

**Roberts Bank Development
a report on habitat compensation**

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ROBERTS BANK DEVELOPMENT
A REPORT ON HABITAT COMPENSATION

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ABSTRACT

The Westshore Terminal coal port facility, situated on Roberts Bank in the Fraser River estuary, is presently undergoing the first stage of a two year expansion project which will increase the total size of the port approximately four times. The dredging and landfill operations associated with this development will ultimately increase the area of the rip-rap shore habitat, and in so doing, provide substrate for colonization by new algal and invertebrate residents.

The present study examined the marine biotic community at three intertidal stations on the coal port's shores in August 1981, prior to the initiation of the dredging operations. The information gathered in that examination was used to estimate the standing crop values of the algae and invertebrate communities which may be expected to establish themselves in the rip-rap habitat of the post-expansion shore. The nature and duration of this colonization process were monitored on a cleared site in the intertidal rip-rap zone, for a period of six months.

The standing crop value was estimated using two methods, based on an increased coal port shore-line distance of 8.36 kilometres and a total area of 182, 666 meters². The first method resulted in a predicted invertebrate standing crop value of 7,109 kilograms ash free dry weight and an algal standing crop value of 13,400 kilograms dry weight.

The second method resulted in a predicted invertebrate standing crop value of 3,904 kilograms ash free dry weight and an algal standing crop value of 7,359 kilograms dry weight.

By monitoring the intertidal recolonization process at a site on the coal port's south-west shore, from July to December, 1981, it was possible to conclude that colonization of the new rip-rap surfaces could be expected to occur within six to eight months, depending on the season in which the new substrates became available and on the ability of nearby populations to supply algal and invertebrate recruits. It may take much longer, perhaps two

to three years, for these new populations to stabilize.

A certain amount of the sand/mud habitat will be destroyed through dredging during the expansion. The eelgrass beds located in the intercauseway area between the coal port and the Tsawwassen ferry terminal have been exposed to erosion and sedimentation. Accordingly, samples of the sand/mud invertebrate community and of the eelgrass (Zostera marina L. and Z. americana den Hartog) were examined in the present study in order to provide information related to the process of habitat compensation in these two areas. The results are part of an ongoing study of the effects of the prolonged dredging of the sand/mud sampling procedure and will be reported at a later date. Certain eelgrass epifaunal organisms are important constituents of the marine food chain and for this reason the relationship between eelgrass shoot density and epifaunal density was examined in the present study. Since epifaunal density appears to be greatest in areas of mid to high shoot densities, it is recommended that eelgrass plants be transplanted at shoot densities of at least 100 shoots/meter². Although Z. americana supported far fewer epifaunal organisms than did the dominant Z. marina, this eelgrass species is an important and productive constituent of the high intertidal zone and should be included in all transplantation projects.

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A number of people have helped with this study. We would like to thank the employees of Westshore Terminal, and especially Mr. G. Scott, the terminal manager, for their kindness and concern. Hugh Tuttle, of Dillingham Corporation (Canada) Ltd. and the engineers at Swan Wooster Engineering Company supplied us with reference point heights and a blue-print of the proposed expansion plans. Mr. Tuttle was also able to give us the value for the length of the new rip rap shoreline, which we used in our total biomass determinations. Mel Kotyk, of the Department of Fisheries and Oceans, helped with many of the technical aspects of this study and confirmed many invertebrate identifications. Judith Fournier of the National Museum of Natural Science in Ottawa identified two polychaete species. Dr. David Garbary, of the Botany Department of U.B.C. confirmed and corrected many of our algal identifications. Margie Nicol and Roswihta Ostendorf helped several times, on very short notice, on middle of the night field trips to the coal port, for which we are very grateful.

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ROBERTS BANK DEVELOPMENT
HABITAT COMPENSATION, 1981

INTRODUCTION

The Westshore Terminal coal port facility is situated at Roberts Bank, one of the largest foreshore areas of the Fraser River estuary (Roberts Bank Environmental Assessment Report, 1979). Represented within the vicinity of the coal port facility are four habitats: sand/mud flats, rock/gravel shores, eelgrass beds and marsh (Fraser River Estuary Study, 1978). Dredging and landfill operations associated with the current port expansion project will ultimately increase the area of the rock/gravel shore habitat and, in doing so, provide substrate for colonization by new algal and invertebrate residents.

The purpose of the present study is five-fold:

- a) to determine algal and invertebrate standing crop values for the subtidal and intertidal rocky shore.
- b) to use the above values in predicting potential standing crop values for the post-expansion rocky shore.
- c) to monitor recolonization of a rocky shore site in order to estimate the time required for a new rip-rap shore to become productive.
- d) to explore possible relationships between eelgrass (Zostera americana den Hartog and Zostera marina L.) shoot density and epifaunal density with respect to future transplantation projects.
- e) to sample invertebrates from the sand/mud habitat adjacent to the coal port for a separate ongoing study of dredging effects.

FIGURE 1.

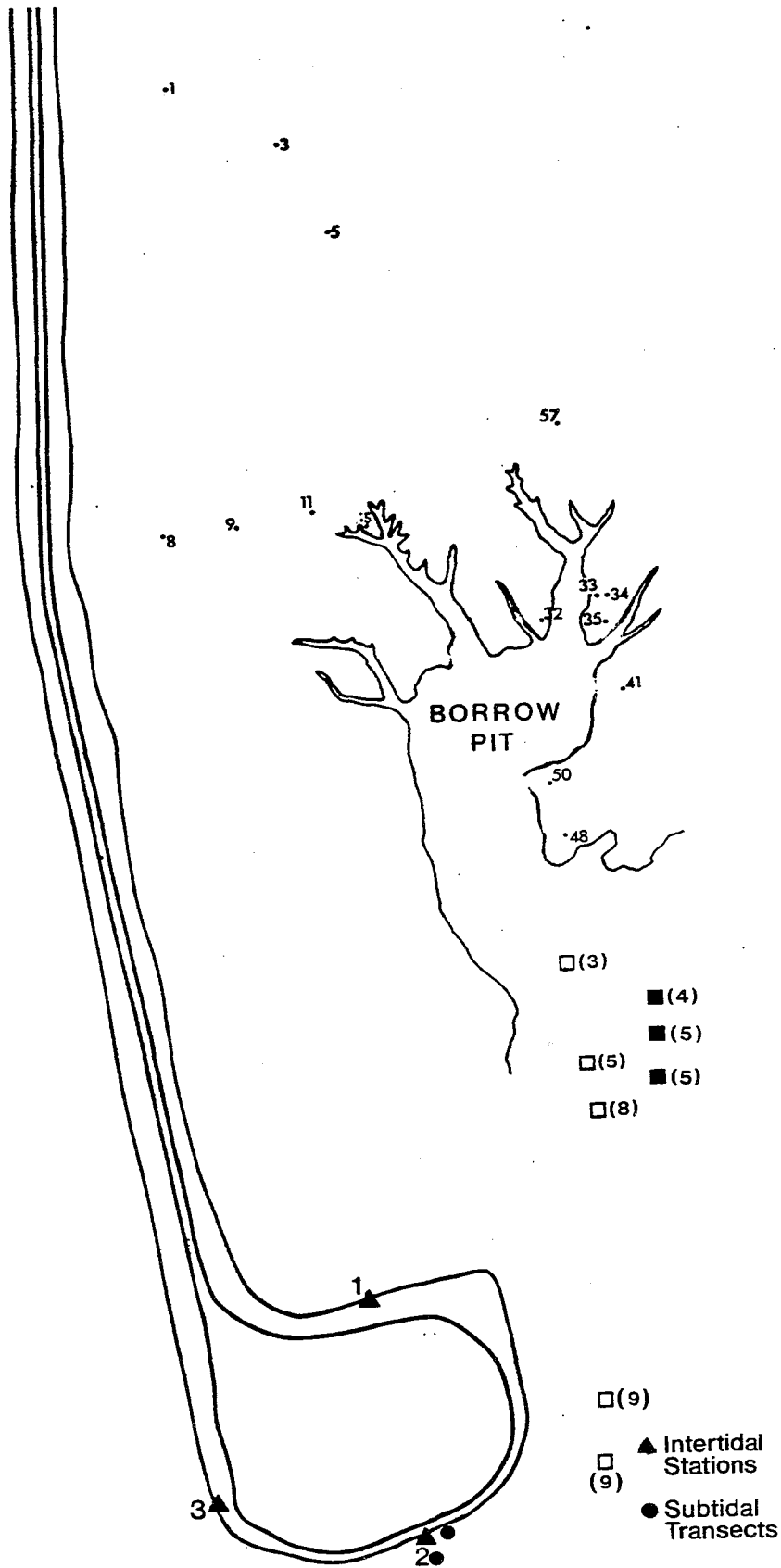
MAP OF THE ROBERTS BANK COAL PORT
AND THE INTERCAUSEWAY AREA WITH
BORROW PIT.

Map drafted from 19 aerial photograph
of the Roberts Bank coal port.

Intertidal and subtidal transects
sampled August 4 - 31, 1981.

Eelgrass quadrats sampled July
28 - 31, 1981. •

Sand/mud 'grabs' sampled August 24th
□ (depth in fathoms)
and September 31, 1981.
■ (depth in fathoms)



METHODS AND MATERIALS

A. Rocky Shore Intertidal and Subtidal Transects

i) Site Descriptions

Station 1 49⁰ 00.85'N. Latitude
 123⁰ 09.50'W. Longitude

This sampling station was located on the sheltered northeast shore of the Roberts Bank Coal Port, east of the causeway, between a small boat launch ramp and the north end of the dock face ("Herring Point"). The beach sloped shallowly (8:1) down to the waterline from the foot of a raised embankment, that ran along the top of the shore. The substrate consisted of cobble on a sand and gravel base.

The beach appeared to be relatively uniform in terms of stratification and topography within intertidal zones, along its length. The transect site was well drained.

A single transect line was laid out along the shore, perpendicular to the low water line and a reference line which was situated at the base of the raised embankment. A systematic method of sampling was adopted and a total of seven - 0.25m² quadrats were sampled at four meter intervals along the transect line from the reference point to low water (1.6m a.d.; August 4, 1981).

The width of the beach from the reference point to low water was measured, and the tidal height of the reference point was determined with the aid of a handheld surveyor's level and a tidal gauge situated just offshore. (See Table 1: Tidal Elevation of Sampling Stations.) The reference point at this station was 4.25m a.d. and width of the beach, from this point to datum was approximately 35 meters.

* All tidal elevations in this report are given with respect to chart datum (a.d. = above datum).

The station was visited and sampled on a single day (August 4, 1981) on which the weather was sunny with a mid-afternoon temperature of 25°C.

Station 2 49° 00.70' N. Latitude
123° 09.70' W. Longitude

This sampling station was located on the southwest (seaward) shore of the Roberts Bank Coal Port. This shore slopes steeply (2½:1) beneath large rip-rap boulders which extend approximately 3 meters beyond datum. It is exposed to heavy wave action during moderate to strong north-west through southeast wind storms.

One intertidal and two subtidal transects were located midway along this shore in August. A reference point was located at the same level as the railway tracks and its elevation was determined, by comparing the corresponding height of the tracks on Swan Wooster/Westshore Terminal blueprint drawings, to be 7.20 meters a.d. The width of the shore at the intertidal transect position was approximately 18 meters, from the reference point to datum.

A total of five - 0.25m² quadrats were positioned at intervals which ranged from one to four meters, depending on stratification and tidal elevation, along the center of the intertidal transect line. (See Table 1). An attempt was made to sample on as many flat boulder surfaces as possible, within the transect, in order to avoid the obvious problem of sampling beneath and between the large rip-rap. This method also eliminated most of the problems of total surface area variability among quadrats (Littler, 1980; Gonor et al., 1978). This meant that certain species of highly mobile organisms, including Hemigrapsus nudus and H. oregonensis, crevice dwellers and organisms present in the substrate beneath the boulders were not sampled at this station. Although a large population of H. nudus was observed it was difficult to capture or even make accurate counts of these animals for use in biomass determinations.

The intertidal transect was visited over a one week period from August 10 - 15, 1981 when the weather remained sunny and warm (25°C).

The two subtidal transects were sampled at this station on August 31, 1981. The first subtidal transect was located immediately below the marked intertidal transect and consisted of ten - 0.25m² quadrats randomly placed within the two vegetation zones described by the contracted divers, which existed along the transect line. (See Appendix 1). This transect extended approximately 26.5 meters beyond the position of the fifth intertidal quadrat, to a depth of approximately 3.5 meters below datum. It was discontinued at this point due to the presence of a sand substrate and the consequent lack of vegetation.

The second subtidal transect, consisting of nine randomly placed 0.25m² quadrats within three vegetation zones, was located approximately 50 meters east of the marked intertidal transect. It extended down the shore approximately 40 meters beyond datum and to a tidal depth below datum of 2.8 meters. The transect was discontinued at this point due to the presence of sand and the consequent lack of vegetation. (See Appendix 1).

Station 3 49° 00.85' N. Latitude
 123° 00.70' W. Longitude

This sampling station was located on the northwest shore of the Roberts Bank Coal Port, facing the mouth of the Fraser River. The beach sloped shallowly (8½:1) down to the water line from the foot of a raised embankment that ran along the top of the shore for the length of the beach. There were three main substrate types present at this site. In the low to mid intertidal zones (0 to 1.8m above datum) the substrate consisted of cobble on a sand and broken shell base; in the mid intertidal zone (1.8 to 2.75m a.d.) there was a rock crest which ran along

the length of the shore and consisted of a single layer of large rip-rap boulders on a sand, gravel and broken shell base; in the high intertidal zone (2.75 to 6.5m a.d.) the substrate consisted of cobble on a sand and gravel base. There were also many large boulders scattered in this zone.

The transect line was positioned perpendicular to a reference line which ran parallel to the water line, fourteen meters from the top of the shore. The reference point was located at the top of the shore, at the base of the raised embankment. A total of ten - 0.25m^2 quadrats were positioned along the center of the transect line at four meter intervals. However, only nine quadrats were finally sampled because the area described by the third quadrat consisted of a bulldozed ridge of small rip-rap within which no living organisms were found. The remaining quadrat locations were representative of the surrounding beach as the strata zones described above were continuous for the length of the shore. The beach was uniformly well-drained and exposed to heavy wave action only during strong north-westerly wind storms.

On several occasions a stream of water approximately ten meters wide, carrying a dense concentration of coal particles, was observed to be flowing from the holding ponds beside the coal train unloading site, down through the beach to the water, approximately fifty meters north of the transect site. Although wave action may have been expected to wash these coal particles back up on to the nearshore area, no depositions of coal dust were observed in the immediate vicinity of the study transect. There were very large deposits of coal throughout the stream-washed area however, and no living organisms were observed there.

The width of the beach from the reference point to datum, measured on August 26, 1981, was approximately 55 meters. The reference point was located at a tidal elevation of 6.56 meters above datum. (See Table 1).

This station was visited over a period of one week (August 25 - 31, 1981) in which the weather ranged from sunny and warm (20°C) to cool and overcast with rain (14°C).

ii) Sample Collection, Processing and Biomass Determinations

Quadrats (0.25m²) were systematically positioned along the center of the transect line located at each of the three intertidal stations. Subtidal samples were collected in 0.25m² quadrats located randomly within vegetation zones along the two subtidal transects at Station 2. In order to minimize error an effort was made to collect all of the organisms present in each quadrat. However, due to time constraints and tidal movements it was necessary to collect subsamples in some cases. Prior to taking the subsample the percent cover of the algal species and the encrusting invertebrates (for example, barnacles) was assessed using the grid method. A photographic record of the subsample location within the intertidal quadrats was made; no photographic record of subtidal quadrats was kept due to underwater camera problems.

The collected organisms from each quadrat were roughly sorted in the field and placed in labelled plastic bags. Barnacles, mussels and limpets were gently scraped from cobble and rip-rap surfaces with scapel blades. A sample of the top two centimeters of sediment was collected from each quadrat at Station 1 and Station 3 and placed in a separate bag. The collected organisms were stored at 0° C for a period of one day to two weeks while the process of collection and biomass determination continued. Cold storage was considered preferable to both freezing and storage in preservative solutions. Freezing and then thawing causes alterations in morphology which would have made species identification very difficult. Formalin and alcohol solutions both significantly affect the determination of dry weights of organisms because they cause soluble materials such as lipids to leach out of the organisms into the solution (Gonor et al., 1978).

Prior to microscopic examination, each sample, including each of the sediment samples, was washed gently through two nested sieves with 500 μ m and 250 μ m pore diameters. The sieve contents were sorted and the organisms present were identified, counted and either preserved or dried for use in the biomass determinations. Species which occurred infrequently or which were very small (<5mm) were not considered important to the overall biomass and were preserved.

The organisms which were dried were placed in labelled aluminum or enamel trays and left in a drying oven at a temperature of 100 $^{\circ}$ C for 24 to 96 hours. According to Winberg (1971) the weight of organisms dried at temperatures below 105 $^{\circ}$ C does not change over time once a constant weight has been reached.

With the exception of limpets, the shells of snails, bivalves and barnacles were not removed prior to ashing. In order to determine whether or not ashing this material for four hours at temperatures of between 500 $^{\circ}$ C and 550 $^{\circ}$ C affected the ash free weight determinations, the dry tissue weights of a subsample of littorines and barnacles were calculated using an alternate method (Holmes et al, 1971). These animals were dried, weighed and then placed in a caustic solution of KOH until all traces of tissue were removed. They were then dried and reweighed. A second subsample from the same population were dried, weighed, ashed and reweighed. Using this information we found that it was necessary to use a correction factor of 4.93% to recalculate, upwards, the dry tissue weights of Balanus glandula.

A shell length/dry tissue weight equation (See Appendix 2) was calculated using a subsample of Mytilus edulis collected intertidally at Roberts Bank on October 9, 1981 and this information was used to determine dry tissue weights of the mussels collected in the transect at Station 3. Seed mussels (<5mm long) were counted but were not considered in biomass determinations.

Macrophytic algae were not ashed; the biomass of all vegetation was calculated using the dry weight values.

