1993 SURVEY OF SEDIMENTS AND TISSUES FROM BOUNDARY BAY AND ROBERTS BANK

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SUMMARY

Since 1986, the B.C Ministry of Environment, Lands and Parks, in partnership with the Fraser River Harbour Commission, has measured contaminant concentrations in sediments, biota, and effluents at sites in the Fraser River and Boundary Bay. This report provides information on sediment contaminant concentrations and toxicity, and tissue contaminant concentrations, at a number of sites in Boundary Bay where we have collected data in the past. It represents a portion of the contribution of the B.C. Ministry of Environment, Lands and Parks to monitoring water quality under the Fraser River Estuary Management Plan (FREMP).

QUALITY CONTROL AND ASSURANCE

The analytical accuracy is based upon analysis of standard reference materials and spike recoveries and was found to be good, generally within the acceptable control limits for each variable. The analytical precision for most metals, PAHs, PCBs, chlorinated phenols, organochlorine and organophosphate pesticides was acceptable at less than a 20% difference. In tissues, some slightly higher precision values for arsenic, anthracene, fluoranthene, phenanthrene, and pyrene were evident.

SEDIMENT CHEMISTRY AND TOXICITY

In the Boundary Bay area, there are five pump stations which discharge drainage water from the land into the Bay. These pump stations are located along the west and north shores of the Bay. We sampled the ditches (three samples formed one composite) leading to the pump stations in order to determine the types of contaminants which might be carried into Boundary Bay from these sources. There are also three rivers which enter on the east side of Boundary Bay. These rivers from north to south are: the Serpentine, Nicomekl, and Little Campbell. We sampled five separate surface (top two cm) sediments from near the mouths of each of these rivers in order to determine what contaminants they may introduce. Finally, we sampled five separate samples from each of a site on Roberts Bank between the coal port jetty and the B.C. Ferry terminal, as well as two locations in Boundary Bay: one near the international border and about mid-point in the Bay, and a second location just north and west from White Rock.

In the sediments from ditches leading to the pump stations, the highest levels of most contaminants were usually found at what we designated as pump station P-2, located north from the border at Beach Grove. We had also found this in our 1989 survey, although concentrations in 1993 were considerably higher than before. We do not know if this reflects additional contaminants entering the Bay, or slight variation in location between years that the samples were collected. The highest individual PAHs were found at pump station P-1.

Copper and mercury concentrations at ambient sites were highest at the offshore site, probably because of the relatively smaller particle size at that site compared to other sites. All mercury concentrations were low enough to be considered no real concern. The highest lead, nickel, and zinc concentrations in sediments were from the mouth of the Serpentine River. In comparison to 1989, the 1993 concentrations of metals were slightly lower at the offshore site, but considerably higher at the inshore site. This latter finding likely reflects variability possibly due to differing sample locations.

The ratio of the simultaneously extracted metals (SEM) to the acid volatile sulphide concentration (AVS) was used to predict potential toxicity of metals in sediments to biota. Only the sediments from the mouth of the Little Campbell River were found to have potential toxicity according to this test, with more SEM than would be compensated for by the AVS present. This means that toxicity of sediments at the mouth of the Little Campbell River could be attributed to metals concentrations.

Sediment toxicity testing using the amphipod Rhepoxynius abronius revealed the most toxic sediments to be from the mouth of the Little Campbell River. The most toxic sediments from ditches leading to the pump houses were from P-4. The solid-phase microtox revealed that the most toxic sediments from ambient sites were from the mouth of the Little Campbell River, while from pump houses these tests showed the most toxic sediments were from P-1 (both the Little Campbell and P-1 had the most toxic sediments according to the sand dollar test), followed closely by P-5.

The tests performed on extracts from sediments were not as conclusive as those performed directly on the sediments. All the liquid phase microtox results (5 minute and 15 minute tests) were non-toxic for all sites.

For sediments from the ambient sites, the highest concentrations of individual PAHs were found in the sediments from the mouth of the Serpentine River. These were below the lowest AET (Apparent Effects Threshold) values for Puget Sound. All PAHs at the offshore site and at the mouth of the Little Campbell River were less than the water quality objectives for Burrard Inlet. As was the case in the 1989 survey, we also found in 1993 that some PAHs were above the water quality objectives for Burrard Inlet but that all were below the AET values.

The analyses of PAHs in the Roberts Bank sediments showed that the individual PAHs (except for fluoranthene and phenanthrene) achieved the water quality objectives for Burrard Inlet.

There is generally little or no concern for chlorinated phenols or PCBs in Boundary Bay sediment since most concentrations were below varying detection limits and water quality objectives. Organochlorine and organophosphate pesticides were not usually detectable in the sediments from the pump stations, river mouths, or ambient sites.

CONTAMINANT LEVELS IN FISH AND CRABS

Several species of fish were collected at each of the two sites in Boundary Bay and one site on Roberts Bank. We analyzed generally five separate individuals of the same species at each site for muscle concentrations in fish or in crabs. Several livers or hepatopancreas were amalgamated to form one sample for analysis of contaminant levels in these types of tissues.

The Canadian Food and Drug Directorate guideline of 3.5 µg/g for arsenic in fish protein was not met in the crabs collected at the Boundary Bay inshore site, but was met in crabs from the offshore site, and in all the fish we collected. Arsenic concentrations in muscle from starry flounder and butter sole from the offshore site were virtually the same in 1989 and 1993, while arsenic concentrations in whole staghorn sculpins from the inshore site may have increased from 1989 to 1993. Arsenic concentrations in crab muscle in 1993 compared to 1989 are higher at the inshore site, but lower at the offshore site.

Copper concentrations in 1993 in muscle from crabs were slightly lower, and in muscle from starry flounder considerably lower, than in 1989, but they were slightly higher in muscle

from starry flounder in 1993 than in 1989. Concentrations in whole staghorn sculpins were virtually the same. We do not believe that there is a trend in these findings.

Lead concentrations in crabs, butter sole, and starry flounder muscle were low and well below the B.C. criteria for consumption of fish and shellfish. The concentrations in whole staghorn sculpins remain virtually unchanged. The lead concentrations in these species may be marginally lower than in 1989.

Mercury concentrations in muscle from crabs and butter sole were about the same as found in 1989, and low enough to not be a concern from a human consumption perspective. Mercury concentrations in the crab hepatopancreas showed that mercury is not bioconcentrating in that body organ. Mercury concentrations in muscle from starry flounders captured at the offshore site were about one-half those we reported for 1989 samples from the same site. Mercury concentrations in whole staghorn sculpins were low and virtually the same as found in 1989.

Nickel concentrations in muscle of crabs, butter sole, and starry flounder do not appear to be higher in 1993 than in 1989; however, concentrations in whole staghorn sculpins do appear to be considerably higher in 1993 than in 1989.

Zinc concentrations in muscle from crabs and whole staghorn sculpins were higher in 1993 than in 1989, while levels in starry flounder and butter sole muscle were lower.

The largest number of detectable PAHs were in whole staghorn sculpins from the inshore site, while phenanthrene was the PAH most frequently detected in the crabs and fish. The fact that we detected PAHs in 1993 and not in 1989 most probably was due to the use of lower analytical detection limits in 1993. Concentrations were lower than the B.C. criteria for PAHs.

There is generally little or no concern for chlorinated phenols or PCBs in Boundary Bay tissues, since most concentrations are below varying detection limits and water quality objectives. As well, organochlorine and organophosphate pesticides were not usually detectable in fish or crabs, although there was some dieldrin measured in crab hepatopancreas from all three sites, indicating that this is likely due to non-site specific contamination with this pesticide. Dieldrin and PCB 1260 were measured at the highest concentration in the hepatopancreas from crabs from Roberts Bank, the sample which also had the highest lipid content.

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1. INTRODUCTION

On April 1, 1986, a five-year agreement was initiated between the Fraser River Harbour Commission and the B.C. Ministry of Environment (MoE). The agreement related to carrying out monitoring in the Fraser River Estuary area, based on a report prepared by the Working Committee on Fraser River Estuary Monitoring (1984). This report was updated by the Fraser River Estuary Management Program (FREMP), and the monitoring information provided in this report represents a portion of the B.C. Ministry of Environment, Lands and Parks contribution to the FREMP Environmental Monitoring Program for 1993/1994. The estuary area under study is the Fraser River downstream from Kanaka Creek, and includes Boundary Bay and Sturgeon and Roberts Banks. The agreement was renewed for a further five years in 1991.

The purpose of the monitoring in 1993 were:

1. To determine concentrations of contaminants at the sites in Boundary Bay where we sampled in 1989 (Swain and Walton, 1990) and infrequently since that time in order to assess if contaminant concentrations have changed.

2. To determine contaminant concentrations adjacent to the five pump stations which carry runoff into the Bay, as well as at the mouths of the three tributaries which enter Boundary Bay.

The locations of the sites monitored in 1993 are shown on Figure 1.

1.1 PROVISIONAL WATER QUALITY OBJECTIVES

The B.C. Ministry of Environment, Lands, and Parks (MoE) is currently establishing Water Quality Objectives on a site-specific basis. One area where the Objectives have been published is Boundary Bay and its tributaries.

Provisional Objectives which are applicable for the results from this survey are (Swain and Holms, 1988):

PCBs: 0.03 µg/g (dry-weight) maximum in bottom surface sediments.

1.2 DESCRIPTION OF THE SAMPLING AREA

In the Boundary Bay area, there are five pump stations which discharge drainage water from the land into the Bay. These pump stations are located along the west and north shores of the Bay. We sampled sediments in the ditches leading to the pump stations in order to determine the types of contaminants which might be carried into Boundary Bay from these sources.

There are also three rivers which enter Boundary Bay on the east side of the Bay. These rivers are from north to south, the Serpentine, Nicomekl, and Little Campbell. We sampled the sediments from near the mouths of these rivers in order to determine what contaminants they may introduce to the Bay.

Finally, we sampled a site on Roberts Bank between the coal port jetty and the B.C. Ferry terminal, as well as two locations in Boundary Bay. The Boundary Bay sites were near the international border and about mid-point in the Bay, and a second location just north and west from

White Rock. At all these locations, we sampled sediments, fish, and Dungeness crabs. All sampling was conducted toward the end of June 1993 (see Appendix 1).

2. MATERIALS AND METHODS

2.1 FIELD METHODS

Sediments: Sediments were collected in the ditches leading to each of the five pump stations, since it was determined in our earlier sampling program that these were the locations where contaminants would be found in measurable quantities.

The samples were collected by scraping the surface with a jar supplied by the laboratory. Three samples collected at each sample site were mixed together in a Pyrex tray using a glass scraper, and then scooped into separate sample jars. The tray and scraper were rinsed with on-site water between each sample point. Between sites, the tray and scraper were rinsed with tap water carried in glass jars, then acetone, and finally hexane. The utensils were then allowed to air-dry.

The offshore sediment samples were taken with a Peterson dredge, and dumped into a plastic tray. The top 5 to 10 cm layer of sediment, not touching the plastic, was scraped off into a sample jar.

Sediments from the three river sites were collected with a Petite Ponar dredge, and emptied into a glass tray, if possible. At stations where the glass tray could not be used, care was taken to ensure that the sediment had not contacted plastic or wood.

All sediments were kept as cool and refrigerated as possible, prior to delivery to the laboratory.

Toxicity testing: Sediment sub-samples or extracts were prepared by the analytical laboratory from sub-samples of the sediments submitted for the chemical analyses. The sediment sub-samples or extracts were forwarded to the Environment Canada Laboratory for toxicity testing using a battery of sediment toxicity tests. River water, as was required for some of the extractions, was collected in laboratory-cleaned four litre amber glass bottles at the time of sediment collections.

Tissues: Tissues were collected using trawls at the inshore and offshore sites in Boundary Bay and at the Roberts Bank site. Details of these trawls are included in Appendix 1.

2.2 ANALYTICAL METHODOLOGY

Much of what follows concerning methodology has been taken directly from the report prepared for the Fraser River Harbour Commission by the contract laboratory, Analytical Service Laboratories (ASL).

2.2.1 SAMPLE PREPARATION AND STORAGE

ASL provided sample containers prepared in a manner suitable for the variables being tested. Required glass jars were acid-washed, solvent-rinsed, and baked in an oven at 250°C. The lids were teflon lined.

When the samples were received at the laboratory, they were catalogued and kept cool until analyzed. The samples were prepared in a clean environment dedicated to this project.

Sediment samples from each site had pore water decanted off the sediment. Then, an approximate 200 gram sub-sample was taken from the larger container after stirring the sediment in that container, and then blending the sample until it was visibly uniform.

The sediments and sediment extracts were prepared using apparatus pre-cleaned with the methods used for the glass jars. A representative portion of each sample was air-dried so as to minimize loss of volatile components. The air-dried portion was homogenized and sieved prior to further analyses.

The leachate extraction procedure was then carried out on prepared sediment fractions using a slightly modified procedure. The water used for the extracts was seawater from Outer Burrard Inlet. No pH adjustment was used through the leachate extraction procedure. Extracts were then submitted to the Aquatic Toxicity Laboratory in North Vancouver, including some samples to which reference toxicants were added as a Quality Assurance (QA) measure.

Sediment sub-samples were submitted to Axys Laboratory for analysis of organotins.

Pre-preparation of the tissue samples consisted of compositing where necessary followed by homogenization in its entirety using a stainless steel high-speed laboratory homogenizer. The homogenizer was rinsed in between samples with dilute acid, dilute sodium hydroxide, reagent grade water, and acetone.

2.2.2 SEDIMENT ANALYTICAL PROCEDURES

All samples were analyzed using methods which were consistent with those used in our earlier study in 1989 (Swain and Walton, 1990).

2.2.2.1 Total and Simultaneously Extracted Metals (SEM)

All samples were analyzed using procedures that were consistent with U.S. EPA Methods 3050, 7000, and 6010. For total metals, a representative sub-sample (5 to 10 grams wet-weight, depending upon the moisture content and the uniformity of the sub-sample) of homogenized sediment was digested using nitric and hydrochloric acids. The resulting extract was bulked to volume with de ionized/distilled water and analyzed as follows:

Cd, Pb background	Determined using a Perkin Elmer Model 2380 dual beam atomic absorption spectrophotometer, in flame mode, equipped with automatic deuterium correction.
As, Se	Determined using a Perkin Elmer Model MHS-20 automated hydride generation system coupled to a Perkin Elmer Model 5000 dual beam atomic absorption spectrophotometer.
Hg	Analyzed using a Pharmica Model U.V. mercury monitor equipped with a 30 cm absorption cell.
All others	Determined in the extract using sequential inductively coupled plasma emission spectrometry (Perkin Elmer Model P40) interfaced with an Epson Equity III+286 Data acquisition system.

For SEM metals, an extract produced by the addition of 6.0 N hydrochloric acid was filtered through a 0.45 µm cellulose nitrate filter paper, and then analyzed using inductively coupled plasma emission spectrometry (Jarrel Ash Model ICAP61), or as follows for mercury.

Hg — Determined in the extract using an LDC Analytical Model mercury Monitor 3200 coupled to an LDC Analytical Model mercury Module. Data collection and calculation were carried out on an IBM compatible 486 data acquisition system.

In evaluating the data generated in this program, data for many metals were not discussed, since those metals are not usually environmentally significant. The data for these metals are included in the data summaries for information purposes.

2.2.2.2 Acid Volatile Sulfide

This analysis was carried out by adding 6.0 N hydrochloric acid to the sediment samples. This results in the production of hydrogen sulfide which is carried into two sodium hydroxide sulfide traps by purified nitrogen gas. The acid volatile sulfide absorbed in the sodium hydroxide was then determined colourimetrically.

2.2.2.3 Chlorinated Phenols

A representative portion of each sample (25 to 40 grams wet-weight, depending upon the moisture content and the uniformity of the sub-sample) was extracted. The procedure is based on U.S. EPA Method 3540/8040. For this, a soxhlet extraction of the dried sediment with dichloromethane, followed by a solvent exchange to hexane and an acid-base partition clean-up. The final extract is acetylated with acetic anhydride and analyzed by dual capillary column gas chromatography with electron capture detection. Data integration was carried out on an IBM compatible 386 data acquisition system running ChromPerfect integration software.

2.2.2.4 Organophosphate Pesticides

This analysis was carried out in accordance with U.S. EPA methods 3540/8040. The procedure involves the soxhlet extraction of the dried sediment with dichloromethane, with subsequent analysis by capillary column gas chromatography with nitrogen phosphorus detection. Data integration was carried out on an IBM compatible 386 data acquisition system running ChromPerfect integration software.

2.2.2.5 Organochlorine Pesticides and Polychlorinated Biphenyl's

A representative portion of each sample (the same 25 to 40 grams wet-weight used for the chlorophenol analysis) was extracted using Method 3540/8080 published by U.S. EPA. This procedure involves the soxhlet extraction of the sample using dichloromethane. The extract was then solvent exchanged to hexane, followed by alumina column clean-up. The resulting extracts were analyzed using capillary column gas chromatography equipped with dual column/dual electron capture detection. Data integration was carried out on an IBM compatible 386 data acquisition system running ChromPerfect integration software.

2.2.2.6 Polycyclic Aromatic Hydrocarbons

A representative portion of each sample (a portion of the same 25 to 40 grams wet-weight used for the other organic analyses) was extracted using a procedure adopted from various

literature sources and from U.S. EPA methods 3540, 3630, and 8270. This procedure involves the soxhlet extraction of the dried sediment with dichloromethane followed by a solvent exchange to hexane and clean-up using silica gel column chromatography. The clean-up procedure has been found to effectively remove aliphatic and heterocyclic hydrocarbons which potentially could interfere with the analysis. The final extract was then analyzed by capillary gas chromatography with mass spectrometer detection on single-ion monitoring mode. Data integration was carried out on a Hewlett Packard UX based work station.

2.2.2.7 Moisture Content

A representative portion of the sample (5 to 10 grams) was dried for twelve hours to a constant weight at 103 ^{o}C. Moisture was then determined gravimetrically by measuring weight loss upon drying.

2.2.2.8 Total Organic Carbon

This analysis was sub-contracted to Chemex Laboratories Limited (North Vancouver, B.C.) and was carried out in accordance with U.S. EPA Method 9060A. A representative portion of each sample (5 to 10 grams) was subjected to a hydrochloric acid leach followed by determination of carbonates using a Leco induction furnace. Total organic carbon was determined as the difference between total carbon value and the carbonate value.

2.2.2.9 Particle Size

This analysis was sub-contracted to Soilcon Laboratories Limited (Richmond, B.C.) Representative portions of each sample (5 to 10 grams) were dry-sieved in accordance with Walton (1978) for sand and silt fractions, and the fine materials (clay fraction) were determined by hydrometer method (Walton, 1978).

2.2.2.10 Tributyltin

Sub-samples of the sediment were sent to Axys Analytical Services Limited (Sidney, B.C.) for analysis.

The method involved solvent extracting dried sub-samples. The extracted compounds were then converted to butyl derivatives with Grignard reagent, and cleaned-up by chromatography. The final extract was analyzed by GC/MS for butyltins, with concentrations being expressed in units of ng/g of tin (Sn).

2.2.2.11 Toxicity Tests

Sediment samples were transported to the Environment Canada Aquatic Toxicity Laboratory and were stored in a room at the laboratory at 4^{o}C prior to testing.

The solid-phase microtox bioluminescence bioassay (Photobacterium phosphoreum) procedure is an acute toxicity test requiring only a 25 minute exposure of the bacteria to the sediment. Any toxic materials which come in contact with the bacteria will interfere with their metabolism and reduce the light output. Each sediment was homogenized and a representative sample was transferred to a tube and centrifuged for 20 minutes. The pore water which surfaced was discarded. A thoroughly mixed 0.30 gram aliquot was used for the test.

A freeze-dried culture of Photobacterium phosphoreum was re-constituted by adding 1.0 mL of distilled water, then was held at 5°C, aspirated with a pipettor 20 times, and then equilibrated for 15 minutes. Fifteen tubes for serial dilutions each had 1.5 mL of solid-phase diluent added, with 3.0 mL also added to the 0.3 gram sample. Twelve tubes had additions of sediment from 10% to 0.005% by weight, with the three remaining tubes serving as controls. After a 10 minute equilibration period, the bacteria were added and allowed to equilibrate for 20 minutes, at which time the serial dilutions were filtered. Five hundred millilitres of filtrate was transferred to the Microtox machine, incubated for five minutes, and then the light level emitted was measured for each.

The other sediment bioassay used the amphipod Rhepoxynius abronius. The Rhepoxynius abronius and the control sediment were collected and sieved from the waters off Washington state. On the day preceding the 10-day amphipod test, 200 grams of sediment were transferred to the bottom of each test vessel, which consisted of one litre flint glass jars which had been washed and rinsed with distilled water. Six replicates were run for each site. Clean seawater was gently poured over the sediment and the test vessels were aerated overnight. Five of the six test vessels were used for the toxicity tests, while the sixth was used for chemistry testing within the laboratory. Twenty amphipods were placed into each of the five vessels, which were constantly illuminated with fluorescent overhead lights and maintained at 14 °C ± 1 °C. A control sediment was run concurrently with the test sediments. At the end of the exposure period, the sediments were sieved (0.5 mm screen) and the amphipods were counted as being either alive or dead. Missing amphipods were considered to be dead.

Leachate for analysis was prepared by ASL for submission to the Aquatic Toxicity Laboratory for testing with the liquid-phase microtox bioluminescence test and the sand dollar test. The procedure to produce the extracts was modified from that outlined by the B.C. Ministry of Environment, Lands, and Parks.

The liquid-phase microtox bioluminescence bioassay (Photobacterium phosphoreum) procedure followed the Standard Assay Procedure prepared for a Microtox Inter-Laboratory Comparison Study (File 2600-BK3-13). The toxicity or EC50 value is the effective concentration of the test material to cause a 50% decrease in light emission. In this case, the exposure period was 5 minutes. Any toxic materials which come in contact with the bacteria will interfere with their metabolism and reduce the light output.

The echinoderm bioassay was performed following the procedures outlined in Van Aggelen (1990). All bioassays were conducted using sand dollars (Denaster excentricus) collected at low tide on Crescent Beach in White Rock. The animals were held in flowing sea water and sediment from the collection site prior to the tests and for control purposes.

2.2.3 TISSUE ANALYTICAL PROCEDURES

All samples were analyzed using methods which were consistent with those used in our earlier study in 1989 (Swain and Walton, 1990).

2.2.3.1 Lipid Content

The analysis was carried out using procedures outlined in AOAC Official Methods of Analysis (AOAC, 1984). The procedure involved a solvent extraction using a combination of

chloroform and methanol in the presence of an enzyme. The extract was then evaporated to dryness, and the residue, which represents the lipid content, was determined gravimetrically.

2.2.3.2 Moisture Content

The analysis was carried out gravimetrically after drying sub-samples to constant weight at 103 °C.

2.2.3.3 Total Metals

All samples were analyzed using procedures adapted from Tetra Tech, U.S. EPA Methods 7000, and 6010. For total metals, a representative sub-sample (5 to 10 grams wet-weight, depending upon the moisture content and the uniformity of the sub-sample) of homogenized tissue was digested using nitric acid and hydrogen peroxide. The resulting extract was bulked to volume with de ionized/distilled water and analyzed as follows:

Cd, Pb	Determined using a Varian Model Spectra AA-300 single beam atomic absorption spectrophotometer, equipped with an automatic Zeeman background-corrected electrothermal atomizer.
As, Se	Determined using a Perkin Elmer Model MHS-20 automated hydride generation system coupled to a Perkin Elmer Model 5000 dual beam atomic absorption spectrophotometer.
Hg	Analyzed using a Pharmica Model U.V. mercury monitor equipped with a 30 cm absorption cell.
All others	Determined in the extract using sequential inductively coupled plasma emission spectrometry (Perkin Elmer Model P40) interfaced with an Epson Equity III+286 Data acquisition system.

2.2.3.4 Polycyclic Aromatic Hydrocarbons

A representative portion of each sample (a portion of the same 25 to 40 grams wet-weight used for the other organic analyses) was extracted using a procedure adopted from various literature sources and from U.S. EPA methods 3540, 3630, and 8270. This procedure involves the soxhlet extraction of the dried sub-sample with dichloromethane followed by a solvent exchange to hexane and clean-up using silica gel column chromatography. The clean-up procedure has been found to effectively remove aliphatic and heterocyclic hydrocarbons which potentially could interfere with the analysis. The final extract was then analyzed by capillary gas chromatography with mass spectrometer detection on single-ion monitoring mode. Data integration was carried out on a Hewlett Packard UX based work station.

2.2.3.5 Chlorinated Phenols

A representative portion of each sample (25 to 40 grams wet-weight, depending upon the moisture content and the uniformity of the sub-sample) was extracted. The procedure is based on U.S. EPA Method 3540/8040. For this, a soxhlet extraction of the dried sub-sample with dichloromethane, followed by a solvent exchange to hexane and an acid-base partition clean-up. The final extract is acetylated with acetic anhydride and analyzed by dual capillary column gas chromatography with electron capture detection. Data integration was carried out on an IBM compatible 386 data acquisition system running ChromPerfect integration software.

2.2.3.6 Polychlorinated Biphenyl's and Organochlorine Pesticides

This analysis was carried out in accordance with U.S. EPA methods 3540/8040. The procedure involves the soxhlet extraction of the dried sub-sample with dichloromethane, followed by a solvent exchange to hexane and an alumina column clean-up procedure. The final extract was analyzed using capillary column gas chromatography coupled with electron capture detection. Data integration was carried out on an IBM compatible 386 data acquisition system running ChromPerfect integration software.

2.2.3.7 Organophosphate Pesticides

This analysis was carried out in accordance with U.S. EPA methods 3540/8040. The procedure involves the soxhlet extraction of the dried sub-sample with dichloromethane. The extract was solvent exchanged to hexane and the final extract was then analyzed by capillary column gas chromatography with nitrogen phosphorus detection. Data integration was carried out on an IBM compatible 386 data acquisition system running ChromPerfect integration software.

2.3 QUALITY ASSURANCE / QUALITY CONTROL

The following is based upon information provided by ASL Laboratories. The U.S. EPA define Quality Assurance (QA) as the "total program for assuring the reliability of monitoring data". Quality control (QC) is limited to "the routine application of procedures for controlling the measurement process." QA is concerned primarily with the tools of the measurement system. Reagents of the highest quality were used and checked for purity, strength, deterioration with time, and contamination. Class A volumetric glassware was thoroughly cleaned and calibrated when necessary. Balances were checked frequently with certified weights and records maintained. All instruments were calibrated on a routine basis, with the maintenance of appropriate standards and operational logs on performance.

Extensive QA measures were taken to ensure that the highest level of precision and accuracy was maintained. All analyses were performed using accepted procedures and included the concurrent analysis of reagent blanks, sample duplicates, analyte spikes, and certified reference materials, where available. Further detailed discussion of the precision and accuracy for each type of analysis is included in the following chapters.

In total, the level of effort extended in the laboratory itself for sediments in terms of blanks, duplicates, standard reference materials, and spikes as a percentage for QA / QC amounted to the following:

Characteristic	# of	Blanks	Reps.	SRMs	Spikes	% QC
Total Metals	35	7	7	7	-	60
SEM	35	7	35	-	-	120
AVS	35	7	35	-	-	120
Tributyltin	9	2	1	2	-	56
PAHs	35	7	7	7	7	80
Chlorinated Phenols	35	7	7	-	7	60
Organochlorine Pesticides and PCBs	35	7	7	-	7	60
Organophosphate Pesticides	35	7	7	-	7	60
TOC	35	-	7	7	-	40
Particle Size	35	-	7	-	-	20

A series of seven analytical batches were processed, with each batch having five samples, one replicate, one method blank, and one or more reference material or sample matrix spike.

For tissues, the following was the level of effort expended in the laboratory in terms of blanks, duplicates, standard reference materials, and spikes as a percentage for QA/QC.

Characteristic	# of	Blanks	Reps.	SRMs	Spikes	% QC
Total Metals	30	3	6	3	-	40
PAHs	29	3	6	-	3	41
Chlorinated Phenols	30	3	6	-	3	40
Organochlorine Pesticides and PCBs	30	3	6	-	3	40
Organophosphate Pesticides	30	3	6	-	3	40

All method blanks for both tissues (n=3) and sediments (n=7) for metals, chlorophenols, PCBs, and organochlorine and organophosphate pesticides had non-detectable (varying detection limits) concentrations.

3. DISCUSSION

We have discussed the data from the different sites in the following sections of the report as follows. We considered the ambient sites to be the two Boundary Bay sites and the three tributary sites. The pump house sites were considered to be non-ambient.

In the following discussion, when at least one-half of the results were above the detection limit, mean concentrations and corresponding standard deviations have been calculated. For values less than the minimum detection limit, we used the absolute value of the detection limit to perform the calculations. If more than one-half the results were below the analytical detection limit, then median concentrations are reported.

Values cited for fish and crabs are expressed on a wet-weight basis, while those for sediments are on a dry-weight basis.

3.1 PHYSICAL CHARACTERISTICS

3.1.1 Sediments

These included particle size distribution, moisture content, and total organic carbon.

At ambient sites, the mean sediment moisture content ranged from 37.4 % at the inshore site (Table 3) to 63.3 % at the offshore site (Table 1). For the ditches leading to the pump stations (Table 11), four of the five were higher and one was lower than this range of values for the ambient sites.

For total organic carbon, the highest mean ambient value was at the mouth of the Little Campbell River at 4.0 % (Table 5) and the lowest at the inshore site at 0.75 % (Table 3). All values at the pump stations were within this range of values.

The particle size of sediments is very important in relating contaminant accumulation, since large quantities of finer sized particles (e.g., silts and clays) will have often higher concentrations of contaminants. For the ambient sites, the largest amount of fine particles were found at the offshore site, with declining amounts (in order) at the Little Campbell site, the Roberts Bank site, the Serpentine River site, the Nicomekl River site, and finally the least at the inshore Boundary Bay site (Table 1) with 88.6% silt and clay. The highest amount of fine particles were associated with the sediments from the ditch leading to pump station P-4 (Table 11), with about 97% silt and clay.

3.1.2 Tissues

These tests for tissues include lipid content and moisture content.

The highest moisture content was associated with a composite sample of six Dungeness crab hepatopancreas samples from the offshore site, with 86.5 % moisture content (Table 22). The lowest was found in a composite liver sample from starry flounders, also from the offshore site, at 77.5 % moisture content (Table 19). Muscle samples typically had a moisture content very close to 80 %.

Some organic compounds will be found typically at higher concentrations in organisms with high lipid content. Lipid concentrations decreased from a maximum of 9.16 % in a composite sample of Dungeness crab hepatopancreas samples from the Roberts Bank site (Table 26), to 0.42 % in muscle from Dungeness crabs from the offshore site (Table 21).

3.2 METALS AND METALLOIDS

Quality assurance/quality control for metals consisted of internal laboratory quantification of standard reference materials, and the internal laboratory analysis of duplicate samples. The analyses of the certified reference materials are included in Figure 2 for total metals in sediments, in Figure 3 for PAHs in sediments, and in Figure 4 for metals in tissues. The results of the duplicate analyses are included in the following sections, representing a measure of laboratory variability.

Following the discussion of each of the individual metals, we will discuss the measurement of acid volatile sulphide and its ratio on a molar equivalent basis to the sum of the following metals: Cd, Cu, Pb, Hg, Ni, and Zn. Although the initial work by Mahony et. al. (1992) related to only cadmium and nickel, we have taken a more conservative approach and included several other metals which are considered acutely toxic in order to initially "screen" the sediment results. In the following discussion, we will focus only on these metals, although we do have data for the following which are only reported in the table: Al, Sb, As, Ca, Cr, Co, Fe, Mg, Mn, and Mo.

In evaluating the data generated in this program, data for many metals will not be discussed, since those metals are not usually environmentally significant. The data for these metals are included in the data summaries for information purposes.

3.2.1 Arsenic

The accuracy for arsenic is shown in Figures 2 (a) for sediments and Figure 4 (a) for tissues. Most of the sediment analyses were within the specified range of values (19.9 to 21.5 µg/g) for the standard reference material. This range is slightly higher than the concentrations found in most of the sediments. Three different tissues with concentrations between about 15 and 27 µg/g were also measured accurately. This range of values reflects some of the concentrations measured in tissues.

Duplicate arsenic analyses were performed on seven sediment samples, and the results were as follows:

Site	Value #1	Value #2	% Difference
Boundary Bay Inshore	4.19	3.24	22.7
Boundary Bay Offshore	10.8	9.91	8.2
Little Campbell River	11.6	11.2	3.4
Nicomekl River	8.47	8.37	1.2
Pump House P-5	5.9	5.86	0.7
Roberts Bank	4.85	4.58	5.6
Serpentine River	8.01	7.14	10.9

As expected, the analytical precision improves with increasing concentrations.

In terms of tissue analyses, duplicate tissue analyses were performed on six samples as follows:

Site	Value #1	Value #2	% Difference
Boundary Bay Inshore	3.04	3.00	1.33
Boundary Bay Inshore	21.8	17.1	27.49
Boundary Bay Offshore	6.84	6.77	1.03
Boundary Bay Offshore	2.40	1.87	28.3
Roberts Bank	0.43	0.35	22.9
Roberts Bank	1.47	1.37	7.3

The analytical precision for the tissues seems to vary widely.

