Metals in Eulachons from the Nass River and Crabs from Alice Arm, B.C.

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ABSTRACT

In 1981, Amax Molybdenum of Canada Ltd. began discharging tailings from its molybdenum mine at Kitsault, British Columbia into Alice Arm. Native Indians living in coastal areas of Northern B.C. expressed concern with respect to the potential for metal contamination of certain food fish and invertebrates as a result of the tailings disposal. In response to this concern, the Department of Fisheries and Oceans carried out a sampling program in 1981 and 1982 to determine the metal content of Nass River eulachons (*Thaleichthys pacificus*) and small numbers of King crab (*Paralithodes camtschatica*) and Tanner crab (*Chionoecetes bairdi*) from Alice Arm. Levels of arsenic, cadmium, chromium, copper, manganese, mercury, molybdenum, nickel, lead and zinc were measured in organisms sampled.

This report presents results of the sampling program and compares them with metal data from organisms previously collected from coastal waters of British Columbia and other selected coastal locations throughout the world.

RÉSUMÉ

En 1981, Amax Molybdenum of Canada, Ltd., commença à dévider les déchets de sa mine de molibdène de Kitsault, Colombie Britannique, dans le bras de rivière Alice. Les Indiens indigènes habitant les régions côtières du nord de la Colombie Britannique s'inquiétèrent de la possibilité d'une contamination de métal de certaines nourritures pour poissons et invertébrés résultant des dépots de déchets. Prenant cette préoccupation en considération, le Ministère des Pêches et Océans mit en exécution, en 1981 et 1982, un programme d'analyses d'échantillons pour définir la contenance de métal des eulakanes de la rivière Nass (*Thaleichthys pacificus*) et du petit nombre de crabes royaux (*Paralithodes camtschatica*) et de crabes des neiges (*Chionoecetes bairdi*) du bras de rivière Alice. Les quantités d'arsenic, de cadmium, de chrome, de cuivre, de manganèse, de mercure, de molibdène, de nickel, de fer et de zinc furent mesurées dans les échantillons d'organismes.

Les résultats du programme d'analyses sont présentés dans ce rapport, et sont comparés aux données précédemment recueillies dans les organismes des eaux côtières de Colombie Britannique et des autres zones côtières sélectionnées dans le monde.

I. INTRODUCTION

Amax Molybdenum of Canada Limited began discharging tailings from its molybdenum mine at Kitsault, British Columbia into Alice Arm in 1981. Alice Arm is an inlet approximately 18.5 km in length which forms part of Observatory Inlet on the north coast of British Columbia (Figure 2). Approximately 12,000 tonnes of tailings are released daily from the Kitsault mining operation into Alice Arm from a submerged outfall at a depth of 50 metres (Burling et al., 1981). This discharge has aroused considerable public concern, in part because of the metal content of the tailings and the potential for metal uptake by aquatic organisms utilized by humans.

A technical assessment of available information relating to the tailings discharge was undertaken by Burling et al. (1981) at the request of the Minister of Fisheries and Oceans. Their assessment indicated that of ten metals for which data were available, molybdenum, lead and zinc are present at higher concentrations in the tailings solids than in Nass River sediments or sediments from freshwater systems which drain into Alice Arm. These metals, as well as cadmium, are found in higher concentrations in the tailings than in the earth's crust (Table 1). With respect to the probable environmental impact of the tailings discharge into Alice Arm, they concluded that the increased loading of cadmium, lead and zinc in marine sediments was expected to be reflected in elevated levels of these metals in certain biota, particularly infaunal and resident benthic species. Molybdenum in the tailings was not expected to result in adverse environmental changes.

Native Indians living in coastal areas of northern British Columbia have expressed continued concern regarding metal contamination of food fish and invertebrates as a result of tailings disposal to Alice Arm from the Amax mine. In particular, contamination of Nass River eulachons which form the basis of a native food fishery of long-standing historical importance was identified as a concern. Eulachons taken in this fishery by modified beam trawl, dipnet and occasionally gillnet are consumed or traded locally as fresh fish, dried and smoked fish or as rendered oil (Langer *et al.*, 1977).

In response to the concerns of the native Indians the Department of Fisheries and Oceans carried out a sampling program to determine the metal content of Nass River eulachons (*Thaleichthys pacificus*). Small numbers of King crab (*Paralithodes camtschatica*) and Tanner crab (*Chionoecetes bairdi*) were also collected from sites in the vicinity of Alice Arm. This report presents results from this sampling program and compares them with metal data from organisms previously collected from coastal waters of British Columbia and selected coastal locations throughout the world.

II. MATERIALS AND METHODS

A. Sample Collection

Eulachon samples were taken from catches obtained by native fishermen operating in a short stretch of the Nass River near Fishery Bay (Figure 1). Fish were caught during ebb tides using modified beam trawls held stationery in the river by poles. In 1981, samples were taken from catches made near Red Bluff (Station 1) and Greenville (Station 2) and in 1982, from two separate catches made in Fishery Bay (Stations 3 and 4).

In 1981, King crabs were taken in traps from Sylvester Bay off Hastings Arm and near Hans Point in Alice Arm; Tanner crabs were collected from Perry Bay in Obervatory Inlet (Figure 2).

B. Sample Preparation

All samples were frozen in the field and shipped to the Department of Fisheries and Oceans/Department of Environment (DFO / DOE) Chemistry Laboratory in West Vancouver for analysis.

In 1981, analyses were performed on pooled samples of eulachon consisting of whole bodies of an unspecified number of fish. Crab leg tissue from individual organisms was also analyzed. In 1982, individual eulachons and pooled samples of ten fish were analyzed. In addition, livers were removed from selected eulachons for individual or pooled (ten livers) analysis.

In 1982 only, the body weight and standard length of each eulachon analyzed was determined.

In preparation for analysis all samples were blended in a Waring blender until homogenous, freeze-dried and then ground using a mortar or blender. Aliquots of approximately one gram were then brought into solution using wet ashing techniques (low temperature ash followed by treatment with nitric acid (HNO_3), hydrochloric acid (HCl) and heat for metal analysis excluding mercury; treatment with sulphuric acid (H_2SO_4), hydrogen peroxide (H_2O_2) and heat for mercury analysis). Samples for mercury analyses were further prepared using volatilization techniques. (See Government of Canada, 1979 for additional methodological details).

C. Sample Analysis

Tissue levels of arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), and zinc (Zn) were determined using the Inductively Coupled Argon Plasma (ICAP) Optical Emission Spectrophotometry method (Government of Canada, 1979). Mercury (Hg) levels (1982 samples only) were determined using flameless atomic absorption spectrometry.

In order to ensure reliability of laboratory results a number of daily and long term checks on quality control were routinely undertaken. On a daily basis laboratory equipment was calibrated using calibration standards; analytical blanks were prepared and analyzed at least in duplicate as a contamination check; substantial numbers of samples were prepared and analyzed in duplicate or more to check for contamination and reproducibility and precision of results; and certified reference materials (NBS SRM 1566 Oyster Tissue and NBS RM 50 Albacore Tuna Tissue) were analyzed to determine accuracy of measurements. In addition, the following long term checks on quality control were carried out on a regular basis: comparison of calibration standards to primary standards and/or certified reference materials; preparation of samples of known metal content for analysis as a check on analyst performance; participation in interlaboratory studies wherein analytical results from a number of laboratories were compared in terms of reproducibility and accuracy.

Detection limits for the analyses undertaken are reported in Table 2 for metals in tissue. As discussed above, samples for metal analyses were prepared in solution. Detection limits for metals in tissue were calculated from those established by the laboratory for metals in solution. As metal analyses were carried out on aliquots of tissue weighing approximately one gram, calculations were based on a dilution of one gram (dry weight) of tissue in 50 mls liquid during sample preparation (with the exception of mercury for which approximately 0.1 gram (dry weight) of tissue is diluted in 50 mls liquid). The variation in the amount of tissue used in sample preparation results in a corresponding variation in tissue detection limits (the minimum detectable quantity of metal in a sample) with less tissue leading to a higher detection limit. Thus detection limits actually vary somewhat with each sample prepared and for this reason, detection limits reported here should be viewed as estimates only.

Detection limits achieved for metal analyses were limited by the analytical procedures utilized in this study. These were considered to be adequate to meet the objective of the study, namely to assess the levels of metals in selected food organisms utilized by Native Indians residing in the vicinity of the Nass River and Alice Arm. It is recognized however, that alternative analytical procedures designed to detect low level concentrations of metals (particularly cadmium, copper and lead) in tissue are currently available and would have produced lower detection limits than those reported herein.

D. Data Analysis

Means and standard deviations were calculated for metal concentrations in individual fish, pooled samples of fish and individual livers at each station except in cases where values below detection limits precluded such calculations.

A two way Analysis of Variance and Newman-Keul's Multiple Range Test were performed on 1982 data only. Insufficient replicates were available for similar treatment of 1981 data. Comparisons between stations 3 and 4 (Fishery Bay) were made for arsenic, cadmium, chromium, copper, manganese, mercury and zinc concentrations in eulachon tissue. Values below detection limits precluded similar statistical treatment for molybdenum, nickel, and lead. Individual eulachons, pooled samples of eulachons and individual livers were compared with respect to accumulation of chromium, copper, manganese, mercury and zinc where sufficient data were available. Values below detection limits precluded similar statistical treatment of arsenic, cadmium, lead, molybdenum and nickel data.

III. RESULTS

Results of metal analyses are shown in Table 3 for eulachon tissue and in Table 4 for crab tissue. All values are expressed in mg kg^{-1} dry weight. In cases where values below detection limits precluded calculation of means and standard deviations, only ranges are reported. Results of individual analyses appear in Appendices I and II.

A. Metal Analyses

In the following, metals found in similar concentrations in eulachon tissue have been grouped for ease of discussion.

1. Eulachons

a. Arsenic, cadmium, lead, mercury, molybdenum and nickel

In 1981, arsenic, cadmium, lead, molybdenum and nickel were below detectable limts in eulachon samples from both Stations 1 and 2. In 1982, concentrations of arsenic, cadmium, molybdenum, nickel and mercury (not measured in 1981) in individual eulachons collected at Stations 3 and 4 were often below detectable limits (ND) and did not exceed 5 mg kg^{-1}:

As: ND - 4.0 mg kg^{-1} (10% of values ND in individual eulachons)
Cd: ND - 0.2 mg kg^{-1} (85% of values ND in individual eulachons)
Hg: 0.1 - 0.2 mg kg^{-1}
Mo: ND - 3.1 mg kg^{-1} (95% of values ND in individual eulachons)
Ni: ND - 2.0 mg kg^{-1} (35% of values ND in individual eulachons)

Lead concentrations were similar to those noted above (ND - 3.0 mg kg^{-1}; 80% of values ND in individual eulachons) with the exception of an eulachon in which a concentration of 7.0 mg kg^{-1} of lead was measured. It is likely that this sample was contaminated during handling in the field or laboratory.

Concentrations of arsenic, cadmium, molybdenum and nickel in liver tissue from individual eulachons collected in 1982 were as follows:

As: ND - 5.0 mg kg^{-1} (75% of values ND in individual livers)
Cd: 0.2 - 1.4 mg kg^{-1}
Mo: ND - 1.1 mg kg^{-1} (80% of values ND in individual livers)
Ni: ND - 13.0 mg kg^{-1} (45% of values ND in individual livers)

Lead values were similar to those noted above (ND - 4.0 mg kg^{-1}) except for an individual liver which had a concentration of 17.0 mg kg^{-1}. It is likely that this liver was contaminated during handling in the laboratory. Mercury was not measured in individual livers but the concentration in pooled samples of ten livers was 0.2 mg kg^{-1}.

b. Chromium, copper and manganese

Chromium, copper and manganese exceeded detectable limits in eulachon tissue but were consistently less than 5 mg kg^{-1}:

	1981 Pooled sample of eulachons Station 1 & 2 (range; n=2)	1982 Individual eulachons Station 3 ($x \pm SD$; n=10)	 Station 4 ($x \pm SD$; n=10)
Cr (mg kg^{-1})	0.9 - 1.0	0.9 $\pm$ 0.4	0.7 $\pm$ 0.3
Cu (mg kg^{-1})	4.8 - 4.9	4.3 $\pm$ 0.8	4.0 $\pm$ 0.9
Mn (mg kg^{-1})	0.5 - 1.9	2.3 $\pm$ 1.8	1.6 $\pm$ 0.5

Individual livers (analyzed in 1982 only) had the following mean chromium, copper and manganese concentrations:

	Station 3 ($x \pm SD$; n=10)	Station 4 ($x \pm SD$; n=10)
Cr (mg kg^{-1})	1.1 $\pm$ 0.4	2.9 $\pm$ 2.6
Cu (mg kg^{-1})	32.7 $\pm$11.4	50.3 $\pm$21.4
Mn (mg kg^{-1})	5.3 $\pm$ 2.1	3.2 $\pm$ 0.5

c. Zinc

Tissue levels of zinc in individual eulachons sampled in 1982 ranged from 17.9 to 61.2 mg kg^{-1} ($x \pm SD$ (n=10): 41.9 $\pm$ 4.6 mg kg^{-1} and 46.8 $\pm$ 11.9 mg kg^{-1} for stations 3 and 4 respectively). Zinc levels measured in 1981 were lower (Station 1 (n=1): 13.3 mg kg^{-1}; Station 2 (n=1): 15.2 mg kg^{-1}).

Mean zinc concentrations in individual liver samples (analyzed in 1982 only) were 122.6 $\pm$ 23.2 mg kg^{-1} and 117.8 $\pm$ 18.0 mg kg^{-1} at stations 3 and 4 respectively.

2. Crabs

Lead, molybdenum and nickel in the King and Tanner crabs collected in 1981 from all locations were below detectable limits. Cadmium, chromium and manganese levels ranged from non-detectable to 0.6 mg kg^{-1};non-detectable to 3.6 mg kg^{-1} and 0.6 - 4.9 mg kg^{-1} respectively. Arsenic values ranged from 9.9 to 49.3 mg kg^{-1} and copper values from 49.1 to 84.1 mg kg^{-1}. Zinc concentrations ranged from 152.0 to 224.0 mg kg^{-1}.