The material collected in the nineteen subtidal quadrats was placed in gunny sacks as it was collected, and stored at 0° C overnight. The next morning the sacks were suspended in tanks of cold circulating sea water and stored for a period of one to eleven days. The contents of each sack were sorted in a box screen with a 250 μ m pore diameter. Small, unidentified organisms were placed in collection jars and stored at 0° C for up to two weeks. Macroinvertebrates and all algae were washed, identified and placed in a drying oven at 100° C immediately. These organisms were dried for 24 to 96 hours, to a constant weight. The organisms stored in the collection jars at 0° C were sorted to species and dried only if it was felt that they contributed significantly to the overall biomass. Most of these animals and algal fragments were preserved in labelled specimen vials in 50% isopropanol.

The dry and ash free weights of subsampled organisms were multiplied by a factor which represented either the total sample size for evenly distributed organisms or percent cover for unevenly distributed species.

TABLE 1

TIDAL ELEVATIONS* OF SAMPLING STATIONS

Quadrat No.	S t a t i o n		
	1	2	3
1.	3.75	5.58	5.08
2.	3.26	3.95	4.61
3.	2.77	3.14	-
4.	2.29	2.30	3.66
5.	1.80	1.92	3.19
6.	1.31		2.71
7.	0.94		2.24
8.			1.76
9.			1.29
10.			1.02
Slope of Shore:	8:1	2½:1	8½:1
Reference Point Height:	4.25m	7.20m	6.56m

* (Meters above tidal datum)

B Recolonization

i) Site Description

The recolonization site was located approximately fifteen meters west of the marked intertidal transect at Station 2 on the south-west shore of the Roberts Bank Coal Port. A 1.0m^2 area on the surface of a large, seaward sloping (5:1) rip-rap boulder, located 1.42m a.d. was cleared on July 22, 1981.

ii) Experimental Procedure

Samples of the invertebrates and algae present prior to clearing the recolonization site were collected and preserved. The percent cover of algae was also recorded. (See Appendix 5).

The 1.0m^2 area was cleared by using wire brushes and large scapel blades to scrape the rock surface, and a propane torch to burn away all remaining traces of algae and sedentary invertebrates. The corners of the cleared area were marked with red spray paint to insure relocation of the site on subsequent visits.

The site was visited every two to three weeks for six months. The site could only be examined during tides of less than 1.6 meters. During each visit meteorological conditions, water turbidity, percent algal cover and invertebrate counts were noted. As frequently as possible photographs were taken to enable a permanent record to be made of the recolonization process. Whenever organisms which had not been previously identified were found at the site, samples were collected for examination in the lab. The number of barnacles present was determined by counting those located in randomly chosen 0.01m^2 quadrats within the site. All other organisms were counted as completely as possible during each visit. The visits to the site were made during daylight hours from July to October. From the middle of October to December nocturnal visits were necessary due to the timing of winter low tides.

On September 24th, a 0.01m^2 quadrat, located in the center of the site was scraped clean, and the organisms present in that area were collected. These organisms were kept at 0°C for 24 hours, then washed, sorted, identified and counted. The ash free weights of the dominant algae and invertebrates sampled were determined.

On December 10th, four 0.01m^2 quadrats, located randomly within the site, were scraped clean and the process of species identification and biomass determination was repeated.

C. The Relationship Between Shoot Density of *Zostera marina* and *Z. americana* and Epifaunal Density at Roberts Bank, July 1981.

In the intercauseway area of Roberts Bank between the coal port and the Tsawwassen ferry terminal, there are extensive eelgrass beds. (See figure 1.) The dominant eelgrass species in the beds is *Zostera marina*; however *Z. americana* is also present. The borrow pit and its associated tidal channels, created by dredging operations during the original construction of the coal port, are situated centrally within these beds and contain little or no vegetation.

ii) Sample Collection and Processing

The eelgrass beds were visited over a four day period in July, 1981 (July 28 to 31), and a total of sixty quadrats of eelgrass were harvested. Four of these (0.25m^2) quadrats were sampled in the *Z. americana* zone at the northern-most extent of the beds. A total of two (0.25m^2) and 54 (0.06m^2) quadrats were sampled, at varying shoot densities, within the *Z. marina* growing throughout the intercauseway area. (See Figure 1.)

Samples were collected at random locations by throwing the quadrat frames ahead of us as we walked over the beds at low tide. When the 0.06m² frames were used, two frames were thrown close together in an effort to make replicate samples. This method was used in an effort to sample as wide an area as possible during the short time period that the beds were exposed at low tide. A photographic record of each quadrat, prior to harvest of the eelgrass shoots, was made.

The eelgrass shoots which arose from the sediment within each quadrat frame were counted and the above-ground portions of each plant were removed by slicing through each shoot at sediment level. Large invertebrates such as the isopod, Idotea resecata, which were observed on the blades were carefully collected. The eelgrass shoot counts per quadrat were recorded and the shoots were placed in labelled plastic bags. A solution of buffered 10% formalin was added to each bag, and the bags were then placed in cold storage (0° C) for 3½ months. The plants and their epiphytes and epifauna remained in good condition throughout this storage period.

Each quadrat was identified on the basis of shoot density. (See Table 2, below.) A random number table was subsequently used to select representative quadrats from each density for epifaunal examination.

Table 2. Shoot Density Categories of Quadrats Sampled in the Eelgrass Beds of the Roberts Bank Intercauseway Area, July, 1981.

Density	Number of Shoots/0.25m ²	
	<u>Z. marina</u>	<u>Z. americana</u>
1. Low	0-24	< 176
2. Mid	25-48	-
3. High	> 48	> 176

The shoots from each sample were rinsed thoroughly in running water on two nested sieves, with pore diameters of 500 μ m and 125 μ m. The epifauna which remained on the blades after rinsing were removed by gently scraping along both surfaces of the blade lengths with the blunt edge of a scalpel. This material was also washed through the sieves. All material caught in the sieves was collected and preserved in labelled jars containing 50% isopropanol and the vital stain, Rose Bengal. Each of the preserved samples was split into fractions using a Folsom splitter and the resultant subsample was examined under a dissecting microscope. The organisms present were counted within twenty faunal divisions according to the classification system described in (Smith et al., 1975). (See Appendix 6).

The shoot of each Zostera plant was examined and the number of blades per shoot was recorded. The length and width of the longest intact blade and the length of the shortest intact blade were measured. When the end of the longest blade in the shoot was broken or decayed, that plant was not considered in the blade length determinations. A record of the general condition of representative Zostera marina plants taken from each density was kept by comparing the number of broken, decayed and intact blades per shoot.

The blade measurements permitted a rough estimate of the total surface area of plants per 0.25m² quadrat to be calculated and the number of epifaunal organisms per 1.0cm² of eelgrass was determined. Blade surface area was calculated for the plants in each representative quadrat sample by multiplying the mean length of the longest and the shortest intact blades in that quadrat by the mean width of the longest intact blade. This value was then multiplied by the mean number of blades per shoot, and by the number of shoots counted in that quadrat. This value was, in turn, multiplied by two to account for both sides of the eelgrass blades.

RESULTS

A Rocky Shore Intertidal and Subtidal Transects

The three intertidal stations exemplify three different types of substrate subject to various degrees of exposure. Not all shores are equally suitable to all organisms and variations in species diversity and relative abundance were evident amongst these three locations.

On the cobble beach of Station 1 the most common species include the barnacles Balanus glandula and Chthamalus dalli, the purple shore crab Hemigrapsus nudus and the checkered periwinkle Littorina scutulata. Both the oyster Crassostrea gigas and a small amount of the alga Ulva fenestrata were present in the lower intertidal. A prominent drift zone extended the length of the beach approximately 4 meters below the reference point. It consisted mainly of Zostera marina with some Laminaria species, U. fenestrata and Enteromorpha species.

Virtually all the biomass at station 1 consisted of invertebrates with the exception of the small sample of U. fenestrata in quadrat 6 (Figure 2). Quadrats 6 and 7 exhibited the largest invertebrate biomass values obtained in this study; these were 38.6973 gms/0.25m² and 49.555 gms/0.25m² respectively (Table 3). Approximately 80% of the aforementioned values represent just two species: B. glandula and H. nudus.

On the rip-rap shore of Station 2 the green shore crab H. oregonensis and limpet Acmaea pelta were usually found, in addition to the common species cited for the previous station. Both species of Hemigrapsus, although frequently observed, were not included in biomass determinations because of difficulties in capturing individuals under and between large rip-rap at this station.

FIGURE 2.

BIOMASS OF INVERTEBRATES (g
Ash Free Dry Weight/0.25m²)
AND ALGAE (g Dry Weight/0.25m²)
COLLECTED FROM ROBERTS BANK
INTERTIDAL STATION 1, AUGUST 4
1981.

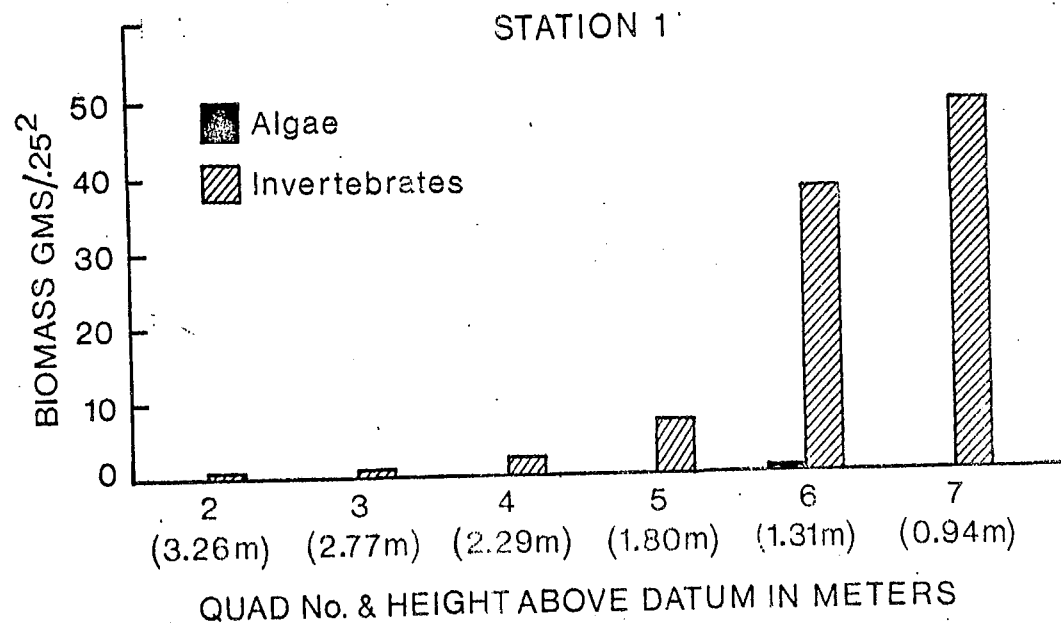


TABLE 3.

BIOMASS OF INVERTEBRATE (g Ash Free Dry Weight/0.25m²) AND ALGAE (g Dry Weight/0.25m²)
COLLECTED FROM ROBERTS BANK COAL PORT INTERTIDAL STATION 1, AUGUST 4, 1981 (7 Quadrats)

TAXA	QUADRAT #													
	#	1 Biomass	#	2 Biomass	#	3 Biomass	#	4 Biomass	#	5 Biomass	#	6 Biomass	#	7 Biomass
<u>Paranemertes</u> <u>peregrina</u> *	0		0		0		0		1	0.0527	0		0	
<u>Armandia</u> <u>brevis</u> *	0		0		0		0		0		0		11	0.1920
<u>Nereis</u> <u>vexillosa</u> *	0		0		0		0		2	0.2685	0		0	
<u>Balanus</u> <u>glandula</u>	0		28	0.1885	3	0.0054	187	0.9302	787	2.3271	7550	19.3490	1465	11.4990
<u>Chthamalus</u> <u>dalli</u>	0		0		0		2	0.0004	2	0.0019	80	0.0700	91	0.7450
<u>Hemigrapsus</u> <u>nudus</u>	0		0		2	0.0422	4	0.4424	33	3.0696	40	11.2300	1	3.3040
<u>Pagurus</u> <u>hirsutiusculus</u>	0		0		0		0		0		20	0.0530	4	0.0530
<u>Protothaca</u> <u>staminea</u>	0		0		0		0		0		0		1	0.1010
<u>Crassostrea</u> <u>gigas</u>	0		0		0		0		0		1	1.1753	0	
<u>Mytilus</u> <u>edulis</u>	0		0		0		0		2	0.0976	100	3.9590	5	0.9030
<u>Collisella</u> <u>pelta</u>	0		0		0		0		0		260	0.7900	25	1.2660
<u>Littorina</u> <u>scutulata</u>	0		0		8	0.1403	204	0.6546	253	0.4888	1410	1.9850	60	1.1880

TABLE 3. continued.....

TAXA	QUADRAT #													
	#	1 Biomass	#	2 Biomass	#	3 Biomass	#	4 Biomass	#	5 Biomass	#	6 Biomass	#	7 Biomass
<u>Notoacmaea</u> <u>persona</u>	0		0		0		0		3	0.0161	10	0.0860	9	0.3040
<u>Ulva</u> <u>fenestrata</u>												0.1570		
TOTAL BIOMASS		-		0.1885		0.1879		2.0276		7.0980		38.6973		49.5550

(* Biomass in g Dry Weight/0.25m²).

Algal diversity and abundance were greater at station 2 than at either of the other stations, with Gigartina papillata and G. corymbifera, Odonthalia floccosa, Fucus gardneri and Enteromorpha spp. occurring most frequently (Figure 3). Petrocoelis* was also common but difficult to sample accurately because it encrusts not only the rock surface but the shells of barnacles and limpets. Only those organisms free of this algal growth were used to determine biomass directly. Those species encrusted by the alga were used in population estimates and these estimates were used, in turn, to calculate total biomass. The biomass totals for the algae are larger, by a factor of 2, than the total invertebrate biomass for this station (Tables 4 & 5).

The gastropod Nucella lamellosa, the common blue mussel Mytilus edulis, the hermit crab Pagurus hirsutiusculus and the limpet Notoacmea persona were frequently observed on the small boulder/gravel substrate of station 3. Common species of station 1 and 2 were also present and together accounted for large diversity of invertebrates at this location. G. papillata, Enteromorpha spp. and Ulva fenestrata were present, although sparse in comparison to the previous transect. Total invertebrate biomass was 4 times greater than the algae. A wide band of drift material composed, primarily of Z. marina and wood fragments, was located approximately five meters above datum.

If the total biomass values for invertebrate and algal species of all three stations are combined to give an overall biomass value, it is possible to examine how the biomass of the coal port intertidal community is distributed. Barnacle species account for 35.23% followed by H. nudus 11.47%, M. edulis 7.54% and L. scutulata 4.01%, and these invertebrate species represent 58.25% of the total biomass. Of the algal species O. floccosa accounted for 7.9% followed by F. gardneri 5.35%, U. fenestrata 4.17% and E. linza, with these four algal species accounting for 20.36% of the total biomass.

* Petrocoelis represents a sporangial phase in the life cycle of some species of Gigartina (Abbott et al., 1976).

FIGURE 3.

BIOMASS OF INVERTEBRATES (g Ash
Free Dry Weight/0.25m²) AND ALGAE
(g Dry Weight/0.25m²) COLLECTED
FROM ROBERTS BANK INTERTIDAL STATION
2, AUGUST 10 - 15, 1981.

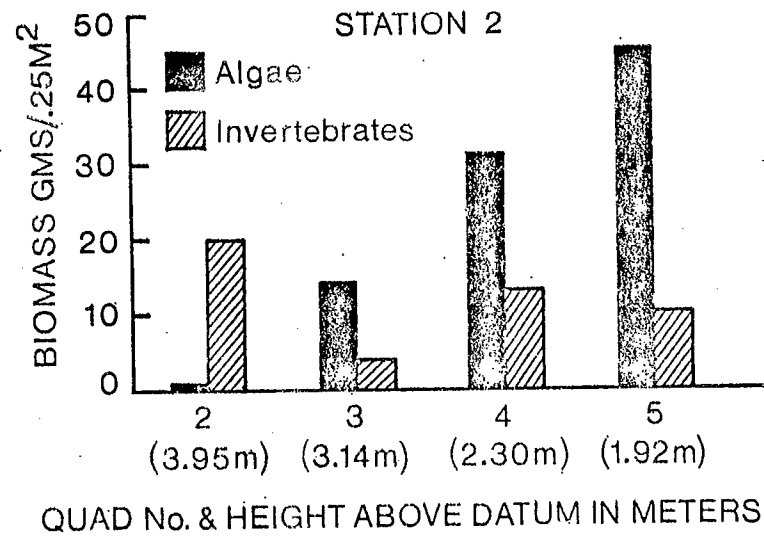


TABLE 4.

BIOMASS OF ALGAE (g Dry Weight/0.25m²) COLLECTED FROM ROBERTS BANK COAL PORT INTERTIDAL STATION 2, AUGUST 10 - 15, 1981 (5 Quadrats)

SPECIES	QUADRAT #				
	1 Biomass	2 Biomass	3 Biomass	4 Biomass	5 Biomass
<u>Enteromorpha</u> <u>intestinalis</u>	-	-	4.1475	-	-
<u>Enteromorpha</u> spp.	-	-	-	0.1538	-
<u>Ulva</u> <u>fenestrata</u>	-	-	0.0889	0.5996	2.6369
<u>Fucus</u> <u>gardneri</u>	-	-	-	17.2093	1.2639
<u>Cryptosiphonia</u> <u>woodii</u>	-	-	-	0.1935	-
<u>Gigartina</u> <u>corymbifera</u>	-	-	2.0909	0.1730	-
<u>G. papillata</u>	-	0.4350	8.3269	9.5451	2.9288
<u>Iridaea</u> <u>cordata</u>	-	-	-	-	8.9539
<u>I. heterocarpa</u>	-	-	-	3.1022	1.4466
<u>Odonthalia</u> <u>floccosa</u>	-	-	-	0.5801	26.7396
<u>Porphyra</u> <u>perforata</u>	-	-	0.1099	0.4140	-
<u>P. smithii</u>	-	-	0.0094	-	0.2509
<u>Porphyra</u> sp.	-	-	0.0051	-	0.2702
TOTAL BIOMASS	-	0.4350	14.7787	31.9706	44.4908

TABLE 5.