3.2.1.1 Arsenic in Sediments

At ambient sites, average arsenic concentrations ranged from 4.6 µg/g at the Boundary Bay inshore site (Table 3) where we also had the smallest amount of fine sediment to 9.5 µg/g at the offshore site (Table 1) where we had the highest amount of fine sediment. Higher concentrations were found in the ditches adjacent to two pump stations (Table 11), P1 (13.3 µg/g) and P2 (26.4 µg/g). The Ministry of Environment has established a water quality objective for arsenic in the sediments of Burrard Inlet, at a maximum of 20 µg/g (Nijman and Swain, 1990). All mean and maximum concentrations except at P2 were below this water quality objective.

In comparison to the findings from the 1989 survey, we also found that the highest arsenic concentrations were at the offshore site, at 10.1 µg/g (Swain and Walton, 1990). However, the arsenic concentrations in the ditches are considerably higher in our 1993 survey, compared to the 1989 survey although the highest concentration (8.68 µg/g) in 1989 was also from Site P2.

3.2.1.2 Arsenic in Crabs and Fish

Arsenic concentrations (dry-weight) in Dungeness crab (C. magister) muscle were an average of 22.4 µg/g at the inshore site in Boundary Bay (Table 16), 2.32 µg/g (Table 21) at the offshore site in Boundary Bay, and 1.32 µg/g (Table 25) in muscle from crabs from Roberts Bank. In terms of wet-weight, these mean concentrations assuming a moisture content of about 80%, are about 4.5 µg/g, 0.46 µg/g, and 0.26 µg/g. The Canadian Food and Drug Directorate (1979) have established a level of 3.5 µg/g in fish protein to protect humans. This was not met in the crabs collected at the inshore site. In comparison to the 1989 survey (Swain and Walton, 1990), arsenic concentrations are higher at the inshore site (4.5 µg/g compared to 3.24 µg/g in 1989), but lower at the offshore site (0.46 µg/g compared to 3.62 µg/g).

In composite samples of crab hepatopancreas, arsenic concentrations were 24 µg/g (3.38 µg/g wet-weight) at the inshore site (Table 17), 9.18 µg/g (1.23 µg/g wet-weight) at the offshore site (Table 22), and 4.18 µg/g (0.76 µg/g wet-weight) at Roberts Bank (Table 26). Crab hepatopancreas samples were not analyzed in 1989.

Starry flounders were collected and analyzed from the offshore site (Table 18) and Roberts Bank (Table 23). Mean concentrations in muscle samples were 5.87 µg/g (1.08 µg/g wet-weight) at the offshore site and 0.41 µg/g at the Roberts Bank site. The value that we have measured in this survey for the offshore site is virtually identical to that reported (Swain and Walton, 1990) for the 1989 survey of 1.02 µg/g (wet-weight). We did not measure arsenic in livers from starry flounder in this survey since our 1989 data revealed that liver and muscle concentrations were nearly identical.

Butter sole from the offshore site had a mean arsenic concentration of 4.18 µg/g (0.81 µg/g wet-weight) in muscle (Table 20). This compares to a mean concentration of 0.88 µg/g (wet-weight) which we reported for butter sole collected from the same site in 1989.

The mean arsenic concentration in whole staghorn sculpins collected from the inshore site had a concentration of 3.03 µg/g (Table 15). This value is about 0.6 µg/g wet-weight. This compares to a mean value of 0.41 µg/g (wet-weight) in 1989 (Swain and Walton, 1990).

Butter sole collected from Roberts Bank (Table 24) had a mean arsenic concentration of 0.82 µg/g (0.16 µg/g wet-weight).

3.2.1.3 Conclusions

Arsenic was measured accurately in both tissues and sediments. The analytical precision for arsenic seems to be better for the sediment analyses than the tissue analyses. Precision for sediments is usually less than a difference of 20%, while it can be as high as 30% for tissue analyses.

All mean and maximum arsenic concentrations in sediments except at pumping station P2 were below the water quality objective for Burrard Inlet of 20 µg/g. This indicates that there is likely not a concern for arsenic concentrations in sediments.

The Canadian Food and Drug Directorate level of 3.5 µg/g arsenic in fish protein was not met in the crabs collected at the inshore site, but was met in crabs from the offshore site, and in all the fish we collected. Arsenic concentrations in muscle from starry flounder and butter sole from the offshore site were virtually the same in 1989 and 1993, while arsenic concentrations in whole staghorn sculpins from the inshore site may have increased from 1989 to 1993. Arsenic concentrations in crabs are higher at the inshore site, but lower at the offshore site.

3.2.2 Cadmium

The accuracy of the cadmium data are shown in Figures 2 (b) for sediments and Figure 4 (b) for tissues. All of the sediment analyses were within the specified range of values (0.23 to 0.25 µg/g) for the standard reference material. This range is slightly lower than many of the concentrations found in the sediments. Three different tissues with concentrations between about 0.07 and 0.10 µg/g and 20 to 30 µg/g were also measured accurately. The lower range of values reflects some of the concentrations measured in tissues.

Duplicate cadmium analyses were performed on seven sediment samples, and the results were as follows:

Site	Value #1	Value #2	% Difference
Boundary Bay Inshore	0.27	0.20	25.9
Boundary Bay Offshore	0.63	0.60	4.8
Little Campbell River	0.39	0.31	20.5
Nicomekl River	0.38	0.32	15.8
Pump House P-5	1.77	1.70	4.0
Roberts Bank	0.15	0.11	26.7
Serpentine River	0.79	0.67	15.2

As expected, the analytical precision for cadmium improves with increasing concentration.

In terms of tissue analyses, duplicate tissue analyses were performed on six samples as follows:

Site	Value #1	Value #2	% Difference
Boundary Bay Inshore	0.093	0.081	14.8
Boundary Bay Inshore	0.059	0.052	13.5
Boundary Bay Offshore	0.029	<0.025	-
Boundary Bay Offshore	0.141	0.134	5.2
Roberts Bank	<0.025	<0.025	0.0
Roberts Bank	0.038	0.036	5.6

The analytical precision for the tissues seems to be fairly good, with all values less than 15%.

3.2.2.1 Cadmium in Sediments

At ambient sites, average cadmium concentrations ranged from 0.22 µg/g at the mouth of the Little Campbell River (Table 5) where we had the second highest amount of fine sediment to 0.63 µg/g at the offshore site (Table 1) where we had the highest amount of fine sediment. Higher cadmium concentrations were found in the ditches adjacent to four of the five pump stations (Table 11), those higher values being from 0.95 µg/g at P-1 to 3.01 µg/g at P-2. The Ministry of Environment has established a water quality objective for cadmium in the sediments of Burrard Inlet, at a maximum of 1.0 µg/g (Nijman and Swain, 1990). All mean and maximum concentrations except at P-2, P-4, and P-5 were below this water quality objective.

In comparison to the findings from the 1989 survey, we also found that the highest cadmium concentrations for ambient stations were at the offshore site, at 1.12 µg/g (Swain and Walton, 1990). Thus, our mean value for 1993 is about one-half of what we found in 1989. The cadmium concentrations in the ditches are considerably higher in our 1993 survey, compared to the 1989 survey, although the highest concentration (1.45 µg/g) in 1989 was also from Site P-2, and was one-half the concentration measured in 1993.

3.2.2.2 Cadmium in Crabs and Fish

Cadmium concentrations (dry-weight) in crab (C. magister) muscle were an average of 0.061 µg/g (0.011 µg/g wet-weight) at the inshore site in Boundary Bay (Table 16), 0.084 µg/g (Table 21) at the offshore site (0.013 µg/g wet-weight) in Boundary Bay, and 0.08 µg/g (Table 25) in muscle from crabs from (0.014 µg/g wet-weight) Roberts Bank. In comparison to the 1989 survey (Swain and Walton, 1990), cadmium concentrations are lower at both the offshore and inshore sites (0.175 µg/g at the inshore and 0.30 µg/g at the offshore).

In composite samples of crab hepatopancreas, cadmium concentrations were 3.2 µg/g (0.452 µg/g wet-weight) at the inshore site (Table 17), 3.0 µg/g (0.405 µg/g wet-weight) at the offshore site (Table 22), and 25.5 µg/g (4.64 µg/g wet-weight) at Roberts Bank (Table 26). Crab hepatopancreas samples were not analyzed in 1989.

Starry flounders were collected and analyzed from the offshore site (Table 18) and Roberts Bank (Table 23). Mean concentrations in muscle samples were not detectable (<0.025 µg/g) at the offshore site and at the Roberts Bank site. The value that we have measured in this survey for the offshore site is virtually identical to that reported (Swain and Walton, 1990) for the 1989 survey of 0.006 µg/g (wet-weight). We did not measure cadmium in livers from starry flounder in this survey, however, our 1989 data revealed that livers were accumulating cadmium..

The mean cadmium concentration in whole staghorn sculpins collected from the inshore site had a concentration of 0.119 µg/g (Table 15), while concentrations in butter sole muscle from Roberts Bank were 0.03 µg/g. In 1989 (Swain and Walton, 1990), the staghorn sculpins had a cadmium concentration of 0.024 µg/g wet-weight.

Butter sole from the offshore site had a mean cadmium concentration of <0.025 µg/g in muscle (Table 20). This compares to a mean concentration of 0.009 µg/g (wet-weight) which we reported for butter sole collected from the same site in 1989.

Butter sole collected from Roberts Bank (Table 24) had a mean cadmium concentration of 0.03 µg/g (0.006 µg/g wet-weight).

3.2.2.3 Conclusions

Cadmium was measured accurately in sediments and tissues. The precision of cadmium measurements was such that tissue data were generally more precise than sediment data.

Cadmium concentrations in sediments were below the water quality objective for Burrard Inlet, except in ditches leading to three of the five pump stations. The highest concentrations in both 1989 and 1993 were at pump station P-2, where the 1993 concentrations were about double those from 1989. For ambient sites, the highest cadmium concentrations in sediments were at the offshore site in both years, but the 1993 concentrations were about one-half those from 1989.

Cadmium concentrations are lower in crab muscle (C. magister) at both the offshore and inshore sites than was found in 1989. Cadmium concentrations in whole staghorn sculpins and muscle from starry flounders and butter sole are low and about at the concentrations (or lower for staghorn sculpins) measured in 1989. Cadmium concentrations in tissues are not a concern.

3.2.3 Copper

The accuracy of the copper data are shown in Figures 2 (d) for sediments and Figure 4 (d) for tissues. All of the sediment analyses were within the specified range of values (37.3 to 41.3 µg/g) for the standard reference material. This range is appropriate for the concentrations found in most of the sediments. Three different tissues with concentrations between about 5 and 470 µg/g were also measured accurately. This range of values reflects some of the concentrations measured in tissues.

Duplicate copper analyses were performed on seven sediment samples, and the results were as follows:

Site	Value #1	Value #2	% Difference
Boundary Bay Inshore	11.2	9.1	18.8
Boundary Bay Offshore	36.1	35.9	0.6
Little Campbell River	32.7	32.6	0.3
Nicomekl River	29.1	26.4	9.3
Pump House P-5	60.9	51.6	15.3
Roberts Bank	24.7	24.2	2.0
Serpentine River	30.8	28.4	7.8

As expected, the analytical precision improves with increasing concentration, with all values less than 20%.

In terms of tissue analyses, duplicate tissue analyses were performed on six samples as follows:

Site	Value #1	Value #2	% Difference
Boundary Bay Inshore	5.08	4.77	6.5
Boundary Bay Inshore	41.5	41.4	0.2
Boundary Bay Offshore	0.95	0.89	6.7
Boundary Bay Offshore	84.4	82.5	2.3
Roberts Bank	1.54	1.39	10.8
Roberts Bank	48.7	48.6	2.3

The analytical precision for the tissues seems to be very good, with all values less than about 10%.

3.2.3.1 Copper in Sediments

At ambient sites, average copper concentrations ranged from 12.2 µg/g at the Boundary Bay inshore site (Table 3) where we had the smallest amount of fine sediment to 35.3 µg/g at the offshore site (Table 1) where we had the highest amount of fine sediment. Higher concentrations were found in the ditches adjacent to four of the five pump stations (Table 11), with values to as high as 144 µg/g at P-2. The Ministry of Environment has established a water quality objective for copper in the sediments of Burrard Inlet, at a maximum of 100 µg/g (Nijman and Swain, 1990). All mean and maximum copper concentrations except at P2 were below the Burrard Inlet water quality objective.

In comparison to the findings from the 1989 survey, we also found that the highest copper concentrations were at the offshore site, at 39.9 µg/g (Swain and Walton, 1990). However, the copper concentrations in the ditches are considerably higher in our 1993 survey, compared to the 1989 survey although the highest concentration (72.7 µg/g) in 1989 was also from Site P2.

3.2.3.2 Copper in Crabs and Fish

Copper concentrations (dry-weight) in crab (C. magister) muscle were an average of 44.2 µg/g at the inshore site in Boundary Bay (Table 16), 67.2 µg/g (Table 21) at the offshore site in Boundary Bay, and 54.3 µg/g (Table 25) in muscle from crabs from Roberts Bank. In terms of wet-weight, these mean concentrations assuming a moisture content of about 80%, are about 8.8 µg/g, 13.4 µg/g, and 10.8 µg/g. In comparison to the 1989 survey (Swain and Walton, 1990), copper concentrations in 1993 are lower at both the inshore and offshore sites (8.8 µg/g compared to 9.25 µg/g in 1989, and 13.4 µg/g compared to 25.7 µg/g, respectively).

In composite samples of crab hepatopancreas, copper concentrations were 331 µg/g (46.5 µg/g wet-weight) at the inshore site (Table 17), 210 µg/g (28.4 µg/g wet-weight) at the offshore site (Table 22), and 881 µg/g (160.3 µg/g wet-weight) at Roberts Bank (Table 26). Crab hepatopancreas samples were not analyzed in 1989.

Starry flounders were collected and analyzed from the offshore site (Table 18) and Roberts Bank (Table 23). Mean copper concentrations in muscle samples were 2.67 µg/g (0.49 µg/g wet-weight) at the offshore site and 1.50 µg/g at the Roberts Bank site. The value that we have measured in this survey for the offshore site is slightly higher than that reported (Swain and Walton, 1990) for the 1989 survey of 0.37 µg/g (wet-weight). We did not measure copper in livers from starry flounder in this survey; however our 1989 data revealed that liver concentrations were considerably higher (5.61µg/g) than muscle concentrations.

The mean copper concentration in whole staghorn sculpins collected from the inshore site had a concentration of 4.60 µg/g (Table 15). This value is about 0.92 µg/g wet-weight. This compares to a mean value of 1.0 µg/g (wet-weight) in 1989 (Swain and Walton, 1990), or virtually the same concentration.

Butter sole from the offshore site had a mean copper concentration of 0.94 µg/g (0.19 µg/g wet-weight) in muscle (Table 20). This compares to a mean concentration of 0.65 µg/g (wet-weight) which we reported for butter sole collected from the same site in 1989.

Butter sole collected from Roberts Bank (Table 24) had a mean copper concentration of 1.85 µg/g (0.36 µg/g wet-weight).

3.2.3.3 Conclusions

Copper was measured accurately in both tissues and sediments. The precision of copper measurements was acceptable at less than 20%.

Copper concentrations in sediments at ambient sites were highest at the offshore site, speculated to be because of the smaller particle size at that site. The copper concentrations in the ditches were highest found in the survey, although our 1993 measurements were considerably higher than we found in 1989. During both surveys, the highest concentrations were at Site P-2.

We found that copper concentrations in 1993 in muscle from crabs were slightly lower, and in muscle from butter sole than we found in 1989, but they were slightly higher in muscle from starry flounder in 1993 than in 1989. Staghorn sculpins were analyzed as whole fish, and had virtually the same copper levels in 1989 and 1990. We do not believe that there is a trend in these findings, or that the copper concentrations are a concern.

3.2.4 Lead

The accuracy of the lead data are shown in Figures 2 (f) for sediments and Figure 4 (f) for tissues. Most of the sediment analyses were within the specified range of values (20.7 to 23.1 µg/g) for the standard reference material. This range is slightly higher than the concentrations found in most of the sediments. Three different tissues with concentrations between about 0.2 and 14 µg/g were also measured accurately. This range of values is higher than the concentrations measured in tissues.

Duplicate lead analyses were performed on seven sediment samples, and the results were as follows:

Site	Value #1	Value #2	% Difference
Boundary Bay Inshore	4.8	3.8	20.8
Boundary Bay Offshore	14.2	14.1	0.7
Little Campbell River	18.2	16.1	11.5
Nicomekl River	16.5	11.7	29.1
Pump House P-5	18.5	17.4	5.9
Roberts Bank	7.0	6.5	7.1
Serpentine River	20.4	18.5	9.3

As expected, the analytical precision generally improves with increasing concentration, with most precision estimates 20% or less.

In terms of tissue analyses, duplicate tissue analyses were performed on six samples as follows:

Site	Value #1	Value #2	% Difference
Boundary Bay Inshore	0.1	<0.05	-
Boundary Bay Inshore	<0.05	<0.05	0.0
Boundary Bay Offshore	<0.05	<0.05	0.0
Boundary Bay Offshore	<0.05	<0.05	0.0
Roberts Bank	<0.05	<0.05	0.0
Roberts Bank	<0.05	<0.05	0.0

The analytical precision for the tissues could not be calculated since the lead concentrations were generally less than the analytical detection limit.

3.2.4.1 Lead in Sediments

At ambient sites, average lead concentrations ranged from 4.42 µg/g at the Boundary Bay inshore site (Table 3) where we had the lowest amount of fine sediment to 18.6 µg/g at the mouth of the Serpentine River (Table 9) which had about three times as much fine sediment as at the inshore site, but only about one-third that found at the offshore site. Higher lead concentrations were found in the ditches adjacent to two pump stations (Table 11, maximum of 58.8 µg/g at P-2). The Ministry of Environment has established a water quality objective for lead in the sediments of 30 µg/g (dry-weight) for Burrard Inlet (Nijman and Swain, 1990), and a long-term objective of 5 µg/g (dry-weight) (Swain, 1989) for the Brunette River. All mean and maximum lead concentrations except at P-1 and P-2 were below the water quality objective for Burrard Inlet.

In comparison to the findings from the 1989 survey, we found at that time that the highest lead concentrations were at the offshore site, at 16.9 µg/g (Swain and Walton, 1990), compared to 14.4 µg/g in this survey. It is likely that this reflects normal fluctuations at the offshore site, as seen below for all the sites:

	1993	**1989**
Boundary Bay Inshore	4.42	2.87
Boundary Bay Offshore	14.4	16.9
Little Campbell River	9.98	12.2
Nicomekl River	11.5	16.6
Serpentine River	18.6	42.1
P-1	57.2	41.5
P-2	58.8	81.8
P-3	6.1	12.9
P-4	16.8	21.5
P-5	18.5	23.8

3.2.4.2 Lead in Crabs and Fish

Lead concentrations (dry-weight) in crab (C. magister) muscle were an average of <0.05 µg/g at the inshore site in Boundary Bay (Table 16), at the offshore site in Boundary Bay (Table 21), and in muscle from crabs from Roberts Bank (Table 25). The B.C. Ministry of Environment have established an alert level of 0.8 µg/g (wet-weight) in edible portions of fish and shellfish (Nagpal, 1987). In comparison to the 1989 survey (Swain and Walton, 1990), lead concentrations were 0.014 µg/g at the inshore site in 1989 and 0.031 µg/g at the offshore site.

In composite samples of crab hepatopancreas, lead concentrations were <0.05 µg/g at the inshore site (Table 17), 0.45 µg/g (0.06 µg/g wet-weight) at the offshore site (Table 22), and <0.05 µg/g at Roberts Bank (Table 26). Crab hepatopancreas samples were not analyzed in 1989.

Starry flounders were collected and analyzed from the offshore site (Table 18) and Roberts Bank (Table 23), with all mean concentrations in muscle samples <0.05 µg/g at both sites. The value that we have measured in this survey for the offshore site is slightly lower than that reported (Swain and Walton, 1990) for the 1989 survey of 0.022 µg/g (wet-weight). We did not measure lead in livers from starry flounder in this survey although our 1989 data revealed a liver concentration of 0.12 µg/g (wet-weight).

The median lead concentration in whole staghorn sculpins collected from the inshore site was <0.05 µg/g (Table 15). This compares to a mean value of 0.015 µg/g (wet-weight) in 1989 (Swain and Walton, 1990).

Butter sole from the offshore site had a mean lead concentration of <0.05 µg/g in muscle (Table 20). This compares to a mean concentration of 0.063 µg/g (wet-weight) which we reported for butter sole collected from the same site in 1989. It would appear that lead concentrations in muscle tissue may have decreased since 1989.

Butter sole collected from Roberts Bank (Table 24) had a mean lead concentration of 0.07 µg/g.

3.2.4.3 Conclusions

Lead measurements were accurate in tissues and sediments. Most of the precision data for duplicate analyses of lead were less than 20%.

The highest lead concentrations in sediments were from the mouth of the Serpentine River and from pumping station P-2, although only the lead in the sediments from P-2 exceeded the water quality objective. There does not appear to be a pattern of decreasing lead concentrations at this time.

Lead concentrations in muscle from crabs, butter sole, and starry flounder were low and well below the B.C. criteria for consumption of fish and shellfish. The lead concentrations in these species may be marginally lower than we found in 1989. The concentrations in whole staghorn sculpins remain virtually unchanged. We are not concerned about lead concentrations in tissues.

3.2.5 Mercury

The accuracy of the mercury data are shown in Figures 2 (h) for sediments and Figure 4 (h) for tissues. All of the sediment analyses were within the specified range of values (0.083 to 0.101 µg/g) for the standard reference material. This range is slightly higher than the concentrations found in most of the sediments. Three different tissues with concentrations between about 0.2 and 2.2 µg/g were also measured accurately. This range of values reflects some of the concentrations measured in tissues..

Duplicate mercury analyses were performed on seven sediment samples, and the results were as follows:

Site	Value #1	Value #2	% Difference
Boundary Bay Inshore	0.034	0.018	47.1
Boundary Bay Offshore	0.071	0.061	14.1
Little Campbell River	0.057	0.051	10.5
Nicomekl River	0.035	0.031	11.4
Pump House P-5	0.040	0.036	10.0
Roberts Bank	0.035	0.035	0.0
Serpentine River	0.043	0.040	7.0

As expected, the analytical precision improves with increasing concentration, with all but one set of values being less than 15%.

In terms of tissue analyses, duplicate tissue analyses were performed on six samples as follows:

Site	Value #1	Value #2	% Difference
Boundary Bay Inshore	0.031	0.029	6.9
Boundary Bay Inshore	0.269	0.254	5.9
Boundary Bay Offshore	0.083	0.068	22.1
Boundary Bay Offshore	0.125	0.123	1.6
Roberts Bank	0.170	0.157	8.3
Roberts Bank	0.296	0.279	6.1

The analytical precision for the tissues seems to be good, with most sets of results having precision of less than 20%.

3.2.5.1 Mercury in Sediments

At ambient sites, average mercury concentrations ranged from 0.030 µg/g at the mouth of the Nicomekl (Table 7) where we had the second lowest amount of fine sediment to 0.058 µg/g at the offshore site (Table 1) where we had the highest amount of fine sediment. Higher mercury concentrations were found in the ditches adjacent to two pump stations (Table 11), P-1 with 0.061 µg/g and P-2 with 0.083 µg/g. The Ministry of Environment has established a water quality objective for mercury in the sediments of Burrard Inlet, at a maximum of 0.15 µg/g (Nijman and Swain, 1990). Swain (1989) proposed a long-term objective for the Brunette River system of 0.07 µg/g (dry-weight). All mean mercury concentrations except at P2 were below the latter water quality objective, while all the concentrations were below the objective for Burrard Inlet.

In comparison to the findings from the 1989 survey, we also found that the highest mercury concentrations were at the offshore site, at 0.078 µg/g (Swain and Walton, 1990). However, the mercury concentrations in the ditches are higher in our 1993 survey, compared to the 1989 survey although the highest concentration (0.069 µg/g) in 1989 was also from Site P2.

3.2.5.2 Mercury in Crabs and Fish

Mercury concentrations (dry-weight) in crab (C. magister) muscle were an average of 0.269 µg/g at the inshore site in Boundary Bay (Table 16), 0.204 µg/g (Table 21) at the offshore site in Boundary Bay, and 0.360 µg/g (Table 25) in muscle from crabs from Roberts Bank. In terms of wet-weight, these mean concentrations assuming a moisture content of about 80%, are about 0.054 µg/g, 0.041 µg/g, and 0.072 µg/g, respectively. The B.C. Ministry of Environment have established a level of from 0.1 to 0.5 µg/g (wet-weight) in fish or shellfish to protect humans,

depending upon the consumption level of the fish or shellfish. This was met in all the crabs collected at all the sites. In comparison to the 1989 survey (Swain and Walton, 1990), mercury concentrations are lower at the inshore site (0.041 µg/g compared to 0.049 µg/g in 1989), but higher at the offshore site (0.054 µg/g compared to 0.053 µg/g).

In composite samples of crab hepatopancreas, mercury concentrations were 0.214 µg/g (0.030 µg/g wet-weight) at the inshore site (Table 17), 0.264 µg/g (0.036 µg/g wet-weight) at the offshore site (Table 22), and 0.379 µg/g (0.069 µg/g wet-weight) at Roberts Bank (Table 26). Crab hepatopancreas samples were not analyzed in 1989. These mercury concentrations in the hepatopancreas show that mercury is not bioconcentrating in that body organ.

Starry flounders were collected and analyzed from the offshore site (Table 18) and Roberts Bank (Table 23). Mean concentrations in muscle samples were 0.154 µg/g (0.028 µg/g wet-weight) at the offshore site and 0.168 µg/g (0.031 µg/g wet-weight) at the Roberts Bank site. The value that we have measured in this survey for the offshore site is about one-half that reported (Swain and Walton, 1990) for the 1989 survey of 0.054 µg/g (wet-weight). We did not measure mercury in livers from starry flounder in this survey since our 1989 data revealed that liver and muscle concentrations were nearly identical (0.050 µg/g).

The mean mercury concentration in whole staghorn sculpins collected from the inshore site had a concentration of 0.048 µg/g (Table 15). This value is about 0.009 µg/g wet-weight. This compares to a mean value of 0.008 µg/g (wet-weight) in 1989 (Swain and Walton, 1990), virtually identical between surveys.

Butter sole from the offshore site had a mean mercury concentration of 0.094 µg/g (0.019 µg/g wet-weight) in muscle (Table 20). This compares to a mean concentration of 0.023 µg/g (wet-weight) which we reported for butter sole collected from the same site in 1989. It would appear that mercury concentrations in muscle tissue of butter sole are virtually the same as in 1989.

Butter sole collected from Roberts Bank (Table 24) had a mean mercury concentration of 0.090 µg/g (0.016 µg/g wet-weight).

3.2.5.3 Conclusions

Mercury was measured accurately in tissues and sediments. The analytical precision for the tissues and sediments was good, with most sets of results having precision of less than 20%.

The highest mercury concentrations in sediments were at the offshore site, and at the ditch leading to pumping station P-2. The mercury concentrations in ditches were higher than we found in 1989. All concentrations were low enough to be considered no real concern.

With respect to benthic samples, mercury concentrations in muscle from crabs and butter sole were about the same as found in 1989, and low enough to not be a concern from a consumption perspective. Mercury concentrations in the crab hepatopancreas showed that mercury is not bioconcentrating in that body organ. Mercury concentrations in muscle from starry flounders captured at the offshore site were about one-half that we reported for 1989 samples from the same site. Mercury concentrations in whole staghorn sculpins were low and virtually the same as found in 1989. We therefore are not concerned about mercury concentrations in tissues.

3.2.6 Nickel

The accuracy of the nickel data are shown in Figures 2 (i) for sediments and Figure 4 (i) for tissues. All of the sediment analyses were within the specified range of values (47.5 to 51.1 µg/g)

for the standard reference material. This range is slightly higher than some of the concentrations found in some of the sediments, but appropriate for most. One tissue with detectable concentrations had about 2.0 to 2.6 µg/g was also measured accurately. This range of values reflects some of the concentrations measured in tissues..

Duplicate nickel analyses were performed on seven sediment samples, and the results were as follows:

Site	Value #1	Value #2	% Difference
Boundary Bay Inshore	23.2	20.6	11.2
Boundary Bay Offshore	38.3	36.6	4.4
Little Campbell River	42.0	41.5	1.2
Nicomekl River	55.7	55.4	0.5
Pump House P-5	60.9	57.2	6.1
Roberts Bank	41.8	41.7	0.2
Serpentine River	61.9	53.5	13.6

As expected, the analytical precision improves with increasing concentration.

In terms of tissue analyses, duplicate tissue analyses were performed on six samples as follows:

Site	Value #1	Value #2	% Difference
Boundary Bay Inshore	2.7	2.0	35.0
Boundary Bay Inshore	<1.0	<1.0	0.0
Boundary Bay Offshore	<1.0	<1.0	0.0
Boundary Bay Offshore	<1.0	<1.0	0.0
Roberts Bank	<1.0	<1.0	0.0
Roberts Bank	<1.0	<1.0	0.0

The analytical precision for the tissues could not be calculated for most duplicate samples since the measured concentrations were generally less than the analytical detection limit. The one value which could be calculated was likely too close to the detection limit to be meaningful.

3.2.6.1 Nickel in Sediments

At ambient sites, average nickel concentrations ranged from 23.9 µg/g at the Boundary Bay inshore site (Table 3) where we had the smallest amount of fine sediment to 51.3 µg/g at the mouth of the Serpentine River (Table 9) which had about three times more fine sediment than we found at the inshore site, but about one-third that we found at the offshore site. Higher nickel concentrations were found in the ditches adjacent to three pump stations (Table 11), at 57.6 µg/g at P-4, 60.9 µg/g at P-5, and 106 µg/g at P-2. The Ministry of Environment has established a water quality objective for nickel in the sediments of Burrard Inlet, at a maximum of 45 µg/g (Nijman and Swain, 1990). All mean nickel concentrations at ambient sites except at the mouths of the Serpentine and Nicomekl rivers, and except at the three pumping stations just cited, were below this water quality objective.

In comparison to the findings from the 1989 survey, we found that the highest nickel concentrations were at the offshore site, at 39.4 µg/g (Swain and Walton, 1990), slightly higher than the mean value for 1993 of 38.0 µg/g. However, the nickel concentrations in the ditches are considerably higher in our 1993 survey, compared to the 1989 survey although the highest concentration (64.9 µg/g) in 1989 was from Site P-5.

3.2.6.2 Nickel in Crabs and Fish

Nickel concentrations (dry-weight) in crab (C. magister) muscle were a median of <1.0 µg/g at the inshore site in Boundary Bay (Table 16), <1.0 µg/g (Table 21) at the offshore site in Boundary Bay, and <1.0 µg/g (Table 25) in muscle from crabs from Roberts Bank. In comparison to the 1989 survey (Swain and Walton, 1990), nickel concentrations cannot be readily compared since the wet-weight equivalents for the 1993 survey would be <0.20 µg/g at the all the sites, and the mean concentrations in 1989 were 0.21 µg/g (wet-weight) at the offshore site and 0.064 µg/g (wet-weight) at the inshore site. Of importance is the fact that nickel concentrations do not appear to have increased.

In composite samples of crab hepatopancreas, nickel concentrations were 1.4 µg/g (0.20 µg/g wet-weight) at the inshore site (Table 17), 2.3 µg/g (0.31 µg/g wet-weight) at the offshore site (Table 22), and 2.1 µg/g (0.38 µg/g wet-weight) at Roberts Bank (Table 26). Crab hepatopancreas samples were not analyzed in 1989.

Starry flounders were collected and analyzed from the offshore site (Table 18) and Roberts Bank (Table 23). Mean concentrations in muscle samples were <1.0 µg/g at both the offshore site and at the Roberts Bank site. At the offshore site, we reported (Swain and Walton, 1990) in the 1989 survey a mean muscle concentration of 0.06 µg/g (wet-weight) and a mean liver concentration of 0.16 µg/g (wet-weight). We did not measure nickel in livers from starry flounder in this survey.

The mean nickel concentration in whole staghorn sculpins collected from the inshore site had a concentration of 2.2 µg/g (Table 15). This value is about 0.44 µg/g wet-weight. In the 1989 survey, the mean concentration was 0.084 µg/g (wet-weight) (Swain and Walton, 1990).

Butter sole from the offshore site had a mean nickel concentration of <1.0 µg/g in muscle (Table 20). This compares to a mean concentration of 0.013 µg/g (wet-weight) which we reported for butter sole collected from the same site in 1989. It would appear that nickel concentrations in muscle tissue of butter sole are virtually the same or lower as in 1989.

Butter sole collected from Roberts Bank (Table 24) had a median nickel concentration of <1.0 µg/g.

3.2.6.3 Conclusions

Nickel was measured accurately in tissues and sediments. The analytical precision for the sediments was less than 15%, while it could not usually be calculated for tissues since the measured concentrations were generally less than the analytical detection limit. The one value for tissues which could be calculated was likely too close to the detection limit to be meaningful.