B. Statistical Analysis

A two way analysis of variance (ANOVA) comparing metal concentrations (all data pooled from individual eulachons, pooled samples of eulachons and individual livers) between stations 3 and 4 indicated that levels of copper and mercury were significantly greater ($p < 0.05$) at station 4 and manganese levels were significantly greater ($p < 0.05$) at station 3. No significant differences (Table 5) in levels of arsenic, cadmium, chromium and zinc were noted for fish sampled at station 3 compared to those taken at station 4. Values below detection limits precluded statistical comparison for molybdenum, nickel and lead. Stations 3 and 4, both located in Fishery Bay, were sampled on the same day using similar gear. Thus it is likely that the statistical difference noted between stations is attributable to natural biological variability and not to real sample differences between the two stations.

There was a significant difference in chromium, copper, manganese, mercury and zinc levels in individual eulachons, pooled samples of eulachons and individual livers (Table 5). Mercury levels in individual eulachons were significantly lower than in pooled eulachon samples. Mercury was the only metal for which a difference was noted between individual and pooled eulachon samples. No data were available for mercury levels in individual livers. Newman-Keul's multiple range test revealed that concentrations of copper, manganese and zinc were significantly higher in liver tissue than in whole bodies (individual and pooled samples) (Table 6). Although the ANOVA indicated that there was a significant difference in chromium accumulation amongst the three tissue types analyzed, it was not possible to group the tissue types into more than one homogenous subset using Newman-Keul's test (Table 6). This can be attributed to the fact that Newman-Keul's test is less powerful than the ANOVA and is sometimes incapable of detecting differences that the ANOVA detects. In addition, Newman-Keul's test is rendered less powerful when measures of standard deviations are dissimilar between groups compared, as is the case with chromium. Values below detectable limits precluded statistical analysis of arsenic, cadmium, lead, molybdenum and nickel data.

C. Length and Weight Measurements

Eulachons analysed in 1982 had a mean standard length of 18 $\pm$ 1 cm and a mean weight of 41.0 $\pm$ 10.5 g. Measurements of individual fish appear in Appendix III.

Lengths and weights were not recorded for eulachons sampled in 1981.

IV. DISCUSSION

Metal levels have been measured in fish and crabs taken from north and south coast British Columbia locations in recent studies. Harbo *et al*. (In prep.) reported tissue metal levels in marine organisms collected from waters adjacent to urban and industrial areas in southern coastal areas. Goyette (1981) and Goyette and Christie (In prep. a, b) reported the results from an on-going sampling program being carried out in Observatory Inlet on the north coast of B.C.. In addition, fish and invertebrate sampling programs in Alice Arm have been conducted by Amax Molybdenum of Canada Ltd. in compliance with federal and provincial government requirements (Littlepage 1978; Amax 1981). A summary of pertinent results from these studies is presented in Tables 7 and 8. These results are compared with data from this study in the following discussion.

In addition to studies described above which were undertaken in British Columbia, there is a sizeable body of literature reporting surveys of metal levels in marine biota from coastal locations throughout the world. No attempt has been made to conduct an exhaustive review of this literature for the purposes of this study. However, some data from the literature on metal levels in fish and crab muscle tissue and fish liver tissue has been collated for comparison with results from this study. These are presented in Appendices IV to VI.

It should be recognized that there are numerous complexities associated with comparing metal levels in marine biota from different studies, a number of which are related to analytical techniques. A variety of sample preparation and laboratory analytical techniques have been routinely employed in metal determination studies. The reliability of results can vary significantly between studies. This is of particular significance with respect to lead values reported in the literature. Chow et al. (1974), Patterson and Settle (1977) and Settle and Patterson (1980) maintain that shortcomings in analytical techniques routinely used to determine levels of lead in tissue have resulted in the reporting of falsely elevated values which render the validity of most published measurements of lead in marine organisms questionable. Variability in sample handling techniques in the field and laboratory can also be of significance in determining the reliability of results as metals in biota are typically found in only trace amounts and sample contamination can lead to anomalies in data. These factors can have a substantial bearing on the comparability of measurements between studies. A further relevant factor pertains to the type of tissue analyzed (eg. dorsal muscle vs. whole body vs. liver). Because metal uptake and accumulation varies with tissue type, direct comparisons of metal levels in different types of tissue may be inappropriate.

Other factors which influence comparability of metal data between studies relate to the organisms sampled. Metal content in tissues is often correlated with age and size of individuals analyzed. The life history stage of an organism can also be a significant factor. For example, tissue levels of metals in organisms such as crabs vary according to the stage of the moulting cycle (Bryan, 1979). Likewise, behavioural and ecological differences between organisms affect the potential for exposure to sources of metals and subsequent metal uptake and accumulation. For example, migrant species are generally less susceptible in terms of metal accumulation to point-sources of contamination than non-migrant species which may reside in the vicinity of a specific discharge.

These complexities associated with comparing metal concentrations in marine biota reported in various studies are thus important in assessing the information presented in the following discussion.

A. Metal Levels in Eulachons

1. Comparison with fish sampled in waters of British Columbia

Arsenic concentrations in eulachons analysed in this study were low compared with values reported by Goyette (1981) for pollock, and Goyette and Christie (In prep. a, b), and Amax (1981) for sole sampled in Alice Arm.[1] Cadmium, chromium, copper, manganese, mercury and nickel concentrations determined in this study were comparable to those previouly reported by Harbo *et al*.(In prep.), Goyette (1981), Goyette and Christie (In prep. a, b) and Amax (1981). Cadmium and copper in eulachons sampled in this study were lower than levels in yellowfin sole and great sculpins from Alice Arm, Hastings Arm and Observatory Inlet reported by Littlepage (1978). Molybdenum was seldom present in concentrations above detectable limits for analyses reported by Goyette (1981), Goyette and Christie (In prep. a, b) Amax (1981) and Littlepage (1978). Molybdenum was below detectable limits in all eulachons analysed in the present study with the exception of a single individual sample which had a molybdenum concentration of 3.1 mg kg^{-1}. This sample was likely contaminated during field or laboratory handling. Lead levels in eulachons from this study were lower than those reported by Littlepage (1978) for yellowfin sole and great sculpins and were comparable to those recorded by Harbo *et al*. (In prep.), Goyette (1981), Goyette and Christie (In prep. a, b) and Amax (1981) with

[1] It should be noted that in these studies samples of either muscle, muscle/skin or whole bodies were analysed. (see Table 7).

the exception of a single individual analysed in this study with a tissue concentration of 7.0 mg kg^{-1}. As mentioned previously, it is probable that this sample was contaminated during field or laboratory handling. Maximum lead levels reported elsewhere were 4.40 mg kg^{-1} in a rockfish sampled by Harbo _et al_. (In prep.) and mean values of 13.8 and 4.2 mg kg^{-1} in yellowfin sole and great sculpins respectively reported by Littlepage (1978). Zinc values reported in this study were within the range reported by Harbo _et al_. (In prep.) for rockfish muscle tissue and lower than mean values in yellowfin sole and great sculpin tissue reported by Littlepage (1978). However, mean tissue concentrations of zinc were higher than reported by Harbo _et al_. (In prep.), Goyette (1981), Goyette and Christie (In prep. a, b) and Amax (1981).

A comparison of 1981 and 1982 data from this study indicates that concentrations of metals in eulachon tissue were similar between samples from 1981 and 1982 for all metals except zinc which was found in lower concentrations in 1981 samples.

It should be noted that liver tissue was not isolated for analysis by Harbo _et al_. (In prep.), Goyette (1981), Goyette and Christie (In prep. b), Amax (1981) or Littlepage (1978). Goyette and Christie (In prep. a) reported results from the analysis of livers from two pollock (_Theragra calcogramma_) taken from Alice Arm in 1980. The small sample size precluded a comparison of their values with those reported herein.

2. Comparison with fish sampled in coastal locations throughout the world

Levels of arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel and zinc in eulachons sampled during this study were within the range of values reported in the literature for metals in fish muscle tissue collected from various parts of the world (Appendix IV). Molybdenum was not typically measured during surveys of metal levels in marine biota reported in the literature reviewed.

There were limited data available in the literature reviewed on metal levels in liver tissue of fish collected during field studies (Appendix V). Levels of arsenic in eulachon liver tissue reported in this study were lower than those reported in the literature for fish sampled in coastal waters of Greenland and the Northwest Territories. Cadmium, mercury and zinc concentrations determined in this study were similar to levels reported in Appendix V though it should be noted that only two liver samples were analyzed for mercury content in this study. Lead values reported in Appendix V are also similar to those determined in this study with the exception of a single liver from a Nass River eulachon which had a lead concentration higher than those reported in the literature. Copper levels measured in Nass River eulachon livers were typically higher than those reported for shorthorn sculpins from the Northwest Territories and Atlantic cod from coastal waters of Norway. No information on chromium, manganese, molybdenum or nickel levels in livers from fish collected during other field surveys were available in the literature reviewed.

B. Metal Levels in Crabs

It should be noted that the following discussion refers to only three King crabs and two Tanner crabs taken during the course of this sampling program.

1. Comparison with crabs sampled in waters of British Columbia

Arsenic concentrations in leg tissue of King and Tanner crabs sampled during this study were typically low compared to values reported in Table 8. Cadmium, chromium, copper, manganese and zinc concentrations determined in this study were comparable to those previously reported by Harbo *et al.* (In prep.), Goyette (1981), Goyette and Christie (In prep. b), and Littlepage (1978) with the exception of a single King crab taken near Hans Point in Alice Arm during this study which had a higher chromium content (3.6 mg kg^{-1}) than elsewhere reported. Molybdenum, nickel and lead levels were below detectable limits in crab tissue analyzed during this study. Goyette (1981) and Goyette and Christie (In prep. a, b) reported molybdenum to be below detectable limits in King crabs, Brown King crabs and *Lithodes spp.* sampled in Alice and Hastings Arms with the exception of a single Brown King crab in which a concentration of 0.40 mg kg^{-1} of molybdenum was measured. Concentrations of ND - 1.60 mg kg^{-1} molybdenum were reported by Goyette and Christie (In prep. a, b) in Tanner crabs from the same area. Littlepage (1978) reported molybdenum concentrations of ND - 1.4 mg kg^{-1} in three species of crabs sampled in Alice Arm, Hastings Arm and Observatory Inlet. Harbo *et al.* (In prep.) reported nickel values ranging from 0.70 - 5.80 mg kg^{-1} in crabs from southern B.C. waters and Goyette and Christie (In prep. a, b) reported values of ND - 4.0 mg kg^{-1} in King and Tanner crabs from Alice and Hastings Arms. Goyette (1981) and Goyette and Christie (In prep. a, b) reported lead levels to be below detectable limits for *Lithodes spp.*, and King and Brown King crabs sampled in 1977 and 1978 and ND - 4.00 mg kg^{-1} in King and Tanner crabs taken in 1980 and 1981 from Alice and Hastings Arm. Littlepage (1978) reported lead concentrations of 0.8 - 3.5 mg kg^{-1} in three species of crabs sampled between 1974 and 1977 in Alice Arm, Hastings Arm and Observatory Inlet.

2. Comparison with decapods sampled in coastal locations throughout the world

Comparison of metal levels in the crabs analyzed for this study with values from the literature reviewed (Appendix VI) indicates that metal concentrations in muscle tissue were comparable for arsenic, cadmium, copper, lead and nickel. Chromium concentrations in King crabs taken from Alice Arm during this study were somewhat higher than in decapods sampled off the coasts of Ireland and western United States but were lower than reported for decapods taken off the Norway coast. Manganese levels in crabs from Alice Arm were less than that reported in the literature for decapods taken off the coast of Ireland and similar to levels reported for decapods taken from the South African coast. A wide range of values for zinc levels in decapod tissue is reported in the literature. Zinc levels in crabs sampled during this study fall within the range reported for decapods taken from waters off the California coast but are higher than those reported for decapods from the coasts of England, Texas and South Africa. Molybdenum was not typically measured during surveys of metal levels in marine biota reported in the literature reviewed.

C. General Discussion

The purpose of this study was to determine the metal content of Nass River eulachons and a small number of crabs collected from sites in the vicinity of Alice Arm in response to concerns of native Indians about metal contamination of food fish and invertebrates.

Crabs sampled from the vicinity of Alice Arm showed metal levels in leg tissue which were typically similar to values reported for B.C. locations and elsewhere in the world.

Nass River eulachons typically exhibited metal levels lower or comparable to those previously reported for fish sampled in B.C. coastal locations with the exception of mean values of zinc which were higher than some levels previously reported for B.C. fish species. Metal levels in eulachon tissue were within ranges reported for studies undertaken elsewhere in the world with the exception of copper levels in liver tissue which were higher in Nass River eulachons than reported in the limited amount of data reported in the literature reviewed.

Eulachon liver tissue showed levels of copper, manganese and zinc substantially greater than found in whole body samples of eulachon. Previous studies have shown that fish livers accumulate metals from the environment in greater concentrations than do other tissues (Phillips and Russo 1978). There is some evidence that the degree of accumulation is directly related to the environmental availability of the metals (Phillips and Russo 1978; Wilson et al. 1980).

In the absence of comparative data on naturally occuring levels of metals in Nass River eulachons and limited data on Alice Arm crabs prior to initiation of mining activity in the area, it is not possible at this time to detect any trends in tissue accumulation of metals. Should future analysis of eulachon tissue suggest a trend of increasing metal concentrations, additional information regarding the distribution and migration patterns of eulachons would be required in order to establish the area in which exposure may have occurred and to establish correlations between elevated metal levels and point sources of metals such as the tailings discharge in Alice Arm. Very little information is currently available regarding movements of eulachons between the time they leave their native rivers as juveniles and return as adults to spawn. However, incidental capture of eulachons in fishing gear and their presence in stomach contents of predator species suggests that eulachons range substantial distances from their spawning grounds (Hart and McHugh 1944; Smith and Saalfield 1955) and that they tend to frequent coastal waters rich in planktonic organisms on which they feed (Smith and Saalfield 1955; Barraclough, 1964). As stated previously, migrant species such as the eulachon are generally less susceptible with respect to metal accumulation from point sources of contamination than are non-migrant species which may reside in the vicinity of a discharge over an extended period of time. In this regard, Alice Arm crabs may be more susceptible than Nass River eulachons to metal accumulation.

Since it has been shown that many organisms possess the ability to regulate tissue concentrations of metals (Bryan 1979) care must be exercised in making assumptions relating metal levels in Nass River eulachons and Alice Arm crabs described in this study to metal contamination of the environment resulting from mining activities.