BIOMASS OF INVERTEBRATES (g Ash Free Dry Weight/0.25m²) COLLECTED FROM THE ROBERTS BANK COAL PORT INTERTIDAL STATION 2, AUGUST 10 - 15, 1981. (5 Quadrats)

TAXA	QUADRAT #									
	#	1 Biomass	#	2 Biomass	#	3 Biomass	#	4 Biomass	#	5 Biomass
<u>Balanus cariosus</u>	0		0		0		10	0.0170	40	0.1170
<u>B. glandula</u>	0			14.58	2040	0.6690	480	0.2220	170	1.228
<u>Chthamalus dalli</u>	0			3.9735	2390	3.1450	2070	2.0300	560	0.7340
Barnacle spp.	0		0		0		355	10.1700	560	3.7670
<u>Pagurus hirsutiusculus</u>	0		0		0		1	0.0071	2	0.0146
<u>Idotea wosnesenskii</u>	0		0		2	0.0209	0		1	0.0171
<u>Collisella digitalis</u>	0		10	0.2450	0		0		0	
<u>C. pelta</u>	0		5	0.0390	77	0.3473	240	0.4283	37	0.1100
<u>Lacuna spp.</u>	0		0		12	0.0408	27	0.0918	175	0.5950
<u>Littorina scutulata</u>	0		1500	1.544	349	0.6363	55	0.0483	38	0.3020
<u>Notoacmaea persona</u>	0		0		0		1	0.0013	0	
<u>N. scutum</u>	0		0		0		1	0.0011	0	
<u>Mytilus edulis</u>	0		60	0.2330	19	0.0642	0		300	3.2100
TOTAL BIOMASS		-		20.6145		4.9236		13.0169		10.0947

FIGURE 4.

BIOMASS OF INVERTEBRATES (g Ash
Free Dry Weight/ 0.25m^2) AND ALGAE
(g Dry Weight/ 0.25m^2) COLLECTED
FROM ROBERTS BANK INTERTIDAL
STATION 3, AUGUST 25-31, 1981.

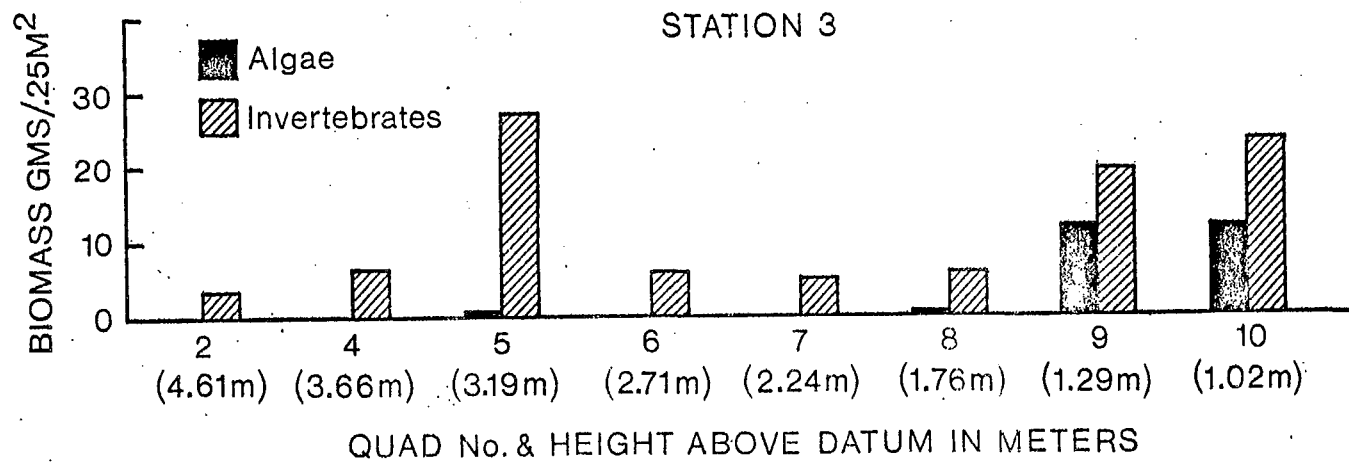


TABLE 6.

BIOMASS OF ALGAE (g Dry Weight/0.25m²) COLLECTED FROM ROBERTS BANK COAL PORT INTERTIDAL STATION 3, AUGUST 25 - 31, 1981. (9 Quadrats)

SPECIES	QUADRAT #			
	5 Biomass	8 Biomass	9 Biomass	10 Biomass
<u>Enteromorpha</u> <u>intestinalis</u>	-	-	0.0932	0.0356
<u>E. linza</u>	-	-	4.6378	1.2000
<u>Ulva</u> <u>fenestrata</u>	-	0.0420	6.5142	7.7024
<u>Gigartina</u> <u>papillata</u>	0.1865	0.0270	1.2000	1.5233
<u>Iridaea</u> <u>cordata</u>	-	-	-	0.5954
<u>Polysiphonia</u> spp.	-	-	-	0.0791
TOTAL BIOMASS	0.1865	0.0690	12.4452	11.1358

TABLE 7.

BIOMASS OF INVERTEBRATES (g Ash Free Dry Weight/0.25m²) COLLECTED FROM ROBERTS BANK COAL PORT INTERTIDAL STATION 3, AUGUST 25 - 31, 1981. (9 Quadrats)

TAXA	QUADRAT #											
	#	2 Biomass	#	4 Biomass	#	5 Biomass	#	6 Biomass	#	7 Biomass	#	8 Biomass
<u>Paranemertes peregri</u> [*]	0		0		0		0		1	0.0679	0	
<u>Nereis vexillosa</u> [*]	0		0		0		0		5	0.3608	6	0.1206
<u>Balanus glandula</u>	0		229	1.0466	11890	16.0795	823	1.1664	430	2.8690	274	1.3245
<u>Chthamalus dalli</u>	0			0.0825	7	0.2970	97	0.1611	0		0	
<u>Hemigrapsus nudus</u>	54	2.9331		3.5188	63	3.7737	32	1.2889	4	0.1751	10	0.8353
<u>H. oregonensis</u>	9	0.1917		0.0201	2	0.0447	12	0.0353	0		0	
<u>Pagurus hirsutiusculus</u>	0		0		21	0.1111	0		0		0	
<u>Gnorisphaeroma oregonensis</u>	0		0		0		0		0		0	
<u>Idotea montereyensis</u>	0		0		0		0		0		1	0.0037
<u>Collisella pelta</u>	0		0		0		2	0.0088	0		5	1.4738
<u>Lacuna spp.</u>	0		0		0		0		0		0	
<u>Littorina scutulata</u>	1	0.0030	228	1.1251	503	2.7432	230	1.1868	73	0.3740	44	0.1344

TABLE 7 continued.....

TAXA	QUADRAT #											
	#	2 Biomass	#	4 Biomass	#	5 Biomass	#	6 Biomass	#	7 Biomass	#	8 Biomass
<u>Notoacmaea</u> <u>persona</u>	0		0		0		0		1	0.0017	1	0.0035
<u>N. scutum</u>	0		0		0		0		0		0	
<u>Nucella</u> <u>lamellosa</u>	0		0		0		0		0		0	
<u>Protothaca</u> <u>staminea</u>	0		0		0		1	0.0041	0		0	
<u>Mytilus edulis</u>	1	0.0278	8	0.2191	448	4.1437	105	2.2199	94	1.1618	135	1.8010
TOTAL BIOMASS		3.1556		6.0122		27.1929		6.0713		5.0103		5.7299

(* Biomass in g Dry Weight/0.25m².)

TABLE 7. continued.....

TAXA	QUADRAT #			
		9		10
	#	Biomass	#	Biomass
<u>Paranemertes</u> <u>peregrina</u> *	0		0	
<u>Nereis</u> <u>vexillosa</u> *	14	0.6804	2	0.0972
<u>Balanus</u> <u>glandula</u>	6380	10.8331	5450	7.3544
<u>Chthamalus</u> <u>dalli</u>	0		4	0.0092
<u>Hemigrapsus</u> <u>nudus</u>	32	2.0328	4	0.8842
<u>H. oregonensis</u>	14	0.6012	10	0.7446
<u>Pagurus</u> <u>hirsutiusculus</u>	52	0.1648	4	0.0118
<u>Gnorisphaeroma</u> <u>oregonensis</u>	6	0.0144	10	0.0356
<u>Idotea</u> <u>montereyensis</u>	0		20	0.0466
<u>Collisella</u> <u>pelta</u>	116	0.4262	66	0.3058
<u>Lacuna</u> spp.	0		158	0.1882
<u>Littorina</u> <u>scutulata</u>	12	0.0110	24	0.1452

TABLE 7. continued.....

TAXA	QUADRAT #			
		9		10
	#	Biomass	#	Biomass
<u>Notoacmaea</u> <u>persona</u>	2	0.1982	0	
<u>N. scutum</u>	6	0.0100	2	0.0166
<u>Nucella</u> <u>lamellosa</u>	0		8	10.0254
<u>Protothaca</u> <u>staminea</u>	0		0	
<u>Mytilus edulis</u>	2460	4.4092	47	3.5952
TOTAL BIOMASS		19.3813		23.4600

(* Biomass in g Dry Weight/0.25m²).

FIGURE 5

BIOMASS OF INVERTEBRATES (g
Ash Free Dry Weight/0.25m²)
AND ALGAE (g Dry Weight/0.25m²)
COLLECTED FROM ROBERTS BANK
SUBTIDAL TRANSECT #1, AUGUST
31, 1981.

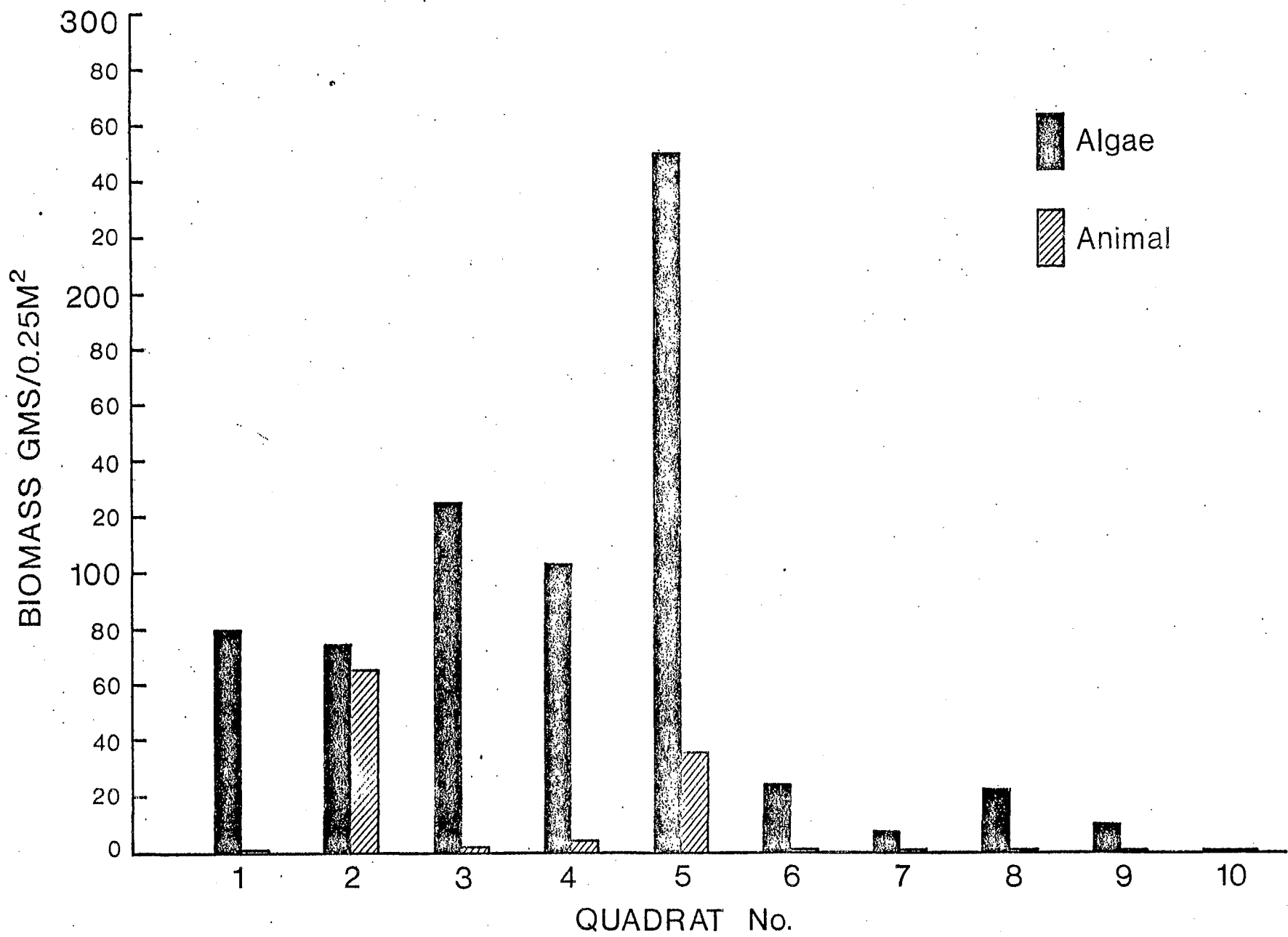


TABLE 8.

BIOMASS OF ALGAE (g Dry Weight/0.25m²) COLLECTED FROM ROBERTS BANK COAL PORT SUBTIDAL
 TRANSECT # 1, AUGUST 31, 1981. (10 Quadrats)

SPECIES	QUADRAT #					
	1 Biomass	2 Biomass	3 Biomass	4 Biomass	5 Biomass	6 Biomass
<u>Enteromorpha</u> <u>intestinalis</u>	-	-	-	-	-	-
<u>E. linza</u>	-	0.0062	0.0047	-	-	-
<u>Ulva</u> <u>fenestrata</u>	26.0680	4.0990	1.228	1.8810	0.2130	20.6840
<u>Fucus</u> <u>gardneri</u>	-	-	-	-	-	-
<u>Laminaria</u> <u>saccharina</u>	-	0.8430	-	-	12.4950	-
<u>Nereocystis</u> <u>leutkeana</u>	-	-	-	-	138.0680	-
<u>Callophyllis</u> <u>flabellulata</u>	-	-	1.0650	0.9900	3.6910	0.0676
<u>Ceramium</u> <u>californicum</u>	-	-	-	-	-	-
<u>Constaninea</u> <u>subulifera</u>	-	0.0719	42.6150	76.5820	61.8550	-
<u>Cryptosiphonia</u> <u>woodii</u>	0.6970	0.2060	-	-	-	-
<u>Farlowia mollis</u>	-	-	-	-	-	-
<u>Gigartina</u> <u>corymbifera</u>	-	-	0.9430	9.4350	11.3128	1.0573
<u>G. papillata</u>	50.9040	13.7490	-	-	-	-

TABLE 8. continued.....

SPECIES	QUADRAT #					
	1 Biomass	2 Biomass	3 Biomass	4 Biomass	5 Biomass	6 Biomass
<u>Gracilaria</u> <u>verrucosa</u>	0.1030	-	-	-	0.1801	1.7000
<u>Grateloupia</u> <u>californica</u>	-	0.2300	-	-	-	-
<u>Iridaea</u> <u>cordata</u>	0.9300	20.4420	60.1960	12.2920	17.6700	0.3130
<u>Microcladia</u> <u>coulteri</u>	0.0864	3.8420	0.5690	0.7100	0.2470	0.0189
<u>Odonthalia</u> <u>floccosa</u>	0.2540	30.5790	-	0.8950	0.2550	-
<u>Polyneura</u> <u>latissima</u>	0.2670	0.0810	19.1300	0.5700	0.8170	0.1340
<u>Polysiphonia</u> sp.	-	0.0684	-	-	-	-
<u>Rhodoglossum</u> <u>affine</u>	0.3420	-	-	-	-	-
<u>Rhodymenia</u> <u>pertusa</u>	0.1880	0.0422	0.1354	-	1.5340	-
<u>Smithora</u> <u>naiadum</u>	-	-	0.0068	-	-	-
<u>Stenogramme</u> <u>interrupta</u>	-	-	-	-	-	-
TOTAL BIOMASS	79.8394	74.2597	125.8900	103.3600	248.3379	23.9748

TABLE 8. continued.....

SPECIES	QUADRAT #			
	7 Biomass	8 Biomass	9 Biomass	10 Biomass
<u>Enteromorpha</u> <u>intestinalis</u>	-	0.2210	0.0434	-
<u>E. linza</u>	-	-	-	-
<u>Ulva</u> <u>fenestrata</u>	1.0060	1.0090	0.8160	-
<u>Fucus</u> <u>gardneri</u>	-	-	-	-
<u>Laminaria</u> <u>saccharina</u>	-	-	-	-
<u>Nereocystis</u> <u>leutkeana</u>	1.4020	-	-	-
<u>Callophyllis</u> <u>flabellulata</u>	-	0.5390	0.1739	-
<u>Ceramium</u> <u>californicum</u>	-	-	-	-
<u>Constaninea</u> <u>subulifera</u>	-	-	0.1320	-
<u>Cryptosiphonia</u> <u>woodii</u>	-	-	0.2470	-
<u>Farlowia mollis</u>	-	-	1.1630	-
<u>Gigartina</u> <u>corymbifera</u>	0.6740	11.1380	1.2330	-
<u>G. papillata</u>	-	0.3060	-	-

TABLE 8. continued.....

