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FRASER RIVER ESTUARY
MARINE ENVIRONMENTAL MONITORING RESULTS
1984-1986

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by

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ABSTRACT

Surveys of selected contaminants in sediments, benthic fish and invetebrates were undertaken in the outer Fraser River Estuary during 1984-1986. Cadmium, copper and lead were found in very high levels in sediments near the Iona sewage treatment plant outfall and were close to background levels or moderately elevated in other portions of the estuary. Trace metal levels were strongly correlated with organic content, but not with sediment particle size. Tissues of intertidal invertebrates reflected trace metal levels in sediments, those animals living near the Iona outfall generally having much higher levels than those elsewhere on the estuary. Limited long-term trend data suggests an overall decrease in tissue levels of trace metals.

Tissues of epibenthic animals obtained by trawl had elevated levels of cadmium and copper off Roberts Bank, and high levels of copper and lead off the Iona sewage treatment plant (Sturgeon Bank). Mercury was within background levels at all locations and less than Canadian guidelines for mercury in fish.

Polychlorinated biphenyls and chlorinated phenols were below detection limits in sediments at all intertidal stations. Polynuclear aromatic hydrocarbons were detected at relatively low concentrations in intertidal and deep benthic sediments near the Iona outfall, but were below detection limits elsewhere on Sturgeon Bank and Roberts Bank.

RÉSUMÉ

Des études de contaminants sélectionnés dans les sédiments, poissons benthiques et invertébrés furent entreprises dans la partie extérieure de l'estuaire de la rivière Fraser en 1984-1986. Du cadmium, cuivre et plomb furent détectés à des niveaux très elévés dans les sédiments près de l'émissaire de l'usine de traitement d'eaux usées Iona et furent près des niveaux de base ou modérément élevés dans d'autres portions de l'estuaire. Les niveaux de métal au niveau de trace furent fortement en corrélation avec le contenu organique, mais pas avec la grosseur des particules de sédiment. Les tissus des invertébrés intertidaux ont reflété les niveaux de métal au niveau de trace dans les sédiments, les animaux vivant près de l'émissaire d'Iona ayant généralement des niveaux beaucoup plus élevés que ceux vivant quelque part d'autre dans l'estuaire. Les clonnées limitées de la tendance à long terme suggère engénéral diminution des niveaux de tissu au niveau de trace.

Les tissus d'animaux épibenthiques obtenus au chalut ont montrés des niveaux élevés de cadmium et cuivre près du banc Roberts, et des niveaux élevés de cuivre et de plomb à proximité de l'usine de traitement d'eaux usées Iona (le banc Sturgeon). Le mercure était dans les limites des niveaux de fond à tous les endroits échantillonnés et était moindre que les lignes directrices canadiennes pour le mercure dans les poissons.

Les niveaux de biphénols polychlorés et phénols chlorés furent moindre que les limites de détection dans les sédiments à toutes les stations intertidales. Des hydrocarbures aromatiques polynucléaires furent détectés à des concentrations relativement basses dans les sédiments intertidaux et profonds benthiques près de l'émissaire d'Iona, mais furent moindre que les limites de détection dans les autres parties du banc Sturgeon et du banc Roberts.

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1 INTRODUCTION

1.1 Purpose

The Fraser River Estuary Management Plan (O'Riordan and Wiebe, 1984) includes provisions for monitoring environmental quality in the estuary. As part of this Plan, a federal/provincial committee developed a recommended approach to monitoring marine environmental quality (Working Committee on Fraser River Estuary Monitoring, 1984). This plan outlined stations, frequency and parameters to be sampled in both freshwater and marine portions of the estuary, and for several compartments of the ecosystem. As a contribution to this program, Environmental Protection studied the distribution of metals and selected organic contaminants in sediment and biota in the outer portion of the estuary during 1984-1986. This report presents results of the study and establishes a baseline for future monitoring.

1.2 Study Area and Sampling Periods

Sampling locations are shown in Figure 1. Survey periods and sampling information is given in Table 1. Station coordinates and parameters measured at each are given in Appendix I. Water column samples, benthic sediment samples and trawls were taken from the research vessel CSS Vector; Intertidal work on Roberts Bank and Sturgeon Bank was supported by the Coast Guard Hovercraft.

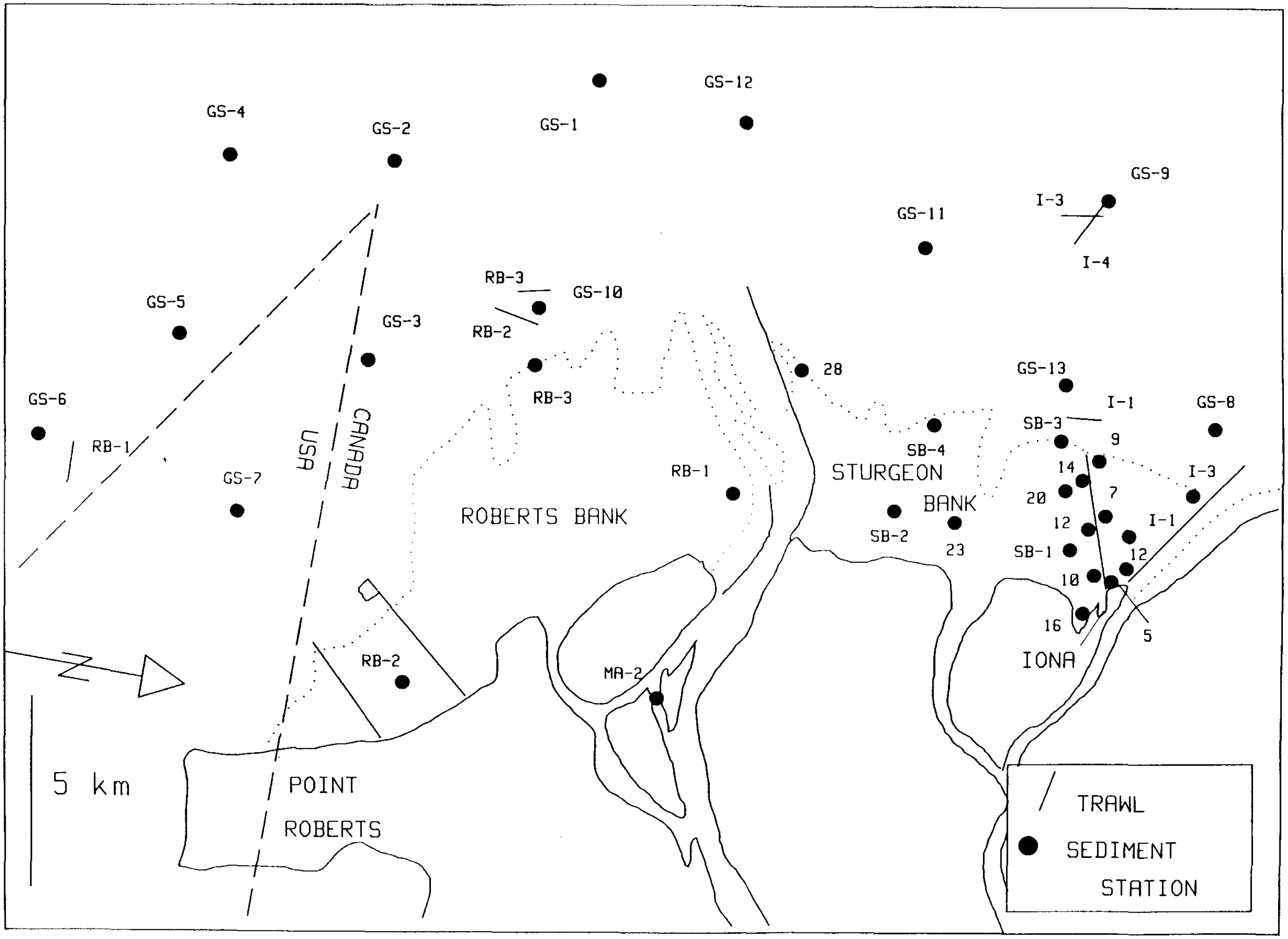

Figure 1 Study area and sampling locations.

TABLE 1 Fraser River Estuary Sampling Dates and Locations

Date	Vessel	Location	Environmental Compartment
10 Sep 84	Vector	Roberts Bank	subtidal sediment, epifauna
14 Nov 84	Vector	Iona	intertidal sediments, epifauna
22 May 85	Hovercraft	Iona, Sturgeon Bank, Main Arm,Roberts Bank	intertidal sediments, infauna
23 Jul 85	Vector	Iona, Roberts Bank,	subtidal sediments, epifauna
27 Nov 85	Vector	Iona, Roberts Bank, Georgia Strait	sediments cores, grab, epifauna*
9 Jan 86	Hovercraft	Iona,Sturgeon Bank, Main Arm, Roberts Bank	intertidal sediments

*Results not available

2 MATERIALS AND METHODS

2.1 Sample Collection

2.1.1 Sediment.

Subtidal sediment grabs were taken using a 0.1 square meter stainless steel Smith-MacIntyre grab. The top two centimetres were removed with a plastic spoon and frozen in standard sediment bags for trace metal analysis. Sediment cores were taken with a Benthos gravity corer equipped with a 60 kg weight, plastic tube and core catcher. The core was extruded from the core tube by inserting a wooden plunger and pushing the sediment out into a surface where it was separated with a wooden spatula and frozen onboard in standard sediment bags for later analysis.

Sediment samples from intertidal mud flats were collected by hand with a plastic spoon for metals and treated as above. Glass, hexane-washed jars were used to store samples for organic analyses.

2.1.2 Tissues.

Tissue samples from subtidal epifauna were collected using a small otter trawl consisting of a 3.8 cm mesh net and a 5.8 metre throat. The trawl was towed with a 3:1 scope for approximately 0.8 km. Trawl catches were enumerated by species with lengths and weights recorded. Tissue samples were taken from selected specimens using a stainless steel scalpel and forceps as follows:

- fish: dorsal muscle with skin removed, liver and gills.
- shrimp: tail muscle (composites of 2) and hepatopancreas (composites of 6).
- crabs: leg and claw muscle and hepatopancreas.

Intertidal infauna for tissue samples were collected at low tide by hand. Bivalves were purged in clean seawater for 24 h before freezing.

2.2 Analytical Procedures

2.2.1 **Sediment.** Sediment samples were analysed for trace metals by the EP Laboratory according to procedures outlined by Swingle and Davidson (1979). Samples were freeze-dried and sieved through a 100-mesh nylon sieve. They were then digested in a 4:1 nitric hydrochloric acid mixture and analsyed for trace metals using a Perkin-Elmer Inductively-Coupled Argon Plasma (ICAP) Optical Emmission Spectrometer. Cadmium and lead levels below the ICAP detection limits were analysed using a Jarrel Ash 850 Atomic Absorption Spectrophotometer (AAS) with a FLA 100 graphite tube furnace.

Oil and grease was determined using a soxlet extraction method with freon as the solvent.

Sediments for particle size were freeze-dried and sieved before weighing. Sediment volatile residue was determined by obtaining the loss of weight upon ignition at 550 C for one hour (Swingle and Davidson, 1979).

Polynuclear aromatic hydrocarbons (PAH) were analysed by GC/MS by the Environment Canada River Road Environmenatal Technology Centre, Ottawa, and by Cantest, Sydney, BC. At River Road, an aliquot of each sediment sample was first subjected to soxhlet extraction with benzene for 18 hours. The extract was then fractionated through an activated silica gel column to remove co-extracted non-target organics. The PAH fraction was finally concentrated to 1 mL and analyzed by GC/MS using Selective Ion Monitoring (SIM) technique.

Prior to solvent extraction each sample was spiked with four deuterium labelled compounds (d10 -Anth. d10 -Pyrene, d12 -B(a)A and d12 -Perylene). The recovery was in the range of 30 to 118%. Cantest used similar methods.

2.2.2 **Tissue.** Tissue trace metal levels were analysed by the EP Laboratory according to procedures described by Swingle and Davidson (1979) as follows: tissue samples were thawed, blended, freeze-dried and oxidized in a low temperature asher. The ash containing the metallic salts was then dissolved in warm concentrated nitric acid. Samples were analysed on the Inductively Coupled Argon Plasma (ICAP) Optical Emission Spectrometer. Tissue levels that were below the ICAP detection limit for cadmium and lead were analysed by the Jarell Ash 850 Atomic Absorption Spectrometer (AAS) with a FLA 100 graphite tube furnace.

For mercury the blended and freeze-dried samples were dissolved in a 4:1 sulfuric acid-water mixure. These solutions were further oxidized with 50% peroxide, heated, cooled and diluted with potasium permanganate. The resultant solutions were then analysed by "cold vapour" AAS with background correction. Values are reported in dry weight. Canadian guidelines for metals in fish and fish products (Fish Inspection Branch, 1983) were converted to dry weight for comparison. Wet:dry ratios used for the conversions were 4.54 for shrimp, 7.39 for mussels and 4.61 for English sole, derived from Goyette and Christie (1983) and considered typical of west coast biota. In the guidelines, "fish products" refers to edible filets and other products for human consumption, while "fish protein" is a manufactured product not necessarily analogous to fish muscle. The guideline for mercury applies to all fish products, while the guidelines for lead and arsenic apply only to fish protein.

2.3 Quality Control

Standard reference materials Lobster Tail (NRC), Oyster Tissue (NBS), Bovine Liver (NBS), BCSS Marine Sediment (NRC) and MESS Marine Sediment (NRC) were analysed with each batch of samples processed. If significant (10%) differences were observed between measured and certified values, methods were checked and the samples re-run. Analytical results for standard reference materials were reported with the data; certified values for these standards are available at the Environment Canada laboratory in West Vancouver.

2.4 Statistical Analysis

Summary statistics were preparéd using "MultiPlan" electronic spreadsheets on a DataPoint minicomputer with standard functions for mean, maximum and minimum, standard deviation and variance. For summary statistics all values less than chemical analytical dection limits were assigned the value of the detection limits.

For statistical comparisons, data were log-transformed as necessary to stabilize the variance and obtain a more normal distribution. Log transformations, comparative statistics and linear regressions were performed on an IBM PC using "StatPro" statistical analysis programs.

3 RESULTS AND DISCUSSION

Sediment and tissue trace metals are compared to reference levels collected in unpolluted, coastal locations during March, 1984 in Barkley Sound, Quatsino Sound, Surf Inlet and Laredo Sound. They were analysed in the same laboratory using the same methods and quality control procedures. These data were reported separately by Harding and Thomas (1987).

3.1 **Sediments**

Sediment contaminant levels are compared to Apparent Effects Threshold (AET) levels developed by Washington State and EPA to provide reference levels for biological effects of contaminants in Puget Sound sediments (Tetra Tech, 1986, 1987). The tests combine both laboratory dose-response experiments and field surveys of benthic communities. AET's are the levels above which toxic effects were always demonstrated; below a given AET some experiments or studies demonstrated effects and some did not. Hence, they are a conservative indicator of environmental degradation. Tetra Tech, Inc. (ibid.) have developed AET's for amphipods, oyster larvae, benthic communities and luminescent bacteria exposed to a variety of organic and inorganic contaminants.

3.1.1 **Sediment Trace Metals.** Results of duplicate analyses from subtidal (107-156 m) sediment grabs taken in south Georgia Strait off Roberts Bank on September 10, 1984, are given in Appendix 2. No strong pattern of spatial distribution of trace metals are apparent. Within station variation was nearly as high as between station variation. Cadmium levels were quite high (max = 7.0 mg/kg at Station 6) compared to baseline levels of 0.4 to 1.3 mg/kg in relatively unpolluted coastal locations (Harding and Thomas, 1987). Quality control results for these samples were double-checked and found to be within the tolerance limits (MESS triplicates = 0.5, 0.6, 0.6 compared to a certified value of 0.59 ± 0.10; and BCSS triplicates = <0.3, <0.3, <0.3 versus a certified value of 0.25 ± 0.04); all units in mg/kg).

Cadmium in both replicates at Station GS-6 were above the Apparent Effects Threshold (AET) of 5.8 mg/kg for effects on marine benthic communities (TetraTech, 1986,1987).

Cadmium was not correlated with aluminum (using log transformed data), which represents the clay content (aluminum silicates make up the bulk of most clays; c.f. National Oceanic and Atmospheric Administration, 1987). Figure 2 shows cadmium as a function of aluminum concentration for the southern Strait of Georgia (September 10, 1984: points labeled "*") and coastal baseline data from Harding and Thomas, 1987 (sampled in March 1984: points labeled with "x"). All Strait of Georgia points for cadmium are outside the 95% confidence limits of the baseline data, indicating pollution above the range of cadmium at unpolluted, coastal locations. Copper and mercury were, however, significantly correlated with Aluminum, using log-transformed data (r= 0.79 for copper and r= 0.85 for mercury; prob= 0.75, d.f.= 8).

Mercury (Appendix 2) was also higher (max = 0.253 mg/kg at Station 1) than in unpolluted coastal areas (0.005 to 0.149 mg/kg; Harding and Thomas, 1987), but less than Tetra Tech's Apparent Effects Thresholds (Tetra Tech 1986, 1987). Copper (mean of duplicates) ranged from 15.6 to 30.2 mg/kg, with the higher levels being at the deepest stations (Appendix 2). Arsenic and lead (Appendix 2) were both below detection limits of 8.0 and 3.0 mg/kg, respectively. Copper, arsenic and lead levels were all well within the range of levels of these metals at unpolluted, coastal locations reported by Harding and Thomas (1987) for unpolluted, coastal sediments of B.C. and less than Tetra Tech's Apparent Effects Thresholds (Tetra Tech, 1986, 1987).

Results for cores taken at Stations GS-11 to GS-13 and one grab at Station GS-10 on November 27, 1985 in Georgia Strait off Sturgeon Bank are given in Appendix 5. Arsenic in surface sediments was less than the detection limit of 0.8 mg/kg at all stations. Surface values for cadmium were all less than detection limits of 0.3 mg/kg, a surprising result in view of the relatively high values found further south in the Strait of Georgia on the September 1984 survey. Quality control results were double checked for this data set to ensure that they did not under represent the cadmium levels.

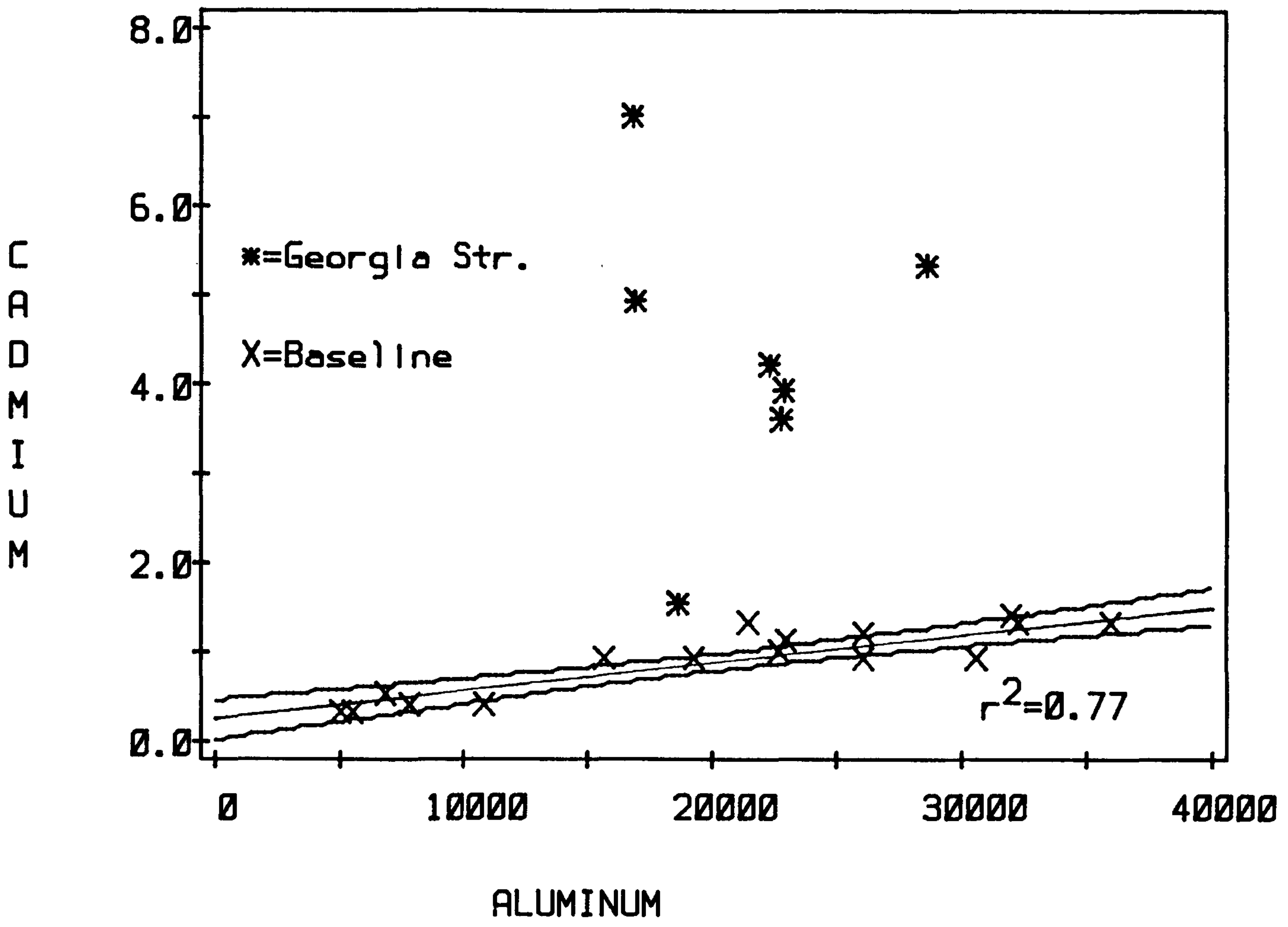

Figure 2 Comparison of cadmium vs. aluminum levels in subtidal sediment off Roberts Bank, September, 1984 (*'s), with baseline levels (X's; from Harding and Thomas, 1987; regression line with 95% confidence intervals).

