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NOAA Technical Memorandum ERL MESA-26

THE INTERTIDAL AND SHALLOW SUBTIDAL BENTHOS OF THE STRAIT OF JUAN DE FUCA SPRING 1976 - WINTER 1977

Carl F. Nyblade

Marine Ecosystems Analysis Program
Boulder, Colorado

March 1978

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / Environmental Research Laboratories

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Friday Harbor Laboratories
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UNITED STATES
DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
Richard A. Frank, Administrator

Environmental Research
Laboratories
Wilmot N. Hess, Director

Completion Report Submitted to
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MARINE ECOSYSTEMS ANALYSIS PROGRAM
ENVIRONMENTAL RESEARCH LABORATORIES

BY

UNIVERSITY OF WASHINGTON
FRIDAY HARBOR LABORATORIES
FRIDAY HARBOR, WASHINGTON 98250

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** Available from Seattle NOAA MESA Puget Sound Project Office

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THE INTERTIDAL AND SHALLOW SUBTIDAL BENTHOS OF THE STRAIT OF JUAN DE FUCA

Carl F. Nyblade

ABSTRACT

With the potential existing for large scale oil shipment through the Strait of Juan de Fuca, a baseline study was initiated to document the distribution, abundance and seasonal variation of the intertidal and shallow subtidal benthos along the Washington coast of the Strait of Juan de Fuca.

Ten study sites, representative of the range of habitats present, were selected and sampled quarterly at high, mid, and low intertidal strata. Once a year sampling was conducted at intermediate intertidal tidal heights and at -5m and -10m relative to MLLW.

Over 900 different plants and animal species were collected during the study year. Dominant groups were algae, molluscs, polychaete annelids, and crustaceans. In the intertidal, rock habitats were the richest in terms of number of species, density, and biomass, followed by cobble, fine sediment, sand, and gravel habitats. Strong vertical zonation was found at all but the most exposed gravel and sand sites. Subtidal study sites were consistently rich. Community comparisons of the areas and levels sampled during this study validated the type habitat approach and the selection of strata to be sampled.

Patchiness of organisms in the communities sampled generally obscured seasonal patterns in populations of component species. However, summed over all levels and areas, summer is most often the peak for species richness, abundance, and biomass and winter most often the low.

I. INTRODUCTION

The Puget Sound region has been subjected to the transportation of crude oil and its refined products for many years with only a few large oil spills (e.g., the Guemes Island spill, see Woodin et al, 1972) and with chronic contamination from smaller spills associated with oil loading activities (see Oil on Puget Sound, 1972) largely confined to refinery sites. The fact that virtually all crude oil used by the region's refineries moved by overland pipeline from Alberta kept oil transport on greater Puget Sound to a minimum. Now, however, the Canadian crude oil supply has been terminated and with this termination has come an increase in marine oil tanker traffic to replace the lost overland supply. It is also possible that the greater Puget Sound region could become a petroleum transshipment point for Alaskan crude oil to supply inland United States refineries. This would greatly increase tanker traffic and the risk of acute and chronic oil pollution of the marine environment in this region.

In order to respond to this threat, a more detailed knowledge of the marine environment of greater Puget Sound was required. In 1974, the Washington State Department of Ecology began their series of Oil Baseline Studies. This work was largely confined to the San Juan Archipelago and the Rosario Strait mainland areas.

By late 1975, it became clear that with the possibility of an oil port at or west of Port Angeles, the Strait of Juan de Fuca should be added as another threatened area. In early 1976, the present study, a component of the Puget Sound Energy-Related Research Project, was initiated to characterize the infaunal and epifaunal communities which inhabit the variety of intertidal and shallow subtidal habitat types found along the Washington coastline of the Strait of Juan de Fuca. The Puget Sound Energy-Related Research Project is a multi-year study, funded by the United States Environmental Protection Agency, and administered through the National Oceanic and Atmospheric Administration's Marine Ecosystem Analysis Puget Sound Project Office. This project is designed to identify the potential ecological consequences of increased petroleum transport and transfer activities anticipated for the greater Puget Sound region.

All these studies have concentrated on intertidal and shallow subtidal benthic communities, which have historically been highly susceptible to the lethal and sublethal effects of petroleum hydrocarbons. These areas are highly productive and also have great recreation, ecological, and economic importance. This is especially true for the Strait of Juan de Fuca. All Fraser River and greater Puget Sound migratory salmonids pass through the Strait. In addition the area is highly productive of bottom fish and of shellfish in Sequim and Discovery Bays. The potential oil threat to the Strait is especially great. Tankers bound for existing refineries will travel it regardless of the fate of Port Angeles as an oil terminal. Oil traffic to Vancouver, British Columbia also transits the Strait of Juan de Fuca. If Port Angeles becomes an oil terminal, the volume of oil transport along the Strait will greatly increase.

Research components of the study consisted of defining the habitat types present along the Strait of Juan de Fuca, largely according to substratum/exposure, selection of ten sites along the length of the Strait representative of these habitat types, quarterly determination of community composition at each site, and the determination of the vertical distribution of the organisms found at each. This information is critical to enable any careful assessment of the impact of man's activities along the Strait, especially in assessing damage to this environment from oil pollution.

This report covers the first year's effort. However, at least one additional year of study is to be conducted. This will then permit documentation of annual variation in populations of organisms.

II. METHODS AND MATERIALS

In general the methodology used in this study was a direct outgrowth of that developed during the Washington State Department of Ecology Baseline Studies (DOE). The overall purpose of this methodology was to provide the best possible data set to document the abundance, distribution, and seasonal variation in populations of organisms of each major habitat type present and to do this with a finite set of resources.

Since the entire coastline could not be sampled, ten study areas were selected which were representative of the intertidal habitats present along the Strait. This was done with a full awareness that soft bottom habitats are not discrete types but are in reality a continuum from finest mud to gravel to cobble. The subtidal region of a study area came along with no selectivity regarding habitat type. It was hoped that they would represent the range of subtidal habitats present.

At each study area the sampling methodology chosen was stratified and random within each stratum, since the entire beach could not be sampled. Because tidal exposure in the intertidal and water depth as it relates to sunlight in the photic zone of the subtidal are the overriding physical factors influencing the distribution of organisms, strata were chosen by tide height and water depth. For seasonal sampling three strata were selected for sampling in the intertidal (high +6', mid +3', low +0') and two in the subtidal (-5m, -10m). DOE baseline experience showed these levels would likely give adequate coverage of the organisms present over the entire tidal and shallow water range at study areas. To provide more information on tidal height and depth distribution, intermediate levels (+7', +5', +4', +2', +1', -2.5m, -7.5m) were sampled once, during the summer quarter, the seasonal period of maximal abundance for the majority of organisms based on previous baseline experience.

The number of times during the year to sample in order to obtain minimal seasonal information on population changes was determined to be four. Again this was based on DOE baseline experience of bimonthly sampling. Little seasonal information is lost by quarterly as opposed to bimonthly sampling.

The number of replicates taken ranged from three to five depending on habitat. This also was based largely on previous baseline experience. Cost-effective deployment of available funding played a major role in number of replicates taken.

Sample (quadrat) size and dead-sieving through 1mm sieves are also key legacies of previous baseline work, where they proved adequate. To insure a data set compatible to previous baseline work was a major factor in determining quadrat treatment methodology.

II-A. Study Areas

The general methodology of this study was a type habitat approach. In early April 1976 the Washington coastline of the Strait of Juan de Fuca was visually surveyed from Port Townsend west to Neah Bay to determine the range and approximate proportion of the habitats present. Since only a finite number of areas could be sampled, ten locations with type habitats representative of those surveyed were selected and were fairly evenly distributed along the Strait (Table 1, Figure 1). An effort was made to select similar habitats east and west of Port Angeles. This proved impossible for rock and mud substrata. There were virtually no consolidated rock areas east of Port Angeles and no fine sediment areas west. So two rock areas were selected west of Port Angeles, two cobble east. A mud area and a mixed mud/sand/gravel area were selected east of Port Angeles. Paired east/west sand and paired gravel areas were also selected.

Figures 2 through 10 give detailed site maps for each study site. Explanations of the maps, driving directions, tidal reference point data, and details on access permissions from private and public agency land owners are presented in Appendix III.

Table 1. Study Areas - (intertidal habitat type)

1.	Kydaka Point - (exposed sand)	124^{o} 48^{o}	22' 16'	20" 14"	W N
2.	Pillar Point - (exposed rock)	124^{o} 48^{o}	06' 12'	03" 51"	W N
3.	Twin Rivers - (exposed gravel)	123^{o} 48^{o}	56' 09'	57 55"	W N
4.	Tongue Point - (exposed rock)	123^{o} 48^{o}	41' 09'	42" 57"	W N
5.	Morse Creek - (exposed cobble)	123^{o} 48^{o}	20' 07'	48" 09"	W N
6.	Dungeness Spit - (exposed gravel)	48^{o} 123^{o}	08' 11'	47" 12"	N W
7.	Jamestown - (sandy mud)	48^{o} 123^{o}	07' 05'	51" 11"	N W
8.	Beckett Point - (gravel/sand/mud)	48^{o} 122^{o}	04' 52'	37" 56"	N W
9.	North Beach (exposed cobble)	48^{o} 122^{o}	08' 46'	36" 59"	N W
10.	North Beach - (exposed sand)	48^{o} 122^{o}	08' 46'	35" 51"	N W

