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CONSERVATION AND PROTECTION
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PACIFIC & YUKON REGION

DATA REPORT

SEDIMENT AND TISSUE TRACE METALS IN HECATE STRAIT, BRITISH COLUMBIA MARCH 1984

Regional Data Report: DR 86-01

By

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REVIEW NOTICE

Data reports are prepared to make preliminary data available without full analysis or interpretation. This report has been reviewed by the Marine Programs Division, Environmental Protection Service, and approved for limited distribution. For further information please contact:

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1 INTRODUCTION

Trace metals are well-known contaminants in offshore drilling wastes, including spent muds, formation waters, rig washing agents and some other discharges (Thomas et al., 1983). Effects of drillings wastes, likely caused by trace metals, have ranged from histopathological damage at the organism level (Arctic Laboratories Ltd., 1979) to species diversity and distribution changes at the community levels (Maurer et al., 1981). Dome Petroleum Ltd. (1979) in a comprehensive review, predicted that accumulation of heavy metals was the only effect of Arctic offshore production drilling that could not easily be mitigated or dismissed as insignificant. On the east coast, a review of environmental concerns related to hydrocarbon development on the Grand Banks noted that, while most impacts of rig discharges would be localized and minor, an exception would be with trace metals associated with process water (Drinnon, 1985). Trace metals are not only good indicators of environmental stress on sea bottom communities, but excellent tracers for monitoring the extent of drilling waste deposition.

To make existing data available on sediment trace metals in Hecate Strait to companies and reviewers assessing impact of proposed West Coast drilling, sediment chemical results were analysed and reported by Sneddon and Holman; 1982. During March, 1984, surveys were completed in Hecate Strait to characterize the levels of trace metals in tissues of fish and invertebrates of bottom communities. The purpose of this study was to define baseline trace metal levels in epibenthic tissue samples obtained from the otter trawl and surface sediment grabs. Relative species abundance was also reported. This study should be regarded as a preliminary review of baseline tissue and sediment trace metal concentrations; future reports will statistically analyze data from several background areas including Hecate Strait, Laredo Sound, Surf Inlet, Masset Inlet and Barkley Sound and Quatsino Sound.

1.1 Study Area

The study area is located approximately 9 nautical miles east of Rose Spit at the north end of the Graham Island, Queen Charlottes Islands,

British Columbia (Figure 1). The sampling stations are shown in Figure 2 and the coordinates are listed in Appendix I.

