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DEPARTMENT OF ENVIRONMENT
ENVIRONMENTAL PROTECTION SERVICE
PACIFIC REGION

BASELINE MARINE ENVIRONMENTAL CONDITIONS AT PORT SIMPSON, B.C., The Site of a Proposed Liquid Natural Gas Plant

RP 82-11

Regional Program Report 82-11

by

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ABSTRACT

The Environmental Protection Service collected baseline environmental data in August, 1981 at Port Simpson, the site of a proposed liquid natural gas plant. Parameters of interest were 1) oceanographic water quality - salinity, temperature, dissolved oxygen and nutrients; and 2) benthic characteristics - subtidal surface sediment partical size, organic content, heavy metal concentrations and macrofauna (grabs and otter trawls). Photographic records and gross community analyses were also made at selected intertidal shoreline sites in Port Simpson Bay.

Results indicate a relatively unimpacted marine environment. Oceanographic parameters were characteristic of B.C. north coastal waters. Fine sediment (L250 um) characterized most stations. Organic content was higher in Port Simpson Bay, likely a result of extensive eel grass (Zostera marina) beds. Heavy metal concentrations were low compared to other north coast locations. Benthic invertebrate fauna was dominated by polychaete worms. Macro-fauna caught in the otter trawl was dominated by brittle stars (Ophiopholis aculeata) and flathead sole (Hippoglossoides elassidon). Similar intertidal shoreline communities were recorded throughout Port Simpson Bay with rockweed, mussels and barnacles dominating.

RÉSUMÉ

En août 1981, à Port Simpson, où l'on prévoit l'installation d'une usine de gaz nature1 liquide, le Service de la protection de l'environnement a rassemblé un certain nombre de données de base sur l'environnement. Paramètres étudiés: 1) qualité océanographique de l'eau, salinité, température, oxygène dissous et substances nutritives; 2) caractéristiques benthiques: sediments superficiels de la zone constamment immergée, taille des particules, composants organiques, degré de concentrtion des métaux lourds et macrogaune (drague et chaluts de mer à double panneau). On a en même temps procédé, à certains endroits précis de la zone intertidale de Port Simpson Bay, à l'établissement d'une documentation photographique et à des analyses générales des colonies recontrées.

Les résultats de ces diverses analyses révèlent que l'environnement marin est rest6 relativement peu touché. On a constaté que les paramètres océanographiques étaient caractéristiques des eaux côtières du nord de la B.C., que les sédiments fins (moins de 250 µm) caractérisaient la plupart des endroits et que les composants organiques étaient plus importants à Port Simpson Bay, probablement en raison d'une prolifération de Zostera marina. Le degré de concentration des métaux lourds était faible par rapport à d'autres endroits de la côte septentrionale. Les invertébrés benthiques étaient surtout représentés par les polychètes. Parmi les échantillons de macrofaune pris à l'aide de chaluts de mer à double panneau on a surtout relevé la présence d'ophiures (Ophiopholis aculeata) et de soles (Hippoglossoides elassidon). Des colonies similaires ont été rencontrées dans toutes les étendues intertidales de Port Simpson Bay, avec prédominance des Fucus sp., des moules et des anatifes.

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SUMMARY

1) A survey was conducted in August, 1981 to collect baseline environmental data at Port Simpson, the site of a proposed liquid natural gas plant. Parameters included physical oceanography, physical, chemical and biological sediment characteristics, benthic fauna and intertidal shoreline examination.

2) Water column profiles of temperature, salinity and dissolved oxygen were typical of those recorded in August for the coast of B.C. Slightly higher temperatures and lower dissolved oxygen values were noted in Port Simpson Bay compared to waters outside Chatham Sound.

3) Nitrate and nitrite levels in the water column were below detection limits. Ammonia was higher in Port Simpson Bay and ortho-phosphate higher in the outside waters of Chatham Sound.

4) Estimates of phytoplankton standing stock as chlorophyll a varied considerably from station to station. Levels were within ranges reported for B.C. coastal waters.

5) Fine subtidal surface sediments were recorded at most stations, with at least half the particles less than 250 urn. Organic content of the sediments varied from 1.2 to 9.7%. Higher levels were associated with sediments containing a large proportion of particles less than 62.5 urn. Elevated levels of organics in Port Simpson Bay is likely related to added input from eel grass (Zostera marina) beds.

6) The heavy metal content of sediments varied considerably from station to station with lowest levels recorded at SO-5 where the proportion of large sediment particles was greatest. Overall, metal concentrations were low compared with data collected off Ridley Island. Sediment

cores in Port Simpson Bay indicated minor changes in metal concentrations over time with highest levels noted in the 5-10 cm layer.

7) Polychaete worms dominated the subtidal invertebrate community at most stations. Species density ranged from 10 to 45 with total numbers of 15 and 177, respectively. The least number of organisms were recorded at SO-5, the station with lowest organics and largest particle size.

8) Macro-fauna caught in the otter trawl was dominated by brittle stars (Ophiopholis aculeata) and flathead sole (Hippoglossoides elassodon).

9) Intertidal shoreline surveys indicated the presence of similar communities throughout Port Simpson Bay. Rockweed, mussels and barnacles dominated. Gross examination suggests unimpacted intertidal communities.

1 INTRODUCTION

Port Simpson Bay (54°34,7'N, 130°26.9'W) is located in northwest British Columbia 30 km north of Prince Rupert (Figure 1). The bay, an area of about 4 km x 5 km, has been indicated by Dome Petroleum as a preferred site for construction of a liquefied natural gas (LNG) process plant and export terminal. Commercial fishing, logging and a large domestic fishery form the basis of the Port Simpson economy. A cannery and net loft are operated by the Port Simpson Indian Band at the townsite 3 km southwest of the proposed LNG facility.

Relatively little site specific information exists regarding the receiving environment and natural resources of Port Simpson Bay aside from a recent environmental assessment by Dome (1981). Even in this, information on oceanographic parameters (physical, chemical and biological), the intertidal community and the subtidal habitat are wide spread, infrequent and several data gaps are identified. Ongoing studies by Dome are providing more baseline data.