TABLE 2 Mean And Maximum Of Selected Trace Metals (mg/kg) At Iona, Sturgeon Bank, Middle Arm And Roberts Bank, May, 1985

AREA			AL	AS	BA	CD	CR	CU	FE	HG	NI	PB	SN	ZN
North Iona	N=5	MEAN	12720	< 8	36.9	0.18	54.0	16.2	30220	0.10	37.0	5.0	< 2.0	60.0
		MAX	14000	< 8	42.6	0.29	71.5	23.6	37800	0.13	50.0	7.0	< 2.0	71.7
South Iona	N=7	MEAN	17486	< 8	59.9	1.40	64.4	88.7	32443	0.38	40.6	44.4	2.14	125.4
		MAX	26000	< 8	122.0	4.68	102.0	308.0	37700	1.29	50.0	166.0	3.0	332.0
Sturgeon Bank	N=4	MEAN	13300	< 8	40.3	0.19	55.6	15.7	30225	0.09	40.3	3.8	< 2.0	59.8
		MAX	17200	< 8	60.1	0.28	81.3	22.3	36400	0.11	49.0	6.0	< 2.0	73.8
Middle Arm	N=1		21600	< 8	98.8	0.66	53.4	35.0	37700	0.11	47.0	< 3.0	< 2.0	87.4
Roberts Bank	N=3	MEAN	11667	< 8	33.4	0.14	42.0	12.1	25433	0.11	35.3	< 3.0	< 2.0	50.4
		MAX	13100	< 8	37.6	0.18	48.3	13.4	28100	0.17	38.0	< 3.0	< 2.0	57.3

STATIONS

North Iona: 3, I-1, 5, 7, 9

South Iona: 10, 16, 12, 14, SB-1, 20, SB-3

Sturgeon Bank: 23, SB-4, SB-2, 28

Middle Arm: MA-2

Roberts Bank: RB-1, RB-3, RB-2

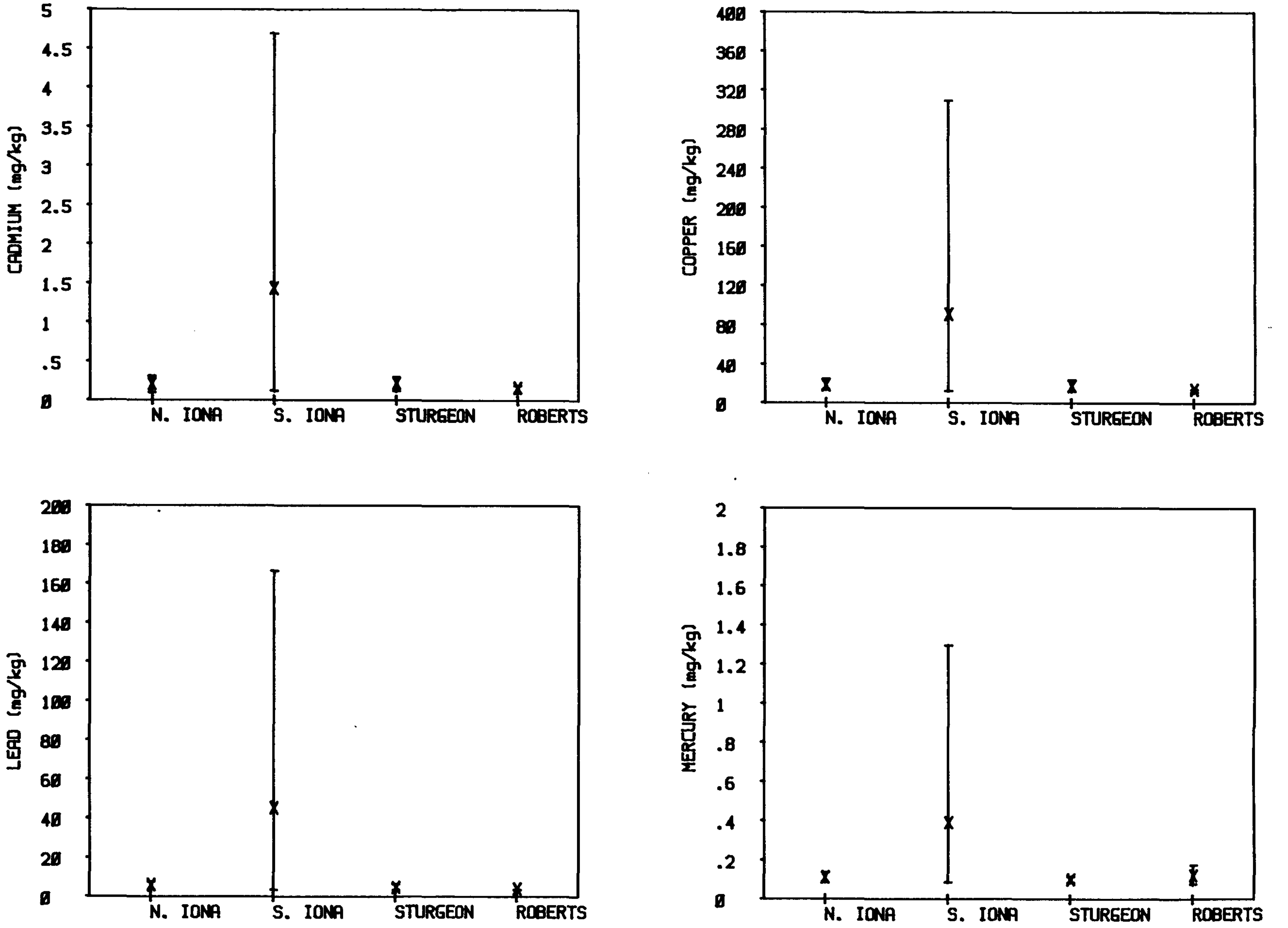

Figure 3 Mean, maximum and minimum trace metals levels (mg/kg dry wt.) in Fraser Estuary intertidal sediments.

If anything, EP lab results were a little high (MESS triplicates = 0.58, 0.70 and 0.60 compared to an NRC certified value of 0.59 ± 0.04; BCSS triplicates = 0.30, 0.40, 0.40 compared to NRC certified value of 0.25 ± 0.04; all units in mg/kg).

Copper in the surface layer of cores was similar to copper levels in the earlier survey, ranging from 15.5 mg/kg at GS-10 off Roberts Bank to 57.0 at GS-8 north of the Iona outfall. Surface mercury concentrations at the GS-10 to GS-13 stations were in the low end of the range of mercury in the earlier grabs at stations GS-1 to GS-7 (0.07 - 0.16 mg/kg). Surface lead concentrations, however, were much higher, ranging from 12.0 mg/kg at GS-10 to 35.0 mg/kg at GS-13. Arsenic, cadmium, and mercury concentrations in surface sediments from these stations were within the range of levels of these metals reported by Harding and Thomas (1987) for unpolluted, coastal sediments of B.C., while copper and lead were higher. Both copper and lead were below Tetra Tech's AET's (Tetra Tech 1986, 1987).

Core profiles (Appendix 5) showed relatively constant trace metal levels with depth in the core, down to 100-160 cm.

Intertidal sediment grab results from May, 1985 were grouped for stations in North Iona (north of the jetty), South Iona (south of the jetty near the sewage treatment plant), Sturgeon Bank and Roberts Bank (Table 2, Appendix 3). A very strong pattern of spatial distribution was observed, with mean levels of cadmium, copper, lead, mercury and other trace metals being generally a factor of two or more higher in the South Iona group than in the other areas (Figure 3). Cadmium was less than 1.0 mg/kg except for the south Iona stations, which averaged 1.4 mg/kg and had a maximum of 4.7 mg/kg. Mean copper ranged from 12.1 to 35.0 mg/kg except at the south Iona stations, which had a mean of 88.7 and a maximum of 308 mg/kg. Mean mercury levels were in the range of 0.9-0.11 mg/kg except at south Iona, where the mean was 0.38 mg/kg. Lead showed a similar pattern, averaging less than 5.0 mg/kg in all areas except Iona with a mean of 44.4 mg/kg.

In January 1986, the FREMP stations (SB-1 to SB-4, RB-1 to RB-3, I-1 and MA-2) were re-sampled to test for seasonal differences in trace metal content(Appendix 4). Mean levels of cadmium, copper and mercury were slightly higher in May (Fraser River pre-freshet) than in January (Fraser

River post-freshet). The differences were significant only for cadmium and mercury however, based on paired t-tests using log-transformed data (t= 1.24, prob.= 0.250, d.f.= 8 for cadmium and t= 1.94, prob.= 0.09, d.f.= 8 for mercury). Variance plots are shown in Figures 4 to 6. Means for arsenic and lead could not be calculated since all or some values were below detection limits. Lower levels after freshet suggest covering by clean sediments from the Fraser River; or the contaminated sediments may have been swept out.

The levels of cadmium, copper and mercury at South Iona, Sturgeon Banks, Middle Arm and Roberts Bank intertidal areas were all well within the range reported by Harding and Thomas (1987) for unpolluted, coastal sediments of B.C. Levels of all trace metals at all intertidal stations were below Tetra Tech's AET's, although cadmium, copper, lead and mercury were very close at south Iona stations.

While not strictly comparable because of station location differences, these results are similar to those found by Pomeroy (1983) in December, 1981. The same laboratory and analytical techniques were used in both surveys, but the stations in December, 1981, were located just off (seaward) Sturgeon Bank, in the area of the proposed deep sea outfall from the sewage treatment plant. Cadmium was below detection limits of around 0.6 mg/kg in the earlier survey, and copper was in the same range (33.1-47.0 mg/kg) as noted in this study. Mercury was generally much higher in the earlier survey, up to 7.58 mg/kg, a level that had been confirmed by repeated analysis; highest concentrations were also near the Iona outfall. Lead was also higher in the previous study, ranging between 10.3 mg/kg and 27.9 mg/kg, except for one value of 166.0 mg/kg station - north, of the Iona outfall.

3.1.2 **Particle Size.** Of the areas sampled, cores off Sturgeon Bank (Stations sampled in GS-8, GS-9 and GS-11 to GS-12 and grab GS-10) had the highest fraction of silt and clay (< 0.063 mm), with values between 38.2 and 77.2% (Appendix 6). Grabs at Stations GS-1 to GS-7 had some what coarser sediment, with most silt and clay fractions between 20.8 and 33.7% (Appendix 7). The stations in deeper water had the highest percentages of silt and clay. Size fractions in intertidal sediments tended to be coarser (most values less than 10% silt and clay) but more variable (ranging from 0.0% silt

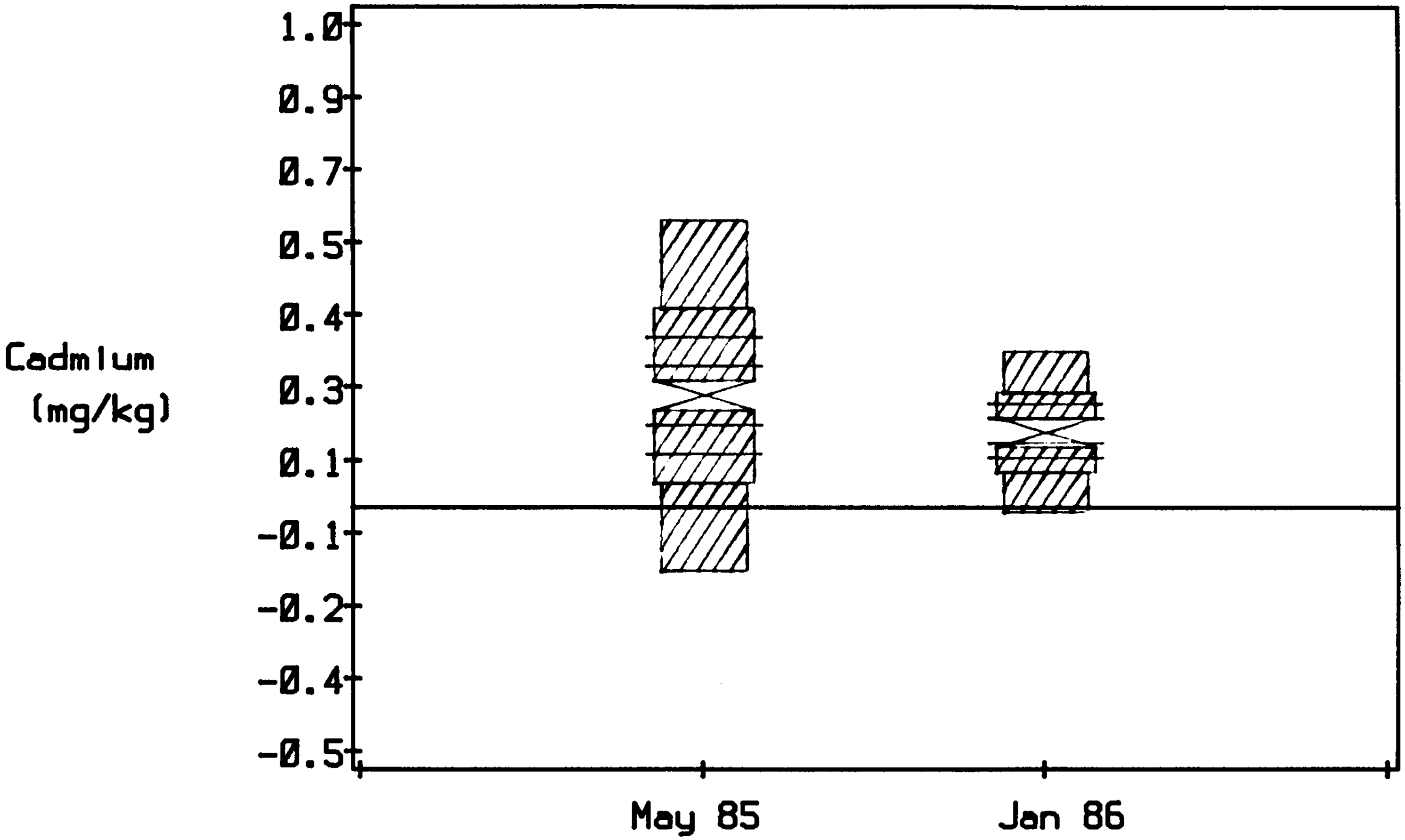

Figure 4 Comparison of cadmium (mg/kg) in intertidal sediments collected in May, 1985 with samples taken in January, 1986. (X = mean; wide and narrow bars = 1 and 2 standard deviations; horizontal lines = 1 and 2 standard errors).

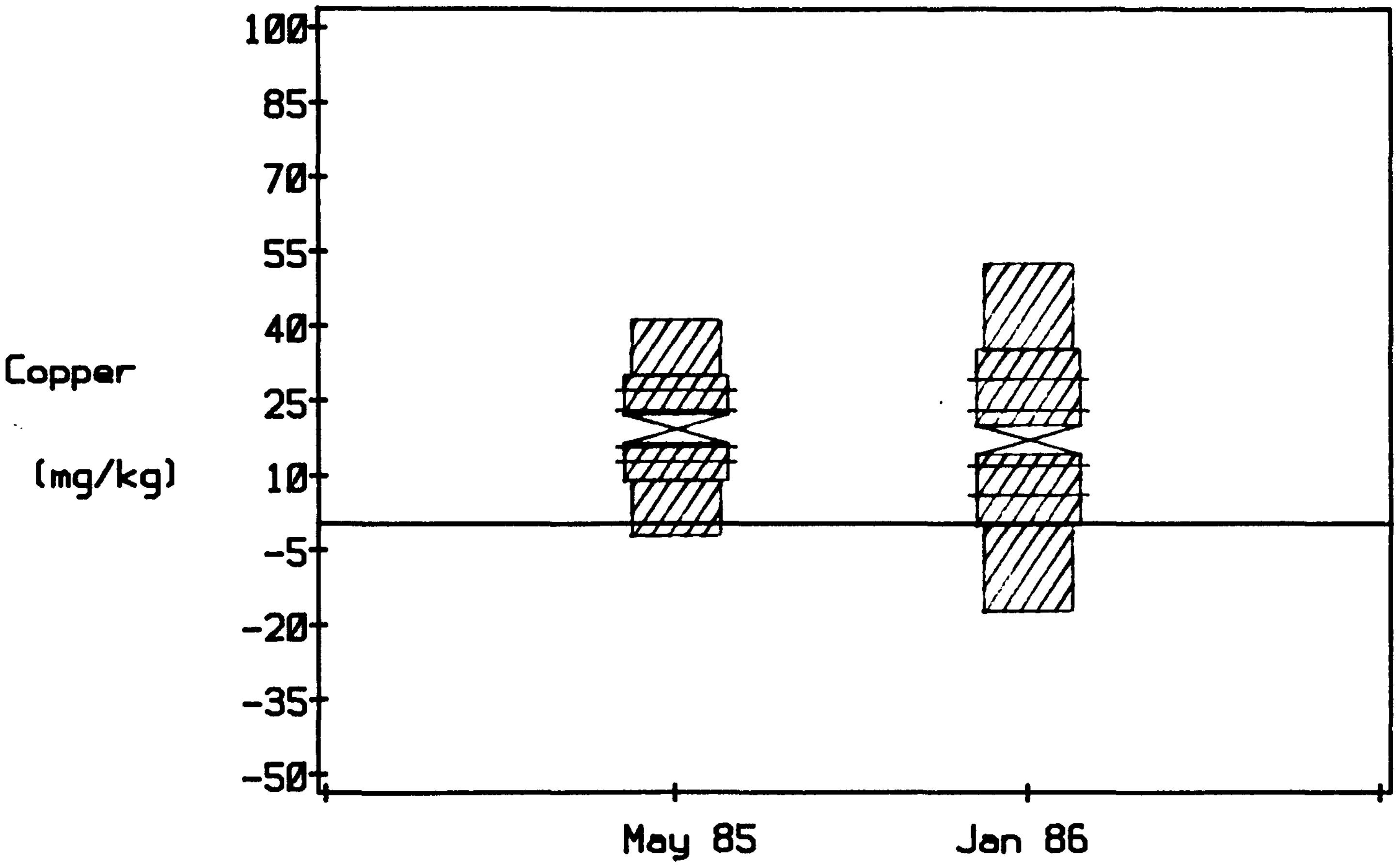

Figure 5 Comparison of copper (mg/kg) in intertidal sediments collected in May, 1985 with samples taken in January, 1986. (X = mean; wide and narrow bars = 1 and 2 standard deviations; horizontal lines = 1 and 2 standard errors).

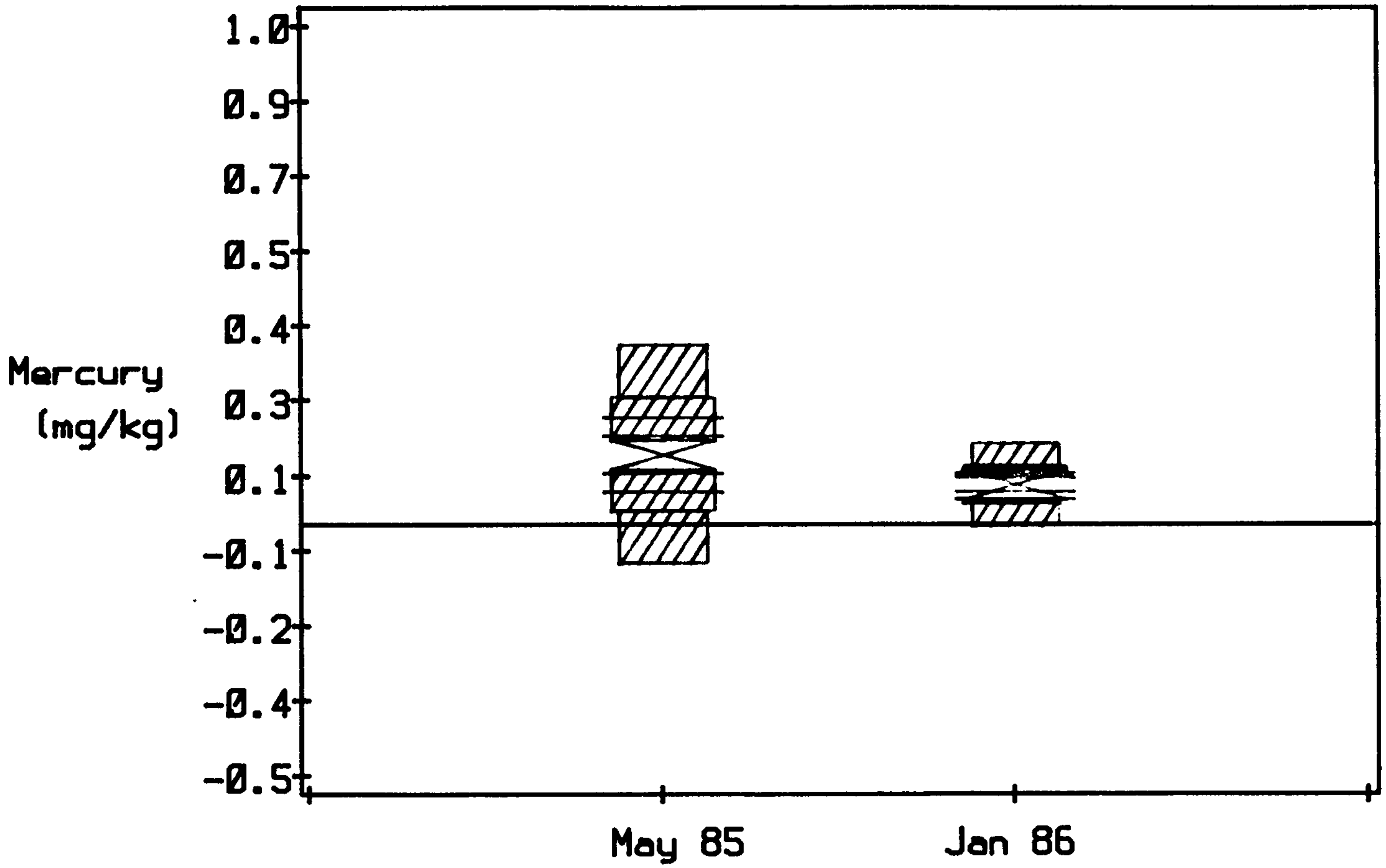

Figure 6 Comparison of mercury (mg/kg) in intertidal sediments collected in May, 1985 with samples taken in January, 1986. (X = mean; wide and narrow bars = 1 and 2 standard deviations; horizontal lines = 1 and 2 standard errors).