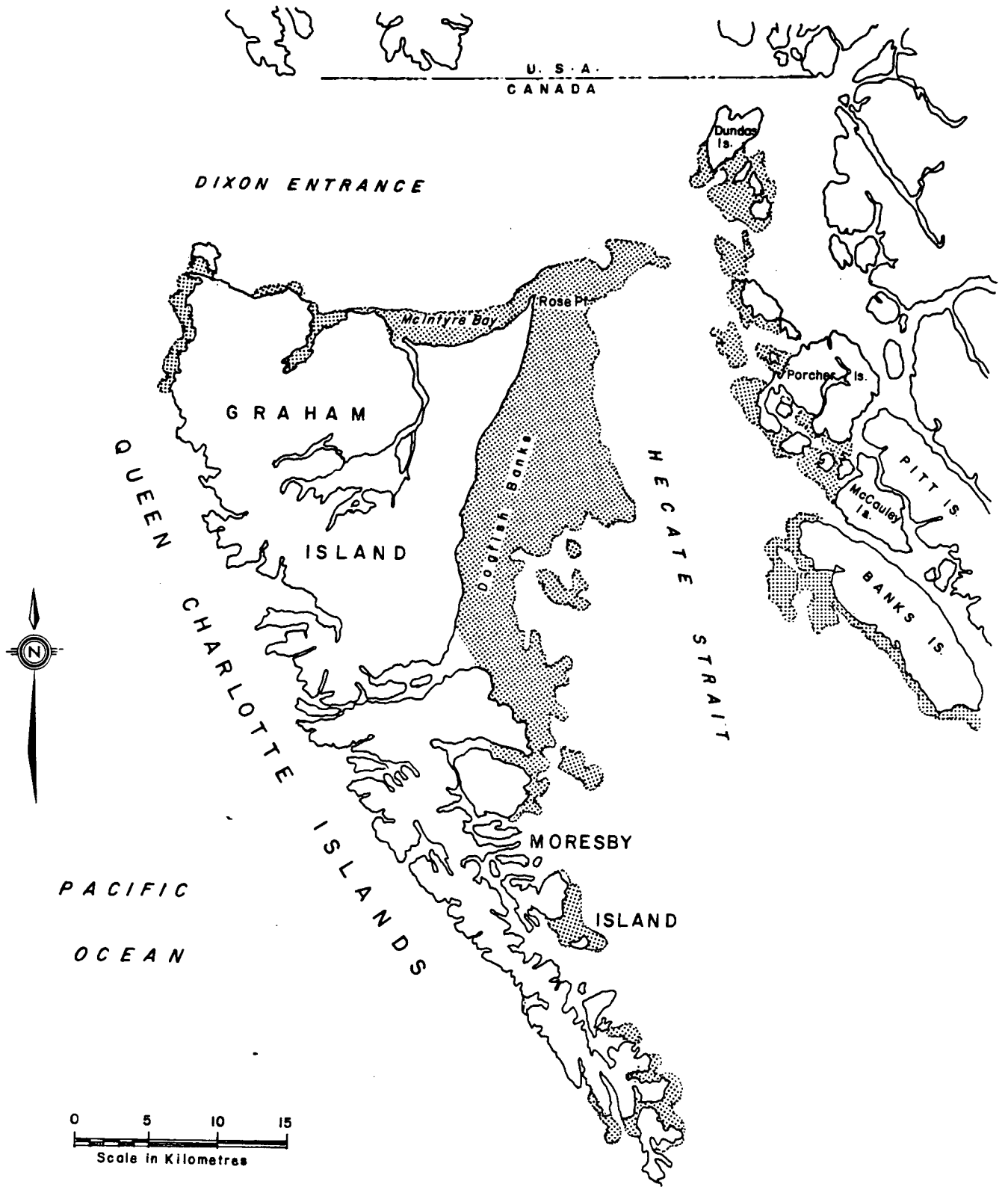

FIGURE 1 LOCATION MAP - HECATE STRAIT

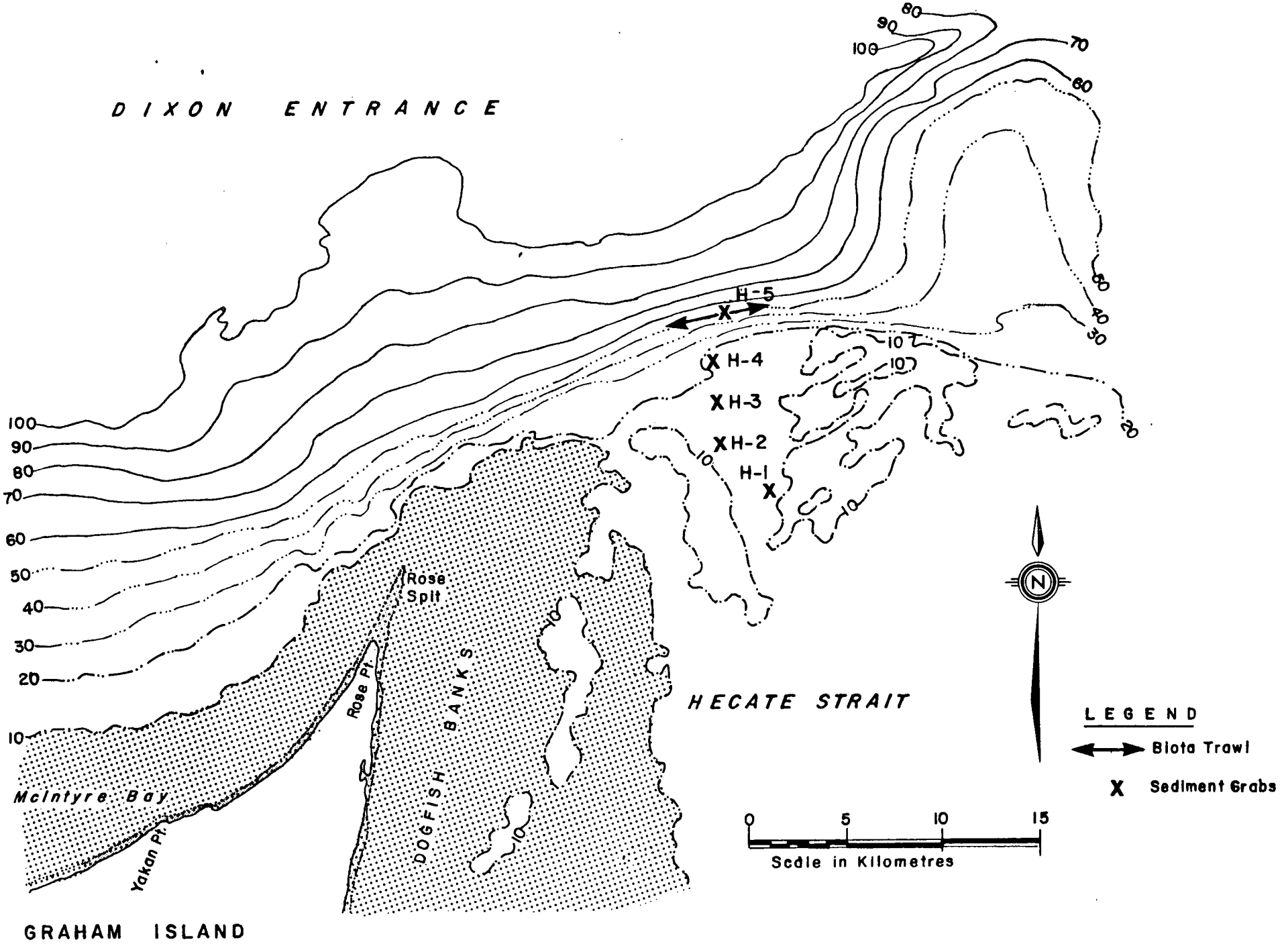

FIGURE 2 SAMPLING STATIONS IN HECATE STRAIT - March 1984

2 MATERIALS AND METHODS

2.1 Tissue Samples

Tissue samples were collected using a small otter trawl which consisted of a 3.8 cm mesh net with a 5.8 metre throat. The trawl was towed with a 3:1 scope for a distance of approximately 0.8 km.

Species collected for trace metal analysis included pandalid shrimp (Pandalopsis dispar); crangon shrimp (Crangon communis); ratfish (Hydrolagus colliei); halibut (Hippoglossus stenolepis); hake (Merluccius productus); skate (Raja kincaidi); rockfish (Scorpaenidae) and all species of flatfish. The total trawl catch was quantified in terms of total number and weight.

The shrimp were beheaded; tail muscle (generally composites of 2) and heptopancreas (composites of 6) were frozen for trace metal analysis. Fish tissue consisted of muscle filets with skin removed. The liver and gills from each fish species were also submitted for trace metal analysis. All biota samples were frozen individually in whirlpac bags.