SPECIES	QUADRAT #			
	7 Biomass	8 Biomass	9 Biomass	10 Biomass
<u>Gracilaria</u> <u>verrucosa</u>	4.2590	0.4210	0.03140	0.2330
<u>Grateloupia</u> <u>californica</u>	-	-	-	-
<u>Iridaea</u> <u>cordata</u>	-	7.3400	4.2880	-
<u>Microcladia</u> <u>coulteri</u>	-	-	0.0194	-
<u>Odonthalia</u> <u>floccosa</u>	0.0700	-	0.9260	-
<u>Polyneura</u> <u>latissima</u>	-	-	-	-
<u>Polysiphonia</u> sp.	-	-	-	-
<u>Rhodoglossum</u> <u>affine</u>	0.0360	-	-	-
<u>Rhodymenia</u> <u>pertusa</u>	-	1.0400	0.4810	-
<u>Smithora</u> <u>naladum</u>	-	-	0.0300	-
<u>Stenogramme</u> <u>interrupta</u>	-	0.0242	-	-
TOTAL BIOMASS	7.4470	22.0382	9.5841	0.2330

TABLE 9.

BIOMASS OF INVERTEBRATES (g Ash Free Dry Weights/0.25m²) COLLECTED FROM THE ROBERTS BANK COAL
PORT SUBTIDAL TRANSECT # 1, AUGUST 31, 1981. (10 Quadrats)

TAXA	QUADRAT #											
	#	1 Biomass	#	2 Biomass	#	3 Biomass	#	4 Biomass	#	5 Biomass	#	6 Biomass
<u>Platynereis</u> <u>bicanaliculata</u> *	0		0		1	0.0001	0		0		0	
<u>Balanus</u> <u>crenatus</u>	52	0.1564	99	0.2646	9	0.1349	0		0		0	
<u>Pugettia</u> <u>gracilis</u>	0		0		1	0.0176	0		0		0	
<u>Amphissa</u> <u>columbiana</u>	0		0		0		6	0.0506	6	0.0132	0	
<u>Lacuna</u> spp.	444	0.1404	382	0.1320	264	0.2164	99	0.0422	17	0.0149	8	0.0043
<u>Margarites</u> <u>lirulatus</u>	6	0.0264	7	0.0203	67	0.4589	42	0.2675	10	0.1411	3	0.0057
<u>Mitrella</u> <u>tuberosa</u>	0		0		0		3	0.0204	0		0	
<u>Notoacmaea</u> <u>scutum</u>	0		0		1	0.0021	2	0.0061	0		1	0.0029
<u>Mytilus</u> <u>edulis</u>	388	0.0938	300	0.00590	0		9	0.0111	0		0	
<u>Katharina</u> <u>tunicata</u>	0		0		0		0		0		0	
<u>Tonicella</u> <u>lineata</u>	0		0		0		1	0.0386	1	0.0161	1	0.0042
<u>Cucumaria</u> <u>miniata</u>	0		0		0		0		3	35.2254	0	

TABLE 9. continued.....

TAXA	QUADRAT #											
	#	1 Biomass	#	2 Biomass	#	3 Biomass	#	4 Biomass	#	5 Biomass	#	6 Biomass
<u>Eupentacta</u> <u>quinquesemita</u>	0		0		0		0		0		0	
<u>Evasterias</u> <u>troschelli</u>	0		0		0		1	3.3607	0		0	
<u>Pisaster</u> <u>ochraceous</u>	0		3	64.3800	0		0		0		0	
<u>Solaster</u> <u>dawsoni</u>	0		0		0		0		0		0	
TOTAL BIOMASS		0.3232		64.7969		0.8298		3.7861		35.4107		0.0171

(* Biomass in g Dry Weight/0.25m²).

TABLE 9. continued.....

TAXA	QUADRAT #							
	#	7 Biomass	#	8 Biomass	#	9 Biomass	#	10 Biomass
<u>Platynereis</u> <u>bicanaliculata*</u>	0		0		0		0	
<u>Balanus</u> <u>crenatus</u>	0		0		0		0	
<u>Pugettia</u> <u>gracilis</u>	1	0.0014	0		0		0	
<u>Amphissa</u> <u>columbiana</u>	0		4	0.0191	2	0.0035	0	
<u>Lacuna</u> spp.	14	0.0476	23	0.0782	8	0.0108	5	0.0016
<u>Margarites</u> <u>lirulatus</u>	0		1	0.0031	2	0.0041	0	
<u>Mitrella</u> <u>tuberosa</u>	0		0		0		1	0.0055
<u>Notoacmaea</u> <u>scutum</u>	0		0		0		0	
<u>Mytilus edulis</u>	0		0		0		0	
<u>Katharina</u> <u>tunicata</u>	0		0		0		0	
<u>Tonicella</u> <u>lineata</u>	0		0		1	0.0093	0	
<u>Cucumaria</u> <u>miniata</u>	0		0		0		0	

TABLE 9. continued.....

TAXA	QUADRAT #							
	#	7 Biomass	#	8 Biomass	#	9 Biomass	#	10 Biomass
<u>Eupentacta</u> <u>quinquesemita</u>	1	0.0085	0		0		0	
<u>Evasterias</u> <u>troschelli</u>	0		0		0		0	
<u>Pisaster</u> <u>ochraceous</u>	0		0		0		0	
<u>Solaster</u> <u>dawsoni</u>	1	0.0515	0		0		0	
TOTAL BIOMASS		0.0575		0.1004		0.0277		0.0071

(* Biomass in g Dry Weight/0.25m²).

FIGURE 6

BIOMASS OF INVERTEBRATES (g
Ash Free Dry Weight/0.25m²)
AND ALGAE (g Dry Weight/0.25m²)
COLLECTED FROM ROBERTS BANK
SUBTIDAL TRANSECT # 2, AUGUST
31, 1981.

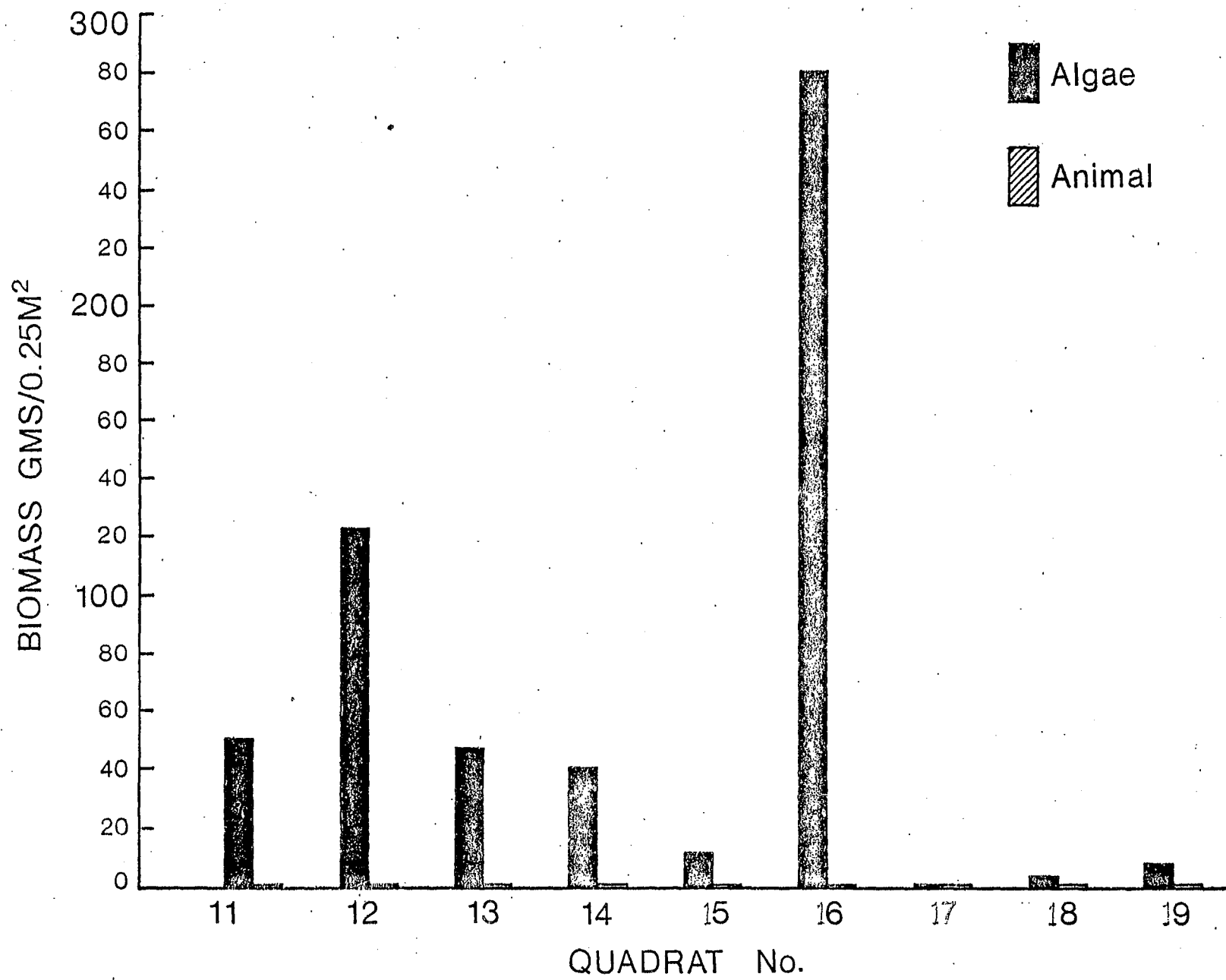


TABLE 10.

BIOMASS OF ALGAE (g Dry Weight/0.25m²) COLLECTED FROM THE ROBERTS BANK COAL PORT
 SUBTIDAL TRANSECT # 2, AUGUST 31, 1981. (9 Quadrats)

SPECIES	QUADRAT #					
	1 Biomass	2 Biomass	3 Biomass	4 Biomass	5 Biomass	6 Biomass
<u>Enteromorpha</u> <u>intestinalis</u>	-	-	-	-	0.0041	-
<u>E. linza</u>	0.0455	-	0.0969	-	-	-
<u>Ulva</u> <u>fenestrata</u>	0.3230	0.2750	0.9869	0.2690	0.1810	3.6650
<u>Fucus gardneri</u>	4.9310	-	-	-	-	-
<u>Laminaria</u> <u>saccharina</u>	-	2.9040	-	-	-	273.8000
<u>Callophyllis</u> <u>flabellulata</u>	-	-	-	1.2180	0.0521	-
<u>Ceramium</u> <u>californicum</u>	-	0.0148	-	-	-	-
<u>Constaninea</u> <u>subulifera</u>	-	61.2960	24.0000	24.9500	-	-
<u>Gigartina</u> <u>corymbifera</u>	-	-	16.8500	9.8790	5.8940	0.8590
<u>G. papillata</u>	19.5720	-	-	-	-	-
<u>Gracilaria</u> <u>verrucosa</u>	11.7670	9.6790	12.6200	2.2960	2.2870	1.8420
<u>Grateloupia</u> <u>californica</u>	-	-	-	-	-	-

TABLE 10. continued.....

SPECIES	QUADRAT #					
	1 Biomass	2 Biomass	3 Biomass	4 Biomass	5 Biomass	6 Biomass
<u>Microcladia</u> <u>coulteri</u>	-	2.7240	0.2350	0.0874	0.0037	-
<u>Odonthalia</u> <u>floccosa</u>	11.2780	35.2080	0.3770	0.1200	-	-
<u>Polyneura</u> <u>latissima</u>	1.1740	9.9270	-	0.2580	0.0891	-
<u>Polysiphonia</u> sp.	-	-	0.0281	-	-	-
<u>Rhodoglossum</u> <u>affine</u>	-	-	-	-	-	-
<u>Rhodymenia</u> <u>pertusa</u>	-	-	0.0789	0.7420	-	-
<u>Smithora</u> <u>naiadum</u>	0.0029	0.0095	0.0018	-	-	-
<u>Stenogramme</u> <u>interrupta</u>	-	-	0.0412	-	-	-
TOTAL BIOMASS	49.0934	122.0400	57.6119	41.3474	12.9120	280.4100

TABLE 10. continued.....

SPECIES	QUADRAT #		
	7 Biomass	8 Biomass	9 Biomass
<u>Enteromorpha</u> <u>intestinalis</u>	-	-	-
<u>E. linza</u>	-	-	-
<u>Ulva</u> <u>fenestrata</u>	-	-	0.6830
<u>Fucus gardneri</u>	-	-	-
<u>Laminaria</u> <u>saccharina</u>	-	-	-
<u>Callophyllis</u> <u>flabellulata</u>	-	-	0.3190
<u>Ceramium</u> <u>californicum</u>	-	-	-
<u>Constaninea</u> <u>subulifera</u>	-	-	-
<u>Gigartina</u> <u>corymbifera</u>	-	-	1.9220
<u>G. papillata</u>	0.1200	-	-
<u>Gracilaria</u> <u>verrucosa</u>	0.1080	4.7930	5.8540
<u>Grateloupia</u> <u>californica</u>	-	-	-

TABLE 10. continued.....

SPECIES	QUADRAT #		
	7 Biomass	8 Biomass	9 Biomass
<u>Microcladia</u> <u>coulteri</u>	-	-	-
<u>Odonthalia</u> <u>floccosa</u>	-	-	-
<u>Polyneura</u> <u>latissima</u>	-	-	-
<u>Polysiphonia</u> sp.	-	-	-
<u>Rhodoglossum</u> <u>affine</u>	-	-	0.0950
<u>Rhodymenia</u> <u>pertusa</u>	-	-	-
<u>Smithora</u> <u>naladum</u>	-	-	-
<u>Stenogramme</u> <u>interrupta</u>	-	-	0.1600
TOTAL BIOMASS	0.2280	4.793	8.7459

TABLE 11.

BIOMASS OF INVERTEBRATES (g Ash Free Dry Weight/0.25m²) COLLECTED FROM THE ROBERTS BANK
COAL PORT SUBTIDAL TRANSECT # 2, AUGUST 31, 1981. (9-Quadrats)

TAXA	QUADRAT #											
	#	11 Biomass	#	12 Biomass	#	13 Biomass	#	14 Biomass	#	15 Biomass	#	16 Biomass
<u>Balanus</u> <u>crenatus</u>	0		2	0.0259		0.0890	0		0		0	
<u>Pagurus</u> <u>hirsutiusculus</u>	0		1	0.0028	0		0		0		0	
<u>Pugettia</u> <u>gracilis</u>	0		1	0.0438	0		0		0		0	
<u>Amphissa</u> <u>columbiana</u>	0		1	0.0194	0		1	0.0050	0		0	
<u>Collisella</u> <u>ochracea</u>	0		0		1	0.0032	0		0		0	
<u>Lacuna</u> spp.	115	0.3910	322	0.1606	41	0.0189	30	0.0173	56	0.0804	18	0.3050
<u>Margarites</u> <u>lirulatus</u>	2	0.0014	23	0.1560	1	0.0009	21	0.0676	8	0.0481	7	0.0557
<u>Mitrella</u> <u>tuberosa</u>	0		0			0.0139	3	0.0163	2	0.0248	2	0.0085
<u>Notoacmaea</u> <u>scutum</u>	1	0.0035	0		0		0		0		0	
<u>Katharina</u> <u>tunicata</u>	1	0.0459	0		0		0		0		0	
<u>Tonicella</u> <u>lineata</u>	1	0.0051	2	0.0975	0		0		0		0	

TABLE 10. continued.....

TAXA	QUADRAT #											
	#	11 Biomass	#	12 Biomass	#	13 Biomass	#	14 Biomass	#	15 Biomass	#	16 Biomass
<u>Eupentacta</u> <u>quinquesemita</u>	1	0.0048	1	0.0048	0		0		3	0.0065	0	
<u>Strongylocen-</u> <u>trotus</u> <u>droebachiensis</u>	0		0		0		0		0		1	0.0073
TOTAL BIOMASS		0.4517		0.5108		0.1259		0.1062		0.1598		0.3765

TABLE 11. continued.....

TAXA	QUADRAT #					
	#	17 Biomass	#	18 Biomass	#	19 Biomass
<u>Balanus</u> <u>crenatus</u>	0		0		0	
<u>Pagurus</u> <u>hirsutiusculus</u>	0		0		0	
<u>Pugettia</u> <u>gracilis</u>	0		0		0	
<u>Amphissa</u> <u>columbiana</u>	0		2	0.0529	3	0.0241
<u>Collisella</u> <u>ochracea</u>	0		0		0	
<u>Lacuna</u> spp.	22	0.0060	33	0.0561	8	0.0077
<u>Margarites</u> <u>lirulatus</u>	0		4	0.0243	0	
<u>Mitrella</u> <u>tuberosa</u>	0		2	0.0237	0	
<u>Notoacmaea</u> <u>scutum</u>	0		0		0	
<u>Katharina</u> <u>tunicata</u>	0		0		0	
<u>Tonicella</u> <u>lineata</u>	1	0.1164	0		0	

TABLE 11. continued.....

TAXA	QUADRAT #					
	#	17 Biomass	#	18 Biomass	#	19 Biomass
<u>Eupentacta</u> <u>quinquesemita</u>	0		0		2	0.0137
<u>Strongylocen-</u> <u>trotus</u> <u>droebachiensis</u>	0		0		0	
TOTAL BIOMASS		0.1224		0.1570		0.1129

The two subtidal transects were basically uniform relative to species diversity and abundance (Tables 8 - 11). Common algae included Gigartina spp., Iridea cordata, Gracilaria verrucosa and U. fenestrata. Quadrats 5 and 16 contained large brown algae Nereocystis leutkeana and Laminaria saccharina respectively (Figures 5 & 6). An inventory of the N. leutkeana bed from the subtidal transects indicated a mean density of 0.17 ± 0.08 plants/m² (See Appendix 1). Algal growth was dense and approximately 12 times greater than the invertebrate biomass; consequently the invertebrate contribution appeared insignificant.

The snail Lacuna sp. was the most ubiquitous invertebrate in the subtidal followed by Margarites lirulatus, Amphissa columbiana and the chiton, Tonicella lineata. Large invertebrate biomass values for quadrats 2 and 5 are due to the numerically small presence of two species of echinoderms, the purple seastar Pisaster ochraceus and the burrowing sea cucumber, Cucumaria miniata.

All the intertidal and subtidal species identified are recorded in Appendices 3 and 4. Tables 3 to 11 deal with the biomass data of individual species. Figures 2 to 6 compare invertebrate/algal biomass amongst quadrats, by station.