All mean nickel concentrations in sediments at ambient sites except at the mouths of the Serpentine and Nicomekl rivers, and except at three of the five pumping stations, were below the water quality objective for Burrard Inlet. Concentrations in sediments from ditches leading to the pumping stations were higher in 1993 than in 1989, while those for the ambient sites were about the same.

In tissues, nickel concentrations in muscle of crabs, butter sole, and starry flounder do not appear to be higher in 1993 than in 1989; however, concentrations in whole staghorn sculpins do appear to be considerably higher in 1993 than in 1989. There are no criteria or objectives on which to assess the implications of these concentrations.

3.2.7 Zinc

The accuracy of the zinc data are shown in Figures 2 (j) for sediments and Figure 4 (j) for tissues. All of the sediment analyses were within the specified range of values (156 to 188 µg/g) for the standard reference material. This range is slightly higher than the concentrations found in most of the sediments, but is appropriate for others. Three different tissues with concentrations between about 20 and 190 µg/g were also measured accurately. This range of values reflects some of the concentrations measured in tissues.

Duplicate zinc analyses were performed on seven sediment samples, and the results were as follows:

Site	Value #1	Value #2	% Difference
Boundary Bay Inshore	60.1	48.9	18.6
Boundary Bay Offshore	106	105	0.9
Little Campbell River	138	137	0.7
Nicomekl River	106	96.8	8.7
Pump House	267	265	0.7
Roberts Bank	73.7	73.2	0.7
Serpentine River	160	143	10.6

As expected, the analytical precision improves at higher concentrations, with all values being less than 20%, and most less than 10%.

In terms of tissue analyses, duplicate tissue analyses were performed on six samples as follows:

Site	Value #1	Value #2	% Difference
Boundary Bay Inshore	96.4	95.6	0.8
Boundary Bay.Inshore	302	293	3.1
Boundary Bay Offshore	31.7	31.2	1.6
Boundary Bay Offshore	279	260	7.3
Roberts Bank	32.5	32.0	1.6
Roberts Bank	288	281	2.5

The analytical precision for the tissues seems at these high concentrations (relative to the analytical detection limit) to be very good, below 10%.

3.2.7.1 Zinc in Sediments

At ambient sites, average zinc concentrations ranged from 60.4 µg/g at the Boundary Bay inshore site (Table 3) where we had the smallest amount of fine sediment to 131.1 µg/g at the mouth of the Serpentine River (Table 9) which had about three times more fine sediment than we found at the inshore site, but about one-third that we found at the offshore site. Higher zinc concentrations were found in the ditches adjacent to four of the five pump stations, with the highest being 350 µg/g at P-2 (Table 11). A water quality objective for zinc in sediments in the Brunette River system (Swain, 1989) is a maximum of 70 µg/g (dry-weight), while an objective for Burrard Inlet (Nijman and Swain, 1990) is a maximum of 150 µg/g (dry-weight), both being long-term objectives. All mean zinc concentrations except at the four pumping stations (except P-3) were below this water quality objective.

In comparison to the findings from the 1989 survey, we also found that the highest zinc concentrations were at the offshore site, at 105 µg/g (Swain and Walton, 1990). However, the zinc concentrations in the ditches are considerably higher in our 1993 survey, compared to the 1989 survey although the highest concentration (173 µg/g) in 1989 was also from Site P2.

3.2.7.2 Zinc in Crabs and Fish

Zinc concentrations (dry-weight) in crab (C. magister) muscle were an average of 308 µg/g at the inshore site in Boundary Bay (Table 16), 267 µg/g (Table 21) at the offshore site in Boundary Bay, and 281 µg/g (Table 25) in muscle from crabs from Roberts Bank. In terms of wet-weight, these mean concentrations assuming a moisture content of about 80%, are about 61.6 µg/g, 53.4 µg/g, and 56.2 µg/g, respectively. In comparison to the 1989 survey (Swain and Walton, 1990), zinc concentrations are higher at both the inshore and offshore sites (61.6 µg/g compared to 43.5 µg/g in 1989, and 53.4 µg/g compared to 34.5 µg/g in 1989, respectively).

In composite samples of crab hepatopancreas, zinc concentrations were 144 µg/g (20.3 µg/g wet-weight) at the inshore site (Table 17), 145 µg/g (19.6 µg/g wet-weight) at the offshore site (Table 22), and 94.7 µg/g (17.3 µg/g wet-weight) at Roberts Bank (Table 26). Crab hepatopancreas samples were not analyzed in 1989.

Starry flounders were collected and analyzed from the offshore site (Table 18) and Roberts Bank (Table 23). Mean zinc concentrations in muscle samples were 37.7 µg/g (6.94 µg/g wet-weight) at the offshore site and 32.0 µg/g (5.9 µg/g wet-weight) at the Roberts Bank site. The value that we have measured in this survey for the offshore site is lower than that reported (Swain and Walton, 1990) for the 1989 survey of 11.0 µg/g (wet-weight). We did not measure zinc in livers from starry flounder in 1993, although our 1989 data revealed that liver concentrations were about 28.5 µg/g (wet-weight) or three times higher than muscle tissue.

The mean zinc concentration in whole staghorn sculpins collected from the inshore site had a concentration of 91.0 µg/g (Table 15). This value is about 18 µg/g wet-weight. In 1989, the mean concentration in whole staghorn sculpins from this site was 13.6 µg/g wet-weight (Swain and Walton, 1990). Zinc concentrations in whole staghorn sculpins are about 50% higher than we found in 1989.

Butter sole from the offshore site had a mean zinc concentration of 30.8 µg/g (5.9 µg/g wet-weight) in muscle (Table 20). This compares to a mean concentration of 12.2 µg/g (wet-weight) which we reported for butter sole collected from the same site in 1989. It would appear that zinc concentrations in muscle tissue of butter sole are about one-half those from 1989.

Butter sole collected from Roberts Bank (Table 24) had a mean zinc concentration of 52.7 µg/g (10.5 µg/g wet-weight).

3.2.7.3 Conclusions

Zinc was measured accurately in tissues and sediments. Precision data for zinc in all sediment samples were all less than 20% for sediments and less than 10% for tissues.

Ambient sediment zinc concentrations were about the same both in 1989 and 1993, although sediments from the ditches leading to the pumping stations were considerably higher in 1993 than in 1989. All ambient sediment concentrations were below the long-term water quality objective for sediments from Burrard Inlet, although concentrations in ditch sediments exceeded them.

Zinc concentrations in muscle from crabs and whole staghorn sculpins were higher in 1993 than in 1989, while levels in starry flounder and butter sole muscle were lower.

3.2.8 Tributyltin

Tributyltin was determined accurately, with two measured concentrations of 1200 and 1260 ng/g for certified range from 1050 to 1490 ng/g for standard reference sediment PAC-1. Blanks had concentrations of <0.3 ng/g and 0.7 ng/g, indicating possibly a small amount of contamination.

Tributyltin was measured at the Roberts Bank site and at the inshore and offshore Boundary Bay sites, in three of the five replicate samples at each site. The values (ng/g dry-weight) were as follows.

Sampling Location	Rep #1	Rep #2	Rep #3
Roberts Bank	1.6	2.7	2.4
Inshore Site	3.1	2.0	2.2
Offshore Site	2.5	3.6	3.1

The data indicate that tributyltin values are slightly higher at the offshore (where we had more fine sediment) than at the inshore site, with a mean of 3.1 ng/g compared to 2.4 ng/g. The mean concentration at the Roberts Bank site was 2.2 ng/g. These tributyltin values are considered to be quite low.

3.3 ACID VOLATILE SULPHIDE AND SIMULTANEOUSLY EXTRACTED METALS

Acid volatile sulphide (AVS) concentrations and simultaneously extracted metals (SEM) concentrations are summarized for the sites in Tables 2,4,6,8,10, and 12 in terms of molar equivalents. Although the initial work by Mahony et. al. (1992) related to only cadmium and nickel, we have taken a more conservative approach and included several other metals which are considered acutely toxic in order to initially "screen" the sediment results. When the ratio of SEM to AVS exceeds 1.0, then the sediment may be toxic.

The sediments from the offshore site (Table 2), the inshore site (Table 4), the Nicomekl River (Table 8), the Serpentine River (Table 10), and the pump stations (Table 12) all had ratios of SEM to AVS of less than 1.0. This indicates that these sediments should not be acutely toxic due to metals.

The only site monitored where the SEM to AVS ratio exceeded 1.0:1.0 was for the mouth of the Little Campbell River. All five replicates had ratios greater than 1.0:1.0 (Table 6).

3.4 SEDIMENT TOXICITY TESTS

The sediments from the different sites were tested for toxicity with a variety of toxicity tests. First, the sediments were tested directly with the amphipod Rhepoxynius abronius (10-day test) and the 25-minute exposure microtox solid-phase test which uses the bioluminescent bacterial species Photobacterium phosphoreum. Extracts from the sediments were also tested for the

microtox liquid-phase test using the same photobacterium, as well as the sand dollar sperm bioassay.

The solid-phase results using EC50 values (the effective concentration (%) to cause 50% reduction in the light emitted by the bacteria) showed that there was great discrepancy among results for even the same site. For example, the site with the highest percentage was the Roberts Bank site (Table 27), with one EC50 of 2.14%. Sediments from the same site were also at EC50 values as low as 0.0775%. The most toxic sediments from ambient sites were from the offshore site when this test was used, with results from 0.05% to 0.2988% (Table 27). The highest toxicity for the pump house sediments were from P-2, with an EC50 of 0.004%. It has been reported that for this test, tests of clean sediments have EC50 values of 2% or greater (Van Aggelen, pers. comm.).

Testing using the amphipod Rhepoxynius abronius revealed the most toxic sediments to be from the mouth of the Little Campbell River, with % survival rates from 52% to 89% (mean 67%). The most toxic sediments from ditches leading to the pump houses were from P-4, with a survival rate of 54% (Table 27).

The tests performed on the extracts from the sediments were not as conclusive as those tests performed directly on the sediments. All the liquid phase microtox results (5 minute and 15 minute tests) were non-toxic for all sites, while the tests on the sand dollar (Denaster excentricus) showed the lowest sperm fertilization rate 2% to 100%) to be associated with the sediments from the mouth of the Little Campbell River for ambient sites and pump house P-1(Table 27).

3.5 POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

The accuracy of the PAH data is summarized in Figure 3 for the individual PAHs where certified reference values were above detection. The results of the data generated within the laboratory itself (i.e. when known to the analyst) were usually within the certified range of values. Thus, we have confidence that the data generated generally were accurate. In terms of precision, the following results (% Diff. is the percentage difference between duplicate analyses of the same sample) for PAHs in sediments were obtained:

PAH	% Diff	% Diff	% Diff	% Diff	% Diff	% Diff	% Diff
Acenaphthene	0.0	0.0	0.0	0.0	0.0	14.3	20.0
Ancenaphthylene	0.0	12.5	0.0	0.0	0.0	0.0	33.3
Anthracene	68.8	18.2	11.1	11.1	44.4	26.5	27.3
Benzo(a)anthracene	5.3	21.9	4.3	12.9	33.3	27.3	20.5
Benzo(a)pyrene	0.0	0.0	0.0	0.0	0.0	46.8	27.0
Benzo(b)fluoranthene	11.1	22.6	2.1	21.6	0.0	40.0	22.3
Benzo(ghi)perylene	0.0	7.3	8.5	0.0	0.0	34.9	21.6
Benzo(k)fluoranthene	0.0	0.0	0.0	0.0	0.0	40.5	19.1
Chrysene	22.2	16.9	0.0	37.8	40.0	15.9	18.4
Dibenzo (ah) anthracene	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fluoranthene	40.5	7.8	3.8	51.6	3.3	47.3	26.6
Fluorene	0.0	8.3	16.7	9.1	20.0	0.0	10.0
Indeno(1,2,3-cd)pyrene	0.0	14.6	5.4	0.0	0.0	0.0	25.0
Naphthalene	0.0	11.8	4.5	8.3	5.7	6.8	22.2
Phenanthrene	44.2	8.5	3.5	49.0	0.0	16.6	41.1
Pyrene	29.6	6.1	1.8	41.2	9.4	48.1	22.8

These data indicate that precision can vary considerably between samples. The American Public Health Association (APHA) (1989) cite a range of acceptable precision for base neutrals (PAHs) of 60% to 140% for low level duplicates and from 80% to 120% for high level duplicates. Individual duplicate measurements which did not meet these criteria were for anthracene (0.005 and 0.016 µg/g dry-weight), fluoranthene (0.089 and 0.184 µg/g, 0.150 and 0.079 µg/g dry-weight), phenanthrene (0.026 and 0.051 µg/g dry-weight), and pyrene (0.070 and 0.135 µg/g dry-weight).

All duplicates for tissue analyses were below varying analytical detection limits.

Spike recoveries (%) for seven sediment analyses at concentrations of 0.1µg/g, 0.2 µg/g, and 0.8 µg/g were as follows:

Polyaromatic Hydrocarbons	MAXIMUM	MINIMUM	MEAN	STD DEV
Acenaphthene	76	53	65.9	9.6
Acenaphthylene	69	48	59.4	7.2
Anthracene	97	68	85.3	9.4
Benzo(a)anthracene	103	81	93.3	6.7
Benzo(a)pyrene	101	86	93.9	5.0
Benzo(b)fluoranthene	114	93	98.7	7.0
Benzo(ghi)perylene	114	79	99.0	11.7
Benzo(k)fluoranthene	116	78	102.1	12.5
Chrysene	109	84	97.0	9.4
Dibenzo(a,h)anthracene	148	89	111.4	18.6
Fluoranthene	106	88	94.7	6.7
Fluorene	97	77	87.7	7.1
Indeno(1,2,3-cd)pyrene	118	87	100.7	10.4
Naphthalene	82	51	66.9	12.7
Phenanthrene	102	75	90.6	9.7
Pyrene	104	76	92.1	9.3

The APHA (1989) cite acceptance levels from 70% to 130% for the recovery of known additions to samples of base/neutral compounds. These minima were not achieved for the analyses of acenaphthene, acenaphthylene, anthracene, and naphthalene, while the maxima was exceeded for dibenzo (a,h) anthracene.

For tissues, three spike recoveries were run, with calculated % recoveries as shown below.

Polyaromatic Hydrocarbons	MAXIMUM	MINIMUM	MEAN	STD DEV
Acenaphthene	90	79	84.7	5.5
Acenaphthylene	89	71	80.7	9.1
Anthracene	97	90	92.3	4.0
Benzo(a)anthracene	107	96	100.0	6.1
Benzo(a)pyrene	99	91	94.7	4.0
Benzo(b)fluoranthene	100	95	97.7	2.5
Benzo(ghi)perylene	105	98	100.3	4.0
Benzo(k)fluoranthene	104	96	99.3	4.2

Polyaromatic Hydrocarbons	MAXIMUM	MINIMUM	MEAN	STD DEV
Chrysene	108	99	103.3	4.5
Dibenzo(a,h)anthracene	104	100	102.3	2.1
Fluoranthene	102	99	100.3	1.5
Fluorene	93	86	89.3	3.5
Indeno(1,2,3-cd)pyrene	101	98	99.7	1.5
Naphthalene	69	58	62.0	6.1
Phenanthrene	101	94	96.3	4.0
Pyrene	103	96	99.7	3.5

All the percent recoveries except for naphthalene in tissues met the APHA (1989) acceptance levels from 70% to 130% for the recovery of known additions to samples of base/neutral compounds.

3.5.1 PAHs in Sediments

The following are the water quality objectives for PAHs in the sediments from Burrard Inlet (Nijman and Swain (1990).

PAH	Objective (µg/g dry-weight)
Acenaphthene	0.05
Ancenaphthylene	0.06
Anthracene	0.10
Benzo(a)anthracene	0.13
Benzo(a)pyrene	-
Benzo(b+k)fluoranthene	0.32
Benzo(ghi)perylene	0.07
Chrysene	0.14
Dibenzo (ah)anthracene	0.06
Fluoranthene	0.17
Fluorene	0.05
Indeno(1,2,3-cd)pyrene	0.06
Naphthalene	0.20
Phenanthrene	0.15
Pyrene	0.26

At sites considered to be ambient in nature, when the water quality objectives (based on Puget Sound apparent effects thresholds) were used as a screening tool, the following individual PAHs are higher in the sample with the maximum concentration than the long-term objectives at the sites indicated:

Inshore site: benzo (a) anthracene : 0.138 µg/g compared to objective of 0.13 µg/g
benzo (ghi) perylene : 0.073 µg/g compared to objective of 0.07 µg/g
fluoranthene : 0.282 µg/g µg/g compared to objective of 0.17 µg/g
fluorene : 0.064 µg/g µg/g compared to objective of 0.05 µg/g
indeno(1,2,3-cd) pyrene : 0.072 µg/g µg/g compared to objective of 0.0.06 µg/g
phenanthrene : 0.304 µg/g µg/g compared to objective of 0.15 µg/g

Nicomekl R. benzo (a) anthracene : 0.170 µg/g compared to objective of 0.13 µg/g
chrysene : 0.229 µg/g compared to objective of 0.14 µg/g
fluoranthene : 0.649 µg/g µg/g compared to objective of 0.17 µg/g
fluorene : 0.065 µg/g µg/g compared to objective of 0.05 µg/g
phenanthrene : 0.235 µg/g µg/g compared to objective of 0.15 µg/g
pyrene : 0.433 µg/g compared to objective of 0.26 µg/g

Serpentine R. anthracene: 0.17 µg/g compared to objective of 0.10 µg/g
benzo (a) anthracene : 0.327 µg/g compared to objective of 0.13 µg/g
benzo (ghi) perylene : 0.073 µg/g compared to objective of 0.07 µg/g
chrysene : 0.433 µg/g compared to objective of 0.14 µg/g
fluoranthene : 1.03 µg/g µg/g compared to objective of 0.17 µg/g
fluorene : 0.078 µg/g µg/g compared to objective of 0.05 µg/g
indeno(1,2,3-cd) pyrene : 0.087 µg/g µg/g compared to objective of 0.0.06 µg/g
phenanthrene : 0.372 µg/g µg/g compared to objective of 0.15 µg/g
pyrene : 0.652 µg/g compared to objective of 0.26 µg/g

This shows that at the ambient sites, the highest concentrations of individual PAHs were found in the sediments from the mouth of the Serpentine River. These were below the lowest AET values for Puget Sound of 0.96 µg/g for anthracene, 1.3 µg/g for benzo (a) anthracene, 0.7 µg/g for benzo (ghi) perylene, 1.4 µg/g for chrysene, 1.7 µg/g for fluoranthene, 0.5 µg/g for fluorene, 0.6 µg/g for indeno(1,2,3-cd) pyrene, 1.5 µg/g for phenanthrene, and 2.6 µg/g for pyrene (Nijman and Swain, 1990). All PAHs at the offshore site and at the mouth of the Little Campbell River were less than the water quality objectives for Burrard Inlet. The analyses of PAHs in the Roberts Bank sediments showed (Table 13) that the individual PAHs (except slight exceedances for fluoranthene and phenanthrene) were less than the water quality objectives for Burrard Inlet (Nijman and Swain, 1990).

In comparison to the findings from the 1989 survey, we also found that some PAHs were above the water quality objectives for Burrard Inlet but that all were below the AET values (Swain and Walton, 1990).

In the ditches leading to the pump stations, the highest concentrations of PAHs were found at sites P-1 and P-2, sites bordered by residential developments. The highest individual PAHs were found at P-1, where six of the PAHs (benzo (b+k) fluoranthene, benzo (ghi) perylene, chrysene, fluoranthene, indeno (1,2,3-cd) pyrene, and pyrene) all exceeded the individual water quality objectives but not the AET values. At P-2 which had lower PAH concentrations than found at P-1, individual PAHs which exceeded the objectives were benzo (ghi) perylene, fluoranthene, and indeno (1,2,3-cd) pyrene.

3.5.2 PAHs in Crabs and Fish

Most PAHs were at non-detectable concentrations (below varying detection limits) at most sites. However, there were some exceptions to this. We have identified and summarized those in the following Table. Within the Table, we identify the data summary table (e.g., T. 15, or Table 15) from which the data are summarized, the location of the sample (Insh=Inshore site, Offsh=offshore site, and Rbt B=Roberts Bank site), the tissue type (M=muscle, L=liver, and Hpt =hepatopancreas), and the organism (St.Sc=staghorn sculpin, C=Dungeness Crab, Fl.=starry flounder, and Bs.=butter sole). The units are expressed as µg/g (dry-weight).

Species	St.Sc	CHpt	Fl.M	Fl. L	Bs.M	C.M	CHpt	Fl.M	Bs.M	C.M	CHpt
Location	Insh	Insh	Offsh	Offsh	Offsh	Offsh	Offsh	Rbt B	Rbt B	Rbt B	Rbt B
PAH/Table	T.15	T.17	T.18	T.19	T.20	T.21	T.22	T.23	T.24	T.25	T.26
Acenaphthene									0.039		
Ancenaphthylene									0.039		
Benzo(a)anthracene	0.023										
Benzo(a)pyrene	0.034										
Benzo(b)fluoranthene	0.042										
Benzo(ghi)perylene	0.028							0.024			
Chrysene	0.03							0.015			
Dibenzo (ah)anthracene								0.021			
Fluoranthene	0.016						0.011				
Fluorene				0.031		0.011		0.007	0.018		0.033
Indeno(1,2,3-cd)pyrene	0.026							0.027			
Naphthalene		0.033	0.008	0.040		0.009	0.041	0.014	0.057	0.043	0.038
Phenanthrene	0.007	0.032	0.006	0.030	0.018	0.015	0.040	0.022	0.016	0.011	0.034
Pyrene	0.015										

The data indicate that the largest number of detectable PAHs were in the whole staghorn sculpin from the inshore site. In 1989, we did not identify PAHs in any of the staghorn sculpins which we analyzed from the inshore site (Swain and Walton, 1990); however, our detection limits in 1993 were about five times lower than in 1989. The highest PAH concentrations were found in samples from Roberts Bank for 6 of the 14 individual PAHs, 7 of 14 from the inshore site, and only 1 of 14 from the offshore site. The PAHs at the inshore site are likely from the tributaries which carry road runoff, while those at Roberts Bank are possibly from the coal port.

We found phenanthrene in all the organisms with detectable concentrations, and the highest concentrations were in either liver or hepatopancreas samples, usually in the order of three to five times higher than in muscle from the same species. In 1989, we did not identify PAHs in any of the hepatopancreas samples which we analyzed (Swain and Walton, 1990); however, as stated earlier, our detection limits in 1993 were about five times lower than in 1989.

The Ministry of Environment, Lands, and Parks have established water quality criteria for benzo (a) pyrene to protect humans from the consumption of PAHs (Nagpal, 1993). The criteria are that the maximum recommended concentration should not exceed 4 000 µg/g (wet-weight) for consumers of less than 50 g/week, 2 000 µg/g (wet-weight) for consumers of less than 100 g/week, and 1 000 µg/g (wet-weight) for consumers of less than 200 g/week. All concentrations in all the samples easily achieved these criteria.

3.5.3 Conclusions

Individual duplicate measurements of individual PAHs which did not meet the criteria for acceptable precision were determined for anthracene, fluoranthene, phenanthrene, and pyrene.

For sediments from the ambient sites, the highest concentrations of individual PAHs were found in the sediments from the mouth of the Serpentine River. These were below the lowest AET values for Puget Sound. All PAHs at the offshore site and at the mouth of the Little Campbell River were less than the water quality objectives for Burrard Inlet. In comparison to the findings from the 1989 survey, we also found that some PAHs were above the water quality objectives for Burrard Inlet but that all were below the AET values.

The analyses of PAHs in the Roberts Bank sediments showed that the individual PAHs (except slight exceedances for fluoranthene and phenanthrene) achieved the water quality objectives for Burrard Inlet.

In the ditches leading to the pump stations, the highest concentrations of PAHs were found at sites P-1 and P-2, sites bordered by residential developments. The highest individual PAHs were found at P-1, where six of the PAHs (benzo (b+k) fluoranthene, benzo (ghi) perylene, chrysene, fluoranthene, indeno (1,2,3-cd) pyrene, and pyrene) exceeded the individual water quality objectives but not the AET values.

The largest number of detectable PAHs were in whole staghorn sculpins from the inshore site, while phenanthrene was the PAH most frequently detected in the crabs and fish. The fact that we detected PAHs in 1993 and not in 1989 likely was due to the use of lower analytical detection limits in 1993.

3.6 CHLORINATED PHENOLS AND POLYCHLORINATED BIPHENYL'S (PCBs)

Included in the category of chlorinated phenols are tri-, tetra-, and penta- chlorophenols. The accuracy of the chlorinated phenol and PCB data were not assessed with the usual standard reference materials but with spikes. Blanks were used to determine whether there was contamination present, and all blanks for the seven batches were below varying detection limits.

In terms of precision, all the values for different isomers of tri-, tetra-, and penta-chlorophenols were below detection (0.005 µg/g dry-weight). All the PCB duplicates were also below the 0.010 µg/g (dry-weight) detection limit for sediments and 0.05 µg/g for tissues.

The American Public Health Association et. al. (1989) cite an acceptable percent recovery for the analysis of acids (chlorophenols, catechols, and guaiacols) as being within a range from 60% to 140%, while for base/neutral compounds (PCBs), as being 70% to 130%. Therefore, we conclude that all the chlorinated phenol data and most of the PCB data were within acceptable limits for precision.

Spike recoveries were also performed for chlorinated phenolics in the seven batches of analyses of sediments, as follows:

Chlorinated Phenols	MAXIMUM	MINIMUM	MEAN	STD DEV
2,3,4-Trichlorophenol	76	62	69.9	5.6
2,3,5-Trichlorophenol	80	68	73.3	4.4
2,4,5-Trichlorophenol	78	64	68.6	4.6
2,4,6-Trichlorophenol	86	66	76.4	7.3
2,3,4,5-Tetrachlorophenol	83	72	78.3	4.2
2,3,4,6-Tetrachlorophenol	94	75	85.4	6.6
2,3,5,6-Tetrachlorophenol	94	70	83.0	7.8
Pentachlorophenol	120	72	90.1	16.5
Polychlorinated Biphenyl's	**MAXIMUM**	**MINIMUM**	**MEAN**	**STD DEV**
PCB 1260	99	66	86.0	13.9

The data for the spike recoveries indicate that the acceptable percent recovery for the analysis of acids (chlorophenols) cited by the American Public Health Association et. al. (1989)

(being within a range from 60% to 140%) was achieved for all of the trichlorophenol isomers. For base/neutral compounds such as PCBs, the recovery should be within the range from 70% to 130%. This minimum was not quite achieved for the PCB 1260.

For tissues, the percent spike recoveries for three samples were as follows:

Chlorinated Phenols	MAXIMUM	MINIMUM	MEAN	STD DEV
2,3,4-Trichlorophenol	89	55	74.7	17.6
2,3,5-Trichlorophenol	75	68	72.7	4.0
2,4,5-Trichlorophenol	78	67	74.3	6.4
2,4,6-Trichlorophenol	107	97	102.0	5.0
2,3,4,5-Tetrachlorophenol	83	68	76.3	7.6
2,3,4,6-Tetrachlorophenol	80	66	71.3	7.6
2,3,5,6-Tetrachlorophenol	76	66	71.0	5.0
Pentachlorophenol	76	60	69.0	8.2
Polychlorinated Biphenyl's	**MAXIMUM**	**MINIMUM**	**MEAN**	**STD DEV**
PCB 1260	104	82	95.7	11.9

This shows that the percent recovery acceptance criteria of the APHA (1989) were achieved in tissues except for the minimum of 2,3,4-trichlorophenol.

3.6.1 Chlorinated Phenols and PCBs in Sediments

All the chlorophenol and PCB analyses for sediments from the ambient sites and the ditches leading to the pump stations had non-detectable concentrations (0.005 µg/g and 0.010 µg/g, respectively. In comparison to the findings from the 1989 survey, we also found that the chlorophenol concentrations at all the sites were below the same detection limit, but that there were PCBs detected at 0.017 µg/g at the offshore site (Swain and Walton, 1990). However, this concentration was still below the water quality objective of 0.030 µg/g, dry-weight (Swain and Holms, 1988). PCBs were also detected in 1989 in the ditches leading to P-2 and P-4 (Swain and Holms, 1988). Therefore, it would appear that the elimination of PCBs is reducing their concentration in the ambient environment.

3.6.2 Chlorinated Phenols and PCBs in Crabs and Fish

All the chlorophenol and PCB analyses for tissues had non-detectable concentrations (0.005 µg/g and 0.05 µg/g, dry-weight, respectively), except for the hepatopancreas of crabs. The composite hepatopancreas samples from each of the three sites had non-detectable concentrations of PCB 1242, PCB 1248, and PCB 1254. For PCB 1260, concentrations were 0.4 µg/g from the inshore site (Table 17), 0.9 µg/g from the offshore site (Table 22), and 1.2 µg/g in crabs from Roberts Bank (Table 26) which also had the highest lipid content. In comparison to the findings from the 1989 survey, we also found that the there were measurable concentrations of PCBs in the hepatopancreas, at 0.035 µg/g, wet-weight (Swain and Walton, 1990).

3.6.3 Conclusions

We could not assess the precision of chlorinated phenol or PCB measurements except in a very gross manner (i.e., there were no apparent "false" positives).

There is generally little or no concern for chlorinated phenols or PCBs in Boundary Bay sediment and tissues, since most concentrations are below varying detection limits and water quality objectives. As expected, the highest PCB 1260 concentrations were associated with the tissues with the highest lipid content (Roberts Bank crab hepatopancreas).

3.7 ORGANOCHLORINE PESTICIDES

The accuracy of the organochlorine pesticide data could not be assessed since there are no standard reference materials available for these.

In terms of precision, most of the sets of tissue and sediment duplicates were for samples with non-detectable (varying detection limits) organochlorine pesticide concentrations. Therefore, the precision appears to be satisfactory. The few exceptions were as follows, with the duplicate results reported (µg/g dry-weight), followed by the calculated percent difference:

Organochlorine Pesticide	Nicomekl R sediment	Serpentine R sediment	Roberts Bank crab hepatopancreas
4,4'-DDD	0.001/0.001/**0.0%**	0.003/0.003/**0.0%**	
4,4'-DDE		0.0030/0.0033/**9.1%**	
4,4'-DDT	0.0006/0.0007/**14.3%**	0.001/0.001/**0.0%**	
Dieldrin			0.68/0.69/**1.47%**
Endosulfan I		0.002/0.002/**0.0%**	
Endosulfan II		0.005/0.004/**20%**	

Spike recoveries (%) for the seven batches of sediment samples are summarized below.

Organochlorine Pesticides	MAXIMUM	MINIMUM	MEAN	STD DEV
Aldrin	113	88	97.9	9.3
gamma-BHC (Lindane)	112	88	96.4	8.4
cis-Chlordane (alpha)	123	86	100.3	12.2
trans-Chlordane (gamma)	112	85	94.6	9.0
4,4'-DDD	160	85	104.4	25.4
4,4'-DDE	127	90	103.1	12.3
4,4'-DDT	145	90	118.0	20.1
Dieldrin	123	86	101.6	12.2
Endosulfan I	122	85	98.7	11.9
Endosulfan II	119	85	98.9	11.8
Endosulfan Sulfate	116	88	102.9	8.8
Endrin	124	85	102.7	15.1
Heptachlor	141	79	96.7	20.8
Heptachlor Epoxide	109	83	97.7	9.2
Methoxychlor	148	90	113.7	21.3

The data for the spike recoveries indicate that the acceptable percent recovery for the analysis of organochlorine pesticides cited by the American Public Health Association et. al. (1989) (being within a range from 50% to 140%) easily was achieved, except for the maxima for 4,4'-DDD, 4,4'-DDT, heptachlor, and methoxychlor.

Spike recoveries for the three batches of tissue samples are summarized below.

Organochlorine Pesticides	MAXIMUM	MINIMUM	MEAN	STD DEV
Aldrin	95	88	90.3	4.0
gamma-BHC (Lindane)	95	87	90.0	4.4
cis-Chlordane (alpha)	96	92	94.3	2.1
trans-Chlordane (gamma)	105	96	99.7	4.7
4,4'-DDD	100	84	92.0	8.0
4,4'-DDE	100	95	97.0	2.6
4,4'-DDT	112	100	105.7	6.0
Dieldrin	105	100	103.3	2.9
Endosulfan I	100	90	95.3	5.0
Endosulfan II	96	88	92.0	4.0
Endosulfan Sulfate	96	60	83.7	20.5
Endrin	110	95	103.0	7.5
Heptachlor	105	90	95.7	8.1
Heptachlor Epoxide	95	88	91.7	3.5
Methoxychlor	108	100	104.3	4.0

The acceptance criteria of the APHA (1989) was met for all tissue samples.

3.7.1 Organochlorine Pesticides in Sediments

Organochlorine pesticides in sediments were usually below varying detection limits except for those identified below with their corresponding maximum concentrations.