2.1.1 Analytical Procedures - Tissue. Tissue trace metal analyses were conducted at the West Vancouver Laboratory according to procedures outlined by Swingle and Davidson (1979) which were basically 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 analyzed on the Inductive Coupled Argon Plasma (ICAP) Optical Emission Spectrometer. Tissue levels that were below the ICAP detection limit for cadmium and lead were analyzed by the Jarrell Ash 850 AAS with a FLA 100 garaphite tube furnace.

For mercury analysis, the blended and freeze-dried samples were dissolved in a 4:1 sulfuric acid-water mixture. These solutions were further oxidized with 50% peroxide, heated, cooled and diluted with potassium permanganate. The resultant solutions were then analyzed by "cold vapour" AAS (Atomic Absorption Spectrometer) with background correction.

2.2 Sediment Samples

Sediment surface grabs were taken at five stations (refer to Figure 2) using a stainless steel Smith-MacIntyre grab. The top 2 centimetres were retained for trace metal analysis. Samples were frozen onboard in whirlpac bags.

2.2.1 Analytical Procedures - Sediment. Frozen sediment samples were analyzed by the West Vancouver Laboratory for trace metals according to the procedure outlined by Swingle and Davidson (1979). The samples were freeze-dried and sieved through an 100-mesh nylon sieve. They were then digested in a 4:1 nitric-hydrochloric acid mixture and analyzed for trace metals using ICAP. Low level cadmium and lead levels were obtained using the Jarrell Ash 850 AAS with a FLA 100 graphite tube furnace.

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) are analysed with each batch of samples processed. If significant differences are observed between measured and certified values, methods are checked and the samples re-run. Quality control results are recorded, and are available for inspection. Detection limits for ICAP results are summarized in Appendix IV.

3 RESULTS AND DISCUSSION

3.1 Biota

3.1.1 Tissue Trace Metals. Mean tissue metal concentrations from the various organisms obtained at the trawl site are summarized in Table 1. The standard deviation, variance, maximum, and minimum levels have also been included. Refer to Appendix II for the raw tissue data.

Metal levels in shrimp could be considered as baseline concentrations (Hall et al, 1978) with the exception of lead in tail muscle for Crangon communis (mean level - .99 mg/kg) and Pandalopsis dispar (mean level - 1.16 mg/kg). Most metals were higher in the hepotopancreas than in the tail muscle (i.e. copper - 1180 vs. 13.45 mg/kg; zinc - 131 vs. 50.93 mg/kg; cadmium - 31.5 vs. 0.18 mg/kg, arsenic - 125 vs. 69.25 mg/kg; molybdenum - .7 vs. .4 mg/kg and manganese 16.5 vs. 3.78 mg/kg).

Muscle, liver, and gill tissue from the bottom-dwelling fish were analyzed for trace metal concentrations (Table 1). The metal levels can generally be considered as baseline levels (Hall et al., 1978). Higher concentrations of copper, zinc, cadmium, arsenic, iron, and manganese were found in the liver whereas higher levels of aluminum and barium were found in the gills. Molybdenum, lead, and mercury varied considerably in the specified tissues. Most metal concentrations were consistant in fish muscle with the exception of arsenic which was lower in Antherestes stomias (Arrowtooth Flounder), Hippoglossus stenolepis (Pacific Halibut) and Scorpaenidae (Rockfish); mean levels for these species ranged between 5.00 and 14.71 mg/kg opposed to 39.00 - 111.00 mg/kg for the other bottom-dwelling fish sampled.

Comparison of invertebrate (shrimp) and vertebrate (fish) muscle tissue metal levels showed higher concentrations of copper, zinc, cadmium, and aluminum in shrimp respective concentrations were approximately 13 mg/kg compared to < 2 mg/kg for copper, 50-60 mg/kg compared to 16-25 mg/kg for zinc, .18-.43 mg/kg compared to .08-1.8 mg/kg for cadmium and 30-87 mg/kg compared to 4-12 mg/kg for aluminum.

TABLE 1 MEAN TRACE METAL LEVELS IN BIOTA FROM HECATE STRAIT - MARCH 1984

	Al	As	Ba	Be	Cd	Cr	Cu	Fe	Hg	Mn	Mo	Pb	Zn
SHRIMP - Crangon communis - Muscle													
n=4 mean	87.00	47.00	0.94	0.10	0.43	0.63	13.60	146.50	0.12	3.84	0.48	0.99	58.33
max.	120.00	52.00	1.15	0.10	0.49	0.80	15.02	233.00	0.17	5.55	0.50	1.10	59.60
min.	67.00	44.00	0.07	0.09	0.37	0.50	12.30	110.00	0.03	3.10	0.40	0.85	56.60
SHRIMP - Pandalopsis dispar - Hepatopancreas													
	41.00	125.00	0.41	0.08	31.50	0.60	1180.0	181.00	0.37	16.50	0.70	0.71	131.00
SHRIMP - Pandalopsis dispar - Muscle													
n=24 mean	30.88	69.25	0.23	0.08	0.18	0.52	13.45	103.39	0.15	3.78	0.40	1.16	50.93
S.D.	24.78	18.89	0.13	0.00	0.22	0.14	3.18	103.24	0.06	7.54	0.00	0.25	7.51
var.	614.29	356.80	0.02	0.00	0.05	0.02	10.14	10658.32	0.00	56.89	0.00	0.06	56.44
max.	120.00	133.00	0.56	0.09	1.19	0.90	24.20	502.00	0.31	38.90	0.40	1.42	83.60
min.	7.00	19.00	0.08	0.08	0.10	0.40	7.20	24.30	0.07	1.28	0.40	0.16	45.40
FLOUNDER - Artherestes stomias - Muscle Arrowtooth flounder													
n=7 mean	12.71	14.71	0.24	0.08	0.16	0.83	1.67	32.70	0.43	1.44	0.40	1.43	20.84
S.D.	6.92	10.70	0.26	0.00	0.04	0.47	1.18	19.66	0.39	1.05	0.00	0.29	5.82
var.	47.90	114.57	0.07	0.00	0.00	0.22	1.39	386.69	0.15	1.11	0.00	0.08	33.88
max.	21.00	34.00	0.78	0.08	0.22	1.80	4.00	70.70	1.20	3.54	0.40	1.83	31.90
min.	4.00	4.00	0.08	0.08	0.11	0.40	0.70	12.20	0.25	0.39	0.40	1.01	13.40
FLOUNDER - Atherestes stomias - Gill													
n=4 mean	273.25	20.00	1.11	0.09	0.36	0.63	3.17	590.25	0.37	8.56	0.43	1.28	90.03
max.	397.00	30.00	1.73	0.10	0.45	1.00	3.30	821.00	0.70	13.00	0.50	1.42	110.00
min.	154.00	8.00	0.50	0.08	0.29	0.40	2.90	388.00	0.03	5.48	0.40	1.11	74.20