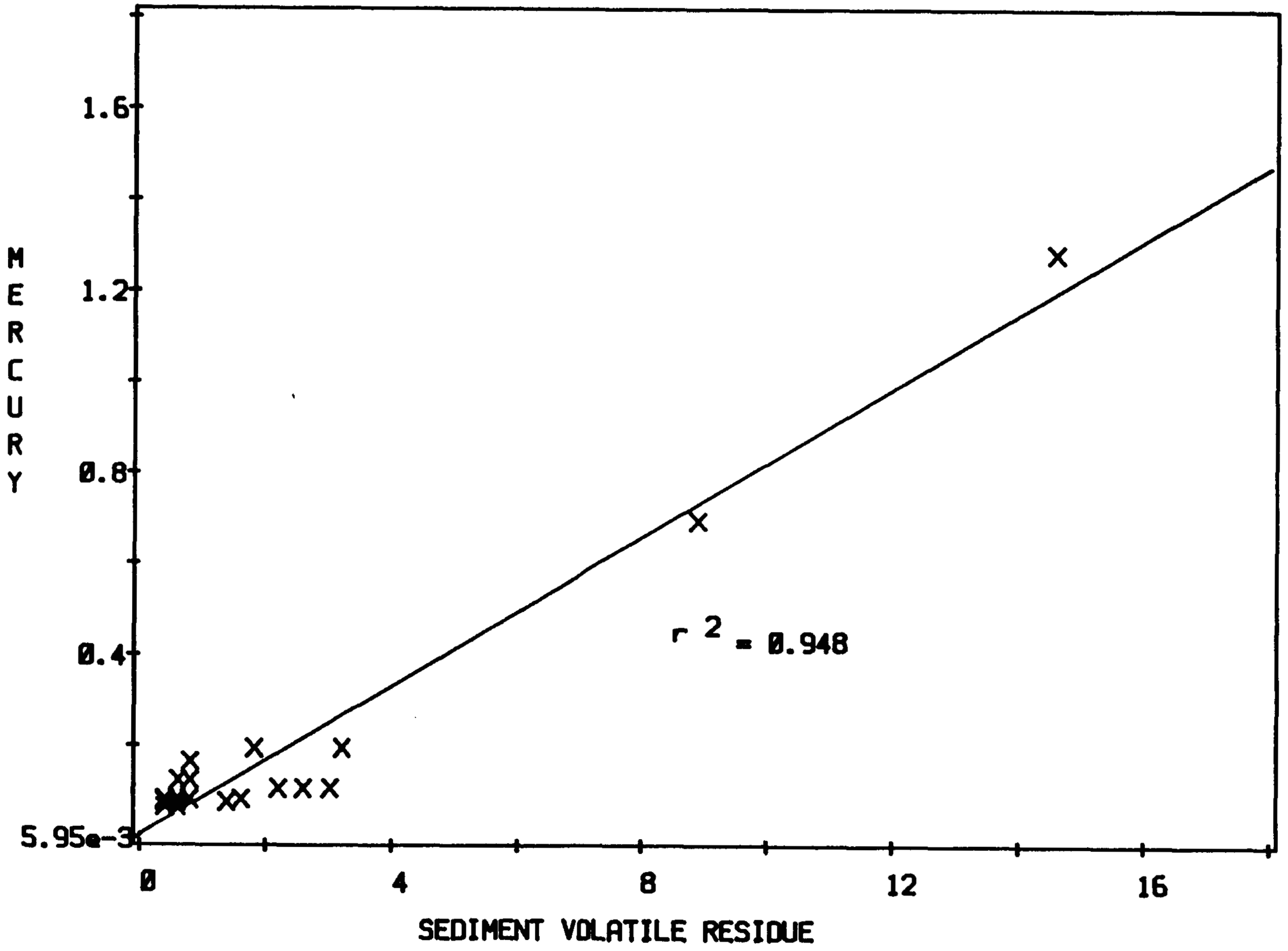

Figure 7 Linear regression of mercury (mg/kg) vs. sediment volatile residue (%), May, 1985.

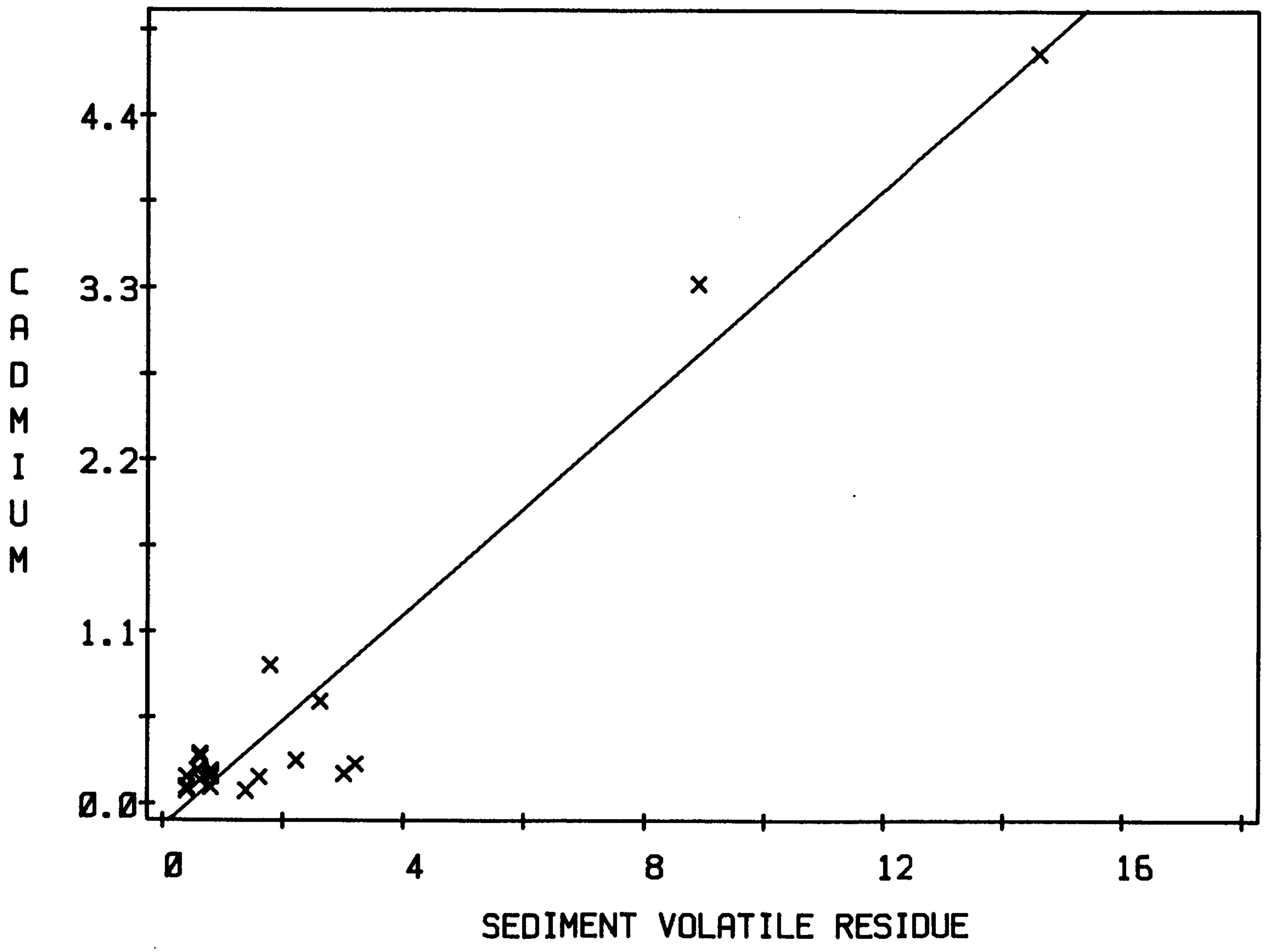

Figure 8 Linear regression of cadmium (mg/kg) vs. sediment volatile residue (%), May, 1985.

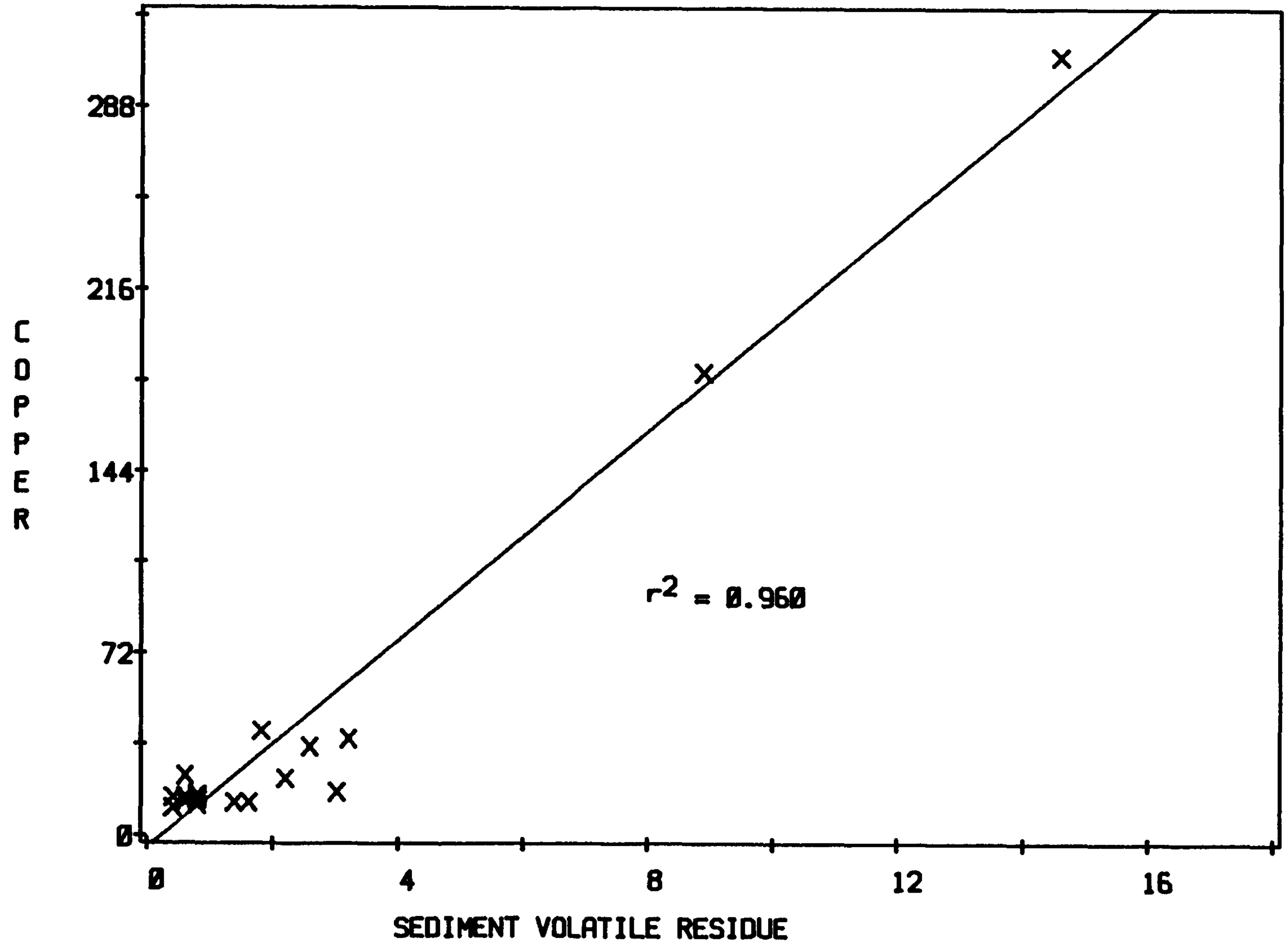

Figure 9 Linear regression of copper (mg/kg) vs. sediment volatile residue (%), May, 1985.

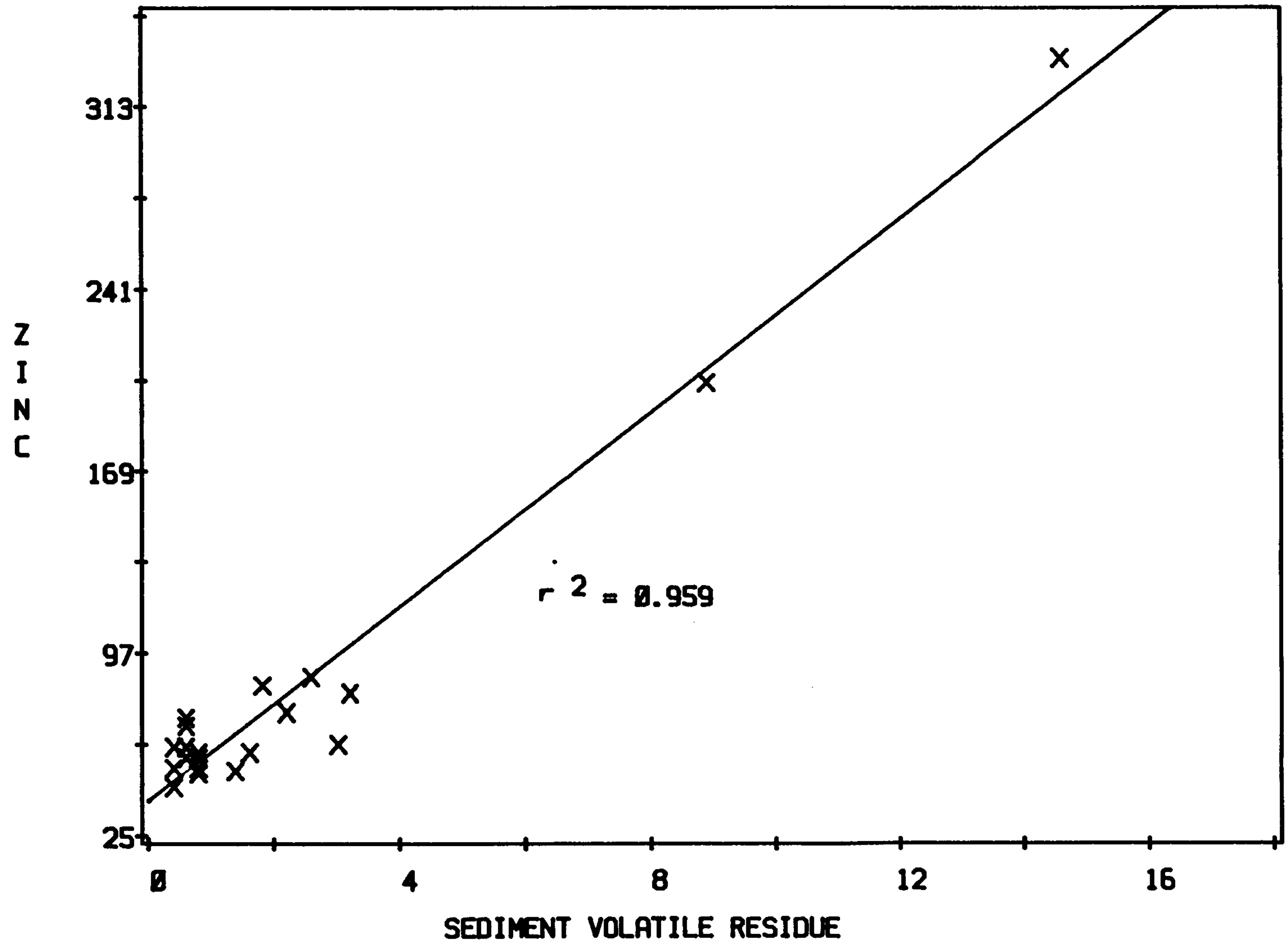

Figure 10 Linear regression of zinc (mg/kg) vs. sediment volatile residue (%), May, 1985.

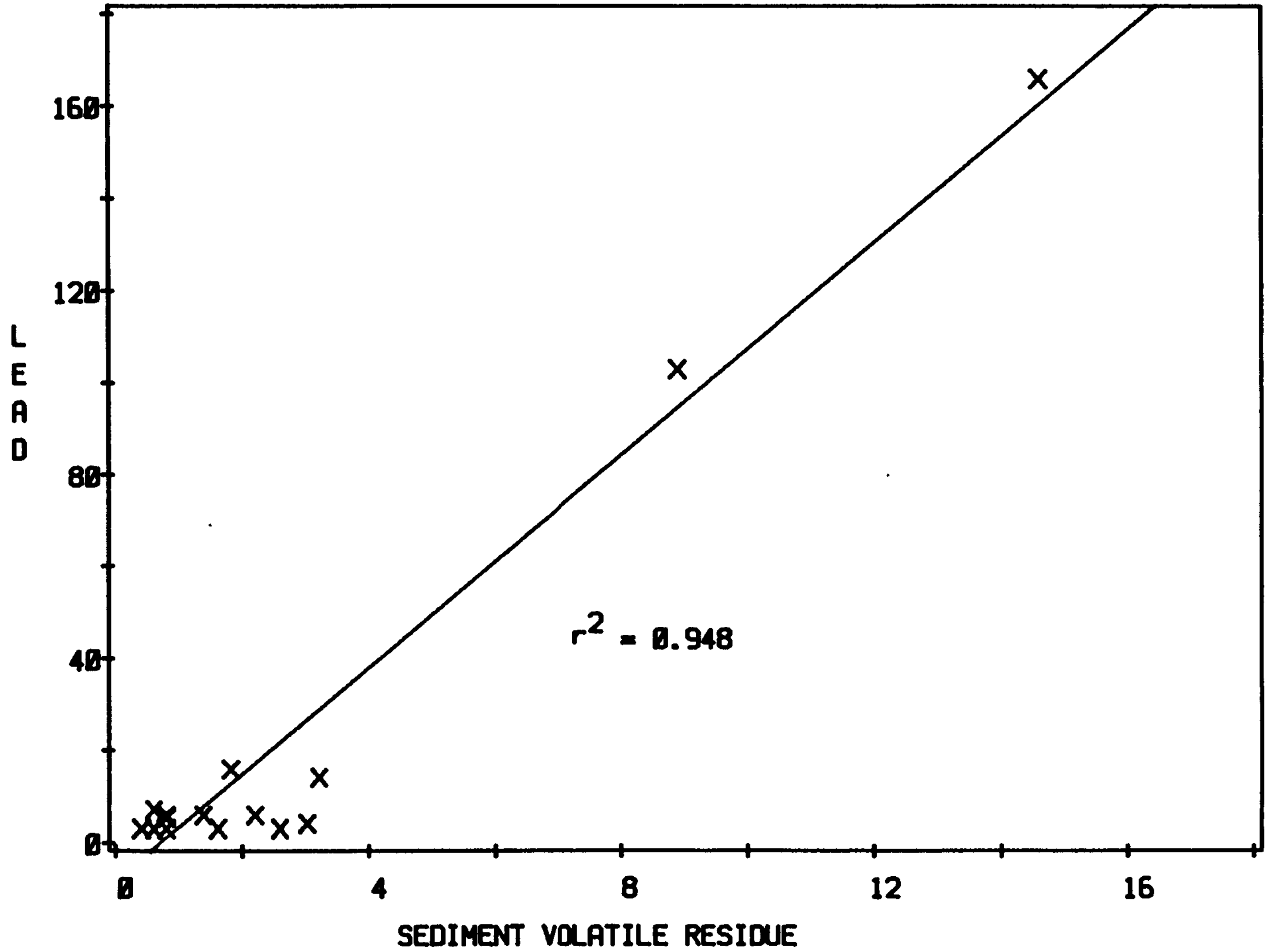

Figure 11 Linear regression of lead (mg/kg) vs. sediment volatile residue (%), May, 1985.