Organochlorine Pesticide	Nicomekl R sediment	Serpentine R sediment	Pump house P-1
4,4'-DDD	0.002	0.005	0.001
4,4'-DDE	0.004	0.0036	0.0021
4,4'-DDT	0.0017	0.001	
Endosulfan I		0.002	
Endosulfan II		0.004	

This shows that the pump houses and the tributaries may be contributing minor quantities of organochlorine pesticides to the Bay. In 1989, we found endosulfan-II at the mouth of the Nicomekl River at 0.0015 µg/g, and measurable concentrations at P-1 of 0.003 µg/g DDD, 0.002 µg/g DDT, and 0.0012µg/g endosulfan-II (Swain and Walton, 1990). The other pump stations had some other minor quantities of some organochlorine pesticides in 1989 which were not evident in the 1993 data.

3.7.2 Organochlorine Pesticides in Crabs and Fish

Most of the organochlorine pesticides were below varying analytical detection limits. The few exceptions to this were for dieldrin in the composite crab hepatopancreas (0.16 µg/g dry-weight at inshore site-Table 17, 0.52 µg/g dry-weight at offshore site-Table 22, and 0.68 µg/g dry-weight at Roberts Bank-Table 26). We expected that the highest concentration would be in the crab hepatopancreas from the Roberts Bank site since it had the highest lipid content. In 1989,

DDE was detected in the crab hepatopancreas; however, dieldrin was not (Swain and Walton, 1990).

Methoxychlor was detected in one starry flounder muscle sample from the offshore site (Table 18) at a concentration of 0.06 µg/g dry-weight. In 1989, we did not measure methoxychlor in any fish sample; however, we did detect DDE in most (Swain and Walton, 1990).

3.7.3 Conclusions

The analytical precision for the organochlorine pesticides was very good.

Organochlorine pesticides were not usually detectable in the sediments or fish or crabs, although there was some dieldrin measured in crab hepatopancreas from all three sites, indicating that this is likely due to non-site specific contamination with this pesticide and its presence is related to the lipid content of the organisms.

3.8 ORGANOPHOSPHATE PESTICIDES

The accuracy of the organophosphate pesticide data could not be assessed with standard reference materials since there are none available.

In terms of precision, all sets of sediment and tissue duplicates were for samples with non-detectable (varying detection limits) organophosphate pesticide concentrations. Therefore, the precision appears to be satisfactory (i.e., no "false" positives).

Spike recoveries for the seven batches of sediment samples are summarized below.

Organophosphate Pesticides	MAXIMUM	MINIMUM	MEAN	STD DEV
Azinphos methyl	134	86	107.1	18.2
Carbophenothion	107	77	94.7	10.0
Diazinon	106	63	87.9	16.7
Dimethoate	108	54	89.9	18.9
Fensulfothion	112	66	97.0	17.7
Fenthion	110	77	96.3	13.5
Fonofos	103	73	94.4	12.0
Malathion	123	91	108.4	11.2
Methamidophos	110	54	82.6	21.2
Mevinphos	104	74	90.3	11.7
Parathion	108	70	90.6	14.6
Parathion Methyl	108	84	95.6	9.1
Phosmet	124	92	103.9	12.0

The data for the spike recoveries indicate that the acceptable percent recovery for the analysis of organophosphate pesticides cited by the American Public Health Association et. al. (1989) (being within a range from 50% to 200%) easily was achieved.

Spike recoveries for the three batches of tissue samples are summarized below.

Organophosphate Pesticides	MAXIMUM	MINIMUM	MEAN	STD DEV
Azinphos methyl	100	66	87.3	18.6
Carbophenothion	107	71	92.7	19.1
Diazinon	97	72	86.0	12.8
Dimethoate	101	79	93.0	12.2
Fensulfothion	88	50	70.7	19.2
Fenthion	107	70	88.3	18.5
Fonofos	110	74	93.7	18.2
Malathion	93	61	80.7	17.2
Methamidophos	114	80	93.7	18.0
Mevinphos	99	64	86.0	19.2
Parathion	105	70	86.7	17.6
Parathion Methyl	108	70	93.3	20.4
Phosmet	115	66	93.7	25.1

The APHA (1989) acceptance criteria were achieved for all organophosphate pesticides in tissues.

3.8.1 Organophosphate Pesticides in Sediments

All the sediment samples had non-detectable concentrations (varying detection limits) of organophosphate pesticides. Organophosphate pesticides were not tested for in 1989 (Swain and Walton, 1990). The laboratory did report that in numerous instances, small "hits" of methamidophos were detected below the method detection limit of the mass selective detector. Two randomly selected sediment extracts were sent to Enviro-Test Laboratories Limited (Edmonton, Alberta) for verification by liquid chromatography mass spectrometry; however, the presence of this compound could not be positively identified.

3.8.2 Organophosphate Pesticides in Crabs and Fish

All the tissue samples had non-detectable concentrations (varying detection limits) of organophosphate pesticides. Organophosphate pesticides were not tested for in 1989 (Swain and Walton, 1990). The laboratory did report that in numerous instances, as was the case with sediments, small "hits" of methamidophos were detected below the method detection limit of the mass selective detector. Two randomly selected sediment extracts were sent to Enviro-Test Laboratories Limited (Edmonton, Alberta) for verification by liquid chromatography mass spectrometry; however, the presence of this compound could not be positively identified.

3.8.3 Conclusions

Organophosphate pesticides are not a concern in Boundary Bay in tissues or sediments.

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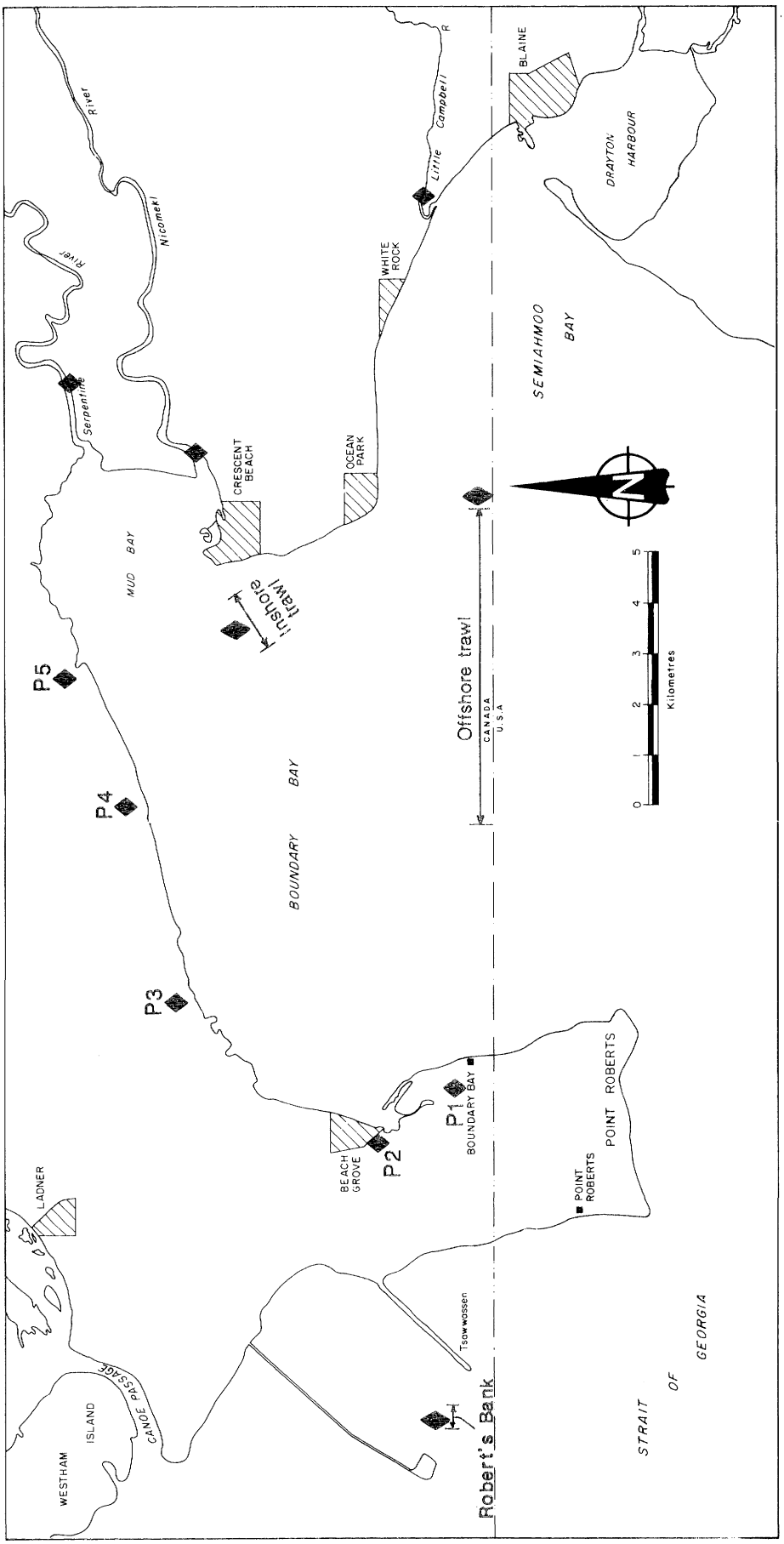

FIGURE 1 SAMPLING SITES–1993

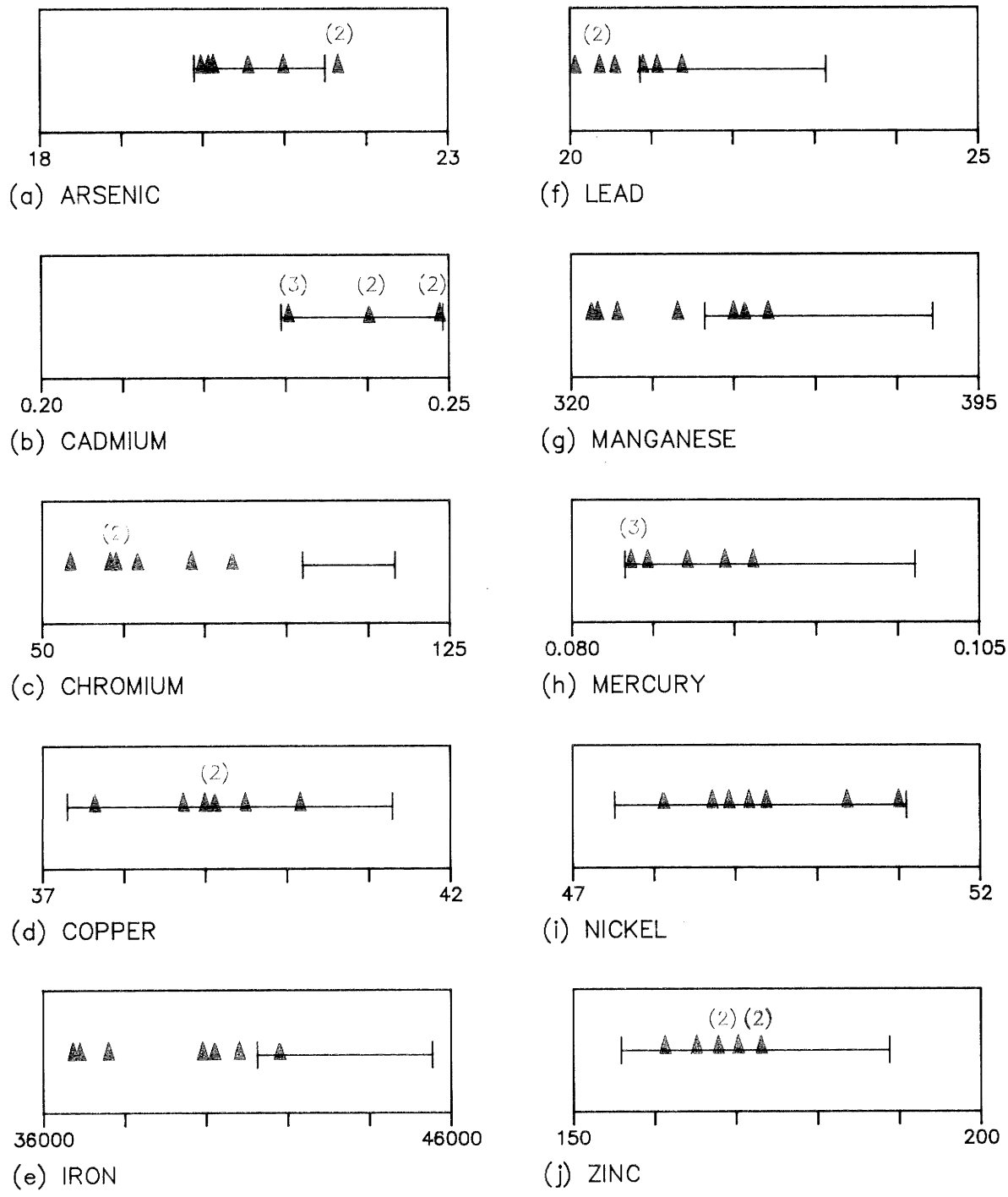

FIGURE 2: ACCURACY OF TOTAL METALS CONCENTRATIONS IN STANDARD REFERENCE MATERIAL MESS-2 FOR SEDIMENTS

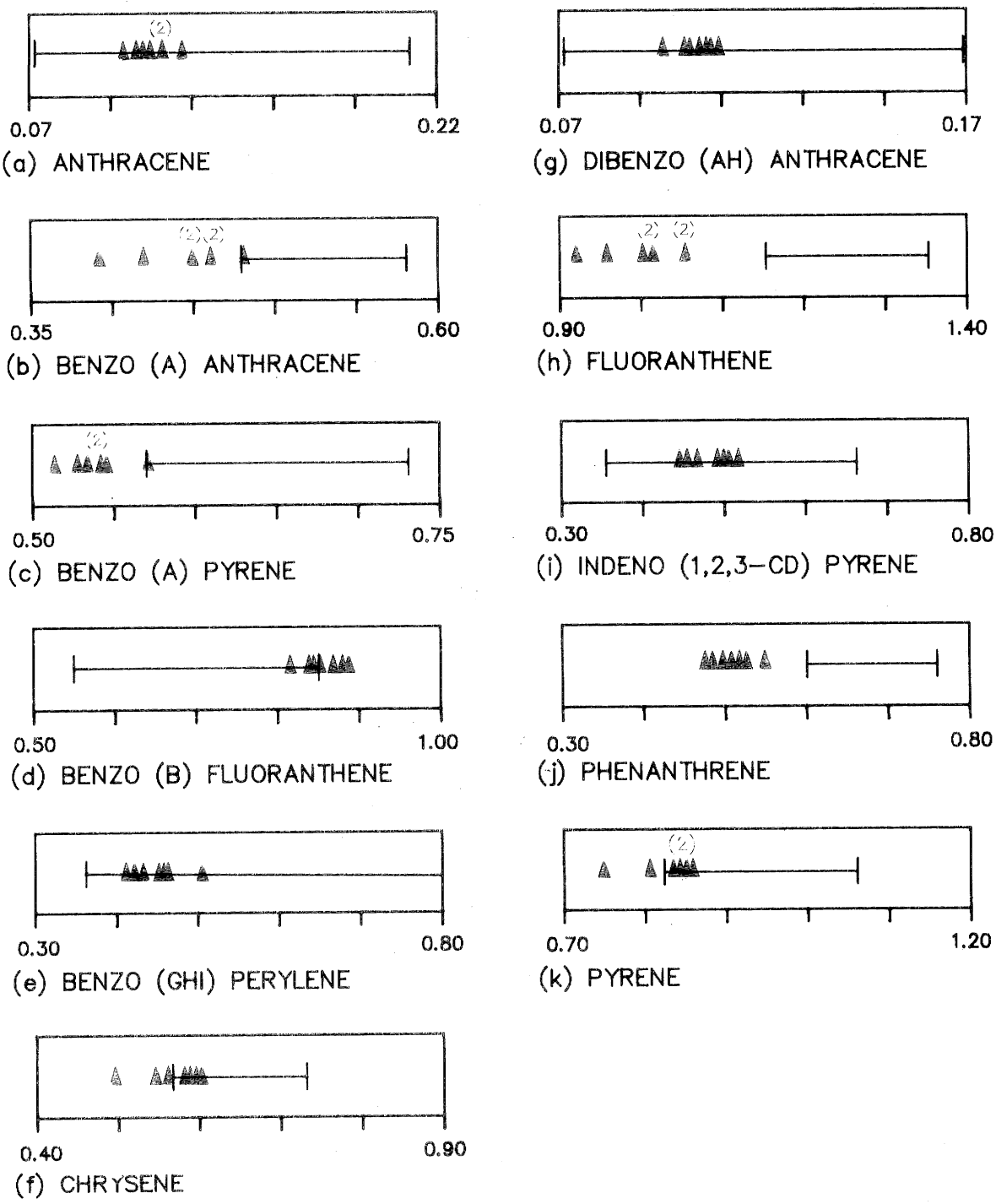

FIGURE 3: ACCURACY OF PAH CONCENTRATIONS IN STANDARD REFERENCE MATERIAL HS–4 FOR SEDIMENTS

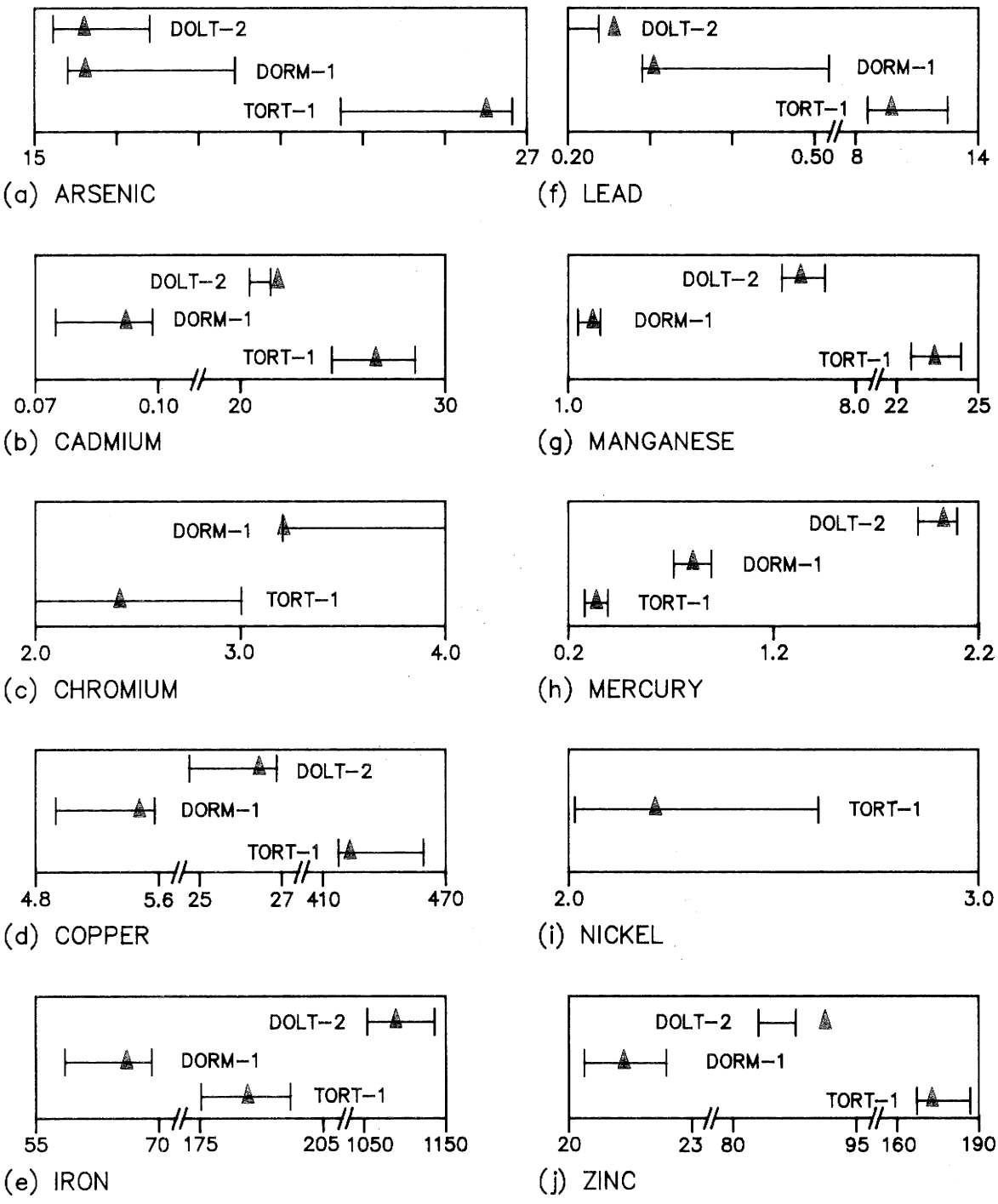

FIGURE 4: ACCURACY OF METALS CONCENTRATIONS IN STANDARD REFERENCE MATERIALS FOR TISSUES

PLATE 1 - VIEW OF BOUNDARY BAY LOOKING NORTH AT LOW TIDE.

PLATE 2 - VIEW OF TYPICAL PUMPING STATION (P-5) WHICH CONVEYS LAND DRAINAGE TO BOUNDARY BAY

PLATE 3 - VIEW OF BOUNDARY BAY LOOKING UPSTREAM INTO SERPENTINE RIVER.

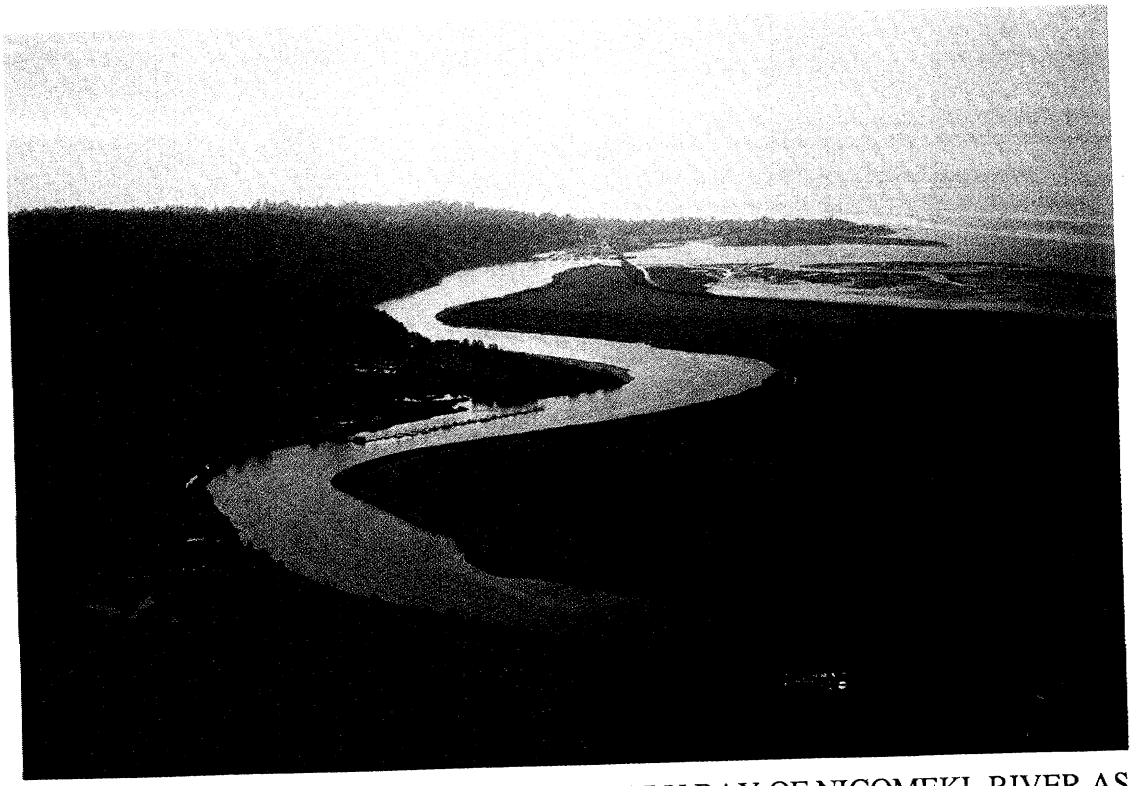

PLATE 4 - VIEW FROM EAST FROM BOUNDARY BAY OF NICOMEKL RIVER AS IT ENTERS THE BAY.

PLATE 7 - LOOKING SOUTH FROM BOUNDARY BAY INTO DRAYTON HARBOUR (WASHINGTON STATE, U.S.A.).

PLATE 8 - VIEW OF ROBERTS BANK BETWEEN FERRY TERMINAL (MID-FOREGROUND) AND COAL PORT (MIDDLE RIGHT).

TABLE 1
SUMMARY OF SEDIMENT DATA FOR THE OFFSHORE SITE (µg/g dry-weight)

Physical Tests	MAX.	MIN.	MEAN	STD. DEV.
Moisture %	65.3	60.8	63.3	1.6
Total Metals				
Aluminum	31300	27700	29280	1470
Arsenic	10.1	8.8	9.5	0.5
Barium	132	107.0	120.6	9.6
Cadmium	0.67	0.59	0.63	0.03
Chromium	62.1	54.9	58.5	3.3
Cobalt	9.3	7.2	8.3	0.8
Copper	36.2	33.6	35.3	1.1
Iron	32800	29900	31580	1130
Lead	15.6	13.8	14.4	0.7
Manganese	351	320	336	15
Mercury	0.062	0.053	0.058	0.004
Molybdenum	6.5	4.5	5.5	1.4
Nickel	39.2	35.8	38.0	1.4
Selenium	0.77	0.68	0.73	0.03
Strontium	112	88.8	97.5	9.3
Tin	<30	<30	<30	0.0
Titanium	1980	1610	1808	159
Vanadium	80.5	69.9	75.14	4.37
Zinc	106	96.7	103.1	3.8
Extractable Metals				
Aluminum	2440	2050	2266	152
Antimony	<15	<15	<15	0.0
Arsenic	<15	<15	<15	0.0
Cadmium	<0.5	<0.5	<0.5	0.0
Calcium	3440	3200	3346	90
Chromium	4.8	3.1	3.8	0.7
Cobalt	<0.5	<0.5	<0.5	0.0
Copper	7.7	4.3	5.98	1.54
Iron	5030	4270	4570	334
Lead	10	7.6	9.4	1.0
Magnesium	3650	3370	3542	144
Manganese	30.4	23.4	26.9	2.7
Mercury	<0.025	<0.025	<0.025	0.000
Molybdenum	<5.0	<5.0	<5.0	0.0
Nickel	4.4	3.2	3.6	0.5
Selenium	<5.0	<5.0	<5.0	0.0
Zinc	30.7	23.4	27.0	3.3
Inorganic Parameters				
Acid Volatile Sulphide	1100	799	933	148
Organo-metallics				
Tributyltin	0.0036	0.0025	0.0031	0.0006

TABLE 1
CONT'D

Polyaromatic Hydrocarbons	MAX.	MIN.	MEAN	STD. DEV.
Acenaphthene	0.008	0.005	0.006	0.002
Acenaphthylene	0.031	0.007	0.014	0.010
Anthracene	0.076	0.018	0.035	0.024
Benzo(a)anthracene	0.138	0.050	0.081	0.038
Benzo(a)pyrene	0.113	0.049	0.070	0.027
Benzo(b)fluoranthene	0.143	0.061	0.092	0.034
Benzo(ghi)perylene	0.073	0.035	0.048	0.016
Benzo(k)fluoranthene	0.062	0.026	0.038	0.015
Chrysene	0.14	0.054	0.083	0.036
Dibenzo(a,h)anthracene	<0.020	<0.020	<0.020	0.000
Fluoranthene	0.282	0.099	0.163	0.077
Fluorene	0.064	0.01	0.025	0.022
Indeno(1,2,3-cd)pyrene	0.072	0.033	0.049	0.017
Naphthalene	0.048	0.016	0.034	0.012
Phenanthrene	0.304	0.066	0.137	0.097
Pyrene	0.24	0.099	0.152	0.058
Chlorinated Phenols				
2,3,4-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,6-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,5-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
Pentachlorophenol	<0.005	<0.005	<0.005	0.000
Polychlorinated Biphenyl's				
PCB 1242	<0.010	<0.010	<0.010	0.000
PCB 1248	<0.010	<0.010	<0.010	0.000
PCB 1254	<0.010	<0.010	<0.010	0.000
PCB 1260	<0.010	<0.010	<0.010	0.000

TABLE 1
CONT'D

Organochlorine Pesticides	MAX.	MIN.	MEAN	STD. DEV.
Aldrin	<0.001	<0.001	<0.001	0.000
gamma-BHC (Lindane)	<0.001	<0.001	<0.001	0.000
cis-Chlordane (alpha)	<0.001	<0.001	<0.001	0.000
trans-Chlordane (gamma)	<0.001	<0.001	<0.001	0.000
4,4'-DDD	<0.001	<0.001	<0.001	0.000
4,4'-DDE	<0.0005	<0.0005	<0.0005	0.0000
4,4'-DDT	<0.001	<0.001	<0.001	0.000
Dieldrin	<0.001	<0.001	<0.001	0.000
Endosulfan I	<0.001	<0.001	<0.001	0.000
Endosulfan II	<0.001	<0.001	<0.001	0.000
Endosulfan Sulfate	<0.010	<0.010	<0.010	0.000
Endrin	<0.0005	<0.0005	<0.0005	0.0000
Heptachlor	<0.0005	<0.0005	<0.0005	0.0000
Heptachlor Epoxide	<0.010	<0.010	<0.010	0.000
Methoxychlor	<0.005	<0.005	<0.005	0.000
Toxaphene	<0.030	<0.030	<0.030	0.000
Organophosphate Pesticides				
Azinphos methyl	<0.05	<0.05	<0.05	0.00
Carbophenothion	<0.01	<0.01	<0.01	0.00
Diazinon	<0.02	<0.02	<0.02	0.00
Dimethoate	<0.02	<0.02	<0.02	0.00
Fensulfothion	<0.01	<0.01	<0.01	0.00
Fenthion	<0.02	<0.02	<0.02	0.00
Fonofos	<0.02	<0.02	<0.02	0.00
Malathion	<0.01	<0.01	<0.01	0.00
Methamidophos	<0.9	<0.9	<0.9	0.0
Mevinphos	<0.05	<0.05	<0.05	0.00
Parathion	<0.01	<0.01	<0.01	0.00
Parathion Methyl	<0.02	<0.02	<0.02	0.00
Phosmet	<0.03	<0.03	<0.03	0.00
Organic Parameters				
Total Organic Carbon C	2.26	2.12	2.21	0.07
Particle Size				
Gravel (>2.00mm) %	0.5	0.1	0.3	0.3
Sand (2.00mm - 0.063mm) %	20.9	6.4	11.3	5.7
Silt (0.063mm - 4um) %	54.1	42.1	49.3	4.8
Clay (<4um) %	48.6	24.8	39.3	8.8

number of samples = 5

TABLE 2
METALS DATA FOR THE OFFSHORE SITE EXPRESSED AS MMOL/KG

Total Metals (mmol/kg)	Rep #1	Rep #2	Rep #3	Rep #4	Rep #5
Aluminum T-Al	700	526	574	426	608
Arsenic T-As	0.04	0.03	0.03	0.05	0.03
Barium T-Ba	1.09	0.75	0.99	0.42	0.99
Cadmium T-Cd	0.0028	0.0022	0.0018	0.0017	0.0024
Chromium T-Cr	0.92	0.70	0.79	0.61	0.84
Cobalt T-Co	0.14	0.13	0.12	0.13	0.12
Copper T-Cu	0.25	0.19	0.16	0.19	0.18
Iron T-Fe	408.26	331.26	333.05	333.05	358.12
Lead T-Pb	0.03	0.02	0.02	0.02	0.02
Manganese T-Mn	5.33	4.33	4.70	4.04	5.19
Mercury T-Hg	0.00	0.00	0.00	0.00	0.00
Nickel T-Ni	0.49	0.36	0.37	0.42	0.40
Selenium T-Se	0.00	0.00	0.00	0.00	0.00
Zinc T-Zn	1.10	0.86	0.80	0.94	0.92
Extractable Metals	**(mmol/kg)**				
Aluminum Al	49.66	45.22	37.03	40.77	37.43
Antimony Sb	<0.12	<0.12	<0.12	<0.12	<0.12
Arsenic As	<0.20	<0.20	<0.20	<0.20	<0.20
Cadmium Cd	<0.004	<0.004	<0.004	<0.004	<0.004
Calcium Ca	59.13	55.39	49.90	49.65	47.65
Chromium Cr	0.04	0.03	0.03	0.03	0.03
Cobalt Co	<0.0008	0.01	0.02	<0.0008	0.01
Copper Cu	0.02	0.01	0.01	0.03	0.02
Iron Fe	53.00	46.20	44.77	46.91	45.30
Lead Pb	<0.01	0.01	<0.01	<0.01	<0.01
Magnesium Mg	55.96	54.72	48.55	44.02	43.20
Manganese Mn	0.28	0.26	0.22	0.25	0.23
Mercury Hg	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum Mo	<0.05	<0.05	<0.05	<0.05	<0.05
Nickel Ni	0.05	0.03	0.03	0.03	0.03
Selenium Se	<0.05	<0.05	<0.05	<0.05	<0.05
Zinc Zn	0.30	0.28	0.25	0.25	0.25
Sum of Cd, Cu, Pb, Hg, Ni, & Zn	0.37	0.34	0.29	0.31	0.30
Acid Volatile Sulphide	21.62	13.07	7.30	8.55	4.80

TABLE 3
SUMMARY OF SEDIMENT DATA FOR THE INSHORE SITE (µg/g dry-weight)