CONTINUED...

TABLE 1 MEAN TRACE METAL LEVELS IN BIOTA FROM HECATE STRAIT - MARCH 1984
(Continued)

	Al	As	Ba	Be	Cd	Cr	Cu	Fe	Hg	Mn	Mo	Pb	Zn
FLOUNDER - Atherestes stomias - Liver													
n=4 mean	4.75	41.25	0.08	0.08	19.83	0.45	52.68	52.68	0.18	5.79	0.40	0.99	146.50
max.	6.00	72.00	0.08	0.08	23.70	0.50	76.40	1690.00	0.32	6.72	0.40	1.16	165.00
min.	4.00	19.00	0.08	0.08	10.00	0.40	26.90	356.00	0.05	4.35	0.40	0.82	115.00
HALIBUT - Hippoglossus stenolepis - Muscle						Halibut							
	4.00	8.00	0.08	0.08	0.14	0.60	0.80	10.70	0.03	0.89	0.40	2.00	18.50
HALIBUT - Hippoglossus stenolepis - Gill													
	28.00	4.00	0.13	0.08	0.20	0.40	2.50	143.00	0.05	3.82	0.40	1.27	78.30
HALIBUT - Hippoglossus stenolepis - Liver													
	4.00	52.00	0.08	0.08	9.50	0.60	36.50	523.00	0.10	4.92	0.60	1.16	186.00
RATFISH - Hydrolagus colliei - Gill						Ratfish							
	35.00	12.00	0.20	0.08	0.52	0.40	3.40	193.00	0.22	4.93	0.40	0.84	66.90
RATFISH - Hydrolagus colliei - Liver													
	11.00	19.00	0.08	0.08	10.50	0.50	65.00	1970.00	0.07	4.75	0.40	0.97	271.00
SOLE - Glyptocephalus zachirus - Muscle													
	10.00	62.00	0.12	0.08	0.11	0.70	0.80	80.90	0.02	1.35	0.40	1.85	16.30

CONTINUED...

TABLE 1 MEAN TRACE METAL LEVELS IN BIOTA FROM HECATE STRAIT - MARCH 1984
(Continued)

	Al	As	Ba	Be	Cd	Cr	Cu	Fe	Hg	Mn	Mo	Pb	Zn
SOLE - Glyptocephalus zachirus - Liver													
	4.00	17.00	0.09	0.09	1.50	0.40	4.30	203.00	0.04	4.18	0.40	0.58	75.00
SOLE - Inopsetta ischyra - Muscle													
n=3 mean	10.00	65.33	0.28	0.08	0.18	0.63	1.87	23.53	0.05	1.09	0.40	1.26	21.80
max.	22.00	77.00	0.55	0.08	0.21	0.70	2.40	38.50	0.09	1.67	0.40	2.00	23.30
min.	4.00	57.00	0.08	0.08	0.12	0.60	0.90	11.40	0.02	0.53	0.40	0.59	19.60
SOLE - Inopsetta isychyra - Gill													
n=2 mean	92.50	6.00	3.03	0.08	0.08	1.30	2.30	265.50	0.08	10.24	0.40	0.64	99.10
max.	118.00	6.00	5.38	0.08	0.10	2.90	2.90	372.00	0.11	11.10	0.40	0.77	122.00
min.	67.00	6.00	0.68	0.08	0.05	1.70	1.70	159.00	0.04	9.37	0.40	0.51	76.20
SOLE - Inopsetta ischyra - Liver													
n=3 mean	4.00	58.33	0.08	0.08	0.71	0.47	89.47	263.33	0.13	7.86	0.57	0.57	125.13
max.	4.00	111.00	0.08	0.08	0.95	0.60	149.00	424.00	0.18	10.70	0.90	0.84	184.00
min.	4.00	16.00	0.08	0.08	0.28	0.40	25.60	60.00	0.04	4.31	0.40	0.15	55.40
SOLE - Lepidopsetta bilineata - Muscle													
	5.00	64.00	0.08	0.08	0.15	0.40	0.70	25.60	0.23	2.64	0.40	1.42	20.70

CONTINUED...