The metal levels reported herein and available information regarding the life history of the eulachon would suggest that metal uptake and accumulation in these fish as a result of the tailings discharge into Alice Arm is not likely.

V. ACKNOWLEDGMENTS

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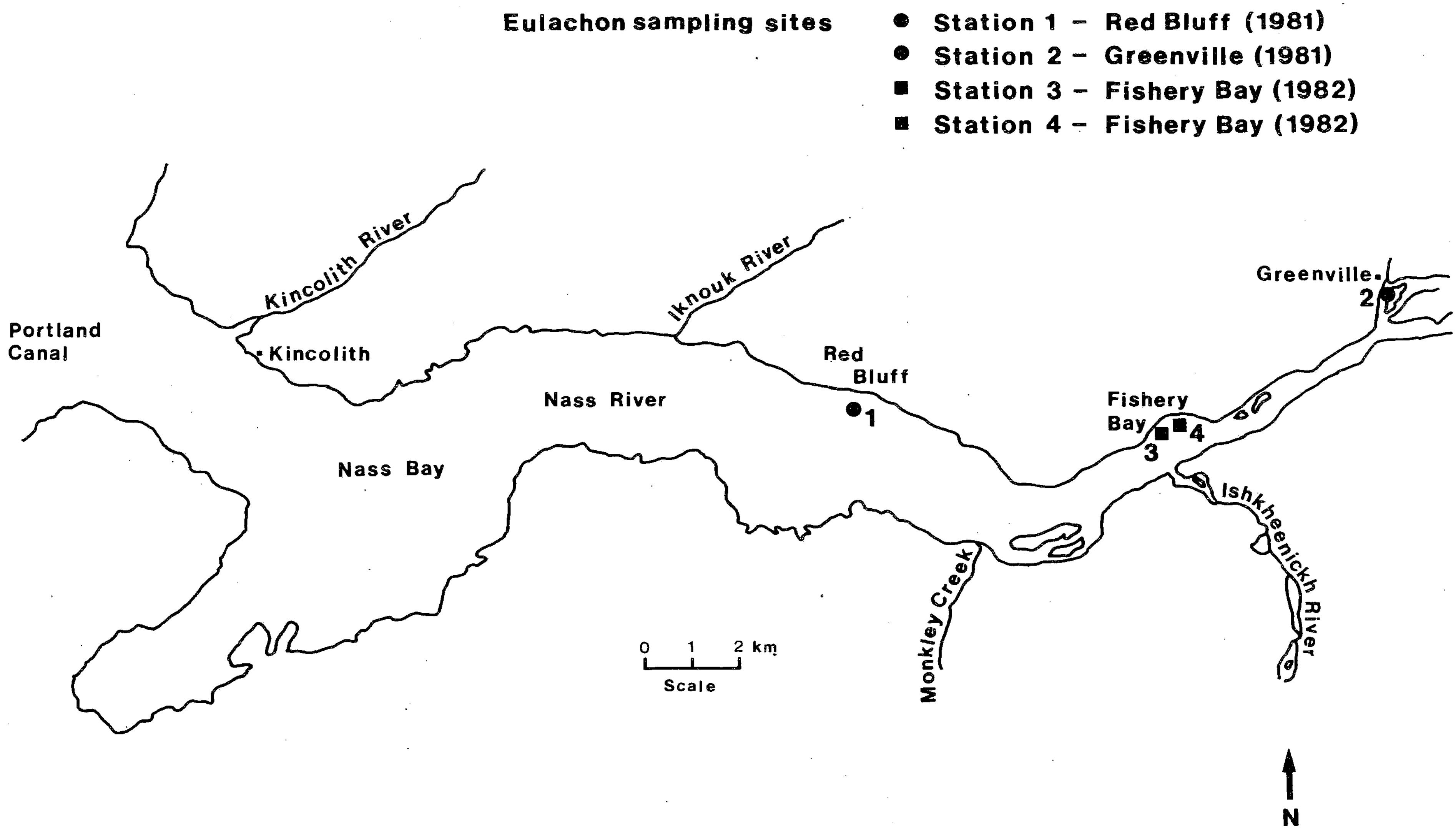
FIGURE 1

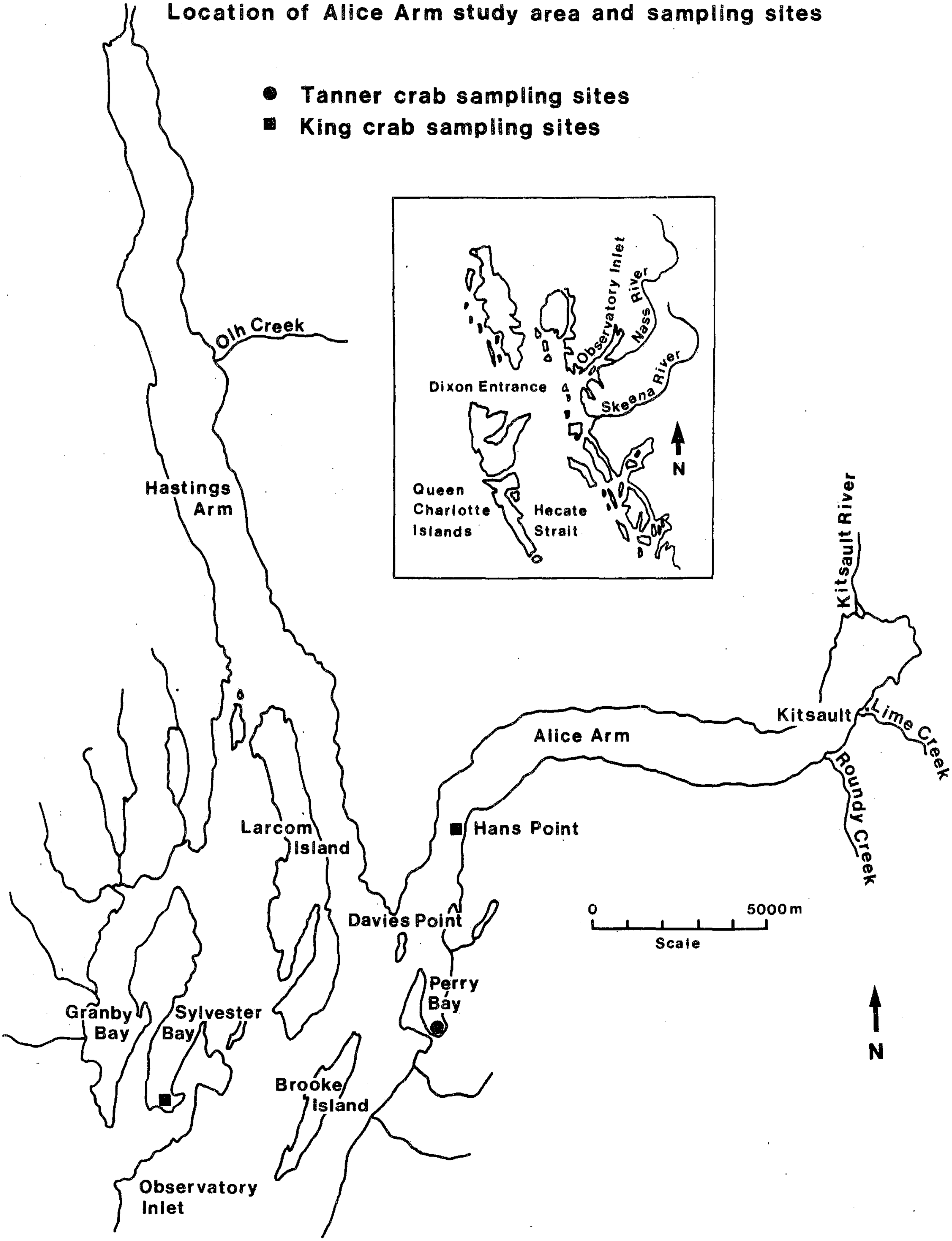
Location of Nass River study area and sampling sites



Source: Adapted from Langer et al. (1977)

FIGURE 2

Location of Alice Arm study area and sampling sites



Source: Adapted from Goyette (1981)

Table 1 - Metal content of Amax tailings, Nass River sediments, freshwater sediments in the Alice Arm drainage system and the earth's crust (adapted from Burling *et*. *al*. 1981).

	Total Metal Concentration (mg kg^{-1})								
Material	As	Cd	Cu	Pb	Mn	Hg	Mo	Ni	Zn
Tailings[a]	<1.7	8.6	15.8	52	365	<1.15	95	4.4	314
Nass River sediments[b]	13	-	44	10	1,375	0.088	2.5	51	122
Freshwater sediments, Alice Arm drainage[b]	29	-	58	23.5	1,734	0.134	7.9	40	176
Earth's crust	5	0.15	70	16	1,000	0.5	15	80	132

a: mean values (n=3 except for As and Hg where n=2)
b: average values

Table 2 - Detection limits for metal analyses

Metals in Tissue* (mg kg^{-1})

	1981	1982
As	3.8±0.2	2.5±0.2
Cd	0.2±0.05	0.1±0.05
Cr	0.4±0.05	0.3±0.05
Cu	0.3±0.03	0.3±0.03
Pb	2.0±0.1	1.0±0.1
Mn	0.05±0.003	0.05±0.003
Hg	-	0.10±0.02
Mo	0.8±0.05	0.3±0.05
Ni	2.0±0.2	1.0±0.2
Zn	0.3±0.05	0.1±0.05

* Metal detection limits in tissue were calculated assuming a dilution of one gram (dry weight) of tissue in 50 mls liquid during sample preparation except in the case of mercury (Hg) for which a dilution of 0.1 gram (dry weight) of tissue in 50 mls liquid was assumed. Any variation in the amount of tissue used in sample preparation results in a corresponding variation in tissue detection limits (less tissue leading to a higher detection limit). Thus detection limits actually vary somewhat with each sample prepared and for this reason, detection limits reported here should be viewed as estimates only.

NOTE: A modification in analytical technique resulted in improved detection limits for most metals in 1982 relative to 1981.

Table 3 - Metal levels in eulachon tissue (mg kg^{-1} Dry Weight)

Station	Sampling Date	Tissue Type	n	As $\bar{X} \pm SD$ (Range)	Cd $\bar{X} \pm SD$ (Range)	Cr $\bar{X} \pm SD$ (Range)	Cu $\bar{X} \pm SD$ (Range)	Pb $\bar{X} \pm SD$ (Range)	Mn $\bar{X} \pm SD$ (Range)	Hg $\bar{X} \pm SD$ (Range)	Mo $\bar{X} \pm SD$ (Range)	Ni $\bar{X} \pm SD$ (Range)	Zn $\bar{X} \pm SD$ (Range)
1 (Red Bluff)	19/03/81	Pooled sample of unknown no. bodies	1	ND	ND	0.9	4.8	ND	0.5	-	ND	ND	13.3
2 (Greenville)	22/03/81	Pooled sample of unknown no. bodies	1	ND	ND	1.0	4.9	ND	1.9	-	ND	ND	15.2
3 (Fishery Bay)	29/03/82	Individual body	10	* (ND-4.0)	* (ND-0.2)	0.9±0.4 (0.5-1.7)	4.3±0.8 (3.1-5.8)	* (ND-7.0)	2.3±1.8 (1.1-7.0)	0.1±0.0	ND	* (ND-2.0)	41.9±4.6 (37.1-49.8)
		Pooled sample of 10 bodies	3	3.0±0.0	ND	0.8±0.3 (0.5-1.0)	4.6±0.2 (4.5-4.8)	ND	1.8±0.3 (1.5-2.0)	0.2±0.1 (0.1-0.2)	ND	* (ND-5.0)	48.1±3.4 (45.0-51.8)
		Individual liver	10	* (ND-4.0)	0.6±0.3 (0.3-1.2)	1.1±0.4 (0.7-2.2)	32.7±11.4 (12.2-45.6)	* (ND-3.0)	5.3±2.1 (2.6-8.5)	-	* (ND-0.7)	* (ND-7.0)	(122.6±23.2) (85.2-156.0)
		Pooled sample of 10 livers	1	4.0	0.7	0.7	22.0	ND	4.0	0.2	ND	ND	113.0
4 (Fishery Bay)	29/03/82	Individual body	10	* (ND-4.0)	* (ND-0.1)	0.7±0.3 (0.3-1.4)	4.0±0.9 (1.9-5.0)	ND	1.6±0.5 (0.7-2.1)	0.2±0.0	* (ND-3.1)	* (ND-2.0)	46.8±11.9 (17.9-61.2)
		Pooled sample of 10 bodies	5	* (ND-3.0)	* (ND-0.2)	0.8±0.2 (0.5-1.1)	4.7±0.6 (4.0-5.5)	* (ND-1.0)	1.5±0.1 (1.3-1.6)	0.2±0.0	ND	* (ND-2.0)	49.2±3.0 (45.9-53.6)
		Individual liver	10	* (ND-5.0)	1.0±0.5 (0.2-1.4)	2.9±2.6 (0.7-7.5)	50.3±21.4 (16.6-85.7)	* (ND-17.0)	3.2±0.5 (2.5-3.9)	-	* (ND-1.1)	* (ND-13.0)	117.8±18.0 (95.3-135.0)
		Pooled sample of 10 livers	1	3.0	0.9	0.5	40.9	ND	2.9	0.2	0.6	ND	109.0

* Values below detection limits precluded calculation of mean and standard deviation

NOTE: ND - non-detectable

Table 4 - Metal levels in crab tissue (mg kg^{-1} Dry weight)

Species	Station	Sampling Date	Tissue Type	n	$\bar{X} \pm$ SD (Range)	$\bar{X} \pm$ SD (Range)	$\bar{X} \pm$ SD (Range)	$\bar{X} \pm$ SD (Range)	$\bar{X} \pm$ SD (Range)
King Crab (*Paralithodes camtschatica*)	Sylvester Bay	31/03/81	Leg tissue	1	As	Cd	Cr	Cu	Pb
					9.9	ND	1.1	59.1	ND
					Mn	Hg	Mo	Ni	Zn
					1.1	--	ND	ND	224.0
King Crab (*Paralithodes camtschatica*)	Hans Point	01/04/81	Leg tissue	2	As	Cd	Cr	Cu	Pb
					40.1±2.3	*	2.4±1.8	80.1±5.7	ND
					(38.5-41.7)	(ND-0.6)	(1.1-3.6)	(76.0-84.1)	
					Mn	Hg	Mo	Ni	Zn
					3.9±1.5	--	ND	ND	206.0±1.4
					(2.8-4.9)				(205.0-207.0)
Tanner Crab (*Chionoecetes bairdi*)	Perry Bay	02/04/81	Leg Tissue	2	As	Cd	Cr	Cu	Pb
					44.3±7.1	ND	*	58.7±13.5	ND
					(39.3-49.3)		(ND-0.8)	(49.1-68.2)	
					Mn	Hg	Mo	Ni	Zn
					0.7±0.1	--	ND	ND	153.0±1.4
					(0.6-0.7)				(152.0-154.0)

* Values below detection limits precluded calculation of mean and standard deviation.