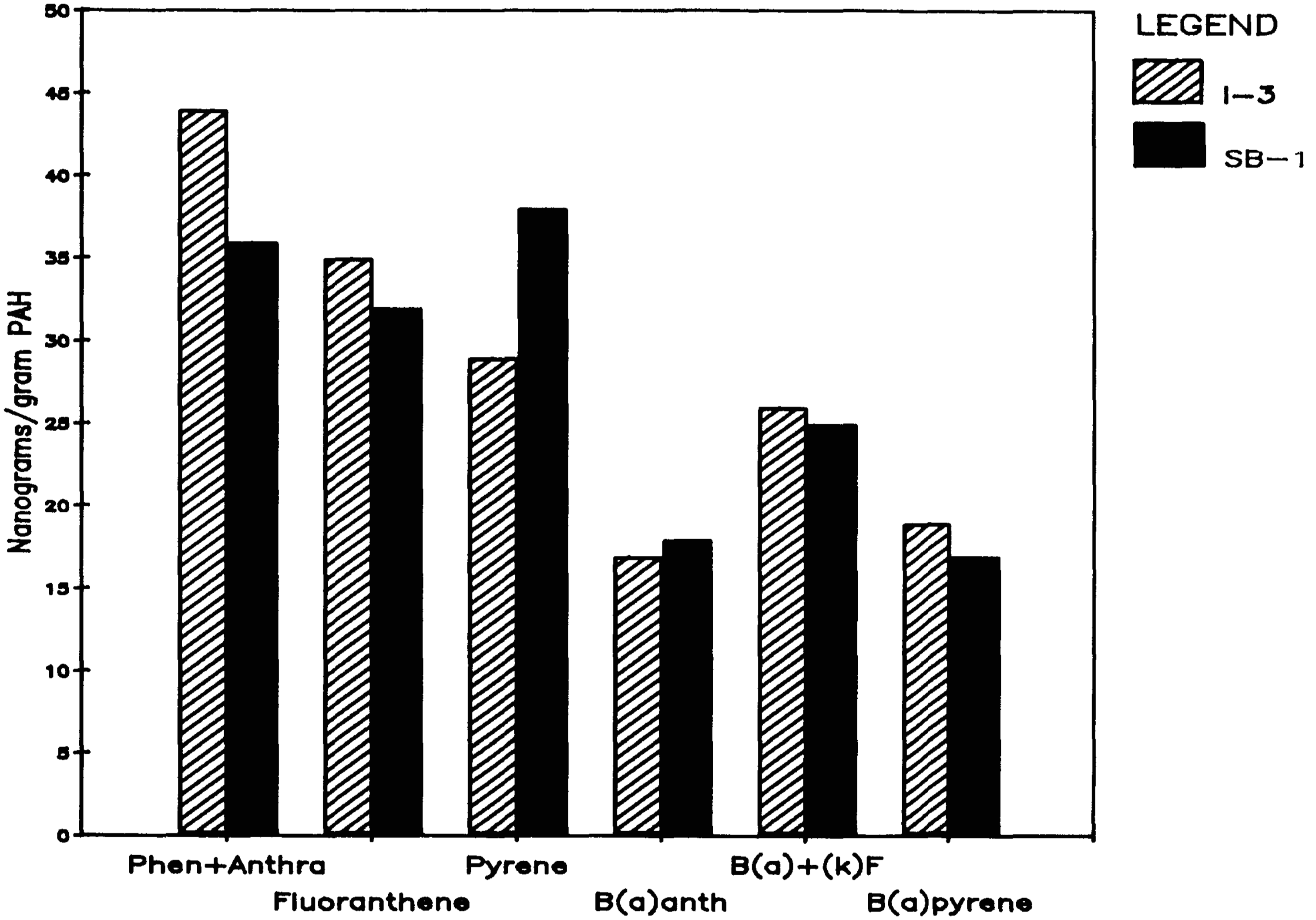

Figure 12 Polynuclear aromatic hydrocarbons (nq/kq) in sediments at Stations I-3 and SB-1.

and clay to 25.9% on Sturgeon Banks, and 32.8% in the Main Arm in May, 1985; Appendix 8; maxima somewhat higher in January, 1986, Appendix 9). Overall, there was no correlation of trace metal levels with sediment particle size.

3.1.3 **Organic Carbon Content.** Sediment organic content, measured as sediment volatile residue (SVR) by weight loss on ignition, was very homogenous in deep sediments off Iona (Stations GS-9 to GS-12) in November, 1985 (Appendix 6). All values were between 3.0% and 6.0%. By contrast, SVR on Sturgeon and Roberts Banks in both May, 1985 and January, 1986, was generally lower but more variable (Appendix 8,9). Most values were less than 1.0%, but several were over 3.0% and a few were over 8.0%.

Trace metals at intertidal stations in May 1985, were strongly correlated with organic content ($r^2 > 0.9$ for Cd, Cu, Hg, Zn and Pb as the dependent variable regressed against Sediment Volatile Residue as the independent variable; Figures 7- 11). The highest values for both organic content and trace metal levels were at the two stations nearest the Iona sewage treatment plant outfall.

3.1.4 **Organic Chemicals.** Polychlorinated biphenyls and chlorinated phenols sampled in intertidal sediments in May, 1985, were below detection limits at all intertidal stations (Table 3). Polynuclear aromatic hydrocarbons sampled in deep sediments off Iona (Stn. GS-13) and in intertidal sediments near the Iona outfall (Stn. SB-1) were detected by the Environment Canada lab at River Road, Ottawa at relatively low levels (Total PAH 166-170 ng/g; Table 4; Figure 12). These levels are well below the AET's established for Puget Sound (Tetra Tech 1986, 1987). Elsewhere, they were below detection limits on Sturgeon and Roberts Banks. PAH's were also analysed by Cantest in sediment collected in January, 1986 from stations I-1, SB-3, SB-4,23, RB-2, RB-3, and MA-2. All results were negative, i.e., PAH's were non-detectable at all stations. Detection limits are given in Appendix 10. These results are not considered comparable to those by the River Road lab due to analytical and sample collection (season) differences.

TABLE 3 **Sediment Polychlorinated Biphenyls And Pentachlorophenol/Tetrachlorophenol (ug/g) At Iona, Sturgeon Bank, Main Arm, and Roberts Bank, May, 1985**

STATION #	PCB	Pentachlorophenol Tetrachlorphenol
GS-1	< 0.02	< 0.001
SB-1	< 0.02	< 0.001
SB-2	< 0.02	< 0.001
SB-3	< 0.02	< 0.001
SB-4	< 0.02	< 0.001
MA-2	< 0.02	< 0.001
RB-1	< 0.02	< 0.001
RB-2	< 0.02	< 0.001

TABLE 4 Sediment Polynuclear Aromatic Hydrocarbons At Iona, November 27, 1985 And At Roberts Bank, January 9, 1986 In ng/g (uncorrected for recovery).

PAH	27 Nov 85		9 Jan 86		
	GS-3	GS-10	SB-1	SB-2	RB-1
Acenaphthylene	-	-	-	-	-
Acenaphthene	-	-	-	-	-
Fluorene	-	-	-	-	-
Phenanthrene + Anthracene	44	-	36	-	-
Fluoranthene	35	-	32	-	-
Pyrene	29	-	38	-	-
Benzo(a)anthracene	17	-	18	-	-
Chrysene + Tripene	-	-	-	-	-
Benzo(b)+(k)Fluranthene	26	-	25	-	-
Benzo(e)Pyrene	-	-	-	-	-
Benzo(a)Pyrene	-	-	-	-	-
Perylene	19	-	17	-	-
D-Phenanthrene-Pyrene	-	-	-	-	-
D(ah)anthracene	-	-	-	-	-
Benzo(ghi)Perylene	-	-	-	-	-
TOTAL	170	-	166	-	-
Recovery %					
d10-anthracene	51	49	56	52	38
d10-pyrene	76	76	98	82	66
d12-Benzo(a)Anthracene	74	75	93	83	68
d12-Perylene	30	31	51	34	30

Note: " - " denotes values below detection limit of 2-8 ng/g sample

3.2 Biota

3.2.1 Trace Metals In Deep Water Species Only data for commercially and recreationally fished species are reported.

Trawls were completed in the south Georgia Strait off Roberts Bank on September 10, 1984 (Table 5, Appendix 11), off Iona on November 13, 1984 (Appendix 12), and off Sturgeon Bank during July 1985 (Table 6, Appendix 13). Trawl catches from Stations R-1 to R-3 off Roberts Bank were combined, as very few specimens were caught.

Only three species were common to both the Roberts Bank (September, 1984; Table 5) and Sturgeon Bank (May, 1985; Table 6) surveys: Dover sole (*Microstomas pacificus*), sidestripe shrimp (*Pandalus dispar*), and hake (*Merluccius productus*). Sidestripe shrimp were also obtained in November, 1984 (Appendix 12). Also, mercury and low-level (Flameless AA) lead and cadmium were not analysed in the latter survey, making comparisons difficult. Mean arsenic levels in sidestripe shrimp were similar off Roberts Bank and Iona in September and November, 1984 (39.8 mg/kg and 43.5 mg/kg, respectively). The concentration of arsenic in this species was higher off Sturgeon Bank in May, 1985, however (73.6 and 69.3 mg/kg at I-3 and I-6, respectively). Mean copper in sidestripe shrimp was similar at Roberts Bank and Iona in September and November 1984 surveys (16.7 mg/kg and 16.9 mg/kg, respectively), but was higher off Sturgeon Bank in May, 1985 (51.7 mg/kg at I-6 vs. 16.7 mg/kg off Roberts Bank). These differences could be due to variations in space or time or other factors; similar differences were not noted in hake or Dover sole.

Mean, maximum and minimum levels of arsenic, cadmium, mercury and lead are shown for several commercial species in Figures 13 and 14.

Arsenic was above the Guidelines level in edible tissues of sidestripe shrimp, prawns (*Pandalus platyceros*), Dover sole, Dungeness crab (*Cancer magister*). The mean levels were; however, similar to levels in sidestripe shrimp, prawns, Dungeness crab and Dover sole from unpolluted, coastal locations reported by Harding and Thomas (1987). The highest mean values recorded in this survey - 60.0 mg/kg in Dover sole muscle from Roberts Bank, 64.0 mg/kg in Dover sole muscle from I-6, 69.3 mg/kg in sidestripe

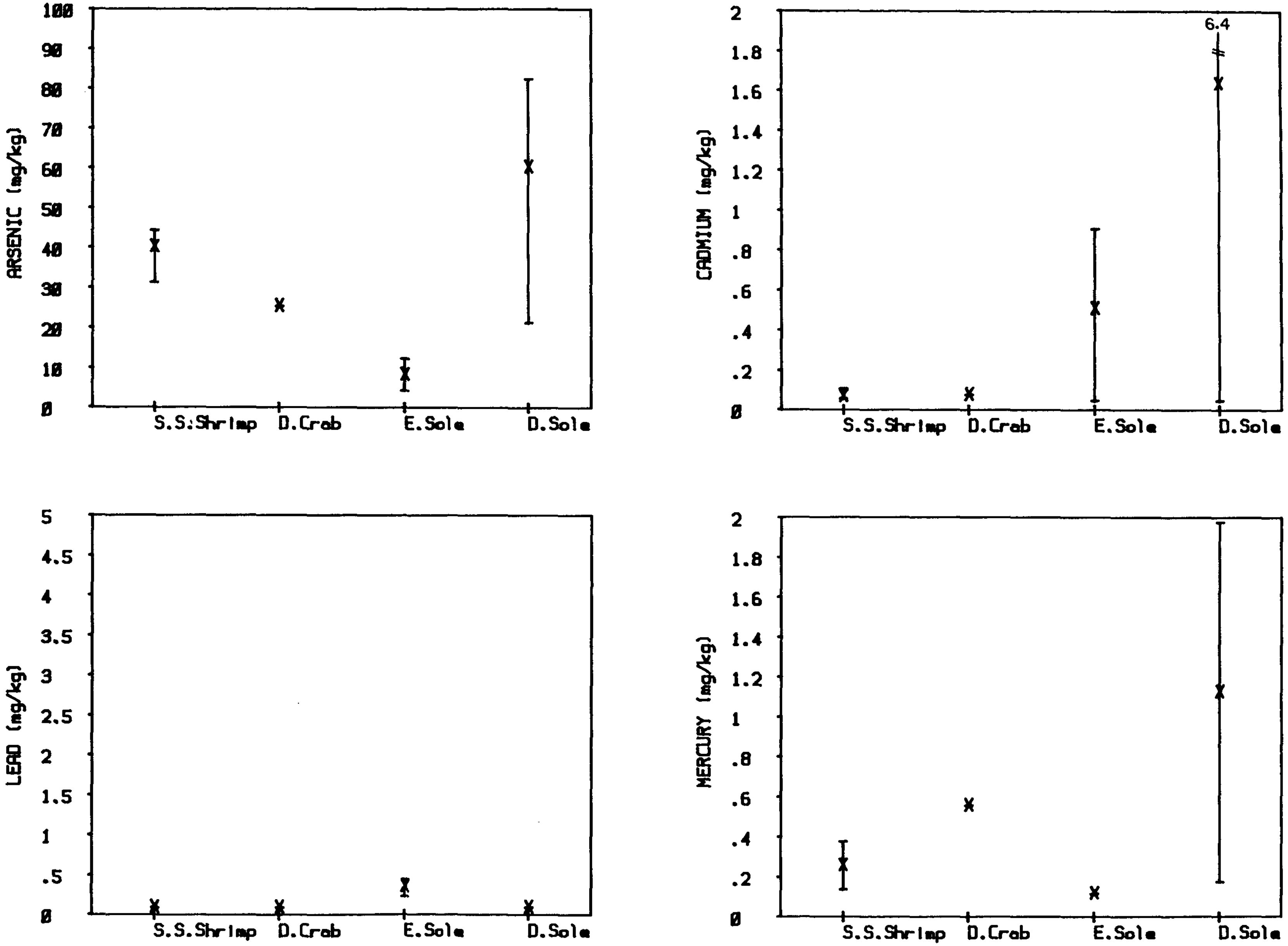

Figure 13 Mean, maximum and minimum trace metal concentrations (mg/kg dry wt.) in edible tissues of harvested fish and invertebrate species, Southern Georgia Strait, September 1984. (s.s. shrimp=sidestripe shrimp; D. crab=Dungeness crab; E. sole= English sole; D. sole=Dover sole).

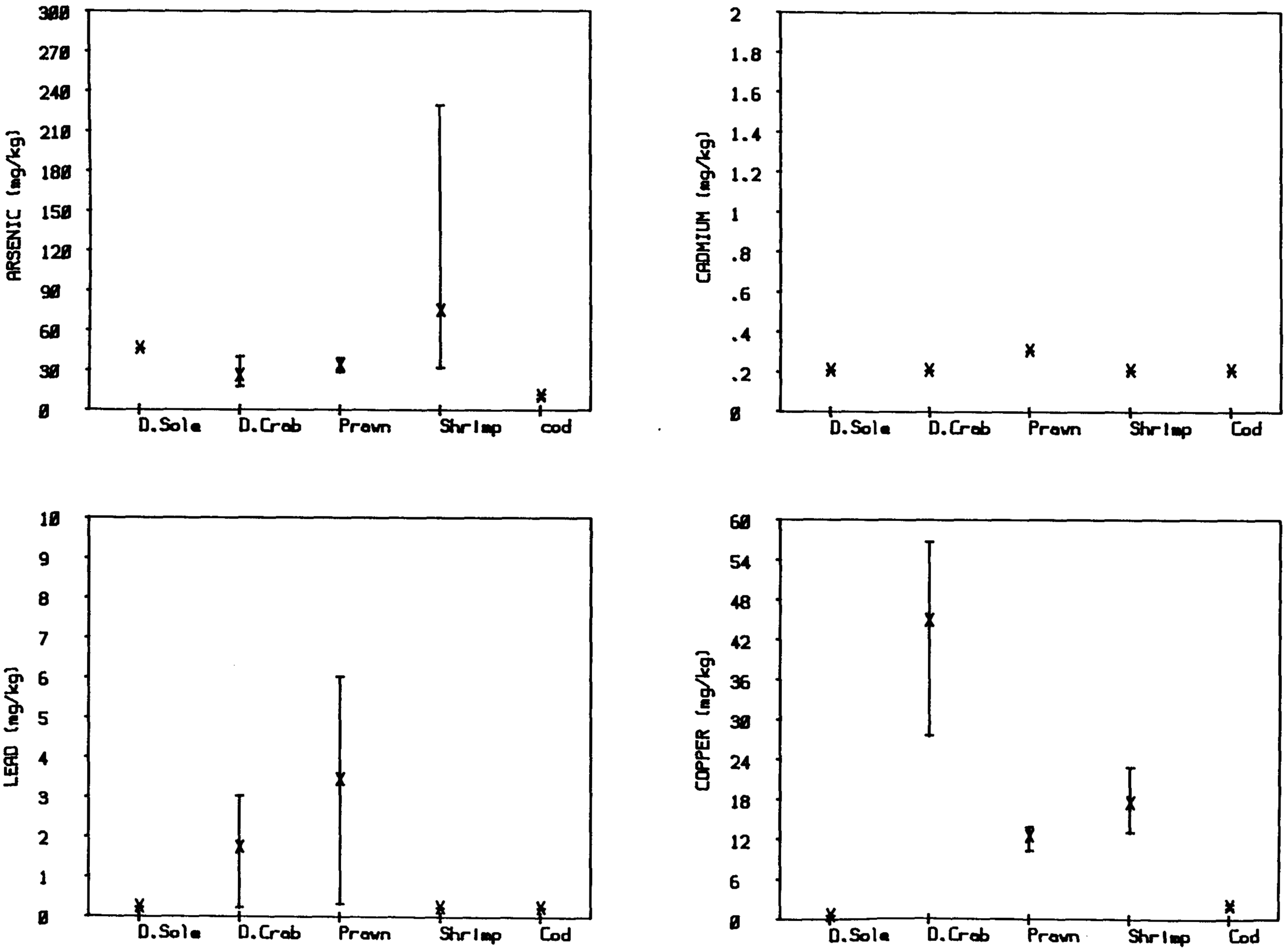

Figure 14 Mean, maximum and minimum trace metal concentrations (mg/kg dry wt.) in edible tissues of harvested fish and invertebrate species, Sturgeon Bank, July, 1985 (shrimp=sidestripe shrimp; D. crab=Dungeness crab; D. sole=Dover sole).

TABLE 5 Summary Statistics Of Selected Trace Metals In Fish And Invertebrates
Traweled Off Roberts Bank, (Stations R-2 and R-3 combined)
September, 1984.
(mg/kg dry wt.)

	AL	AS	BA	CD	CR	CU	FE	HG	NI	PB	SN	ZN
		SHRIMP			Pandalopsis dispar				MUSCLE			
MIN	4	31	0.08	0.05	0.4	13.4	6.5	0.13	2	0.08	0.8	36.5
MAX	7	44	0.12	0.1	0.9	18.4	20.4	0.37	2	0.08	0.8	44.4
MEAN(6)	4.83	39.83	0.09	0.06	0.52	16.68	12.15	0.25	2.00	0.08	0.80	40.12
C.V.	0.27	0.12	0.19	0.34	0.40	0.11	0.44	0.35	0.00	0.00	0.00	0.07
		SHRIMP			Crangon communis				WHOLE			
MIN	66	18	1.98	0.41	0.4	55.9	111	0.1	2	0.08	0.8	50.8
MAX	204	29	3.27	0.75	0.7	120	485	0.14	2	0.21	0.8	62.2
MEAN(3)	123.67	24.00	2.56	0.64	0.57	84.20	273.67	0.12	2.00	0.12	0.80	57.23
C.V.	0.58	0.23	0.26	0.31	0.27	0.39	0.70	0.18	0.00	0.61	0.00	0.10
		CRAB			Cancer magister				MUSCLE			
	11	25	1.9	0.07	0.5	19.8	34.2	0.55	2	0.08	0.8	245
		CRAB			Cancer magister				GILL			
	268	29	3.46	1.9	1.6	195	1090	0.33	7	0.3	0.8	170
	1460	65	15.5	3.2	5.4	138	3960	0.75	9	2.34	0.9	412
		CRAB			Cancer magister				HEPATOPANCREAS			
	11	49	0.48	2.6	0.4	86.7	183	0.93	7	0.08	0.7	56.8
	44	157	1.49	5.3	1	1820	218	1.27	7	0.09	0.9	160
		SOLE			Parophrys vetulus				MUSCLE			
	12	14	0.23	0.91	0.6	25.4	588	-	2	0.43	0.9	116
	4	6	0.08	0.04	2.8	1.2	22.4	0.11	2	0.22	0.8	16.1

TABLE 5 Summary Statistics Of Selected Trace Metals In Fish And Invertebrates
From A Trawl Off Roberts Bank, (Stations R-2 and R-3 combined)
September, 1984. (Continued, page 2)
(mg/kg dry wt.)

	AL	AS	BA	CD	CR	CU	FE	HG	NI	PB	SN	ZN
		SOLE			Parophrys vetulus				GILL			
	20	4	1.3	0.04	1.1	2.2	172	0.09	2	0.25	0.9	66.3
		SOLE			Microstomus pacificus				MUSCLE			
MIN	4	21	0.08	0.04	0.6	0.8	15.2	0.17	2	0.08	0.8	14.6
MAX	45	82	0.2	6.44	2	25.3	3410	1.97	2	0.08	0.8	133
MEAN(4)	14.25	60	0.11	1.63	1.4	7.35	867.7	1.125	2	0.08	0.8	45.9
C.V.	1.44	0.46	0.55	1.95	0.45	1.63	1.95	0.66	0.00	0.00	0.00	1.27
		SOLE			Microstomus pacificus				GILL			
	50	20	3.09	0.08	23	2.5	314	0.18	14	0.09	0.9	55.2
		SOLE			Microstomus pacificus				LIVER			
	16	53	0.1	3.1	0.9	31.5	741	-	2	0.2	1	116
		HAKE			Merluccius productus				MUSCLE			
	4	4	0.09	0.04	0.5	1.3	12.9	0.07	2	0.2	0.9	15.2
		HAKE			Merluccius productus				GILL			
	18	5	6.6	0.07	1.3	1.6	138	-	2	0.2	1	91.6
		HAKE			Merluccius productus				LIVER			
	6	5	0.1	2.3	0.5	17.2	379	0.07	2	0.3	1	56.7

TABLE 6. Summary Statistics Of Selected Trace Metals (mg/kg) In Fish And Invertebrates From Trawls Off Iona And Sturgeon Bank, July, 1985.