Physical Tests	MAXIMUM	MINIMUM	MEAN	STD. DEV.
Moisture %	40.1	35.7	37.4	1.8
Total Metals				
Aluminum T-Al	18900	11500	15300	2732
Arsenic T-As	5.55	3.64	4.572	0.81
Barium T-Ba	81.3	31.7	63.52	20.13
Cadmium T-Cd	0.31	0.19	0.244	0.05
Chromium T-Cr	47.6	31.7	40.02	6.21
Cobalt T-Co	8.3	7.1	7.52	0.48
Copper T-Cu	15.9	9.9	12.2	2.24
Iron T-Fe	22800	18500	19700	1841
Lead T-Pb	5.2	3.6	4.42	0.62
Manganese T-Mn	293	222	259.2	30.2
Mercury T-Hg	0.154	0.019	0.052	0.060
Molybdenum T-Mo	<4.0	<4.0	<4.0	0.0
Nickel T-Ni	28.6	21.3	23.9	3.0
Selenium T-Se	0.26	0.14	0.18	0.05
Strontium T-Sr	80.5	47	65.6	12.6
Tin T-Sn	<30	<30	<30	0.0
Titanium T-Ti	1530	984	1255	201
Vanadium T-V	54.4	34.5	46.2	7.8
Zinc T-Zn	71.6	52.3	60.4	7.2
Extractable Metals				
Aluminum Al	1340	999	1134	145
Antimony Sb	<15	<15	<15	0.0
Arsenic As	<15	<15	<15	0.0
Cadmium Cd	<0.5	<0.5	<0.5	0.0
Calcium Ca	2370	1910	2098	191
Chromium Cr	1.9	1.4	1.6	0.2
Cobalt Co	0.9	0.6	0.7	0.2
Copper Cu	1.8	0.8	1.2	0.4
Iron Fe	2960	2500	2638	186
Lead Pb	2.7	<2.5	<2.5+	-
Magnesium Mg	1360	1050	1198	143
Manganese Mn	15.5	12	13.6	1.4
Mercury Hg	<0.025	<0.025	<0.025	0.000
Molybdenum Mo	<5.0	<5.0	<5.0	0.0
Nickel Ni	2.8	1.5	2.0	0.5
Selenium Se	<5.0	<5.0	<5.0	0.0
Zinc Zn	19.9	16.1	17.5	1.6
Inorganic Parameters				
Acid Volatile Sulphide	693	154	354.8	212.1
Organo-metallics				
Tributyltin	0.003	0.002	0.002	0.001

TABLE 3
CONT'D

Polyaromatic Hydrocarbons	MAXIMUM	MINIMUM	MEAN	STD. DEV.
Acenaphthene	<0.005	<0.005	<0.005	0.000
Acenaphthylene	<0.005	<0.005	<0.005	0.000
Anthracene	0.01	0.005	0.008	0.000
Benzo(a)anthracene	0.042	0.019	0.030	0.010
Benzo(a)pyrene	0.027	0.024	0.026	0.000
Benzo(b)fluoranthene	0.052	0.024	0.038	0.010
Benzo(ghi)perylene	0.021	0.021	0.021	0.000
Benzo(k)fluoranthene	<0.020	<0.020	<0.020	0.000
Chrysene	0.069	0.023	0.039	0.020
Dibenzo(a,h)anthracene	<0.020	<0.020	<0.020	0.000
Fluoranthene	0.084	0.046	0.065	0.020
Fluorene	0.005	0.005	0.005	0.000
Indeno(1,2,3-cd)pyrene	0.023	0.023	0.023	0.000
Naphthalene	0.005	0.005	0.005	0.000
Phenanthrene	0.043	0.020	0.030	0.010
Pyrene	0.073	0.039	0.056	0.010
Chlorinated Phenols				
2,3,4-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,6-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,5-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
Pentachlorophenol	<0.005	<0.005	<0.005	0.000
Polychlorinated Biphenyl's				
PCB 1242	<0.010	<0.010	<0.010	0.000
PCB 1248	<0.010	<0.010	<0.010	0.000
PCB 1254	<0.010	<0.010	<0.010	0.000
PCB 1260	<0.010	<0.010	<0.010	0.000

TABLE 3
CONT'D

Organochlorine Pesticides	MAXIMUM	MINIMUM	MEAN	STD. DEV.
Aldrin	<0.001	<0.001	<0.001	0.000
gamma-BHC (Lindane)	<0.001	<0.001	<0.001	0.000
cis-Chlordane (alpha)	<0.001	<0.001	<0.001	0.000
trans-Chlordane (gamma)	<0.001	<0.001	<0.001	0.000
4,4'-DDD	<0.001	<0.001	<0.001	0.000
4,4'-DDE	<0.0005	<0.0005	<0.0005	0.0000
4,4'-DDT	<0.001	<0.001	<0.001	0.000
Dieldrin	<0.001	<0.001	<0.001	0.000
Endosulfan I	<0.001	<0.001	<0.001	0.000
Endosulfan II	<0.001	<0.001	<0.001	0.000
Endosulfan Sulfate	<0.010	<0.010	<0.010	0.000
Endrin	<0.0005	<0.0005	<0.0005	0.0000
Heptachlor	<0.0005	<0.0005	<0.0005	0.0000
Heptachlor Epoxide	<0.010	<0.010	<0.010	0.000
Methoxychlor	<0.005	<0.005	<0.005	0.000
Toxaphene	<0.030	<0.030	<0.030	0.000
Organophosphate Pesticides				
Azinphos methyl	<0.05	<0.05	<0.05	0.00
Carbophenothion	<0.01	<0.01	<0.01	0.00
Diazinon	<0.02	<0.02	<0.02	0.00
Dimethoate	<0.02	<0.02	<0.02	0.00
Fensulfothion	<0.01	<0.01	<0.01	0.00
Fenthion	<0.02	<0.02	<0.02	0.00
Fonofos	<0.02	<0.02	<0.02	0.00
Malathion	<0.01	<0.01	<0.01	0.00
Methamidophos	<0.9	<0.9	<0.9	0.0
Mevinphos	<0.05	<0.05	<0.05	0.00
Parathion	<0.01	<0.01	<0.01	0.00
Parathion Methyl	<0.02	<0.02	<0.02	0.00
Phosmet	<0.03	<0.03	<0.03	0.00
Organic Parameters				
Total Organic Carbon C	0.83	0.67	0.75	0.07
Particle Size				
Gravel (>2.00mm) %	0.7	0.2	0.4	0.2
Sand (2.00mm - 0.063mm) %	86.7	77.2	82.6	3.6
Silt (0.063mm - 4um) %	12.1	6.3	9.5	2.2
Clay (<4um) %	10	5.1	7.6	1.8

number of samples = 5

TABLE 4
METALS DATA FOR THE INSHORE SITE EXPRESSED AS MMOL/KG

Total Metals (mmol/kg)	Rep # 1	Rep # 2	Rep # 3	Rep # 4	Rep # 5
Aluminum T-Al	1160	1041	1027	1082	1116
Arsenic T-As	0.13	0.12	0.12	0.13	0.13
Cadmium T-Cd	0.0054	0.0052	0.0060	0.0057	0.0056
Chromium T-Cr	1.19	1.06	1.06	1.15	1.17
Cobalt T-Co	0.14	0.16	0.15	0.14	0.12
Copper T-Cu	0.57	0.53	0.55	0.56	0.57
Iron T-Fe	587.32	535.39	556.88	578.37	569.41
Lead T-Pb	0.08	0.07	0.07	0.07	0.07
Manganese T-Mn	6.35	5.83	5.84	6.17	6.39
Mercury T-Hg	0.00	0.00	0.00	0.00	0.00
Molybdenum T-Mo	0.05	0.07	<	<	<
Nickel T-Ni	0.67	0.61	0.64	0.67	0.65
Selenium T-Se	0.01	0.01	0.01	0.01	0.01
Zinc T-Zn	1.62	1.48	1.59	1.58	1.62
Extractable Metals	**mmol/kg**				
Aluminum Al	81	76	90	87	86
Antimony Sb	<	<	<	<	<
Arsenic As	<	<	<	<	<
Cadmium Cd	<	<	<	<	<
Chromium Cr	0.07	0.06	0.08	0.09	0.06
Cobalt Co	<	<	<	<	<
Copper Cu	0.07	0.11	0.11	0.12	0.07
Iron Fe	80.40	76.46	90.07	76.46	85.77
Lead Pb	0.05	0.05	0.05	0.04	0.05
Manganese Mn	0.47	0.43	0.55	0.52	0.48
Mercury Hg	<	<	<	<	<
Molybdenum Mo	<	<	<	<	<
Nickel Ni	0.06	0.05	0.05	0.07	0.06
Selenium Se	<	<	<	<	<
Zinc Zn	0.39	0.36	0.47	0.47	0.39
Sum Cd, Cu, Pb, Hg, Ni, & Zn	0.56	0.57	0.67	0.70	0.56
Acid Volatile Sulphide	24.95	24.92	27.64	34.31	33.69

TABLE 5
SUMMARY OF LITTLE CAMPBELL RIVER SEDIMENT DATA

Physical Tests	MAX	MIN	MEAN	STD. DEV.
Moisture %	65.7	37.4	50.7	13.8
Total Metals				
Aluminum T-Al	35900	29700	33100	2264
Arsenic T-As	11.2	5.32	7.89	2.20
Barium T-Ba	207	156	190.8	20.8
Cadmium T-Cd	0.31	0.14	0.22	0.09
Chromium T-Cr	62.6	50.7	58.5	4.6
Cobalt T-Co	18.5	10.5	14.8	3.6
Copper T-Cu	34.4	21.6	30.1	5.0
Iron T-Fe	35500	22800	31060	5266
Lead T-Pb	16.1	7.1	10.0	3.64
Manganese T-Mn	1320	549	862	298
Mercury T-Hg	0.051	0.034	0.042	0.010
Molybdenum T-Mo	4.2	<4.0	<4.0+	-
Nickel T-Ni	48.9	29.1	39.7	7.6
Selenium T-Se	0.59	0.20	0.39	0.17
Strontium T-Sr	85.4	67	73.8	8.3
Tin T-Sn	<30	<30	<30	0.0
Titanium T-Ti	1790	1400	1576	145
Vanadium T-V	90.8	66.1	80.2	9.9
Zinc T-Zn	137	72.5	98.7	24.6
Extractable Metals				
Aluminum Al	3370	1990	2876	537
Antimony Sb	<15	<15	<15	0.0
Arsenic As	<15	<15	<15	0.0
Cadmium Cd	<0.5	<0.5	<0.5	0.0
Calcium Ca	3800	2220	2848	676
Chromium Cr	3.4	1.4	2.8	0.8
Cobalt Co	4.8	1.8	3.5	1.9
Copper Cu	16.6	6.2	11.1	3.8
Iron Fe	8100	4220	6100	1436
Lead Pb	9.5	3.9	5.4	2.3
Magnesium Mg	1820	782	1300	377
Manganese Mn	868	318	446	237
Mercury Hg	<0.025	<0.025	<0.025	0.000
Molybdenum Mo	<5.0	<5.0	<5.0	0.0
Nickel Ni	6.8	3	4.9	1.7
Selenium Se	<5.0	<5.0	<5.0	0.0
Zinc Zn	51.3	18.5	28.1	13.7
Inorganic Parameters				
Acid Volatile Sulphide	55.9	8.2	28.2	23.3

TABLE 5
CONT'D

Polyaromatic Hydrocarbons	MAX	MIN	MEAN	STD. DEV.
Acenaphthene	0.006	0.006	0.006	0.000
Acenaphthylene	<0.005	<0.005	<0.005	0.000
Anthracene	0.008	0.008	0.008	0.000
Benzo(a)anthracene	0.046	0.011	0.023	0.016
Benzo(a)pyrene	0.047	0.024	0.036	0.016
Benzo(b)fluoranthene	0.093	0.023	0.047	0.032
Benzo(ghi)perylene	0.043	0.024	0.034	0.013
Benzo(k)fluoranthene	0.034	0.034	0.034	0.000
Chrysene	0.08	0.013	0.035	0.027
Dibenzo(a,h)anthracene	<0.020	<0.020	<0.020	0.000
Fluoranthene	0.13	0.022	0.060	0.042
Fluorene	0.01	0.01	0.01	0.00
Indeno(1,2,3-cd)pyrene	0.053	0.024	0.039	0.021
Naphthalene	0.029	0.007	0.017	0.008
Phenanthrene	0.083	0.015	0.037	0.027
Pyrene	0.113	0.021	0.052	0.036
Chlorinated Phenols				
2,3,4-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,6-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,5-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
Pentachlorophenol	<0.005	<0.005	<0.005	0.000
Polychlorinated Biphenyl's				
PCB 1242	<0.010	<0.010	<0.010	0.000
PCB 1248	<0.010	<0.010	<0.010	0.000
PCB 1254	<0.010	<0.010	<0.010	0.000
PCB 1260	<0.010	<0.010	<0.010	0.000

TABLE 5
CONT'D

Organochlorine Pesticides	MAX	MIN	MEAN	STD. DEV.
Aldrin	<0.001	<0.001	<0.001	0.000
gamma-BHC (Lindane)	<0.001	<0.001	<0.001	0.000
cis-Chlordane (alpha)	<0.001	<0.001	<0.001	0.000
trans-Chlordane (gamma)	<0.001	<0.001	<0.001	0.000
4,4'-DDD	<0.001	<0.001	<0.001	0.000
4,4'-DDE	<0.0005	<0.0005	<0.0005	0.0000
4,4'-DDT	<0.001	<0.001	<0.001	0.000
Dieldrin	<0.001	<0.001	<0.001	0.000
Endosulfan I	<0.001	<0.001	<0.001	0.000
Endosulfan II	<0.001	<0.001	<0.001	0.000
Endosulfan Sulfate	<0.010	<0.010	<0.010	0.000
Endrin	<0.0005	<0.0005	<0.0005	0.0000
Heptachlor	<0.0005	<0.0005	<0.0005	0.0000
Heptachlor Epoxide	<0.010	<0.010	<0.010	0.000
Methoxychlor	<0.005	<0.005	<0.005	0.000
Toxaphene	<0.030	<0.030	<0.030	0.000
Organophosphate Pesticides				
Azinphos methyl	<0.05	<0.05	<0.05	0.00
Carbophenothion	<0.01	<0.01	<0.01	0.00
Diazinon	<0.02	<0.02	<0.02	0.00
Dimethoate	<0.02	<0.02	<0.02	0.00
Fensulfothion	<0.01	<0.01	<0.01	0.00
Fenthion	<0.02	<0.02	<0.02	0.00
Fonofos	<0.02	<0.02	<0.02	0.00
Malathion	<0.01	<0.01	<0.01	0.00
Methamidophos	<0.9	<0.9	<0.9	0.0
Mevinphos	<0.05	<0.05	<0.05	0.00
Parathion	<0.01	<0.01	<0.01	0.00
Parathion Methyl	<0.02	<0.02	<0.02	0.00
Phosmet	<0.03	<0.03	<0.03	0.00
Organic Parameters				
Total Organic Carbon C	7.4	1.3	4.0	2.8
Particle Size				
Gravel (>2.00mm) %	3.3	0.2	1.8	1.2
Sand (2.00mm - 0.063mm) %	31.4	21.5	26.3	4.2
Silt (0.063mm - 4um) %	58.2	33.9	41.7	9.6
Clay (<4um) %	37.1	16	30.2	8.7

number of samples = 5

TABLE 6
METALS DATA FOR THE LITTLE CAMPBELL RIVER EXPRESSED AS MMOL/KG

Total Metals (mmol/kg)	Rep # 1	Rep # 2	Rep # 3	Rep # 4	Rep # 5
Aluminum T-Al	1330.54	1223.06	1100.75	1215.65	1263.83
Arsenic T-As	0.09	0.12	0.07	0.10	0.15
Cadmium T-Cd	<	0.00	<	0.00	0.00
Chromium T-Cr	1.16	1.14	0.98	1.14	1.20
Cobalt T-Co	0.31	0.20	0.18	0.30	0.27
Copper T-Cu	0.50	0.48	0.34	0.54	0.51
Iron T-Fe	635.67	522.86	408.26	583.74	630.29
Lead T-Pb	0.04	0.05	0.03	0.04	0.08
Manganese T-Mn	14.44	17.55	9.99	12.45	24.03
Mercury T-Hg	0.00	0.00	0.00	0.00	0.00
Molybdenum T-Mo	<	0.04	<	<	<
Nickel T-Ni	0.74	0.61	0.50	0.83	0.71
Selenium T-Se	0.00	0.01	0.01	0.00	0.01
Zinc T-Zn	1.45	1.61	1.11	1.29	2.10
Extractable Metals	**mmol/kg**				
Aluminum Al	104.89	124.90	73.75	110.45	118.97
Antimony Sb	<	<	<	<	<
Arsenic As	<	<	<	<	<
Cadmium Cd	<	<	<	<	<
Calcium Ca	82.28	121.19	84.87	98.59	140.84
Chromium Cr	0.12	0.11	0.05	0.11	0.13
Cobalt Co	0.17	0.09	0.07	0.18	0.16
Copper Cu	0.40	0.36	0.23	0.62	0.46
Iron Fe	240.54	199.40	156.40	233.86	300.21
Lead Pb	0.19	0.14	0.16	0.16	0.35
Magnesium Mg	52.63	48.18	28.98	67.45	43.73
Manganese Mn	11.79	11.90	14.16	12.64	32.17
Mercury Hg	<	<	<	<	<
Molybdenum Mo	<	<	<	<	<
Nickel Ni	0.20	0.12	0.11	0.23	0.25
Selenium Se	<	<	<	<	<
Zinc Zn	0.72	0.80	1.10	0.69	1.90
Sum Cu, Cd, Pb, Hg, Ni, & Zn	1.50	1.43	1.60	1.69	2.96
Acid Volatile Sulphide	0.30	1.22	0.26	<0.16	1.74

TABLE 7
SUMMARY OF SEDIMENT DATA FOR THE NICOMEKL RIVER (µg/g dry-weight)

Physical Tests	MAX.	MIN.	MEAN	STD. DEV.
Moisture %	43.9	33.7	39.8	3.9
Total Metals				
Aluminum T-Al	21300	16900	19040	1835
Arsenic T-As	8.47	5.82	6.8	1.1
Barium T-Ba	214	88	128	50
Cadmium T-Cd	0.38	0.28	0.3	0.04
Chromium T-Cr	61.8	46.9	53.8	5.5
Cobalt T-Co	18.3	14.6	16.4	1.4
Copper T-Cu	29.1	16.2	21.2	4.9
Iron T-Fe	33400	25100	27820	3306
Lead T-Pb	16.5	8.6	11.5	3.6
Manganese T-Mn	408	366	387	15
Mercury T-Hg	0.035	0.023	0.030	0.005
Molybdenum T-Mo	<4.0	<4.0	<4.0	0.0
Nickel T-Ni	55.7	41.1	45.5	5.9
Selenium T-Se	0.29	0.12	0.2	0.1
Strontium T-Sr	79.8	68.6	73.5	4.3
Tin T-Sn	<30	<30	<30	0.0
Titanium T-Ti	1590	1280	1432	111
Vanadium T-V	74.4	60.5	68.1	5.4
Zinc T-Zn	105	87.7	94.1	7.1
Extractable Metals				
Aluminum Al	2020	1320	1662	274
Antimony Sb	<15	<15	<15	0.0
Arsenic As	<15	<15	<15	0.0
Cadmium Cd	<0.5	<0.5	<0.5	0.0
Calcium Ca	2320	1470	1922	346
Chromium Cr	3.4	1.6	2.1	0.7
Cobalt Co	2.8	2.3	2.4	0.2
Copper Cu	5	2.4	4.0	1.1
Iron Fe	3960	2750	3528	483
Lead Pb	11.7	3.7	6.1	3.3
Magnesium Mg	1190	646	928	210
Manganese Mn	90.9	43.1	63.1	18.2
Mercury Hg	<0.025	<0.025	<0.025	0.000
Molybdenum Mo	<5.0	<5.0	<5.0	0.0
Nickel Ni	6.4	3.9	5.1	1.0
Selenium Se	<5.0	<5.0	<5.0	0.0
Zinc Zn	52.6	31	38.8	8.3
Inorganic Parameters				
Acid Volatile Sulphide	180	47.5	127.3	50.8

TABLE 7
CONT'D

Polyaromatic Hydrocarbons	MAX.	MIN.	MEAN	STD. DEV.
Acenaphthene	0.049	0.008	0.025	0.022
Acenaphthylene	0.006	0.006	0.006	0.000
Anthracene	0.034	0.008	0.022	0.013
Benzo(a)anthracene	0.170	0.025	0.076	0.058
Benzo(a)pyrene	0.063	0.031	0.042	0.018
Benzo(b)fluoranthene	0.196	0.028	0.080	0.068
Benzo(ghi)perylene	0.039	0.039	0.039	0.000
Benzo(k)fluoranthene	0.076	0.025	0.043	0.028
Chrysene	0.229	0.020	0.090	0.083
Dibenzo(a,h)anthracene	<0.020	<0.020	<0.020	0.000
Fluoranthene	0.649	0.114	0.338	0.216
Fluorene	0.065	0.010	0.027	0.023
Indeno(1,2,3-cd)pyrene	0.045	0.020	0.033	0.018
Naphthalene	0.021	0.010	0.014	0.005
Phenanthrene	0.235	0.025	0.081	0.087
Pyrene	0.433	0.095	0.241	0.138
Chlorinated Phenols				
2,3,4-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,6-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,5-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
Pentachlorophenol	<0.005	<0.005	<0.005	0.000
Polychlorinated Biphenyl's				
PCB 1242	<0.010	<0.010	<0.010	0.000
PCB 1248	<0.010	<0.010	<0.010	0.000
PCB 1254	<0.010	<0.010	<0.010	0.000
PCB 1260	<0.010	<0.010	<0.010	0.000

TABLE 7
CONT'D

Organochlorine Pesticides	MAX.	MIN.	MEAN	STD. DEV.
Aldrin	<0.001	<0.001	<0.001	0.000
gamma-BHC (Lindane)	<0.001	<0.001	<0.001	0.000
cis-Chlordane (alpha)	<0.001	<0.001	<0.001	0.000
trans-Chlordane (gamma)	0.002	0.002	0.000	0.000
4,4'-DDD	0.004	0.001	0.000	0.001
4,4'-DDE	0.0017	0.0007	0.0000	0.0000
4,4'-DDT	<0.001	<0.001	<0.001	0.000
Dieldrin	<0.001	<0.001	<0.001	0.000
Endosulfan I	<0.001	<0.001	<0.001	0.000
Endosulfan II	<0.001	<0.001	<0.001	0.000
Endosulfan Sulfate	<0.010	<0.010	<0.010	0.000
Endrin	<0.0005	<0.0005	<0.0005	0.0000
Heptachlor	<0.0005	<0.0005	<0.0005	0.0000
Heptachlor Epoxide	<0.010	<0.010	<0.010	0.000
Methoxychlor	<0.005	<0.005	<0.005	0.000
Toxaphene	<0.030	<0.030	<0.030	0.000
Organophosphate Pesticides				
Azinphos methyl	<0.05	<0.05	<0.05	0.00
Carbophenothion	<0.01	<0.01	<0.01	0.00
Diazinon	<0.02	<0.02	<0.02	0.00
Dimethoate	<0.02	<0.02	<0.02	0.00
Fensulfothion	<0.01	<0.01	<0.01	0.00
Fenthion	<0.02	<0.02	<0.02	0.00
Fonofos	<0.02	<0.02	<0.02	0.00
Malathion	<0.01	<0.01	<0.01	0.00
Methamidophos	<0.9	<0.9	<0.9	0.0
Mevinphos	<0.05	<0.05	<0.05	0.00
Parathion	<0.01	<0.01	<0.01	0.00
Parathion Methyl	<0.02	<0.02	<0.02	0.00
Phosmet	<0.03	<0.03	<0.03	0.00
Organic Parameters				
Total Organic Carbon C	1.70	1.18	1.50	0.21
Particle Size				
Gravel (>2.00mm) %	1	0.3	0.6	0.3
Sand (2.00mm - 0.063mm) %	85.5	63.4	74.2	9.3
Silt (0.063mm - 4um) %	22	7	14.4	6.4
Clay (<4um) %	16	6.6	11.0	3.5

number of samples = 5

TABLE 8
METALS DATA FOR THE NICOMEKL RIVER EXPRESSED AS MMOL/KG

Total Metals (mmol/kg)	Rep # 1	Rep # 2	Rep # 3	Rep # 4	Rep # 5
Aluminum T-Al	626.36	693.07	759.78	659.71	789.43
Arsenic T-As	0.09	0.08	0.08	0.08	0.11
Cadmium T-Cd	0.00	0.00	0.00	0.00	0.00
Chromium T-Cr	0.90	1.02	1.07	0.99	1.19
Cobalt T-Co	0.25	0.28	0.31	0.26	0.29
Copper T-Cu	0.30	0.30	0.35	0.25	0.46
Iron T-Fe	449.44	499.58	460.19	483.46	598.06
Lead T-Pb	0.04	0.04	0.07	0.04	0.08
Manganese T-Mn	7.12	7.05	6.66	6.95	7.43
Mercury T-Hg	0.00	0.00	0.00	0.00	0.00
Molybdenum T-Mo	<	<	<	<	<
Nickel T-Ni	0.73	0.76	0.70	0.73	0.95
Selenium T-Se	0.00	0.00	0.00	0.00	0.00
Zinc T-Zn	1.35	1.42	1.61	1.34	1.48
Extractable Metals	**mmol/kg**				
Aluminum Al	61.52	55.22	74.87	48.92	67.45
Antimony Sb	<	<	<	<	<
Arsenic As	<	<	<	<	<
Cadmium Cd	<	<	<	<	<
Calcium Ca	48.40	42.42	54.39	36.68	57.88
Chromium Cr	0.03	0.03	0.07	0.03	0.04
Cobalt Co	0.04	0.04	0.05	0.04	0.04
Copper Cu	0.06	0.05	0.08	0.04	0.08
Iron Fe	68.22	60.70	70.91	49.24	66.79
Lead Pb	0.02	0.03	0.06	0.02	0.02
Magnesium Mg	36.08	35.34	44.02	26.58	48.96
Manganese Mn	1.65	0.93	1.21	0.78	1.17
Mercury Hg	<	<	<	<	<
Molybdenum Mo	<	<	<	<	<
Nickel Ni	0.09	0.07	0.10	0.07	0.11
Selenium Se	<	<	<	<	<
Zinc Zn	0.54	0.54	0.80	0.47	0.61
Sum of Cd, Cu, Pb, Hg, Ni, & Zn	0.71	0.70	1.04	0.60	0.81
Acid Volatile Sulphide	3.87	3.87	5.61	1.48	5.02

TABLE 9
SUMMARY OF SEDIMENT DATA FOR THE SERPENTINE RIVER (µg/g dry-weight)

Physical Tests	MAX.	MIN.	MEAN	STD. DEV.
Moisture %	48.8	47.0	48.0	0.8
Total Metals				
Aluminum T-Al	22700	11300	18140	4580
Arsenic T-As	12.1	7.14	8.44	2.08
Barium T-Ba	136	61.9	107.4	31.1
Cadmium T-Cd	0.69	0.36	0.56	0.15
Chromium T-Cr	55	30.1	44.7	10.4
Cobalt T-Co	28.1	16.1	22.4	5.1
Copper T-Cu	29.1	20.6	25.7	4.0
Iron T-Fe	31500	19600	25320	4616
Lead T-Pb	20.8	14.5	18.6	2.5
Manganese T-Mn	416	213	338	91
Mercury T-Hg	0.045	0.025	0.037	0.008
Molybdenum T-Mo	<4.0	<4.0	<4.0	0.0
Nickel T-Ni	62.1	37.4	51.3	11.4
Selenium T-Se	0.25	0.20	0.22	0.02
Strontium T-Sr	80.3	50.9	68.4	13.0
Tin T-Sn	<30	<30	<30	0.0
Titanium T-Ti	1420	804	1177	264
Vanadium T-V	70.4	40.0	57.2	12.5
Zinc T-Zn	162	83.3	131.1	32.2
Extractable Metals				
Aluminum Al	3450	3090	3234	134
Antimony Sb	<15	<15	<15	0.0
Arsenic As	<15	<15	<15	0.0
Cadmium Cd	0.8	0.6	0.7	0.1
Calcium Ca	3220	2840	2970	146
Chromium Cr	4.5	3.1	3.6	0.5
Cobalt Co	5.1	3.1	4.1	0.9
Copper Cu	8.3	3.7	6.8	1.9
Iron Fe	5730	5220	5424	221
Lead Pb	16.4	13.4	14.7	1.3
Magnesium Mg	1260	892	1067	147
Manganese Mn	143	77.4	106.1	27.3
Mercury Hg	<0.025	<0.025	<0.025	0.000
Molybdenum Mo	<5.0	<5.0	<5.0	0.0
Nickel Ni	13.7	8.6	10.8	2.0
Selenium Se	<5.0	<5.0	<5.0	0.0
Zinc Zn	97.5	66	79.9	12.0
Inorganic Parameters				
Acid Volatile Sulphide	437	141	267	115

TABLE 9
CONT'D

Polyaromatic Hydrocarbons	MAX.	MIN.	MEAN	STD. DEV.
Acenaphthene	0.013	0.005	0.009	0.004
Acenaphthylene	0.03	0.008	0.015	0.010
Anthracene	0.17	0.022	0.067	0.061
Benzo(a)anthracene	0.327	0.065	0.146	0.106
Benzo(a)pyrene	0.137	0.056	0.101	0.036
Benzo(b)fluoranthene	0.297	0.088	0.170	0.079
Benzo(ghi)perylene	0.073	0.043	0.061	0.013
Benzo(k)fluoranthene	0.106	0.033	0.063	0.028
Chrysene	0.433	0.08	0.187	0.142
Dibenzo(a,h)anthracene	0.02	<0.02	<0.02+	-
Fluoranthene	1.03	0.187	0.409	0.354
Fluorene	0.078	0.019	0.042	0.026
Indeno(1,2,3-cd)pyrene	0.087	0.041	0.065	0.018
Naphthalene	0.018	0.009	0.011	0.004
Phenanthrene	0.372	0.121	0.240	0.124
Pyrene	0.652	0.196	0.337	0.188
Chlorinated Phenols				
2,3,4-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,6-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,5-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
Pentachlorophenol	<0.005	<0.005	<0.005	0.000
Polychlorinated Biphenyl's				
PCB 1242	<0.010	<0.010	<0.010	0.000
PCB 1248	<0.010	<0.010	<0.010	0.000
PCB 1254	<0.010	<0.010	<0.010	0.000
PCB 1260	<0.010	<0.010	<0.010	0.000