NOTE: ND - non-detectable

Table 5 - Two way analysis of variance comparison of metal content of fish tissues between stations

SOURCE	SUM OF SQUARES	D. F.	MEAN SQUARE	F	PROBS	
Cu						
MEAN	10783.	1	10783.	76.02322	0.00000	
STATION	627.36	1	627.36	4.42323	0.04121	*
TISSUE	16385.	2	8192.6	57.76234	0.00000	*
ERROR	6240.6	44	141.83			
Cr						
MEAN	53.925	1	53.925	31.41232	0.00000	
STATION	5.0579	1	5.0579	2.94634	0.09311	NS
TISSUE	18.211	2	9.1054	5.30409	0.00864	*
ERROR	75.534	44	1.7167			
Mn						
MEAN	277.02	1	277.02	154.08771	0.00000	
STATION	18.913	1	18.913	10.51972	0.00226	*
TISSUE	63.719	2	31.859	17.72098	0.00000	*
ERROR	79.105	44	1.7978			
Zn						
MEAN	0.20100E +06	1	020100E +06	929.36475	0.00000	
STATION	0.58022	1	0.58022	0.00268	0.95893	NS
TISSUE	64917.	2	32458.	150.07841	0.00000	*
ERROR	9516.2	44	216.28			

SOURCE	SUM OF SQUARES	D. F.	MEAN SOURCE	F	PROB	
As						
MEAN	156.06	1	156.06	387.45288	0.00000	
STATION	0.50000	1	0.50000	1.24139	0.28166	NS
ERROR	6.4444	16	0.40277			
Cd						
MEAN	13.285	1	13.285	75.55237	0.00000	
STATION	0.76050	1	0.76050	4.32516	0.05212	NS
ERROR	3.1650	18	0.17583			
Hg						
MEAN	0.54070	1	0.54070	943.64502	0.00000	
STATION	0.26998E-01	1	0.26998E-01	47.11765	0.00000	*
TISSUE	0.42771E-02	1	0.42771E-02	7.46449	0.01162	*
ERROR	0.13752E-01	24	0.57299E-03			

NS - Not statistically significant at alpha = 0.05

* - Statistically significant at alpha = 0.05

For comparison of Cu, Cr, Mn and Zn levels in eulachons between Stations 3 and 4 all data were pooled for individual eulachons, pooled samples of eulachons and individual livers. For As and Cd, values below detection limits precluded utilization of data except for As in individual eulachons and Cd in individual livers. These data were used to compare As and Cd levels between Stations 3 and 4. No comparisons were made between levels of As and Cd in the various tissue types. Because insufficient data were available for comparisons of Hg levels in liver tissue, only data for individual eulachons and pooled samples of eulachon were used. Values below detectable limits precluded statistical treatment of Pb, Mo and Ni data.

Table 6 - Newman - Keul's Multiple Range Test
comparison of metal content between fish tissues

	Predicted Means		
Metal	Individual Eulachons	Pooled Eulachon Samples	Individual Livers
Chromium	0.7700	0.7184	2.005
Copper	4.145	3.729	41.52
Manganese	1.953	1.739	4.226
Mercury	-	-	-
Zinc	44.32	48.80	120.2

Notes:

1. Solid lines under groups indicate homogenous subsets ($p<0.05$)

2. Values below detection limits precluded statistical treatment of arsenic, cadimium, lead, molybdenum and nickel data.

3. No data were available for mercury levels in individual livers. As comparisons were therefore only possible between concentrations of mercury in individual bodies and pooled samples of bodies, it was not appropriate to subject the data to Newman - Keul's Test.

Table 7 - Summary of metal levels in fish tissue reported in previous studies carried out in British Columbia

Species	Location (Sampling date)	Tissue Type	n	As $\bar{X}$±SD (Range)	Cd $\bar{X}$ ± SD (Range)	Cr $\bar{X}$ ± SD (Range)	Cu $\bar{X}$ ± SD (Range)	Mn $\bar{X}$ ± SD (Range)	Hg $\bar{X}$ ± SD (Range)	Mo $\bar{X}$ ± SD (Range)	Ni $\bar{X}$ ± SD (Range)	Pb $\bar{X}$ ± SD (Range)	Zn $\bar{X}$ ± SD (Range)	Reference
Rockfish (*Sebastes spp.*)	Southern B.C. (1971-3&1976)	muscle	**	-	0.44±0.17 (<0.13-1.00)	-	2.66±2.16 (1.00-10.60)	-	0.26±0.26*** (0.05-1.02)	-	1.46±0.48 (0.33-1.90)	1.32±0.86 (<0.31-4.40)	21.78±15.22 (11.00-80.00)	Harbo *et al.* (In prep.)
Pacific herring (*Clupea harengus*)	Southern B.C. (1971-3&1976)	muscle	**	-	-	-	1.00	-	0.07±0.01*** (0.06-0.09)	-	2.10	-	16.45±9.12 (10.00-22.90)	Harbo *et al.* (In prep.)
Yellowfin sole (*Limanda aspera*)	Alice & Hastings Arms & Observatory Inlet (1974-1977)	-	**	-	10.9±2.05	-	23.3±2.08	-	-	ND	-	13.8±2.42	92.4±7.61	Littlepage (1978)
Great sculpin (*Myoxocephalus polyacanthocephalus*)	Alice & Hastings Arms & Observatory Inlet (1974-1977)	-	**	-	3.0±0.39	-	25.6±4.46	-	-	ND	-	4.2±0.48	149.9±11.79	Littlepage (1978)
Pollock (*Theragra calcogramma*)	Alice Arm A-1 & A-2 (1978)	muscle/skin	4	19.95±8.28 (12.3-30.0)	ND	* (ND-1.20)	8.39±5.51 (2.8-15.7)	-	0.24±0.09 (0.15-0.35)	ND	-	* (ND-4.4)	23.40±3.29 (18.5-25.6)	Goyette (1981)
Pollock (*T. calcogramma*)	Alice Arm A-1&A-3 (1978)	whole body	4	14.75±3.24 (12.1-19.3)	ND	* (ND-2.33)	7.28±2.47 (4.37-9.55)	-	0.13±0.02 (0.11-0.15)	ND	-	ND	38.10±4.43 (35.2-44.7)	Goyette (1981)
Pollock (*T. calcogramma*)	Alice Arm A-1 (May 1980)	muscle	2	20±3 (18-22)	* (ND-0.23)	ND	6.1±0.4 (5.9-6.4)	-	-	ND	-	0.23±0.02 (0.21-0.24)	22.8±4.8 (19.4-26.2)	Goyette and Christie (In prep.a)
Pollock (*T. calcogramma*)	Alice Arm A-3 (May-Jun.81)	muscle	3	32±8 (25-40)	ND	2.07±1.22 (1.00-3.40)	7.5±1.8 (6.2-9.6)	1.15±0.44 (0.74-1.61)	-	ND	* (ND-1.0)	0.69±0.54 (0.06-1.00)	27.3±6.1 (21.6-33.8)	Goyette and Christie (In prep.b)
Pollock (*T. calcogramma*)	Alice Arm A-3 (Oct.1981)	muscle	1	34	0.40	1.50	7.0	2.63	-	ND	4.0	0.16	25.3	Goyette and Christie (In prep.b)
Pollock (*T. calcogramma*)	Hastings Arm H-3 (1978)	muscle/skin	2	30.80±16.40 (19.2-42.4)	ND	1.38±0.22 (1.22-1.53)	6.55±0.11 (6.47-6.63)	-	0.197±0.001 (0.196-0.198)	ND	-	ND	24.45±0.07 (24.4-24.5)	Goyette (1981)
Pollock (*T. calcogramma*)	Hastings Arm H-4 (1978)	whole body	1	ND	ND	1.74	17.3	-	0.133	ND	-	ND	59.3	Goyette (1981)

Table 7 - Cont'd

Species	Location (Sampling Date)	Tissue Type	n	As $\bar{X}$±SD (Range)	Cd $\bar{X}$ ± SD (Range)	Cr $\bar{X}$ ± SD (Range)	Cu $\bar{X}$ ± SD (Range)	Mn $\bar{X}$ ± SD (Range)	Hg $\bar{X}$ ± SD (Range)	Mo $\bar{X}$ ± SD (Range)	Ni $\bar{X}$ ± SD (Range)	Pb $\bar{X}$ ± SD (Range)	Zn $\bar{X}$ ± SD (Range)	Reference
Pollock (*T. calcogramma*)	Chatham Sound C-1 (May 1981)	muscle	2	23±18 (11-36)	6.04±8.43 (0.08-12.00)	2.85±1.91 (1.50-4.20)	9.8±4.5 (6.6-13.0)	1.50±0.99 (0.80-2.20)	-	ND	1.0±0	* (ND-3.00)	31.9±14.4 (21.7-42.1)	Goyette and Christie (In prep.a)
Sole (unidentified)	Alice Arm A-1 (1977)	muscle	1	-	ND	-	9.6	-	-	-	-	ND	32.0	Goyette (1981)
Sole (unidentified)	Hastings Arm H-1 (1977)	muscle	1	-	ND	-	6.1	-	-	-	-	ND	17.0	Goyette (1981)
Flathead sole (*Hippoglossoides elassodon*)	Alice Arm A-1 (1978)	muscle/skin	1	19.1	ND	ND	4.2	-	0.194	ND	-	ND	23.6	Goyette (1981)
Flathead sole (*H. elassodon*)	Alice Arm A-1 (May 1980)	muscle	5	52±22 (29-86)	* (ND-0.05)	ND	5.6±0.9 (4.6-6.7)	-	-	ND	-	0.41±0.27 (0.21-0.87)	19.8±1.7 (17.6-21.6)	Goyette and Christie (In prep.a)
Flathead sole (*H. elassodon*)	Alice Arm (1981)	muscle	21	49.63±29.15 (7.44-121.36)	ND	-	* (ND-1.64)	-	-	ND	-	* (ND-0.15)	22.16±6.15 (12.94-34.60)	Amax (1981)
Flathead sole (*H. elassodon*)	Chatham Sound C-1 (May 1981)	muscle	7	29±16 (8-50)	* (ND-1.10)	2.00±1.64 (0.80-5.40)	5.0±1.8 (2.5-8.1)	1.00±0.26 (0.69-1.42)	-	* (ND-0.30)	* (ND-9.0)	* (ND-2.00)	18.6±2.4 (16.0-22.5)	Goyette and Christie (In prep.a)
Rock sole (*Lepidopsetta bilineata*)	Alice Arm A-3 (October 1980)	muscle	1	80	0.10	1.00	7.5	2.66	-	ND	1.0	ND	46.5	Goyette and Christie (In prep.a)
Dover sole (*Microstomus pacificus*)	Alice Arm A-1 (October 1980)	muscle	1	126	ND	0.50	3.4	1.81	-	ND	ND	0.18	15.4	Goyette and Christie (In prep.a)
Dover sole (*M. pacificus*)	Quatsino Sound Q-1 (September 1981)	muscle	1	195	0	1.36	10.4	0.58	-	ND	ND	ND	20.4	Goyette and Christie (In prep.a)

Table 7 - Cont'd

Species	Location (Sampling Date)	Tissue Type	n	As X̄+SD (Range)	Cd X̄ + SD (Range)	Cr X̄ + SD (Range)	Cu X̄ + SD (Range)	Mn X + SD (Range)	Hg X̄ + SD (Range)	Mo X̄ + SD (Range)	Ni X̄ + SD (Range)	Pb X̄ + SD (Range)	Zn X̄ + SD (Range)	Reference
English sole (Parophrys vetulus)	Alice Arm A-3 (October 1980)	muscle	6	28+23 (12-71)	ND	0.65+0.16 (0.40-0.90)	5.6+5.6 (1.3-16.6)	2.37+1.21 (0.91-4.17)	-	ND	* (ND-7.0)	* (ND-0.34)	33.1+7.2 (23.5-42.8)	Goyette and Christie (In prep.a)
English sole (P. vetulus)	Alice Arm A-3 (May/June 1981)	muscle	4	78+20 (49-92)	ND	1.20+0.33 (0.80-1.60)	3.9+0.7 (3.0-4.6)	1.29+0.18 (1.03-1.41)	-	* (ND-0.20)	ND	1.31+1.19 (0.22-3.00)	24.0+2.7 (21.8-27.8)	Goyette and Christie (In prep.b)
English sole (P. vetulus)	Alice Arm A-3 (October 1981)	muscle	3	96+79 (41-186)	0.10+0	1.00+0.20 (0.80-1.20)	8.8+4.8 (5.5-14.3)	1.88+1.05 (1.11-3.08)	-	ND	1.7+0.6 (1.0-2.0)	0.41+0.52 (0.05-1.00)	27.4+1.3 (26.1-28.7)	Goyette and Christie (In prep.b)
Petrale sole (Eopsetta jordani)	Alice Arm A-3 (May-June 1981)	muscle	3	131+14 (115-142)	ND	2.40+1.47 (1.10-4.00)	4.4+1.6 (3.0-6.2)	2.65+0.61 (1.95-3.08)	-	ND	* (ND-5.0)	2.38+2.00 (0.14-4.00)	22.4+3.0 (20.3-25.9)	Goyette and Christie (In prep.b)
Petrale sole (E. jordani)	Alice Arm A-3 (October 1981)	muscle	3	61+36 (25-96)	* (ND-0.10)	0.90+0.17 (0.70-1.00)	3.7+0.4 (3.4-4.2)	1.72+0.24 (1.55-2.00)	-	ND	* (ND-1.0)	* (ND-0.14)	22.5+2.3 (20.0-24.5)	Goyette and Christie (In prep.b)
Petrale sole (E. jordani)	Quatsino Sound Q-1 (September 1981)	muscle	3	76+26 (50-102)	ND	* (ND-1.83)	3.8+2.2 (2.5-6.3)	0.41+0.07 (0.33-0.46)	-	ND	ND	ND	16.5+0.2 (16.4-16.7)	Goyette and Christie (In prep.a)
Slender sole (Lyopsetta exilis)	Alice Arm A-3 (May/June 1981)	muscle	2	13+5 (9-16)	* (ND-0.10)	1.60+0.85 (1.00-2.20)	4.6+1.3 (3.6-5.5)	2.09+1.09 (1.32-2.86)	-	ND	ND	1.66+1.90 (0.31-3.00)	18.6+1.8 (17.3-19.9)	Goyette and Christie (In prep.b)
Slender sole (L. exilis)	Alice Arm (1981)	muscle	23	38.79+27.11 (8.81-122.86)	ND	-	* (ND-2.10)	-	-	ND	-	* (ND-0.28)	22.60+5.03 (15.42-33.22)	Amax (1981)
Arrowtooth flounder (Atheresthes stomias)	Alice Arm A-1 (May 1980)	muscle	2	18+7 (13-23)	ND	ND	4.5+0.6 (4.1-4.9)	-	-	ND	-	* (ND-0.61)	21.3+4.0 (18.5-24.1)	Goyette and Christie (In prep.a)
Arrowtooth flounder (A. stomias)	Quatsino Sound Q-1(Sept.1981)	muscle	1	ND	ND	0.81	3.3	0.14	-	ND	ND	ND	17.6	Goyette and Christie (In prep.a)