STN	AL	AS	BA	CD	CR	CU	FE	NI	PB	SN	ZN
		SOLE			Antheresthes stomias					GILL	
I-3	18	<4	2.32	<.2	1.8	3.4	136	<2	<2	<.8	106
		SOLE			Antheresthes stomias					LIVER	
I-3	<8	<8	0.3	0.8	<.8	5.1	587	<3	<3	<2	75.3
		SOLE			Antheresthes stomias					MUSCLE	
I-3	<7	9	0.1	<.3	1.4	<.7	15	<3	<3	1	22
		SOLE			Microstomus pacifica					GILL	
I-3	61	<8	3.3	<.3	2.9	2.7	255	<3	<3	<2	127
		SOLE			Microstomus pacifica					MUSCLE	
I-3	<4	45	0.1	<.2	0.6	<.4	10.1	<2	<2	<.8	20.2
		CRAB			Cancer magister					GILL	
I-3	117	<8	3.4	0.5	2.6	281	519	<3	<3	<2	249
I-3	171	14	5.9	0.5	2.5	158	523	<3	<3	3	142
		CRAB			Cancer magister					HEPATOPANCREAS	
I-3	31	62	3.1	37.1	2.3	1800	293	6	3	<2	164
I-3	<7	25	2.2	16.3	1.8	477	246	5	<3	1	103

TABLE 6. Summary Statistics Of Selected Trace Metals (mg/kg) In Fish And Invertebrates From Trawls Off Iona And Sturgeon Bank, July, 1985.

(Continued)

	STN	AL	AS	BA	CD	CR	CU	FE	NI	PB	SN	ZN
			CRAB			Cancer magister					MUSCLE	
MIN	I-3	14	17	1.42	<.2	1.4	27.5	45.4	<2	<2	<.8	128
MAX		154	39	10.9	0.2	3	56.6	361	4	3	<.8	485
MEAN		60.67	24.67	5.59	0.20	2.00	44.70	151.43	2.67	2.33	0.80	260.67
C.V.		1.33	0.50	0.87	0	0.44	0.34	1.20	0.43	0.25	0	0.75
			ROCKFISH			Sebastes ciliatus					GILL	
	I-3	24	8	3.87	<.2	2.4	2.1	150	<2	<2	<.8	69.1
			ROCKFISH			Sebastes ciliatus					LIVER	
	I-3	<7	16	0.2	1.9	1.5	12.7	1410	<3	<3	2	137
			ROCKFISH			Sebastes ciliatus					MUSCLE	
	I-3	<4	12	0.27	<.2	0.7	<.4	14.2	<2	3	<.8	13.6
			HAKE			Merluccius productus					GILL	
MIN	I-3	9	<4	0.23	0.2	1.4	7.3	243	<2	<2	<.8	76.7
MAX		17	<8	0.7	0.5	2.6	10.1	334	<3	<3	<2	132
MEAN		12.67	6.67	0.48	0.33	2.03	8.53	274.67	2.67	2.67	1.60	101.17
C.V		0.32	0.35	0.49	0.46	0.30	0.17	0.19	0.22	0.22	0.43	0.28
			HAKE			Merluccius productus					LIVER	
MIN	I-3	<4	<7	<.08	2.3	0.8	19.1	341	<2	<2	<.8	122
MAX		<7	12	0.1	17	1.8	46.9	600	<3	4	1	313
MEAN		6.00	10.33	0.09	11.27	1.27	32.20	488.33	2.67	3.00	0.93	233.67
C.V.		0.29	0.28	0.12	0.70	0.40	0.43	0.27	0.22	0.33	0.12	0.43

TABLE 6. Summary Statistics Of Selected Trace Metals (mg/kg) In Fish And Invertebrates From Trawls Off Iona And Sturgeon Bank, July, 1985.

(Continued)

	STN	AL	AS	BA	CD	CR	CU	FE	NI	PB	SN	ZN
			HAKE			Merluccius productus					MUSCLE	
MIN	I-3	<4	<4	0.1	<.2	0.9	1.2	11.7	<2	<2	<.8	17.9
MAX		<4	6	0.13	0.3	1.1	2.2	23.2	<2	3	1.4	21.5
MEAN		4.00	5.33	0.11	0.23	1.00	1.80	17.53	2.00	2.33	1.00	20.20
C.V.		0	0.22	0.16	0.25	0.10	0.29	0.33	0	0.25	0.35	0.10
			SHRIMP			Pandalus borealis					MUSCLE	
	I-3	<4	50	0.17	<.2	0.7	17.6	16.8	<2	<2	<.8	39.6
			PRAWN			Pandalus platyceros					HEPATOPANCREAS	
	I-3	28	30	0.6	1.6	2.5	393	613	4	<3	<2	152
			PRAWN			Pandalus platyceros					MUSCLE	
MIN	I-3	8	28	<.1	<.3	1.5	10.1	18.6	<3	<3	<1	44.8
MAX		15	38	0.4	<.3	2.8	13.7	24.1	<3	6	<1	50.7
MEAN		12.67	32.67	0.20	0.30	2.13	12.17	21.87	3.00	4.33	1.00	48.10
C.V.		0.32	0.15	0.87	0	0.30	0.15	0.13	0	0.35	0	0.06
			SOLE			Glyptocephalus zachirus					LIVER	
	I-3	<10	<10	<.2	0.9	1	2	145	<4	<4	<2	90.7
			SOLE			Glyptocephalus zachirus					MUSCLE	
MIN	I-3	<8	19	0.2	<.2	1.6	<.8	13.6	<2	<2	<.8	16.7
MAX		121	46	2.98	<.3	2.2	5.7	221	<3	3	<2	80.1
MEAN		80.00	30.00	1.79	0.23	1.83	4.07	147.87	2.33	2.67	1.20	58.30
C.V.		0.78	0.47	0.80	0.25	0.18	0.70	0.79	0.25	0.22	0.58	0.62

TABLE 6. Summary Statistics Of Selected Trace Metals (mg/kg) In Fish And Invertebrates From Trawls Off Iona And Sturgeon Bank, July, 1985.

(Continued)

	STN	AL	AS	BA	CD	CR	CU	FE	NI	PB	SN	ZN
			SOLE			Psettichthys melanostictus					GILL	
	I-3	20	14	5.6	<.3	3.3	10	85.4	<3	<3	14	123
			SOLE			Psettichthys melanostictus					LIVER	
	I-3	<8	14	0.3	1.8	1	41.3	966	<3	<3	<2	160
			SOLE			Psettichthys melanostictus					MUSCLE	
	I-3	<4	49	0.08	<.2	0.7	<.4	8.6	<2	<2	<.8	16.5
			SHRIMP			Pandalopsis dispar					HEPATOPANCREAS	
MAX		10	151	0.41	42.2	21.5	782	58.3	<3	<3	<1	122
MEAN		7.00	80.00	0.29	27.63	7.60	639.00	52.40	2.33	2.33	0.87	89.27
C.V.		0.43	0.81	0.41	0.50	1.58	0.21	0.10	0.25	0.25	0.13	0.44
			SHRIMP			Pandalopsis dispar					MUSCLE	
MIN	I-3	<4	31	<.08	<.2	0.5	12.9	11.4	<2	<2	<.8	32.7
MAX		7	228	0.34	0.2	1.2	22.7	25.4	<2	2	<.8	58.2
MEAN		4.86	73.57	0.15	0.20	0.79	17.27	17.56	2.00	2.00	0.80	41.60
C.V.		0.30	0.94	0.59	0	0.36	0.24	0.25	0	0	0	0.21
			SOLE			Lyopsetta exilis					LIVER	
	I-3	<8	16	0.3	1.6	1.2	15.5	827	<3	<3	<2	92.3
			SOLE			Lyopsetta exilis					MUSCLE	
MIN	I-3	<4	9	0.2	<.2	0.7	0.9	8.9	<2	<2	<.8	17.9
MAX		39	28	2.45	0.2	2.6	9.1	102	<2	3	<.8	89
MEAN		27.00	19.00	1.60	0.20	1.73	5.30	68.63	2.00	2.33	0.80	58.70
C.V.		0.74	0.50	0.76	0	0.55	0.78	0.76	0	0.25	0	0.63

TABLE 6. Summary Statistics Of Selected Trace Metals (mg/kg) In Fish And Invertebrates From Trawls Off Iona And Sturgeon Bank, July, 1985.

(Continued)

STN	AL	AS	BA	CD	CR	CU	FE	NI	PB	SN	ZN
		COD			Microgadus proximus					GILL	
I-3	9	<7	5.4	0.4	2.5	2.8	98.6	<3	<3	<1	146
I-3	26	15	11.3	<.3	2.6	3.2	108	<3	<3	<1	145
		COD			Microgadus proximus					LIVER	
I-3	<8	11	<.2	1.2	2.2	112	288	<3	<3	<2	205
I-3	<7	<7	0.2	0.5	3.1	44.4	172	<3	<3	<1	133
		COD			Microgadus proximus					MUSCLE	
I-3	<4	11	0.1	<.2	0.7	1.5	18.2	<2	<2	<.8	27.6
I-3	<4	8	0.36	<.2	<.4	2.1	15.2	<2	<2	<.8	29.7
		ROCKFISH			Sebastes entomelas					GILL	
I-3	27	<4	4.05	<.2	2.7	3.2	110	<2	3	0.9	127
		ROCKFISH			Sebastes entomelas					LIVER	
I-3	<4	7	0.09	3	1	22.4	161	<2	2	<.8	142
		ROCKFISH			Sebastes entomelas					MUSCLE	
I-3	<4	25	0.17	<.2	0.5	<.4	13.7	<2	<2	<.8	18.2
		DOGFISH			Squalus acanthias					LIVER	
I-6	<4	12	<.09	0.4	0.6	1.9	111	<2	<2	<.9	8.4
I-6	<4	19	<.08	1.9	<.4	4.6	113	<2	<2	<.8	7.3

TABLE 6. Summary Statistics Of Selected Trace Metals (mg/kg) In Fish And Invertebrates From Trawls Off Iona And Sturgeon Bank, July, 1985.

(Continued)

STN	AL	AS	BA	CD	CR	CU	FE	NI	PB	SN	ZN
		DOGFISH			Squalus acanthias					MUSCLE	
I-6	6	14	<.08	<.2	0.6	0.8	19.9	<2	<2	<.8	8.1
I-6	<4	13	<.08	<.2	0.6	1.1	9.2	<2	<2	<.8	7.1
		SOLE			Microstomus pacifica					GILL	
I-6	177	<8	0.8	0.4	1.5	5.9	539	<3	6	<2	76.8
		SOLE			Microstomuus pacifica					LIVER	
I-6	16	<7	<.1	5.1	0.7	7.8	685	<3	4	<1	61.7
		SOLE			Microstomus pacifica					MUSCLE	
I-6	<7	64	<.1	<.3	1.7	<.7	16.2	<3	<3	<1	20.2
		CRAB			Cancer magister					GILL	
I-6	<4	9	<.08	<.2	<.4	0.8	8.4	<2	3	<.8	19.1
		CRAB			Cancer magister					HEPATOPANCREAS	
I-6	27	23	2.5	18.5	1.3	569	194	3	<3	<2	114
I-6	183	16	3.1	1.4	1.5	335	515	4	7	<1	223
		CRAB			Cancer magister					MUSCLE	
I-6	64	18	4.3	<.3	2.4	35.1	138	<3	36	<1	372
		LINGCOD			Ophiodon elongatus					MUSCLE	
I-6	<4	22	0.1	<.2	0.7	0.6	11.1	<2	<2	<.8	23.4

TABLE 6. Summary Statistics Of Selected Trace Metals (mg/kg) In Fish And Invertebrates From Trawls Off Iona And Sturgeon Bank, July, 1985.

(Continued)

	STN	AL	AS	BA	CD	CR	CU	FE	NI	PB	SN	ZN
			HAKE			Merluccius productus					LIVER	
	I-6	<4	7	0.08	1	<.4	4.7	119	0	<2	<.8	35.5
			SHRIMP			Pandalus borealis					HEPATOPANCREAS	
MIN	I-6	9	32	0.3	6	1.1	333	74	<2	<2	<.8	71.2
MAX		262	55	2.34	10	1.3	547	564	<3	<3	<2	117
MEAN		131.33	43.33	1.39	8.67	1.17	448.00	349.67	2.33	2.33	1.20	87.90
C.V.		0.96	0.27	0.74	0.27	0.10	0.24	0.72	0.25	0.25	0.58	0.29
			SHRIMP			Pandalus borealis					MUSCLE	
MIN	I-6	<7	29	<.1	<.2	<.7	9	12.6	<2	<2	<.8	39.7
MAX		9	81	1.23	<.3	2.3	28.4	44.4	<13	11	<2	85.6
MEAN		10.71	58.29	0.30	0.26	1.17	17.26	24.47	2.57	4.50	1.06	55.49
C.V.		0.32	0.23	0.98	0.20	0.45	0.30	0.46	0.20	0.70	0.39	0.26
			SOLE			Glyptocephalus zachirus					GILL	
	I-6	41	<8	2	<.3	3	7.8	159	<3	4	<2	44.4
			SOLE			Glyptocephalus zachirus					LIVER	
	I-6	17	<6	0.2	2.1	0.9	3.6	416	<3	6	3	65
			SOLE			Glyptocephalus zachirus					MUSCLE	
	I-6	4	<4	<.08	<.2	0.6	1.2	17.3	<2	<2	<.8	11.1

TABLE 6. Summary Statistics Of Selected Trace Metals (mg/kg) In Fish And Invertebrates From Trawls Off Iona And Sturgeon Bank, July, 1985.

(Continued)

	STN	AL	AS	BA	CD	CR	CU	FE	NI	PB	SN	ZN
			SHRIMP			Pandalopsis dispar					HEPATOPANCREAS	
	I-6	13	48	0.19	18.9	<.4	556	52.7	<2	<2	<.8	54.5
			SHRIMP			Pandalopsis dispar					MUSCLE	
MIN	I-6	<4	21	<.08	<.2	<.4	15	12.1	<2	<2	<.8	30.1
MAX		13	120	0.57	17.3	1.4	522	49.1	<2	4	<.8	74.9
MEAN		6.81	69.31	0.20	1.27	0.89	51.71	21.71	2.00	2.31	0.80	56.28
C.V.		0.45	0.33	0.64	3.37	0.30	2.43	0.42	0	0.30	0	0.21
			SOLE			Lyopsetta exilis					GILL	
	I-6	27	13	3.2	<.3	2.7	2.9	107	<3	<3	4	144
			SOLE			Lyopsetta exilis					LIVER	
	I-6	9	<8	<.2	2.6	<.8	42.6	1090	<3	<3	<2	159
			SOLE			Lyopsetta exilis					MUSCLE	
	I-6	<8	9	<.2	<.3	<.8	<.8	15.4	<3	<3	<2	10.3
			POLLOCK			Theragra chalcogramma					GILL	
MIN	I-6	20	<7	4.6	<.3	1.6	3.8	80.9	<3	<3	<1	104
MAX		88	<8	15.9	0.6	4.5	230	949	<3	4	<2	168
MEAN		46.00	7.33	8.93	0.40	2.77	79.23	380.97	3.00	3.33	1.33	143.33
C.V.		0.80	0.08	0.68	0.43	0.55	1.65	1.29	0	0.17	0.43	0.24

TABLE 6. Summary Statistics Of Selected Trace Metals (mg/kg) In Fish And Invertebrates From Trawls Off Iona And Sturgeon Bank, July, 1985.

(Continued)

	STN	AL	AS	BA	CD	CR	CU	FE	NI	PB	SN	ZN
			POLLOCK			Theragra chalcogramma					LIVER	
MIN	I-6	<4	5	<.08	0.3	0.8	40.5	43	<2	<2	<.8	51.3
MAX		13	34	0.3	0.6	4.5	68.7	218	<3	<3	3	12.7
MEAN		7.67	18.00	0.16	0.43	2.07	57.73	139.67	2.67	2.67	1.93	95.43
C.V.		0.62	0.82	0.76	0.35	1.02	0.26	0.64	0.22	0.22	0.57	0.41
			POLLOCK			Theragra chalcogramma					MUSCLE	
MIN	I-6	<4	6	<.08	<.2	0.6	1.2	15.8	<2	<2	<.8	14.4
MAX		<7	25	0.31	<.3	1.6	2.7	28	<3	<3	<1	34.3
MEAN		5.00	17.33	0.16	0.23	1.13	1.87	21.20	2.33	2.33	0.87	21.97
C.V.		0.35	0.58	0.78	0.25	0.44	0.41	0.29	0.25	0.25	0.13	0.49

shrimp from I-6 and 73.6 mg/kg in sidestripe shrimp muscle from I- 3 - are all less than the highest mean levels for these species reported by Harding and Thomas (1987) for unpolluted reference areas. Arsenic levels in English sole (Parophrys vetulus) were below the Guidelines level, and were less than levels reported by Harding and Thomas (1987) for unpolluted, coastal locations. Arsenic levels in cod (Microgadus proximus) were less than the level given in the Guidelines. Arsenic concentrations in livers, hepatopancreas and gill tissues were also similar to those in the reference areas.

Cadmium concentrations in edible muscle of all fish, shrimp and prawns were generally below 0.3 mg/kg, or below detection limits. An exception in shrimp was a mean of 1.27 mg/kg of 16 sidestripe at I-6, which resulted from one anomalously high value of 17.3 mg/kg; all others in that data set were 0.2 mg/kg or less. In fish, one English sole from Roberts Bank had 0.91 mg/kg Cd in muscle and one Dover sole from the same area had 6.4 mg/kg Cd in muscle tissue (three others in the latter data set were below detection limits). These three values in two sole and one shrimp species are well above levels in these species (sole, generally <0.2 mg/kg, max = 2.3 mg/kg; shrimp <0.4 mg/kg) reported by Harding and Thomas (1987) for unpolluted, coastal locations. There are no Canadian guidelines for cadmium in fish.

As expected, in all species cadmium was consistently higher in liver or hepatopancreas than in either muscle or gill tissue, although the levels were within the range at unpolluted, coastal locations in species for which comparative data are available (Harding and Thomas 1987), excluding Dungeness crab. High values included 37.1 and 16.3 mg/kg in hepatopancreas from two Dungeness crabs at I-3, 18.5 mg/kg in hepatopancreas from a Dungeness crag at I-6, and a mean of 27.6 mg/kg (max.= 42.2) in three sidestripe shrimp from I-3.

Copper concentrations in shrimp and prawn tissue were generally in the 12 to 28 mg/kg range, except for a group of 16 sidestripe shrimp in which the mean was 51.7 mg/kg. Except for an anomously high value of 522 mg/kg, all others in that data set were within the range noted above. Copper levels in fish muscle were usually less than 2.0 mg/kg, similar to mean copper levels of about 0.8 to 1.8 at unpolluted, coastal locations reported by Harding and Thomas (1987). Higher levels occurred in an English sole from Roberts Bank (25.4 mg/kg), ratfish (Hydrolagus colei) from Roberts Bank (mean of 3.23 mg/kg, max.= 6.40, n=3), a hake from I-3, Rex sole (Glyptocephalus zachirus) from I-3 (mean of 4.07 mg/kg, max.= 5.7, n=3), and Slender sole (Lyopsetta exilis) from I-3 (mean of 5.3 mg/kg, max.= 9.1, n=3). There is no Canadian guideline for copper in edible fish tissue.

Copper levels in hepatopancreas of shrimp, prawns and Dungeness crab were much higher than in muscle and gill tissue, exceeding 300 mg/kg in prawns, 500 mg/kg in shrimp and 1800 mg/kg in crab. Most fish liver copper levels were less than 10 mg/kg; a few were between 10 and 50 mg/kg and one reached 112 mg/kg in a cod from I-3. The levels for prawns shrimp, and fish are similar to background levels reported by Harding and Thomas (1987).

At the trawl sites off Roberts Bank, mercury was less than 1.0 mg/kg in fish muscle, except for a mean of 1.13 mg/kg in ratfish (max.= 2.0 mg/kg; n=3) and a mean of 1.13 mg/kg in Dover sole (max.= 1.97; n=4). These values are close to the upper limits of background levels reported by Harding and Thomas (1987), but below the Canadian guideline for mercury in fish. Mercury was not noticeably different in hepatopancreas or liver and gill tissue than in muscle tissue. Mercury was not analysed for specimens collected in the trawls off Sturgeon Banks.

Lead concentrations in all tissues of fish were below or near ICAP detection limits of 3.0 mg/kg at I-3 and I-6, and measured less than 1.0 mg/kg by Flameless AA for specimens collected off Roberts Bank. Mean levels for lead in sole in unpolluted, coastal locations were in the range of 1.0 to 3.2 mg/kg (Harding and Thomas, 1987). In edible muscle of prawns, shrimp and Dungeness crabs, however, lead levels were occasionally higher: a mean of 4.33 mg/kg (max.= 6.0, n=4) in prawns from I-3, 36.0 mg/kg in a Dungeness crab from I-6, a mean of 4.5 (max.= 11.0, n= 14) in pink shrimp (Pandalus boerealis) from I-6, and a mean of 2.31 mg/kg, with several individuals above 3.0 mg/kg in sidestripe shrimp from I-6. All of these higher levels are above the Canadian guideline of 2.3 mg/kg, dry weight (converted from the wet weight limit of 0.5 using a standard ratio of 4.54).

TABLE 7. Summary Statistics Of Selected Trace Metals In Clams And Mussels From Sturgeon Bank, May, 1985 (mg/kg dry wt.)