TABLE 9
CONT'D

Organochlorine Pesticides	MAX.	MIN.	MEAN	STD. DEV.
Aldrin	<0.001	<0.001	<0.001	0.000
gamma-BHC (Lindane)	<0.001	<0.001	<0.001	0.000
cis-Chlordane (alpha)	<0.001	<0.001	<0.001	0.000
trans-Chlordane (gamma)	<0.001	<0.001	<0.001	0.000
4,4'-DDD	0.005	0.003	0.004	0.001
4,4'-DDE	0.0036	0.0025	0.0031	0.0004
4,4'-DDT	0.001	0.001	0.001	0.000
Dieldrin	<0.001	<0.001	<0.001	0.000
Endosulfan I	0.002	0.001	0.001	0.001
Endosulfan II	0.004	0.001	0.002	0.001
Endosulfan Sulfate	<0.010	<0.010	<0.010	0.000
Endrin	<0.0005	<0.0005	<0.0005	0.0000
Heptachlor	<0.0005	<0.0005	<0.0005	0.0000
Heptachlor Epoxide	<0.010	<0.010	<0.010	0.000
Methoxychlor	<0.005	<0.005	<0.005	0.000
Toxaphene	<0.030	<0.030	<0.030	0.000
Organophosphate Pesticides				
Azinphos methyl	<0.05	<0.05	<0.05	0.00
Carbophenothion	<0.01	<0.01	<0.01	0.00
Diazinon	<0.02	<0.02	<0.02	0.00
Dimethoate	<0.02	<0.02	<0.02	0.00
Fensulfothion	<0.01	<0.01	<0.01	0.00
Fenthion	<0.02	<0.02	<0.02	0.00
Fonofos	<0.02	<0.02	<0.02	0.00
Malathion	<0.01	<0.01	<0.01	0.00
Methamidophos	<0.9	<0.9	<0.9	0.0
Mevinphos	<0.05	<0.05	<0.05	0.00
Parathion	<0.01	<0.01	<0.01	0.00
Parathion Methyl	<0.02	<0.02	<0.02	0.00
Phosmet	<0.03	<0.03	<0.03	0.00
Organic Parameters				
Total Organic Carbon C	3.42	2.74	3.06	0.27
Particle Size				
Gravel (>2.00mm) %	6.6	0.7	3.1	2.4
Sand (2.00mm - 0.063mm) %	71.5	59.8	65.1	4.5
Silt (0.063mm - 4um) %	24.2	15.6	19.5	3.2
Clay (<4um) %	16.6	9.4	12.2	2.8

number of samples = 5

TABLE 10
METALS DATA FOR THE SERPENTINE RIVER EXPRESSED AS MMOL/KG

Total Metals (mmol/kg)	Rep # 1	Rep # 2	Rep # 3	Rep # 4	Rep # 5
Aluminum T-Al	600.41	841.32	800.55	418.81	700.48
Arsenic T-As	0.10	0.11	0.10	0.16	0.10
Cadmium T-Cd	0.00	0.01	0.01	0.00	0.01
Chromium T-Cr	0.74	1.06	1.02	0.58	0.90
Cobalt T-Co	0.32	0.46	0.48	0.27	0.37
Copper T-Cu	0.35	0.46	0.44	0.32	0.45
Iron T-Fe	406.47	564.04	501.37	350.96	444.07
Lead T-Pb	0.10	0.10	0.09	0.07	0.09
Manganese T-Mn	4.95	7.57	7.50	3.88	6.88
Mercury T-Hg	0.00	0.00	0.00	0.00	0.00
Molybdenum T-Mo	<	<	<	<	<
Nickel T-Ni	0.71	1.05	1.06	0.64	0.91
Selenium T-Se	0.00	0.00	0.00	0.00	0.00
Zinc T-Zn	1.74	2.48	2.34	1.27	2.19
Extractable Metals	**mmol/kg**				
Aluminum Al	127.87	118.97	114.52	120.45	117.49
Antimony Sb	<	<	<	<	<
Arsenic As	<	<	<	<	<
Cadmium Cd	0.01	<	<	0.01	<
Calcium Ca	70.86	73.10	73.60	72.60	80.34
Chromium Cr	0.07	0.07	0.06	0.07	0.09
Cobalt Co	0.06	0.07	0.08	0.05	0.09
Copper Cu	0.10	0.12	0.13	0.06	0.12
Iron Fe	93.83	102.60	95.98	93.47	99.74
Lead Pb	0.08	0.07	0.06	0.08	0.07
Magnesium Mg	46.90	44.85	36.70	51.84	39.25
Manganese Mn	1.41	1.95	2.20	1.50	2.60
Mercury Hg	<	<	<	<	<
Molybdenum Mo	<	<	<	<	<
Nickel Ni	0.16	0.19	0.19	0.15	0.23
Selenium Se	<	<	<	<	<
Zinc Zn	1.10	1.26	1.25	1.01	1.49
Sum of Cd, Cu, Pb, Hg, Ni, & Zn	1.44	1.64	1.64	1.30	1.92
Acid Volatile Sulphide	10.60	10.75	6.67	16.20	5.23

TABLE 11
SUMMARY OF SEDIMENT DATA FROM ADJACENT TO THE PUMP HOUSES
(µg/g dry-weight)

	P 1	P 2	P 3	P 4	P 5
Physical Tests					
Moisture %	63.7	78.6	27.8	73.5	71.8
Total Metals					
Aluminum T-Al	17500	37900	16700	32400	29600
Arsenic T-As	13.3	26.4	4.4	6.46	5.9
Barium T-Ba	68.2	112	101	141	120
Cadmium T-Cd	0.95	3.01	0.2	1.91	1.77
Chromium T-Cr	49.1	60.6	43.5	74.1	58.8
Cobalt T-Co	17.2	31.4	8.8	16	14.7
Copper T-Cu	78.2	144	18.9	46.1	60.9
Iron T-Fe	28100	49100	23100	47600	31400
Lead T-Pb	57.2	58.8	6.1	16.8	18.5
Manganese T-Mn	307	461	274	378	278
Mercury T-Hg	0.061	0.083	0.024	0.044	0.036
Molybdenum T-Mo	<4.0	<16	<4.0	<8.0	<8.0
Nickel T-Ni	40.4	106	37.3	57.6	60.9
Selenium T-Se	0.29	0.75	0.26	0.56	0.44
Strontium T-Sr	84.2	170	59.8	141	133
Tin T-Sn	<30	<120	<30	<60	<60
Titanium T-Ti	1310	1450	1340	1840	1540
Vanadium T-V	58.9	71.2	56.4	82.8	61.6
Zinc T-Zn	211	350	52.3	342	265
Extractable Metals					
Aluminum Al	2730	11900	1270	3900	9400
Antimony Sb	<15	<15	<15	<15	<15
Arsenic As	<15	<15	<15	<15	<15
Cadmium Cd	1.3	<0.5	<0.5	<0.5	<0.5
Calcium Ca	5900	5800	1980	4540	4340
Chromium Cr	7.6	10.8	2.3	6.5	5.6
Cobalt Co	5.4	11.4	1.7	2	<0.5
Copper Cu	5.6	6	3.7	<0.5	<0.5
Iron Fe	8720	23100	2590	15400	7170
Lead Pb	35	34	<2.5	<2.5	<2.5
Magnesium Mg	1420	5630	1200	5850	4340
Manganese Mn	37.8	136	26.8	77.1	32.6
Mercury Hg	<0.025	<0.025	<0.025	<0.025	<0.025
Molybdenum Mo	<5.0	<5.0	<5.0	<5.0	<5.0
Nickel Ni	13.5	50.2	4.6	11.8	12
Selenium Se	<5.0	<5.0	<5.0	<5.0	<5.0
Zinc Zn	115	200	14.8	230	188
Inorganic Parameters					
Acid Volatile Sulphide	3600	11600	122	8750	3720

TABLE 11
CONT'D

Polyaromatic Hydrocarbons	P 1	P 2	P 3	P 4	P 5
Acenaphthene	0.007	<0.005	<0.005	<0.005	<0.005
Acenaphthylene	0.006	<0.005	<0.005	<0.005	<0.005
Anthracene	0.021	0.01	<0.005	<0.005	0.009
Benzo(a)anthracene	0.119	0.063	<0.010	<0.010	0.024
Benzo(a)pyrene	0.17	0.079	<0.020	<0.020	<0.020
Benzo(b)fluoranthene	0.277	0.143	<0.020	<0.020	0.025
Benzo(ghi)perylene	0.182	0.079	<0.020	<0.020	<0.020
Benzo(k)fluoranthene	0.107	0.054	<0.020	<0.020	<0.020
Chrysene	0.188	0.084	<0.010	<0.010	0.04
Dibenzo(a,h)anthracene	0.022	<0.020	<0.020	<0.020	<0.020
Fluoranthene	0.4	0.226	<0.010	0.014	0.061
Fluorene	0.013	0.012	<0.005	<0.005	0.008
Indeno(1,2,3-cd)pyrene	0.164	0.081	<0.020	<0.020	<0.020
Naphthalene	0.03	0.125	0.014	0.052	0.05
Phenanthrene	0.145	0.106	0.005	0.011	0.035
Pyrene	0.337	0.186	<0.010	0.012	0.053
Chlorinated Phenols					
2,3,4-Trichlorophenol	<0.005	<0.005	<0.005	<0.005	<0.005
2,3,5-Trichlorophenol	<0.005	<0.005	<0.005	<0.005	<0.005
2,4,5-Trichlorophenol	<0.005	<0.005	<0.005	<0.005	<0.005
2,4,6-Trichlorophenol	<0.005	<0.005	<0.005	<0.005	<0.005
2,3,4,5-Tetrachlorophenol	<0.005	<0.005	<0.005	<0.005	<0.005
2,3,4,6-Tetrachlorophenol	<0.005	<0.005	<0.005	<0.005	<0.005
2,3,5,6-Tetrachlorophenol	<0.005	<0.005	<0.005	<0.005	<0.005
Pentachlorophenol	<0.005	<0.005	<0.005	<0.005	<0.005
Polychlorinated Biphenyl's					
PCB 1242	<0.010	<0.010	<0.010	<0.010	<0.010
PCB 1248	<0.010	<0.010	<0.010	<0.010	<0.010
PCB 1254	<0.010	<0.010	<0.010	<0.010	<0.010
PCB 1260	<0.010	<0.010	<0.010	<0.010	<0.010

TABLE 11
CONT'D

Organochlorine Pesticides	P 1	P 2	P 3	P 4	P 5
Aldrin	<0.001	<0.001	<0.001	<0.001	<0.001
gamma-BHC (Lindane)	<0.001	<0.001	<0.001	<0.001	<0.001
cis-Chlordane (alpha)	<0.001	<0.001	<0.001	<0.001	<0.001
trans-Chlordane (gamma)	<0.001	<0.001	<0.001	<0.001	<0.001
4,4'-DDD	0.001	<0.001	<0.001	<0.001	<0.001
4,4'-DDE	0.0021	<0.0005	<0.0005	<0.0005	<0.0005
4,4'-DDT	<0.001	<0.001	<0.001	<0.001	<0.001
Dieldrin	<0.001	<0.001	<0.001	<0.001	<0.001
Endosulfan I	<0.001	<0.001	<0.001	<0.001	<0.001
Endosulfan II	<0.001	<0.001	<0.001	<0.001	<0.001
Endosulfan Sulfate	<0.010	<0.010	<0.010	<0.010	<0.010
Endrin	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Heptachlor	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Heptachlor Epoxide	<0.010	<0.010	<0.010	<0.010	<0.010
Methoxychlor	<0.005	<0.005	<0.005	<0.005	<0.005
Toxaphene	<0.030	<0.030	<0.030	<0.030	<0.030
Organophosphate Pesticides					
Azinphos methyl	<0.05	<0.05	<0.05	<0.05	<0.05
Carbophenothion	<0.01	<0.01	<0.01	<0.01	<0.01
Diazinon	<0.02	<0.02	<0.02	<0.02	<0.02
Dimethoate	<0.02	<0.02	<0.02	<0.02	<0.02
Fensulfothion	<0.01	<0.01	<0.01	<0.01	<0.01
Fenthion	<0.02	<0.02	<0.02	<0.02	<0.02
Fonofos	<0.02	<0.02	<0.02	<0.02	<0.02
Malathion	<0.01	<0.01	<0.01	<0.01	<0.01
Methamidophos	<0.9	<0.9	<0.9	<0.9	<0.9
Mevinphos	<0.05	<0.05	<0.05	<0.05	<0.05
Parathion	<0.01	<0.01	<0.01	<0.01	<0.01
Parathion Methyl	<0.02	<0.02	<0.02	<0.02	<0.02
Phosmet	<0.03	<0.03	<0.03	<0.03	<0.03
Organic Parameters					
Total Organic Carbon C	3.95	2.27	0.43	3.24	4.78
Particle Size					
Gravel (>2.00mm) %	2.4	2.1	0.6	<0.1	1.4
Sand (2.00mm - 0.063mm) %	76.2	59.8	72.8	3	23.5
Silt (0.063mm - 4um) %	10.9	11.5	16.6	45.5	73.9
Clay (<4um) %	10.5	26.6	10	51.5	1.2

number of samples = 5

TABLE 12
METALS DATA FOR THE SEDIMENTS NEAR THE PUMP STATIONS EXPRESSED AS MMOL/KG

Total Metals mmol/kg	P 1	P 2	P 3	P 4	P 5
Aluminum T-Al	648.59	1404.67	618.94	1200.82	1097.05
Arsenic T-As	0.18	0.35	0.06	0.09	0.08
Cadmium T-Cd	0.01	0.03	0.00	0.02	0.02
Chromium T-Cr	0.94	1.17	0.84	1.43	1.13
Cobalt T-Co	0.29	0.53	0.15	0.27	0.25
Copper T-Cu	1.23	2.27	0.30	0.73	0.96
Iron T-Fe	503.16	879.19	413.63	852.33	562.25
Lead T-Pb	0.28	0.28	0.03	0.08	0.09
Manganese T-Mn	5.59	8.39	4.99	6.88	5.06
Mercury T-Hg	0.00	0.00	0.00	0.00	0.00
Molybdenum T-Mo	<	<	<	<	<
Nickel T-Ni	0.69	1.81	0.64	0.98	1.04
Selenium T-Se	0.00	0.01	0.00	0.01	0.01
Zinc T-Zn	3.23	5.35	0.80	5.23	4.05
Extractable Metals	**mmol/kg**				
Aluminum Al	101.18	441.04	47.07	144.54	348.39
Antimony Sb	<	<	<	<	<
Arsenic As	<	<	<	<	<
Cadmium Cd	0.01	<	<	<	<
Calcium Ca	147.21	144.71	49.40	113.27	108.28
Chromium Cr	0.15	0.21	0.04	0.13	0.11
Cobalt Co	0.09	0.19	0.03	0.03	<
Copper Cu	0.09	0.09	0.06	<	<
Iron Fe	156.14	413.63	46.38	275.75	128.39
Lead Pb	0.17	0.16	<	<	<
Magnesium Mg	58.42	231.64	49.37	240.69	178.56
Manganese Mn	0.69	2.48	0.49	1.40	0.59
Mercury Hg	<	<	<	<	<
Molybdenum Mo	<	<	<	<	<
Nickel Ni	0.23	0.86	0.08	0.20	0.20
Selenium Se	<	<	<	<	<
Zinc Zn	1.76	3.06	0.23	3.52	2.88
Sum of Cd, Cu, Pb, Hg, Ni, & Zn	2.26	4.17	0.36	3.72	3.08
Acid Volatile Sulphide	112.29	361.82	3.81	272.93	116.03

TABLE 13
SUMMARY OF SEDIMENT DATA FOR ROBERTS BANK (µg/g dry-weight)

Physical Tests	MAX	MIN	MEAN	STD. DEV.
Moisture %	44.8	34.2	41.5	4.3
Total Metals				
Aluminum T-Al	25300	21500	23160	1573
Arsenic T-As	6.04	4.1	5.12	0.71
Barium T-Ba	125	101	112	10
Cadmium T-Cd	0.18	0.14	0.16	0.02
Chromium T-Cr	64.9	51.5	56.9	5.6
Cobalt T-Co	14.8	11.9	12.8	1.2
Copper T-Cu	28.8	24.2	26.1	2.1
Iron T-Fe	33900	28000	30700	2763
Lead T-Pb	7.6	6.4	7.1	0.5
Manganese T-Mn	457	376	411	40
Mercury T-Hg	0.039	0.033	0.036	0.002
Molybdenum T-Mo	4.1	4.1	4.1	0.0
Nickel T-Ni	51.7	41.8	45.48	4.31
Selenium T-Se	0.33	0.26	0.30	0.03
Strontium T-Sr	89.9	72.7	82.4	6.8
Tin T-Sn	<30	<30	<30	0.0
Titanium T-Ti	1790	1320	1536	178
Vanadium T-V	77.8	64.4	70.8	6.4
Zinc T-Zn	90.1	73.7	80.9	6.5
Extractable Metals				
Aluminum Al	1800	1260	1608	208
Antimony Sb	<15	<15	<15	0
Arsenic As	<15	<15	<15	0
Cadmium Cd	<0.5	<0.5	<0.5	0.0
Calcium Ca	3850	3110	3516	307
Chromium Cr	2.6	1.7	2.2	0.3
Cobalt Co	2	1.5	1.7	0.3
Copper Cu	4.9	2.5	3.8	1.0
Iron Fe	4890	3770	4508	448
Lead Pb	4	3.1	3.6	0.4
Magnesium Mg	2420	1630	2208	326
Manganese Mn	66.3	52.9	61.6	5.4
Mercury Hg	<0.025	<0.025	<0.025	0.000
Molybdenum Mo	<5.0	<5.0	<5.0	0.0
Nickel Ni	5.5	4.2	5.0	0.5
Selenium Se	<5.0	<5.0	<5.0	0.0
Zinc Zn	16.9	12.6	15.1	1.7
Inorganic Parameters				
Acid Volatile Sulphide	787	88.7	413.3	312.4
Organo-metallics				
Tributyltin	0.0027	0.0016	0.0022	0.0006

TABLE 13
CONTINUED

Polyaromatic Hydrocarbons	MAX	MIN	MEAN	STD. DEV.
Acenaphthene	0.008	0.005	0.007	0.000
Acenaphthylene	<0.005	<0.005	<0.005	0.000
Anthracene	0.037	0.01	0.023	0.010
Benzo(a)anthracene	0.083	0.019	0.055	0.030
Benzo(a)pyrene	0.05	<0.02	0.036	0.010
Benzo(b)fluoranthene	0.088	0.031	0.061	0.020
Benzo(ghi)perylene	0.038	<0.020	0.029	0.010
Benzo(k)fluoranthene	0.034	<0.020	0.028	0.010
Chrysene	0.126	0.035	0.084	0.040
Dibenzo(a,h)anthracene	<0.020	<0.020	<0.020	0.000
Fluoranthene	0.153	0.043	0.083	0.040
Fluorene	0.053	0.015	0.039	0.020
Indeno(1,2,3-cd)pyrene	0.028	0.021	0.025	0.000
Naphthalene	0.063	0.021	0.049	0.020
Phenanthrene	0.184	0.052	0.129	0.050
Pyrene	0.133	0.043	0.076	0.030
Chlorinated Phenols				
2,3,4-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,6-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,5-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
Pentachlorophenol	<0.005	<0.005	<0.005	0.000
Polychlorinated Biphenyl's				
PCB 1242	<0.010	<0.010	<0.010	0.000
PCB 1248	<0.010	<0.010	<0.010	0.000
PCB 1254	<0.010	<0.010	<0.010	0.000
PCB 1260	<0.010	<0.010	<0.010	0.000

TABLE 13
CONTINUED

Organochlorine Pesticides	MAX	MIN	MEAN	STD. DEV.
Aldrin	<0.001	<0.001	<0.001	0.000
gamma-BHC (Lindane)	<0.001	<0.001	<0.001	0.000
cis-Chlordane (alpha)	<0.001	<0.001	<0.001	0.000
trans-Chlordane (gamma)	<0.001	<0.001	<0.001	0.000
4,4'-DDD	<0.001	<0.001	<0.001	0.000
4,4'-DDE	<0.0005	<0.0005	<0.0005	0.0000
4,4'-DDT	<0.001	<0.001	<0.001	0.000
Dieldrin	<0.001	<0.001	<0.001	0.000
Endosulfan I	<0.001	<0.001	<0.001	0.000
Endosulfan II	<0.001	<0.001	<0.001	0.000
Endosulfan Sulfate	<0.010	<0.010	<0.010	0.000
Endrin	<0.0005	<0.0005	<0.0005	0.0000
Heptachlor	<0.0005	<0.0005	<0.0005	0.0000
Heptachlor Epoxide	<0.010	<0.010	<0.010	0.000
Methoxychlor	<0.005	<0.005	<0.005	0.000
Toxaphene	<0.030	<0.030	<0.030	0.000
Organophosphate Pesticides				
Azinphos methyl	<0.05	<0.05	<0.05	0.00
Carbophenothion	<0.01	<0.01	<0.01	0.00
Diazinon	<0.02	<0.02	<0.02	0.00
Dimethoate	<0.02	<0.02	<0.02	0.00
Fensulfothion	<0.01	<0.01	<0.01	0.00
Fenthion	<0.02	<0.02	<0.02	0.00
Fonofos	<0.02	<0.02	<0.02	0.00
Malathion	<0.01	<0.01	<0.01	0.00
Methamidophos	<0.9	<0.9	<0.9	0.0
Mevinphos	<0.05	<0.05	<0.05	0.00
Parathion	<0.01	<0.01	<0.01	0.00
Parathion Methyl	<0.02	<0.02	<0.02	0.00
Phosmet	<0.03	<0.03	<0.03	0.00
Organic Parameters				
Total Organic Carbon C	1.67	0.87	1.34	0.29
Particle Size				
Gravel (>2.00mm) %	0.3	0.1	0.2	0.1
Sand (2.00mm - 0.063mm) %	76.2	54.6	59.9	9.2
Silt (0.063mm - 4um) %	30.2	15.4	26.9	6.4
Clay (<4um) %	15.1	8.1	13.0	2.9

number of samples = 5

TABLE 14
METALS DATA FOR THE SEDIMENTS FROM ROBERTS BANK EXPRESSED AS MMOL/KG

Total Metals (mmol/kg)	Rep # 1	Rep # 2	Rep # 3	Rep # 4	Rep # 5
Aluminum T-Al	896.91	845.02	937.68	815.37	796.84
Arsenic T-As	0.08	0.07	0.07	0.05	0.06
Cadmium T-Cd	0.00	0.00	0.00	0.00	0.00
Chromium T-Cr	1.16	1.03	1.25	1.04	0.99
Cobalt T-Co	0.21	0.22	0.25	0.20	0.20
Copper T-Cu	0.40	0.44	0.45	0.38	0.38
Iron T-Fe	596.27	537.18	607.02	506.74	501.37
Lead T-Pb	0.03	0.04	0.04	0.03	0.03
Manganese T-Mn	8.32	7.06	8.25	6.97	6.85
Mercury T-Hg	0.00	0.00	0.00	0.00	0.00
Molybdenum T-Mo	<	<	0.04	<	<
Nickel T-Ni	0.88	0.74	0.82	0.72	0.71
Selenium T-Se	0.00	0.00	0.00	0.00	0.00
Zinc T-Zn	1.29	1.23	1.38	1.16	1.13
Extractable Metals	**mmol/kg**				
Aluminum Al	46.70	62.64	58.93	66.71	63.01
Antimony Sb	<	<	<	<	<
Arsenic As	<	<	<	<	<
Cadmium Cd	<	<	<	<	<
Calcium Ca	77.59	94.31	83.33	87.33	96.06
Chromium Cr	0.03	0.05	0.04	0.05	0.04
Cobalt Co	0.03	0.03	0.03	0.03	0.03
Copper Cu	0.04	0.06	0.05	0.08	0.07
Iron Fe	67.51	86.49	82.19	87.56	79.86
Lead Pb	0.01	0.02	0.02	0.02	0.02
Magnesium Mg	67.06	95.87	96.69	99.57	95.04
Manganese Mn	0.96	1.11	1.13	1.21	1.20
Mercury Hg	<	<	<	<	<
Molybdenum Mo	<	<	<	<	<
Nickel Ni	0.07	0.09	0.09	0.09	0.09
Selenium Se	<	<	<	<	<
Zinc Zn	0.19	0.25	0.22	0.26	0.24
Sum of Cd, Cu, Pb, Hg, Ni, & Zn	0.32	0.41	0.38	0.45	0.41
Acid Volatile Sulphide	2.77	21.43	24.55	10.85	4.87

TABLE 15
SUMMARY OF CONTAMINANT CONCENTRATIONS IN STAGHORN SCULPINS FROM THE INSHORE SITE (µg/g dry-weight)

	Maximum	Minimum	Mean	Std Dev
Physical Tests				
Lipid Content %	2.08	1.61	1.78	0.26
Moisture %	81.9	77.7	80.2	2.2
Total Metals				
Aluminum T-Al	95	40	67	28
Arsenic T-As	3.48	2.56	3.03	0.46
Barium T-Ba	1.98	0.93	1.52	0.54
Cadmium T-Cd	0.194	0.081	0.119	0.065
Chromium T-Cr	4.8	1.4	3.4	1.8
Cobalt T-Co	<1.0	<1.0	<1.0	0.0
Copper T-Cu	5.39	3.32	4.60	1.12
Iron T-Fe	186	90.7	146.6	49.7
Lead T-Pb	0.09	<0.05	<0.05+	-
Manganese T-Mn	12.2	5.17	7.83	3.81
Mercury T-Hg	0.071	0.029	0.048	0.021
Molybdenum T-Mo	<2.0	<2.0	<2.0	0.0
Nickel T-Ni	3.4	1.3	2.2	1.1
Selenium T-Se	1.36	1.28	1.32	0.04
Strontium T-Sr	197	121	148	43
Tin T-Sn	<15	<15	<15	0.0
Titanium T-Ti	5	2	3	2
Vanadium T-V	<2.0	<2.0	<2.0	0.0
Zinc T-Zn	97.2	80.1	91.0	9.4
Polyaromatic Hydrocarbons				
Acenaphthene	<0.005	<0.005	<0.005	0.000
Acenaphthylene	<0.005	<0.005	<0.005	0.000
Anthracene	<0.005	<0.005	<0.005	0.000
Benzo(a)anthracene	0.023	<0.010	<0.010+	-
Benzo(a)pyrene	0.034	<0.020	<0.020+	-
Benzo(b)fluoranthene	0.042	<0.020	<0.020+	-
Benzo(ghi)perylene	0.028	<0.020	<0.020+	-
Benzo(k)fluoranthene	<0.020	<0.020	<0.020	0.000
Chrysene	0.03	<0.010	<0.010+	-
Dibenzo(a,h)anthracene	<0.020	<0.020	<0.020	0.000
Fluoranthene	0.016	<0.010	<0.010+	-
Fluorene	<0.005	<0.005	<0.005	0.000
Indeno(1,2,3-cd)pyrene	0.026	<0.020	<0.020+	-
Naphthalene	<0.005	<0.005	<0.005	0.000
Phenanthrene	0.007	<0.005	0.006	0.001
Pyrene	0.015	<0.010	<0.010+	-

TABLE 15
CONTINUED

Chlorinated Phenols	MAXIMUM	MINIMUM	MEAN	STD. DEV.
2,3,4-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,6-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,5-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
Pentachlorophenol	<0.005	<0.005	<0.005	0.000
Polychlorinated Biphenyl's				
PCB 1242	<0.05	<0.05	<0.05	0.00
PCB 1248	<0.05	<0.05	<0.05	0.00
PCB 1254	<0.05	<0.05	<0.05	0.00
PCB 1260	<0.05	<0.05	<0.05	0.00
Organochlorine Pesticides				
Aldrin	<0.005	<0.005	<0.005	0.000
gamma-BHC (Lindane)	<0.005	<0.005	<0.005	0.000
cis-Chlordane (alpha)	<0.005	<0.005	<0.005	0.000
trans-Chlordane (gamma)	<0.005	<0.005	<0.005	0.000
4,4'-DDD	<0.005	<0.005	<0.005	0.000
4,4'-DDT	<0.005	<0.005	<0.005	0.000
Dieldrin	<0.005	<0.005	<0.005	0.000
Endosulfan I	<0.005	<0.005	<0.005	0.000
Endosulfan II	<0.005	<0.005	<0.005	0.000
Endosulfan Sulfate	<0.02	<0.02	<0.02	0.00
Endrin	<0.005	<0.005	<0.005	0.000
Heptachlor	<0.005	<0.005	<0.005	0.000
Heptachlor Epoxide	<0.02	<0.02	<0.02	0.00
Methoxychlor	<0.02	<0.02	<0.02	0.00
Toxaphene	<0.15	<0.15	<0.15	0.00
Organophosphate Pesticides				
Azinphos methyl	<0.2	<0.2	<0.2	0.0
Carbophenothion	<0.05	<0.05	<0.05	0.00
Diazinon	<0.1	<0.1	<0.1	0.0
Dimethoate	<0.1	<0.1	<0.1	0.0
Fensulfothion	<0.05	<0.05	<0.05	0.00
Fenthion	<0.1	<0.1	<0.1	0.0
Fonofos	<0.1	<0.1	<0.1	0.0
Malathion	<0.05	<0.05	<0.05	0.00
Methamidophos	<3.5	<3.5	<3.5	0.0
Mevinphos	<0.2	<0.2	<0.2	0.0
Parathion	<0.05	<0.05	<0.05	0.00
Parathion Methyl	<0.1	<0.1	<0.1	0.0
Phosmet	<0.1	<0.1	<0.1	0.0

number of samples = 3 (composite samples of 4,4, and 6 individuals)

TABLE 16
SUMMARY OF CONTAMINANT CONCENTRATIONS IN CRAB MUSCLE FROM THE INSHORE SITE (µg/g dry-weight)

	MAXIMUM	MINIMUM	MEAN	STD. DEV.
Physical Tests				
Lipid Content %	0.72	0.44	0.59	0.12
Moisture %	82.1	81.2	81.5	0.4
Total Metals				
Aluminum T-Al	<15	<15	<15	0.0
Arsenic T-As	28.3	14.2	22.4	6.1
Barium T-Ba	1.32	0.59	0.92	0.32
Cadmium T-Cd	0.066	0.059	0.061	0.003
Chromium T-Cr	<1.0	<1.0	<1.0	0.0
Cobalt T-Co	1.4	<1	<1	-
Copper T-Cu	48.6	41.5	44.2	3.2
Iron T-Fe	58.5	42.6	49.9	6.7
Lead T-Pb	<0.05	<0.05	<0.05	<0.05
Manganese T-Mn	2.69	1.66	2.08	0.45
Mercury T-Hg	0.309	0.235	0.269	0.032
Molybdenum T-Mo	<2.0	<2.0	<2.0	0.0
Nickel T-Ni	1.2	<1.0	<1.0+	-
Selenium T-Se	2.03	1.86	1.95	0.08
Strontium T-Sr	167	116	142	23
Tin T-Sn	<20	<15	<15+	-
Titanium T-Ti	1	<1	<1+	-
Vanadium T-V	<2.0	<2.0	<2.0	0.0
Zinc T-Zn	318	293	308	11
Polyaromatic Hydrocarbons				
Acenaphthene	<0.005	<0.005	<0.005	0.000
Acenaphthylene	<0.005	<0.005	<0.005	0.000
Anthracene	<0.005	<0.005	<0.005	0.000
Benzo(a)anthracene	<0.010	<0.010	<0.010	0.000
Benzo(a)pyrene	<0.020	<0.020	<0.020	0.000
Benzo(b)fluoranthene	<0.020	<0.020	<0.020	0.000
Benzo(ghi)perylene	<0.020	<0.020	<0.020	0.000
Benzo(k)fluoranthene	<0.020	<0.020	<0.020	0.000
Chrysene	<0.010	<0.010	<0.010	0.000
Dibenzo(a,h)anthracene	<0.020	<0.020	<0.020	0.000
Fluoranthene	<0.010	<0.010	<0.010	0.000
Fluorene	<0.005	<0.005	<0.005	0.000
Indeno(1,2,3-cd)pyrene	<0.020	<0.020	<0.020	0.000
Naphthalene	<0.005	<0.005	<0.005	0.000
Phenanthrene	<0.005	<0.005	<0.005	0.000
Pyrene	<0.010	<0.010	<0.010	0.000

TABLE 16
(CONTINUED)

Chlorinated Phenols	MAXIMUM	MINIMUM	MEAN	STD. DEV.
2,3,4-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,6-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,5-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
Pentachlorophenol	<0.005	<0.005	<0.005	0.000
Polychlorinated Biphenyl's				
PCB 1242	<0.05	<0.05	<0.05	0.00
PCB 1248	<0.05	<0.05	<0.05	0.00
PCB 1254	<0.05	<0.05	<0.05	0.00
PCB 1260	<0.05	<0.05	<0.05	0.00
Organochlorine Pesticides				
Aldrin	<0.005	<0.005	<0.005	0.000
gamma-BHC (Lindane)	<0.005	<0.005	<0.005	0.000
cis-Chlordane (alpha)	<0.005	<0.005	<0.005	0.000
trans-Chlordane (gamma)	<0.005	<0.005	<0.005	0.000
4,4'-DDD	<0.005	<0.005	<0.005	0.000
4,4'-DDT	<0.005	<0.005	<0.005	0.000
Dieldrin	<0.005	<0.005	<0.005	0.000
Endosulfan I	<0.005	<0.005	<0.005	0.000
Endosulfan II	<0.005	<0.005	<0.005	0.000
Endosulfan Sulfate	<0.02	<0.02	<0.02	0.00
Endrin	<0.005	<0.005	<0.005	0.000
Heptachlor	<0.005	<0.005	<0.005	0.000
Heptachlor Epoxide	<0.02	<0.02	<0.02	0.00
Methoxychlor	<0.02	<0.02	<0.02	0.00
Toxaphene	<0.15	<0.15	<0.15	0.00
Organophosphate Pesticides				
Azinphos methyl	<0.2	<0.2	<0.2	0.0
Carbophenothion	<0.05	<0.05	<0.05	0.00
Diazinon	<0.1	<0.1	<0.1	0.0
Dimethoate	<0.1	<0.1	<0.1	0.0
Fensulfothion	<0.05	<0.05	<0.05	0.00
Fenthion	<0.1	<0.1	<0.1	0.0
Fonofos	<0.1	<0.1	<0.1	0.0
Malathion	<0.05	<0.05	<0.05	0.00
Methamidophos	<3.5	<3.5	<3.5	0.0
Mevinphos	<0.2	<0.2	<0.2	0.0
Parathion	<0.05	<0.05	<0.05	0.00
Parathion Methyl	<0.1	<0.1	<0.1	0.0
Phosmet	<0.1	<0.1	<0.1	0.0

number of samples = 4

TABLE 17
SUMMARY OF CONTAMINANT CONCENTRATIONS IN CRAB HEPATOPANCREAS FROM THE INSHORE SITE (µg/g dry-weight)