The Environmental Protection Service (EPS) undertook a survey in August, 1981 designed to obtain more complete site specific information and comparative data upon which to base future impact assessment. Measurements of water quality (salinity, temperature, dissolved oxygen and nutrients and phytoplankton standing stock) and sediemnt characteristics (particle size, organic and heavy metal content) were made. Species composition of benthic (grabs and otter trawls) and intertidal shoreline communities throughout Port Simpson Bay were also determined.

2 MATERIALS AND METHODS

Oceanographic, benthic and shoreline sampling were conducted August 4 and 5, 1981 from the research vessel C.F.A.V. ENDEAVOUR. Station positions are given in Appendix I.

2.1 Oceanographic Sampling

Oceanographic parameters were sampled at stations indicated on Figure 2. Water samples were obtained from selected depths using N.I.O. bottles with paired, protected reversing thermometers. Temperatures were read and recorded within 5 minutes and re-calculated to the temperature at depths using the equation of Sverdrup et al (1946). Salinity was measured using a Guideline salinometer ("Autosal" Model 8400). The azide modification of the Winkler method (Swingle and Davidson, 1979) was used in determining dissolved oxygen concentration. Percent saturation of dissolved oxygen in seawater was calculated according to the equation outlined in Gameson and Robertson (1955).

Water samples collected for dissolved nutrient analyses at 0, 2, 5 and 10 m were stored frozen (Strickland and Parsons, 1971). Nitrate, nitrite, ammonia, and ortho-phosphate concentrations were determined on an Autoanalyzer at the EPS chemistry laboratory according to methods described by Swingle and Davidson (1979).

Phytoplankton standing stocks were estimated using active chlorophyll a and phaeopigemnt concentrations. One litre water samples from 0, 2, 5 and 10 m depths at each of the oceanographic stations were filtered onto 0.45 μm GF/C filters. The filters were treated with $MgCO_3$ prior to storage in the frozen state. Pigments were extracted with 90% acetone and analysis performed according to Strickland and Parsons (1971).

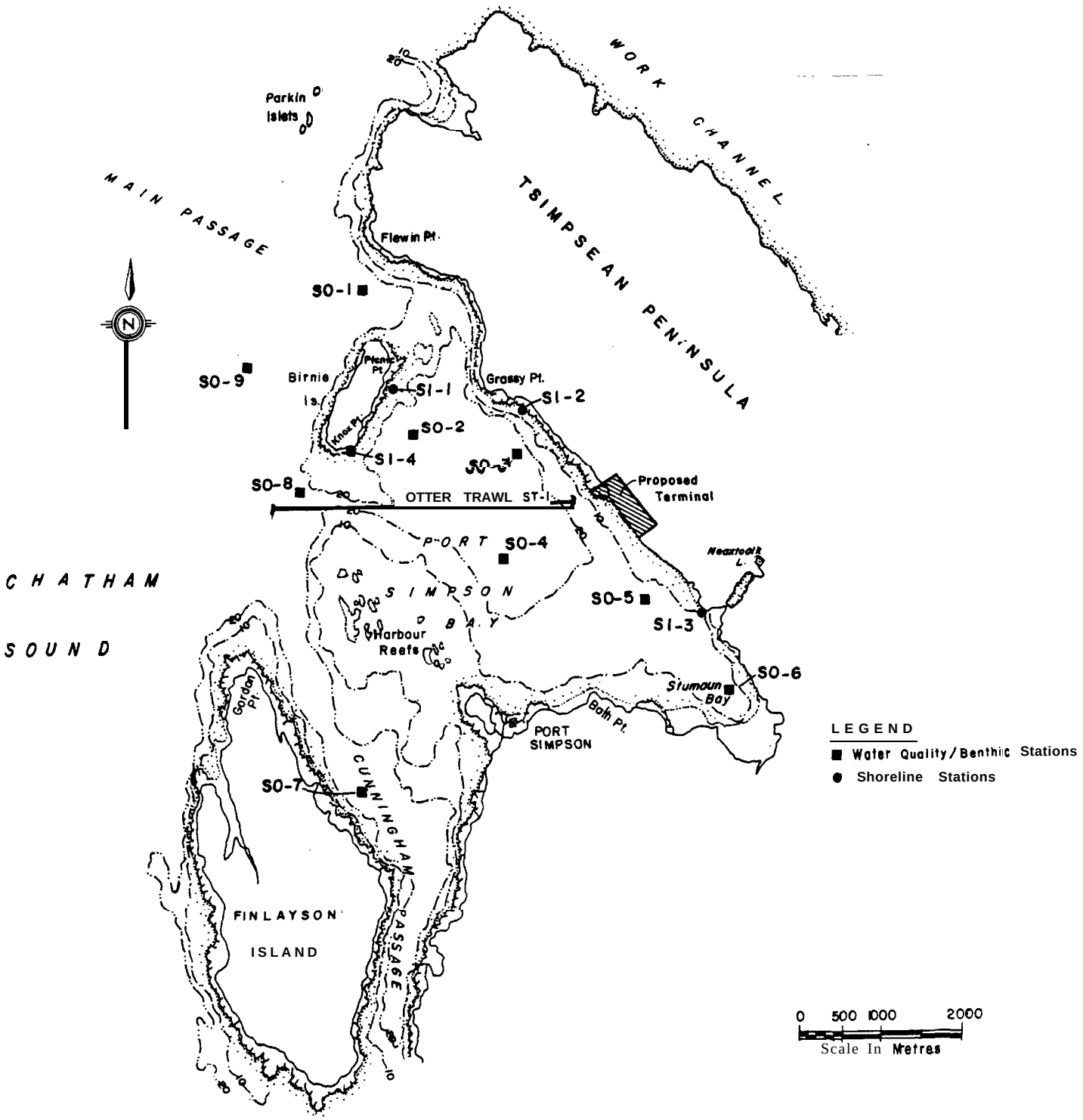

FIGURE 2 SAMPLING SITES FOR WATER QUALITY / BENTHIC, SHORELINE AND OTTER TRAWL STATIONS

2.2 Benthic Sampling

2.2.1 Sediments. Sediment samples were otained with a Smith-McIntyre grab sampler from stations SO-1 to SO-9 (Figure 2). Sub-samples from the top 2-3 cm were removed for particle size distribution, organic content and heavy metal concentrations. These were stored frozen in "Whirlpak" bags until analysed at the EPS chemistry laboratory.