Table 7 - Cont'd

Species	Location (Sampling Date)	Tissue Type	n	As $\bar{X} \pm SD$ (Range)	Cd $\bar{X} \pm SD$ (Range)	Cr $\bar{X} \pm SD$ (Range)	Cu $\bar{X} \pm SD$ (Range)	Mn $\bar{X} \pm SD$ (Range)	Hg $\bar{X} \pm SD$ (Range)	Mo $\bar{X} \pm SD$ (Range)	Ni $\bar{X} \pm SD$ (Range)	Pb $\bar{X} \pm SD$ (Range)	Zn $\bar{X} \pm SD$ (Range)	Reference
Arrowtooth flounder (*A. stomias*)	Chatham Sound C-1 (May 1981)	muscle	3	25±11 (14-35)	ND	1.17±0.35 (0.80-1.50)	5.7±3.3 (2.9-9.3)	0.75±0.21 (0.60-0.99)	-	* (ND-0.70)	1.7±1.2 (1.0-3.0)	* (ND-2.00)	21.1±3.9 (17.2-25.0)	Goyette and Christie (In prep.a)
Rex sole (*Glyptocephalus zachirus*)	Quatsino Sound Q-1 (September 1981)	muscle	1	128	ND	0.79	2.9	2.01	-	ND	ND	ND	22.5	Goyette and Christie (In prep.a)
Rex sole (*G. zachirus*)	Chatham Sound C-1 (May 1981)	muscle	7	59±12 (37-70)	* (ND-0.50)	0.97±0.15 (0.70-1.10)	6.7±10.2 (1.9-29.8)	1.15±0.57 (0.71-2.38)	-	ND	* (ND-8.0)	* (ND-1.00)	17.2±3.9 (12.5-24.9)	Goyette and Christie (In prep.a)

* Values below detection limits precluded calculation of mean and standard deviation.

** n values are as follows:
Rockfish: Cd-31; Cu-34; Pb-35; Hg-49; Ni-8; Zn-40
Pacific herring: Cu, Ni-1; Hg-4; Zn-2
Yellowfin sole: Cu-15; Cd, Pb, Mo, Zn-16
Great sculpin: Cu-13; Cd, Pb, Mo-15; Zn-14

*** Mercury (Hg) values are in mg kg^{-1} wet weight for data from Harbo *et al*. (In prep.).

NOTE:

(1) ND - non-detectable

(2) Means, standard deviations and ranges for Goyette (1981), Goyette and Christie (In prep.a,b) and Amax (1981) data have been calculated from raw data provided in the reports; those for Harbo *et al*. (In prep.) are presented here as they appear in the original report.

Table 8 - Summary of metal levels in crab tissue reported in previous studies carried out in British Columbia

Species	Location (Sampling date)	Tissue Type	n	As $\bar{X}$±SD (Range)	Cd $\bar{X}$ ± SD (Range)	Cr $\bar{X}$ ± SD (Range)	Cu $\bar{X}$ ± SD (Range)	Mn $\bar{X}$ ± SD (Range)	Hg $\bar{X}$ ± SD (Range)	Mo $\bar{X}$ ± SD (Range)	Ni $\bar{X}$ ± SD (Range)	Pb $\bar{X}$ ± SD (Range)	Zn $\bar{X}$ ± SD (Range)	Reference
Red Rock Crab (*Cancer productus*)	Southern BC (1971-3 & 1976)	edible tissue	**	-	0.53±0.11 (0.50-1.00)	-	29.98±16.05 (14.00-96.00)	-	0.12±0.14* (0.02-0.65)	-	2.17±1.87 (0.70-5.80)	1.24±0.71 (0.48-3.00)	252.59±45.97 (190.00-360.00)	Harbo *et al.* (In prep.)
Dungeness Crab (*C. magister*)	Southern BC (1971-3 & 1976)	edible tissue	**	-	0.51±0.25 (0.20-2.00)	-	40.87±17.37 (4.50-87.00)	-	0.15±0.11* (0.03-0.59)	-	1.84±1.40 (0.90-5.70)	1.73±1.00 (0.20-3.52)	195.21±51.56 (18.00-430.00)	Harbo *et al.* (In prep.)
Dungeness Crab (*C. magister*)	Alice Arm Lime Creek (1976/77)	leg muscle	2	-	0.68±0.06 (0.63-0.72)	-	35.0±0.0	-	-	-	-	1.35±0.2 (1.2-1.5)	195.0±21.2 (180.0-210.0)	Goyette (1981)
Dungeness Crab (*C. magister*)	Alice & Hasting Arms & Observatory Inlet (1974-1977)	-	**	-	1.0±0.23	-	64.6±5.71	-	-	1.4±0.14	-	3.5±0.51	247.0±17.06	Littlepage (1978)
King crab (*Paralithodes camtschatica*)	Alice Arm A-3 (May-June 1981)	leg muscle	1	28	0.10	1.10	52.9	1.93	-	ND	1.0	2.00	221.0	Goyette and Christie (In prep.b)
King Crab (*P. camtschatica*)	Hastings Arm H-1 (June 1977)	leg muscle	1	-	ND	-	47.0	-	-	-	-	ND	200.0	Goyette (1981)
Brown King crab (*Lithodes aequispina*)	Alice & Hastings Arms & Observatory Inlet (1974-1977)	-	6	-	0.3±0.03	-	147.9±11.32	-	-	1.2±0.13	-	1.8±0.57	216.0±6.70	Littlepage (1978)
Brown King crab (*L. aequispina*)	Alice Arm A-1 (May 1980)	leg muscle	1	49	ND	ND	4.0	-	-	ND	-	0.12	17.9	Goyette and Christie (In prep.a)
Brown King crab (*L. aequispina*)	Alice Arm A-1 (October 1980)	leg muscle	1	164	0.80	1.30	91.8	9.66	-	ND	2.0	0.05	215.0	Goyette and Christie (In prep.a)

Table 8 Continued

Species	Location (Sampling date)	Tissue Type	n	As $\bar{X}$±SD (Range)	Cd $\bar{X}$ ± SD (Range)	Cr $\bar{X}$ ± SD (Range)	Cu $\bar{X}$ ± SD (Range)	Mn $\bar{X}$ ± SD (Range)	Hg $\bar{X}$ ± SD (Range)	Mo $\bar{X}$ ± SD (Range)	Ni $\bar{X}$ ± SD (Range)	Pb $\bar{X}$ ± SD (Range)	Zn $\bar{X}$ ± SD (Range)	Reference
Brown King crab (*L. aequispina*)	Alice Arm A-1 (October 1981)	leg muscle	1	115	0.20	1.50	99.8	6.55	-	0.40	3.0	ND	214.0	Goyette and Christie (In prep.b)
Brown King crab (*L. aequispina*)	Alice Arm A-2 (October 1981)	leg muscle	2	133±9 (126–139)	0.30±0.14 (0.20–0.40)	0.80±0.00	85.7±24.4 (68.5–103.0)	10.66±8.55 (4.61–16.70)	-	ND	1.0±0.0	* (ND-2.00)	172.5±12.0 (164.0–181.0)	Goyette and Christie (In prep.b)
Brown King crab (*L. aequispina*)	Hastings Arm H-1 (June 1977)	leg muscle	2	-	1.55±0.5 (1.2–1.9)	-	24.5±2.1 (23.0–26.0)	-	-	-	-	ND	225.0±7.1 (220.0–230.)	Goyette (1981)
Crab (*Lithodes spp.*)	Alice Arm A-1 & A-2 (October 1978)	leg muscle	5	105.0±20.7 (91.4–141.0)	ND	1.2±0.2 (1.02–1.46)	50.0±22.5 (25.1–83.7)		ND	ND	-	ND	186.8±6.9 (179.0–194.0)	Goyette (1981)
Crab (*L. spp.*)	Hastings Arm H-2 (October 1978)	leg muscle	1	104.0	ND	ND	85.3	-	ND	ND	-	ND	189.0	Goyette (1981)
Tanner crab (*Chionoecetes bairdi*)	Alice & Hastings Arms & Observatory Inlet (1974-1977)	-	6	-	0.8±0.15	-	50.5±5.06	-	-	ND	-	0.8±0.09	212.3±23.07	Littlepage (1978)
Tanner crab (*C. bairdi*)	Alice Arm A-1 (October 1980)	leg muscle	1	56	0.20	0.50	57.9	26.10	-	ND	2.0	1.00	131.0	Goyette and Christie (In prep.a)
Tanner crab (*C. bairdi*)	Alice Arm A-3 (October 1980)	leg muscle	1	111	0.20	0.50	53.7	2.36	-	ND	4.0	1.00	116.0	Goyette and Christie (In prep.a)
Tanner crab (*C. bairdi*)	Alice Arm A-1 (May-June 1981)	leg muscle	2	72±21 (57–86)	0.30±0.00	0.80±0.14 (0.70–0.90)	42.8±0.7 (42.3–43.3)	62.80±62.51 (18.60–107.00)	-	0.45±0.21 (0.30–0.60)	1.0±0.0	2.00±0.00	120.0±26.9 (101.0–139.0)	Goyette and Christie (In prep.b)

Table 8 Continued

Species	Location (Sampling Date)	Tissue Type	n	As $\bar{X}$ ± SD (Range)	Cd $\bar{X}$ ± SD (Range)	Cr $\bar{X}$ ± SD (Range)	Cu $\bar{X}$ ± SD (Range)	Mn $\bar{X}$ ± SD (Range)	Hg $\bar{X}$ ± SD (Range)	Mo $\bar{X}$ ± SD (Range)	Ni $\bar{X}$ ± SD (Range)	Pb $\bar{X}$ ± SD (Range)	Zn $\bar{X}$ ± SD (Range)	Reference
Tanner crab (<u>C. bairdi</u>)	Alice Arm A-3 (May-June 1981)	leg muscle	2	79±1 (79-80)	ND	1.00±0.57 (0.60-1.40)	26.7±5.9 (22.6-30.9)	0.35±0.09 (0.29-0.42)	-	ND	ND	1.00±0.00	109.0±17.0 (97.0-121.00)	Goyette and Christie (In prep.b)
Tanner crab (<u>C. bairdi</u>)	Alice Arm A-1 (October 1981)	leg muscle	2	145±7 (140-150)	0.30±0.00	1.05±0.07 (1.00-1.10)	44.8±6.1 (40.5-49.1)	23.45±10.68 (15.90-31.00)	-	* (ND-1.60)	* (ND-1.0)	3.00±1.41 (2.00-4.00)	122.0±4.2 (119.0-125.0)	Goyette and Christie (In prep.b)
Tanner crab (<u>C. bairdi</u>)	Alice Arm A-1 (October 1981)	leg muscle	3	134±7 (127-141)	0.87±0.46 (0.60-1.40)	0.93±0.15 (0.80-1.10)	48.1±23.3 (34.1-75.0)	25.92±25.35 (6.15-54.50)	-	0.30±0.00	* (ND-2.0)	* (ND-2.00)	137.3±10.7 (128.0-149.0)	Goyette and Christie (In prep.b)
Tanner crab (<u>C. bairdi</u>)	Alice Arm A-2 (October 1981)	leg muscle	1	207	0.50	0.60	77.5	47.90	-	ND	ND	0.24	134.0	Goyette and Christie (In prep.b)
Tanner crab (<u>C. bairdi</u>)	Alice Arm A-3 (October 1981)	leg muscle	1	119	0.21	0.50	73.0	2.80	-	ND	ND	ND	130.0	Goyette and Christie (In prep.b)
Tanner crab (<u>C. bairdi</u>)	Hastings Arm H-1 (May-June 1981)	leg muscle	3	137±37 (111-179)	0.53±0.21 (0.30-0.70)	0.83±0.15 (0.70-1.00)	85.5±8.4 (75.8-90.6)	37.07±20.12 (19.90-59.20)	-	* (ND-0.30)	* (ND-2.0)	2.00±0.00	132.0±24.2 (110.0-158.0)	Goyette and Christie (In prep.b)
Tanner crab (<u>C. bairdi</u>)	Hastings Arm H-2 (Oct.1981)	leg muscle	3	125±32 (89-147)	0.43±0.21 (0.20-0.60)	0.77±0.21 (0.60-1.00)	46.1±9.5 (35.3-53.1)	32.89±35.36 (5.86-72.90)	-	* (ND-0.30)	* (ND-1.0)	* (ND-1.00)	129.7±17.0 (112.0-146.0)	Goyette and Christie (In prep.b)

* Mercury (Hg) values are in mg kg^{-1} wet weight for data from Harbo <u>et al</u>.(In prep.).