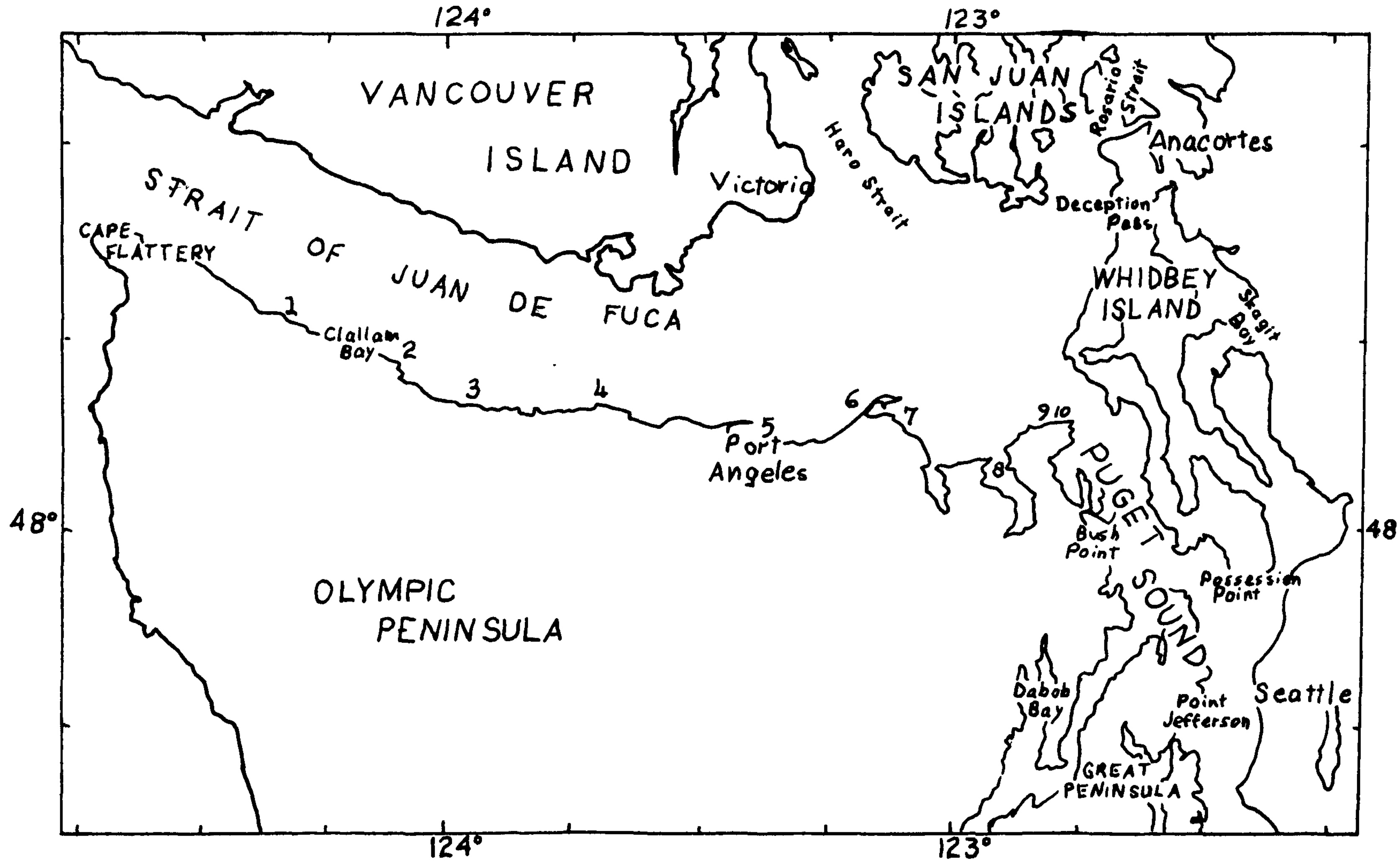


Figure 1. Map of Study Sites

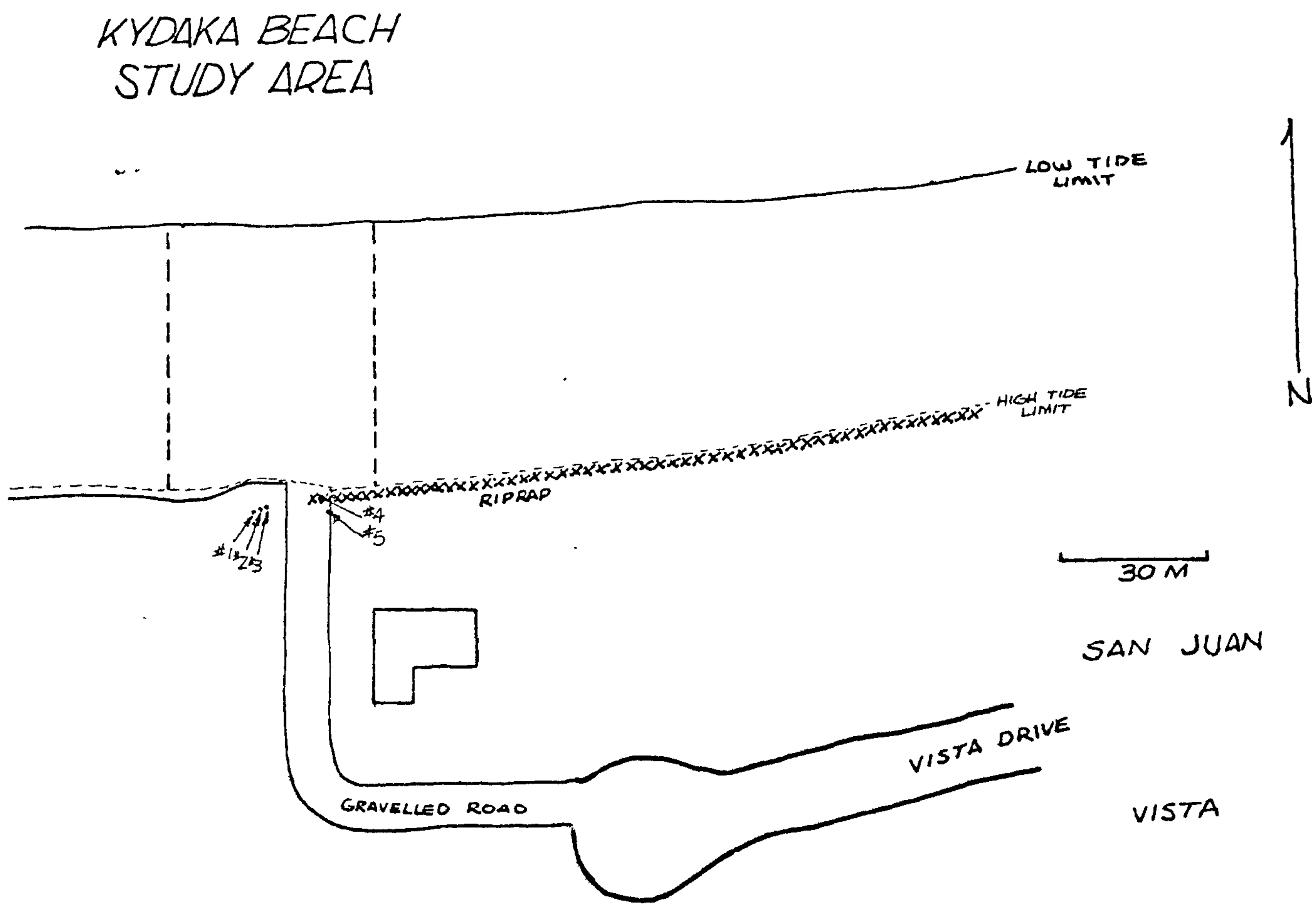
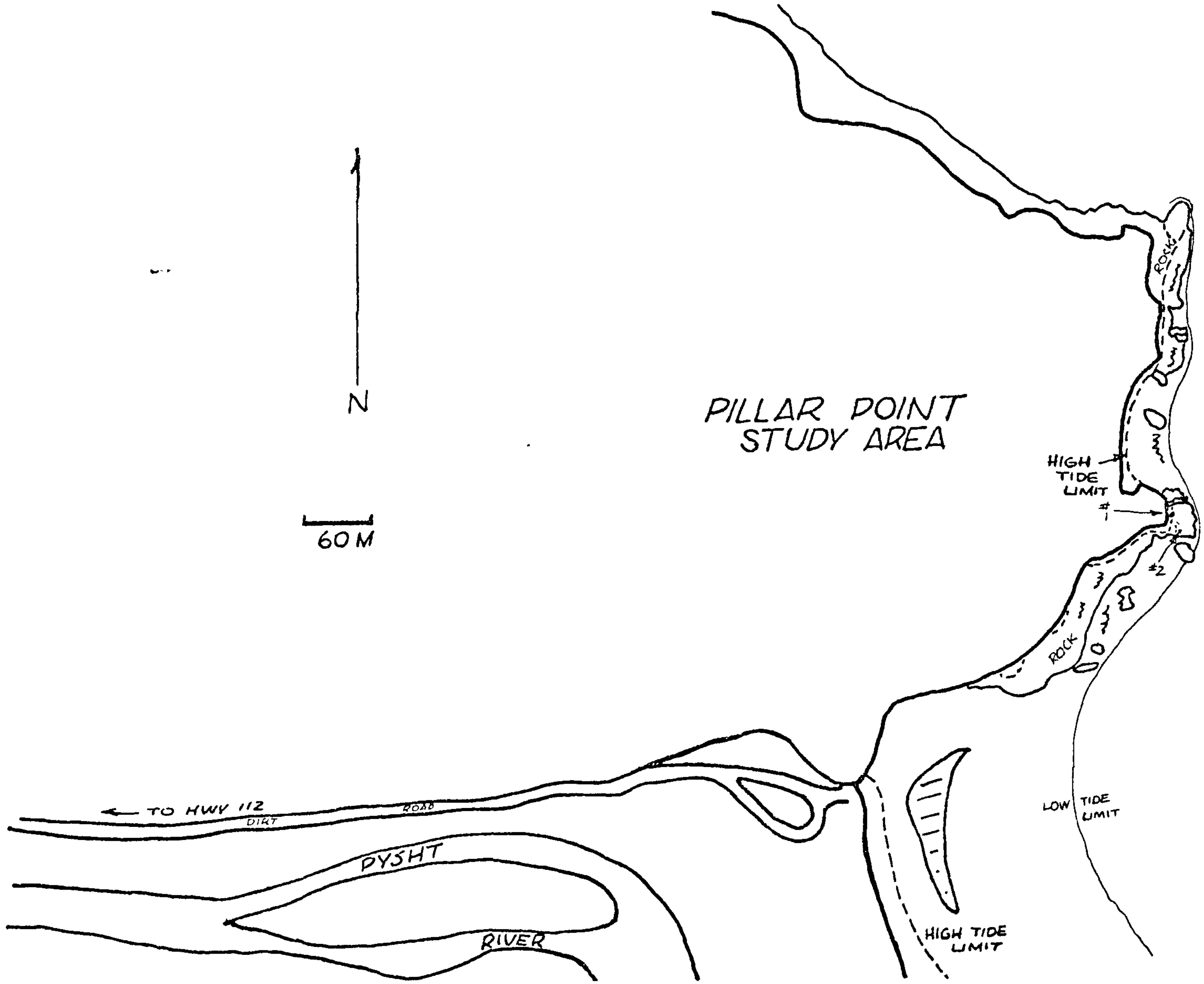

KYDAKA BEACH
STUDY AREA
LOW TIDE
LIMIT
HIGH TIDE
LIMIT
N
RIPRAP
#4
#5
#1 2 3
30 M
SAN JUAN
VISTA DRIVE
VISTA
GRAVELLED ROAD

Figure 2.