Species diversity was determined using the Shannon and Weaver (1968) formula $H'(d) = -\sum pi \log_2 pi$ ($pi = ni/N$, ni = number of individuals in the i species, N = total number of individuals sampled). Evenness with which individuals are divided among the species was described using the formula $J = -\sum \frac{pi \log_2 pi}{\log_2 S}$ where S is the total number of species, J max = 1 (Pielou, 1966).

Sediment heavy metals, mercury (Hg), and organic content were analysed according to the methods described by Swingle and Davidson (1979).

Sediment particle size distribution was determined by wet sieving through three sizes of screens (500 μm, 250 μm and 62.5 μm). The fraction retained on each screen was weighed and expressed as a percentage of the total sample weight.

2.2.2 Benthic Fauna. Benthic invertebrates, infauna and epifauna, were removed from 3 litres of sediment at selected stations by sieving through a 500 um screen. The organisms were fixed in a solution of 10% buffered formalin and subsequently preserved in 70% isopropanol prior to identification.

An otter trawl, ST-1, was done in Port Simpson Bay (Figure 2) to sample fish and large benthic invertebrates. Contents of the net towed over a distance of approximately 0.5 nautical miles were identified and enumerated.

2.3 Intertidal Shoreline Surveys

Intertidal communities were surveyed at stations SI-1, 2, 3 and 4 during low tide periods (Figure 2). The plant and animal community at each station was noted and photographs taken for future reference.

3 RESULTS AND DISCUSSION

3.1 Physical Oceanography

Oceanographic data are presented in Appendix II. Temperature, salinity and dissolved oxygen profiles were typical of those recorded for the coast of British Columbia (northeast Pacific) in August (Thomson, 1981). Some spatial variation was noted between stations outside in Chatham Sound and those inside Port Simpson Bay (Table 1). The mean temperatures of stations outside were lower and salinity, dissolved oxygen and percent saturation higher compared to mean values for stations in the bay, as would be expected for an embayed area. Within the bay, the highest temperature and lowest salinity and dissolved oxygen values were noted in Stumaun Bay (Appendix II). Shallower water and fresh water input exist in this area.

3.2 Dissolved Nutrients

Dissolved nutrient data for the top 10 m of the water column are presented in Appendix III. Nitrate (LO.010 mg/l) and nitrate (LO.005 mg/l) were generally below detection limit throughout the study area. Ammonia levels, when detectable, were higher in the bay. However, ortho-phosphate had a reverse pattern with noticably higher levels in Chatham Sound where surface values averaged 0.0128 mg/l compared to 0.0081 mg/l inside the bay. At all stations, phosphate concentration at 10 m were about double that at the surface (Appendix III).

3.3 Phytoplankton Standing Stock

Phytoplankton standing stock estimates based on pigment content are presented in Appendix IV. Active chlorophyll a and phaeopigment (degraded chlorophyll a) varied greatly from station to station and with depths. Chlorophyll a values ranged from not detectable to 1.34 ug/l at the surface from 0.27 to 1.87 ug/l at 10 meters.

TABLE 1: MEAN OCEANOGRAPHIC CONDITIONS IN THE SURFACE WATERS AT STATIONS IN CHATHAM SOUND AND PORT SIMPSON BAY

STATION	DEPTH (m)	TEMPERATURE (°C)	SALINITY (o/oo)	DISSOLVED OXYGEN (mg/l)	% SATURATION
Chatham Sound	0	14.71	25.835	10.05	119.15
(1, 7, 8, 9)	2	13.89	25.850	10.58	123.62
	5	13.01	26.520	10.56	121.32
	10	12.14	27.260	9.84	108.82
Port Simpson Bay	0	15.56	25.068	9.28	111.48
(2, 3, 4, 5, 6)	2	15.40	25.317	9.56	114.59
	5	13.73	25.879	9.76	113.46
	10	12.55	27.817	9.45	108.51

3.4 Sediment Characteristics

3.4.1 Sediment Size Distribution. Visual examination of grab material at sampling time indicated the subtidal substrate to be composed primarily of fine grey mud with some gravel and sand (Appendix V).

The percent composition of selected size fractions in surface sediments varied considerably from station to station (Table 2). For example, the L62.5 µm fraction ranged from 3% to 59%. No distinct difference was noted for stations in Chatham Sound verses those in Port Simpson Bay. Aside from Station SO-1 (74% G250 µm), more than 50% of the sediment sample consisted of size fractions below 250 µm. Station SO-6 in Stumaun Bay was the highest at 91%.

3.4.2 Organic Content. Surface sediment organic content varied considerably from station to station ranging between 1.2 and 9.7% (Table 3). Highest values were recorded in Stumaun Bay (SO-6) where sediment L62.5 µm predominated. This relationship of high organic content to small particle size persisted at all stations (Fig. 3).

Somewhat higher organic content in Port Simpson Bay compared to Chatham Sound may reflect restricted water movement and the addition of material from eel grass (Zostera) beds which are abundant in the area. The range of organics compares favorably with data collected in Douglas Channel and Chatham Sound at 2-12% (Pomeroy, unpublished data).

3.4.3 Heavy Metals. Considerable spatial variation existed over the study area for surface sediment heavy metal concentrations (Appendix VI). No relationship with sediment particle size or organic content was evident aside from Station SO-5. This location, in the southern portion of the bay, had the lowest heavy metal content, percent composition of sediment L62.5 µm (3%) and organic content (1.2%).

