, 101; (for 1260): #180, 153, 138, 170. Other isomerids were considered for individual samples only.

(7) The following rules were observed for comparing isomerid results: of the three most abundant components sought, at least two must be detected, or the contribution of the Aroclor mixture was deemed to be zero; for combining disparate results from different isomerids, a "greater than" value (limited by detectability) and a "less than" value (limited by freedom from interference) should be determined. In general, outlying values (differing by a factor of 10 from the average of the other three isomerids considered) were discarded and the remaining results averaged.

(8) The results for up to four isomerids are compared to arrive at the best estimate of Aroclor concentration. For Aroclor 1260, it is possible to identify isomerids that have only trivial concentrations in 1254 or 1248: IUPAC #s 153, 138 and 170. IUPAC # 180 was also considered. For Aroclor 1248 and 1254, no unique isomerids that are major components of one mixture but not of the other exist. However, simple ratios of some isomerids can be used to discern the probable proportions of 1248 versus 1254: we used the IUPAC 60/77 ratio. When the concentration of each isomerid is scaled up to the mass of the entire Aroclor, and the ratio of 60 to 77 is taken, it is 0.25 for pure 1248 and 2.0 for pure 1254. A mixture of the two will fall between these two ratios.

(9) The estimated contributions of 1248, 1254 and 1260 were computed by averaging the target isomerids for each groups, applying the proportions for 1248/1254 estimated by the ratio of isomerids, and then each was summed to produce a total PCB estimate. Table E-1

compares PCB quantitation for study samples based on (1) total isomerid measurement (51 components only); (2) total PCB estimation based on the 1:2:6 assumption used in Year 1; (3) estimation of separate levels in Aroclor mixtures according to the above described procedure. Figure E-1 displays the isomerid-sum PCB quantitation compared with the Aroclor-based estimates. Regression fitting between these two methods shows good agreement, with the total coefficient of variability based on these two approaches to total PCB estimation being 31%.

It is recognized that this approach is simply a more limited version of least-squares fitting of isomerid data to Aroclor patterns as has been reported by some investigators. However, such computer-based quantitation approaches have not been widely adopted by environmental investigators. The present method attempts to provide a consistent method for estimating Aroclor content, without requiring special computational tools.

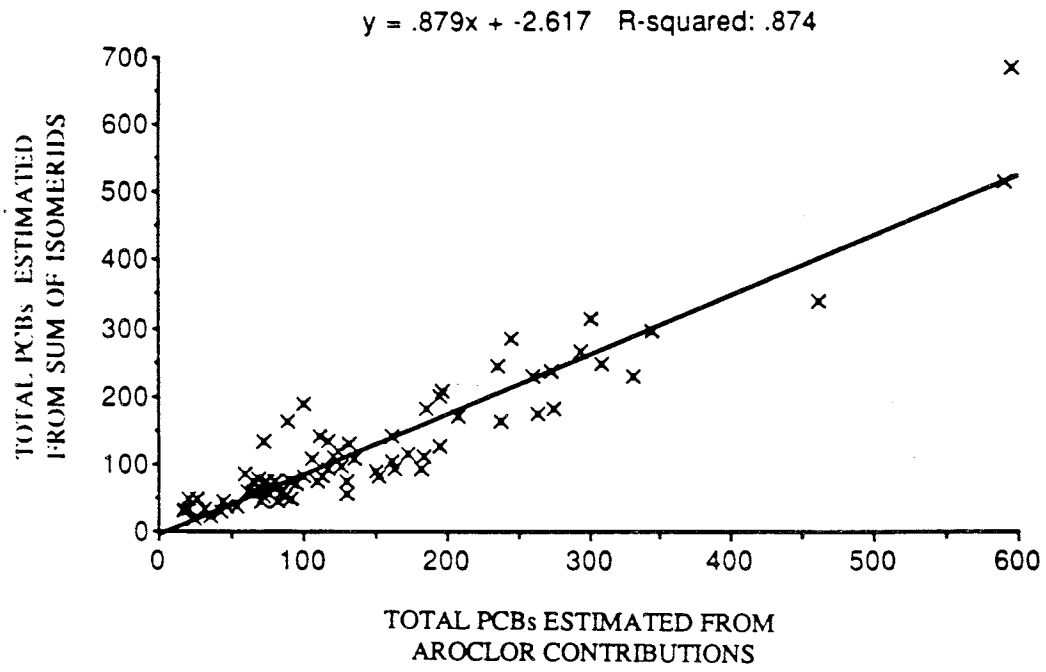


Figure E-1. Total PCBs estimated from Arochlor contributions.