	AL	AS	BA	CD	CR	CU	FE	HG	NI	PB	SN	ZN
		CLAM			Macoma balthica							
MIN	195	5	3.5	0.2	1.1	18	622	0.14	3	2	0.8	161
MAX	940	20	9.6	1.8	3.3	68.2	2360	0.37	7	9	3	373
MEAN(8)	400.6	10.1	6.0	0.7	2.3	29.6	1167.4	0.23	4.6	5.1	1.3	248.5
C.V.	0.66	0.43	0.35	0.79	0.32	0.56	0.52	0.52	0.28	0.54	0.58	0.27
		CLAM			Cryptomya californiana							
MIN	125	5	2.2	0.2	1	14	301	0.07	2	2	1	88.7
MAX	470	30	8.5	3.7	3	74.2	1030	0.42	10	10	5	268
MEAN(11)	224.5	10.2	4.2	1.7	1.8	25.6	595.7	0.29	5.2	4.9	1.8	170.1
C.V.	0.58	0.78	0.50	0.89	0.32	0.67	0.39	0.66	0.53	0.63	0.88	0.39
		MUSSEL			Mytilus edulis							
MIN	379	4	2.9	3.2	2.2	11.4	897	0.42	4	4	0.8	155
MAX	650	8	4.1	4.1	3.4	20.1	1470	0.85	5	8	0.8	183
MEAN(4)	527.0	6.0	3.3	3.5	2.7	16.0	1174.3	0.57	4.5	6.3	0.8	170.5
C.V.	0.21	0.30	0.17	0.12	0.21	0.23	0.20	0.34	0.13	0.27	0	0.08

3.2.2 Trace Metals In Intertidal Species. Intertidal clams and mussels were collected in May 1985, in conjunction with sediment sampling, and analysed for trace metals. Species collected were the deposit-feeding clams, Cryptomya californiana and Macoma balthica and the mussel, Mytilus edulis. Summary statistics by species, with all stations grouped together, are given in Table 7; data for each station are in Appendix 14.

Figure 15 shows concentrations of chromium, copper, mercury and zinc in Macoma balthica for this survey and a survey by DeMill in 1976. These are the metals that EP laboratory quality control records indicate that analytical results are comparable during this period (P. Kluckner. EP Laboratory Manager, pers. comm.). The stations shown are those for which Macoma sp. was collected on both surveys, arranged in increasing distance from the outfall (Station 14 is adjacent to the outfall channel, although some distance from the actual outfall). DeMill gave the mean of 5 samples from each station, each sample containing 2 clams for mercury, and single analyses of pooled samples, each consisting of several dozen individual clams, for other trace metals. Our data are from single analyses of pooled samples consisting of several individuals. Also, DeMill's mercury data, expressed as wet weight, were converted to dry weight (using a mean dry:wet ratio of 6.71 calculated from his data), which introduces another source of variation. His other trace metal data were given in both wet and dry weight.

Despite the above qualifiers, the data for clams from the two surveys nine years apart show strong coherence by station, and suggest an overall very slightly declining trend.

In mussels the mean (n=4, Stations 5 and 7) levels of arsenic, cadmium, copper, chromium, mercury and lead were all less than the means for these metals reported by Harding and Thomas (1987) at a reference location. All four values for lead, however, exceeded Canadian Guidelines (converted to dry weight) for lead in fish products.

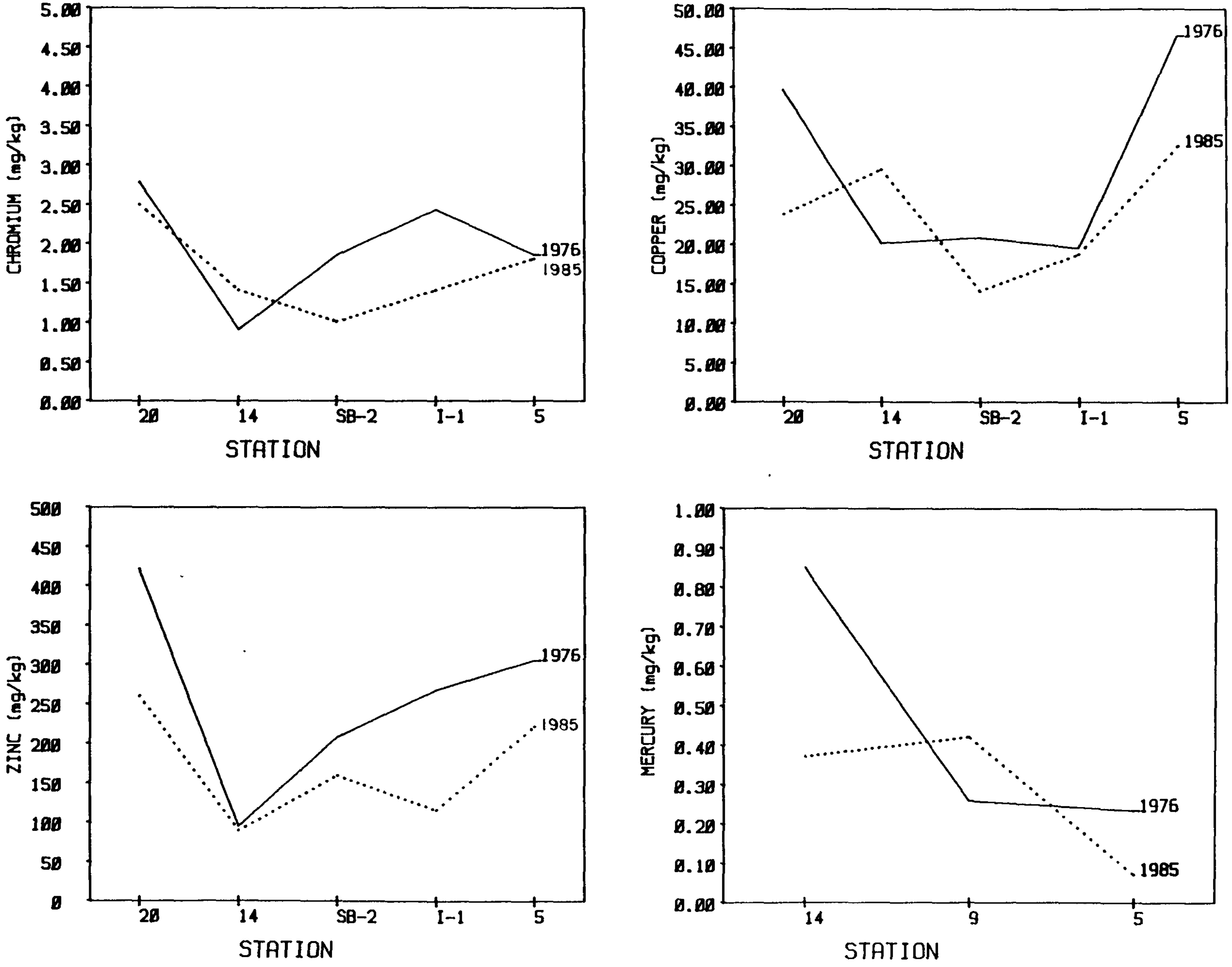

Figure 15 Chromium, copper, mercury and zinc (mg/kg dry wt.) in the intertidal clam, *Macoma Balthica*, from Sturgeon Banks, 1976 (from DeMill, 1984) and 1985.

4 CONCLUSIONS

1. Cadmium concentrations were all well above background in sub-tidal sediments off Roberts Bank, and some were at levels known to cause acute, adverse biological effects on marine life.

2. Mercury concentrations at some subtidal stations off Roberts Bank were above background levels, but less than the levels shown to consistently cause acute, adverse biological effects.

3. Copper and lead in subtidal sediments off Sturgeon Bank were above the range of these metals at unpolluted reference stations, but below the levels shown to consistently cause acute, adverse biological effects.

4. Intertidal sediments near the Iona sewage treatment plant outfall had concentrations of cadmium, copper, lead and mercury much higher than intertidal sediments more distant from the outfall. Cadmium and copper were above the lower limit of the range of concentrations known to impact marine, benthic communities and all four metals were very near the levels shown to consistently cause adverse, acute biological effects.

5. Seasonal differences in intertidal surface sediment trace metal content were noted, with spring (pre-freshet) levels being slightly higher.

6. Intertidal stations generally had coarser sediments with less organic carbon content than subtidal stations, except that stations near the Iona sewage treatment plant had very high organic carbon content. Trace metals in intertidal sediments were statistically correlated with organic carbon content.

7. Polychlorinated biphenyls (PCB's) and chlorinated phenols (PCP's) were below detection limits in intertidal stations. Polynuclear aromatic hydrocarbons (PAH's) detected in interdtidal and subtidal sediments near the Iona outfall were below the levels shown to consistently cause acute, adverse biological effects, and were below detection limits in other areas of Sturgeon and Roberts Banks.

8. In edible tissues of commercial fish and invertebrate species, arsenic was frequently above the Canadian guidelines for fish protein, but within the range of levels of these metals at unpolluted, coastal locations.

9. Limited data suggest uptake of cadmium by individual fish and shrimp in deep water off Roberts Bank, where sediment cadmium levels were unusually high. The high tissue levels observed were not greater than the sediment concentrations, however, indicating a lack of bioconcentration.

10. Elevated (above background) levels of copper occurred in a variety of fish from deep water off both Sturgeon and Roberts Bank.

11. Mercury in fish muscle from deep waters of Roberts Bank was within the upper limits of background levels, and below the Canadian guidelines for mercury in fish. Samples from deep water off Sturgeon Banks were not analysed for mercury.

12. In edible muscle of prawns, Dungeness crab and pink shrimp from deep water off Sturgeon Bank, lead concentrations occassionally exceeded Canadian guidelines for lead in fish protein.

13. Long term trend data suggest a slight decrease in trace metals in intertidal clams from stations near the Iona sewage treatment plant outfall, however, results are statistically inconclusive.

14. In edible mussels, mean levels of arsenic, cadmium, copper, chromium and mercury were all less than background levels. Values for lead, however, exceeded Canadian Guidelines for lead in fish protein.

5 REFERENCES

DeMill, D. 1984. Heavy metals in Fraser River Estuary clams. EPS Regional Program Report 84-17.

Fish Inspection Branch 1983. Fish inspectors' procedures manual. Department of Fisheries and Oceans, Ottawa.

Goyette, D. and P. Christie 1982. Environmental studiesin Alice and Hastings Arm, British Columbia Part I: Baseline Studies Amax/Kitsault Mine - Sediment and tissue trace metals from two abandoned mine sites - B.C. Molybdenum and Anyox, 1976-1980. EPS Regional Program Report 82-13.

Harding, L. and M. Thomas 1987. Baseline sediment and tissue trace metals in Barkley Sound, Quatsino Sound, Surf Inlet and Laredo Sound, British Columbia. EP Regional Program Report 87-06.

National Oceanic and Atmospheric Administration 1987. Status and Trends Program for Marine Environmental Quality Progress Report. Rockville, MD.

O'Riordan, J. and J. Wiebe 1984. Fraser River Estuary Management Program. B.C. Ministry of Environment and Environment Canada.

Pomeroy, W.M. 1983. Receiving Environment Studies Conducted in the Vicinity of Iona Island Sewage Treatment Plant, Vancouver, B.C. regional Program Report 83-10.

Swingle, R.B. and J.W. Davidson 1979. Environmental laboratory manual, January 1979. Departments of Environment and Fisheries and Oceans.

REFERENCES (Continued)

Tetra Tech, Inc. 1986. Development of sediment quality values for Puget Sound. Puget Sound Dredged Disposal Analysis Reports. U.S Army Corps of Engineers, Washington State Dept. of Natural Resources, Environmental Protection Agency Region 10, and Washington State Department of Ecology. Seattle.

Tetra Tech, Inc. 1987. Apparent Effects Thresholds-AET. Tech Notes, May 1987. Seattle.

Working Committee on Fraser River Estuary Monitoring, 1984. Fraser River Estuary Monitoring: A Recommended Approach.

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APPENDICES

Appendix I Sample Locations, Fraser River Estuary 1984-1986

20 SEPT 84

Stn.	LOCATIONS	
No.	Lat. (N)	Long. (W)
ROBERTS BANK		
1	49 03.70	123 23.60
2	49 00.50	123 21.70
3	49 00.50	123 14.80
4	48 56.60	123 21.70
5	48 56.60	123 14.50
6	48 52.00	123 07.75
7	48 58.20	123 09.00
Trawl-1	48 53.22	123 10.90
	48 53.10	123 10.20

13-14 NOV 84

Stn.	LOCATIONS	
No.	Lat. (N)	Long. (W)
IONA		
Trawl-1	49 13.11	123 18.13
	49 11.63	123 18.20

7-8 May 85

Stn.	LOCATIONS	
No.	Lat. (N)	Long. (W)
20	49 11.75	123 14.85
23	49 11.10	123 13.35
28	49 07.40	123 16.60
I-1	49 13.35	123 14.60
I-2	49 13.70	123 12.50
MA-2	49 05.55	123 08.15
NA-2	49 15.20	123 15.25
NA-3	49 14.90	123 16.10
RB-1	49 06.50	123 13.90
RB-2	49 01.60	123 06.90
RB-3	49 03.50	123 15.60
SB-1	49 12.15	123 13.60
SB-2	49 09.20	123 13.70
SB-3	49 11.70	123 16.50
SB-4	49 09.60	123 16.30

Appendix I (Continued)

27 Nov 85

Stn.	LOCATIONS	
No.	Lat. (N)	Long. (W)
IONA		
I-2(I)		
Trawl-1	49 13.02	123 20.67
-51		
	49 12.59	123 21.04
I-2(II)		
Trawl-2	49 12.83	123 20.85
	49 12.44	123 21.21
CANOE PASS		
I-7(I)		
Trawl-1	49 02.54	123 12.69
	49 02.21	123 16.90
I-7(II)		
Trawl-2	49 02.65	123 17.81
	49 02.21	123 16.90
I-1		
I-2	49 13.20	123 20.75
I-3	49 11.50	123 18.20
I-4		
I-5	49 06.70	123 23.40
I-7	49 02.40	123 17.20

Appendix I (Continued)

9 Jan 86

Stn. No.	LOCATIONS Lat. (N)	Long. (W)
23	49 11.10	123 13.35
I-1	49 13.35	123 14.60
MA-2	49 05.55	123 08.15
RB-1	49 06.50	123 13.90
RB-2	49 01.60	123 06.90
RB-3	49 03.50	123 15.60
SB-1	49 12.15	123 13.60
SB-2	49 09.20	123 13.70
SB-3	49 11.70	123 16.50
SB-4	49 09.60	123 16.30

APPENDIX 2 Subtidal Sediment Trace Metals (mg/kg) Off Roberts Bank, September, 1984.

Sediment Grab Stn	DEPTH (m)	AL	AS	BA	BE	CA	CD	CO	CR	CU	FE	HG	MG	MN	MO	NA	NI	P	PB	SI	SN	SR	TI	V	ZN
GS-1	256	22800	<8	72.9	<.2	8060	3.9	11.8	40.5	26.5	28100	.244	11000	372	<.8	7560	28.0	910	<3	1330	<2	58.0	1590	70.9	76.6
GS-1	256	26300	<8	84.6	<.2	8590	5.3	13.0	45.2	28.7	30200	.253	11900	390	<.8	8450	31.0	955	<3	1310	<2	65.6	1820	79.2	83.2
GS-2	242	28600	<8	87.0	0.2	8720	5.3	5.4	45.3	30.7	31200	.226	12800	403	<.8	10300	30.0	1020	<3	1280	<2	72.2	2010	81.8	86.0
GS-2	242	27800	<8	84.2	<.2	8680	5.1	8.1	45.5	29.6	30800	.222	11800	383	<.8	9170	28.0	958	<3	1200	<2	68.7	1880	80.5	85.7
GS-3	140	16900	<8	57.1	<.2	8000	4.9	13.2	48.2	20.6	30900	.144	10800	409	<.8	7000	33.0	1000	<3	740	<2	51.5	2000	89.3	65.0
GS-3	140	14900	<8	44.5	<.2	8830	3.6	13.3	68.7	14.9	34500	.137	12100	463	<.8	5500	47.0	952	<3	1180	<2	50.3	2310	105.0	62.2
GS-4	222	22300	<8	65.3	<.2	7120	4.2	5.8	36.5	23.8	27400	.205	9920	379	<.8	8230	24.0	928	<3	1010	<2	56.2	1540	67.2	74.2
GS-4	218	25200	<8	68.6	<.2	7860	1.3	12.3	42.3	27.9	30800	.191	11200	374	<.8	8710	27.0	951	<3	1020	<2	61.0	1710	76.1	86.1
GS-5	149	18600	<8	45.5	<.2	6570	1.5	7.6	31.2	16.6	25000	.124	7800	250	<.8	5320	18.0	752	<3	1040	<2	46.1	1360	60.1	65.8
GS-5	161	18000	<8	51.4	<.2	6500	1.2	11.6	30.4	15.8	25000	.134	7850	265	<.8	5370	17.0	816	<3	1140	<2	45.5	1380	60.3	63.9
GS-6	155	16800	<8	59.5	0.4	7350	7.0	6.7	37.1	14.7	27600	.087	7840	285	<.8	5990	19.0	730	<3	950	<2	46.3	1690	79.0	58.0
GS-6	155	18100	<8	70.4	<.2	7670	5.8	11.9	38.8	16.4	27900	.120	8260	294	<.8	6250	19.0	728	<3	1500	<2	49.2	1850	82.0	57.7
GS-7	107	22700	<8	73.9	<.2	7820	3.6	8.2	38.3	17.8	27400	.232	9270	303	<.8	6720	22.0	835	<3	1690	<2	57.9	1920	74.9	70.8
GS-7	107	20600	<8	62.0	<.2	6970	1.0	5.1	36.2	18.9	27300	.147	8810	278	<.8	5910	21.0	831	<3	1090	<2	51.0	1680	70.0	71.3

APPENDIX 3 Intertidal Sediment Trace Metals (mg/kg) At Iona, Sturgeon Bank, Middle Arm and Roberts Bank, May, 1985 *

AREA	AL	BA	CA	CD	CO	CR	CU	FE	HG	MG	MN	NA	NI	P	PB	SI	SR	TI	V	ZN
NORTH IONA																				
3	11700	33.6	7710	0.14	7.7	56.6	12.6	30400	0.09	7880	351	1180	36	708	3	80	34.5	1250	79.8	59.8
I-1	11600	30.8	5980	0.08	10.4	41.8	12.4	23700	0.08	6840	366	1050	31	670	6	60	31	941	55.7	50.6
5	13100	38.8	9060	0.22	7.4	48.8	15.1	28900	0.09	7900	317	1430	33	835	5	90	41	1370	68.6	58.3
7	13200	42.6	8270	0.19	11.1	51.1	17.3	30300	0.11	8330	337	1360	35	877	4	70	38.3	1400	72	60.8
9	14000	38.6	11500	0.29	15.3	71.5	23.6	37800	0.13	9120	1430	1680	50	908	7	80	49	1760	104	71.7
MEAN	12720	36.88	8504	0.18	10.38	53.96	16.2	30220	0.10	8014	560.2	1340	37	799.6	5	76	38.76	1344.2	76.02	60.24
SOUTH IONA																				
10	26000	97.5	10300	3.35	10	82.5	183	37400	0.70	11300	357	4440	42	1470	103	90	67.3	1450	74.3	204
16	26000	122	8130	4.68	15.7	102	308	37700	1.29	11100	346	3790	46	2330	166	70	82.2	1320	75.4	332
12	16300	52.3	8430	0.90	12.7	63.6	41.5	34000	0.20	9020	347	2060	41	1060	16	70	45.1	1680	82.3	84.6
14	12500	32.7	9060	0.20	8.5	48.1	15.6	29500	0.13	8110	311	1050	36	907	6	80	38.4	1420	74	55.6
SB-1	17300	53.4	8250	0.25	11.5	54.2	38.4	33800	0.20	9690	362	2330	36	1220	14	80	46.6	1380	71.8	81.4
20	11900	29.5	7240	0.10	4.9	43.8	11.4	26200	0.09	7440	322	920	33	757	3	60	33.2	1230	65.5	51.3
SB-3	12400	31.9	7570	0.32	12.8	56.7	23.2	28500	0.08	8060	1770	980	50	772	3	90	36.5	1290	77.8	68.7
MEAN	17486	59.9	8426	1.40	10.87	64.41	88.73	32443	0.38	9245.7	545	2224.3	40.57	1216.6	44.43	77.14	49.9	1395.7	74.44	125.37
STURGEON BANK																				
23	17200	60.1	8890	0.28	13.7	48	22.3	32100	0.11	9320	453	1910	35	988	6	70	47.5	1490	70.3	73.8
SB-4	11400	28.7	7670	0.22	13.3	54.3	14.9	27200	0.07	8110	1040	880	45	738	3	80	36.3	1440	74.1	55.3
SB-2	12100	31.1	6650	0.10	8.5	38.8	11.1	25200	0.08	7330	359	1100	32	724	3	70	33.9	1160	60.2	51.8
28	12500	41.1	8440	0.17	14.3	81.3	14.4	36400	0.09	9340	906	940	49	731	3	80	38.1	1680	106	59.8
MEAN	13300	40.3	7913	0.19	12.45	55.6	15.68	30225	0.09	8525	689.5	1207.5	40.25	795.25	3.75	75	38.95	1442.5	77.65	59.8
MIDDLE ARM																				
MA-2	21600	98.8	9740	0.66	15.9	53.4	35	37700	0.11	11000	598	1160	47	947	3	60	56.6	1320	70.1	87.4
ROBERTS BANK																				
RB-1	11500	37.6	7650	0.18	10.5	40.4	13.4	24900	0.17	7930	534	750	38	715	3	60	33.6	1090	56.4	49.3
RB-3	10400	26.5	7210	0.08	8.5	37.4	10.2	23300	0.07	7570	330	880	35	653	3	80	29	1060	56	44.5
RB-2	13100	36.2	7690	0.17	6.4	48.3	12.8	28100	0.08	8230	289	2020	33	862	3	50	36	1220	65.4	57.3
MEAN	11667	33.4	7517	0.14	8.47	42.03	12.13	25433	0.11	7910	384.33	1216.7	35.33	743.33	3	63.33	32.87	1123	59.27	50.37

*Arsenic, berylium, molybdenum and tin were all below detection limits (8, 0.2, 0.8 and 2.0 mg/kg respectively).