B. Recolonization

After all organisms were removed from the study site on July 22, a log of 9 visits made over a 144 day period was maintained (see Appendix 5). Few new residents were observed after the first nine days but over the following ten day period a dense Enteromorpha linza/E. intestinalis mat rapidly grew to cover 60% of the site. The percentage cover of the mat continued to increase over 32 days until September 24, at which time it began to recede (Table 12). Limpets were observed within nine days of clearing and were presumed to have been recruited from the sides of the recolonization rock where large populations were evident. The number of limpets increased over the 144 day period while the number of littorines remained relatively constant from September to December. Estimates of barnacle populations and biomass determinations were made at various times in the study (Table 12, 13 and 14). The number of barnacle species and associated biomass increased over the study period. Enteromorpha species percentage cover and biomass, as of December 10th had dramatically declined from its earlier dense cover of the rock surface. A complete list of species observed and identified from the recolonization site is included in Appendix 2.

C. The Relationship Between Shoot Density of Zostera marina and Z. americana to Epifaunal Density at Roberts Bank, July 1981.

Zostera americana was found growing in relatively dense assemblages (usually more than 200 shoots/0.25m²) along the northern and western perimeters of the eelgrass beds in the Roberts Bank intercauseway area. These plants are restricted to higher tidal elevations than the dominant Z. marina plants which were found throughout the intercauseway area at mid to low tidal elevations. A large zone of exposed sand/mud substrate and sparse algal growth was observed in a central area north of the heads of the tidal channels which run through the eelgrass beds and empty into the large borrow pit. No eelgrass was observed in this zone or in the beds of any of the large tidal channels.

TABLE 12.

TOTAL COUNTS OF FOUR INVERTEBRATE SPECIES AND PERCENT COVER OF ENTEROMORPHA SPECIES/METER²
RECORDED ON THE RECOLONIZATION SITE, JULY 22 TO DECEMBER 10, 1981.

DATE EXAMINED	NO. OF INDIVIDUALS/M ²				% COVER
	LIMPET SPECIES	LITTORINA SCUTULATA	BALANUS GLANDULA	CHTHAMALUS DALLI	ENTEROMORPHA SPP.
July 22	0	0	0	0	0
July 31	3	3	0	0	0
Aug. 10	not counted	not counted	0	0	60%
Aug. 13	not counted	not counted	0	0	not observed (Tide too high)
Sept. 11	103	25	1500	250	90%
Sept. 24	113	50	(9000)	(1800)	75%
Oct. 21	148	not counted	3200	1000	60%
Nov. 3	160	20	not counted	not counted	50%
Nov. 19	98	20	not counted	not counted	45%
Dec. 10	156	25	7600	2600	25%

TABLE 13.

BIOMASS OF INVERTEBRATES (g Ash Free Dry Weight and Dry Weight) AND ALGAE (g Dry Weight)
COLLECTED FROM A 0.01M² QUADRAT IN THE CENTER OF THE RECOLONIZATION SITE, SEPTEMBER 24, 1981.

SPECIES	# INDIVIDUALS/0.01M ²	DRY WEIGHT	ASH FREE DRY WEIGHT	BIOMASS	
				g/0.25m ²	g/1.0m ²
<u>Enteromorpha linza</u>		0.6280	-	9.42	37.68
<u>Enteromorpha spp.</u>		0.5902	-	8.85	35.41
<u>Balanus glandula</u>	90	0.2403	0.0118	0.295	1.180
<u>Chthamalus dalli</u>	18	0.0098	0.0001	0.003	0.010

TABLE 14.

BIOMASS OF INVERTEBRATES (g Ash Free Dry Weight and g Dry Weight) AND ALGAE (g Dry Weight) COLLECTED IN FOUR 0.01M² QUADRATS RANDOMLY LOCATED WITHIN THE RECOLONIZATION SITE, DECEMBER 10, 1981.

SPECIES	# INDIVIDUALS/0.01M ²	DRY WEIGHT	ASH FREE DRY WEIGHT	BIOMASS	
				g/0.25m ²	g/1.0m ²
<u>Enteromorpha</u> <u>linza</u>		0.0460	-	0.144	0.575
<u>Balanus</u> <u>glandula</u>	$\bar{X} = 76$	$\bar{X} = 0.4889$	$\bar{X} = 0.0241$	0.602	2.41
<u>Chthamalus</u> <u>dalli</u>	$\bar{X} = 26$	$\bar{X} = 0.2193$	$\bar{X} = 0.0099$	0.250	0.99

The mean shoot density observed in the 56 Z. marina quadrats sampled in this study was 34 shoots /0.25m² ± 14.7. In an unpublished survey carried out on July 29 - 30, 1981 on Robert's Bank, Gordon also found a mean density of 34 shoots /0.25m² ± 9.1 in the area in which our study was made.

The leaves of the Z. americana plants collected in the two representative quadrat samples chosen for detailed examination in this study had a mean width of 0.18 ± 0.030 cm. and a mean length of 17.2 ± 3.49 cm. There was an average of five leaves per shoot. (See Table 15).

The Z. americana blades appeared to be much freer of encrusting epifauna and algal epiphytes than the Z. marina blades examined in this study. Table 16 shows the relationship between the number of taxa, individual organisms and eelgrass shoot density of Z. americana. Although the number of epifaunal taxa described was the same for each density category of these plants, it was found that the blades of the low density shoots supported more than three times the number of epifaunal organisms than did the blades from the high density shoots.

Certain organisms were observed on the Z. americana plants which were not found in the Z. marina samples. For example, the gastropod Batillaria zonalis was found in large numbers in most of the Z. americana quadrats; none were found in the quadrats containing Z. marina. These gastropods were usually observed at the base of the eelgrass plants of just below the substrate surface. In addition to the presence of the B. zonalis, a small number of tanaid crustaceans were found on the Z. americana plants examined in this study. (See Table 16.) No tanaids were found in the Z. marina samples.

TABLE 15.

AERIAL DIMENSIONS OF EELGRASS
(*Zostera americana*) PLANTS IN
LOW SHOOT DENSITY (<176 shoots/
0.25m²) AND HIGH SHOOT DENSITY
(>176 shoots/0.25m²) SAMPLES
COLLECTED ON ROBERTS BANK,
JULY 28 - 31, 1981.

DIMENSIONS	SHOOT DENSITY		MEAN OVERALL (+S.D.)
	LOW	HIGH	
# Shoots/0.25m ²	46 n=1	345 n=1	196
Mean # Blades/Shoot	6 n=5	5 n=22	5 n=27
Mean Length Shortest Intact Blade (cm)	4.8+ n=5	11.1+3.5 n=19	9.4+3.55 n=20
Mean Length Longest Intact Blade (cm)	15.6+4.62 n=5	17.7+2.88 n=15	17.2+3.49 n=20
Mean Width Longest Intact Blade (cm)	0.20+0.008 n=5	0.18+0.030 n=21	0.18+0.03 n=26
Mean Blade Surface Area (cm ²)/0.25m ² Quadrat	1126	8942	5034

The leaves of the Z. marina shoots collected in the twelve representative quadrat samples chosen for detailed examination in this study had a mean width of 0.69 cm. The mean length of the longest intact blade per shoot varied with shoot density. (See Tables 17, 18 & 19.) The longest intact blades occurred in the mid density quadrats where the blades had a mean length of 149.6 ± 24.70 cm (n=18). In the four quadrats with low shoot density the mean length of the longest intact blade per shoot was 124.2 ± 28.6 cm (n=11) and in the four quadrats with high shoot density the mean length of this blade was 113.8 ± 42.10 cm. (n=41). There was an average of five leaves per shoot.

Tables 20, 21 and 22 show the relationship between the number of taxa, individual organisms and eelgrass shoot density of Z. marina. Approximately the same number of epifaunal taxa were described in each of the three shoot densities of Z. marina; a mean of twelve taxa were described in the mid and high shoot density samples and a mean of eleven taxa were described in the low shoot density samples. The number of individual organisms present on the eelgrass increased with shoot density. However the number of organisms present on the eelgrass, with respect to total blade surface area per quadrat, was much greater in the low shoot density samples than it was in the mid and high shoot density samples. Table 22 shows the mean number of individuals counted from each shoot density with respect to both total quadrat surface area and plant surface area. Figure 7 illustrates the comparison between the number of organisms/cm² plant surface area and the number of organisms/0.25m² quadrat sample.

The Z. marina plants examined in this study supported a greater number of both epifaunal taxa and individual organisms than did the Z. americana plants. The Z. marina blades from the low shoot density quadrats supported approximately seventeen times more organisms than those of the low shoot density Z. americana. Similarly, the high density Z. marina shoots supported almost one hundred times more organisms than did the high density Z. americana shoots (See Tables 20, 21 and 22.)

TABLE 16.

COUNTS OF EPIFAUNA REMOVED FROM
EELGRASS (Zostera americana) IN
LOW SHOOT DENSITY (<176 shoots/
0.25m²) AND IN HIGH SHOOT DENSITY
(>176 shoots/0.25m²) SAMPLES
COLLECTED ON ROBERTS BANK,
JULY 28 - 31, 1981.

Faunal Divisions adopted from
Smith et al., 1975.

TAXA	SHOOT DENSITY	
	LOW	HIGH
HYDROIDA	Present	Present
NEMATODA	48	1040
POLYCHAETA	0	0
OSTRACODA	24	0
HARPACTICOIDA	1744	8408
CYCLOPOIDA	0	0
CALANOIDA	72	208
COPEPODA LARVAE	80	0
CUMACEA	0	0
AMPHIPODA	952	192
ISOPODA	0	16
TANAIDACEA	32	8
PYCNOGONIDA	0	0
HALICARIDAE	16	0
MESOGASTROPODA	8	0
GASTROPODA EGG MASSES	0	0
CEPHALASPIDEA EGG MASSES	0	8
BIVALVIA	0	48
ECTOPROCTA	-	-
UNIDENTIFIED LARVAE	0	0
TOTAL	2976	9928

TABLE 17.

AERIAL DIMENSIONS OF EELGRASS
(*Zostera marina*) PLANTS IN THE
FOUR LOW SHOOT DENSITY (0 - 24
shoots/0.25m²) QUADRATS COLLECTED
ON ROBERTS BANK, JULY 28 - 31, 1981.

DIMENSIONS	QUADRAT #				OVERALL MEAN
	9	15	50	34	
# Shoots/0.25m ²	20	13	21	13	17
Mean # Blades/ Shoot	4 n=2	5 n=2	4 n=2	3 n=5	5 n=11
Mean Length Shortest Intact Blade (cm)	71.5+8.0 n=2	67.3+11.25 n=2	65.5+6.00 n=2	84.7+25.0 n=5	72.3+8.67 n=11
Mean Length Longest Intact Blade (cm)	147.0+3.0 n=2	110.5+2.5 n=2	126.5+11.5 n=2	119.7+37.9 n=5	124.2+28.6 n=11
Mean Width Longest Intact Blade (cm)	0.70+0.05 n=2	0.63+0.08 n=2	0.70+0.00 n=2	0.69+0.12 n=5	0.68+0.09 n=11
Mean Blade Surface Area (cm ²) 0.25m ²	12236	7223	11290	5500	9062

DIMENSIONS	QUADRAT #				OVERALL MEAN
	8	33	41	48	
# Shoots/0.25m ²	42	29	46	33	38
Mean # Blades/ Shoot	4 n=4	5 n=3	5 n=6	5 n=5	5 n=15
Mean Length Shortest Intact Blade (cm)	65.7+23.4 n=3	43.4+13.2 n=2	78.4+21.6 n=3	58.5+12.2 n=2	61.6+14.6 n=10
Mean Length Longest Intact Blade (cm)	142.4+23.2 n=4	163.2+9.3 n=3	158.3+22.3 n=6	136.9+24.5 n=5	149.6+24.7 n=18
Mean Width Longest Intact Blade (cm)	0.55+0.08 n=4	0.80+0.002 n=3	0.78+0.08 n=6	0.79+0.13 n=5	0.73+0.13 n=18
Mean Blade Surface Area (cm ²) <hr/> 0.25m ²	19228	23966	42464	25509	27792

TABLE 19.

AERIAL DIMENSIONS OF EELGRASS
(*Zostera marina*) PLANTS IN THE
FOUR HIGH SHOOT DENSITY (48
shoots/0.25m²) QUADRATS COLLECTED
ON ROBERTS BANK, JULY 28 - 31, 1981.

DIMENSIONS	QUADRAT #				OVERALL MEAN
	5	32	35	57	
# Shoots/0.025m ²	85	50	54	58	62
Mean # Blades/Shoot	5 n=10	4 n=8	5 n=5	5 n=9	5 n=31
Mean Length Shortest Intact Blade (cm)	46.2+24.8 n=17	31.2+13.6 n=5	68.1+23.6 n=2	54.3+37.2 n=5	49.9+15.42 n=27
Mean Length Longest Intact Blade (cm)	84.2+24.8 n=21	106.6+15.4 n=7	178.0+21.1 n=5	143.1+40.5 n=9	113.8+42.1 n=41
Mean Length Shortest Intact Blade (cm)	0.58+0.13	0.71+0.09	0.70+0.09	0.64+0.13	0.64+0.12
Mean Blade Surface Area (cm ²) 0.25m ²	32144	19568	46513	36637	33716

TABLE 20.

COUNTS OF EPIFAUNA REMOVED FROM
EELGRASS (Zostera marina) IN LOW
SHOOT DENSITY (0 - 24 shoots/0.25m²)
QUADRATS COLLECTED ON ROBERTS BANK,
JULY 28 - 31, 1981.

Faunal Divisions adopted from Smith
et al., 1975.

TAXA	QUADRAT #			
	9	15	50	34
HYDROIDA	Present	Present	Present	Present
NEMATODA	69667	60734	30250	47484
POLYCHAETA	267	33	33	933
OSTRACODA	1867	0	1067	700
HARPACTICOIDA	87667	29967	44867	60234
CYCLOPOIDA	0	0	0	383
CALANOIDA	0	100	0	117
COPEPODA LARVAE	92934	78667	24567	26584
CUMACEA	800	0	0	0
AMPHIPODA	133	0	100	767
ISOPODA	0	67	67	300
TANAIDACEA	0	0	0	0
PYCNOGONIDA	0	0	0	0
HALICARIDAE	1067	33	0	0
MESOGASTROPODA	0	0	167	250
GASTROPODA EGG MASSES	0	10800	0	1783
CEPHALASPIDEA EGG MASSES	0	0	0	0
BIVALVIA	0	367	83	450
ECTOPROCTA	-	-	-	Present
UNIDENTIFIED LARVAE	0	0	0	0
TOTAL	254402	180768	101201	139885

TABLE 21.

COUNTS OF EPIFAUNA REMOVED FROM
EELGRASS (Zostera marina) IN MID
SHOOT DENSITY (25 - 48 shoots/
0.25m²) QUADRATS COLLECTED ON
ROBERT'S BANK, JULY 28 - 31, 1981.

Faunal Divisions adopted from Smith
et al., 1975.

TAXA	QUADRAT #			
	8	33	41	48
HYDROIDA	Present	Present	Present	Present
NEMATODA	77,534	57,100	33,034	59,700
POLYCHAETA	933	33	1,333	667
OSTRACODA	533	267	1,700	533
HARPACTICOIDA	297,002	55,934	77,267	69,801
CYCLOPOIDA	0	0	800	0
CALANOIDA	67	267	0	0
COPEPODA LARVAE	not counted	37,667	9,267	12,600
CUMACEA	67	0	0	0
AMPHIPODA	1,667	167	1,100	1,033
ISOPODA	0	133	367	200
TANAIDACEA	0	0	0	0
PYCNOGONIDA	0	0	267	333
HALICARIDAE	1,067	0	267	267
MESOGASTROPODA	0	167	0	100
GASTROPODA EGG MASSES	0	0	0	0
CEPHALISPIDEA EGG MASSES	0	0	0	0
BIVALVIA	800	733	1,867	2,033
ECTOPROCTA	-	Present	Present	Present
UNIDENTIFIED LARVAE	1,600	0	0	0
TOTAL	381,270	152,468	127,268	147,267

TABLE 22.

COUNTS OF EPIFAUNA REMOVED FROM
EELGRASS (Zostera marina) IN HIGH
SHOOT DENSITY (48 shoots/0.25m²)
QUADRATS COLLECTED ON ROBERTS
BANK, JULY 28 - 31, 1981.

Faunal Divisions adopted from Smith
et al., 1975.

TAXA	QUADRAT #			
	5	32	35	57
HYDROIDA	Present	Present	Present	Present
NEMATODA	47232	151267	184535	102067
POLYCHAETA	384	133	21000	867
OSTRACODA	4224	800	3467	4800
HARPACTICOIDA	164480	89067	166668	115334
CYCLOPOIDA	0	0	0	267
CALANOIDA	0	533	0	533
COPEPODA LARVAE	46976	35733	9333	8333
CUMACEA	256	0	0	0
AMPHIPODA	1152	600	800	1000
ISOPODA	0	267	1867	333
TANAIDACEA	0	0	0	0
PYCNOGONIDA	0	0	133	733
HALICARIDAE	256	0	933	1867
MESOGASTROPODA	0	200	267	333
GASTROPODA EGG MASSES	0	0	0	0
CEPHALISPIDEA EGG MASSES	0	0	0	0
BICALVIA	4736	133	0	3333
ECTOPROCTA	-	Present	Present	-
UNIDENTIFIED LARVAE	0	0	0	0
TOTAL	269696	287733	370003	239800

TABLE 23.