TABLE 1 MEAN TRACE METAL LEVELS IN BIOTA FROM HECATE STRAIT - MARCH 1984
(Continued)

	Al	As	Ba	Be	Cd	Cr	Cu	Fe	Hg	Mn	Mo	Pb	Zn
SOLE - Parophrys vetulus - Muscle													
n=2 mean	4.00	34.00	0.09	0.08	0.95	0.60	1.45	14.25	0.11	0.63	0.40	1.86	19.50
max.	4.00	39.00	0.09	0.08	1.80	0.70	2.10	16.40	0.14	0.69	0.40	1.92	19.60
min.	4.00	29.00	0.08	0.08	0.10	0.50	0.80	12.10	0.07	0.56	0.40	1.79	19.40
SOLE - Parophrys vetulus - Gill													
n=2 mean	34.00	4.00	1.57	0.08	0.20	0.95	2.00	173.50	0.02	7.21	0.40	0.07	68.45
max.	50.00	4.00	2.79	0.08	0.20	1.50	2.70	219.00	0.02	12.10	0.40	0.88	70.70
min.	18.00	4.00	0.34	0.08	0.20	0.40	1.30	128.00	0.02	2.32	0.40	0.51	66.20
SOLE - Parophrys vetulus - Liver													
	4.00	33.00	0.08	0.08	3.60	0.80	24.30	469.00	0.19	4.53	0.40	1.38	146.00
HAKE - Merlucius productus - Muscle													
	50.00	53.00	0.35	0.08	0.08	0.50	2.30	153.00	0.48	6.32	0.40	1.39	25.50
SKATE - Raja kincaidi - Muscle													
	9.00	111.00	0.42	0.08	0.15	0.70	1.10	26.30	0.48	2.53	0.40	1.77	20.50
SKATE - Raja kincaidi - Liver													
	4.00	15.00	0.08	0.08	0.80	0.40	6.60	125.00	0.10	2.45	0.40	1.53	28.60

CONTINUED...

TABLE 1 MEAN TRACE METAL LEVELS IN BIOTA FROM HECATE STRAIT - MARCH 1984
(Continued)

	Al	As	Ba	Be	Cd	Cr	Cu	Fe	Hg	Mn	Mo	Pb	Zn
ROCKFISH - SCORPAENIDAE - Muscle	4.00	5.00	0.08	0.08	0.18	0.50	2.70	12.00	0.29	0.29	0.40	1.33	16.30
ROCKFISH - SCORPAENIDAE - Liver	4.00	4.00	0.08	0.08	1.30	0.50	14.70	167.00	-	1.80	0.40	0.35	55.10

3.1.2 Quantitative Analysis. Quantitative biota data (species identification/number/total weight) obtained at the trawl site, H-1 is summarized in Appendix III. Crangon communis and Pandalopsis dispar appear to be the most dominant species of shrimp, whereas Antheresthes stomias (Arrowtooth flounder) was the dominant fish species. This information will be valuable for future comparisons with other baseline areas.

3.2 Sediment Trace Metals

The mean trace metal content found from the sediment grabs are shown in Table 2.

Surface sediment metal levels were comparable between the five stations (H-1 to H-5) with the exception of lead, iron and manganese which were considerably higher at Stations H-3 and H-4; respective concentrations were 23-24 mg/kg compared to 3-5 mg/kg for lead, 98,800-93,200 mg/kg compared to 15,200-33,300 mg/kg for iron and 402-416 mg/kg compared to 197-262 mg/kg for manganese.

Sediment samples were also collected by the Pacific Geoscience Centre northern Hecate Strait during June and September, 1979 and analysed for trace metals by EPS (Sneddon and Holman, 1982). The trace metal levels obtained from this survey are compared with the 1984 sediment levels in Table 3. The metal concentrations have not substantially changed between the two sampling periods and can be considered as baseline levels.

TABLE 2 TRACE METALS IN SURFACE SEDIMENT GRABS FROM HECATE STRAIT - MARCH 1984 (ug/g dry weight)

STATION	DEPTH (m)	Al	As	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	Mg
H-1	111	7760	8	24.1	0.2	24100	0.4	4.8	15.0	3.6	15200	0.053	3290
H-2	32	6810	8	17.3	0.2	10600	0.5	7.0	21.6	4.7	33300	0.053	2760
H-3	40	5030	8	11.1	0.2	7410	0.3	14.2	43.8	5.0	98800	0.029	2080
H-4	37	5500	8	10.5	0.2	7810	0.3	15.8	45.2	3.3	93200	0.047	2100
H-5	121	10850	8	36.9	0.2	16950	0.4	9.1	18.5	5.1	16750	0.068	2555

STATION	DEPTH (m)	Mn	Mo	Na	Ni	P	Pb	Si	Sn	Sr	Ti	V	Zn
H-1	111	197	0.8	2230	9	640	3	1960	3	161.5	814	50	24.0
H-2	32	262	0.8	1340	5	873	5	2040	6	62.6	1390	114	26.1
H-3	40	402	0.8	1010	3	855	24	1740	8	39.4	2330	319	41.5
H-4	37	416	0.8	850	3	898	23	640	8	39.9	2240	306	37.1
H-5	121	242	0.8	3320	11	809	4	685	4	109.5	907	54	36.9

TABLE 3 TRACE METAL CONCENTRATIONS IN HECATE STRAIT MARINE SEDIMENTS - 1979 VS. 1984

METAL	RANGE - MG/KG DRY WEIGHT	
	1979*	1984
Cu	2.68 - 11.2	3.3 - 5.1
Pb	< 9.65 - 21.6	3 - 24
Cd	< .5 - 1.64	.3 - .5
Zn	13.2 - 48.3	24.0 - 41.5
Mo	< 17.9 - < 24.7	0.8
As	-	8.0
Fe	16,500 - 49,400	15,200 - 98,800
Al	5,050 - 18,000	5,030 - 10,850

* Sneddon and Holman (1982) - Stations 1-14

4 REFERENCES

1. Arctic Laboratories Ltd., 1979. Histopathological Evaluation of Organisms from Timgmairk K-19, Ukaalert C-50, Ukalerk QC-50 and Kenalooak J-94. For Dome Petroleum Ltd.

2. Dome Petroleum Ltd., 1979. Environmental Overview of Beuafort Sea Development.

3. Drinnan, R.W., 1985. A Review of Environmental Concerns Related to Hydrocarbon Development on the Grand Banks. For Environment Canada, March, 1985.