APPENDIX 4 Intertidal Sediment Trace Metals (mg/kg) At Iona, Middle Arm, Roberts Bank and Sturgeon Bank, January, 1986 *

Area	Station	AL	BA	BE	CA	CD	CO	CR	CU	FE	HG	MG	MN	NA	NI	P	PB	SN	SR	TI	V	ZN
	23	17900	96.0	0.60	9800	0.18	47.00	68.0	27.0	32300	0.10	10700	705	2700	40	970	11.0	6.0	76.0	2070	91.0	130
Iona	I-1	12900	57.0	<.2	7000	0.11	7.40	48.0	12.0	24000	0.06	8200	613	1900	30	680	3.0	4.0	52.0	1470	70.0	70
Middle Arm	MA-2	16900	87.0	0.50	10500	0.24	9.00	38.0	12.0	29100	0.08	9800	491	1700	40	810	6.0	3.0	60.0	1260	55.0	69
Roberts Bank	RB-1	13100	54.0	0.20	8300	0.16	10.60	33.0	<8	25100	0.06	8900	770	1500	30	680	<3	3.0	43.0	1080	48.0	54
Roberts Bank	RB-2	11900	52.0	<.2	7600	0.11	28.00	48.0	9.0	22800	0.05	7700	349	1700	40	770	<3	3.0	49.0	1500	71.0	63
Roberts Bank	RB-3	11800	38.0	<.2	9000	0.10	29.00	37.0	<8	21300	0.06	8300	385	1200	30	660	<3	4.0	41.0	1160	53.0	46
Sturgeon Bank	SB-1	23100	120.0	0.60	9900	0.34	8.10	84.0	63.0	40000	0.18	12600	616	4800	50	1 600	29.0	5.0	89.0	1960	97.0	148
Sturgeon Bank	SB-2	12400	49.0	0.40	8200	0.09	11.70	55.0	9.0	24700	0.05	8200	615	1500	40	740	<3	5.0	53.0	1710	79.0	71
Sturgeon Bank	SB-3	13500	56.0	0.20	7700	0.13	10.00	72.0	15.0	25500	0.08	9100	915	1700	50	740	6.0	8.0	51.0	1460	70.0	80
Sturgeon Bank	SB-4	14200	65.0	0.30	8500	0.11	21.00	84.0	17.0	26200	0.07	9600	1 230	1600	60	730	3.0	7.0	61.0	1860	85.0	80

*Arsenic, molybdenum and silicon were all below detection limits (8.0, 8.0 and 200 mg/kg respectively).

APPENDIX 5 Trace Metals (mg/kg) In Sediment Cores At Iona, November, 1985

STATION	CORE DEPTH (cm)	AL	AS	BA	BE	CA	CD	CO	CR	CU	FE	HG	MG	MN	MO	NA	NI	P	PB	SI	SN	SR	TI	V	ZN
I-2	0-10	28800.0	<8	78.9	0.7	8720.0	<.3	13.4	49.3	47.6	37500.0	0.16	13600.0	481.0	<.8	7790.0	38.0	1110.0	28.0	220.0	6.0	61.3	1400.0	81.5	104.0
	10-20	30200.0	<8	52.0	0.7	8700.0	<.3	11.3	24.7	26.4	38000.0	0.15	14400.0	291.0	27.5	9100.0	24.0	1040.0	36.0	220.0	<2	39.4	782.0	46.1	61.4
	20-30	31600.0	<8	87.2	0.7	8690.0	<.3	17.6	49.9	51.3	38000.0	0.14	15200.0	464.0	<.8	9710.0	39.0	1040.0	35.0	210.0	4.0	64.8	1420.0	83.1	111.0
	70-80	31900.0	<8	77.9	0.9	8620.0	<.3	16.2	43.7	44.9	37300.0	0.14	15400.0	399.0	4.4	8380.0	39.0	937.0	36.0	200.0	6.0	56.0	1330.0	74.4	94.0
	150-160	30700.0	<8	83.9	0.8	8820.0	<.3	16.8	46.4	45.8	38400.0	0.14	14800.0	462.0	<.8	7370.0	39.0	984.0	27.0	220.0	4.0	60.4	1480.0	81.5	92.8
I-1	0-10	29600.0	<8	89.0	0.6	8680.0	<.3	17.7	53.3	57.0	38300.0	.151*	15100.0	492.0	<.8	7800.0	43.0	1120.0	30.0	190.0	7.0	64.0	1420.0	85.6	113.0
	10-20	29500.0	<8	86.7	0.6	8290.0	<.3	14.2	51.1	57.3	37700.0	0.13	15100.0	469.0	<.8	7570.0	43.0	1060.0	33.0	180.0	6.0	60.6	1320.0	82.1	116.0
	20-30	29500.0	<8	85.7	0.6	8530.0	<.3	16.6	51.2	54.0	37700.0	0.17	15100.0	465.0	<.8	8080.0	44.0	1010.0	33.0	160.0	5.0	62.6	1340.0	82.6	112.0
	70-80	29800.0	<8	88.0	0.6	8250.0	<.3	13.1	47.1	54.8	37300.0	0.14	15500.0	469.0	<.8	7830.0	40.0	961.0	28.0	160.0	5.0	59.2	1360.0	80.4	105.0
	150-160	32400.0	<8	71.0	0.8	9260.0	<.3	14.0	31.6	34.7	39500.0	0.13	17000.0	370.0	23.6	7630.0	34.0	1050.0	39.0	160.0	<2	47.5	1040.0	56.5	64.4
I-3	0-10	28200.0	<8	81.9	0.8	8410.0	<.3	15.7	44.8	47.9	34900.0	0.16	14800.0	433.0	<.8	7380.0	38.0	1070.0	35.0	150.0	7.0	58.7	1300.0	73.5	95.8
	10-20	27000.0	<8	82.0	0.6	8470.0	<.3	15.7	48.1	50.6	35400.0	0.11	14500.0	448.0	<.8	6260.0	41.0	1030.0	28.0	150.0	7.0	57.9	1300.0	77.0	100.0
	20-30	26800.0	<8	76.9	0.7	8720.0	<.3	13.2	42.9	45.7	36000.0	0.13	14500.0	434.0	<.8	6170.0	41.0	1010.0	29.0	150.0	4.0	55.9	1170.0	70.4	93.6
	70-80	26700.0	<8	80.8	0.6	8870.0	<.3	16.6	50.1	48.2	36000.0	0.10	15200.0	459.0	<.8	5640.0	45.0	979.0	21.0	160.0	7.0	58.4	1370.0	77.8	96.3
	120-130	26800.0	<8	89.9	0.5	8700.0	<.3	14.0	48.3	48.0	35600.0	0.11	14400.0	484.0	<.8	5270.0	41.0	966.0	18.0	140.0	8.0	60.0	1470.0	79.7	94.4
I-4	0-10	28200.0	<8	84.4	0.7	8940.0	<.3	16.2	48.9	49.2	36200.0	0.11	14300.0	465.0	<.8	6530.0	41.0	1050.0	28.0	160.0	4.0	59.9	1410.0	78.9	97.4
	10-20	27500.0	<8	82.8	0.7	9040.0	<.3	12.1	48.1	45.5	35800.0	0.12	14000.0	458.0	<.8	6400.0	40.0	1050.0	26.0	140.0	6.0	59.4	1360.0	77.2	95.6
	20-30	27200.0	<8	83.0	0.6	9100.0	<.3	14.4	50.2	49.0	37200.0	0.10	14300.0	480.0	<.8	6310.0	43.0	1070.0	24.0	150.0	6.0	60.0	1360.0	80.0	101.0
	70-80	27600.0	<8	80.8	0.6	9540.0	<.3	13.3	50.1	47.0	37200.0	0.12	15200.0	467.0	<.8	6400.0	44.0	1020.0	21.0	160.0	4.0	60.3	1380.0	78.0	97.2
	90-100	27700.0	<8	84.3	0.5	9400.0	<.3	15.1	45.4	45.8	36500.0	0.12	14500.0	451.0	<.8	5640.0	38.0	993.0	19.0	150.0	5.0	57.7	1340.0	75.1	92.6
I-5	0-10	24600.0	<8	67.3	0.7	8870.0	<.3	13.6	38.4	36.4	31700.0	0.09	12100.0	399.0	<.8	5780.0	32.0	1010.0	27.0	170.0	3.0	53.9	1200.0	65.5	79.1
	10-20	25000.0	<8	74.5	0.6	8700.0	<.3	12.5	40.9	38.3	31100.0	0.11	12300.0	411.0	<.8	6530.0	33.0	954.0	24.0	150.0	8.0	58.5	1320.0	71.2	84.9
	20-30	25200.0	<8	78.1	0.6	8860.0	<.3	13.7	43.0	40.5	31600.0	0.13	12600.0	413.0	<.8	6540.0	36.0	960.0	20.0	140.0	6.0	59.3	1330.0	72.6	88.5
	70-80	26400.0	<8	82.5	0.6	9420.0	0.4	15.5	47.3	44.0	33900.0	.114*	13400.0	472.0	<.8	6620.0	38.0	924.0	18.0	160.0	5.0	66.2	1540.0	79.5	95.3
	120-130	24600.0	<8	69.5	0.7	9330.0	<.3	13.1	40.2	36.8	31900.0	0.10	12600.0	417.0	<.8	5870.0	35.0	1010.0	21.0	160.0	6.0	58.3	1370.0	68.7	81.2
GRAB I-7		13300.0	<8	33.9	0.7	8540.0	<.3	13.5	53.0	15.5	31600.0	0.07	11200.0	404.0	<.8	1600.0	41.0	880.0	12.0	150.0	7.0	40.7	1810.0	92.3	53.9

APPENDIX 6 Particle Size And Volatile Residue In Sediment Cores At Iona, November, 1985

STN NUMBER	CORE DEPTH (cm)	MEDIAN PARTICLE SIZE	Silt & Clay %	Volatile Residue %
I-2	0-10	silt & clay	53.6	5.79
	10-20	v. fine sand	38.2	5.61
	20-30	silt & clay	53.5	5.25
	70-80	silt & clay	53.5	4.89
	150-160	silt & clay	66.6	3.96
I-1	0-10	v. fine sand	41.8	4.86
	10-20	silt & clay	53.6	4.47
	20-30	silt & clay	65.1	4.06
	70-80	silt & clay	66.4	4.01
	150-160	silt & clay	68.5	3.23
I-3	0-10	silt & clay	66.9	4.39
	10-20	silt & clay	67.1	3.87
	20-30	silt & clay	53.5	3.46
	70-80	silt & clay	73	3.28
	120-130	silt & clay	77.2	3.01
I-4	0-10	silt & clay	61.6	4.61
	10-20	silt & clay	57.5	4.15
	20-30	silt & clay	63.7	4.21
	70-80	v. fine sand	42.5	3.81
	90-100	silt & clay	59.9	3.61
I-5	0-10	silt & clay	43.9	5.23
	10-20	v. fine sand	41.3	5.26
	20-30	silt & clay	55.3	4.85
	70-80	silt & clay	50.1	4.70
	120-130	silt & clay	49.5	4.65
I-7	grab	fine sand	1.8	1.27

Appendix 7 Subtidal Sediment Oil and Grease, Particle Size and Volatile Residue, off Roberts Bank, September, 1984

Station	Oil & Grease	Median Particle Size	Silt & Clay %	Volatile Residue %
GS-1	128	v. fine sand	31.70	4.19
GS-1	2345	v. fine sand	32.30	4.16
GS-7	170	v. fine sand	20.90	2.85
GS-7	140	v. fine sand	20.60	2.94
GS-6	102	v. fine sand	10.00	2.08
GS-6	209	fine sand	11.40	2.47
GS-3	77	fine sand	7.20	2.21
GS-3	160	fine sand	.90	.95
GS-2	298	fine sand	35.40	4.06
GS-2	276	fine sand	32	4.92
GS-4	86	v. fine sand	36.50	4.18
GS-4	602	v. fine sand	29.90	4.45
GS-5	110	v. fine sand	29.20	3.24
GS-5	160	v. fine sand	24.80	3.07

Appendix 8 Intertidal Sediment Oil And Grease, Particle Size And Volatile Residue, Iona, Middle Arm and Roberts Bank, May, 1985

STATION #	OIL & GREASE	MEDIAN PARTICLE SIZE	SILT & CLAY %	VOLATILE RESIDUE %
		NORTH IONA		
I-3	< 100	medium sand	0.6	0.60
I-1	< 100	fine sand	0.3	1.38
5*	< 100	fine sand	2.8	0.80
7*	200	fine sand	7.2	3.00
9*	< 100	medium sand	0.4	0.60
		SOUTH IONA		
10*	9000	medium sand	17.2	8.90
16*	12100	medium sand	20.2	14.60
12*	1000	fine sand	10.5	1.79
14*	< 100	fine sand	2.4	0.80
SB-1	500	v. fine sand	18.7	3.21
20	< 100	fine sand	0.7	0.80
SB-3	< 100	medium sand	0.0	0.60
23	< 100	v. fine sand	25.9	2.20
SB-4	< 100	fine sand	0.1	0.59
SB-2	100	fine sand	1.4	0.40
28	< 100	medium sand	0.0	0.40
		MIDDLE ARM		
MA-2	< 100	fine sand	32.8	2.60
		ROBERTS BANK		
RB-1	< 100	fine sand	0.3	0.79
RB-3	< 100	fine sand	0.3	0.40
RB-2	200	v. fine sand	15.8	1.60

Appendix 9 Intertidal Sediment Particle Size And Volatile Residue At Iona, Sturgeon Bank, Middle Arm and Roberts Bank, January 9, 1986.

Area	Station	Median Particle Size	Silt & Clay %	Volatile Residue %
	23	silt & clay	39.7	2.20
Iona	I-1	fine sand	0.5	0.94
Middle Arm	MA-2	silt & clay	50.4	2.34
Roberts Bank	RB-1	v. fine sand	1.5	1.05
Roberts Bank	RB-2	v. fine sand	4.1	1.31
Roberts Bank	RB-3	fine sand	0.2	0.87
Sturgeon Bank	SB-1	v. fine sand	35.3	3.32
Sturgeon Bank	SB-2	fine sand	0.7	0.95
Sturgeon Bank	SB-3	fine sand	0.2	0.80
Sturgeon Bank	SB-4	fine sand	0.1	0.76

Appendix 10 Polynuclear Aromatic Hydrocarbons (ug/g) In Intertidal Sediments On Sturgeon And Roberts Banks, January, 1986

COMPOUNDS	SB-3	I-1	SB-4	RB-2	RB-3	MA-2	23	23 (Split)
Acenaphthene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Acenaphthylene	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18
Anthracene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Benzidine	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2
Benzo (a) anthracene	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Benzo (a) pyrene	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13
Benzo (b) fluoranthene	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24
Benzo (ghi) perylene	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21
Benzo (k) fluoranthene	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13
Chrysene	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13
Dibenzo (a,h) anthracene	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13
Fluoranthene	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11
Fluorene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Indeno (1,2,3-cd) pyrene	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19
Naphthalene	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Phenanthrene	<0.27	<0.27	<0.27	<0.27	<0.27	<0.27	<0.27	<0.27
Pyrene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,2-Dichlorobenzene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,3-Dichlorobenzene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,4-Dichlorobenzene	<0.22	<0.22	<0.22	<0.22	<0.22	<0.22	<0.22	<0.22
2-Chloronaphthalene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Surrogate Standard: % Recovery								
d5-Nitrobenzene	94	120	120	110	102	104	90	98
Decafluorobiphenyl	72	67	68	66	70	70	66	67
d14-Terphenyl	70	80	85	93	82	75	70	71
Amt spiked (ug)	100	100	100	100	100	100	100	100

APPENDIX 11 Trace Metals (mg/kg) In Fish And Invertebrates From Trawls Off Roberts Bank* (Stations R-2 and R-3 Combined), September, 1984

AL	AS	BA	BE	CA	CD	CO	CR	CU	FE	HG	MG	MN	MO	NA	NI	P	PB	SB	SI	SN	SR	TI	V	ZN
		SHRIMP			Pandalopsis dispar				MUSCLE															
4	44	<.08	<.08	746	0.05	<.4	<.4	17.80	14.80	0.23	1440	1.39	<.4	6770	<2	10900	<.08	<4	13	<.8	6.78	8.4	<.4	38.0
<4	40	<.08	<.08	1070	0.05	<.4	<.4	16.20	6.50	0.13	1370	1.08	<.4	7830	<2	9820	<.08	<4	12	<.8	8.57	7.8	<.4	40.0
<4	44	0.08	<.08	909	0.05	<.4	<.4	18.40	6.80	0.25	1420	0.96	<.4	6510	<2	10500	<.08	<4	13	<.8	10.20	7.7	<.4	40.1
<4	38	<.08	<.08	968	0.05	<.4	<.4	13.40	10.60	0.19	1390	0.92	<.4	7300	<2	9020	<.08	<4	12	<.8	10.70	6.8	<.4	36.5
7	31	0.12	<.08	1020	0.08	0.5	0.90	16.20	13.80	0.37	1430	0.92	<.4	7600	<2	9830	<.08	<4	12	<.8	11.40	7.7	0.6	44.4
6	42	<.08	<.08	827	0.1	<.4	0.60	18.10	20.40	0.32	1570	1.37	<.4	7900	<2	10900	<.08	<4	13	<.8	7.72	8.2	<.4	41.1
		SHRIMP			Orangon communis				WHOLE															
204	25	3.27	<.08	34800	0.75	0.8	0.60	76.70	485.00	0.11	3730	11.80	<.4	16600	<2	7910	<.08	<4	49	<.8	445.00	10.8	1.6	58.7
66	18	2.42	<.08	38300	0.41	<.4	<.4	55.90	111.00	0.14	3670	5.25	<.4	16200	<2	7200	0.21	<4	37	<.8	496.00	7.9	0.6	50.8
101	29	1.98	<.08	30300	0.75	0.5	0.70	120.00	225.00	0.10	3760	8.30	<.4	17800	<2	7740	<.08	<4	34	<.8	394.00	8.8	1.6	62.2
		CRAB			Cancer magister				MUSCLE															
11	25	1.90	<.08	8100	0.07	<.4	0.50	19.80	34.20	0.55	1650	8.45	<.4	5980	<2	13000	<.08	<4	23	<.8	128.00	8.5	<.4	245.0
		CRAB			Cancer magister				GILL															
268	29	3.46	<.08	4570	1.9	4.5	1.60	195.00	1090.00	0.33	3670	12.90	<.4	31100	7	6660	0.3	<4	34	<.8	107.00	6.8	2.0	170.0
1460	65	15.50	<.09	10800	3.2	16.2	5.40	138.00	3960.00	0.75	7090	63.70	<.4	55600	9	10300	2.34	<4	141	<.9	246.00	32.2	8.0	412.0
		CRAB			Cancer magister				HEPATOPANCREAS															
11	49	0.48	<.07	2500	2.6	3.6	<.4	86.70	183.00	0.93	1080	5.36	<.4	11000	7	7220	<.08	<4	13	<.7	50.80	0.5	0.5	56.8
44	157	1.49	<.09	3290	5.3	10.6	1.00	1820.00	218.00	1.27	3240	14.70	1.5	28800	7	10500	<.09	<4	20	<.9	71.90	0.3	2.0	160.0

APPENDIX 11 (Continued)

AL	AS	BA	BE	CA	CD	CO	CR	CU	FE	HG	MG	MN	MO	NA	NI	P	PB	SB	SI	SN	SR	TI	V	ZN
		SOLE				Parophrys vetulus			MUSCLE															
12	14	0.23	<.09	1230	0.91	1.6	0.60	25.40	588.00	-	776	6.74	<.4	6160	<2	11800	0.43	<4	22	<.9	8.57	10.7	<.4	116.0
<4	6	<.08	<.08	837	<.04	<.4	2.80	1.20	22.40	0.11	1200	0.82	<.4	2080	<2	8880	0.22	<4	14	<.8	3.15	7.6	0.4	16.1
		SOLE				Parophrys vetulus			GILL															
20	4	1.30	<.09	52700	0.04	<.4	1.10	2.20	172.00	0.09	1490	16.90	<.4	10700	<2	30700	0.25	<4	26	<.9	210.00	17.9	<.4	66.3
		SOLE				Microstomus pacificus			MUSCLE															
45	82	0.20	<.08	2330	6.4	8.1	0.60	25.30	3410.00	1.97	730	3.75	<.4	6390	2	9680	<.08	<4	86	<.8	13.10	5.3	2.0	133.0
<4	77	<.08	<.08	523	<.04	<.4	2.00	2.30	24.30	1.20	1170	0.56	<.4	13200	<2	11800	<.08	<4	43	<.8	3.33	7.4	<.4	18.5
<4	60	<.08	<.08	564	0.04	<.4	1.20	1.00	21.30	1.16	1110	0.62	<.4	11700	<2	10500	<.08	<4	36	<.8	3.60	6.3	<.4	17.5
<4	21	<.08	<.08	613	<.04	<.4	1.80	0.80	15.20	0.17	1290	0.78	<.4	2450	<2	9650	<.08	<4	21	<.8	1.95	7.7	<.4	14.6
		SOLE				Microstomus pacificus			GILL															
50	20	3.09	<.09	43100	0.08	0.9	23.00	2.50	314.00	0.18	1340	30.40	<.4	14000	14	25000	<.09	<4	35	<.9	260.00	7.4	1.2	55.2
		SOLE				Microstomus pacificus			LIVER															
16	53	0.10	<.1	360	<.2	2.3	0.90	31.50	741.00	-	620	5.20	<.5	6600	<2	9940	0.2	<5	20	<1	2.40	29.9	3.8	116.0
		HAKE				Merluccius productus			MUSCLE															
<4	<4	<.09	<.09	518	<.04	<.4	0.50	1.30	12.90	0.07	1570	1.99	<.4	2530	<2	10900	0.2	<4	13	<.9	1.49	7.5	<.4	15.2
		HAKE				Merluccius productus			GILL															
18	<5	6.60	<.1	66600	0.07	<.5	1.30	1.60	138.00	-	1810	47.60	<.5	11200	<2	38200	0.2	<5	20	<1	221.00	15.8	<.5	91.6
		HAKE				Merluccius productus			LIVER															
6	<5	<.1	<.1	370	<.2	0.8	<.5	17.20	379.00	0.07	490	22.80	<.5	3640	<2	7060	0.3	<5	10	<1	2.00	13.7	<.5	56.7