Figure 3.


N
60 M
PILLAR POINT
STUDY AREA
ROCKS
HIGH TIDE LIMIT
#1
#2
ROCK
LOW TIDE LIMIT
HIGH TIDE LIMIT
TO HWY 112
DIRT ROAD
PYSHT
RIVER

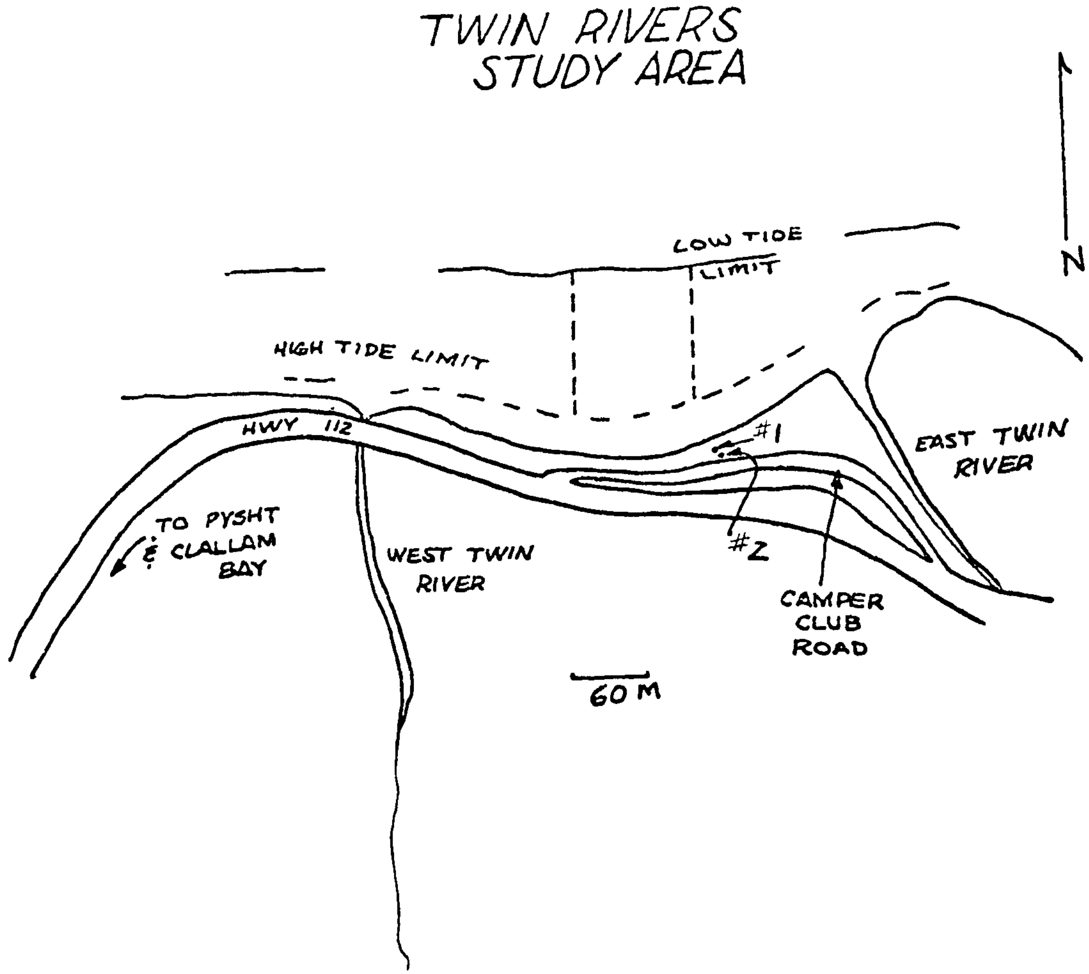

TWIN RIVERS
STUDY AREA
N
LOW TIDE
LIMIT
HIGH TIDE LIMIT
HWY 112
#1
#2
EAST TWIN
RIVER
TO PYSHT
& CLALLAM
BAY
WEST TWIN
RIVER
CAMPER
CLUB
ROAD
60 M

Figure 4.

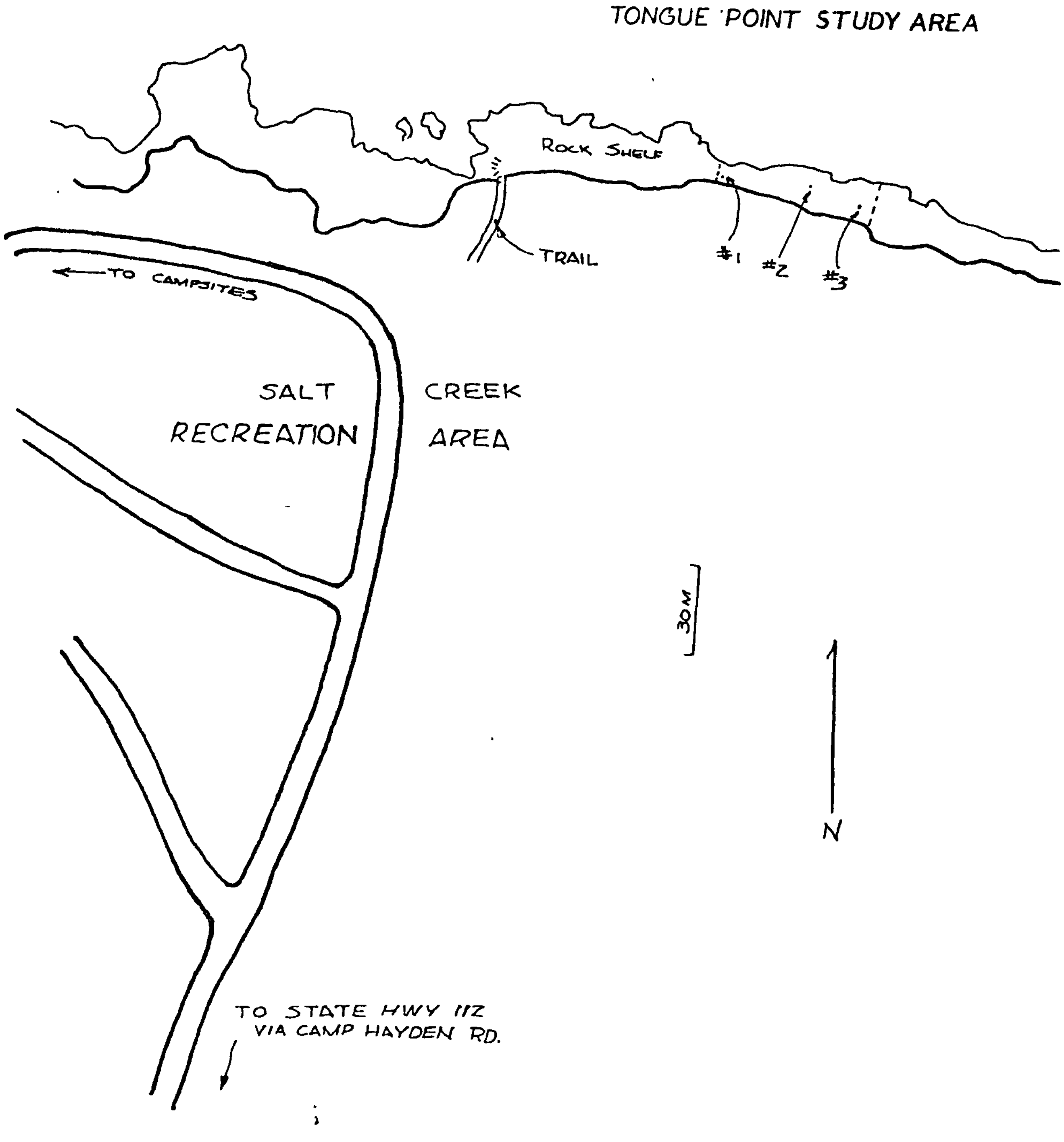

TONGUE POINT STUDY AREA
ROCK SHELF
TRAIL
#1
#2
#3
TO CAMPSITES
SALT CREEK
RECREATION AREA
30M
N
TO STATE HWY 112
VIA CAMP HAYDEN RD.

Figure 5.