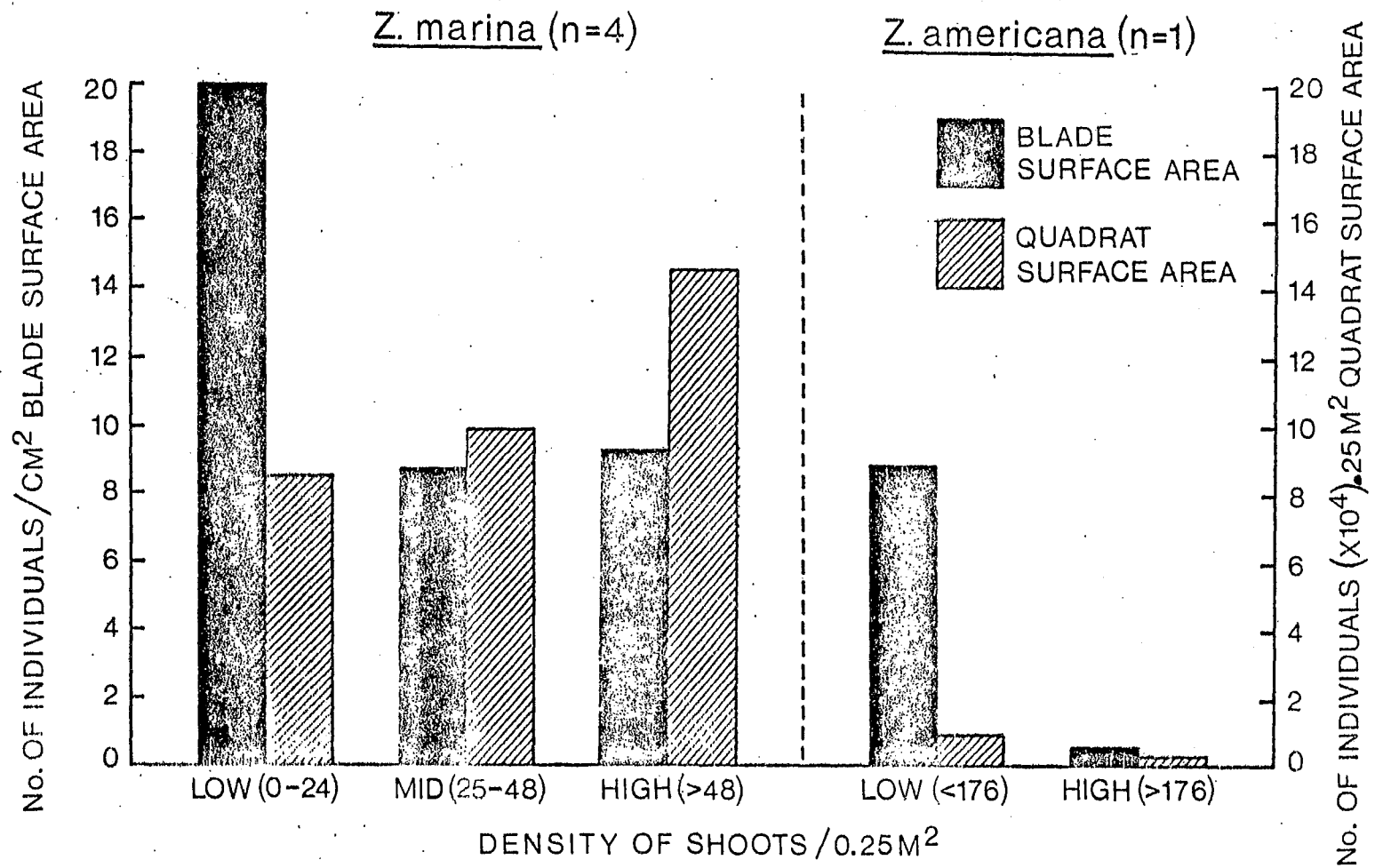
MEAN NUMBER OF EPIFAUNAL ORGANISMS/CM²
EELGRASS BLADE SURFACE AREA AND MEAN
NUMBER OF EPIFAUNAL ORGANISMS/0.25M²
AT VARYING SHOOT DENSITIES (Zostera
americana and Z. marina).

Eelgrass shoots collected on Roberts
Bank, July 28 - 31, 1981.

SHOOT DENSITY	MEAN NO. OF INDIVIDUALS /cm ²	MEAN NO. OF INDIVIDUALS /0.25m ²
<p>A. <u>Zostera americana</u> n=1</p> <p>LOW (<176 shoots) 0.25m²</p> <p>HIGH (>176 shoots) 0.25m²</p>	<p>8.8</p> <p>0.33</p>	<p>9,920</p> <p>2,976</p>
<p>B. <u>Zostera marina</u> n=4</p> <p>LOW (0 -24 shoots) 0.25m²</p> <p>MID (25-48 shoots) 0.25m²</p> <p>HIGH (>48 shoots) 0.25m²</p>	<p>20.0 (±6.63)</p> <p>8.7 (±6.52)</p> <p>9.3 (±2.97)</p>	<p>169,064 (±56,737)</p> <p>202,068 (±103,889)</p> <p>289,558 (±48,628)</p>

FIGURE 7.

THE RELATIONSHIP BETWEEN THE DENSITY OF EPIFAUNA AND TOTAL BLADE SURFACE AREA (cm^2) AND QUADRAT SURFACE AREA (0.25m^2) AT LOW, MEDIUM AND HIGH SHOOT DENSITIES OF EELGRASS (Zostera americana and Z. marina).



Many types of organisms, including polychaetes, cyclopoids, cumaceans, pycnogonids and bryozoans, were observed in the Z. marinas samples but not in the Z. americana samples. It is possible that many of these organisms would have been found on the Z. americana plants if a larger number of quadrats containing these plants had been examined.

Several other species of macroinvertebrates, not collected in this study were abundant in the eelgrass beds during the week in which our field collection took place. These animals included the sea star, Pisaster ochraceus, kelp crabs (Pugettia spp.), shrimps, and the nudibranch, Hermisenda crassicornis. In addition to these animals, the cephalispideans, Aglaja diomedea and Haminoea vesicula, and their egg masses (those of the latter species present in great abundance) were observed throughout the eelgrass beds.

DISCUSSION

A. Rocky Shore Intertidal and Subtidal Transects

Variations in the physical and biological parameters at each rocky shore station have some degree of influence on the types of species present on the coal port perimeter. Run off from the Fraser River results in fresh/salt water mixing producing lower salinities in the estuary than open ocean water. Although many Littorina scutulata were collected, only a few L. sitkana were ever observed intertidally. L. scutulata appears to have a higher tolerance to reduced salinities than does L. sitkana (Ricketts et al., 1968). The instability of the cobble substrate of station 1 does not provide a suitable substrate for attachment of algae. The absence of algal species reduces competition for primary space (Dayton, 1971). This situation, as well as the complete absence of associated predators, may be the reason barnacles were most abundant at this location. Conversely large numbers of Pisaster ochraceus were present in the vicinity of station 2, and although they prefer to prey on Mytilus edulis, if these are not available they will opt for barnacles (Ricketts, et al., 1968). This factor and the abundance of algal species competing for space at this site may explain the lower invertebrate values of station 2 in comparison to station 1.

Large numbers of Nucella lamellosa were present only in the lower intertidal zone of station 3. These carnivorous gastropods feed on a number of species, including barnacles (Carefoot, 1977) which conceivably could have affected invertebrate biomass values. Pagurus hirsutiusculus occurs frequently at this station which is interesting to note since larger individuals of these hermit crabs are said to prefer the shells of Nucella species (Kozloff, 1973). The abundance of M. edulis at this location may reflect the absence of P. ochraceus and reduced competition with algae for available surface area.

Although studies have been done on biomass and biomass/productivity ratios in the intertidal (Allen, 1971; Banse, 1980; Batzli, 1969; Burke, et al., 1974) few have produced data which

relate to the species considered in this study. Batzili's (1969) figures on biomass distribution in the rocky intertidal of the San Juan Islands are comparable with our results for L. scutulata, N. lamellosa and Acmaea pelta. Further, Batzli found in his study (1969) that community biomass was divided among a few dominants. In all the quadrats sampled for invertebrates and algae in the present study a minimum of 70% of total quad biomass was contributed by three or fewer species.

Rip rap and sand/cobble act as artificial production units which favor the growth of macroalgae which do not normally grow on sandflats (Pomeroy & Levings, 1980). The rich and diverse subtidal algal growth surrounding the coal port is dependent upon the substrate introduced by the port's construction (see Appendix 1).

When the current expansion is completed the perimeter of the Westshore terminal facility will have increased from 11.12 km to 12.25 km (Tuttle, 1982, Personal Communication). Approximately 3.89 km of the new figure is retained perimeter (the vicinity of station 2) and the shoreline there will be relatively unchanged. The remaining 8.36 km will be new rip rap shoreline which will have potential for invertebrate and algal colonization. Station 2 represents the type of community expected to develop on the introduced rip rap, and data from this site was used to calculate predicted standing crop values.

The beach width from highest high water (large tides) mark to datum for station 2 is taken to be 12 metres. Pomeroy and Levings (1980) describe the dimensions of rip rap to be approximately 1.2 m on each side but only an estimated 3.39m^2 is actually presented. Accounting for a space loss factor between blocks of $6400\text{ m}^2/\text{km}$ (Levings 1982, Pers. comm.) a 1.0 km shore, 12 metres in width, presents $21,850\text{ m}^2$. Using these figures, new rip rap shoreline at the coal port presents a total of approximately $182,666\text{ m}^2$.

It is necessary now to compute the invertebrate/algae biomass of one square meter of Station 2 in order to arrive at the projected standing crop values for the new shoreline. One method of determining biomass for the new shore area involves totalling the invertebrate/algae biomass of all five quadrats and calculating the respective mean values for an area of one meter. These figures are then multiplied by 182,666 m² to give the standing crop values.

<u>Invertebrates:</u>	Mean Biomass	= 9.73g ash free dry wt./0.25m ²
	Station 2	x 4 = 38.92g a.f.d.w./m ²
		38.92g a.f.d.w./m ² x 182,666m ²
		(total area presented)
		= <u>7109kg ash free dry wt./8.36km</u>
		new shoreline

<u>Algae:</u>	Mean Biomass	= 18.34g dry wt./0.25m ² x 4 =
	Station 2	73.36g dry wt./m ²
		73.36g dry wt./m ² x 182,666m ²
		(total area presented)
		= <u>13,400kg dry wt./8.36km</u>
		new shoreline

The second method involves calculating invertebrate/algae biomass over a meter section of beach twelve meters in width, that is the distance between low water and high water. The biomass values of the five quadrats are totalled. As they only account for 1.25m of beach they must be expanded to 12.0 meters by multiplying by 9.6. This results in a figure indicating the grams of biomass for a 1.0 meter section of shore perimeter. There are 8360 meters of perimeter in total, so the numbers derived by the previous step are increased again by a factor of 8360. This results in predicted standing crop values via method 2.

Invertebrates: Mean Biomass = 48.65 g ash free dry wt./1.25m²
Station 2

48.65 g a.f.d.w./1.25m² x 9.6 = 467.0 g a.f.d.w.
1.0 m strip of beach
12 meters wide

467.0 g a.f.d.w./1.0m x 8360m new shoreline
= 3904 kg ash free dry wt./8.36 km new shoreline

Algae : Mean Biomass = 91.70 g dry wt./1.25m²
Station 2

91.70 g d.w./1.25m² x 9.6 = 880.3 g d.w.
1.0 meter strip of beach
12 meters wide

880.3 g d.w./1.0m x 8360m new shoreline
= 7359 g dry wt./8.36km new shoreline

Barnacles are the dominant species in the intertidal accounting for as much as 64% of the predicted invertebrate standing crop. As energy flows determined for B. glandula are among the highest recorded for equilibrium animal populations (Wu et al., 1979), the barnacles could be expected to be a major influence on productivity of the new shoreline. Barnacles channel large amounts of energy each year into the production of larvae (Wu et al., 1978). Rosenthal and Hempel (1970) (cited in Barnes, 1977) suggest the importance of these larvae as a food source for juvenile herring. This is particularly relevant to Roberts Bank because the eelgrass beds near the coal port are used extensively by herring as spawning substrate (Environmental Assessment Panel, 1979). The high lipid content of barnacle larvae has also been shown to be important for the timing of metamorphosis in certain fish larvae (Barnes, 1977). Not only do the larvae form a considerable portion of the zooplankton but they are constant in their relative abundance (Bainbridge et al., 1971 cited in Barnes, 1977).

Many species exhibit seasonal fluctuations in biomass (Wu et al., 1978,1979; Batzli, 1969). This factor was not incorporated into the results of this study as transects were sampled on one occasion only. More accurate estimates would require sampling over a minimum of one year. Also estimates of invertebrate standing crop are somewhat conservative as the Hemigrapsus species, which were abundant at Station 2, were not included. Finally, the predicted standing crop values cannot be viewed in isolation but should be examined in conjunction with losses of standing crop occurring in the sand/mud and eelgrass habitats as a result of the current dredging and landfill operations.

B. Recolonization

The dominant life form present on the recolonization site during the period from July to December, was an algal mat consisting predominately of Enteromorpha intestinalis and E. linza. This algal mat supported a large number of other organisms including limpets, gastropods, chitons, amphipods, copepods and chironomid larvae. (See Appendix 4.) Perhaps the only organisms present on the rock face which did not benefit from the association with this algal mat were the barnacles, Balanus glandula and Chthamalus dalli. Barnacles and algae must compete for primary settlement and growing sites on the surface of hard intertidal substrates (Dayton, 1971), and consequently the presence of a dense algal mat may have inhibited barnacle recruitment at the site.

The two Enteromorpha species dominated the original biotic community of the rock face on which the recolonization site was located and these plants quickly reestablished themselves after the site had been cleared. By the first week of August, they again dominated the rock's biotic community, by occupying 60% of the site's surface. (See Table 12). The decline in algal percent cover which began in October may have been associated with a natural seasonal dieback, or may have occurred as a result of increased water

turbidity caused by the coal port expansion's dredging operations. Although no depositions of the fine dredge sediment were ever observed on the recolonization site itself, large deposits, up to six centimeters deep, were found at the bases of adjacent boulders in October, November and December. It appears, from this study, that both species of Enteromorpha are relatively resilient and so could be expected to readily colonize the new rock substrates introduced by the coal port expansion.

A large settlement of barnacles (B. glandula and C. dalli) took place in September, 1981. Preliminary population estimates of 1500 and 250 barnacles/m², (respectively), were made on September 11th, on the basis of counts recorded from several randomly placed 0.01m² quadrats within the recolonization site. (See Table 12; Appendix 4). Later counts revealed that these preliminary estimates were not large enough. The subsequent increases in barnacle population estimates were probably not due to further barnacle settlements, for a 0.01m² area cleared in the center of the site on September 24th, did not gain any new barnacle recruits until early November. (See Appendix 4). Similarly, the information gathered when the single 0.01m² quadrat was cleared on September 24, resulted in a much larger population estimate of barnacles than was later determined for the site. It was very difficult, without performing large scale destructive sampling within the recolonization site to accurately count the tiny, newly settled barnacles in September, when Enteromorpha covered 90% of the site. As the barnacles grew and the algal mat receded, it became easier to count animals within the randomly selected quadrats. The transient limpet population, present on the site could have been expected to limit the success of barnacle settlement by eating, pushing or dislodging the cyprid or newly metamorphosed barnacle recruits (Dayton, 1971); however the December 10th counts (See Table 12) probably reflect the most accurate estimates of the barnacle population because at that time only a small amount of the rock surface was still covered with Enteromorpha.

In December, the biomass of barnacles collected in five randomly selected 0.01m^2 quadrats was determined. (See Table 14). The biomass of C. dalli was calculated to be 0.250g ash free weight/ 0.25m^2 and that of B. glandula was calculated to be 0.602g ash free weight/ 0.25m^2 . These values are considerably lower than the values determined for barnacle populations at a similar tidal height in the Station 2 intertidal transect in August, 1981. The biomass of C. dalli and B. glandula at a tidal elevation of 1.92m at that time, was 0.734g ash free weight/ 0.25m^2 and 1.228g ash free weight/ 0.25m^2 , respectively. This probably indicates that a longer period of time is required for barnacles to fully establish themselves on the new rip rap surfaces. It may also indicate that the presence of Enteromorpha on over 90% of the rock surface at the time of barnacle settlement did interfere with the success of that recruitment.

The only algal species present on the surface of the recolonization site before it was cleared which returned during the period in which the rock was monitored was Ulothrix flacca. Other algal species originally present included Gigartina papillata, Polysiphonia pacifica and Monostroma sp. (See Appendix 4). These algae had not returned to the site by December. It is possible that recruitment of these species is more strictly seasonal than is that of the two Enteromorpha species and Ulothrix flacca. New species of algae such as Blidingia minima var subsalsa, a common inhabitant of estuaries and brackish water (Abbott et al., 1976) and Porphyra sp. were observed for the first time at the site in September.

Highly mobile, transient animals such as the rock crabs, Hemigrapsus nudus and H. oregonensis, and the hermit crab, Pagurus hirsutiusculus, were frequently observed on the recolonization site throughout the monitored period.

Although the monitoring project was terminated just as

the percent cover of the Enteromorpha mat, and consequently, the population of invertebrates associated with it, had drastically declined it is probable that this was only the result of the short-term disruption of the site due to seasonal dieback and increased water turbidity and sediment load caused by the nearby dredging operations. The diversity of animals and algae present in the intertidal transect sampled at this station was relatively high, and many of the species of organisms observed in the intertidal transect were eventually found on the recolonization site. We conclude that the new rip rap surfaces introduced by the coal port expansion will be readily colonized, provided that adjacent populations can supply sufficient recruits to the new area. This colonization may be expected to take at least six to eight months, depending on the season in which the new substrate becomes available. Invertebrate larvae, such as barnacle cyprids, undergo two large settlements each year. The largest or primary settlement occurs in April or May while the smaller secondary settlement occurs in September. (Wu et al., 1978, 1979). If the substrate became available in October, after the secondary settlement had occurred no invertebrates would be expected to settle until the spring. It may take longer than 8 months for the biotic communities present on the new substrates to achieve the level of productivity observed in the intertidal communities on the coal port's shores prior to the terminal's expansion.

C. The Relationship Between Shoot Density of *Zostera marina* and *Z. americana* and Epifaunal Density at Roberts Bank, July, 1981.