Surface metal levels at Port Simpson were on average low compared to sediments collected from Chatham Sound off Ridley Island and

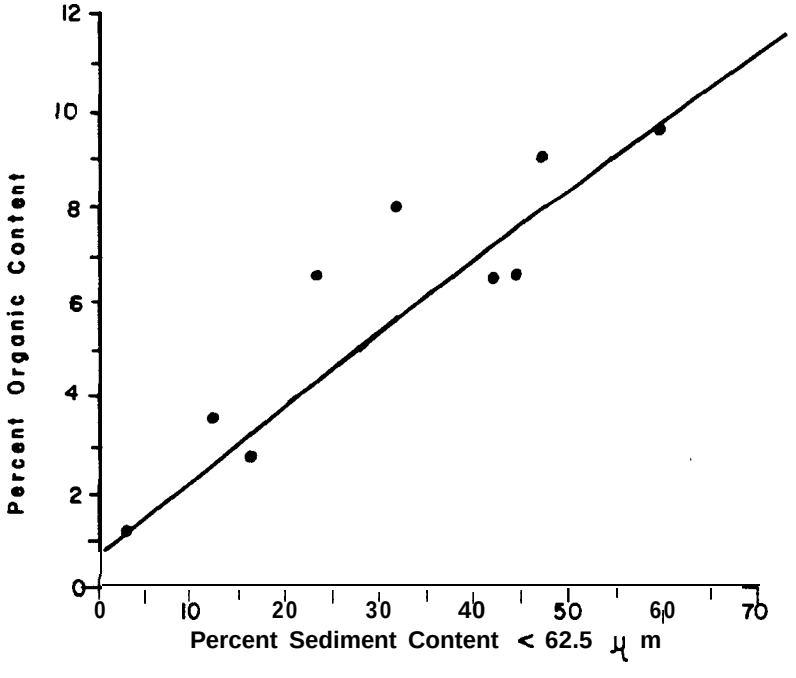

FIGURE 3 GRAPH OF PERCENT ORGANIC CONTENT VERSUS PERCENT SEDIMENT CONTENT $<62.5\mu m$

TABLE 2: PERCENT COMPOSITION OF SELECTED SIZE FRACTIONS IN SURFACE SEDIMENTS

STATION	Sediment Size (% Compostion) 6500 µm	500-250 µm	250-62.5 µm	L62.5 µm
so-1	39	35	14	12
so-2	23	19	26	32
so-3	8	12	33	47
so-4	8	13	34	45
so-5	11	32	54	3
SO-6	1	8	32	59
so-7	11	16	57	16
SO-8	1	11	46	42
so-9	**3**	**12**	**62**	**23**

TABLE 3: PERCENT ORGANIC CONTENT OF SURFACE SEDIMENTS AS VOLATILE RESIDUE

STATION	VOLATILE RESIDUE (%)
so-1	3.6
so-2	7.9
so-3	9.0
so-4	6.4
so-5	1.2
SO-6	9.7
so-7	2.9
SO-8	6.5
so-9	6.6

from Prince Rupert Harbour (Table 4).

Sediment cores taken at Stations SO-Z and SO-3, about 1.2 km apart, had different levels of heavy metals (Appendix VII). SO-3 closest to the proposed LNG site had lower concentrations throughout the core than did station SO-2. At both stations, highest heavy metal levels appeared to be in the 5-10 cm depth of the core.

3.5 Benthic Fauna

3.5.1 Grabs. Polychaetes dominated the subtidal invertebrate community at all stations except SO-2 where molluscs (bivalves) were most abundant (Appendix VIII). The number of species (species density) ranged from 10 to SO-3 to 45 at SO-5. These stations had total numbers of individuals of 15 and 177, respectively, per 3 litres of sediment. Station . . SO-5 had the lowest organic content (Table 3) and proportion of sediment L62.5 μm (Table 2).

Results of statistical comparisons, of stations are presented in Table 5. Evenness, or the degree of similarity among different species abundances, was lowest at station SO-l, (0.768) and SO-5 (0.892) indicating high numbers of certain species. Diversity indices varied from 4.648 at SO-5, the shallowest station, to 3.000 at SO-3, as per species density.

Benthic sampling conducted in Port Simpson Bay in November, 1974 by Lee Doran Associates (1975) produced results similiar to those noted in the present study. Species density and numbers were comparable to the EPS study at the 46-48 m depth with some common species. In both studies, the most abundant and diverse fauna was associated with the shallowest station. However, the present study reports twice the abundance and about three times the diversity reported by Lee Doran Associates.

3.5.2 Otter Trawl. Fauna caught in the otter trawl are listed in Appendix IX. The two dominant species were the brittle star

TABLE 4: MEAN CONCENTRATIONS OF HEAVY METALS IN SURFACE SEDIMENTS COLLECTED IN THE PRINCE RUPERT - PORT SIMPSON AREA

	Cu (ppm)	Fe (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)
Port Simpson	24.8	30550	433.0	20.4	8.13	82.1
Chatham Sound (Ridley Isl.)	33.9	42233	708.7	25.3	11.00	106.7
Prince Rupert Harbour	417.8	45666	525.5	22.4	70.90	423.6

TABLE 5: SPECIES DIVERSITY AND EVENNESS VALUES CALCULATED AT SELECTED STATIONS FOR INVERTEBRATE COMMUNITIES FROM GRABS

STATION	DEPTH (m)	NUMBER OF SPECIES	TOTAL INDIVIDUALS	DIVERSITY[a] INDEX	EVENNESS[b]
so-1	55	30	143	3.803	0.768
so-2	46	14	26	3.061	0.922
so-3	46	10	15	3.000	0.903
so-4	51	21	41	4.269	0.957
so-5	24	45	177	4.648	0.892

[a] Shannon & Weaver

[b] Pielou

(Ophiopholis aculeata, 85) and the flathead sole (Hippoglossoides elassadon, 68). Spider crabs (Hyas lyratus, 32) were also abundant.

The large number of sole (Plate 1) suggest the presence of a major resource which should be further studied. These may serve as a good indicator of future habitat change and contaminant buildup.