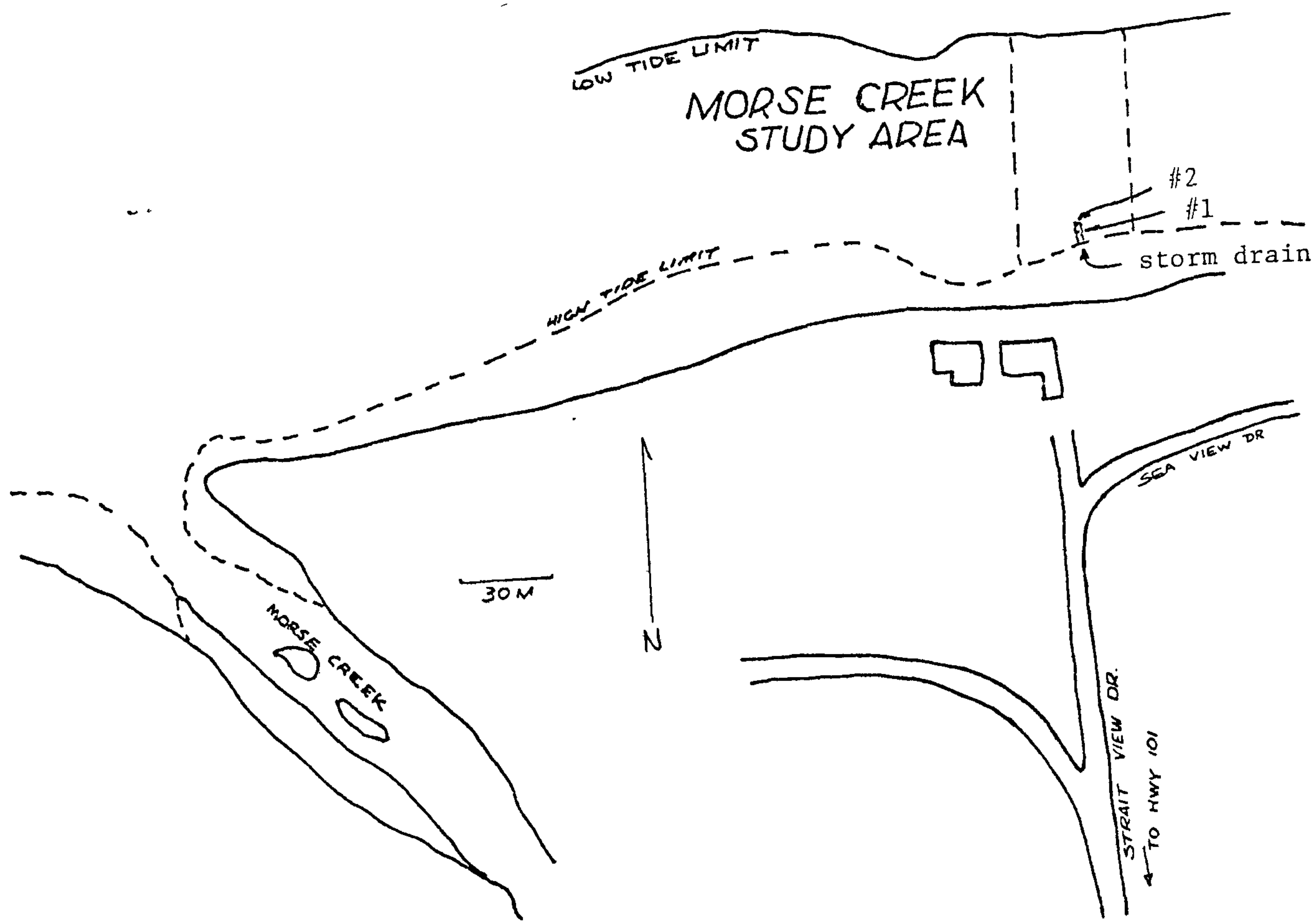

LOW TIDE LIMIT
MORSE CREEK
STUDY AREA
#2
#1
storm drain
HIGH TIDE LIMIT
SEA VIEW DR
30 M
N
MORSE CREEK
STRAIT VIEW DR.
TO HWY 101

Figure 6.

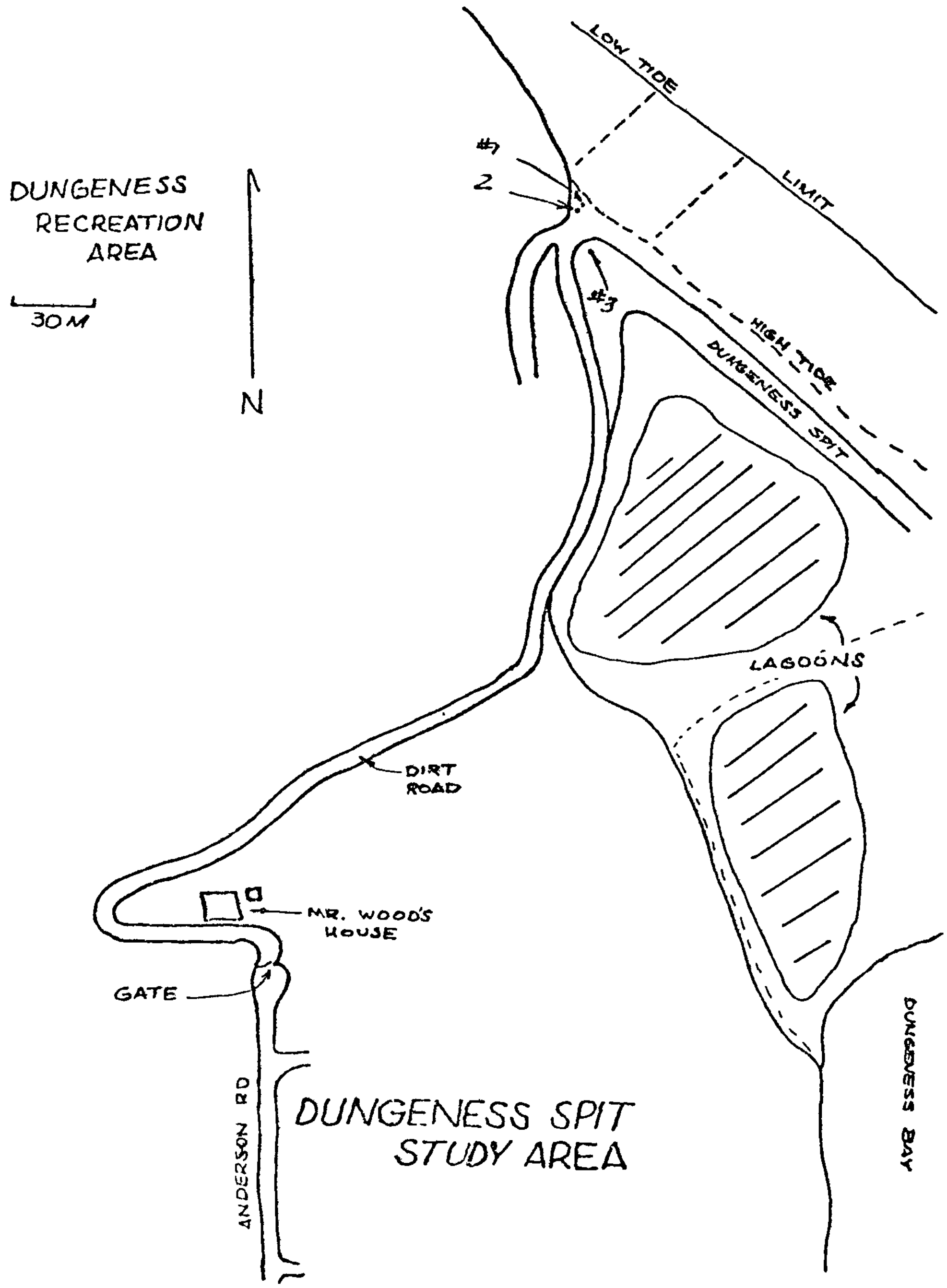
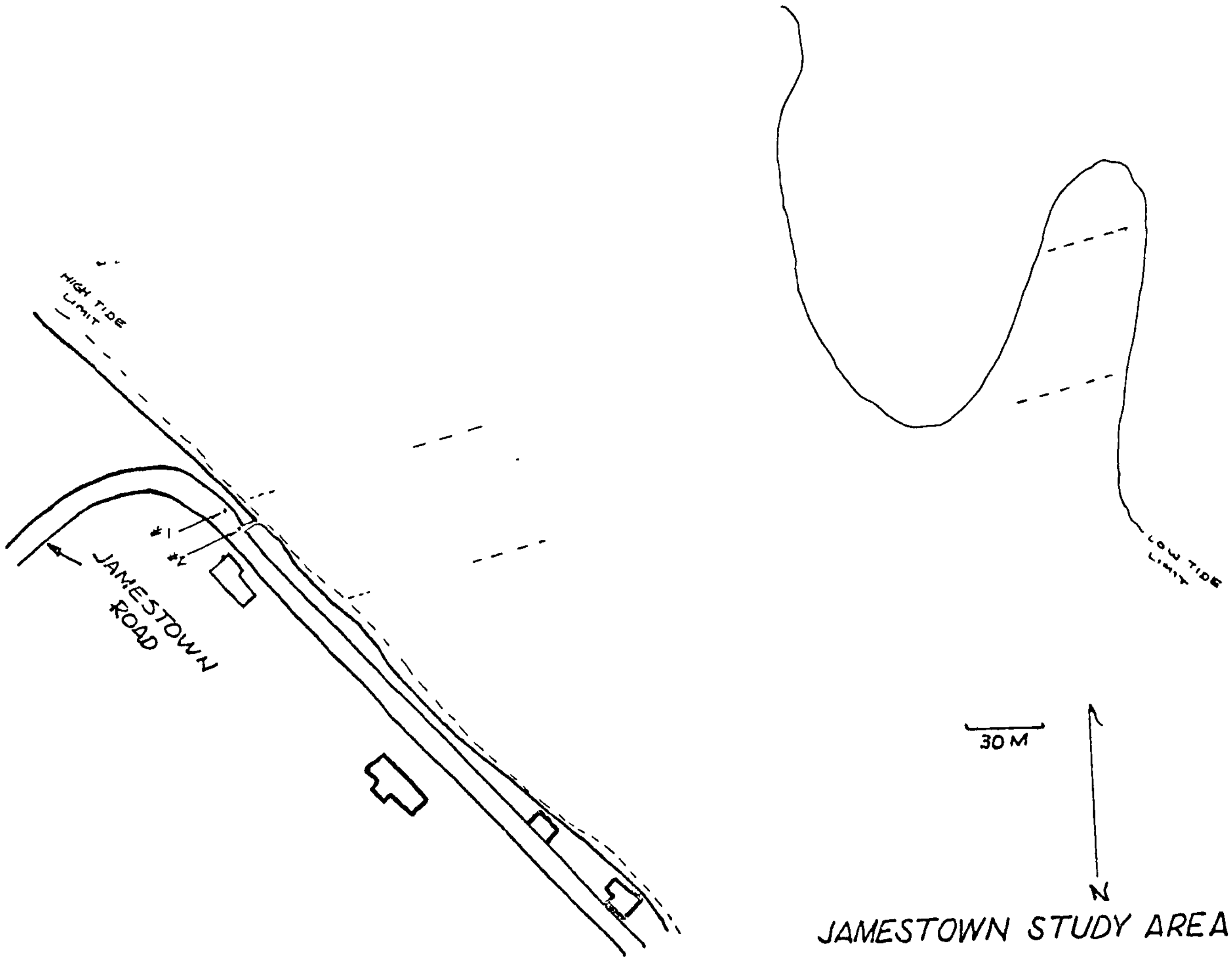

DUNGENESS RECREATION AREA
30 M
N
LOW TIDE LIMIT
#1
2
#3
HIGH TIDE
DUNGENESS SPIT
LAGOONS
DIRT ROAD
MR. WOOD'S HOUSE
GATE
ANDERSON RD
DUNGENESS BAY
DUNGENESS SPIT STUDY AREA

Figure 7.