Appendix 12 Selected Trace Metals (mg/kg) in Prawn and Shrimp Trawled at I-3 off Iona, November, 1984

	Al	As	Ba	Cd	Cr	Cu	Hg	Pb	Zn
Pandalus playceras -Muscle		PRAWN							
	38.00	71.00	2.64	0.04	0.70	27.40	0.46	0.08	41.80
	71.00	24.00	3.86	0.04	0.80	38.60	0.21	0.09	46.50
Mean	54.50	47.50	3.25	0.04	0.75	33.00	0.34	0.09	44.15
Pandalis dispar -Muscle		SIDESTRIPE							
	32.00	42.00	0.34	0.16	0.80	22.30	0.15	0.08	45.60
	10.00	58.00	0.09	0.04	0.60	13.20	0.17	0.08	42.90
	13.00	45.00	0.33	0.04	1.00	11.70	0.18	0.08	46.00
	10.00	42.00	0.11	0.05	0.60	22.00	0.48	0.08	48.60
Mean	16.25	43.50	0.22	0.05	0.80	16.85	0.33	0.08	47.30

APPENDIX 13 Trace Metals (mg/kg) In Fish And Invertebrates From Trawls At Iona And Sturgeon Bank, July, 1985

TISSUE	ORGANISM	STN	AL	AS	BA	CD	CR	CU	FE	NI	PB	SN	ZN
gill	ARROWTOOTH FLOUNDER	I-3	18	<4	2.32	<.2	1.8	3.4	136	<2	<2	<.8	106
liver	ARROWTOOTH FLOUNDER	I-3	<8	<8	0.3	0.8	<.8	5.1	587	<3	<3	<2	75.3
muscle	ARROWTOOTH FLOUNDER	I-3	<7	9	0.1	<.3	1.4	<.7	15	<3	<3	1	22
gill	DOVER SOLE	I-3	61	<8	3.3	<.3	2.9	2.7	255	<3	<3	<2	127
muscle	DOVER SOLE	I-3	<4	45	0.1	<.2	0.6	<.4	10.1	<2	<2	<.8	20.2
gill	DUNGENESS CRAB	I-3	117	<8	3.4	0.5	2.6	281	519	<3	<3	<2	249
gill	DUNGENESS CRAB	I-3	171	14	5.9	0.5	2.5	158	523	<3	<3	3	142
h-pancreas	DUNGENESS CRAB	I-3	31	62	3.1	37.1	2.3	1800	293	6	3	<2	164
h-pancreas	DUNGENESS CRAB	I-3	<7	25	2.2	16.3	1.8	477	246	5	<3	1	103
muscle	DUNGENESS CRAB	I-3	154	17	10.9	<.2	3	50	361	4	3	<.8	128
muscle	DUNGENESS CRAB	I-3	14	18	1.42	<.2	1.6	27.5	47.9	<2	2	<.8	169
muscle	DUNGENESS CRAB	I-3	14	39	4.46	0.2	1.4	56.6	45.4	<2	<2	<.8	485
gill	DUSKY ROCKFISH	I-3	24	8	3.87	<.2	2.4	2.1	150	<2	<2	<.8	69.1
liver	DUSKY ROCKFISH	I-3	<7	16	0.2	1.9	1.5	12.7	1410	<3	<3	2	137
muscle	DUSKY ROCKFISH	I-3	<4	12	0.27	<.2	0.7	<.4	14.2	<2	3	<.8	13.6
gill	PACIFIC HAKE	I-3	12	<8	0.5	0.5	2.1	10.1	243	<3	<3	<2	94.8
gill	PACIFIC HAKE	I-3	9	<4	0.23	0.2	1.4	7.3	247	<2	<2	<.8	76.7
gill	PACIFIC HAKE	I-3	17	<8	0.7	0.3	2.6	8.2	334	<3	<3	<2	132
liver	PACIFIC HAKE	I-3	<7	12	0.1	14.5	1.2	30.6	524	<3	<3	<1	313
liver	PACIFIC HAKE	I-3	<4	12	<.08	17	0.8	46.9	600	<2	<2	<.8	236
liver	PACIFIC HAKE	I-3	<7	<7	<.1	2.3	1.8	19.1	341	<3	4	1	122
muscle	PACIFIC HAKE	I-3	<4	<4	0.1	0.3	0.9	1.2	11.7	<2	<2	<.8	17.9
muscle	PACIFIC HAKE	I-3	<4	6	0.13	<.2	1.1	2	17.7	<2	3	1.4	21.5
muscle	PACIFIC HAKE	I-3	<4	6	0.1	<.2	1	2.2	23.2	<2	<2	<.8	21.2
muscle	PINK SHRIMP	I-3	<4	50	0.17	<.2	0.7	17.6	16.8	<2	<2	<.8	39.6

APPENDIX 13 (Continued)

TISSUE	ORGANISM	STN	AL	AS	BA	CD	CR	CU	FE	NI	PB	SN	ZN
h-pancreas	PRAWN	I-3	28	30	0.6	1.6	2.5	393	613	4	<3	<2	152
muscle	PRAWN	I-3	15	28	<.1	<.3	2.8	13.7	24.1	<3	<3	<1	48.3
muscle	PRAWN	I-3	15	38	0.1	<.3	1.5	10.1	18.6	<3	4	<1	44.8
muscle	PRAWN	I-3	8	32	0.4	<.3	2.1	12.7	22.9	<3	6	<1	50.7
liver	REX SOLE	I-3	<10	<10	<.2	0.9	1	2	145	<4	<4	<2	90.7
muscle	REX SOLE	I-3	<8	46	0.2	<.3	1.6	<.8	13.6	<3	<3	<2	16.7
muscle	REX SOLE	I-3	121	19	2.98	<.2	2.2	5.7	221	<2	3	<.8	80.1
muscle	REX SOLE	I-3	111	25	2.19	<.2	1.7	5.7	209	<2	<2	<.8	78.1
gill	SANDSOLE	I-3	20	14	5.6	<.3	3.3	10	85.4	<3	<3	14	123
liver	SANDSOLE	I-3	<8	14	0.3	1.8	1	41.3	966	<3	<3	<2	160
muscle	SANDSOLE	I-3	<4	49	0.08	<.2	0.7	<.4	8.6	<2	<2	<.8	16.5
h-pancreas	SIDESTRIPE SHRIMP	I-3	<7	151	0.3	42.2	21.5	782	58.3	<3	<3	<1	122
h-pancreas	SIDESTRIPE SHRIMP	I-3	<4	65	0.41	26.2	0.8	619	49	<2	<2	<.8	100
h-pancreas	SIDESTRIPE SHRIMP	I-3	10	24	0.17	14.5	0.5	516	49.9	<2	<2	<.8	45.3
muscle	SIDESTRIPE SHRIMP	I-3	7	228	0.34	<.2	1.1	22.7	19.5	<2	<2	<.8	58.2
muscle	SIDESTRIPE SHRIMP	I-3	<4	69	0.1	<.2	0.9	13.4	18.4	<2	<2	<.8	47.5
muscle	SIDESTRIPE SHRIMP	I-3	7	46	0.11	0.2	0.5	13.1	25.4	<2	2	<.8	38.9
muscle	SIDESTRIPE SHRIMP	I-3	<4	31	<.08	<.2	0.5	12.9	11.4	<2	<2	<.8	32.7
muscle	SIDESTRIPE SHRIMP	I-3	<4	47	0.14	<.2	0.6	17.4	14.8	<2	2	<.8	40.2
muscle	SIDESTRIPE SHRIMP	I-3	<4	49	0.15	0.2	0.7	20.8	17	<2	<2	<.8	35.7
muscle	SIDESTRIPE SHRIMP	I-3	<4	45	0.12	<.2	1.2	20.6	16.4	<2	<2	<.8	38
liver	SLENDER SOLE	I-3	<8	16	0.3	1.6	1.2	15.5	827	<3	<3	<2	92.3
muscle	SLENDER SOLE	I-3	<4	20	0.2	<.2	0.7	0.9	8.9	<2	3	<.8	17.9
muscle	SLENDER SOLE	I-3	38	9	2.45	<.2	1.9	5.9	95	<2	<2	<.8	69.2
muscle	SLENDER SOLE	I-3	39	23	2.14	0.2	2.6	9.1	102	<2	<2	<.8	89

APPENDIX 13 (Continued)

TISSUE	ORGANISM	STN	AL	AS	BA	CD	CR	CU	FE	NI	PB	SN	ZN
h-pancreas	DUNGENESS CRAB	I-6	27	23	2.5	18.5	1.3	569	194	3	<3	<2	114
h-pancreas	DUNGENESS CRAB	I-6	183	16	3.1	1.4	1.5	335	515	4	7	<1	223
muscle	DUNGENESS CRAB	I-6	64	18	4.3	<.3	2.4	35.1	138	<3	36	<1	372
muscle	LINGCOD	I-6	<4	22	0.1	<.2	0.7	0.6	11.1	<2	<2	<.8	23.4
liver	PACIFIC HAKE	I-6	<4	7	0.08	1	<.4	4.7	119	<2	<2	<.8	35.5
h-pancreas	PINK SHRIMP	I-6	9	55	0.3	10	1.3	464	74	<3	<3	<2	71.2
h-pancreas	PINK SHRIMP	I-6	123	43	1.54	10	1.1	547	411	<2	2	<.8	117
h-pancreas	PINK SHRIMP	I-6	262	32	2.34	6	1.1	333	564	2	<2	<.8	75.5
muscle	PINK SHRIMP	I-6	13	52	0.15	0.2	1.5	14.1	28	<2	2	<.8	48.6
muscle	PINK SHRIMP	I-6	<7	63	0.2	<.3	1.5	22.1	18.4	<3	<3	<1	53.4
muscle	PINK SHRIMP	I-6	12	70	0.38	<.2	0.9	21.4	25.8	<2	3	<.8	65.2
muscle	PINK SHRIMP	I-6	12	61	<.2	<.3	0.9	17.6	20.8	<3	11	<2	51.6
muscle	PINK SHRIMP	I-6	9	49	<.1	<.3	<.7	11.9	13	<3	<3	<1	39.7
muscle	PINK SHRIMP	I-6	9	29	0.1	<.3	<.7	9	12.6	<3	5	<1	40.4
muscle	PINK SHRIMP	I-6	9	81	0.2	<.3	<.7	16.2	19	<3	8	<1	60
muscle	PINK SHRIMP	I-6	<7	63	0.6	<.3	<.7	13.2	13	<3	9	<1	46.2
muscle	PINK SHRIMP	I-6	<8	63	<.2	<.3	2.3	15.9	17.9	<3	3	<2	47.2
muscle	PINK SHRIMP	I-6	<7	70	<.1	<.3	1.8	18.4	15	<3	8	<1	52.5
muscle	PINK SHRIMP	I-6	19	69	0.35	<.2	1.8	28.4	43.1	<2	<2	<.8	85.3
muscle	PINK SHRIMP	I-6	13	57	1.23	<.2	1.3	23.3	34.3	<2	<2	<.8	85.6
muscle	PINK SHRIMP	I-6	11	40	0.24	<.2	0.9	13.1	37.3	<2	<2	<.8	43.1
muscle	PINK SHRIMP	I-6	14	49	0.2	<.2	0.7	17.1	44.4	<2	<2	<.8	58
gill	REX SOLE	I-6	41	<8	2	<.3	3	7.8	159	<3	4	<2	44.4
liver	REX SOLE	I-6	17	<6	0.2	2.1	0.9	3.6	416	<3	6	3	65
muscle	REX SOLE	I-6	4	<4	<.08	<.2	0.6	1.2	17.3	<2	<2	<.8	11.1
h-pancreas	SIDESTRIPE SHRIMP	I-6	13	48	0.19	18.9	<.4	556	52.7	<2	<2	<.8	54.5
muscle	SIDESTRIPE SHRIMP	I-6	13	52	0.24	17.3	0.6	522	49.1	<2	<2	<.8	74.9
muscle	SIDESTRIPE SHRIMP	I-6	6	75	0.3	0.2	0.8	15	21.7	<2	4	<.8	56.4
muscle	SIDESTRIPE SHRIMP	I-6	<4	84	0.09	<.2	1.2	21.1	13	<2	<2	<.8	61.9

APPENDIX 13 (Continued)

TISSUE	ORGANISM	STN	AL	AS	BA	CD	CR	CU	FE	NI	PB	SN	ZN
muscle	SIDESTRIPE SHRIMP	I-6	<4	120	0.12	<.2	1.3	26.8	14.8	<2	<2	<.8	69.8
muscle	SIDESTRIPE SHRIMP	I-6	<4	103	<.08	<.2	1.4	27.6	12.1	<2	<2	<.8	69
muscle	SIDESTRIPE SHRIMP	I-6	10	78	0.15	<.2	0.9	21.2	18.1	<2	4	<.8	60.2
muscle	SIDESTRIPE SHRIMP	I-6	12	66	0.17	<.2	1	16.9	18.7	<2	<2	<.8	52.1
muscle	SIDESTRIPE SHRIMP	I-6	9	75	0.35	<.2	0.8	16.9	18.5	<2	<2	<.8	48.5
muscle	SIDESTRIPE SHRIMP	I-6	6	73	0.13	<.2	0.6	16.5	16.7	<2	<2	<.8	58.6
muscle	SIDESTRIPE SHRIMP	I-6	10	51	0.16	<.2	1	15.4	31.8	<2	2	<.8	46.6
muscle	SIDESTRIPE SHRIMP	I-6	<4	55	0.11	<.2	0.7	16.7	15.9	<2	3	<.8	40.6
muscle	SIDESTRIPE SHRIMP	I-6	7	72	0.2	<.2	1.1	17.2	29.5	<2	<2	<.8	49.8
muscle	SIDESTRIPE SHRIMP	I-6	5	43	0.12	<.2	0.9	16.4	25.6	<2	<2	<.8	55.5
muscle	SIDESTRIPE SHRIMP	I-6	<4	64	0.16	<.2	0.8	19.4	15.8	<2	<2	<.8	58.4
muscle	SIDESTRIPE SHRIMP	I-6	7	77	0.57	<.2	0.7	24.4	23.5	<2	<2	<.8	68.1
muscle	SIDESTRIPE SHRIMP	I-6	4	21	0.17	<.2	0.4	33.8	22.5	<2	<2	<.8	30.1
gill	SLENDER SOLE	I-6	27	13	3.2	<.3	2.7	2.9	107	<3	<3	4	144
liver	SLENDER SOLE	I-6	9	<8	<.2	2.6	<.8	42.6	1090	<3	<3	<2	159
muscle	SLENDER SOLE	I-6	<8	9	<.2	<.3	<.8	<.8	15.4	<3	<3	<2	10.3
gill	WALLEYE POLLOCK	I-6	20	<7	6.3	<.3	1.6	3.9	80.9	<3	4	1	104
gill	WALLEYE POLLOCK	I-6	30	<7	15.9	<.3	4.5	3.8	113	<3	<3	<1	158
gill	WALLEYE POLLOCK	I-6	88	<8	4.6	0.6	2.2	230	949	<3	3	<2	168
liver	WALLEYE POLLOCK	I-6	13	34	0.3	0.4	4.5	40.5	158	<3	<3	<2	127
liver	WALLEYE POLLOCK	I-6	<4	5	<.08	0.3	0.9	68.7	43	<2	<2	<.8	51.3
liver	WALLEYE POLLOCK	I-6	<6	15	<.1	0.6	0.8	64	218	<3	<3	3	108
muscle	WALLEYE POLLOCK	I-6	<4	25	0.31	<.2	1.6	2.7	28	<2	<2	<.8	34.3
muscle	WALLEYE POLLOCK	I-6	<4	6	<.08	0.2	0.6	1.2	15.8	<2	<2	<.8	14.4
muscle	WALLEYE POLLOCK	I-6	<7	21	<.1	<.3	1.2	1.7	19.3	<3	<3	<1	17.2

APPENDIX 14 Trace Metals (ug/g) In Clams And Mussels From Sturgeon Bank May, 1985.

STATION	AL	AS	BA	BE	CA	CD	CO	CR	CU	FE	HG	MG	MN	MO	NA	NI	P	PB	SB	SI	SN	SR	TI	V	ZN
			CLAM		Macoma balthica																				
1-1	125	6	2.7	<.1	8740	1.0	1.7	1.4	18.7	301	-	7640	26.2	1.9	53700	5	7380	9	<5	90	<1	65.3	9.6	1.1	115
28	470	<20	8.5	<.5	15300	3.2	2.0	<2	21.0	1030	-	6930	34.5	8.0	54900	<9	9190	<9	<20	230	<5	92.7	39.5	2.0	239
5	253	11	5.0	<.1	14200	0.2	3.2	1.8	32.5	874	0.07	5590	35.0	<.5	34400	3	9480	2	<5	250	<1	82.6	13.5	1.3	222
20	377	6	7.2	<.1	32300	3.6	4.0	2.5	23.8	855	-	7070	30.7	1.7	47100	4	6710	5	<5	370	<1	173.0	14.3	1.7	260
SB-3	201	6	3.8	<.1	8220	0.5	2.2	1.6	14.1	530	-	9670	22.5	0.7	59600	3	7270	4	<5	240	<1	74.6	11.4	1.0	149
9	247	6	3.2	<.1	7640	0.3	2.4	1.5	16.2	602	0.42	4230	23.6	1.0	26600	2	6370	<2	<5	220	<1	47.3	12.0	1.3	167
SB-4	130	<30	2.8	<.5	3710	2.0	<3	<3	21.0	384	-	7790	14.2	<3	60700	<10	8730	<10	<30	120	<5	63.2	38.0	<3	115
SB-3	210	<10	5.7	<.2	58900	<.5	1.0	<1	14.0	545	-	5310	26.6	4.0	40800	<5	6390	<5	<10	130	<2	217.0	19.9	<1	159
14	150	5	2.8	<.1	23000	<.2	2.3	1.6	74.2	592	0.37	5130	19.5	<.5	34900	2	7980	<2	<5	80	<1	172.0	9.8	0.7	268
14	147	<5	2.4	<.1	4630	3.5	1.8	1.4	29.6	500	-	7960	16.8	<.5	50500	7	8270	<2	<5	100	<1	53.9	10.3	0.9	88.8
NA-2	160	7	2.2	<.1	5210	3.7	1.8	1.6	16.8	340	-	10100	16.7	<.5	63200	7	7420	4	<5	270	<1	63.8	10.3	1.0	88.7
			CLAM		Cryptomya californica																				
1-1	284	5	5.0	<.1	10200	1.8	3.2	2.3	36.3	752	-	4940	39.7	3.6	36400	3	9330	9	<5	60	<1	63.1	12.7	1.9	201
53	283	8	4.8	<.08	12300	<.2	3.3	1.9	27.3	918	0.14	5210	38.1	0.4	33600	4	10400	2	<4	48	<.8	67.9	9.1	1.4	263
28	940	20	9.6	<.3	2900	<.7	8.0	3.0	18.0	2360	-	5420	80.1	6.0	37700	<7	6450	9	<20	820	<3	39.9	41.5	5.0	161
20	657	9	8.4	<.09	34700	0.4	6.4	3.1	25.4	1630	-	6770	48.5	<.5	41900	6	6200	4	<5	493	<.9	163.0	22.8	2.8	214
9	263	11	4.8	<.1	6130	1.2	2.9	1.8	21.1	657	0.19	6070	33.2	1.2	40300	4	9900	<2	<5	260	<1	54.6	13.1	1.4	304
SB-3	375	10	6.9	<.1	26000	0.7	4.0	2.2	18.5	920	-	6990	29.9	1.1	42300	4	7120	6	<5	330	<1	140.0	15.3	1.8	262
14	195	9	3.5	<.1	3750	<.2	6.7	3.3	68.2	1480	0.37	6020	30.9	<.5	34500	5	9690	5	<5	80	<1	45.2	16.7	2.2	373
SB-2	208	<9	5.1	<.2	13200	<.4	2.5	1.1	21.8	622	-	6030	31.8	5.7	44700	<4	6940	<4	<9	100	<2	79.0	16.5	<.9	210
			MUSSEL		Mytilus edulis																				
7	558	<4	3.3	<.08	60900	4.1	3.4	3.0	11.4	1150	0.85	11800	50.0	<.4	76900	4	5180	4	<4	552	<.8	229.0	15.3	2.2	183
7	650	7	2.9	<.08	7230	3.5	4.1	3.4	20.1	1470	0.51	9350	45.5	<.4	65300	5	7710	8	<4	118	<.8	59.5	17.8	2.8	180
5	521	5	4.1	<.08	29000	3.2	3.5	2.3	15.2	1180	0.50	9090	56.4	<.4	65100	4	7340	7	<4	118	<.8	230.0	15.2	2.5	155
5	379	8	3.0	<.08	17500	3.2	2.7	2.2	17.4	897	0.42	8610	50.0	<.4	63500	5	6650	6	<4	117	<.8	142.0	10.7	4.3	164