3.6 Intertidal Fauna

Dominant or common flora and fauna from the four shoreline survey transects are listed in Appendix X. The intertidal community at all sites was quite similar in that rockweed (Fucus sp.), mussels (Mytilus edulis) and barnacles (Balanus glandula, B. cariosus) were common in high and mid intertidal regions. Plates 2 and 3 provide some indication of the abundance and distribution of biota for two of the transects. The type of biota present was indicative of an unimpacted environment.

Detailed species composition at the shoreline sites was not done due to time constraints. The photographic surveys and gross examinations are intended to provide information on major habitat changes.

Plate 1.

Sole and other benthic fauna caught in otter trawl.

Plate 2.

Intertidal station SI-2 with Fucus sp. dominant. Arrow indicates shoreline transect for detailed photography.

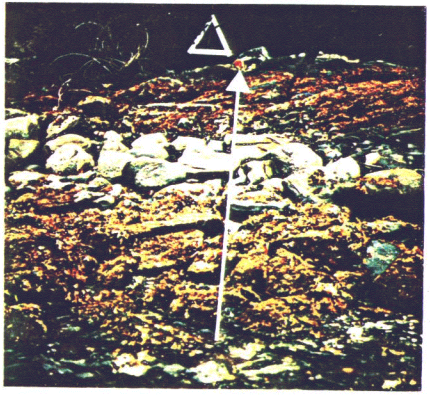

Plate 3.

Intertidal station SI-3 with Fucus sp. dominant. Arrow indicates shoreline transect for detailed photography.

REFERENCES

1. Dome Petroleum Ltd. Volume Three. Environmental Setting and Assessment for a Liquefied Natural Gas Terminal, Grassy Point, Port Simpson Bay, Northern British Columbia. December 1981.

2. Lee Doran Associates Ltd. Prince Rupert Bulk Loading Facility. Phase 2. Environmental Assessments of Alternatives Vol. 4 (1975).

3. Gameson, A.L.H. and K.J. Robertson. The Solubility of Oxygen in Pure Water and Seawater. J. Appl. Chem. 5:502 (1955).

4. Pielou, E.C. The Measurements of Diversity in Different Types of Biological Collections. J. Theor. Biol. 13:131-144 (1966).

5. Shannon, C.E. and W. Weaver. The Mathematical Theory of Communication. Urbana, University of Illinois Press, (1963).

6. Strickland, J.D.H. and T.R. Parsons. A Practical Handbook of Seawater Analysis. Bull. Fish. Res. Board Can. 167:311 p. (1971).

7. Svedrup, J.V., M.W. Johnson and R.H. Fleming. The Oceans: Their Physics, Chemistry and General Biology. Prentice-Hall, New York. 1087 p (1946).

8. Swingle, R.B. and J.W. Davidson. Environmental Laboratory Manual. Department of Enviornment, Environmental Protection Service, 1979.

9. Thomson, R.E. Oceanography of the British Columbia Coast. Can. Spec. Publ. Fish. Aquat. Sci. 56:291 p, (1981).

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APPENDIX I

POSITIONS OF SAMPLING STATIONS

APPENDIX I POSITIONS OF SAMPLING STATIONS

STATION		LATITUDE	LONGTITUDE
OCEANOGRAPHIC/BENTHIC			
so - 1		54" 36.5' N	130° 27.3' W
so - 2		54" 35.6' N	130" 26.8' W
so - 3		54" 35.4' N	130" 25.7' W
so - 4		54° 34.75' N	130" 26.9' W
so - 5		54" 35.5' N	130" 24.3' W
SO - 6		54° 34.9' N	130° 24.5' W
so - 7		54° 33.3' N	130" 27.4' W
SO - 8		54° 35.2' N	130" 28.1' W
so - 9		54° 36.2' N	130° 28.1' W
INTERTIDAL			
SI - 1		54" 35.95' N	130° 27.0' W
SI - 2		54" 35.70' N	130" 25.6' W
SI - 3		54" 34.35' N	130" 23.6' W
SI - 4		54° 35.35' N	130° 27.5' W
TRAWL TRACK			
ST - 1	START	54" 35.10' N	130" 28.4' W
	STOP	54" 35.05' N	130" 25.2' W

APPENDIX II

PHYSICAL OCEANOGRAPHIC DATA, August 4, 1981

APPENDIX II PHYSICAL OCEANOGRAPHIC DATA; August 4, 1981

STATION (Sampling time-PDT)*	DEPTH (m)	TEMPERATURE (°C)	SALINITY (o/oo)	DISSOLVED OXYGEN (mg/l)	% SATURATION
so - 1	0	14.94	25.565	10.30	122.50
(1255-	2	14.11	25.760	10.45	122.32
1318)	5	13.01	26.326	10.70	122.82
	10	12.52	26.721	10.35	106.43
	25	9.69	31.082	6.86	75.46
	50	8.03	31.199	6.00	63.94
	Bottom = 60				
so - 2	0	15.26	25.340	9.59	114.66
(1420-	2	15.23	25.347	9.70	115.91
1457)	5	14.28	25.596	10.00	117.34
	10	12.38	27.718	9.82	112.19
	25	9.27	31.338	6.70	73.11
	35	8.29	31.861	6.05	64.74
	Bottom = 50				
so - 3	0	15.49	25.251	9.53	114.40
(1503-	2	15.34	25.317	9.75	116.73
1527)	5	15.19	25.480	9.81	117.22
	10	12.52	27.038	9.95	114.12
	25	9.76	32.726	7.10	79.10
	Bottom = 50				
so - 4	0	15.39	25.97	9.60	115.05
(1011-	2	15.39	25.314	9.45	113.27
1038)	5	14.78	25.708	9.75	115.70
	10	11.91	28.226	9.30	105.52
	25	9.23	32.326	6.20	68.05
	45	7.86	32.174	5.50	58.37
	Bottom = 55				
so - 5	0	15.62	25.124	9.20	110.65
(0750-	2	15.39	25.473	9.50	113.99
0922)	5	12.03	26.571	9.90	111.40
	10	12.08	28.100	8.60	97.87
	20	9.86	30.931	6.90	76.12
	Bottom = 26				
SO - 6	0	16.07	24.332	8.50	102.64
(0933-	2	15.64	25.134	9.40	113.09
0958)	5	12.37	26.041	9.35	105.64
	10	13.86	27.201	9.60	112.85
	20	10.24	30.881	8.30	92.34
	Bottom = 20				