Figure 8.


HIGH TIDE LIMIT
#1
#2
JAMESTOWN ROAD
LOW TIDE LIMIT
30 M
N
JAMESTOWN STUDY AREA

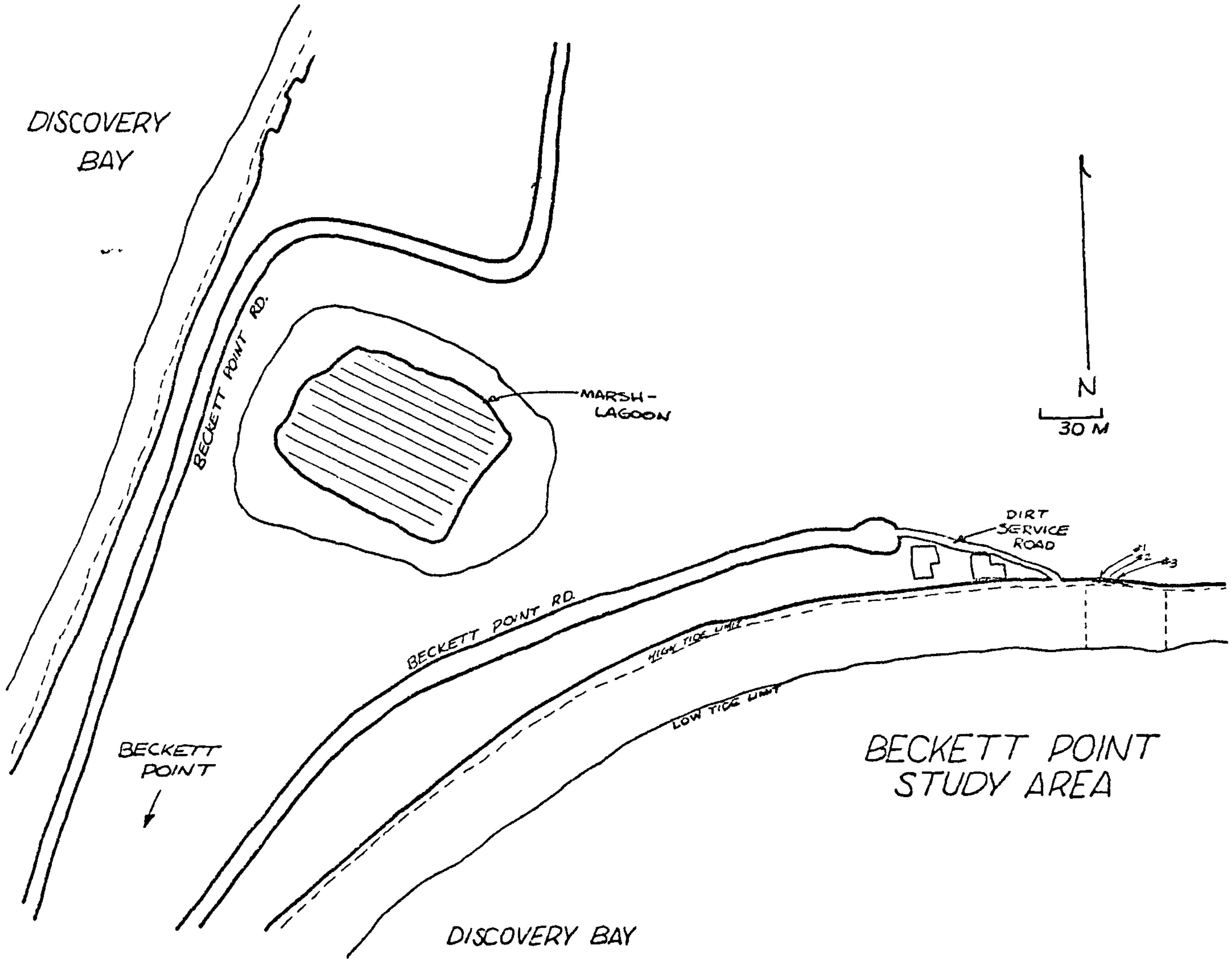

DISCOVERY BAY
BECKETT POINT RD.
MARSH-LAGOON
N
30 M
DIRT SERVICE ROAD
BECKETT POINT RD.
LOW TIDE LIMIT
BECKETT POINT
BECKETT POINT STUDY AREA
DISCOVERY BAY

Figure 9.

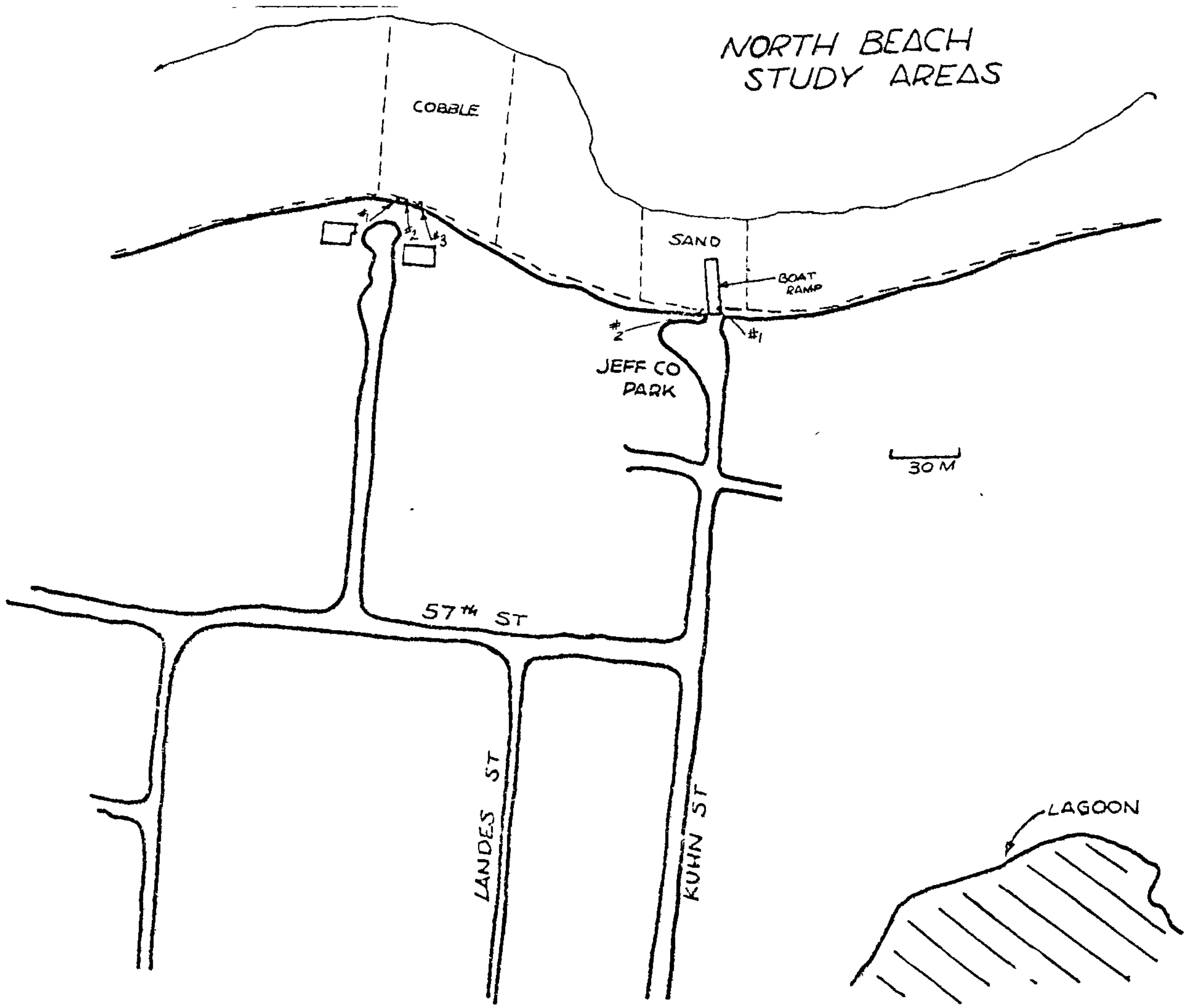

NORTH BEACH
STUDY AREAS
COBBLE
SAND
BOAT RAMP
#1
#2
#3
#2
#1
JEFF CO
PARK
30 M
57th ST
LANDES ST
KUHN ST
LAGOON

Figure 10.

II-B. Field Sampling Procedures

A variety of techniques were employed to accommodate the different types of habitats sampled. Two sampling schemes were used: one to establish the vertical distributional data for each site, and another to establish abundance data for each site. The scheme used to determine vertical distribution was implemented once during the study. The scheme used to establish abundance was utilized four (4) times, once during each season.

II-B-1. Method of Stratified Random Sampling to Document Representative Abundance of Organisms

II-B-1-a. Permanent Reference Points. All study sites had at least one permanent tidal reference point marked on an immovable object on the backshore or in the intertidal. Each mark was calibrated approximately to a tidal height either from a USCGS marker, if close by, or from a given water level under average weather conditions using NOAA tidal predictions and any appropriate corrections in them known for the specific location.

The reference marks had several purposes. Using a transit they permitted a relative tidal height determination for all quadrats sampled at the study site. They permitted return to the same heights for any subsequent sampling. They also would permit eventual exact tidal height determination of all quadrats if the absolute tidal height of the reference points were ever determined.

The reference line was a line located parallel to the water at the upper tidal boundary of each site's high intertidal zone. The reference line length varied from area to area. The objective was to stay within the same habitat type at each site. In linearly homogeneous areas a length of up to 100 m was used. In more heterogeneous or physically restricted areas, as little as 25 m was available.