Physical Tests	
Lipid Content %	2.15
Moisture %	85.9
Total Metals	
Aluminum T-Al	<15
Arsenic T-As	24
Barium T-Ba	1.07
Cadmium T-Cd	3.2
Chromium T-Cr	<1.0
Cobalt T-Co	1.5
Copper T-Cu	331
Iron T-Fe	475
Lead T-Pb	<0.05
Manganese T-Mn	18.6
Mercury T-Hg	0.214
Molybdenum T-Mo	<2.0
Nickel T-Ni	1.4
Selenium T-Se	6.87
Strontium T-Sr	235
Tin T-Sn	<20
Titanium T-Ti	<1
Vanadium T-V	<2.0
Zinc T-Zn	144
Polyaromatic Hydrocarbons	
Acenaphthene	<0.005
Acenaphthylene	<0.005
Anthracene	<0.005
Benzo(a)anthracene	<0.010
Benzo(a)pyrene	<0.020
Benzo(b)fluoranthene	<0.020
Benzo(ghi)perylene	<0.020
Benzo(k)fluoranthene	<0.020
Chrysene	<0.010
Dibenzo(a,h)anthracene	<0.020
Fluoranthene	<0.010
Fluorene	<0.005
Indeno(1,2,3-cd)pyrene	<0.020
Naphthalene	0.033
Phenanthrene	0.032
Pyrene	<0.010

TABLE 17
(CONTINUED)

Chlorinated Phenols	
2,3,4-Trichlorophenol	<0.005
2,3,5-Trichlorophenol	<0.005
2,4,5-Trichlorophenol	<0.005
2,4,6-Trichlorophenol	<0.005
2,3,4,5-Tetrachlorophenol	<0.005
2,3,4,6-Tetrachlorophenol	<0.005
2,3,5,6-Tetrachlorophenol	<0.005
Pentachlorophenol	<0.005
Polychlorinated Biphenyl's	
PCB 1242	<0.1
PCB 1248	<0.1
PCB 1254	<0.1
PCB 1260	0.4
Organochlorine Pesticides	
Aldrin	<0.01
gamma-BHC (Lindane)	<0.01
cis-Chlordane (alpha)	<0.01
trans-Chlordane (gamma)	<0.01
4,4'-DDD	<0.01
4,4'-DDT	<0.01
Dieldrin	0.16
Endosulfan I	<0.01
Endosulfan II	<0.01
Endosulfan Sulfate	<0.04
Endrin	<0.01
Heptachlor	<0.01
Heptachlor Epoxide	<0.04
Methoxychlor	<0.04
Toxaphene	<0.3
Organophosphate Pesticides	
Azinphos methyl	<0.5
Carbophenothion	<0.1
Diazinon	<0.2
Dimethoate	<0.2
Fensulfothion	<0.1
Fenthion	<0.2
Fonofos	<0.2
Malathion	<0.1
Methamidophos	<3.5
Mevinphos	<0.5
Parathion	<0.1
Parathion Methyl	<0.2
Phosmet	<0.2

TABLE 18
SUMMARY OF CONTAMINANT CONCENTRATIONS IN STARRY FLOUNDER MUSCLE FROM THE OFFSHORE SITE (µg/g dry-weight)

	MAXIMUM	MINIMUM	MEAN	STD. DEV.
Physical Tests				
Lipid Content %	0.92	0.35	0.60	0.29
Moisture %	82.9	80.4	81.6	1.3
Total Metals				
Aluminum T-Al	<15	<15	<15	0.0
Arsenic T-As	8.08	2.26	5.87	3.15
Barium T-Ba	<0.50	<0.50	<0.50	0.00
Cadmium T-Cd	0.025	<0.025	<0.025+	-
Chromium T-Cr	<1.0	<1.0	<1.0	0.0
Cobalt T-Co	<1.0	<1.0	<1.0	0.0
Copper T-Cu	4.04	1.54	2.67	1.27
Iron T-Fe	25.6	10	16.5	8.1
Lead T-Pb	<0.05	<0.05	<0.05	0.00
Manganese T-Mn	0.96	0.5	0.76	0.24
Mercury T-Hg	0.211	0.092	0.154	0.060
Molybdenum T-Mo	<2.0	<2.0	<2.0	0.0
Nickel T-Ni	<1.0	<1.0	<1.0	0.0
Selenium T-Se	2.71	1	1.60	0.97
Strontium T-Sr	2.17	1.13	1.67	0.52
Tin T-Sn	<15	<15	<15	0.0
Titanium T-Ti	<1	<1	<1	0.0
Vanadium T-V	<2.0	<2.0	<2.0	0.0
Zinc T-Zn	40.9	31.3	37.7	5.5
Polyaromatic Hydrocarbons				
Acenaphthene	<0.005	<0.005	<0.005	0.000
Acenaphthylene	<0.005	<0.005	<0.005	0.000
Anthracene	<0.005	<0.005	<0.005	0.000
Benzo(a)anthracene	<0.010	<0.010	<0.010	0.000
Benzo(a)pyrene	<0.020	<0.020	<0.020	0.000
Benzo(b)fluoranthene	<0.020	<0.020	<0.020	0.000
Benzo(ghi)perylene	<0.020	<0.020	<0.020	0.000
Benzo(k)fluoranthene	<0.020	<0.020	<0.020	0.000
Chrysene	<0.010	<0.010	<0.010	0.000
Dibenzo(a,h)anthracene	<0.020	<0.020	<0.020	0.000
Fluoranthene	<0.010	<0.010	<0.010	0.000
Fluorene	<0.005	<0.005	<0.005	0.000
Indeno(1,2,3-cd)pyrene	<0.020	<0.020	<0.020	0.000
Naphthalene	0.008	<0.005	<0.005+	-
Phenanthrene	0.006	<0.005	<0.005+	-
Pyrene	<0.010	<0.010	<0.010	0.000

TABLE 18
(CONTINUED)

	MAXIMUM	MINIMUM	MEAN	STD. DEV.
Chlorinated Phenols				
2,3,4-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,6-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,5-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
Pentachlorophenol	<0.005	<0.005	<0.005	0.000
Polychlorinated Biphenyl's				
PCB 1242	<0.05	<0.05	<0.05	0.00
PCB 1248	<0.05	<0.05	<0.05	0.00
PCB 1254	<0.05	<0.05	<0.05	0.00
PCB 1260	<0.05	<0.05	<0.05	0.00
Organochlorine Pesticides				
Aldrin	<0.005	<0.005	<0.005	0.000
gamma-BHC (Lindane)	<0.005	<0.005	<0.005	0.000
cis-Chlordane (alpha)	<0.005	<0.005	<0.005	0.000
trans-Chlordane (gamma)	<0.005	<0.005	<0.005	0.000
4,4'-DDD	<0.005	<0.005	<0.005	0.000
4,4'-DDE	<0.005	<0.005	<0.005	0.000
4,4'-DDT	<0.005	<0.005	<0.005	0.000
Dieldrin	<0.005	<0.005	<0.005	0.000
Endosulfan I	<0.005	<0.005	<0.005	0.000
Endosulfan II	<0.005	<0.005	<0.005	0.000
Endosulfan Sulfate	<0.005	<0.005	<0.005	0.000
Endrin	<0.02	<0.02	<0.02	0.00
Heptachlor	<0.005	<0.005	<0.005	0.000
Heptachlor Epoxide	<0.005	<0.005	<0.005	0.000
Methoxychlor	<0.02	<0.02	<0.02+	0.00
Toxaphene	0.06	<0.02	<0.15	-
	<0.15	<0.15		0.00
Organophosphate Pesticides				
Azinphos methyl	<0.2	<0.2	<0.2	0.0
Carbophenothion	<0.05	<0.05	<0.05	0.00
Diazinon	<0.1	<0.1	<0.1	0.0
Dimethoate	<0.1	<0.1	<0.1	0.0
Fensulfothion	<0.05	<0.05	<0.05	0.00
Fenthion	<0.1	<0.1	<0.1	0.0
Fonofos	<0.1	<0.1	<0.1	0.0
Malathion	<0.05	<0.05	<0.05	0.00
Methamidophos	<3.5	<3.5	<0.2	0.0
Mevinphos	<0.2	<0.2	<0.05	0.00
Parathion	<0.05	<0.05	<0.1	0.0
Parathion Methyl	<0.1	<0.1	<0.1	0.0
Phosmet	<0.1	<0.1	<0.1	0.0

number of samples = 3

TABLE 19
SUMMARY OF CONTAMINANT CONCENTRATIONS IN A COMPOSITE SAMPLE OF STARRY FLOUNDER LIVERS FROM THE OFFSHORE SITE (µg/g dry-weight)

Physical Tests	
Lipid Content %	7.89
Moisture %	77.5
Polyaromatic Hydrocarbons	
Acenaphthene	<0.005
Acenaphthylene	<0.005
Anthracene	<0.005
Benzo(a)anthracene	<0.010
Benzo(a)pyrene	<0.020
Benzo(b)fluoranthene	<0.020
Benzo(ghi)perylene	<0.020
Benzo(k)fluoranthene	<0.020
Chrysene	<0.010
Dibenzo(a,h)anthracene	<0.020
Fluoranthene	<0.010
Fluorene	0.031
Indeno(1,2,3-cd)pyrene	<0.020
Naphthalene	0.04
Phenanthrene	0.03
Pyrene	<0.010

TABLE 20
SUMMARY OF CONTAMINANT CONCENTRATIONS IN BUTTER SOLE MUSCLE FROM THE OFFSHORE SITE (µg/g dry-weight)

	MAXIMUM	MINIMUM	MEAN	STD. DEV.
Physical Tests				
Lipid Content %	0.78	0.56	0.66	0.11
Moisture %	81.3	80.2	80.8	0.6
Total Metals				
Aluminum T-Al	<15	<15	<15	0.0
Arsenic T-As	6.77	0.79	4.18	3.07
Barium T-Ba	<0.50	<0.50	<0.50	0.00
Cadmium T-Cd	<0.025	<0.025	<0.025	0.000
Chromium T-Cr	<1.0	<1.0	<1.0	0.0
Cobalt T-Co	<1.0	<1.0	<1.0	0.0
Copper T-Cu	1.16	0.76	0.94	0.20
Iron T-Fe	16.2	10.5	14.0	3.0
Lead T-Pb	<0.05	<0.05	<0.05	0.00
Manganese T-Mn	1.08	0.59	0.84	0.25
Mercury T-Hg	0.109	0.068	0.094	0.023
Molybdenum T-Mo	<2.0	<2.0	<2.0	0.0
Nickel T-Ni	<1.0	<1.0	<1.0	0.0
Selenium T-Se	1.2	0.97	1.10	0.12
Strontium T-Sr	6.56	3.57	5.31	1.56
Tin T-Sn	<15	<15	<15	0.0
Titanium T-Ti	<1	<1	<1	0.0
Vanadium T-V	<2.0	<2.0	<2.0	0.0
Zinc T-Zn	33.6	27.2	30.8	3.3
Polyaromatic Hydrocarbons				
Acenaphthene	<0.005	<0.005	<0.005	0.000
Acenaphthylene	<0.005	<0.005	<0.005	0.000
Anthracene	<0.005	<0.005	0.011	0.000
Benzo(a)anthracene	<0.010	<0.010	<0.010	0.000
Benzo(a)pyrene	<0.020	<0.020	<0.020	0.000
Benzo(b)fluoranthene	<0.020	<0.020	<0.020	0.000
Benzo(ghi)perylene	<0.020	<0.020	<0.020	0.000
Benzo(k)fluoranthene	<0.020	<0.020	<0.020	0.000
Chrysene	<0.010	<0.010	<0.010	0.000
Dibenzo(a,h)anthracene	<0.020	<0.020	<0.020	0.000
Fluoranthene	<0.010	<0.010	<0.010	0.000
Fluorene	<0.005	<0.005	<0.005	0.000
Indeno(1,2,3-cd)pyrene	<0.020	<0.020	<0.020	0.000
Naphthalene	<0.005	<0.005	0.005	0.000
Phenanthrene	0.018	<0.005	0.010	0.007
Pyrene	<0.010	<0.010	<0.010	0.000

TABLE 20
CONTINUED

Chlorinated Phenols	MAXIMUM	MINIMUM	MEAN	STD. DEV.
2,3,4-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,6-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,5-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
Pentachlorophenol	<0.005	<0.005	<0.005	0.000
Polychlorinated Biphenyl's				
PCB 1242	<0.05	<0.05	<0.05	0.00
PCB 1248	<0.05	<0.05	<0.05	0.00
PCB 1254	<0.05	<0.05	<0.05	0.00
PCB 1260	<0.05	<0.05	<0.05	0.00
Organochlorine Pesticides				
Aldrin	<0.005	<0.005	<0.005	0.000
gamma-BHC (Lindane)	<0.005	<0.005	<0.005	0.000
cis-Chlordane (alpha)	<0.005	<0.005	<0.005	0.000
trans-Chlordane (gamma)	<0.005	<0.005	<0.005	0.000
4,4'-DDD	<0.005	<0.005	<0.005	0.000
4,4'-DDE	<0.005	<0.005	<0.005	0.000
4,4'-DDT	<0.005	<0.005	<0.005	0.000
Dieldrin	<0.005	<0.005	<0.005	0.000
Endosulfan I	<0.005	<0.005	<0.005	0.000
Endosulfan II	<0.005	<0.005	<0.005	0.000
Endosulfan Sulfate	<0.02	<0.02	<0.02	0.00
Endrin	<0.005	<0.005	<0.005	0.000
Heptachlor	<0.005	<0.005	<0.005	0.000
Heptachlor Epoxide	<0.02	<0.02	<0.02	0.00
Methoxychlor	<0.02	<0.02	<0.02	0.00
Toxaphene	<0.15	<0.15	<0.15	0.00
Organophosphate Pesticides				
Azinphos methyl	<0.2	<0.2	<0.2	0.0
Carbophenothion	<0.05	<0.05	<0.05	0.00
Diazinon	<0.1	<0.1	<0.1	0.0
Dimethoate	<0.1	<0.1	<0.1	0.0
Fensulfothion	<0.05	<0.05	<0.05	0.00
Fenthion	<0.1	<0.1	<0.1	0.0
Fonofos	<0.1	<0.1	<0.1	0.0
Malathion	<0.05	<0.05	<0.05	0.00
Methamidophos	<3.5	<3.5	<3.5	0.0
Mevinphos	<0.2	<0.2	<0.2	0.0
Parathion	<0.05	<0.05	<0.05	0.00
Parathion Methyl	<0.1	<0.1	<0.1	0.0
Phosmet	<0.1	<0.1	<0.1	0.0

number of samples = 3

TABLE 21
SUMMARY OF CONTAMINANT CONCENTRATIONS IN DUNGENESS CRAB MUSCLE (N=4) FROM THE OFFSHORE SITE (µg/g dry-weight)

Physical Tests	MAXIMUM	MINIMUM	MEAN	STD. DEV.
Lipid Content %	0.53	0.28	0.42	0.13
Moisture %	84.9	83.7	84.5	0.7
Total Metals				
Aluminum T-Al	44	16	30	20
Arsenic T-As	2.67	2.07	2.32	0.27
Barium T-Ba	0.76	0.58	0.69	0.10
Cadmium T-Cd	0.141	0.034	0.084	0.054
Chromium T-Cr	1.1	<1.0	<1.0+	-
Cobalt T-Co	<1.0	<1.0	<1.0	0.0
Copper T-Cu	84.4	54.4	67.2	12.5
Iron T-Fe	74.1	33	47.3	19.3
Lead T-Pb	<0.05	<0.05	<0.05	0.00
Manganese T-Mn	1.5	1.07	1.34	0.20
Mercury T-Hg	0.334	0.125	0.204	0.094
Molybdenum T-Mo	2.6	2.6	2.6	0.0
Nickel T-Ni	<1.0	<1.0	<1.0	0.0
Selenium T-Se	2.71	1.92	2.27	0.35
Strontium T-Sr	307	256	278	22
Tin T-Sn	<15	<15	<15	0.0
Titanium T-Ti	2	2	2.0	0.0
Vanadium T-V	<2.0	<2.0	<2.0	0.0
Zinc T-Zn	286	238	267	21
Polyaromatic Hydrocarbons				
Acenaphthene	<0.005	<0.005	<0.005	0.000
Acenaphthylene	<0.005	<0.005	<0.005	0.000
Anthracene	<0.005	<0.005	<0.005	0.000
Benzo(a)anthracene	<0.010	<0.010	<0.010	0.000
Benzo(a)pyrene	<0.020	<0.020	<0.020	0.000
Benzo(b)fluoranthene	<0.020	<0.020	<0.020	0.000
Benzo(ghi)perylene	<0.020	<0.020	<0.020	0.000
Benzo(k)fluoranthene	<0.020	<0.020	<0.020	0.000
Chrysene	<0.010	<0.010	<0.010	0.000
Dibenzo(a,h)anthracene	<0.020	<0.020	<0.020	0.000
Fluoranthene	<0.010	<0.010	<0.010	0.000
Fluorene	0.011	<0.005	0.008	0.003
Indeno(1,2,3-cd)pyrene	<0.020	<0.020	<0.020	0.000
Naphthalene	0.009	<0.005	0.007	0.002
Phenanthrene	0.015	<0.005	0.010	0.006
Pyrene	<0.010	<0.010	<0.010	0.000

TABLE 21
CONTINUED

Chlorinated Phenols	MAXIMUM	MINIMUM	MEAN	STD. DEV.
2,3,4-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,6-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,5-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
Pentachlorophenol	<0.005	<0.005	<0.005	0.000
Polychlorinated Biphenyl's				
PCB 1242	<0.05	<0.05	<0.05	0.00
PCB 1248	<0.05	<0.05	<0.05	0.00
PCB 1254	<0.05	<0.05	<0.05	0.00
PCB 1260	<0.05	<0.05	<0.05	0.00
Organochlorine Pesticides				
Aldrin	<0.005	<0.005	<0.005	0.000
gamma-BHC (Lindane)	<0.005	<0.005	<0.005	0.000
cis-Chlordane (alpha)	<0.005	<0.005	<0.005	0.000
trans-Chlordane (gamma)	<0.005	<0.005	<0.005	0.000
4,4'-DDD	<0.005	<0.005	<0.005	0.000
4,4'-DDE	<0.005	<0.005	<0.005	0.000
4,4'-DDT	<0.005	<0.005	<0.005	0.000
Dieldrin	<0.005	<0.005	<0.005	0.000
Endosulfan I	<0.005	<0.005	<0.005	0.000
Endosulfan II	<0.005	<0.005	<0.005	0.000
Endosulfan Sulfate	<0.02	<0.02	<0.02	0.00
Endrin	<0.005	<0.005	<0.005	0.000
Heptachlor	<0.005	<0.005	<0.005	0.000
Heptachlor Epoxide	<0.02	<0.02	<0.02	0.00
Methoxychlor	<0.02	<0.02	<0.02	0.00
Toxaphene	<0.15	<0.15	<0.15	0.00
Organophosphate Pesticides				
Azinphos methyl	<0.2	<0.2	<0.2	0.0
Carbophenothion	<0.05	<0.05	<0.05	0.00
Diazinon	<0.1	<0.1	<0.1	0.0
Dimethoate	<0.1	<0.1	<0.1	0.0
Fensulfothion	<0.05	<0.05	<0.05	0.00
Fenthion	<0.1	<0.1	<0.1	0.0
Fonofos	<0.1	<0.1	<0.1	0.0
Malathion	<0.05	<0.05	<0.05	0.00
Methamidophos	<3.5	<3.5	<3.5	0.0
Mevinphos	<0.2	<0.2	<0.2	0.0
Parathion	<0.05	<0.05	<0.05	0.00
Parathion Methyl	<0.1	<0.1	<0.1	0.0
Phosmet	<0.1	<0.1	<0.1	0.0

TABLE 22
SUMMARY OF CONTAMINANT CONCENTRATIONS IN A COMPOSITE OF SIX CRAB HEPATOPANCREAS SAMPLES FROM THE OFFSHORE SITE (µg/g dry-weight)

Physical Tests	
Lipid Content %	4.96
Moisture %	86.5
Total Metals	
Aluminum T-Al	<15
Arsenic T-As	9.18
Barium T-Ba	1.13
Cadmium T-Cd	3
Chromium T-Cr	<1.0
Cobalt T-Co	1.3
Copper T-Cu	210
Iron T-Fe	225
Lead T-Pb	0.45
Manganese T-Mn	7.05
Mercury T-Hg	0.264
Molybdenum T-Mo	<2.0
Nickel T-Ni	2.3
Selenium T-Se	7.25
Strontium T-Sr	229
Tin T-Sn	<15
Titanium T-Ti	1
Vanadium T-V	<2.0
Zinc T-Zn	145
Polyaromatic Hydrocarbons	
Acenaphthene	<0.005
Acenaphthylene	<0.005
Anthracene	<0.005
Benzo(a)anthracene	<0.010
Benzo(a)pyrene	<0.020
Benzo(b)fluoranthene	<0.020
Benzo(ghi)perylene	<0.020
Benzo(k)fluoranthene	<0.020
Chrysene	<0.010
Dibenzo(a,h)anthracene	<0.020
Fluoranthene	0.011
Fluorene	<0.005
Indeno(1,2,3-cd)pyrene	<0.020
Naphthalene	0.041
Phenanthrene	0.04
Pyrene	<0.010

TABLE 22
CONTINUED

Chlorinated Phenols	
2,3,4-Trichlorophenol	<0.005
2,3,5-Trichlorophenol	<0.005
2,4,5-Trichlorophenol	<0.005
2,4,6-Trichlorophenol	<0.005
2,3,4,5-Tetrachlorophenol	<0.005
2,3,4,6-Tetrachlorophenol	<0.005
2,3,5,6-Tetrachlorophenol	<0.005
Pentachlorophenol	<0.005
Polychlorinated Biphenyl's	
PCB 1242	<0.1
PCB 1248	<0.1
PCB 1254	<0.1
PCB 1260	0.9
Organochlorine Pesticides	
Aldrin	<0.01
gamma-BHC (Lindane)	<0.01
cis-Chlordane (alpha)	<0.01
trans-Chlordane (gamma)	<0.01
4,4'-DDD	<0.01
4,4'-DDE	<0.01
4,4'-DDT	<0.01
Dieldrin	0.52
Endosulfan I	<0.01
Endosulfan II	<0.01
Endosulfan Sulfate	<0.04
Endrin	<0.01
Heptachlor	<0.01
Heptachlor Epoxide	<0.04
Methoxychlor	<0.04
Toxaphene	<0.3
Organophosphate Pesticides	
Azinphos methyl	<0.5
Carbophenothion	<0.1
Diazinon	<0.2
Dimethoate	<0.2
Fensulfothion	<0.1
Fenthion	<0.2
Fonofos	<0.2
Malathion	<0.1
Methamidophos	<3.5
Mevinphos	<0.5
Parathion	<0.1
Parathion Methyl	<0.2
Phosmet	<0.2

TABLE 23
SUMMARY OF CONTAMINANT CONCENTRATIONS IN STARRY FLOUNDER MUSCLE FROM THE ROBERTS BANK SITE (µg/g dry-weight)

Physical Tests	MAXIMUM	MINIMUM	MEAN	STD. DEV.
Lipid Content %	0.89	0.81	0.86	0.04
Moisture %	82.2	81.1	81.7	0.6
Total Metals				
Aluminum T-Al	<15	<15	<15	0.0
Arsenic T-As	0.45	0.36	0.41	0.05
Barium T-Ba	<0.50	<0.50	<0.50	0.00
Cadmium T-Cd	<0.025	<0.025	<0.025	0.000
Chromium T-Cr	1.4	1.1	1.3	0.2
Cobalt T-Co	<1.0	<1.0	<1.0	0.0
Copper T-Cu	1.54	1.45	1.50	0.05
Iron T-Fe	12.2	9.6	11.0	1.3
Lead T-Pb	<0.05	<0.05	<0.05	0.00
Manganese T-Mn	0.57	0.49	0.52	0.04
Mercury T-Hg	0.17	0.166	0.168	0.002
Molybdenum T-Mo	<2.0	<2.0	<2.0	0.0
Nickel T-Ni	<1.0	<1.0	<1.0	0.0
Selenium T-Se	1.07	0.84	0.99	0.13
Strontium T-Sr	1.82	1.49	1.65	0.17
Tin T-Sn	<15	<15	<15	0.0
Titanium T-Ti	<1	<0.50	<1	0.0
Vanadium T-V	<2.0	<2.0	<2.0	0.0
Zinc T-Zn	32.3	31.7	32.0	0.3
Polyaromatic Hydrocarbons				
Acenaphthene	<0.005	<0.005	<0.005	0.000
Acenaphthylene	<0.005	<0.005	<0.005	0.000
Anthracene	<0.005	<0.005	<0.005	0.000
Benzo(a)anthracene	<0.010	<0.010	<0.010	0.000
Benzo(a)pyrene	<0.020	<0.020	<0.020	0.000
Benzo(b)fluoranthene	<0.020	<0.020	<0.020	0.000
Benzo(ghi)perylene	0.024	<0.020	<0.020+	-
Benzo(k)fluoranthene	<0.020	<0.020	<0.020	0.000
Chrysene	0.015	<0.010	<0.010+	-
Dibenzo(a,h)anthracene	0.021	<0.020	<0.020+	-
Fluoranthene	<0.010	<0.010	<0.010	0.000
Fluorene	0.007	<0.005	<0.005+	-
Indeno(1,2,3-cd)pyrene	0.027	<0.020	<0.020+	-
Naphthalene	0.014	<0.005	<0.005+	-
Phenanthrene	0.022	<0.005	<0.005+	-
Pyrene	<0.010	<0.010	<0.010	0.000

TABLE 23
CONTINUED

Chlorinated Phenols	MAXIMUM	MINIMUM	MEAN	STD. DEV.
2,3,4-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,6-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,5-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
Pentachlorophenol	<0.005	<0.005	<0.005	0.000
Polychlorinated Biphenyl's				
PCB 1242	<0.05	<0.05	<0.05	0.00
PCB 1248	<0.05	<0.05	<0.05	0.00
PCB 1254	<0.05	<0.05	<0.05	0.00
PCB 1260	<0.05	<0.05	<0.05	0.00
Organochlorine Pesticides				
Aldrin	<0.005	<0.005	<0.005	0.000
gamma-BHC (Lindane)	<0.005	<0.005	<0.005	0.000
cis-Chlordane (alpha)	<0.005	<0.005	<0.005	0.000
trans-Chlordane (gamma)	<0.005	<0.005	<0.005	0.000
4,4'-DDD	<0.005	<0.005	<0.005	0.000
4,4'-DDE	<0.005	<0.005	<0.005	0.000
4,4'-DDT	<0.005	<0.005	<0.005	0.000
Dieldrin	<0.005	<0.005	<0.005	0.000
Endosulfan I	<0.005	<0.005	<0.005	0.000
Endosulfan II	<0.005	<0.005	<0.005	0.000
Endosulfan Sulfate	<0.02	<0.02	<0.02	0.00
Endrin	<0.005	<0.005	<0.005	0.000
Heptachlor	<0.005	<0.005	<0.005	0.000
Heptachlor Epoxide	<0.02	<0.02	<0.02	0.00
Methoxychlor	<0.02	<0.02	<0.02	0.00
Toxaphene	<0.15	<0.15	<0.15	0.00
Organophosphate Pesticides				
Azinphos methyl	<0.2	<0.2	<0.2	0.0
Carbophenothion	<0.05	<0.05	<0.05	0.00
Diazinon	<0.1	<0.1	<0.1	0.0
Dimethoate	<0.1	<0.1	<0.1	0.0
Fensulfothion	<0.05	<0.05	<0.05	0.00
Fenthion	<0.1	<0.1	<0.1	0.0
Fonofos	<0.1	<0.1	<0.1	0.0
Malathion	<0.05	<0.05	<0.05	0.00
Methamidophos	<3.5	<3.5	<3.5	0.0
Mevinphos	<0.2	<0.2	<0.2	0.0
Parathion	<0.05	<0.05	<0.05	0.00
Parathion Methyl	<0.1	<0.1	<0.1	0.0
Phosmet	<0.1	<0.1	<0.1	0.0

number of samples = 3

TABLE 24
SUMMARY OF CONTAMINANT CONCENTRATIONS IN BUTTER SOLE MUSCLE FROM THE ROBERTS BANK SITE (µg/g dry-weight)

Physical Tests	MAXIMUM	MINIMUM	MEAN	STD. DEV.
Lipid Content %	1.64	0.32	0.85	0.70
Moisture %	82.1	77.6	80.2	2.3
Total Metals				
Aluminum T-Al	168	<15	<15+	-
Arsenic T-As	1.22	0.6	0.82	0.34
Barium T-Ba	5.6	<0.50	<0.5+	-
Cadmium T-Cd	0.031	0.031	0.031	0.000
Chromium T-Cr	6.2	<1.0	<1.0+	-
Cobalt T-Co	<1.0	<1.0	<1.0	0.0
Copper T-Cu	3.47	0.96	1.85	1.41
Iron T-Fe	270	6.7	95.9	150.8
Lead T-Pb	0.07	0.07	0.07	0.00
Manganese T-Mn	20.7	0.58	7.38	11.54
Mercury T-Hg	0.129	0.051	0.090	0.039
Molybdenum T-Mo	<2.0	<2.0	<2.0	0.00
Nickel T-Ni	3.1	<1.0	<1.0+	-
Selenium T-Se	1.29	0.96	1.14	0.17
Strontium T-Sr	134	2.55	48.18	74.37
Tin T-Sn	<15	<15	<15	0.0
Titanium T-Ti	12	<1	<1+	-
Vanadium T-V	<2.0	<2.0	<2.0	0.0
Zinc T-Zn	97.8	29.5	52.7	39.1

Polyaromatic Hydrocarbons	
Acenaphthene	0.039
Acenaphthylene	0.039
Anthracene	<0.005
Benzo(a)anthracene	<0.010
Benzo(a)pyrene	<0.020
Benzo(b)fluoranthene	<0.020
Benzo(ghi)perylene	<0.020
Benzo(k)fluoranthene	<0.020
Chrysene	<0.010
Dibenzo(a,h)anthracene	<0.020
Fluoranthene	<0.010
Fluorene	0.018
Indeno(1,2,3-cd)pyrene	<0.020
Naphthalene	0.057
Phenanthrene	0.016
Pyrene	<0.010

TABLE 24
CONTINUED

Chlorinated Phenols	Maximum	Minimum	Mean	Std. Dev.
2,3,4-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,6-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,5-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
Pentachlorophenol	<0.005	<0.005	<0.005	0.000
Polychlorinated Biphenyl's				
PCB 1242	<0.05	<0.05	<0.05	0.00
PCB 1248	<0.05	<0.05	<0.05	0.00
PCB 1254	<0.05	<0.05	<0.05	0.00
PCB 1260	<0.05	<0.05	<0.05	0.00
Organochlorine Pesticides				
Aldrin	<0.005	<0.005	<0.005	0.000
gamma-BHC (Lindane)	<0.005	<0.005	<0.005	0.000
cis-Chlordane (alpha)	<0.005	<0.005	<0.005	0.000
trans-Chlordane (gamma)	<0.005	<0.005	<0.005	0.000
4,4'-DDD	<0.005	<0.005	<0.005	0.000
4,4'-DDE	<0.005	<0.005	<0.005	0.000
4,4'-DDT	<0.005	<0.005	<0.005	0.000
Dieldrin	<0.005	<0.005	<0.005	0.000
Endosulfan I	<0.005	<0.005	<0.005	0.000
Endosulfan II	<0.005	<0.005	<0.005	0.000
Endosulfan Sulfate	<0.02	<0.02	<0.02	0.00
Endrin	<0.005	<0.005	<0.005	0.000
Heptachlor	<0.005	<0.005	<0.005	0.000
Heptachlor Epoxide	<0.02	<0.02	<0.02	0.00
Methoxychlor	<0.02	<0.02	<0.02	0.00
Toxaphene	<0.15	<0.15	<0.15	0.00
Organophosphate Pesticides				
Azinphos methyl	<0.2	<0.2	<0.2	0.0
Carbophenothion	<0.05	<0.05	<0.05	0.00
Diazinon	<0.1	<0.1	<0.1	0.0
Dimethoate	<0.1	<0.1	<0.1	0.0
Fensulfothion	<0.05	<0.05	<0.05	0.00
Fenthion	<0.1	<0.1	<0.1	0.0
Fonofos	<0.1	<0.1	<0.1	0.0
Malathion	<0.05	<0.05	<0.05	0.00
Methamidophos	<3.5	<3.5	<3.5	0.0
Mevinphos	<0.2	<0.2	<0.2	0.0
Parathion	<0.05	<0.05	<0.05	0.00
Parathion Methyl	<0.1	<0.1	<0.1	0.0
Phosmet	<0.1	<0.1	<0.1	0.0

number of samples = 3

TABLE 25
SUMMARY OF CONTAMINANT CONCENTRATIONS IN MUSCLE FROM FOUR DUNGENESS CRABS FROM THE ROBERTS BANK SITE (µg/g dry-weight)