** N values are as follows: Red rock crab: Cd-23; Cu-30; Hg-36; Ni-6; Pb-25; Zn-29
Dungeness crab (Harbo <u>et al</u>. In prep.): Cd-50; Cu-70; Hg-93; Ni-11; Pb-29; Zn-70
Dungeness crab (Littlepage 1978): Cd-7; Cu, Zn-14; Pb-13; Mo-4

NOTE: (1) ND - non-detectable.
(2) Means, standard deviations and ranges for Goyette (1981) and Goyette and Christie (In prep. a, b) data have been calculated from raw data provided in the reports; those for Harbo <u>et al</u>.(In prep.) are presented here as they appear in the original report.

Appendix 1 - Results of metal analyses of eulachon and crab tissue - 1981 (mg kg^{-1} Dry Weight)

Species	Station	Sampling Date	Tissue Type	n	As	Cd	Cr	Cu	Pb	Mn	Hg	Mo	Ni	Zn
Eulachon * (*Thaleichthys pacificus*)	1-Red Bluff	19/03/81	Pooled sample of unknown no. bodies	1	<7.3	<0.4	0.9	4.8	<3.9	0.5	-	<1.5	<3.9	13.3
Eulachon (*T. pacificus*)	2-Greenville	22/03/81	Pooled sample of unknown no. bodies	1	<7.2	<0.4	1.0	4.9	<3.9	1.9	-	<1.4	<3.9	15.2
King Crab (*Paralithodes camtschatica*)	Head of Sylvester Bay	31/03/81	Leg tissue	1	9.9	<0.4	1.1	59.1	<4.0	1.1	-	<1.5	<4.0	224.0
King Crab (*P. camtschatica*)	1/2 mi. south of Hans Pt; 15 fathoms	01/04/81	Leg tissue	1	38.5	<0.4	1.1	84.1	<4.0	2.8	-	<1.5	<4.0	207.0
King Crab (*P. camtschatica*)	1/2 mi. south of Hans Pt; 15 fathoms	01/04/81	Leg tissue	1	41.7	0.6	3.6	76.0	<3.9	4.9	-	<1.5	<3.9	205.0
Tanner Crab (*Chionoecetes bairdi*)	Perry Bay	02/04/81	Leg tissue	1	39.3	<0.4	0.8	49.1	<3.8	0.7	-	<1.4	<3.8	154.0
Tanner Crab (*C. bairdi*)	Perry Bay 15 fathoms	02/04/81	Leg tissue	1	49.3	<0.4	<0.7	68.2	<3.9	0.6	-	<1.5	<3.9	152.0

* NOTE: Metal values for this sample are means of two subsample values.

Appendix II - Results of metal analyses of eulachon tissue - 1982 (mg kg^{-1} Dry Weight)

							Metal Levels						
Station	Sampling Date	Tissue Type	n	As	Cd	Cr	Cu	Pb	Mn	Hg	Mo	Ni	Zn
3 - Fishery Bay	29/03/82	Individual body	1	3.0	<0.1	0.5	3.4	1.0	1.4	0.1	<0.2	1.0	34.5
			1	2.0	<0.1	0.6	4.5	<1.0	1.4	0.1	<0.2	<1.0	45.4
			1	3.0	0.1	1.7	4.6	2.0	7.0	0.1	<0.2	2.0	45.9
			1	<3.0	<0.1	1.0	5.3	1.0	2.0	0.1	<0.3	2.0	49.8
			1	4.0	<0.1	1.6	5.8	<1.0	1.8	0.1	<0.2	2.0	40.4
			1	2.0	<0.1	0.7	4.3	<1.0	1.4	0.1	<0.2	2.0	43.4
			1	3.0	<0.1	0.6	3.1	<1.0	2.0	0.1	<0.2	<1.0	40.0
			1	2.0	<0.1	0.5	4.4	<1.0	1.5	0.1	<0.2	<1.0	38.5
			1	3.0	<0.1	1.0	4.4	7.0	3.7	0.1	<0.2	2.0	43.7
			1	3.0	0.2	0.6	3.4	<1.0	1.1	0.1	<0.2	1.0	37.1
3 - Fishery Bay	29/03/82	Pooled sample of	10	3.0	<0.1	1.0	4.5	<1.0	1.8	0.1	<0.2	<1.0	47.6
		bodies	10	3.0	<0.1	0.8	4.8	<1.0	2.0	0.2	<0.3	5.0	51.8
			10	3.0	<0.1	0.5	4.5	<1.0	1.5	0.2	<0.2	<1.0	45.0
3 - Fishery Bay	29/03/82	Individual livers	1	3.0	0.3	1.0	37.4	<1.0	3.0	0.3	<0.2	2.0	85.2
			1	<6.0	0.3	2.2	45.6	<2.0	7.1	-	<0.6	5.0	144.0
			1	4.0	0.6	0.9	17.0	<1.0	4.3	-	<0.3	2.0	85.4
			1	<4.0	0.8	1.3	12.2	<2.0	5.5	-	<0.4	<2.0	120.0
			1	4.0	0.5	0.7	38.3	<1.0	5.6	-	<0.3	<1.0	115.0
			1	<8.0	1.2	1.3	38.0	3.0	2.8	-	<0.8	7.0	156.0
			1	<6.0	0.3	0.9	43.7	<3.0	2.6	-	0.7	<3.0	129.0
			1	<6.0	0.9	1.0	22.4	<2.0	8.5	-	<0.6	2.0	128.0
			1	<4.0	0.9	1.0	36.8	<2.0	7.3	-	<0.4	<2.0	141.0
			1	<5.0	0.4	1.0	35.9	<2.0	6.5	-	<0.5	<2.0	122.0
3 - Fishery Bay	29/03/82	Pooled Sample of livers	10	4.0	0.7	0.7	22.0	<1.0	4.0	0.2	<0.2	<1.0	113.0

Appendix II Cont'd

Station	Sampling Date	Tissue Type	n	Metal Levels									
				As	Cd	Cr	Cu	Pb	Mn	Hg	Mo	Ni	Zn
4 - Fishery Bay	29/03/82	Individual body	1	3.0	<0.1	0.5	4.2	<1.0	1.4	0.2	<0.2	<1.0	43.7
			1	2.0	<0.1	0.7	4.7	<1.0	2.1	0.2	<0.2	1.0	61.2
			1	3.0	<0.1	0.8	3.7	<1.0	2.0	0.2	<0.2	1.0	50.2
			1	3.0	<0.1	0.6	4.7	<1.0	1.2	0.2	<0.2	<1.0	43.5
			1	3.0	<0.1	0.5	5.0	<1.0	1.8	0.2	3.1	1.0	42.5
			1	4.0	<0.1	0.6	3.9	<1.0	1.6	-	<0.3	2.0	54.7
			1	3.0	0.1	1.4	4.0	<1.0	2.0	0.2	<0.2	1.0	45.5
			1	4.0	<0.1	0.6	3.3	<1.0	1.8	0.2	<0.2	<1.0	56.5
			1	3.0	<0.1	0.6	4.3	<1.0	1.2	0.2	<0.3	<1.0	52.0
			1	<1.0	0.0	0.3	1.9	<0.4	0.7	0.2	<0.1	0.5	17.9
4 - Fishery Bay	29/03/82	Pooled sample of bodies	10	3.0	<0.1	0.7	4.2	1.0	1.4	0.2	<0.2	1.0	48.5
			10	<3.0	<0.1	0.9	4.6	1.0	1.3	0.2	<0.3	2.0	50.6
			10	3.0	<0.1	1.1	4.0	<1.0	1.6	0.2	<0.3	<1.0	47.6
			10	3.0	0.1	0.6	5.5	1.0	1.5	0.2	<0.2	1.0	53.6
			10	3.0	0.2	0.8	5.0	<1.0	1.5	0.2	<0.2	1.0	45.9
4 - Fishery Bay	29/03/82	Individual livers	1	<8.0	2.0	1.8	58.5	4.0	2.8	-	1.0	13.0	130.0
			1	<7.0	1.0	1.6	50.0	<3.0	2.8	-	<0.7	<3.0	119.0
			1	4.0	0.2	1.0	16.6	<1.0	3.8	-	<0.3	2.0	77.4
			1	<6.0	0.6	1.5	74.2	<3.0	2.9	-	<0.6	<3.0	123.0
			1	<7.0	1.4	0.7	30.9	<3.0	2.5	-	0.8	<3.0	116.0
			1	<8.0	1.1	7.5	47.2	3.0	3.2	-	<0.8	9.0	132.0
			1	<9.0	1.1	7.4	58.7	4.0	3.5	-	<0.9	6.0	95.3
			1	5.0	0.6	1.0	56.0	<2.0	3.2	-	<0.5	<2.0	135.0
			1	<5.0	1.3	2.1	85.7	3.0	2.9	-	<0.5	4.0	126.0
			1	<9.0	0.8	4.2	25.4	17.0	3.9	-	1.1	4.0	124.0
4 - Fishery Bay	29/03/82	Pooled sample of livers	10	3.0	0.9	0.5	40.9	<1.0	2.9	0.2	0.6	<1.0	109.0

Appendix III   Standard lengths and weights of eulachons sampled in 1982

NOTE: Samples 1 - 10: Station 3 (Fishery Bay) Individual bodies.
11 - 13: Station 3 (Fishery Bay) Pooled samples of 10 bodies.
14 - 23: Station 3 (Fishery Bay) Individual livers.
24 : Station 3 (Fishery Bay) Pooled sample of 10 livers.

Samples 25 - 34: Station 4 (Fishery Bay) Individual bodies.
35 - 44: Station 4 (Fishery Bay) Individual livers.
45 : Station 4 (Fishery Bay) Pooled sample of 10 livers.
46 - 50: Station 4 (Fishery Bay) Pooled samples of 10 bodies.

SAMPLE	LENGTH (cm)	WEIGHT (g)	SAMPLE	LENGTH (cm)	WEIGHT (g)	SAMPLE	LENGTH (cm)	WEIGHT (g)
1	18	37.6	12	17	34.6	14	19	62.2
2	17	36.8		18	45.9	15	16	31.0
3	18	48.1		16	31.0	16	19	54.4
4	18	40.7		18	39.5	17	17	38.9
5	16	28.1		18	51.2	18	18	44.0
6	18	51.4		18	43.2	19	18	52.5
7	17	34.2		18	45.3	20	17	47.9
8	19	68.9		18	40.8	21	17	31.0
9	19	51.5		18	47.5	22	18	45.5
10	18	32.6		18	53.8	23	17	37.0
11	18	49.6	13	17	48.5	24	17	39.7
	18	40.0		18	46.8		19	36.6
	15	27.2		17	30.8		19	51.7
	19	67.6		18	59.8		19	41.5
	18	57.5		19	50.5		16	40.1
	15	30.4		17	34.8		15	24.0
	17	36.6		16	32.8		16	27.2
	18	55.4		18	54.5		18	53.2
	16	30.7		18	48.8		19	57.8
	18	50.0		18	39.2		16	30.9

Appendix III - (Con't)

SAMPLE	LENGTH (cm)	WEIGHT (g)	SAMPLE	LENGTH (cm)	WEIGHT (g)	SAMPLE	LENGTH (cm)	WEIGHT (g)
25	18	37.8	46	17	33.3	49	17	37.4
26	18	32.3		17	36.1		17	35.6
27	18	29.7		17	26.8		18	39.5
28	20	51.1		18	41.6		16	20.7
29	18	35.6		18	46.1		20	49.7
30	15	17.5		18	47.8		17	34.5
31	18	29.8		17	29.0		17	40.5
32	17	24.7		17	36.5		17	48.2
33	17	34.5		17	36.3		18	41.9
34	18	42.8		18	45.2		17	24.1
35	17	34.2	47	19	52.4	50	17	25.5
36	19	43.0		18	44.1		19	48.0
37	19	36.3		17	33.2		17	33.1
38	18	42.3		16	32.8		18	46.2
39	19	37.5		17	32.6		18	46.5
40	18	39.9		18	45.6		19	66.1
41	18	30.2		17	37.6		18	50.7
42	18	40.2		20	72.4		18	46.5
43	20	50.9		18	42.7		17	26.3
44	17	27.6		18	40.4		18	46.9
45	15	30.6	48	17	34.9			
	20	53.6		18	34.4			
	20	43.0		18	53.0			
	18	27.2		17	33.3			
	18	36.2		18	41.1			
	20	57.3		20	48.0			
	20	52.1		17	23.0			
	17	31.0		16	22.6			
	18	42.4		18	36.1			
	19	53.0		18	52.8			

Appendix IV

Summary of metal levels
in marine fish muscle tissue
reported in selected studies
carried out in coastal locations
throughout the world

Appendix IV

ARSENIC

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
Marine fish	1 - 5	Canada - W. Coast	Phillips and Russo (1978)
Shorthorn sculpin (*Myoxocephalus scorpius*)	40 ± 20	Canada - NWT	Bohn and Fallis (1978)
Offshore fish	<1.0 - 1.8 (n=26)	Nr. Sargasso Sea E. of Gulf Stream	Windom *et al.* (1973)
Inshore fish	<1.0 - 6.4 (n=51)	USA - E. Coast	Windom *et al.* (1973)
Fish	<0.025 - 14.5	Australia	Reish *et al.* (1982)
Fish	0.1 - 4.4*	Australia	Reish *et al.* (1978)
Fish	26 - 83	Canada - Arctic	Reish *et al.* (1978)
Greenland cod (*G. ogac*)	23.9 - 152 (n=4)	Greenland	Bohn (1975)
Spotted wolffish (*Anarhichas minor*)	17.1 - 195 (n=13)	Greenland	Bohn (1975)
Greenland halibut (*Reinhardtius hippoglossoides*)	14.7 - 307 (n=9)	Greenland	Bohn (1975)
Shorthorn sculpin (*M. scorpius*)	19.3 - 72.3 (n=5)	Greenland	Bohn (1975)
American plaice (*H. platessoides*)	17.0 - 290 (n=4)	Greenland	Bohn (1975)
Sculpins (*M. spp.*)	5.72 - 40.2	Canada - NWT (1979)	Fallis (1982)
Marine fish (4 species)	2.5 - 5.4	NE Atlantic	Phillips (1977)
Marine fish (3 species)	1.7 - 8.7	United Kingdom	Phillips (1977)
Black marlin	0.1 - 1.65*	Australia	Phillips (1977)