II-B-1-b. Transect Lines. A transect line was established parallel to the reference line each time a study site was sampled. Samples were taken along this transect at predetermined heights in the intertidal (+6', +3', +0' quarterly; +7', +5', +4', +2', +1' once) determined by transit relative to the reference points and at predetermined depths in the subtidal (-5 m, -10 m quarterly; -2.5 m, -7.5 m once).

To assure the randomness required for statistical analysis of quantitative data, the transect line positions were chosen without bias. This was done by choosing a random number which fell within the meter boundaries of the reference line for the first transect line.

II-B-1-c. Quadrat Locations and Number. Absolute sampling depths in the subtidal of -5 m and -10 m relative to MLLW were determined before each sample set with a calibrated lead line and/or by utilization of a calibrated divers depth gauge.

Three intertidal levels were sampled at each study site using horizontal transect lines, parallel to the reference line. The horizontal sampling levels in the intertidal were approximately +6 ft. (high intertidal), +3 ft. (mid-intertidal) and 0 ft. (low intertidal). The same levels were sampled repeatedly each season. The heights of the horizontal levels were located by measuring from the reference line using a transit.

The locations of quadrats to be sampled along the transect were determined from a random number table. Each site's sample set included 4 quadrats per horizontal sampling level in rock habitats, 5 in gravel, 4 in cobble, 5 in sand, 3 in mud, and 3 in mud/gravel mixture.

II-B-1-d. Timing of Sampling. Abundance data were collected during the spring (April through early June), summer (July through early September), fall (October through early December) and winter (January through early March), see Appendix II, Table 1 .

II-B-2. Method of Random Sampling to Document Vertical Distribution of Organisms

II-B-2-a. Permanent Reference Points and Reference Line. The permanent reference points and reference line were the same as that established for collection of abundance data at each study site.

II-B-2-b. Transect Lines. Each time an intertidal station was sampled for distribution data, transect lines were placed perpendicular to the reference line. Samples were taken along these transect lines. Depending upon the habitat type, one or more transect lines were used. In mud and sand where the community was more evenly distributed, and working distances longer, one transect line was used. However, if the area were variable horizontally, then two transects were made. On gravel, cobble, and rock habitats, two or more parallel transect lines were used.

To assure the randomness required for statistical analysis of quantitative data, the transect line positions were chosen without bias. This was done by choosing a random number which fell within the meter boundaries of the reference line for the transect lines. A transit was used to assure that the transect lines were perpendicular to the reference line.

II-B-2-c. Quadrat Locations and Number. The transect line distance was measured from the reference line to the lowest practical sampling level based upon the low tides during the sampling period. Sampling of quadrats was conducted at one-foot tidal height increments in the intertidal from +7 ft. to 0 ft. and at 2.5 m tidal depth increments in the subtidal from 0 m to -10 m referenced to zero tidal height. Abundance quadrat samples taken during the same sampling period sufficed for the +6 ft., +3 ft., 0 ft., -5 m, and -10 m levels, and were used in the analysis of vertical distribution data.

II-B-2-d. Timing of Sampling. Distribution data were collected during the summer quarter (July, August).

II-B-3. Methods of Sampling Quadrats

II-B-3-a-1. Rock - intertidal (Spring, Summer, and Fall 1976)

A 0.25 m^2 (50 cm x 50 cm) quadrat frame, divided into twenty-five 0.01 m^2 (10 cm x 10 cm) subsections, was placed over each quadrat location. First, an estimate of the percentage of the quadrat area covered by algae was made based upon the averaged estimates of two or more observers. Then, all the algae within the entire 0.25 m^2 area were removed. Next, the larger (>5 mm) invertebrates were removed by hand from within the 0.25 m^2 frame. Finally, five 0.01 m^2 subsections were selected randomly and separately scraped clean of all algae and invertebrates. All samples were containerized and labelled separately for sorting and analysis.

II-B-3-a-2. Rock - intertidal (Winter 1977)

Because of thick algal turfs encountered at the study areas required laboratory subsampling during processing, a field subsampling procedure was instituted beginning Winter 1977.

A 0.25 m^2 (50 cm x 50 cm) quadrat frame sectioned into twenty-five 0.01 m^2 (10 cm x 10 cm) units was placed over each quadrat location. First, an estimate of the percentage of the quadrat area covered by algae was made based upon the averaged estimate of two or more observers. Next, five 0.01 m^2 subsections were selected randomly, and separately scraped clean of all algae and invertebrates. All samples were containerized and labelled separately for sorting and analysis. Then, all the remaining algae within the entire 0.25 m^2 area was removed. Next, the remaining larger (>5 mm) invertebrates were removed by hand from within the 0.25 m^2 frame.

II-B-3-b. Gravel - intertidal (Spring - Winter)

A 0.05 m^2 (22.5 cm x 22.5 cm) quadrat was used at each sample location. Sediment from within these frames was removed to a depth of 15 cm, containerized, fixed in formaldehyde, and, later, transported to the laboratory, and dead-sieved through a 1 mm screen. Then, large (0.25 m^2 x 30 cm deep) cores were independently taken at an equal number of randomly selected quadrat locations, and live-sieved through a 12.5 mm screen to retain large invertebrates. The organisms were preserved in 10 percent formaldehyde/sea water. All samples were containerized and labelled separately for sorting and analysis.

II-B-3-c-1. Cobble - intertidal (Spring, Summer, and Fall 1976)

A 0.25 m^2 (50 cm x 50 cm) quadrat frame, which was subsectioned into twenty-five 0.01 m^2 (10 cm x 10 cm) units, was placed over the quadrat location. All the algae within the entire 0.25 m^2 area were removed by hand. The larger (>5 mm) invertebrates were removed by hand from the surface of the 0.25 m^2 area and from beneath the larger cobble. Each rock was replaced after the removal of these larger organisms.

Five randomly selected 0.01 m^2 (10 cm x 10 cm) subsections within the 0.25 m^2 frame were scraped clean of all remaining algae and invertebrates and containerized separately.

Next, 0.05 m^2 (22.5 cm x 22.5 cm) frames were placed randomly within the 0.25 m^2 frame, and sediment from within the smaller frames removed to a depth of 15 cm. This sediment was containerized and preserved separately in formaldehyde.

II-B-3-c-2. Cobble - intertidal (Winter 1977)

Because of thick algal turfs encountered at the study areas required laboratory subsampling during processing, a field subsampling procedure was instituted beginning Winter 1977.

A 0.25 m^2 (50 cm x 50 cm) quadrat frame, subsectioned into twenty-five 0.01 m^2 (10 cm x 10 cm) units, was placed over the quadrat location. First, five randomly selected 0.01 m^2 (10 cm x 10 cm) subsections within the 0.25 m^2 frame were scraped clean of all algae and invertebrates and containerized separately. Then all the remaining algae within the entire 0.25 m^2 area was removed by hand. The larger (>5 mm) invertebrates remaining were removed by hand from the surface of the 0.25 m^2 area and from beneath the larger cobbles. Each rock was replaced after the removal of organisms.

Next, a 0.05 m^2 (22.5 cm x 22.5 cm) frame was placed randomly within the 0.25 m^2 frame, and sediment from within the smaller frame removed to a depth of 15 cm. This sediment was containerized and preserved separately in formaldehyde.

In addition, large (0.25 m^2 x 30 cm deep) cores were dug and live-sieved through a 12.5 mm screen at an equal number of randomly selected quadrat numbers independent of the other quadrats. The organisms retained were preserved in formaldehyde.

II-B-3-d. Sand - intertidal (Spring - Winter)

Same method as in gravel.

II-B-3-e. Mud and mud/gravel mixture - intertidal (Spring - Winter)

Same method as in gravel.

II-B-3-f. Rock - subtidal (Spring - Winter)

Rock areas were sampled by SCUBA divers. Randomly selected 0.25 m^2 areas were scraped clean of all organisms at each depth, which were sucked up by airlift into a fine (<<1 mm) mesh bag. The organisms collected were processed in the same manner as those captured in intertidal rock scrapes.

II-B-3-g. Soft sediments - subtidal (Spring - Winter)

Soft bottom areas were sampled with a 0.1 m^2 (31.6 cm x 31.6 cm) Van Veen grab sampler. The organisms collected were processed in the same manner as those captured in intertidal cobble, gravel, sand, and mud habitats.

II-B-3-h. Quadrat Rejection

Some quadrats may fall upon obviously dissimilar habitat types (e.g., tide pools, deep crevices, logs) and would result in an erroneous sample. Those quadrats which were obviously nonrepresentative of the habitat type being sampled were rejected and another quadrat chosen at the same location.

II-B-3-i. Sample Number

The following numbers of samples were taken at each of the horizontal transect levels each season for abundance data:

II-B-3-i-1. Rock - intertidal: Four quadrats, consisting of a 0.25 m^2 scrape and five 0.01 m^2 subsections from within each 0.25 m^2 quadrat.

II-B-3-i-2. Gravel - intertidal: five quadrats consisting of 0.05 m^2 x 15 cm deep samples and five consisting of 0.25 m^2 x 30 cm deep samples.

II-B-3-i-3. Cobble - intertidal: four 0.25 m^2 quadrats, consisting of a 0.25 m^2 scrape with five 0.01 m^2 subsections and one 0.05 m2 x 15 cm sediment, and four quadrats consisting of a 0.25 m^2 x 30 cm deep sample.

II-B-3-i-4. Sand - intertidal: five quadrats, each 0.05 m^2 x 15 cm deep and five 0.25 m^2 x 30 cm deep quadrats.

II-B-3-i-5. Mud and mud-gravel mixture - intertidal: three 0.05 m^2 x 15 cm deep quadrats and three 0.25 m^2 x 30 cm deep quadrats.

II-B-3-i-6. Rock - subtidal: four quadrats, consisting of four 0.25 m^2 scrapes.

II-B-3-i-7. Soft-subtidal: three quadrats, consisting of three 0.1 m^2 Van Veen grab samples.

The following numbers of quadrats were collected at each of the horizontal transects once during the summer sampling period:

II-B-3-i-8. Rock - intertidal: two quadrats, consisting of a 0.25 m^2 scrape with five 0.01 m^2 subsections each.

II-B-3-i-9. Gravel, sand, mud, and mud/gravel mixture - intertidal: two 0.05 m^2 x 15 cm deep quadrats and two 0.25 m^2 x 30 cm deep quadrats.