Physical Tests	MAXIMUM	MINIMUM	MEAN	STD. DEV.
Lipid Content %	0.76	0.47	0.60	0.12
Moisture %	83.6	81.6	82.5	0.9
Total Metals				
Aluminum T-Al	<15	<15	<15	0.0
Arsenic T-As	1.47	1.10	1.32	0.17
Barium T-Ba	<0.50	<0.50	<0.50	0.00
Cadmium T-Cd	0.128	0.038	0.08	0.05
Chromium T-Cr	<1.0	<1.0	<1.0	0.0
Cobalt T-Co	<1.0	<1.0	<1.0	0.0
Copper T-Cu	58.2	48.7	54.3	4.4
Iron T-Fe	55.7	33.4	40.5	10.4
Lead T-Pb	<0.05	<0.05	<0.05	0.00
Manganese T-Mn	1.81	1.18	1.62	0.29
Mercury T-Hg	0.437	0.279	0.36	0.08
Molybdenum T-Mo	<2.0	<2.0	<2.0	0.0
Nickel T-Ni	<1.0	<1.0	<1.0	0.0
Selenium T-Se	2.19	1.47	1.89	0.31
Strontium T-Sr	162	97.4	120.9	28.6
Tin T-Sn	<15	<15	<15	0.0
Titanium T-Ti	<1	<1	<1	0.0
Vanadium T-V	<2.0	<2.0	<2.0	0.0
Zinc T-Zn	324	249	281	31
Polyaromatic Hydrocarbons				
Acenaphthene	<0.005	<0.005	<0.005	0.000
Acenaphthylene	<0.005	<0.005	<0.005	0.000
Anthracene	<0.005	<0.005	<0.005	0.000
Benzo(a)anthracene	<0.010	<0.010	<0.010	0.000
Benzo(a)pyrene	<0.020	<0.020	<0.020	0.000
Benzo(b)fluoranthene	<0.020	<0.020	<0.020	0.000
Benzo(ghi)perylene	<0.020	<0.020	<0.020	0.000
Benzo(k)fluoranthene	<0.020	<0.020	<0.020	0.000
Chrysene	<0.010	<0.010	<0.010	0.000
Dibenzo(a,h)anthracene	<0.020	<0.020	<0.020	0.000
Fluoranthene	<0.010	<0.010	<0.010	0.000
Fluorene	<0.005	<0.005	<0.005	0.000
Indeno(1,2,3-cd)pyrene	<0.020	<0.020	<0.020	0.000
Naphthalene	0.043	<0.005	0.016	0.018
Phenanthrene	0.011	<0.005	0.008	0.003
Pyrene	<0.010	<0.010	<0.010	0.000

TABLE 25
CONTINUED

Chlorinated Phenols	Maximum	Minimum	Mean	Std. Dev.
2,3,4-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,5-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,4,6-Trichlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,5-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,4,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
2,3,5,6-Tetrachlorophenol	<0.005	<0.005	<0.005	0.000
Pentachlorophenol	<0.005	<0.005	<0.005	0.000
Polychlorinated Biphenyl's				
PCB 1242	<0.05	<0.05	<0.05	0.00
PCB 1248	<0.05	<0.05	<0.05	0.00
PCB 1254	<0.05	<0.05	<0.05	0.00
PCB 1260	<0.05	<0.05	<0.05	0.00
Organochlorine Pesticides				
Aldrin	<0.005	<0.005	<0.005	0.000
gamma-BHC (Lindane)	<0.005	<0.005	<0.005	0.000
cis-Chlordane (alpha)	<0.005	<0.005	<0.005	0.000
trans-Chlordane (gamma)	<0.005	<0.005	<0.005	0.000
4,4'-DDD	<0.005	<0.005	<0.005	0.000
4,4'-DDE	<0.005	<0.005	<0.005	0.000
4,4'-DDT	<0.005	<0.005	<0.005	0.000
Dieldrin	<0.005	<0.005	<0.005	0.000
Endosulfan I	<0.005	<0.005	<0.005	0.000
Endosulfan II	<0.005	<0.005	<0.005	0.000
Endosulfan Sulfate	<0.02	<0.02	<0.02	0.00
Endrin	<0.005	<0.005	<0.005	0.000
Heptachlor	<0.005	<0.005	<0.005	0.000
Heptachlor Epoxide	<0.02	<0.02	<0.02	0.00
Methoxychlor	<0.02	<0.02	<0.02	0.00
Toxaphene	<0.15	<0.15	<0.15	0.00
Organophosphate Pesticides				
Azinphos methyl	<0.2	<0.2	<0.2	0.0
Carbophenothion	<0.05	<0.05	<0.05	0.00
Diazinon	<0.1	<0.1	<0.1	0.0
Dimethoate	<0.1	<0.1	<0.1	0.0
Fensulfothion	<0.05	<0.05	<0.05	0.00
Fenthion	<0.1	<0.1	<0.1	0.0
Fonofos	<0.1	<0.1	<0.1	0.0
Malathion	<0.05	<0.05	<0.05	0.00
Methamidophos	<3.5	<3.5	<3.5	0.0
Mevinphos	<0.2	<0.2	<0.2	0.0
Parathion	<0.05	<0.05	<0.05	0.00
Parathion Methyl	<0.1	<0.1	<0.1	0.0
Phosmet	<0.1	<0.1	<0.1	0.0

number of samples = 4

TABLE 26
SUMMARY OF CONTAMINANT CONCENTRATIONS IN DUNGENESS CRAB HEPATOPANCREAS FROM THE ROBERTS BANK SITE (µg/g dry-weight)

Physical Tests	
Lipid Content %	9.16
Moisture %	81.8
Total Metals	
Aluminum T-Al	<15
Arsenic T-As	4.18
Barium T-Ba	1.03
Cadmium T-Cd	25.5
Chromium T-Cr	<1.0
Cobalt T-Co	4
Copper T-Cu	881
Iron T-Fe	555
Lead T-Pb	<0.05
Manganese T-Mn	5.59
Mercury T-Hg	0.379
Molybdenum T-Mo	<2.0
Nickel T-Ni	2.1
Selenium T-Se	7.46
Strontium T-Sr	71.3
Tin T-Sn	<15
Titanium T-Ti	<1
Vanadium T-V	<2.0
Zinc T-Zn	94.7
Polyaromatic Hydrocarbons	
Acenaphthene	<0.005
Acenaphthylene	<0.005
Anthracene	<0.005
Benzo(a)anthracene	<0.010
Benzo(a)pyrene	<0.020
Benzo(b)fluoranthene	<0.020
Benzo(ghi)perylene	<0.020
Benzo(k)fluoranthene	<0.020
Chrysene	<0.010
Dibenzo(a,h)anthracene	<0.020
Fluoranthene	<0.010
Fluorene	0.033
Indeno(1,2,3-cd)pyrene	<0.020
Naphthalene	0.038
Phenanthrene	0.034
Pyrene	<0.010

TABLE 26
(CONTINUED)

Chlorinated Phenols	
2,3,4-Trichlorophenol	<0.005
2,3,5-Trichlorophenol	<0.005
2,4,5-Trichlorophenol	<0.005
2,4,6-Trichlorophenol	<0.005
2,3,4,5-Tetrachlorophenol	<0.005
2,3,4,6-Tetrachlorophenol	<0.005
2,3,5,6-Tetrachlorophenol	<0.005
Pentachlorophenol	<0.005
Polychlorinated Biphenyl's	
PCB 1242	<0.1
PCB 1248	<0.1
PCB 1254	<0.1
PCB 1260	1.2
Organochlorine Pesticides	
Aldrin	<0.01
gamma-BHC (Lindane)	<0.01
cis-Chlordane (alpha)	<0.01
trans-Chlordane (gamma)	<0.01
4,4'-DDD	<0.01
4,4'-DDE	<0.01
4,4'-DDT	<0.01
Dieldrin	0.68
Endosulfan I	<0.01
Endosulfan II	<0.01
Endosulfan Sulfate	<0.04
Endrin	<0.01
Heptachlor	<0.01
Heptachlor Epoxide	<0.04
Methoxychlor	<0.04
Toxaphene	<0.3
Organophosphate Pesticides	
Azinphos methyl	<0.5
Carbophenothion	<0.1
Diazinon	<0.2
Dimethoate	<0.2
Fensulfothion	<0.1
Fenthion	<0.2
Fonofos	<0.2
Malathion	<0.1
Methamidophos	<3.5
Mevinphos	<0.5
Parathion	<0.1
Parathion Methyl	<0.2
Phosmet	<0.2

TABLE 27

SUMMARY OF TOXICOLOGICAL DATA

SITE	SAND DOLLAR MEAN FERTILIZED @ 100% CONCEN'N	MICROTOX (SOLID PHASE - EC50%)	MICROTOX (5 MINUTE & 15 MINUTE TESTS)	AMPHIPOD (Rhepoxynius abronius) % Survival
BDY. BAY INSHORE #1	96%	0.1183	NON-TOXIC	88%
BDY. BAY INSHORE #2	73%	0.1532	NON-TOXIC	92%
BDY. BAY INSHORE #3	73%	0.3494	NON-TOXIC	97%
BDY. BAY INSHORE #4	92%	0.3355	NON-TOXIC	88%
BDY. BAY INSHORE #5	98%	0.4010	NON-TOXIC	99%
BDY. BAY OFFSHORE #1	90%	0.2988	NON-TOXIC	89%
BDY. BAY OFFSHORE #2	95%	0.2286	NON-TOXIC	87%
BDY. BAY OFFSHORE #3	95%	0.2907	NON-TOXIC	80%
BDY. BAY OFFSHORE #4	96%	0.0501	NON-TOXIC	75%
BDY. BAY OFFSHORE #5	98%	0.0923	NON-TOXIC	91%
LITTLE CAMPBELL # 1	100%	0.5404	NON-TOXIC	89%
LITTLE CAMPBELL # 2	2% FID50=82%	0.6583	NON-TOXIC	65%
LITTLE CAMPBELL # 3	95%	0.5403	NON-TOXIC	52%
LITTLE CAMPBELL # 4	78%	0.5936	NON-TOXIC	74%
LITTLE CAMPBELL # 5	19%	0.7083	NON-TOXIC	55%
NICOMEKL R. # 1	94%	0.2668	NON-TOXIC	91%
NICOMEKL R. # 2	96%	0.1910	NON-TOXIC	88%
NICOMEKL R. # 3	97%	0.2547	NON-TOXIC	95%
NICOMEKL R. # 4	92%	0.7655	NON-TOXIC	97%
NICOMEKL R. # 5	84%	0.6634	NON-TOXIC	95%
PUMP HOUSE #1	79%	0.139	NON-TOXIC	97%
PUMP HOUSE #2	91%	0.0040	NON-TOXIC	88%
PUMP HOUSE #3	95%	0.8301	NON-TOXIC	88%
PUMP HOUSE #4	92%	0.0099	NON-TOXIC	54%
PUMP HOUSE #5	81%	0.0320	NON-TOXIC	74%
ROBERTS BANK# 1	90%	2.1412	NON-TOXIC	97%
ROBERTS BANK# 2	74%	0.1996	NON-TOXIC	86%
ROBERTS BANK# 3	89%	0.0775	NON-TOXIC	91%
ROBERTS BANK# 4	87%	0.6522	NON-TOXIC	90%
ROBERTS BANK# 5	83%	0.6414	NON-TOXIC	96%
SERPENTINE R.#1	97%	0.1134	NON-TOXIC	71%
SERPENTINE R.#2	87%	0.2740	NON-TOXIC	58%
SERPENTINE R.#3	90%	0.4544	NON-TOXIC	75%
SERPENTINE R.#4	84%	0.1181	NON-TOXIC	89%
SERPENTINE R.#5	86%	0.8894	NON-TOXIC	83%

Appendix 1

Field Data Collection Information

beak consultants limited

160 - 14480 River Road
Richmond, B.C.
V6V 1L4

Off. (604) 278-7714
Fax (604) 278-7741

15 July 1993

BC Environment
Environmental Protection
15326- 103A Avenue
Surrey, B.C. V3R 7A2

Attention: Dr. Doug Walton

Dear Doug:

Attached are the field observations and data sheets for the sediment and biota sampling at Boundary Bay and Roberts Bank. A copy of the field notes and the data sheets was also forwarded to Les Swain and the data sheets only were delivered with the samples to ASL. The samples were delivered to ASL on 15 July at 1615.

Please contact me at your convenience if you require any further assistance regarding the sampling program details.

Yours truly,

Len Fanning, Senior Biologist, Principal

BC ENVIRONMENT - BOUNDARY BAY / ROBERTS BANK
BIOTA AND SEDIMENT SAMPLING FIELD NOTES

June 21, 1993

1300 Left Steveston. Weather overcast, wind SW 10 knots.
Set 6 crab traps at Roberts Bank.

1700 Arrived White Rock pier.

June 22, 1993

1300 Left White Rock. Weather overcast, wind SW 15-20 knots
Set 6 crab traps in Crescent Beach in deepest portion of navigational channel.
Wind SW 15-20 knots

1445 Arrived White Rock pier.

June 25, 1993

0930 Left White Rock Pier. Weather clear, wind SW 5 knots
Sediment sampling position (Boundary Bay Offshore):
49°00.14'N
122°48.50'W Depth 12.5 m
Substrate fine silt/sand with light surface layer, Polychaetes and clam shells present.

1100 TRAWL 1 Start: 49°00.26'N
122°48.13'W Depth 11.9 m

1135 Finish: 49°00.64'N
122°49.02'W Depth 12.4 m
Good catch of flatfish, Dungeness crabs, sculpins, midshipman, Pacific cod, Seapens, and starfish

1230 Picked up 6 crab traps:
≈60 legal sized ♂ Dungeness crabs, 10 ♀ Dungeness crabs

1300-1330 Travelled to Crescent Beach (Boundary Bay Inshore)
Picked up 6 crab traps at entrance to Crescent Beach
3 legal sized ♂ Dungeness crabs, 6 rock crabs

1430 Sediment sampling: 100 m D/S of rail bridge in channel
49°03.57'N
122°52.45'W Depth 4.4 m (low tide)
Substrate black silt/sand throughout with clam shells. No observed biological life. Strong odour.

1515 Completed sediment sampling.

1545 TRAWL 2 Start: 49°03.05'N
122°54.00'W Depth 4.0 m

Finish: 49°02.33'N
122°54.73'W Depth 9.4 m
Good catch 3 legal sized ♂ Dungeness crabs, juvenile sole, rock crab, Tomcod, sculpins, starfish, Shiner Perch, and 3 dogfish

1615-1745 Travelled to Roberts Bank. Weather clear, calm.

1745 TRAWL 3 Start: 49°01.07'N
123°08.52'W Depth 10.0 m
Turn around: 49°00.73'N
123°08.88'W Depth 15.5 m

1815 Finish: 49°01.03'N
123°08.60'W Depth 16.1 m

Good catch of sole, midshipman, skate, Starry flounder, Gunnels and Tomcod.

1830 Picked up 6 crab traps: ≈50 legal sized ♂ Dungeness crabs

1910 Sediments - site between coal dock and Ferry causeway.
No sample: 49°00.62'N
123°08.78'W Depth 6.2 m

Substrate too sandy. Moved into channel closer to coal dock.
49°00.75'N
123°08.92'W Depth 15.0 m

Substrate silt/fine sand - some samples with strong odour. Samples in same area varied in texture and appearance from clean with no odour to black decomposing sediment with strong odour.

2000 Completed sampling at Roberts Bank

2200 Arrived in Steveston. Offloaded samples for delivery and temporary storage in the Beak laboratory

BC ENVIRONMENT BOUNDARY BAY / ROBERTS BANK BIOTA SAMPLING DATA, JUNE 1993

SPECIES	SAMPLE No.	LENGTH (cm)	WEIGHT (g)	TISSUE WEIGHT (g)[1]	SAMPLE No.	TISSUE WEIGHT (g)[2]
Plainfin Midshipman	BBOS-1	20.1	89.0	89.0		
Plainfin Midshipman	BBOS-2	17.9	68.0	68.0		
Plainfin Midshipman	BBOS-3	16.0	41.5	41.5		
Plainfin Midshipman	BBOS-4	15.5	37.0	37.0		
Plainfin Midshipman	BBOS-5	13.8	30.3	30.3		
Plainfin Midshipman	BBOS-6	13.5	21.5	21.5		
Shiner Perch	BBOS-7	12.5	21.0	21.0		
Shiner Perch	BBOS-7	10.5	17.8	17.8		
Shiner Perch	BBOS-7	11.5	23.2	23.2		
				62.0		
Starry Flounder	BBOS-8	34.5	501.0	113.8	BBOS-9	7.7
Starry Flounder	BBOS-10	28.5	339.2	98.5	BBOS-9	7.9
Starry Flounder	BBOS-11	23.5	160.8	42.5	BBOS-9	2.4
Starry Flounder	BBOS-12	26.5	222.5	61.1	BBOS-9	2.5
Starry Flounder	BBOS-13	23.5	180.3	31.5	BBOS-9	1.0
Starry Flounder	BBOS-14	23.0	160.0	44.3	BBOS-9	2.2
Starry Flounder	BBOS-15	23.0	165.0	49.5	BBOS-9	2.8
Starry Flounder	BBOS-16	19.5	92.0	21.0	BBOS-9	1.6
						28.1
Plainfin Midshipman	BBOS-17	15.0	35.2	35.2		
Plainfin Midshipman	BBOS-18	12.5	18.5	18.5		

SPECIES	SAMPLE No.	LENGTH (cm)	WEIGHT (g)	TISSUE WEIGHT (g)[1]	SAMPLE No.	TISSUE WEIGHT (g)[2]
Plainfin Midshipman	BBOS-19	15.0	36.2	36.2		
Plainfin Midshipman	BBOS-20	14.5	28.5	28.5		
Snake Prickleback	BBOS-21	28.0	38.3	38.3		
Snake Prickleback	BBOS-22	22.0	14.0	27.0		
Pacific Cod	BBOS-23	19.5	65.2	65.2		
Pacific Cod	BBOS-24	17.5	49.0	49.0		
Pacific Cod	BBOS-25	17.0	43.8	43.8		
Pacific Cod	BBOS-26	17.0	43.5	43.5		
Pacific Cod	BBOS-27	14.5	30.5	30.5		
Staghorn Sculpin	BBOS-28	15.0	42.2	42.2		
Staghorn Sculpin	BBOS-29	15.0	42.2	42.2		
Staghorn Sculpin	BBOS-30	13.8	33.5	33.5		
Staghorn Sculpin	BBOS-31	13.8	35.7	35.7		
Staghorn Sculpin	BBOS-32	11.5	16.4	16.4		
Dungeness Crab	BBOS-75	18.0	860.0	140.0	BBOS-74	20.2
Dungeness Crab	BBOS-76	18.6	760.0	151.5	BBOS-74	9.9
Dungeness Crab	BBOS-77	18.3	790.0	182.3	BBOS-74	9.3
Dungeness Crab	BBOS-78	17.5	700.0	136.4	BBOS-74	7.6
Dungeness Crab	BBOS-79	18.4	840.0	164.6	BBOS-74	13.5
Dungeness Crab	BBOS-80	18.7	970.0	172.6	BBOS-74	13.5
						60.5

BC ENVIRONMENT BOUNDARY BAY / ROBERTS BANK BIOTA SAMPLING DATA, JUNE 1993

SPECIES	SAMPLE No.	LENGTH (cm)	WEIGHT (g)	TISSUE WEIGHT (g)[1]	SAMPLE No.	TISSUE WEIGHT (g)[2]
Dungeness Crab	BBOS-81	18.5	920.0	142.2		
Dungeness Crab	BBOS-82	18.3	820.0	145.2		
Butter Sole	BBOS-83	30.5	288.3	107.0	BBOS-84	4.0
Butter Sole	BBOS-85	23.0	136.5	44.0	BBOS-84	1.6
Butter Sole	BBOS-85	26.5	186.2	50.0	BBOS-84	3.8
Butter Sole	BBOS-85	23.0	124.5	39.5	BBOS-84	1.6
Butter Sole	BBOS-85	23.0	123.6	40.0	BBOS-84	2.8
				173.5		13.8
Butter Sole	BBOS-86	28.5	241.5	80.2	BBOS-87	3.0
Butter Sole	BBOS-86	24.5	146.7	43.3	BBOS-87	2.0
Butter Sole	BBOS-86	22.0	117.0	22.0	BBOS-87	1.1
				145.5		6.1
Butter Sole	BBOS-88	25.5	171.5	50.5	BBOS-89	1.5
Butter Sole	BBOS-88	24.5	149.0	48.1	BBOS-89	1.9
Butter Sole	BBOS-88	24.0	131.5	50.9	BBOS-89	0.6
				149.5		4.0
Butter Sole	BBOS-90	26.0	199.5	45.0	BBOS-91	1.0
Butter Sole	BBOS-90	24.0	146.3	19.0	BBOS-91	0.5
Butter Sole	BBOS-90	23.0	127.3	37.7	BBOS-91	0.5
Butter Sole	BBOS-90	21.0	105.0	35.3	BBOS-91	0.5
Butter Sole	BBOS-90	22.5	123.5	30.0	BBOS-91	0.5

BC ENVIRONMENT BOUNDARY BAY / ROBERTS BANK BIOTA SAMPLING DATA, JUNE 1993

SPECIES	SAMPLE No.	LENGTH (cm)	WEIGHT (g)	TISSUE WEIGHT (g)[1]	SAMPLE No.	TISSUE WEIGHT (g)[2]
				167.0		3.0
English Sole	BBOS-92	21.5	95.0	37.5	BBOS-93	0.5
English Sole	BBOS-92	21.0	82.3	20.0	BBOS-93	1.5
English Sole	BBOS-92	21.0	81.5	15.5	BBOS-93	2.0
English Sole	BBOS-92	19.5	63.5	30.0	BBOS-93	0.6
English Sole	BBOS-92	25.0	149.5	27.7	BBOS-93	0.5
English Sole	BBOS-92	23.0	116.5	14.8	BBOS-93	1.3
				145.5		6.4
English Sole	BBOS-94	21.5	94.5	23.5	BBOS-95	1.6
English Sole	BBOS-94	22.5	104.3	29.0	BBOS-95	1.0
English Sole	BBOS-94	21.0	91.0	25.0	BBOS-95	1.0
English Sole	BBOS-94	21.5	98.2	29.5	BBOS-95	1.3
English Sole	BBOS-94	21.5	85.5	26.0	BBOS-95	2.2
English Sole	BBOS-94	22.0	101.9	24.0	BBOS-95	1.3
				157.0		8.4

[1] Wet weight of muscle tissue or whole specimen
[2] Wet weight of fish liver or crab hepatopancreas

BC ENVIRONMENT BOUNDARY BAY / ROBERTS BANK BIOTA SAMPLING DATA, JUNE 1993

SPECIES	SAMPLE No.	LENGTH (cm)	WEIGHT (g)	TISSUE WEIGHT (g)[1]	SAMPLE No.	TISSUE WEIGHT (g)[2]
Staghorn Sculpin	BBIS-33	22.6	149.5	149.5		
Staghorn Sculpin	BBIS-34	15.5	51.0	51.0		
Staghorn Sculpin	BBIS-34	16.0	57.6	57.6		
Staghorn Sculpin	BBIS-34	15.0	49.7	49.7		
				158.3		
Staghorn Sculpin	BBIS-35	15.0	44.2	44.2		
Staghorn Sculpin	BBIS-35	14.8	48.6	48.6		
Staghorn Sculpin	BBIS-35	15.0	37.5	37.5		
Staghorn Sculpin	BBIS-35	14.0	35.2	35.2		
				165.5		
Staghorn Sculpin	BBIS-36	13.0	33.5	33.5		
Staghorn Sculpin	BBIS-36	13.0	30.0	30.0		
Staghorn Sculpin	BBIS-36	13.0	29.5	29.5		
Staghorn Sculpin	BBIS-36	13.0	28.0	28.0		
Staghorn Sculpin	BBIS-36	13.0	26.0	26.0		
Staghorn Sculpin	BBIS-36	12.8	27.0	27.0		
				174.0		
Staghorn Sculpin	BBIS-37	12.0	21.0	21.0		
Staghorn Sculpin	BBIS-37	12.5	15.5	25.5		
Staghorn Sculpin	BBIS-37	12.0	14.0	24.0		
Staghorn Sculpin	BBIS-37	12.0	15.0	25.0		

BC ENVIRONMENT BOUNDARY BAY / ROBERTS BANK BIOTA SAMPLING DATA, JUNE 1993

SPECIES	SAMPLE No.	LENGTH (cm)	WEIGHT (g)	TISSUE WEIGHT (g)[1]	SAMPLE No.	TISSUE WEIGHT (g)[2]
Staghorn Sculpin	BBIS-37	11.0	19.0	19.0		
Staghorn Sculpin	BBIS-37	11.0	17.0	17.0		
Staghorn Sculpin	BBIS-37	11.0	13.5	13.5		
Staghorn Sculpin	BBIS-37	10.5	12.5	12.5		
				157.5		
Buffalo Sculpin	BBIS-38	13.0	63.2	59.7		
Buffalo Sculpin	BBIS-38	12.0	53.8	50.1		
				109.8		
Padded Sculpin	BBIS-97	10.5	21.0	21.8		
Buffalo Sculpin	BBIS-39	12.6	43.2	43.2		
Buffalo Sculpin	BBIS-39	11.4	37.0	37.0		
Buffalo Sculpin	BBIS-39	11.0	36.8	36.8		
Buffalo Sculpin	BBIS-39	10.2	29.5	29.5		
Buffalo Sculpin	BBIS-39	9.5	23.0	23.0		
				169.5		
Great Sculpin	BBIS-96	7.5	7.9	6.0		
Plainfin Midshipman	BBIS-40	16.0	46.0	46.0		
Plainfin Midshipman	BBIS-40	14.5	35.5	35.5		
				81.5		
Pacific Tomcod	BBIS-41	15.5	51.7	51.7		
Pacific Tomcod	BBIS-41	15.0	50.8	50.8		

BC ENVIRONMENT BOUNDARY BAY / ROBERTS BANK BIOTA SAMPLING DATA, JUNE 1993

SPECIES	SAMPLE No.	LENGTH (cm)	WEIGHT (g)	TISSUE WEIGHT (g)[1]	SAMPLE No.	TISSUE WEIGHT (g)[2]
Pacific Tomcod	BBIS-41	14.8	44.0	44.0		
				146.5		
Pacific Tomcod	BBIS-42	15.5	46.5	46.5		
Pacific Tomcod	BBIS-42	14.8	45.8	45.8		
Pacific Tomcod	BBIS-42	14.0	37.7	37.7		
Pacific Tomcod	BBIS-42	14.5	43.7	43.7		
				173.7		
Pacific Tomcod	BBIS-43	14.0	38.5	38.5		
Pacific Tomcod	BBIS-43	14.5	39.5	39.5		
Pacific Tomcod	BBIS-43	14.8	43.1	43.1		
Pacific Tomcod	BBIS-43	14.0	42.9	42.9		
				164.0		
Pacific Tomcod	BBIS-44	13.8	39.5	39.5		
Pacific Tomcod	BBIS-44	13.5	35.0	35.0		
Pacific Tomcod	BBIS-44	13.0	28.4	28.4		
Pacific Tomcod	BBIS-44	13.0	30.6	30.6		
Pacific Tomcod	BBIS-44	13.3	29.7	29.7		
Pacific Tomcod	BBIS-44	13.0	31.1	31.1		
				194.3		
Dungeness Crab	BBIS-95	17.6	559.2	86.0	BBIS-45	13.0
Dungeness Crab	BBIS-95	15.8	540.0	78.0	BBIS-45	12.1

BC ENVIRONMENT BOUNDARY BAY / ROBERTS BANK BIOTA SAMPLING DATA, JUNE 1993

SPECIES	SAMPLE No.	LENGTH (cm)	WEIGHT (g)	TISSUE WEIGHT (g)[1]	SAMPLE No.	TISSUE WEIGHT (g)[2]
Dungeness Crab	BBIS-95	15.8	512.5	105.0	BBIS-45	14.9
				269.0		40.0
Dungeness Crab	BBIS-46	15.9	495.3	68.0	BBIS-47	8.0
Dungeness Crab	BBIS-46	15.8	518.6	82.3	BBIS-47	13.5
Dungeness Crab	BBIS-46	15.2	460.5	63.2	BBIS-47	11.5
Dungeness Crab	BBIS-46	15.0	443.8	47.0	BBIS-47	11.0
Dungeness Crab	BBIS-46	13.8	378.9	14.7	BBIS-47	10.5
Dungeness Crab	BBIS-46	13.3	313.4	10.0	BBIS-47	11.4
				285.2		65.7

[1] Wet weight of muscle tissue or whole specimen
[2] Wet weight of fish liver or crab hepatopancreas

BC ENVIRONMENT BOUNDARY BAY / ROBERTS BANK BIOTA SAMPLING DATA, JUNE 1993

SPECIES	SAMPLE No.	LENGTH (cm)	WEIGHT (g)	TISSUE WEIGHT (g)[1]	SAMPLE No.	TISSUE WEIGHT (g)[2]
Starry Flounder	RB-48	32.8	492.0	111.2	RB-49	11.3
Starry Flounder	RB-48	30.5	421.1	76.1	RB-49	6.2
Starry Flounder	RB-48	28.5	306.2	72.6	RB-49	7.5
				229.9		25.0
Pacific Tomcod	RB-50	23.0	183.5	183.5		
Pacific Tomcod	RB-50	12.0	26.5	26.5		
				210.0		
Plainfin Midshipman	RB-51	20.0	88.0	88.0		
Plainfin Midshipman	RB-51	20.0	76.5	76.5		
Plainfin Midshipman	RB-51	14.5	41.9	41.9		
				206.4		
Staghorn Sculpin	RB-52	10.0	14.2	14.2		
Staghorn Sculpin	RB-52	9.0	10.0	10.0		
Staghorn Sculpin	RB-52	9.8	11.0	11.0		
				35.2		
Big Skate	RB-53	22.5	82.8	82.8		
Big Skate	RB-53	19.8	54.6	54.6		
				137.4		
English Sole	RB-54	24.0	135.5	23.0	RB-55	3.2
English Sole	RB-54	24.0	132.3	21.0	RB-55	3.0
English Sole	RB-54	19.5	69.5	4.0	RB-55	1.5

BC ENVIRONMENT BOUNDARY BAY / ROBERTS BANK BIOTA SAMPLING DATA, JUNE 1993

SPECIES	SAMPLE No.	LENGTH (cm)	WEIGHT (g)	TISSUE WEIGHT (g)[1]	SAMPLE No.	TISSUE WEIGHT (g)[2]
Starry Flounder	RB-48	32.8	492.0	111.2	RB-49	11.3
Starry Flounder	RB-48	30.5	421.1	76.1	RB-49	6.2
Starry Flounder	RB-48	28.5	306.2	72.6	RB-49	7.5
				229.9		25.0
Pacific Tomcod	RB-50	23.0	183.5	183.5		
Pacific Tomcod	RB-50	12.0	26.5	26.5		
				210.0		
Plainfin Midshipman	RB-51	20.0	88.0	88.0		
Plainfin Midshipman	RB-51	20.0	76.5	76.5		
Plainfin Midshipman	RB-51	14.5	41.9	41.9		
				206.4		
Staghorn Sculpin	RB-52	10.0	14.2	14.2		
Staghorn Sculpin	RB-52	9.0	10.0	10.0		
Staghorn Sculpin	RB-52	9.8	11.0	11.0		
				35.2		
Big Skate	RB-53	22.5	82.8	82.8		
Big Skate	RB-53	19.8	54.6	54.6		
				137.4		
English Sole	RB-54	24.0	135.5	23.0	RB-55	3.2
English Sole	RB-54	24.0	132.3	21.0	RB-55	3.0
English Sole	RB-54	19.5	69.5	4.0	RB-55	1.5

SPECIES	SAMPLE No.	LENGTH (cm)	WEIGHT (g)	TISSUE WEIGHT (g)[1]	SAMPLE No.	TISSUE WEIGHT (g)[2]
English Sole	RB-54	19.0	51.6	3.8	RB-55	0.8
English Sole	RB-54	18.5	53.2	3.5	RB-55	0.6
English Sole	RB-54	18.0	45.8	3.4	RB-55	0.5
English Sole	RB-54	16.0	40.2	3.2	RB-55	0.4
				61.9		10.0
Dungeness Crab	RB-58	17.3	660.0	130.5	RB-56	12.5
Dungeness Crab	RB-59	17.8	740.0	137.2	RB-56	20.0
Dungeness Crab	RB-60	18.3	790.0	125.5	RB-56	18.0
Dungeness Crab	RB-61	18.6	790.0	158.5	RB-56	31.1
Dungeness Crab	RB-62	18.3	790.0	153.0	RB-56	20.4
						102.0
Dungeness Crab	RB-63	18.4	900.0	106.5	RB-57	22.6
Dungeness Crab	RB-64	18.7	700.0	188.0	RB-57	17.0
Dungeness Crab	RB-65	17.0	670.0	126.5	RB-57	17.0
Dungeness Crab	RB-66	17.3	670.0	88.3	RB-57	-
						56.6
Penpoint Gunnel	RB-67	17.5	33.3	33.3		
Crescent Gunnel	RB-98	12.0	7.2	7.2		
Pacific Sanddab	RB-69	22.0	160.0	43.5	RB-68	4.1
Pacific Sanddab	RB-69	23.0	152.3	45.5	RB-68	4.3
				89.3		8.5

SPECIES	SAMPLE No.	LENGTH (cm)	WEIGHT (g)	TISSUE WEIGHT (g)[1]	SAMPLE No.	TISSUE WEIGHT (g)[2]
Butter Sole	RB-70	14.0	27.0			
Butter Sole	RB-70	14.5	30.5			
			57.5			
Butter Sole	RB-72	28.0	225.2	90.0	RB-71	2.7
Butter Sole	RB-73	26.0	199.2	60.6	RB-71	1.3
				150.6		4.0

Wet weight of muscle tissue or whole specimen
Wet weight of fish liver or crab hepatopancreas