Appendix IV Cont'd

CADMIUM

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
Marine fish	0.002 - 0.033	Norway	Phillips and Russo (1978)
Shorthorn sculpin (*M. scorpius*)	1.4 $\pm$ 0.3	Canada, NWT	Bohn and Fallis (1978)
Herring (*Clupea harengus*)	≤0.002* (n=10)	Baltic Sea (1976)	Stoeppler and Nurnberg (1979)
Marine fish	≤0.001 - 0.170* (n=28)	North Sea (1976 & 1978)	Stoeppler and Nurnberg (1979)
Marine fish	≤0.001 - 0.770* (n=30)	Mediterranean Sea (1976 - 1977)	Stoeppler and Nurnberg (1979)
Offshore fish	<0.1 - 1.6 (n=26)	nr. Sargasso Sea E. of Gulf Stream	Windom *et al.* (1973)
Inshore fish	<0.1 - 1.3 (n=51)	USA - E. Coast	Windom *et al.* (1973)
Fish	<0.01 - 0.07*	USA - California Coast	Reish *et al.* (1982)
Fish	1.7 - 122	Atlantic Ocean	Reish *et al.* (1982)
Fish	0.05 - 0.6*	England	Reish *et al.* (1978)
Fish	<0.01*	USA - California Coast	Reish *et al.* (1978)
Fish	0.05 - 0.25*	USA - New York Coast	Reish *et al.* (1978)
Fish	1.94 - 2.5	England	Reish *et al.* (1978)
Fish	0.01 - 0.1*	Australia	Reish *et al.* (1978)
Fish	<0.1 - 6.1	USA - Texas Coast	Reish *et al.* (1978)
Fish	0.26 - 1.6	Canada - Arctic	Reish *et al.* (1978)
Fish	0.1 - 0.7	Israel	Reish *et al.* (1978)
Fish	100 - 200	Mexico - Baja Coast	Reish *et al.* (1978)

Appendix IV Cont'd

CADMIUM (con't)

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
Fish	0.01 - 0.03	Norway	Reish *et al.* (1978)
Sculpins (*M. spp.*)	0.08 - 6.05	Canada - NWT (1979)	Fallis (1982)
Marine fish	<0.05 - 0.18*	Britain	Phillips (1977)
Herring (whole body)	<0.2 - 0.2	Norway	Phillips (1977)
Marine fish (8 species)	0.6 - 1.0	Britain	Phillips (1977)
Marine fish	<0.005 - 0.13	Norway	Phillips (1977)
Marine fish (4 species)	0.05 - 0.98	Atlantic	Phillips (1977)
Marine fish (<40 km offshore)	0.11*	England/Wales	Phillips (1977)
Marine fish (>40 km offshore)	0.07*	Irish Sea	Phillips (1977)
Marine fish (>40 km offshore)	0.12*	North Sea	Phillips (1977)
Marine fish	<0.05*	Iceland/Barents Sea/ Norway	Phillips (1977)
Marine fish (4 species)	<0.03 - 0.12*	Scotland	Phillips (1977)
Marine fish (8 species)	0.002 - 0.016*	New Zealand	Phillips (1977)
Marine fish (3 species)	0.03	United Kingdom	Phillips (1977)
Marine fish (5 species)	<0.05 - 0.9	Britain	Phillips (1977)
Black marlin	0.05 - 0.40*	Australia	Phillips (1977)
Marine fish (10 species)	0.08 - 3.2	Spain/Portugal Coasts	Phillips (1977)
Marine fish (9 species)	0.11 - 1.44*	Britain	Phillips (1977)

Appendix IV Cont'd

CHROMIUM

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
Fish	<0.01 - 0.12*	USA - California Coast	Reish *et al.* (1982)
Fish	0.27 - 0.5	Fr. Antilles	Reish *et al.* (1982)
Fish	<0.01 - 0.07*	USA - California Coast	Reish *et al.* (1978)
Fish	<0.6*	USA - New York Coast	Reish *et al.* (1978)
Fish	0.6 - 4.9	Israel	Reish *et al.* (1978)
Fish	1 - 2	Norway	Reish *et al.* (1978)
Fish	<0.5 - 0.58*	Britain	Phillips (1977)
Fish (8 species)	0.9 - 1.7	United Kingdom	Phillips (1977)
Fish (8 species)	0.01 - 0.03*	New Zealand	Phillips (1977)

Appendix IV Cont'd

COPPER

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
Shorthorn sculpin (*M. scorpius*)	4.1 ± 2.0	Canada - NWT	Bohn and Fallis (1978)
Herring (*C. harengus*)	0.421*	Baltic Sea (1976)	Stoeppler and Nurnberg (1979)
Marine fish	0.104 - 0.220* (n=24)	North Sea (1976 & 1978)	Stoeppler and Nurnberg (1979)
Marine fish	0.180 - 0.53*	Mediterranean Sea (1976 - 1977)	Stoeppler and Nurnberg (1979)
Offshore fish	1.6 - 23.0 (n=26)	nr. Sargasso Sea E. of Gulf Stream	Windom *et al.* (1973)
Inshore fish	<0.3 - 10.0 (n=51)	USA - E. Coast	Windom *et al.* (1973)
Bluefish (*Pomatomus saltatrix*)	0.51 (n=1)	USA - E. Coast (1971 - 1972)	Cross *et al.* (1973)
Fish	<0.02 - 4.3*	USA - California Coast	Reish *et al.* (1982)
Fish	0.08 - 2.4*	Baltic Sea	Reish *et al.* (1982)
Fish	0.2 - 36.9*	England	Reish *et al.* (1978)
Fish	<0.02 - 0.2*	USA - California Coast	Reish *et al.* (1978)
Fish	0.3 - 13.8*	USA - New York Coast	Reish *et al.* (1978)
Fish	0.1 - 2.8*	Australia	Reish *et al.* (1978)
Fish	1.3 - 10	USA - Texas Coast	Reish *et al.* (1978)
Fish	1.7 - 7.7	Canada - Arctic	Reish *et al.* (1978)
Fish	0.7 - 8.3	Israel	Reish *et al.* (1978)
Fish	1 - 6	Norway	Reish *et al.* (1978)

Appendix IV Cont'd

COPPER (con't)

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
Fish	<0.5 - 1.80*	Britain	Phillips (1977)
Herring (whole body)	3.4 - 7.2	Norway	Phillips (1977)
Fish (8 species)	2.2 - 3.0	United Kingdom	Phillips (1977)
Fish (<40 km offshore)	0.95*	England/Wales	Phillips (1977)
Fish (>40 km offshore)	0.80*	Irish Sea	Phillips (1977)
Fish (>40 km offshore)	<0.50*	North Sea	Phillips (1977)
Fish	1.80*	Iceland/Barents Sea/ Norway	Phillips (1977)
Fish (4 species)	0.08 - 4.28*	Scotland	Phillips (1977)
Fish (8 species)	0.11 - 0.59*	New Zealand	Phillips (1977)
Fish (5 species)	3.0 - 6.6	Britain	Phillips (1977)
Black marlin	0.3 - 1.2*	Australia	Phillips (1977)
Fish (10 species)	0.6 - 8.0	Spain/Portugal Coasts	Phillips (1977)
Fish (9 species)	0.5 - 4.6*	Britain	Phillips (1977)

Appendix IV Cont'd

LEAD

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
Albacore tuna (*Thunnus alalunga*)	0.0003 *	USA - California coast (1971)	Patterson and Settle (1977)
Albacore tuna (*T. alalunga*)	0.0004 *	USA - California coast (1973)	Patterson and Settle (1977)
Marine fish	0.020 - 1.330	S. Baltic Sea and N. Atlantic	Phillips and Russo (1978)
Herring (*C. harengus*)	≤0.01* (n=10)	Baltic Sea (1976)	Stoeppler and Nurnberg (1979)
Marine fish	≤0.01 - 0.260* (n=28)	North Sea (1976 & 1978)	Stoeppler and Nurnberg (1979)
Marine fish	≤0.01* (n=30)	Mediterranean Sea (1975 - 1977)	Stoeppler and Nurnberg (1979)
Fish	<0.08*	USA - California Coast	Reish *et al.* (1982)
Fish	2.9 - 23.9	Fr. Antilles	Reish *et al.* (1982)
Fish	0.01 - 1.4*	Baltic Sea	Reish *et al.* (1982)
Fish	0.1 - 5.29*	England	Reish *et al.* (1978)
Fish	<0.01 - 2.0*	USA - California Coast	Reish *et al.* (1978)
Fish	<1.7*	USA - New York Coast	Reish *et al.* (1978)
Fish	16.7 - 21.2	England	Reish *et al.* (1978)
Fish	0.001 - 0.24*	USA - California Coast	Reish *et al.* (1978)
Fish	0.1 - 4.1*	Australia	Reish *et al.* (1978)
Fish	<0.2 - 8.6	USA - Texas Coast	Reish *et al.* (1978)

Appendix IV Cont'd

LEAD (con't)

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
Fish	0.14 - 5.34	Canada - Nova Scotia Coast	Reish et al. (1978)
Fish	0.04 - 5.3	Israel	Reish et al. (1978)
Sculpins (M. spp.)	0.09 - 1.13	Canada - NWT (1979)	Fallis (1982)
Fish	<0.5 - 0.99*	Britain	Phillips (1977)
Herring (whole body)	3.2 - 12.2	Norway	Phillips (1977)
Fish (8 species)	5.8 - 15.0	United Kingdom	Phillips (1977)
Fish (<40 km offshore)	0.66*	England/Wales	Phillips (1977)
Fish (>40 km offshore)	0.50*	Irish Sea	Phillips (1977)
Fish (>40 km offshore)	<0.50*	North Sea	Phillips (1977)
Fish	<0.50*	Iceland/Barents Sea/ Norway	Phillips (1977)
Fish (4 species)	<0.2 - 1.2*	Scotland	Phillips (1977)
Fish (8 species)	0.16 - 0.87*	New Zealand	Phillips (1977)
Fish (5 species)	<0.2	Britain	Phillips (1977)
Black marlin	0.1 - 0.9*	Australia	Phillips (1977)
Fish (10 species)	1.2 - 7.0	Spain/Portugal Coasts	Phillips (1977)
Gillichthys mirabilis	0.11 - 1.86	USA - California Coast (1974-1975)	Somero *et al.* (1977)

Appendix IV Cont'd

MANGANESE

ORGANISM	CONCENTRATION (mg kg^{-1} dry weight)	LOCALITY	REFERENCE
Estuarine fish	19 - 35	USA - N. Carolina Coast	Phillips and Russo (1978)
Calico bass (*Paralabrax clathratus*)	0.5	USA - California Coast	Phillips and Russo (1978)
Bluefish (*P. saltatrix*)	0.24 (n=1)	USA - N. Carolina Coast (1971 - 1972)	Cross *et al.* (1973)
Fish	0.18 - 2.5*	USA - New York Coast	Reish *et al.* (1978)
Fish (8 species)	20 - 48	United Kingdom	Phillips (1977)
Fish (8 species)	0.08 - 1.15*	New Zealand	Phillips (1977)

Appendix IV Cont'd

MERCURY

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
Bluefin tuna (*Thunnus thyunnus*)	0.40	N. Atlantic	Phillips and Russo (1978)
Snapper (*Chrysophrys curratus*)	0.25	New Zealand	Phillips and Russo (1978)
Dogfish (*Squalus acanthias*)	0.35	USA - NE Coast	Phillips and Russo (1978)
Dogfish (*S. acanthias*)	0.60	USA - Oregon Coast	Phillips and Russo (1978)
Blue marlin (*Makaira nigricans*)	2.42	USA - Hawaii	Phillips and Russo (1978)
Herring (*C. harengus*)	0.063* (n=10)	Baltic Sea (1976)	Stoeppler and Nurnberg(1979)
Marine fish	0.010 - 0.260* (n=33)	North Sea (1976 & 1978)	Stoeppler and Nurnberg(1979)
Marine fish	0.069 - 0.520* (n=37)	Mediterranean Sea (1976 - 1977)	Stoeppler and Nurnberg(1979)
Offshore fish	0.1 - 2.3 (n=26)	nr. Sargasso Sea E. of Gulf Stream	Windom *et al*. (1973)
Inshore fish	0.1 - 4.5 (n=51)	USA - E. Coast	Windom *et al*. (1973)
Marine fish	<0.005 - 0.45 (n=180)	Canada - E. Coast (1972)	Freeman *et al*. (1974)
Fish	0.1 - 1.5	Australia	Reish *et al*. (1982)
Fish	0.04 - 0.79*	USA - California Coast	Reish *et al*. (1982)
Fish	0.004 - 0.88*	Baltic Sea	Reish *et al*. (1982)
Fish	0.55 - 5.67*	S. Africa	Reish *et al*. (1982)
Fish	0.5*	Red Sea	Reish *et al*. (1982)

Appendix IV Cont'd

MERCURY (con't)

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
Fish	0.06 - 0.147*	USA - California Coast	Reish *et al.* (1978)
Fish	0.03 - 2.06*	England	Reish *et al.* (1978)
Fish	0.026 - 0.478	Andamen Sea	Reish *et al.* (1978)
Fish	0.048 - 0.45*	USA - California Coast	Reish *et al.* (1978)
Fish	<0.03 - 2.0*	USA - New York Coast	Reish *et al.* (1978)
Fish	0.00008 - 0.038*	USA - Hawaii	Reish *et al.* (1978)
Fish	0.03 - 0.94*	Australia	Reish *et al.* (1978)
Fish	0.01 - 3.0*	Australia	Reish *et al.* (1978)
Fish	0.02 - 0.77*	USA - Alaska Coast	Reish *et al.* (1978)
Fish	0.06 - 1.28*	USA - Washington Coast	Reish *et al.* (1978)
Fish	0.06 - 1.23*	USA - Oregon Coast	Reish *et al.* (1978)
Fish	0.04 - 2.11*	USA - California Coast	Reish *et al.* (1978)
Fish	0.01 - 1.3*	USA - Alaska Coast	Reish *et al.* (1978)
Fish	0.04 - 1.46*	Canada - B.C. Coast	Reish *et al.* (1978)
Fish	0.1 - 1.43*	USA - Washington/ Oregon Coast	Reish *et al.* (1978)
Fish	0.03 - 1.1*	USA - New England Coast	Reish *et al.* (1978)
Fish	0.1 - 2.6	Australia	Reish *et al.* (1978)
Fish	0.74 - 2.34	Japan	Reish *et al.* (1978)
Fish	0.14 - 0.315	Japan	Reish *et al.* (1978)

Appendix IV Cont'd

MERCURY (con't)