II-B-3-i-10. Cobble - intertidal: two quadrats, consisting of a 0.25 m^2 scrape with five 0.01 m^2 subsections and a 0.05 m^2 x 15 cm deep core each and two quadrats of 0.25 m^2 x 30 cm deep cores.

II-B-3-i-11. Rock - subtidal: four quadrats, consisting of four 0.25 m^2 scrapes.

II-B-3-i-12. Soft - subtidal: two quadrats, consisting of two 0. 1 m^2 Van Veen grabs.

II-B-4. Field Processing Procedures

II-B-4-a. Field sample handling

Samples collected in the field were containerized separately and tagged according to location, date, quadrat number, and collection method. Samples from each different collection method within a quadrat were stored and tagged individually.

II-B-4-b. Supporting measurements

Temperature and salinity of the shoreline water 0.25 m below the surface were obtained and recorded along with prevailing weather conditions. Temperatures were measured generally to the nearest 0.1°C with a metal thermometer. Salinities were measured to the nearest 0.1‰ with an AO refractometer.

Beach compositions (grain-size) were recorded from the horizons sampled during Spring 1976. From each horizon in the intertidal, two random sediment samples were collected with a cylindrical corer 7.5 cm in diameter to a depth of 15 cm. Subtidal sediment samples were collected from each depth from two separate Van Veen grabs.

All intertidal and rock subtidal quadrats were photographed before sampling was carried out.

II-B-4-c. Preservation

All live-sieved samples and algae were preserved in the field in a 10 percent buffered (Ca CO_3) formaldehyde/sea water solution. Algae are stored in darkness to prevent bleaching. Long-term preservation is in 70 percent ethanol/ 15 percent glycerin solution for animals, and in 10 percent buffered formaldehyde solution for plants.

Appendix III contains a more detailed explanation of the field sampling methodology and copies of the field notes taken during each sampling period.

II-C. Laboratory Sample Processing

II-C-1. 0.01 m^2 Scrapes - rock and cobble habitats

The five subsamples were kept separate at all times. Each was emptied into a sorting pan. The organisms larger than 1 mm were then identified, weighed, and containerized for long-term storage in the appropriate preservative. Generally, rock subsamples were never sieved.

II-C-2. 0.05 m^2 x 15 cm and 0.1 m^2 Van Veen grab samples - cobble, gravel, sand, mud habitats

The samples were sieved through a 1 mm sieve after 24-hour fixation. They were dyed with Rose Bengal for at least 2 days. The organisms were then placed in a sorting pan, visible organisms removed, identified, weighed, and containerized for storage.

II-C-3. $0.25\ m^2$ scrape samples - rock and cobble habitats

All organisms were identified, wet weighed, and containerized for storage. When the scrapes contained fine sediment, they were sieved after fixation through a 1 mm sieve. When a large volume of uniform algal turf was collected, about 25% of it was fully processed as a laboratory subsample.

II-C-4. $0.25\ m^2$ x 30 cm deep, 12.5 mm live sieved samples - cobble, gravel, sand, and mud habitats

The organisms collected in these samples were identified and weighed as in the $0.25\ m^2$ scrape samples above.

Detailed descriptions of these procedures are given in Appendix III.

Identification of all organisms was attempted to the species level for those plants and animals 1 mm in size or larger. Appendix III contains extensive details of the level of taxonomy used with each taxon, giving references, laboratory working keys, and other useful notes.

The number of individuals of each species obtained within each quadrat from each sampling method was determined. Combined wet weights for all species whose individuals' aggregate weight exceeded 0.1 gram were determined. No polychaetes were weighed because of the unavailability of an automatic balance with a 0.01 g accuracy.

The samples from each collection method and from each quadrat were preserved, containerized, and stored separately. The sample containers holding organisms from a variety of collection methods at one quadrat were placed in a larger container filled with preservative, thus holding all of an individual quadrat's samples. Algae are preserved in formaldehyde and invertebrates in 70 percent alcohol with 15 percent glycerin. All samples obtained from this program have been added to the Washington State baseline sample repository at the University of Washington Friday Harbor Laboratories with appropriate archival labelling.

The standard dry mechanical sieving technique was used in all sediment analyses. An explanation of terminology and formulae used is given in Appendix II.

II-D. Sources of Sampling Error

Despite the precision of the methodology just described, the real world of biological field sample collection and laboratory processing provide for many sources of sampling error. Perhaps the most serious revolve around the field collection of the samples. Soft sediment intertidal sampling has by far the least error factor. The most serious would be the inadequacy of the area and/or depth sampled to collect an adequate number of specimens. Another problem arises if there is excess water present while digging out the sample. Many organisms get washed from the sediment into this water. The most serious source of error in intertidal rock sampling is the problem of accurately determining the quadrat boundaries, particularly the 0.01 m^2 subsamples. The more the rock deviates from perfectly flat, the larger the problem. Cobble represents the extreme in this error problem. Another rock/cobble error involves field counting of small barnacles. When their number is high and/or crew morale low because of sitting relatively immobile for hours in foul weather, this source for error increases. Mistakes made in the field generally are not detectable once the sample has been collected.

Generally errors in laboratory processing can be corrected by referring back to the sample. An exception is during the sieving and initial picking of organisms. The residue is not retained. Laboratory errors arise in counting, weighing, and mis-identification of species. Another major problem is clerical errors made each time the data are transferred or numerically manipulated.

II-E. Data Analysis

The Data Management Plan for the Puget Sound Energy-Related Research Project and the MESA Puget Sound Project received from the Seattle Project Office dated 15 January 1976 with subsequent revisions has been followed in this study. Raw data in the form of keypunched cards have been submitted to the Project Office on a quarter-by-quarter basis for ultimate archival in the United States Environmental Data Service. All study data are available through the E.D.S.

A variety of data analyses have been used in this report. Each is listed and described below.

II-E-1. Species Richness:

The total number of species found at a given study area stratum is a useful summary figure which gives a measure of the complexity of the community. Species richness reflects only presence, not relative or absolute abundance. In this report species richness was the total number of identification categories/study area stratum sampling period. It was thus summed over the replicates. The identification categories include both species and higher taxonomic categories where identification to species was not possible. Using higher taxa tended to underestimate "real" species richness where the category included a number of species not taken to species level elsewhere (e.g., Oligochaeta). However, it overestimated where the higher taxa resulted from some specimens unidentifiable to species (e.g., fragments or immaturity) when other specimens were identifiable to species. To give an example, assume the sample contained species A as the only member of family B, but it occurred in both immature forms which had only familial characteristics and mature forms identificable to species A. This single species would yield two species richness categories: Family B spp. (juv.) and Species A.

II-E-2. Diversity - H':

A better measure of community complexity is one which weighs relative abundance. A community with the number of organisms spread evenly across constituent species is more diverse (complex) than one with an equal number of species with one overwhelmingly dominant numerically. The following formula for diversity has been used (see Pielou, 1975, for a description of its use and calculation):

$$H' = \sum_{i=1}^{s} pi \log pi$$

This weighs both species number and the evenness of their occurrence. In cases of low diversity the index does not differentiate between low diversity due to low species richness or due to the overwhelming dominance in number (or biomass if that is the measure of an "individual" used) of one or a very small number of species. In order to combine plants (biomass) and animals (individuals) into a single H', plant biomass was converted to individuals (0.1 g = 1). (Algae of <0.1 g were considered 0.1 g for this index.)

II-E-3. Total number:

Since most animals occur as discrete individuals, their mean total number at a given stratum by season gives useful information on overall community seasonal abundance. The total number is the number of individuals for categories where individuals are counted. It, therefore, excludes, for example, most plants, hydroids, sponges, bryozoans, and ascidians, organisms which are colonial or which do not occur as discrete individuals.

II-E-4. Total biomass:

Total number is not useful for algal rich communities. In these total biomass is a much better measure of seasonal overall community abundance. Biomass, standing crop, is also a first step to information on community productivity and energetics. The total biomass is the biomass of categories where 0.1 g or more was present. When the"<0.1 g"'s seemed significant compared to the other biomass, the species richness was multiplied by 0.1 g, added to the small real weight, and entered as a less than weight. Polychaetes were not weighed because a minimum of 0.1 g would provide no useful information since the vast majority of polychaete identification categories never approach 0.1 g in weight.

II-E-5. Similarity index:

Once more than one stratum has been sampled, it becomes very interesting to compare the similarity of the communities at different strata and/or study areas. A very sensitive measure of similarity would be one which compares not only species lists but also the relative abundance of species. In the present study, it was felt that the extra sensitivity given by this type of measure did not warrant its computational complexity. The similarity index as used in this study is merely the percent of co-occurring identification categories between two areas over all seasons; i.e., a comparison of the total species lists.

$$\text{Similarity Index } \underset{X}{\text{Area}} : \underset{Y}{\text{Area}} = 100\left[\frac{\text{Co-occurring id. categories X} + \text{co-occurring id. categories Y}}{\text{Species Richness X} + \text{Species Richness Y}}\right]$$

The values range from 0 to 100% similarity. Where identification categories consist of lumped species, an overestimate of similarity could occur. Where they reflected juveniles or damaged specimens present also as identifiable species, an underestimate could occur. Also an elimination of higher taxa would remove most organisms from the sparse fauna areas (oligochaetes, nemerteans, nematodes, etc.).

III. RESULTS

Replicate samples were successfully collected all four seasons at all ten study areas and at all strata within each area. Intermediate height/depth replicate samples were successfully collected summer quarter at all ten study areas.

All intertidal samples were completely processed to a final data set per quarter. The first quarter subtidal samples were completely processed. The second, third, and fourth quarter subtidal samples were initially processed to concentrate the organisms and then curated for long term storage.

Over nine hundred species of plants and animals were identified to species during the course of this study. Crustaceans were most numerous (250+), followed by algae (225+), annelids (200+), and molluscs (125+).

In general, although each stratum of each study area had a unique community, distinct substratum/exposure-associated communities were recognizable. The results are presented below by study area. These are arranged in increasing substratum fineness and where habitat types were paired, the eastern then western site.