Zostera marina is the dominant eelgrass species of the world's northern temperate coastal zones and supports a wide variety of other organisms including birds, fish, invertebrates and algae (Phillips, 1969). *Z. marina*'s high growth rate results in the production of an average of 300-600 g dry weight/m²/year (Thayer et al., 1975). Phillips (1974) found that *Z. marina* growing in Puget Sound, Washington produces an average of 581g dry weight/m²/year. This high growth rate places the eelgrass ecosystem among

the world's most biologically productive systems (Thayer et al., 1975).

Eelgrass systems are very complex communities with a great deal of inherent spatial heterogeneity and consequently, provide a wide selection of microhabitats for a variety of specialized organisms. The plants provide shelter and prime feeding and spawning habitat for many species of fish and invertebrates (Kikuchi, 1980). The rhizomes, stems and leaves provide a large substrate surface area for the attachment of epiphytic algae and invertebrates whose total biomass may often be as great as that of the eelgrass plants themselves (Thayer et al., 1975). Dense populations of epifaunal organisms were found on the eelgrass plants examined in the present study.

The epifaunal populations of two species of eelgrass (Zostera marina and Z. americana) were examined in this study. Although only one representative sample from each of the high and low shoot density quadrats of Z. americana was examined during this study it was clear that these plants supported far fewer epifaunal organisms than did the Z. marina plants. The relative blade surface areas of the two species of Zostera may partially account for the distribution of epifauna. More likely however, the difference in the density of epifauna is related to the location of the Z. americana plants in the high intertidal zone, the season in which the plants were collected and the physical condition of the blades. Burt (1979), in his study at Boundary Bay, found that the biomass of Z. americana epiphytes (attached algae) peaked in early June when these plants were subjected to higher air temperatures and increased desiccation during daily exposure periods. He also suggested that the peak in epiphytic biomass might be related to large growth increases in the host plants. The samples examined in the present study were collected in late July on days in which the weather was very warm (25°C) and sunny. It is possible that the conditions of increased desiccation

experienced in the high intertidal zone during that time had resulted in a decrease in the epifaunal population.

The low shoot density sample of Z. americana was collected at a slightly lower tidal height than was the high density sample. Since the former sample contained more than three times as many epifaunal organisms on a leaf area basis (see Table 23), this may indicate that desiccation was an important limiting factor in their distribution. No real conclusions can be made however, on the basis of two samples.

Unlike the Z. americana plants, most of the Z. marina plants collected in this study were densely covered with hydroids, bryozoans, diatoms and epiphytic algae. Epifaunal density/ 0.25m^2 increased with shoot density and ranged from a mean of 169,064 to 289,558 organisms. (See Table 23).

Burt (1979) noted that epiphytic biomass of Z. marina plants peaked in mid-August in 1978 and so it is likely that the collection made in the present study also represents an annual peak in epifaunal biomass. The conditions which make the epiphytic bloom possible could also be expected to enhance the growth of epifaunal organisms. Burt also found that the timing of the peak in epiphytic biomass was related to the tidal height of the host plant. The peak occurred later in the season for epiphytes growing on low intertidal plants than it did for those growing on high intertidal plants. Burt attributed the timing of this shift to a desiccation gradient. Although no tidal heights were measured in the present study it may be possible to relate shoot density to tidal elevation. Moody (1975), in his study on southern Roberts Bank, found that the lowest tidal elevations had the lowest eelgrass shoot densities ($40\text{ shoots}/\text{m}^2$). Middle elevations had shoot densities ranging from $67 - 77\text{ shoots}/\text{m}^2$ and the highest elevations had intermediate shoot densities ($53\text{ shoots}/\text{m}^2$). Although the relative shoot densities were greater

than these values in the present study (see Tables 17, 18 and 19) it is probable that shoot densities are also dependent on tidal height in the Roberts Bank intercauseway area, in which case a desiccation gradient could partially account for the density of epifaunal populations. However, since sampling was done only once during the summer season it is difficult to assess any pattern of epifaunal distribution over time using the results of the present study.

Very few studies have been made in which the epifauna of eelgrass has been enumerated. Marsh (1971) reported that the dominant epifaunal taxa identified in his study of the Z. marina beds of the York River, Virginia were Gastropoda (43.2% of the fauna), Amphipoda (18.5%), Isopoda (16.7%) and Polychaeta (15.6%). However, Marsh used a 0.5mm sieve to catch the organisms that were washed from the surfaces of the eelgrass blades and he did not count organisms such as nematodes. In the present study a 0.125mm sieve was used to capture the organisms washed from the eelgrass blades and organisms such as nematodes and copepod larvae were counted because it was felt that these organisms were important constituents of the epifauna. The dominant taxa found on Z. marina included Harpacticoida (46.8% of the fauna), Nematoda (33.5%) and copepod larvae (18.5%). (See Tables 17, 18 and 19). Marsh (1971) also noted that while dominant epifaunal species could be expected to be present year-round in densities which varied with the season and the condition of the host plants, certain other species peaked sharply in abundance during brief periods and then disappeared. It may be assumed from this result that the list of epifaunal taxa compiled in the present study may be incomplete.

Previous studies have examined the structure of infaunal populations in eelgrass beds, and it is likely that there is a close relationship between the densities of infaunal and epifaunal populations (Marsh, 1971). Orth (1971) found infaunal densities ranging from 2347 to 32,907 organisms/m² in Z. marina beds in the Chesapeake Bay - York River estuary. The epifaunal densities deter-

mined in the present study are much greater than these values (See Table 23) and may reflect differences in sampling methods and in hydrographic conditions. Orth (1971) noted in his study that infaunal densities increased with eelgrass shoot density. A similar relationship between epifaunal densities eelgrass shoot density was observed in the present study.

In a study done on the infaunal populations of the Nanaimo estuary, Sibert (1979) reported that nematodes, harpacticoid copepods and crustacean larvae were the most numerically dominant taxa collected. Other, less abundant taxa included micro-annelids, amphipods, cumaceans and ostracods. Nematodes, harpacticoids and copepod larvae were also the most abundant constituents of the eelgrass epifauna in the present study. (See Tables 16, 20, 21 and 22). Annelids, amphipods, cumaceans and ostracods were also observed.

Bawden and her associates (1973) reported that nematodes and harpacticoids were also among the most numerically abundant meiofaunal organisms present in the sediments of Roberts and Sturgeon Banks.

In the present study, when the total plant surface area of Z. marina per sampling quadrat (0.25m^2) at each shoot density was calculated (See Tables 20, 21 and 22), we found that the concentration of epifaunal organisms was approximately twice as great in the low density quadrats as it was in the other two shoot densities. Burt (1979) suggested that the epiphytic populations of Z. marina may bloom during periods when the eelgrass is undergoing a decline, perhaps as a result of increased detrital concentrations on the blade surfaces or as a result of other types of chemical exudates released by the host plants. It is possible that the low density plants were undergoing a faster rate of decline than were the mid or high density plants, both of which supported approximately the same number of organisms/ cm^2 of blade surface. However,

the physical condition of the blades in the representative samples examined here did not vary significantly among shoot densities. In fact, the percentage of intact blades present in the high and low shoot density categories was approximately the same.

The information presented in this study indicates a relationship between eelgrass shoot density and epifaunal density which should be considered during future eelgrass transplantation projects in the Roberts Bank area. Since epifaunal populations appear to reach maximum numbers in areas of mid to high shoot density, it is suggested that the eelgrass be transplanted with these data in mind. Certain epifaunal constituents, such as harpacticoids, are important food items in the diet of juvenile salmon (Sibert, 1979). These fish are residents of the Roberts Bank intercauseway area and eelgrass beds throughout the spring and summer months (Greer et al., 1979).

In order to gain a more complete understanding of the epifaunal community of the eelgrass ecosystem on Roberts Bank it would be necessary to sample epifaunal populations at shoot densities of known tidal heights over at least a one year period. It would also be informative to make simultaneous collections of epifauna and infauna in the eelgrass beds.

SUMMARY

A. Rocky Shore Intertidal and Subtidal Transects

A single intertidal transect was sampled at each of three stations located on the Roberts Bank coal port shore in August, 1981. Two subtidal transects through the kelp beds were sampled by divers at Station 2 on the seaward shore of the coal port on August 31, 1981.

Invertebrates and algae sampled in these transects were counted, identified and dried. The dry weights of algae and the ash free dry weights of invertebrates were used to determine biomass and standing crop values.

The perimeter of the pre-expansion shore was 11.12km. The perimeter of the post-expansion shore will be approximately 12.25 km. Based on data collected in the intertidal transect on the rip-rap shore of Station 2, pre-expansion and post-expansion standing crop values were estimated using two methods.

- Using the first method the pre-expansion invertebrate standing crop value was estimated to be 9,456 kilograms ash free dry weight. The post-expansion invertebrate standing crop value was predicted to be 10,417 kilograms ash free dry weight. This represents an increase in invertebrate standing crop of 961 kilograms ash free dry weight.
- Using the second method the pre-expansion invertebrate standing crop value was estimated to be 5,193 kilograms ash free dry weight. The post-expansion invertebrate standing crop value was predicted to be 5,721 kilograms ash free dry weight. This represents an increase in invertebrate standing crop value of 528 kilograms ash free dry weight.

- Using the first method the pre-expansion algal standing crop value was estimated to be 17,824 kilograms dry weight. The post-expansion algal standing crop value was predicted to be 19,636 kilograms dry weight. This represents an increase in algal standing crop value of 1,812 kilograms dry weight.

- Using the second method the pre-expansion algal standing crop value was estimated to be 9,789 kilograms dry weight. The post-expansion algal standing crop value was predicted to be 10,784 kilograms dry weight. This represents an increase in algal standing crop of 995 kilograms dry weight.

The mean density of Nereocystis leutkeana (Bull kelp) in the beds located on the coal port's seaward shore on August 31, 1981 was estimated to be 0.17 ± 0.08 plants/m².

B. Recolonization

A 1.0 meter² area cleared on the rip-rap of the coal port's seaward shore was monitored every two or three weeks for six months from July 22 to December 10, 1981.

A photographic record of the recolonization process was kept at each visit. Species counts and the percent cover of algae on the site were also recorded at each visit.

It was concluded that the colonization of the rip-rap shore made available by the coal port expansion could be expected to occur within six to eight months. The rate of colonization would be dependent on the season in which the new substrate became available and on the ability of nearby algae and invertebrate populations to supply recruits to the new area. It may take longer than eight months for the new biotic community to attain the level of productivity of the pre-expansion shore.

C. The Relationship Between Shoot Density of *Zostera marina* and *Z. americana* and Epifauna Density at Roberts Bank, July, 1981.

Z. americana and *Z. marina* were sampled in the intercauseway area of Roberts Bank on July 28-31, 1981. Plants were harvested in a total of six - 0.25m² quadrats and fifty-four - 0.06m² quadrats.

Z. americana was found growing in the high intertidal zone along the northern and western perimeters of the eelgrass beds. *Z. marina* were found throughout the intercauseway area at mid to low tidal elevations.

The mean density of *Z. marina* found in the sampled area was 34 shoots (± 14.7)/0.025m².

Areal dimensions of eelgrass blades were determined for use in examination of the relationship between blade surface area and epifaunal density. Although epifaunal density/blade surface area appeared to be greater in low shoot density, than it was in mid or high shoot densities, it was concluded that this was probably a seasonal effect.

The density of epifaunal organisms increased with eelgrass shoot density. It was concluded, on the basis of this observation, that eelgrass plants should be transplanted at shoot densities of at least 100 shoots/m². Epifaunal organisms such as certain species of harpacticoid copepods, which were found in large numbers on the eelgrass blades sampled in this study, are important constituents in the diet of juvenile salmonids which live in the Fraser River estuary during the spring and summer.

Z. americana supports fewer epifaunal organisms than does *Z. marina*. However, since *Z. americana* occupies a different

position in the beds (high intertidal) than Z. marina does, it is recommended that Z. americana also be included in future transplantation projects.

D. Sand/Mud "Grab" Samples

Five "Grab" samples were taken in the sand/mud habitat at Roberts Bank on August 24, 1981 at depths ranging from three to nine fathoms.

Three "Grab" samples were taken in the sand/mud habitat at Roberts Bank on September 31, 1981 at depths ranging from four to five fathoms.

The data collected on these sampling dates are part of an ongoing study to determine the amount of resource production associated with the sand/mud habitat before and after the current dredging operations are completed. This study will continue throughout the two year expansion period, and results will be presented at a later date.

A P P E N D I C E S

Archipelago Marine Research

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September 7, 1981

To: Cam McKenzie
National Harbours Board

Macroinvertebrate Survey and Macrophyte Inventory at the Robert's Bank Coal Terminal

On August 31, 1981 Archipelago Marine Research conducted a subtidal macroinvertebrate survey and macrophyte inventory along the southwest (seaward) rip-rap slope of the Robert's Bank coal terminal. Two transects were run perpendicular to the shoreline and a total of nineteen 1/4 meter quadrat samples taken for macroinvertebrate identification and biomass determination. In addition the standing crop of bull kelp (*Nereocystis luetkeana*) was surveyed and species lists constructed for fish and large conspicuous invertebrates.

The first transect was located below an existing, marked intertidal transect. The second transect was located approximately 150 m. southeast of the first location. This transect was staked and will be positioned accurately at a later date. In each case a sinking transect line, marked at one meter intervals, was positioned by divers perpendicular to the shoreline. The termination of any significant vegetation determined the deep end of the transect. The divers then swam the transect, noting substrate type, vegetation cover and any significant patterns of subtidal zonation. Quadrat sample locations were then determined randomly for each of the vegetation zones. Sampling was conducted by the divers handpicking all visible vegetation and invertebrates contained within a 1/4 square meter quadrat at each of the sample locations. The samples were placed in marked burlap bags and later delivered to the dive tender. The results are summarized in figures one and two.

The bull kelp (*Nereocystis*) inventory was conducted by a diver swimming on each side of the transect line, counting all macrophyte stipes within one meter of the transect line. For this purpose the diver carried a measured meter stick. Thus for each meter of transect length, two square meters were surveyed for *Nereocystis*. The results are also summarized in figures one and two. As *Nereocystis* is an annual plant which dies back in the fall, the densities reported here may be less than midsummer values. A number of old, senescent plants were observed, indicating that the bed had begun to die back. Also many of the plants were attached to small rocks and thus subject to waveborn transport in rough weather. Interestingly, a number of young plants were observed. This stage of development of *Nereocystis* is not usually seen in the Strait of Georgia until March.

After completion of the transect work the divers swam parallel to the shoreline, in both the rip-rap and sand/cobble zones, noting all fish species

observed as well as any large, conspicuous invertebrates which may not have been collected in the quadrat samples, From these notations and casual observations made during the transect work, a species list has been constructed and is included with this report.

Figure 1 Transect 1

Time: 10:30 PDT

Depth

3 ft.

Zone 1: Substrate consisted primarily of rip-rap boulders. Overall cover of vegetation on the bottom was approximately 80%, primarily red algae.
5 quadrat samples taken.
No Nereocystis plants counted.

15m.

11 ft.

Zone 2: Sand/cobble substrate (60/40) with occasional rocks and boulders. Vegetation cover 30-40%, primarily kelps (Nereocystis and Laminaria sp.) and red algae.
5 quadrat samples taken.
4 Nereocystis plants counted.
Nereocystis density - 0.13 plants/m².
Beyond zone 2 was sand substrate with no vegetation.

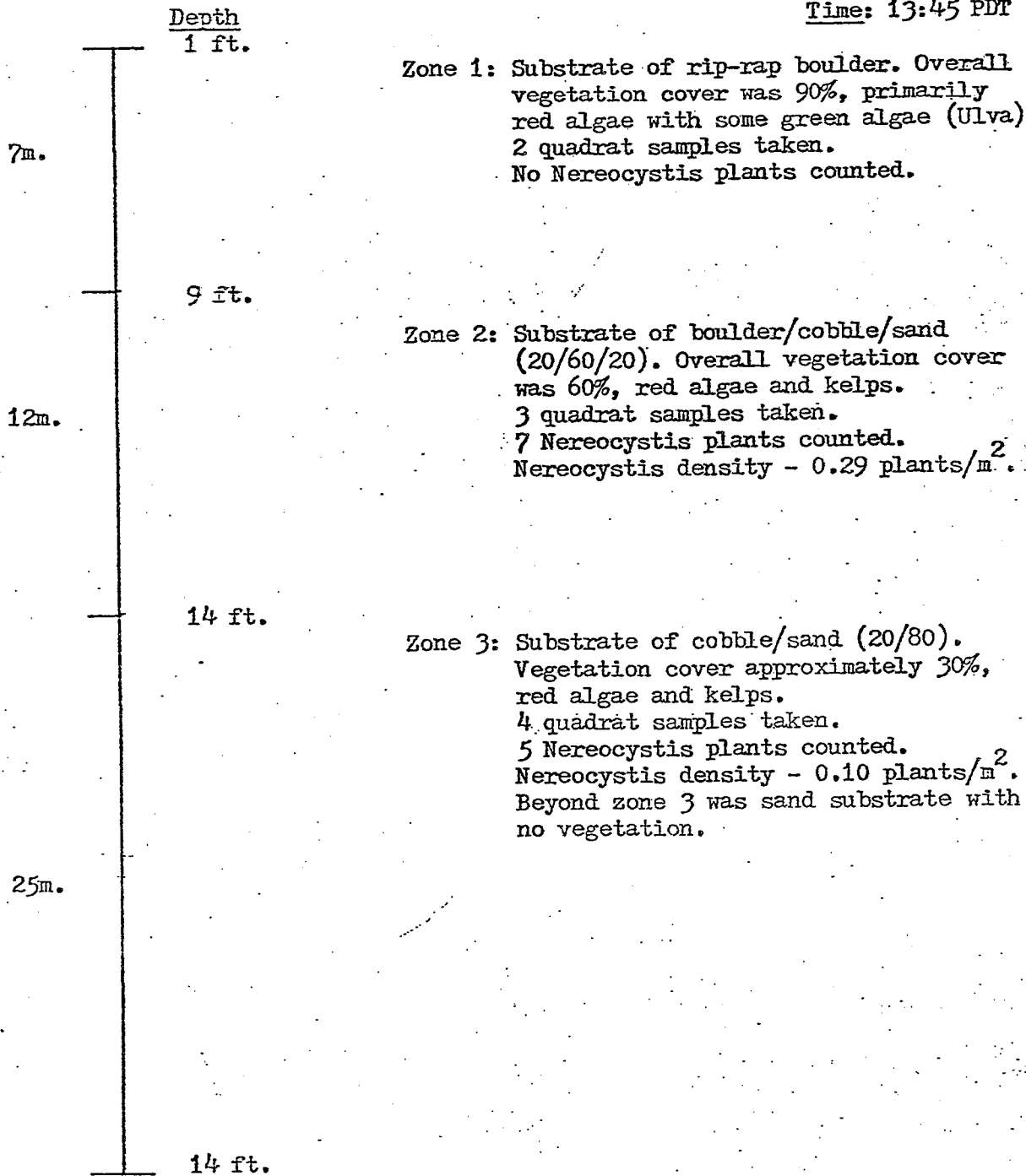
15m.