APPENDIX II (Continued) PHYSICAL OCEANOGRAPHIC DATA; August 4, 1981

STATION (Sampling time-PDT)*	DEPTH (m)	TEMPERATURE (°C)	SALINITY (o/oo)	DISSOLVED OXYGEN (mg/l)	% SATURATION
so - 7	0	13.97	26.216	10.20	119.39
(1612-	5	13.71	26.451	10.20	118.92
1638)	10	13.37	26.628	10.22	118.45
		12.17	26.712	9.90	112.58
	25	10.19	30.597	7.35	81.53
	50	7.86	30.369	5.71	60.68
	Bottom = 60				
SO - 8	0	14.78	26.067	10.00	118.95
(1052-	2	13.67	26.394	10.65	124.02
1125)	5	----------SAMPLE		LOST----------	
	10	11.84	28.076	9.35	105.83
	25	9.49	31.119	7.00	76.67
	50	7.95	31.145	5.90	62.31
	Bottom = 60				
so - 9	0	15.17	25.495	9.69	115.75
(1354-	2	14.06	25.794	11.05	129.25
1405)	5	12.66	26.607	10.75	122.69
	10	12.03	27.532	9.75	110.42
	25	9.88	30.912	7.10	78.36
	50	8.10	32.106	6.05	64.55
	90	--	--	4.70	--
	Bottom = 100				

*low tide at 1100 PDT 1.0 m

APPENDIX III

DISSOLVED NUTRIENT DATA (mg/l)

August 4, 1981

APPENDIX III DISSOLVED NUTRIENT DATA (mg/l); August 4, 1981
(Continued)

STATION (Sampling time)	DEPTH	ORTHO-PHOSPHATE	NITRATE	NITRITE	AMMONIA
so - 1	0	0.0119	< 0.010	< 0.0050	< 0.0050
(1255-	2	0.0122	< 0.010	< 0.0050	< 0.0050
1318)	5	0.0116	< 0.010	< 0.0050	< 0.0050
	10	0.0197	< 0.010	< 0.0050	< 0.0050
so - 2	0	0.0090	< 0.010	< 0.0050	0.0056
(1420-	2	0.0086	< 0.010	< 0.0050	< 0.0050
1457)	5	0.0100	< 0.010	< 0.0050	0.0050
	10	0.0220	< 0.010	< 0.0050	0.0078
so - 3	0	0.0076	< 0.010	< 0.0050	0.0050
(1502-	2	0.0082	< 0.010	< 0.0050	0.0050
1527)	5	0.0116	< 0.010	< 0.0050	0.0085
	10	0.0201	< 0.010	< 0.0050	0.0100
so - 4	0	0.0093	< 0.010	< 0.0050	< 0.0050
(1011-	2	0.0073	< 0.010	< 0.0050	0.0063
1038)	5	0.0083	< 0.010	< 0.0050	< 0.0050
	10	0.0170	< 0.010	0.0050	0.0083
so - 5	0	0.0080	< 0.010	< 0.0050	< 0.0050
(0750-	2	0.0063	< 0.010	< 0.0050	< 0.0050
0922)	5	0.0088	< 0.010	< 0.0050	0.0050
	10	0.0153	< 0.010	< 0.0050	0.0083
SO - 6	0	0.0069	< 0.010	< 0.0050	< 0.0050
(0933-	2	0.0073	< 0.010	< 0.0050	< 0.0050
0958)	5	0.0091	< 0.010	< 0.0050	< 0.0050
	10	0.0136	< 0.010	< 0.0050	0.0075
so - 7	0				
(1612-	2				
1638)	5		SAMPLE LOST		
	10				
SO - 8	0	0.0120	< 0.010	< 0.0050	< 0.0050
(1052-	2	0.0137	< 0.010	< 0.0050	< 0.0050
1125)	5		SAMPLE LOST		
	10	0.0240	< 0.010	< 0.0050	0.0055
so - 9	0	0.0137	< 0.010	< 0.0050	0.0053
(1354-	2	0.0126	< 0.010	< 0.0050	< 0.0050
1405)	5	0.0157	< 0.010	< 0.0050	0.0061
	10	0.0278	0.009	< 0.0050	0.0072

APPENDIX IV

CHLOROPHYLL *a* AND PHAEOPIGMENT DATA (ug/l)

August 4, 1981

APPENDIX IV CHLOROPHYLL *a* AND PHAEOPIGMENT DATA (ug/l); August 4, 1981

STATION (Sampling time)	DEPTH (m)	CHLOROPHYLL *a*	PHAEOPIGMENT
SO - 1 (1255-1318)	0	0.80	0.13
	2	1.87	1.68
	5	1.34	19.81
	10	--	--
SO - 2 (1420-1457)	0	0.00	1.07
	2	0.53	0.40
	5	0.53	0.40
	10	1.07	1.18
SO - 3 (1502-1527)	0	0.27	0.80
	2	0.00	1.07
	5	0.80	0.51
	10	0.80	0.51
SO - 4 (1011-1038)	0	0.53	0.96
	2	1.34	2.27
	5	1.34	2.27
	10	1.60	0.83
SO - 5 (0750-0922)	0	1.34	2.27
	2	1.34	2.27
	5	0.27	0.67
	10	0.80	0.13
SO - 6 (0933-0958)	0	1.34	2.27
	2	0.53	0.40
	5	0.80	1.26
	10	0.27	0.80
SO - 7 (1612-1638)	0	1.07	0.24
	2	1.07	2.86
	5	0.80	0.88
	10	0.80	1.26
SO - 8 (1052-1125)	0	0.53	0.59
	2	0.27	0.80
	5	1.34	0.91
	10	1.87	1.12
SO - 9 (1354-1405)	0	1.34	2.27
	2	0.80	0.88
	5	1.60	0.64
	10	1.87	0.94

APPENDIX V

VISUAL CHARACTERISTICS OF SEDIMENT GRAB SAMPLES

August 4, 1981

APPENDIX V VISUAL CHARACTERISTICS OF SEDIMENT GRAB SAMPLES; August 4, 1981

STATION	DEPTH (m)	SEDIMENT CHARACTERISTICS
SO - 1	60	Mud on surface, blue soft clay below with some gravel.
so - 2	50	Grey mud.
so - 3	50	Grey mud.
so - 4	55	Grey mud.
so - 5	26	Grey sand/silt
SO - 6	20	Grey loose mud.
so - 7	60	Grey mud with some gravel.
SO-8	60	Grey mud.
so - 9	100	Grey mud.