4. Hall, R.A., E.G. Zook and G.M. Meaburn, 1978. National Marine Fisheries Service Survey of Trace Elements in the Fishery Resource. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Division.,

5. Maurer, D., W. Leathem and C. Menzie, 1981. The Impact of Drilling Fluid and Well Cuttings on Polychaete Feeding Guilds from U.S. Northeastern Continental Shelf. Marine Pollution Bulletin 12(10): 342-347.

6. Sneddon, H. and N. Holman, November 1982. Trace Metals in Hecate Strait Marine Sediments, June-September, 1979. EPS Manuscript Report.

7. Swingle, R.B. and J.W. Davidson, 1979. Environmental Laboratory Manual, Laboratory Services, Department of Environment and Fisheries and Oceans.

8. Thomas, D.J., G.D. Greene, W.S. Duval, K.C. Milne and M.S. Hutcheson, 1982. Offshore Oil and Gas Production Waste Characteristics, Treatment Methods, Biological Effects and their Applications to Canadian Regions. Arctic Laboratories Limited. Environmental Sciences Limited (ESL) and Seakem Consulting Limited.

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6 APPENDICES

APPENDIX I SAMPLING STATION COORDINATES - HECATE STRAIT - MARCH 1984

STATION	PARAMETER	DEPTH (m)	LATITUDE	LONGITUDE
H-1	Sediment	111	54°12.5'N	131°21.00'W
H-2	Sediment	32	54°13.78	131°22.74'W
H-3	Sediment	40	54°15.48	131°23.55'W
H-4	Sediment	37	54°16.84'N	131°24.20'W
H-5	Sediment	121	52°18.42'N	131°24.97'W
H-5	Trawl	start:	54°18.34'N	131°24.26'W
		finish:	54°18.18'N	131°25.96'W

APPENDIX II TISSUE TRACE METALS IN BIOTA - MARCH 1984 (mg/g - Dry Weight)

Al	As	Ba	Be	Cd	Cr	Cu	Fe	Hg	Mn	Mo	Pb	Zn	% MOISTURE
SHRIMP - Crangon communis - Muscle													
67.00	47.00	0.70	0.10	0.39	0.50	14.20	126.00	-	3.30	0.50	1.10	58.80	75.7%
120.00	44.00	1.15	0.09	0.48	0.80	12.70	233.00	0.03	5.55	0.40	0.85	56.60	76.2%
83.00	45.00	0.90	0.10	0.37	0.50	12.30	117.00	0.15	3.10	0.50	0.90	-	73.6%
78.00	52.00	1.00	0.10	0.49	0.70	15,20	110.00	0.17	3.40	0.50	1.10	59.60	75.4%
SHRIMP - Pandalopsis dispar - Hepatopancreas													
41.00	125.00	0.41	0.08	31.50	0.60	1180.00	181.00	0.37	16.50	0.70	0.71	131.00	67.3%
SHRIMP - Pandalopsis dispar - Muscle													
30.00	59.00	0.46	0.08	0.12	0.40	12.40	164.00	0.14	2.94	0.40	0.16	47.10	76.2%
120.00	57.00	0.50	0.08	0.12	0.50	9.70	502.00	0.20	38.90	0.40	1.20	50.10	76.1%
38.00	80.00	0.24	0.08	0.14	0.40	17.80	147.00	0.31	2.07	0.40	0.98	46.80	76.7%
12.00	65.00	0.12	0.08	0.14	0.50	13.90	37.30	0.09	1.58	0.40	1.35	50.70	76.8%
23.00	72.00	0.20	0.08	0.14	0.50	15.00	74.80	0.14	1.70	0.40	1.28	47.70	75.3%
37.00	133.00	0.31	0.08	0.20	0.70	24.20	82.30	0.15	2.42	0.40	1.42	83.60	76.4%
26.00	61.00	0.22	0.08	0.14	0.50	14.00	67.80	0.08	2.01	0.40	1.22	52.60	76.0%
23.00	57.00	0.20	0.08	0.14	0.40	11.10	64.10	0.08	1.94	0.40	1.21	50.10	77.0%
9.00	90.00	0.11	0.08	0.14	0.40	11.40	32.60	0.13	1.36	0.40	1.20	52.00	76.6%
67.00	56.00	0.36	0.08	0.13	0.50	11.40	158.00	0.10	3.71	0.40	1.03	49.30	74.3%
7.00	75.00	0.08	0.08	0.21	0.50	12.00	24.30	0.25	1.79	0.40	1.20	52.00	76.6%
29.00	69.00	0.23	0.08	0.15	0.40	12.40	56.60	0.07	1.63	0.40	0.97	50.20	76.3%
28.00	70.00	0.24	0.08	1.19	0.70	13.90	73.20	0.09	3.17	0.40	1.17	51.00	76.5%
23.00	72.00	0.19	0.08	0.15	0.80	13.80	65.50	0.12	2.14	0.40	1.35	47.30	76.8%
12.00	74.00	0.11	0.08	0.13	0.50	13.40	31.30	0.09	1.28	0.40	1.18	47.50	76.7%
26.00	62.00	0.25	0.08	0.11	0.70	13.90	234.00	0.13	2.54	0.40	1.01	52.20	74.4%
24.00	72.00	0.15	0.08	0.12	0.40	15.30	59.90	0.23	1.97	0.40	1.30	49.80	75.1%
20.00	74.00	0.12	0.08	0.12	0.60	15.50	54.70	0.09	1.78	0.40	1.28	47.80	73.4%
21.00	19.00	0.25	0.08	0.13	0.50	7.20	218.00	0.14	5.46	0.40	1.37	56.00	75.2%
13.00	61.00	0.10	0.08	0.11	0.40	13.70	30.30	0.12	1.58	0.40	1.15	45.40	75.6%

CONTINUED...