16 ft.

Total Transect Length - 30m.

Figure 2 Transect 2

Time: 13:45 PDT



Total Transect Length - 44m.

Fish and Large Invertebrate Species List

Robert's Bank Coal Terminal - August 31, 1981.

Rip - Rap Zone

Fish: Tubesnout - Aulhynchus flavidus
Striped Perch - Embiotoca lateralis
Pile Perch - Rhacochilus vacca
Lingcod - Ophiodon elongatus
Greenling - Hexagrammos sp.
~~Common~~ rockfish - Sebastes caurimus
uni. rockfish - Sebastes sp.
small sculpins (cottids)

Invertebrates: Burrowing cucumbers - Cucumaria miniata
Ochre star - Pisaster ochraceus
small limpets
small chitons
Rock crab - Cancer productus
yellow sponge

Sand/Cobble Zone

Fish: Striped Perch - Embiotoca lateralis
Lingcod - Ophiodon elongatus
Greenling - hexagrammos sp.
Rex sole - Glyptocephalus zachirus
Red Irish lord - Hemilepidotus hemilepidotus
flatfish (juveniles and subadults)
small sculpins (cottids)

Invertebrates: Sea pens - Ptilosarcus gurneyi
Horse clams - Tresus nuttalli
cucumber - Parastycopus californicus
Burrowing cucumber - Cucumaria miniata
Rock crab - Cancer productus
Dungeness crab - Cancer magister
Tube worms
Burrowing anemones

APPENDIX 2

MUSSEL SHELL LENGTH / DRY TISSUE WEIGHT

EQUATION

Mytilus edulis collected at Roberts Bank October 9, 1981

BASIC STATISTICS:

	X	Y
MEAN	14.925	0.036
VARIANCE	42.79	2.0×10^{-3}
STANDARD DEV.	6.541	0.049
STANDARD ERR.	0.198	0.00
DATA RANGES	4.94-39.5	1.0×10^{-3} - 0.326
SAMPLE SIZE	216	216

$$\text{Dry Tissue Weight} = A \times L^{2.76}$$

COEFFICIENTS:

$$A = 1.324244603 \times 10^{-5}$$

$$B = 2.76618712$$

$$R \text{ SQUARE} = 0.911792394$$

$$\text{STANDARD ERROR (Y/X)} = 0.0148238978$$

APPENDIX 3.

<u>Roberts Bank Development</u>	Material collected July - December, 1981
<u>Intertidal Marine Invertebrates and Algae</u>	
A. <u>Invertebrates</u>	
Phylum Porifera	
Class Demospongiae	<u>Halichondria panicea</u>
Phylum Cnidaria	
Class Hydrozoa	<u>Phialidium hemisphericum</u>
Phylum Nemertea	
Class Enopla	<u>Paranemertes peregrina</u>
Phylum Nematoda	Present
Phylum Annelida	
Class Polychaeta	<u>Armandia brevis</u> <u>Nereis vexillosa</u> Polynoidae spp.
Phylum Arthropoda	
Class Crustacea	
Subclass Cirripedia	<u>Balanus crenatus</u> <u>B. glandula</u> <u>Chthamalus dalli</u>
Subclass Copepoda	Calanoida spp. Cyclopoida spp. Harpacticoida spp.
Subclass Eucarida	<u>Hemigrapsus nudus</u> <u>H. oregonensis</u> <u>Pagurus hirsutiusculus</u>
Subclass Malacostraca	<u>Ampithoe lacertosa</u> <u>A. simulans</u> <u>A. valida</u>

	<u>Corophium acherusicum</u>
	<u>C. brevis</u>
	<u>C. insidiosum</u>
	<u>Gnorisphaeroma oregonensis</u>
	<u>Hyale frequens</u>
	<u>Idotea (Pentidotea) montereyensis</u>
	<u>I. wosnesenskii</u>
	<u>Synidotea bicuspidata</u>
Class Insecta	<u>Paraclunio</u> sp.
	Halicaridae spp.
Phylum Mollusca	
Class Bivalvia	
Subclass Heterodonta	<u>Protothaca staminea</u>
Subclass Pteriomorpha	<u>Crassostrea gigas</u>
	<u>Mytilus edulis</u>
Class Gastropoda	
Subclass Prosobranchia	<u>Barleeia halotiphila</u>
	<u>Collisella digitalis</u>
	<u>C. pelta</u>
	<u>Lacuna variegata</u> (?)
	<u>Lacuna</u> spp. (juveniles)
	<u>Eittorina scutulata</u>
	<u>L. sitkana</u>
	<u>Notoacmaea persona</u>
	<u>N. scutum</u>
	<u>Nucella lamellosa</u>
Class Polyplacophora	<u>Katharina tunicata</u>
Phylum Echinodermata	
Class Asteroidea	<u>Pisaster ochraceous</u>
Phylum Ectoprocta (Bryozoa)	
Class Gymnolaemata	<u>Membranipora villosa</u>
	<u>Tubulipora pacifica</u>

B. Algae

Division Chlorophyta

Blidingia minima var subsalsa

Enteromorpha intestinalis

E. linza

Monstroma sp.

Ulothrix flacca

Ulva fenestrata

Division Phaeophyta

Fucus gardneri

Division Rhodophyta

Callophyllis flabellulata

Cryptosiphonia woodii

Gigartina papillata

Iridaea cordata

I. heterocarpa

Odonthalia floccosa

Petrocoelis

Polysiphonia pacifica

Polysiphonia spp.

Porphyra perforata

P. smithii

Porphyra sp.

Pterisiphonia bipinnata

APPENDIX 4.

<u>Roberts Bank Development</u>	Material collected August 31, 1981
<u>Subtidal Marine Invertebrate and Algae</u>	
A. <u>Invertebrates</u>	
Phylum Porifera	
Class Demospongiae	<u>Haliclona permollis</u>
Phylum Cnidaria	
Class Hydrozoa	<u>Obelia</u> sp. <u>Thuiaria</u> sp.
Class Anthozoa	<u>Metridium</u> sp.
Phylum Nematoda	Present
Phylum Annelida	
Class Polychaeta	<u>Arabellidae</u> sp. <u>Arctonoe fragilis</u> <u>Capitellidae</u> sp. <u>Chitinopoma groenlandica</u> <u>Eteone longa</u> <u>Nereis latescens</u> <u>N. pelagica</u> <u>N. vexillosa</u> <u>Platynereis bicanaliculata</u> <u>Sabellidae</u> sp. <u>Spirorbis spirillum</u> <u>S. vitreus</u> <u>Typosyllis</u> sp.
Phylum Arthropoda	
Class Crustacea	
Subclass Cirripedia	<u>Balanus crenatus</u>

Subclass Copepoda	Harpacticoida spp.
Subclass Eucarida	<u>Pagurus beringanus</u>
	<u>P. granosimanus</u>
	<u>P. hirsutiusculus</u>
	<u>Pugettia gracilis</u>
Subclass Malacostraca	<u>Ampithoe lacertosa</u>
	<u>A. simulans</u>
	<u>Anisogammarus pugettensis</u>
	<u>Calliopiella</u> sp.
	<u>Corophium acherusicum</u>
	<u>Hyale frequens</u>
	<u>H. grandicornis californica</u>
	<u>Idotea (Pentidotea) aculeata</u>
	<u>I. montereyensis</u>
	<u>Leptochelia dubia</u>
	<u>Parapleustes pugettensis</u>
Subclass Ostracoda	Present
Class Insecta	<u>Actacarus</u> sp.
	<u>Copidognathus</u> sp.
Phylum Mollusca	
Class Bivalvia	
Subclass Heterodonta	<u>Clinocardium</u> sp. (juveniles)
	<u>Tresus</u> sp.
Subclass Pteriomorpha	<u>Mytilus edulis</u>
Class Gastropoda	
Subclass Prosobranchia	<u>Amphissa columbiana</u>
	<u>Amphissa</u> sp.
	<u>Bittium</u> sp.
	<u>Collisella ochracea</u>
	<u>C. pelta</u>
	<u>Crepipatella</u> sp. (?)
	<u>Lacuna variegata</u> (?)
	<u>Littorina scutulata</u>
	<u>Margarites helcinus</u>
	<u>M. lirulatula</u>
	<u>Mitrella tuberosa</u>

	<u>Notoacmaea scutum</u>
	<u>Nucella lamellosa</u>
	<u>Trichotropus cancellata</u>
Subclass Opisthobranchia	<u>Archidoris odhneri</u>
	<u>Hermisenda crassicornis</u>
Subclass Polyplacophora	<u>Basiliochiton heathii</u> (?)
	<u>Ischnochiton</u> sp.
	<u>Katharina tunicata</u>
	<u>Mopalia lignosa</u>
	<u>Mopalia</u> spp. (juveniles)
	<u>Tonicella lineata</u>
Phylum Echinodermata	
Class Asteroidea	<u>Evasterias troschelii</u>
	<u>Pisaster ochraceous</u>
	<u>Solaster dawsoni</u>
Class Echinoidea	<u>Strongylocentrotus</u> <u>droebachiensis</u>
Class Holothuroidea	<u>Cucumaria miniata</u>
	<u>Eupentacta quinquesemita</u>
Phylum Ectoprocta (Bryozoa)	
Class Gymnolaemata	<u>Dendrobeania lichenoides</u>
	<u>Membranipora serrilamella</u>
	<u>M. villosa</u>
	<u>Crisia occidentalis</u>
	<u>Crisulipora occidentalis</u>

B. Algae

Division Chlorophyta

Enteromorpha intestinalis

E. linza

Ulva fenestrata

Division Phaeophyta

Desmarestia aculeata

Fucus gardneri

Laminaria saccharina

Nereocystis leutkeana

Division Rhodophyta

Ahnfeltia plicata

Audouinella vaga

Callophyllis flabellulata

Callophyllis sp.

Ceramium californicum

Constaninea subulifera

Cryptosiphonia woodii

Erythrotrichia sp.

Farlowia mollis

Gigartina corymbifera

G. papillata

Gracilaria verrucosa

Grateloupia doryphora

Hildenbrandia prototypus

Iridea cordata

Lithothamnion sp.

Microcladia coulteri

Odonthalia floccosa

Platythamnion sp.

Pleonosporium sp.

Polyneura latissima

Polysiphonia pacifica

P. paniculata

Polysiphonia spp.

Pterosiphonia bipinnata

P. gracilis

Prionitis lanceolata

Rhodoglossum affine

Rhodymenia pertusa

Scagelia corallina var occidentale

Smithora naiadum

Stenogramme interrupta

LOG OF VISITS TO RECOLONIZATION SITE

ROBERTS BANK

DATE

DESCRIPTION

22 July
(overcast; 18°C)

A 1.0 m² area, located on a horizontal, flat rock face approximately 1.4m above datum on the south-west perimeter of the coal port was scraped clean and torched.

Prior to clearing the following organisms were collected from the chosen site:

Enteromorpha intestinalis

E. linza

65% cover

Ulothrix flacca

Gigartina papillata

Monostroma sp.

Polysiphonia pacifica

Balanus glandula

Chthamalus dalli

Ampithoe simulans

Chironomid larvae

Littorina scutulata

Collisella pelta

31 July

Few limpets and littorines present.

10 August
(Sunny; 25°C)

Organisms present included:

Enteromorpha intestinalis

E. linza

60% cover

Ulothrix flacca

Ulva fenestrata (attached to Collisella pelta shells)

Collisella pelta

Littorina scutulata

Diptera spp.

13 August
(Sunny; 20°C)

Organisms present included:

Enteromorpha intestinalis
E. linza

Ulothrix flacca

Littorina scutulata
L. sitkana (with egg cases)
Lacuna sp.

Ampithoe simulans
A. lacertosa

Chironomid larvae

11 September
(Overcast; some
sunny breaks;
16°C)

Organisms present included:

Enteromorpha intestinalis - dense mat covering 90% of the
site.

E. linza is also present and overlies the
E. intestinalis in the center of the site.

Coal or diesel
slick present
offshore; water
very turbid; lots
of drift Zostera.

Littorina scutulata 25/1 m²

Notoacmea persona 1/1 m²

Collisella pelta 102/1 m²
(With some Porphyra sp. and Ulva sp. attached to the
shells)

Bivalve (probably Mytilus edulis) seed

Katharina tunicata 1 (3 cm long)/1 m²

There had been a dense settlement of barnacles:

Balanus glandula 150/0.1 m²

Chthamalus dalli 25/0.1 m²

24 September
(Overcast; 12°C)

Organisms present included:

Water very turbid

Enteromorpha intestinalis
E. linza 75% cover

Littorina scutulata 50/1 m²

Notoacmea scutum 1/1 m²

Collisella pelta 112/1 m²

24 September
(cont'd)

A 0.01 m² area, located in the center of the recolonization site was scraped clean and the biomass of major organisms collected was determined:

Name	#	Dry Wt(g)	Ash Free Wt (g)
<u>Enteromorpha</u> spp.		0.5902	
<u>E. linza</u>		0.6280	
<u>Littorina scutulata</u>	4	0.0516	0.0006
<u>Collisella pelta</u>	1	0.0230	0.0045
<u>Balanus glandula</u>	90	0.2403	0.0115
<u>Chthamalus dalli</u>	18	0.0098	0.0001

In addition, the following organisms were identified and preserved:

Name	#
<u>A. Algae</u>	
<u>Blidingia minima</u> var <u>subsalsa</u>	Present
<u>Ulothrix flacca</u>	Present

B. Invertebrates

1. Cnidaria

Phialidium hemisphericum 1 colony

2. Nematoda 100

3. Annelida

Polynoid worm 1

4. Mollusca

Lacuna sp. juveniles 15

Littorina sp. juveniles 31

Mytilus edulis seed 300

5. Arthropoda

Copepoda spp. 1

Cyclopoida sp. 1

Harpacticoida sp. 6

24 September
(cont'd)

Name	#
5. Arthropoda cont'd	
Isopoda	
<u>Gnorisphaeroma oregonensis</u>	6
Amphipoda	
<u>Caprella laeviuscula</u>	3
<u>Ampithoe simulans</u>	34
<u>A. lacertosa</u>	18
<u>Corophium brevis</u>	33
<u>C. insidiosum</u>	17
<u>C. achervsicum</u>	25
<u>Hyale frequens</u>	23
Insecta	
Halicaridae spp.	3
Chironomid larvae	3

9 October
(Overcast, windy;
10°C)

Heavy surf and a 1.5 m low tide made observation of the site very difficult. The Enteromorpha cover appeared to be receding from the perimeters of the site, towards the center.

21 October
(Clear, dark-
0600; 3°C)
Water very turbid.
Fine sediment present
at base of rocks
surrounding the
recolonization site.)

Organisms present included:

<u>Enteromorpha</u> spp.	60% cover

Limpets	148/1 m ²
<u>Mytilus edulis</u> seed	
<u>Pagurus hirsutiusculus</u>	5/1 m ²

In order to determine the number of barnacles present on the site six areas (0.05 m²) were randomly chosen and the number of barnacles present in each was counted:

Sample #	Name	# Present
1	<u>B. glandula</u>	25
	<u>C. dalli</u>	4
2	<u>B. glandula</u>	16
3	<u>B. glandula</u>	13

In dense Enteromorpha mat.

21 October
(cont'd)

Sample #	Name	# Present
4	<u>B. glandula</u>	50
	<u>C. dalli</u>	8
5	<u>B. glandula</u>	36
	<u>C. dalli</u>	9
6	<u>B. glandula</u>	50
	<u>C. dalli</u>	37

Mean number of B. glandula/0.05 m² - 31

Mean number of C. dalli/0.05 m² - 9

3 November
(Overcast, light
rain; dark - 0300;
12°C)

Further degradation of the Enteromorpha mat was observed. This mat now represented approximately 50% total cover.

There had been a small (25) settlement of barnacles in the 0.01 m² area which had been scraped clean on 24 September.

In addition, the following organisms were observed:

Littorina scutulata 20

Collisella pelta 160

Notoacmea scutum

Balanus glandula

Chthamalus dalli

10 December
(clear, calm; dark -
2300; 12°C)

Further degradation of Enteromorpha, which now sparsely covers approximately 25% of the quadrat. Only one patch of the Porphyra remains. The entire rock is almost denude of algae. The 0.01 m² area remains bare. Four quadrats were randomly chosen, scraped clean and the biomass of major organisms determined.

Name	Subsample	#	Dry wt (g)	Tissue dry wt (g)
<u>B. glandula</u>	1	37	0.2271	0.0119
	2	95	0.4485	0.0264
	3	100	0.5086	0.0334
	4	72	0.7562	0.025
<u>C. dalli</u>	1	3	0.0081	0.0008
	2	45	0.2142	0.0187
	3	38	0.1108	0.0143
	4	16	0.0554	0.0059

EELGRASS EPIFAUNAL DIVISIONS

Faunal Divisions adopted from Smith et al., 1975.

Hydroida

Nematoda

Polychaeta (Errantia)

Ostracoda

Harpacticoida

Calanoida

Cyclopoida

Copepoda larvae

Cumacea

Amphipoda

Isopoda

Tanaidacea

Pycnogonida

Halicaridae

Mesogastropoda

Eggs (Gastropoda)

Eggs (Cephalaspidea)

Bivalvia

Ectoprocta

Unidentified larvae

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