APPENDIX VI

SURFACE SEDIMENTS HEAVY METAL DATA

August 4, 1981

APPENDIX VI SURFACE SEDIMENT HEAVY METAL DATA; August 4, 1981

STATION	cu (ppm)	Fe (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm	Hg (ppm)
SO - 1	31.1	37000	643.0	37.3	6.83	95.2	0.6
SO - 2	29.6	35600	462.0	22.3	8.85	96.3	< 0.6
SO - 3	24.7	31100	406.0	18.8	8.32	84.2	< 0.6
SO - 4	26.5	32600	418.0	21.2	9.10	87.7	< 0.6
SO - 5	9.6	16200	224.0	< 6.4	<6.42	38.2	< 0.6
SO - 6	34.0	33000	403.0	17.3	7.96	102.0	0.6
SO - 7	15.5	24500	408.0	15.4	<6.37	61.1	0.6
SO - a	25.1	31800	449.0	20.6	8.85	85.0	< 0.6
SO - 9	27.2	33200	488.0	23.9	10.50	89.0	< 0.6

APPENDIX VII

HEAVY METAL CONCENTRATIONS IN SEDIMENT CORES

August 4, 1981

APPENDIX VII HEAVY METAL CONCENTRATIONS IN SEDIMENT CORES; August 4, 1981

STATION	DEPTH (cm)	cu (ppm)	Mn (ppm)	Ni ppm)	Pb (ppm).	Zn (ppm)	Fe (ppm)	Cd (ppm)	Hg (ppm)
so - 2	o - 5	30.2	436.0	22.1	10.9	89.2	32800	< 0.65	< 0.6
	5 - 10	30.2	456.0	24.7	10.7	88.6	35600	< 0.65	< 0.6
	50 - 60	27.6	433.0	23.4	7.9	84.4	34000	< 0.64	< 0.6
so - 3	o - 5	21.7	341.0	17.8	7.42	71.0	26100	< 0.65	< 0.6
	5 - 10	24.3	376.0	20.4	8.86	77.0	28200	< 0.65	< 0.6
	50 - 60	16.8	304.0	17.1	6.58	57.9	22800	< 0.65	0.6

APPENDIX VIII

BENTHIC INVERTEBRATES FROM GRAB SAMPLES TAKEN

August 4, 1981

APPENDIX VIII BENTHIC INVERTEBRATES FROM GRAB SAMPLES

TAXA	STATION SO- 1	2	3	4	5
Nemertea					
Unid spec.	1			2	
Annelida					
Polychaeta					
Polynoidae sp.				1	2
Peisidice aspera					1
Eteone longa					2
Notophylum sp (juv.)	1				
Gyptis brevipalpa					2
Exogone sp.					4
Odontosyllis sp.					1
Syllis alternata	2				6
Nephtys caeca	3	1	2		
Nephtys cornuta				3	11
Nephtys sp (juv.)	3				
Glycera capitata			1		1
Goniada brunnea		1		2	
Goniada maculata					1
Onuphis conchylega				1	
Onuphis iridescens			1		6
Lumbrinereis luti					1
Lumbrinereis sp	7	1		2	7
Ninoe gemmea	2				
Scoloplos pugettensis					4
Orbiniidae sp (juv.)	1				
Aricidea lopezi					2
Aricidea neosvecica	3				
Aricidea uschakovi	1				
Paraonis sp.				3	2
Prionospio cirrifera				1	1
Prionospio steenstrupi				1	

Continued...

APPENDIX VIII BENTHIC INVERTEBRATES FROM GRAB SAMPLES
(Continued)

TAXA	STATION SO- 1	2	3	4'	5
Prionospio sp.				1	
Spionidae sp.					1
Disomidae sp.	1				
Magelona japonica					7
Spiochaetopterus costarum	13				
Chaetozone setosa	1			3	1
Cirratulidae sp.	3	1		4	26
Cossura longicirrata				1	
Brada sachalina				1	
Scalibregma inflatum					1
"Sternaspis scutata	1				1
Decamastus gracilis					4
Axiothella rubrocincta		1		3	1
Maldane glebifex	17	1	1		
Maldane sp	2				
Myriochele oculata	47			1	2
Ovenia sp	1				
Pectinaria californieusis	1	2	1	3	
Pista cristata					1
Terebellides stroemi	1		5	1	1
Polycirrus caliendrum	5				
Terebellidae sp.		1			
Sabellidae sp.					4
Sipuncula					
Unid spec.	1				
Echiura					
Unid spec.	2				
Mollusca					
Gastropoda					
Thais sp. (juv.)					3

Continued...

APPENDIX VIII BENTHIC INVERTEBRATES FROM GRAB SAMPLES
(Continued)

TAXA	STATION SO- 1	2	3	4	5
Opistobranchia					
Cylichna sp.		1			2
Pelecypoda					
Yoldia gardneri	1				
Nucula tenuis		3			12
Acila castrensis					9
Diplodontidae sp. (juv.)	6	4		4	12
Macoma calcorea		4			7
Composomyax subdiaphana		4		2	1
Unid spec.	1				1
Unid spec. (juv.)					10
Arthropoda					
Amphipoda					
Gammaridea					
Ampelisca sp. I	3				
Ampelisca sp. II					1
Anonyx .				1	1
Phoxocephal idae sp.	4	1			1
Gammaridea sp. I	4				
Unid spec.					6
Tanaidacea					
Leptochelia sp.					1
Cumacea					
Eudorella sp.				2	
Decapoda					
Brachyura sp.					3

Continued...