APPENDIX II TISSUE TRACE METALS IN BIOTA - MARCH 1984 (mg/g - Dry Weight) (Continued)

Al	As	Ba	Be	Cd	Cr	Cu	Fe	Hg	Mn	Mo	Pb	Zn	% MOISTURE
SHRIMP - Pandalopsis dispar - Muscle													
26.00	68.00	0.15	0.08	0.11	0.40	10.50	62.00	0.21	2.19	0.40	1.28	48.20	77.1%
19.00	62.00	0.16	0.09	0.11	0.40	11.20	46.00	0.21	1.36	0.40	1.06	47.60	76.3%
76.00	75.00	0.56	0.08	0.10	0.90	14.20	139.00	0.17	3.80	0.40	1.23	-	76.7%
32.00	79.00	0.21	0.08	0.10	0.40	14.80	56.70	0.16	1.46	0.40	1.25	47.60	77.5%
FLOUNDER - Artherestes stomias - Muscle													
4.00	4.00	0.08	0.08	0.11	0.60	1.50	14.40	0.25	0.39	0.40	1.69	17.40	83.4%
4.00	34.00	0.08	0.08	0.15	0.50	1.10	12.20	1.20	0.75	0.40	1.83	13.40	81.0%
16.00	8.00	0.12	0.08	0.15	1.80	*11.40	32.80	0.08	0.98	0.40	1.27	21.70	82.3%
11.00	11.00	0.11	0.08	0.19	0.70	1.50	27.30	0.28	0.93	0.40	1.46	17.60	85.05
21.00	25.00	0.78	0.08	0.13	0.90	0.70	70.70	0.68	3.54	0.40	1.01	22.10	81.7%
13.00	10.00	0.39	0.08	0.15	0.90	1.20	29.70	0.27	1.65	0.40	1.22	21.80	83.6%
20.00	11.00	0.10	0.08	0.22	0.40	4.00	41.80	0.25	1.83	0.40	1.56	31.90	84.8%
FLOUNDER - Artherestes stomias - Gill													
362.00	12.00	1.50	0.10	0.45	0.70	*26.10	639.00	-	10.00	0.50	1.40	110.00	84.9%
154.00	30.00	0.50	0.08	0.37	0.40	2.90	513.00	-	5.77	0.40	1.17	94.10	79.6%
180.00	8.00	0.72	0.08	0.33	0.40	3.30	388.00	0.03	5.48	0.40	1.42	74.20	83.3%
397.00	30.00	1.73	0.08	0.29	1.00	3.30	821.00	0.07	13.00	0.40	1.11	81.80	83.0%
FLOUNDER - Artherestes stomias - Liver													
4.00	39.00	0.08	0.08	22.40	0.40	76.40	356.00	0.25	6.38	0.40	1.16	159.00	76.6%
4.00	72.00	0.08	0.08	23.20	0.50	47.10	1690.00	0.11	4.35	0.40	0.85	115.00	74.6%
5.00	35.00	0.08	0.08	23.70	0.40	60.30	814.00	0.32	5.69	0.40	1.13	165.00	79.4%
6.00	19.00	0.08	0.08	10.00	0.50	26.90	683.00	0.05	6.72	0.40	0.82	147.00	72.6%

CONTINUED...

APPENDIX II TISSUE TRACE METALS IN BIOTA - MARCH 1984 (mg/g - Dry Weight) (Continued)

Al	As	Ba	Be	Cd	Cr	Cu	Fe	Hg	Mn	Mo	Pb	Zn	% MOISTURE
HALIBUT - Hippoglossus stenolepis - Muscle													
4.00	8.00	0.08	0.08	0.14	0.60	0.80	10.70	0.03	0.89	0.40	2.00	18.50	81.6%
HALIBUT - Hippoglossus stenolepis - Gill													
28.00	4.00	0.13	0.08	0.20	0.40	2.50	143.00	0.05	3.82	0.40	1.27	78.30	83.1%
HALIBUT - Hippoglossus stenolepis - Liver													
4.00	52.00	0.08	0.08	9.50	0.60	36.50	523.00	0.10	4.92	0.60	1.16	186.00	76.2%
RATFISH - Hydrolagus colliei - Gill													
35.00	12.00	0.20	0.08	0.52	0.40	3.40	193.00	0.22	4.93	0.40	0.84	66.90	83.4%
RATFISH - Hydrolagus colliei - Liver													
11.00	19.00	0.08	0.08	10.50	0.50	65.00	1970.00	0.07	4.75	0.40	0.97	271.00	76.0%
SOLE - Glyptocephalus zachirus - Muscle													
10.00	62.00	0.12	0.08	0.11	0.70	0.80	80.90	0.02	1.35	0.40	1.85	16.30	81.8%

CONTINUED...

APPENDIX II TISSUE TRACE METALS IN BIOTA - MARCH 1984 (mg/g - Dry Weight) (Continued)