ORGANISM	CONCENTRATION (mg·kg^{-1} dry wt.)	LOCALITY	REFERENCE
Fish	<0.1 - 0.7*	Norway	Reish *et al.* (1978)
American eel (*Anguilla rostrata*)	0.03 - 3.50*	Canada - Nova Scotia Coast	Sherbin (1979)
American eel (*A. rostrata*)	0.02 - 0.70*	Canada - PEI Coast	Sherbin (1979)
American eel (*A. rostrata*)	0.08 - 0.41*	Canada - Newfoundland/ Labrador Coast	Sherbin (1979)
Marine fish	0.02 - 3.82*	Canada - New Brunswick Coast	Sherbin (1979)
Pacific herring (*C. harengus*)	0.01 - 0.28*	Canada - B.C. Coast	Garrett *et al.* (1980)
Anchovy (*Engraulis mordax*)	0.01 - 0.36*	Canada - B.C. Coast	Garrett *et al.* (1980)
Pacific salmon (*O. spp.*)	0.01 - 0.28*	Canada - B.C. Coast	Garrett *et al.* (1980)
Groundfish	<0.01 - 2.50*	Canada - B.C. Coast	Garrett *et al.* (1980)
Halibut (*Hippoglossus stenolepis*)	0.03 - 3.57*	Canada - B.C. Coast	Garrett *et al.* (1980)
Albacore (*T. alalunga*)	0.19 - 0.38*	Canada - B.C. Coast	Garrett *et al.* (1980)
Cartilaginous fish	<0.02 - 2.02*	Canada - B.C. Coast	Garrett *et al.* (1980)
Sculpins (*M. spp.*)	0.08 - 1.22	Canada - NWT (1979)	Fallis (1982)
Fish (7 species)	0.05 - 4.16*	Sweden	Phillips (1977)

Appendix IV Cont'd

MERCURY (con't)

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
Fish	0.05 - 0.49*	Britain	Phillips (1977)
Fish	0.25 - 7.27	Norway	Phillips (1977)
Fish (4 species)	0.12 - 0.25	Atlantic Ocean	Phillips (1977)
Fish (<40 km offshore)	0.29*	England/Wales	Phillips (1977)
Fish (>40 km offshore)	0.21*	Irish Sea	Phillips (1977)
Fish (>40 km offshore)	0.10*	North Sea	Phillips (1977)
Fish	0.06*	Iceland/Barents Sea/ Norway	Phillips (1977)
Fish (3 species)	0.15 - 1.8	United Kingdom	Phillips (1977)
Sand flathead	0.03 - 1.06*	Australia	Phillips (1977)
Black marlin	0.5 - 16.5*	Australia	Phillips (1977)
Fish (10 species)	0.5 - 0.79	Spain/Portugal Coasts	Phillips (1977)

Appendix IV Cont'd

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
NICKEL			
Pacific salmon (*Oncorhynchus spp.*)	1.70		Phillips and Russo (1978)
Marine fish	>7.0	England - NE Coast	Phillips and Russo (1978)
Fish	<0.01 - 0.67*	USA - California Coast	Reish *et al.* (1982)
Fish	<0.01 - 0.85*	USA - California Coast	Reish *et al.* (1978)
Fish	<0.01 - 1.7*	USA - New York Coast	Reish *et al.* (1978)
Fish	0 - 10.8	Israel	Reish *et al.* (1978)
Fish	3 - 9	Norway	Reish *et al.* (1978)
Fish (8 species)	2.1 - 3.5	United Kingdom	Phillips (1977)
Fish (8 species)	0.02 - 0.07*	New Zealand	Phillips (1977)
Fish (9 species)	0.5 - 7.2*	Britain	Phillips (1977)

Appendix IV Cont'd

ZINC

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
Shorthorn sculpin (*M. scorpius*)	43 ± 12.0	Canada - NWT	Bohn and Fallis (1978)
Offshore fish	8 - 81 (n=26)	nr. Sargasso Sea E. of Gulf Stream	Windom *et al.* (1973)
Inshore fish	7 - 397 (n=51)	USA - E. Coast	Windom *et al.* (1973)
Bluefish (*P. saltatrix*)	4.78 (n=1)	USA - E. Coast (1971 - 1972)	Cross *et al.* (1973)
Fish	<1.2 - 6.6*	USA - California Coast	Reish *et al.* (1982)
Fish	1.2 - 32	Baltic Sea	Reish *et al.* (1982)
Fish	6 - 95.8*	England	Reish *et al.* (1978)
Fish	1.3 - 4.3*	USA - California Coast	Reish *et al.* (1978)
Fish	2.9 - 45*	USA - New York Coast	Reish *et al.* (1978)
Fish	72.5 - 102.4	England	Reish *et al.* (1978)
Fish	0.5 - 24*	Australia	Reish *et al.* (1978)
Fish	7.5 - 396	USA - Texas Coast	Reish *et al.* (1978)
Fish	15 - 142	Canada - Arctic Coast	Reish *et al.* (1978)
Fish	0.5 - 84	Israel	Reish *et al.* (1978)
Fish	20 - 80	Norway	Reish *et al.* (1978)
Sculpins (*M. spp.*)	34.3 - 127	Canada - NWT (1979)	Fallis (1982)
Fish	4.35 - 6.60*	Britain	Phillips (1977)

Appendix IV Cont'd

ZINC (con't)

ORGANISM	CONCENTRATION (mg kg $^{-1}$ dry wt.)	LOCALITY	REFERENCE
Herring (whole body)	95 - 140	Norway	Phillips (1977)
Fish (8 species)	17 - 36	United Kingdom	Phillips (1977)
Fish (4 species)	44	Atlantic Ocean	Phillips (1977)
Fish (<40 km offshore)	5.52*	England/Wales	Phillips (1977)
Fish (>40 km offshore)	5.70*	Irish Sea	Phillips (1977)
Fish (>40 km offshore)	4.83*	North Sea	Phillips (1977)
Fish	6.10*	Iceland/Barents Sea Norway	Phillips (1977)
Fish (4 species)	1.55 - 23.5*	Scotland	Phillips (1977)
Fish (8 species)	2.8 - 21.0*	New Zealand	Phillips (1977)
Fish (3 species)	15	United Kingdom	Phillips (1977)
Fish (5 species)	23 - 123	Britain	Phillips (1977)
Black marlin	5.8 - 14.6*	Australia	Phillips (1977)
Fish (10 species)	19 - 120	Spain/Portugal Coasts	Phillips (1977)
Fish (9 species)	1.9 - 119*	Britain	Phillips (1977)

* wet weight

Appendix V

Summary of metal levels
in marine fish liver tissue
reported in selected studies
carried out in coastal locations
throughout the world

Appendix V

ARSENIC

ORGANISM	CONCENTRATION (mg·kg^{-1} dry wt.)	LOCALITY	REFERENCE
Shorthorn sculpin (*M. scorpius*)	81 ± 53	Canada - NWT	Bohn and Fallis (1978)
Greenland cod (*G. ogac*)	7.6 - 46.3 (n=6)	Greenland	Bohn (1975)
Spotted wolffish (*A. minor*)	19.3 - 55.9 (n=6)	Greenland	Bohn (1975)
Greenland halibut (*R. hippoglossoides*)	23.7 - 228 (n=8)	Greenland	Bohn (1975)
Shorthorn sculpin (*M. scorpius*)	20.1 - 126 (n=5)	Greenland	Bohn (1975)
American plaice (*H. platessoides*)	78.2 - 512 (n=3)	Greenland	Bohn (1975)

Appendix V Cont'd

CADMIUM

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
Shorthorn sculpin (*M. scorpius*)	4.1 ± 3.1	Canada - NWT	Bohn and Fallis (1978)
Marine fish	0.170 - 3.90* (n=11)	North Sea (1976 - 1978)	Stoeppler and Nurnberg (1979)
Marine fish	0.008 - 0.780* (n=11)	Mediterranean Sea (1976 - 1978)	Stoeppler and Nurnberg (1979)
Atlantic cod (*Gadus morrhua*)	ND - 1.0	Norway	Stenner and Nickless (1974)

COPPER

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
Shorthorn sculpin (*M. scorpius*)	7.6 ± 5.8	Canada - NWT	Bohn and Fallis (1978)
Atlantic cod (*G. morrhua*)	8 - 18	Norway	Stenner and Nickless (1974)

Appendix V Cont'd

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
LEAD			
Albacore tuna (*T. alalunga*)	0.0095 *	USA - California Coast (1973)	Patterson and Settle (1977)
Marine fish	0.05 - 0.260* (n=11)	North Sea (1976 - 1978)	Stoeppler and Nurnberg (1979)
Marine fish	<0.03 - 0.530* (n=11)	Mediterranean Sea (1976 - 1978)	Stoeppler and Nurnberg (1979)
Shorthorn sculpin (*M. scorpius*)	0.3 ± 0.2	Canada - NWT	Bohn and Fallis (1978)
Spotted Wolffish (*A. minor*)	0.23 ± 0.10 (fish ≤ 2.5 kg) 0.13 ± 0.05 (fish ≥ 2.8 kg)	Greenland (1973)	Bollingberg and Johansen (1979)
Atlantic cod (*G. morrhua*)	ND - 3	Norway	Stenner and Nickless (1974)
G. mirabilis	0.23 - 2.66	USA - California Coast (1974-1975)	Somero *et al.* (1977)
MERCURY			
Marine fish	0.070 - 0.330* (n=10)	North Sea (1976 - 1978)	Stoeppler and Nurnberg(1979)
Marine fish	0.036 - 0.400* (n=10)	Mediterranean Sea (1976 - 1978)	Stoeppler and Nurnberg(1979)
Marine fish	0.04 - 0.31 (n=19)	Canada - E. Coast (1972)	Freeman *et al.* (1974)
Cartilaginous fish	<0.02 - 2.50	Canada - B.C. Coast	Garrett *et al.* (1980)

Appendix V Cont'd

CADMIUM

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
ZINC			
Shorthorn sculpin (*M. scorpius*)	100 ± 23	Canada - NWT	Bohn and Fallis (1978)
Atlantic cod (*G. morrhua*)	35 - 60	Norway	Stenner and Nickless (1974)

* wet weight

Appendix VI

Summary of metal levels

in decapod leg tissue

reported in selected studies

carried out in coastal locations

throughout the world

Appendix VI

ARSENIC

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
Dungeness crab (*Cancer magister*)	7	Canada - W. Coast	Phillips and Russo (1978)
Portunus spp.	7.9* (n=4)	Italy - W. Coast (1976)	Stoeppler and Nurnberg (1979)
Decapods	0.6 - 11	USA - Texas Coast	Reish *et al.* (1978)
Portunus spp.	0.048* (n=4)	Italy - W. Coast (1976)	Stoeppler and Nurnberg (1979)
Decapods	<0.01 - 0.04*	USA - California Coast	Reish *et al.* (1982)
Decapods	0.003 - 1600	Canada - E. Coast	Reish *et al.* (1982)
Decapods	2.4 - 5.1	Ireland	Reish *et al.* (1982)
Decapods	0.1 - 0.4	USA - Texas Coast	Reish *et al.* (1978)
Decapods	0.03 - 0.15*	S. Africa	Reish *et al.* (1978)
Decapods	0.53 - 3	England	Reish *et al.* (1978)
Decapods	<0.01 - 0.06*	USA - California Coast	Reish *et al.* (1978)
Decapods	5	Norway	Reish *et al.* (1978)

Appendix VI Cont'd

CHROMIUM

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
Decapods	0 - 0.7	Ireland	Reish *et al.* (1982)
Decapods	<0.02 - 0.08*	USA - California Coast	Reish *et al.* (1982)
Decapods	<0.02 - 0.12*	USA - California Coast	Reish *et al.* (1978)
Decapods	0 - 0.03*	S. Africa	Reish *et al.* (1978)
Decapods	8	Norway	Reish *et al.* (1978)

COPPER

Portunus spp.	11.6* (n=4)	Italy - W. Coast (1976)	Stoeppler and Nurnberg (1979)
Decapods	33.4 - 133.9	Ireland	Reish *et al.* (1982)
Decapods	2.5 - 22*	USA - California Coast	Reish *et al.* (1982)
Decapods	9.5 - 41	England	Reish *et al.* (1978)
Decapods	2 - 14*	USA - California Coast	Reish *et al.* (1978)
Decapods	11.5 - 54	USA - Texas Coast	Reish *et al.* (1978)
Decapods	3.3 - 8.2*	S. Africa	Reish *et al.* (1978)
Decapods	175	Norway	Reish *et al.* (1978)

Appendix VI Cont'd

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
LEAD			
Decapods	37.6 - 43.9	Ireland	Reish *et al.* (1982)
Decapods	<0.14*	USA - California Coast	Reish *et al.* (1982)
Decapods	0.1 - 4.13	England	Reish *et al.* (1978)
Decapods	<0.23*	USA - California Coast	Reish *et al.* (1978)
Decapods	<0.2 - <3.5	USA - Texas Coast	Reish *et al.* (1978)
Decapods	0.4 - 0.59*	S. Africa	Reish *et al.* (1978)
MANGANESE			
Decapods	58.3 - 673.3	Ireland	Reish *et al.* (1982)
Decapods	0.24 - 0.42*	S. Africa	Reish *et al.* (1978)
NICKEL			
Decapods	<0.04 - 0.51*	USA - California Coast	Reish *et al.* (1982)
Decapods	9.6 - 15.6	Ireland	Reish *et al.* (1982)
Decapods	<0.03 - 0.26*	USA - California Coast	Reish *et al.* (1978)
Decapods	0.15 - 0.26*	S. Africa	Reish *et al.* (1978)
Decapods	11	Norway	Reish *et al.* (1978)

Appendix VI Cont'd

ZINC

ORGANISM	CONCENTRATION (mg kg^{-1} dry wt.)	LOCALITY	REFERENCE
Decapods	6 - 210*	USA - California Coast	Reish *et al.* (1982)
Decapods	75.6 - 142	Ireland	Reish *et al.* (1982)
Decapods	20 - 48.3	England	Reish *et al.* (1978)
Decapods	8.6 - 97*	USA - California Coast	Reish *et al.* (1978)
Decapods	14 - 75	USA - Texas Coast	Reish *et al.* (1978)
Decapods	14 - 17*	S. Africa	Reish *et al.* (1978)
Decapods	121	Norway	Reish *et al.* (1978)

* wet weight