APPENDIX VIII BENTHIC INVERTEBRATES FROM GRAB SAMPLES
(Continued)

TAXA	STATION SO- 1	2	3	4	5
Echinodermata					
Ophiuroidea					
Ophiura sarsi	5				
Ophiactidae sp.					3
TOTAL NUMBER OF SPECIES	30	14	10	21	45
TOTOL NUMBER OF INDIVIDUALS	143	26	15	41	177

UID = unidentified
juv = juvenile

APPENDIX IX

LISTING OF FAUNA CAUGHT IN OTTER TRAWL

August 4, 1981

APPENDIX IX LISTING OF FAUNA CAUGHT IN THE OTTER TRAWL

TAXA		ABUNDANCE	
Crustacea	Pandalus hypsinotus	2	
	Pandalus goriurus	2	
	Crangon communis	20	
	Mesocrangon munitella	3	
	Spirontocaris prionota	1	
	Spirontocaris truncata	1	
	Hyas lyratus	32	
	Hermit crabs	25	
Asteroidea	Ophiopholis aculeata	85	
	Solaster sp.	4	
	Ludia sp.	2	
	unidentified	14	
Pisces	Hippoglossoides elassodon	68	(8-35 cm long)
	Parophyrus vetalus	10	(27-45 " ")
	Atheresthes stomias	1	(22 " ")
	Hydrolagus colliei	3	(48-50 " ")
	Odontopixus trispinosa	1	(5.5 " ")
	Anoplopoma fimbria	1	(38 " ")
	Theragra chalcogramma	3	(16-19 " ")
	Thaleichthys pacificus	1	(15 " ")
	Radulinus asprellus	2	(11 " ")
Echinoidea	Strongylocentrotus sp.	20	
Holothuroidea	Psolus chitonoides	2	
Cephalopoda	Loligo .	2	
Tunicata	numerous		
Anthozoa	Metridium sp.	1	

APPENDIX X

LISTING OF DOMINANT FAUNA NOTED DURING INTERTIDAL SHORELINE SURVEYS

APPENDIX X LISTING OF DOMINANT FLORA AND FAUNA NOTED DURING INTERTIDAL SHORELINE SURVEYS, August 4, 1981

STATION	TAXA
SI - 1 (1255 hrs)	
High - fine gravel beach littered with bivalve shells	Balanus glandula Enteromorpha sp.
mid - rocky outcrop	Mytilus edulis Littorina sitkana L. scutulata Balanus glandula B. cariosus Fucus sp. Gigartina sp. Enteromorpha sp.
SI - 2 (1100 hrs)	
High - rocky bluff	Balanus cariousus Littorina sitkana L. scutulata Thais sp. Mytilus edulis Gnorimosphaeroma sp. Hemigrapsus nudis Fucus sp. (90% of site covered)
mid - rocky bluff	Littorina sitkana L. scutulata Thais sp. Hemigrapsus nudis Mytdlus l i s Balanus sp. (hundreds of L1mm barnacles)

Continued...

APPENDIX X LISTING OF DOMINANT FLORA AND FAUNA NOTED DURING INTERTIDAL SHORELINE SURVEYS, August 4, 1981

(Continued)

STATION	TAXA
SI - 2 (1100 hrs) (con't.)	
mid rocky bluff	Fucus sp. (70% of site covered)
	Enteromorpha sp.
	Halosacchion sp.
	Ulva sp.
low - rocky substrate interspersed with gravel	Hemigrapsus nudis
	H. oregonesis
	Thais sp.
	Mytilus l i s
	Ulva sp.
	Halosacchion sp.
	Pylaiella littoralis
	Leathesia difformis
SI - 3 (1000 hrs)	
High - Upheaved rock face	Balanus glandula
	B. cariosus
	Thais sp.
	Littorina sitkana
	L. scutulata
	Hemigrapsus sp.
	Fucus sp. (75% of site covered)
mid - rock face	Thais sp.
	Balanus cariosus
	Gnorimosphaerorma sp.
	Pisaster ochraceous

Continued...

APPENDIX X LISTING OF DOMINANT FLORA AND FAUNA NOTED DURING INTERTIDAL SHORELINE SURVEYS, Aug. 4, 1981

(Continued)

STATION	TAXA
SI - 3 (1000 hrs) (Con't.)	
mid - rock face	Idotea sp.
	Fucus sp. (75% of site covered)
	Leathesia difformis
	Ulva sp.
low - rounded boulders	Hemigrapsis nudus
	Anthopleura eleganotissima
	Pisaster ochraceous
	Thais sp.
	Fucus sp. (50% of site covered)
	Leathesia difformis
	Enteromorpha sp.
	Ulva sp.
Rich bed of eelgrass (Zostera marina) at low water containing small	Pycnopodia sp.
SI - 4 (1205 hrs)	
High - rocky bluff	Littorina sitkana
	L. scutulata
	Balanus cariosus
	Mytilus edulis
	Thais sp.
	Hemigrapsus nudus
	H. oreganensis
	Limpets
	Verrucaria sp.
	Pylaiella littoralis
	Fucus sp. (80% of site covered)

Continued...

APPENDIX X LISTING OF DOMINANT FLORA AND FAUNA NOTED DURING INTERTIDAL SHORELINE SURVEYS, August 4, 1981

(Continued)

STATION	TAXA
SI - 4 (1205 hrs) (Con't.)	
mid - Rocky Bluff	Thais sp. Littorina sitkana L. scutulata Balanus glandula B. cariosus Hemigrapsus medies Pisaster ochraceous Cthalanus dalli Limpets Fucus sp. (40-50% of site covered) Pylaiella littoralis Enteromorpha sp.
low - Rocky bluff	Pisaster ochraceous Thais sp. Anthopleuro elegantissima A. xanthogrammica Balanus glandula B. cariosus Katharina tunicata Ulva sp. Enteromorpha sp. Neroeocystis sp.