Al	As	Ba	Be	Cd	Cr	Cu	Fe	Hg	Mn	Mo	Pb	Zn	% MOISTURE
SOLE - Glyptocephalus zachirus - Liver													
4.00	17.00	0.09	0.09	1.50	0.40	4.30	203.00	0.04	4.18	0.40	0.58	75.00	83.0%
SOLE - Inopsetta ischyra - Muscle													
4.00	77.00	0.08	0.08	0.21	0.60	0.90	11.40	0.09	0.53	0.40	2.00	19.60	81.7%
22.00	62.00	0.20	0.08	0.12	0.60	2.30	38.50	0.02	1.08	0.40	0.59	22.50	80.8%
4.00	57.00	0.55	0.08	0.20	0.70	2.40	20.70	0.03	1.67	0.40	1.19	23.30	81.2%
SOLE - Inopsetta ischyra - Gill													
67.00	6.00	5.38	0.08	0.05	1.90	1.70	159.00	0.04	11.10	0.40	0.51	122.00	79.0%
118.00	6.00	0.68	0.08	0.10	0.70	2.90	372.00	0.11	9.37	0.40	0.77	76.20	84.6%
SOLE - Isopsetta ischyra - Liver													
4.00	16.00	0.08	0.08	0.28	0.40	25.60	60.00	0.04	4.31	0.40	0.15	55.40	48.6%
4.00	48.00	0.08	0.08	0.90	0.40	93.80	306.00	0.17	8.57	0.40	0.84	136.00	71.1%
4.00	111.00	0.08	0.08	0.95	0.60	149.00	424.00	0.18	10.70	0.90	0.73	184.00	75.7%
SOLE - Lepidopsetta bilineata - Muscle													
5.00	64.00	0.08	0.08	0.15	0.40	0.70	25.60	0.23	2.64	0.40	1.42	20.70	81.0%

CONTINUED...

APPENDIX II TISSUE TRACE METALS IN BIOTA - MARCH 1984 (mg/g - Dry Weight) (Continued)

Al	As	Ba	Be	Cd	Cr	Cu	Fe	Hg	Mn	Mo	Pb	Zn	% MOISTURE
SOLE - Parophrys vetulus - Muscle													
4.00	39.00	0.09	0.08	0.10	0.50	0.80	12.10	0.14	0.69	0.40	1.92	19.60	82.0%
4.00	29.00	0.08	0.08	0.18	0.70	2.10	16.40	0.07	0.56	0.40	1.79	19.40	79.0%
SOLE - Parophrys vetulus - Gill													
18.00	4.00	2.79	0.08	0.20	1.50	1.30	128.00	0.02	12.10	0.40	0.51	70.70	46.8%
50.00	4.00	0.34	0.08	0.20	0.40	2.70	219.00	0.02	2.32	0.40	0.88	66.20	79.7%
SOLE - Parophrys vetulus - Liver													
4.00	33.00	0.08	0.08	3.60	0.80	24.30	469.00	0.19	4.53	0.40	1.38	146.00	74.7%
HAKE - Merluccius productus - Muscle													
50.00	53.00	0.35	0.08	0.08	0.50	2.30	153.00	0.48	6.32	0.40	1.39	25.50	80.7%
SKATE - Raja kincaidi - Muscle													
9.00	111.00	0.42	0.08	0.15	0.70	1.10	26.30	0.48	2.53	0.40	1.77	20.50	79.4%
SKATE - Raja kincaidi - Liver													
4.00	15.00	0.08	0.08	0.80	0.40	6.60	125.00	0.10	2.45	0.40	1.53	28.60	48.3%

CONTINUED...

APPENDIX II TISSUE TRACE METALS IN BIOTA - MARCH 1984 (mg/g - Dry Weight) (Continued)

Al	As	Ba	Be	Cd	Cr	Cu	Fe	Hg	Mn	Mo	Pb	Zn	% MOISTURE
ROCKFISH - SCORPAENIDAE - Muscle													
4.00	5.00	0.08	0.08	0.18	0.50	2.70	12.00	0.29	0.29	0.40	1.33	16.30	79.3%
ROCKFISH - SCORPAENIDAE - Liver													
4.00	4.00	0.08	0.08	1.30	0.50	14.70	167.00	-	180	0.40	0.35	55.10	51.1%

* Not used in statistical calculations

APPENDIX III QUANTITATIVE BIOTA ANALYSIS - HECATE STRAIT - MARCH 1984
(Station H-1)

SPECIES	COMMON NAME	NUMBER	TOTAL WEIGHT (g)
MOLLUSCA - Gastropods			
Trichotropis cancellata	Harry shell	2	-
	Moonsnail	1	-
ARTHROPODA - Isopods	-	1	-
- Caridea			
Crangon communis		91	111
Pandalopsis dispar	Sidestripe Shrimp	49	588
Pandalis borealis	Pink Shrimp	19	-
Pasiphae pacifica	Glass Shrimp	1	-
Spirontocaris sp.	-	1	-
BRANCHYURA			
Hyas lyratus	Lyre Crab	4	-
ECHINODERMATA			
- ASTEROIDEA	-	1	-
- OPHIURODEA	Basket Star	1	-
Gorgoncephalus eucnemis			
- HOLOTHURODIA			
Chiridota sp.	Brittle Star	Several	-
CORDATA - PISCES			
Parophyrys vetulus	English Sole	1	252
Glyptocephalus zachirus	Rex Sole	3	150
Gadus macrocephalus	Pacific Cod	3	2049
Hippoglossus stenolepis	Pacific Halibut	1	1400
Clupea harengus pallasi	Pacific Herring	6	92
Antheresthes stomias	Arrowtooth Flounder	10	-
Raja kincaidi	Black Skate	1	400
Boccaio sp.	Rockfish	1	< 50
Hydrolagus colliei	Ratfish	4	200

APPENDIX IV TRACE METAL DETECTION LIMITS

METAL	CONCENTRATION (ug/g)	
	Biota	Sediment
As	4	8
Ba	.08	.20
Be	.08	.20
Cd	.20	.30
Co	.40	.80
Cr	.40	.80
Cu	.40	.80
Mn	.08	.20
Mo	.40	.80
Ni	2.0	3.0
P	4.0	8.0
Pb	2.0	3.0
Sb	4.0	-
Sn	.80	2.0
Sr	.08	.20
Ti	.20	.30
V	.40	.80
Zn	.20	.30
Al	4.0	8.0
Fe	.40	80
Si	8.0	20
Ca	8.0	20
Mg	8.0	20
Na	8.0	20