The data are given largely in tabular format. The tables in the "Results" section are abridged, normalized to 1 m^2 surface area, and include only the community species which are dominant by virtue of their high biomass, numerical abundance, or trophic importance. The values for species richness, diversity, total number (normalized to 1 m^2), and total biomass (per 1 m^2) were taken from the complete data sets given in Appendix I.

The Appendix I unabridged tables give number of replicates, means, and standard deviations in the sampled quadrat size; i.e., 0.05 m^2 x 15 cm or 0.25 m^2 (rock scrape). Cobble and rock entries are hybrid values obtained by normalizing the subsamples to 0.25 m^2 and adding them together. Fourth quarter methodology precluded adding the 0.01 m^2 subsamples with the residual 0.2 m^2 scrape. In this case values for both sizes were normalized to 0.25 m^2 and species by species the value was selected for the table which would give the best measure of the true value in the quadrat. In general for small organisms the 0.01 m^2 normalized value was taken, while for large organisms the 0.2 m^2 normalized value was used. ✓ means present but not quantified.

A note of caution: The tables in the "Results" section are abridged, and the values are means normalized to 1 m^2 surface area, rock and cobble x4, intertidal soft bottom x20, VanVeen grab x10.

Appendix I tables must be consulted for the complete data. All statements concerning patchiness are based on the replicate variance seen in Appendix I table standard deviations.

Results of the physical parameters measured (water temperature and salinity, sediment grain size analysis, and weather) are presented in Appendix II. Where noteworthy, they are mentioned in the study area results presented below.

Tongue Point

The substratum at Tongue Point over the tide heights and the depths sampled was solid rock. This rock was relatively smooth and flat with few pools or large crevices, and it sloped rather uniformly from +6' to 0'. This site was strongly exposed to local wave action from the north. However, oceanic swells generally were fairly well damped this far into the Strait.

Table 2a presents a summary of the biological community over the four quarters of sampling at +6'. This community was dominated by a few species of red algae, herbivorous gastropods, and planktivorous barnacles. Alaria was present in some quantity in the spring, but declined and vanished in the following quarters. It probably burned off during summer low tides. The other algae showed no consistent pattern of seasonal change, while the herbivores increase in number and biomass from spring through fall, declining in the winter. Between 1 May (Tongue Point sampling) and 15 May (Pillar Point sampling), a massive barnacle recruitment occurred in the entire region. Spring barnacle data here represented the population level prior to this major event. Barnacle number and biomass peaked in the fall and then declined. The small crustaceans intimately associated with the barnacles (Pancolus, Dynamenella, gammarids, and dipteran larvae) showed a similar seasonal pattern.

The massive barnacle recruitment dominates the seasonal changes in diversity, total number, and biomass. Although species richness increased from spring to summer (35 to 56) diversity declined because of the numerical dominance of the recently recruited barnacles. Number and biomass reflect the barnacle changes, both peaking in the fall.

Examination of the means and standard deviations in the Tongue Point +6 Appendix I table illustrate the spatial patchiness of the organisms in the +6 community. Still dramatic population changes such as that of the barnacles showed through this variance.

Table 2b gives the abridged results for Tongue Point +3. This community was structurally dominated by the brown alga Alaria, articulated corraline algae (Corallina and Bossiella), mussels, and barnacles. Associated with these are organisms which eat them--the herbivorous chitons (Cyanoplax) and gastropods (Collisella, Notoacmea, and Onchidella) and the carnivorous Thais and Leptasterias--and small organisms which inhabited the structure they provided--nematodes, polychaetes, oligochaetes, tanaids, isopods, amphipods, insect larvae, and the small Cucumaria. With the exceptions of Alaria which showed a summer peak, the massive barnacle recruitment, and perhaps the fall peaks of the largely detritivorous nematodes, oligochaetes, and Cucumaria pseudocurata, little consistent seasonal change in populations appeared, largely because of the patchiness of the major structural dominants. Corallina is a long-lived perennial alga which

Table 2a. Tongue Point +6 per m^2

	Spr 76		Sum 76		Fall 76		Win 77	
	#	wt	#	wt	#	wt	#	wt
Phaeophyta								
Alaria spp.		111.6		25.6		0		0
Rhodophyta								
Endocladia muricata		29.2		18.8		44.4		29.6
Gigartina papillata		26.0		60.8		15.6		54.0
Halosaccion glandiforme		36.4		73.2		16.4		73.2
Porphyra spp.		1.2		0		<0.4		7.2
Mollusca								
Gastropoda								
Collisella digitalis	131.2	90.0	251.2	136.0	499.2	176.8	225.2	98.4
Collisella strigatella	24.0	4.4	9.2	0.8	145.2	14.4	20.0	1.2
Littorina sitkana	29.2	0.4	313.2	20.0	1401.2	8.4	575.2	
Bivalvia								
Musculus pygmaeus	0		2550.0	2.4	62.0	0	5200.0	18.4
Mytilus spp.	16.4	1.6	121.2	3.2	907.2	28.8	138.8	9.6
Crustacea								
Cirripedia								
Balanus spp.	67.2	8.8	9922.0	235.6	14601.6	1116.4	3955.6	393.2
Chthamalus dalli	15.2	1.2	126.0	<0.4	3837.2	96.4	2635.2	70.0
Tanaidacea								
Pancolus californiensis	0		1523.2		1573.2	0.4	1055.2	
Isopoda								
Dynamenella sheareri	33.2		782.0	0.4	11745.2	43.6	4285.2	13.2
Amphipoda								
Gammaridea spp.	12.4	<0.4	211.2	<0.4	409.2	1.2	365.2	
Insecta								
Dipteran larvae spp.	8.0	<0.4	30.0	<0.4	1642.0	4.0	165.2	<0.4

Table 2a. Tongue Point +6 per m^2

	Spr 76	Sum 76	Fall 76	Win 77
Species Richness	35	56	43	55
Diversity, H^1	2.64	1.89	2.07	2.18
Total Number	495.6	15993.6	36995.2	18949.6
Total Biomass (g)	327.6	829.6	1588.4	964.8

Table 2b. Tongue Point +3 per m^2

	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Phaeophyta								
Alaria spp.		474.8		1380.4		1290.4		256.0
Rhodophyta								
Bossiella plumosa		99.6		34.4		522.8		97.2
Corallina vancouveriensis		1248.8		29.6		1526.8		445.2
Halosaccion glandiforme		11.2		232.0		97.2		144.0
Cnidaria								
Anthozoa								
Anthopleura elegantissima	416.0	50.0	246.8	40.4	379.2	14.0	50.0	9.2
Nematoda spp.	273.2	<0.4	646.0	<0.4	1628.0	<0.4	385.2	<0.4
Mollusca								
Amphineura								
Cyanoplax dentiens	38.0	0.8	45.2	0.4	61.2	2.8	30.0	14.0
Gastropoda								
Barleeia haliotiphila	5887.2	6.0	534.0	<0.4	1111.2		1210.0	
Collisella pelta	21.2	16.8	68.0	15.6	31.2	12.8	22.4	13.2
Notoacmea scutum	156.0	20.8	112.0	35.6	7.2	<0.4	10.0	1.2
Onchidella borealis	32.0	0.8	149.2	4.0	158.0	1.2	460.0	10.0
Thais spp.	44.0	1.6	62.4	22.0	29.6	3.2	20.0	<0.4
Bivalvia								
Mytilus spp.	1038.4	80.8	427.2	119.6	1323.2	76.4	260.0	1.2
Annelida								
Polychaeta								
Syllidae spp.	60.4		77.2		53.2		480.0	
Oligochaeta spp.	12.0		82.0		535.2		315.2	

Table 2b. Tongue Point +3 per m^2

	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Crustacea								
Cirripedia								
Balanus spp.	85.2	53.2	29422.0		1076.0		495.2	44.0
Tanaidacea								
Pancolus californiensis	440.0	0.4	576.0	<0.4	185.2	<0.4	437.2	<0.4
Isopoda								
Dynamenella sheareri	9356.0	26.4	1814.0	3.2	1271.2		2045.2	
Idotea spp.	885.2	10.0	107.2	1.2	46.4	4.8	70.0	1.2
Amphipoda								
Gammaridea spp.	7535.6		5481.6		5920.4	13.6	1430.0	
Decapoda								
Pagurus h. hirsutiusculus	44.0	1.6	24.0	32.0	66.0	2.8	0	
Insecta								
Dipteran larvae spp.	152.0	<0.4	5462.0		1642.0	4.0	130.0	<0.4
Echinodermata								
Asteroidea								
Leptasterias hexactis	2.0	0.4	1.2	0.8	5.2	0.4	10.0	<0.4
Holothuroidea								
Cucumaria pseudocurata	1459.2	35.2	3511.2	79.2	4629.2	105.6	1702.4	33.2
Species Richness	116		103		104		90	
Diversity, H'	2.53		2.04		2.78		3.20	
Total Number	29323.6		49499.2		23198.4		11464.4	
Total Biomass (g)	2468.0		2314.0		3876.4		1641.2	

occurred in discrete patches of very dense algal turf.

Species richness was fairly constant over the year. Diversity was depressed in the spring quarter because of the barnacle recruitment. That recruitment was mainly responsible for the total number peaking in the summer. Biomass peaked in the fall largely because both Alaria and large Corallina patches were sampled.

Table 2c presents the summary results of Tongue Point +0. This community was structured by the brown algae Alaria and Hedophyllum, the seagrass Phyllospadix, the boring clam Hiatella arctica, and the large barnacles Balanus cariosus and B. nubilis. Important herbivores were the chitons, Lacuna, and the spider crab Pugettia gracilis and carnivores, Cancer oregonesis and Leptasterias. Small organisms associated with the structural organisms included the polychaetes, tanaids, isopods, and amphipods. No consistent seasonal population changes were detectable because of the over-riding patchiness of the major structural organisms of this community.

Species richness, diversity, and total biomass were high throughout the year. However, again the extreme patchiness of the large organisms at this level obscured any seasonal trends.

Table 2d gives the abridged results of Tongue -5 m and -10 m. The community at Tongue -5 m was dominated by the kelp Nereocystis and the urchin Strongylocentrotus drobachiensis. Grazers besides the urchins included chitons, Acmaea mitra, Calliostoma, Lirularia, Margarites and Pugettia gracilis. The grazers exerted obvious strong pressure on this community. The only algae present in quantity have thwarted herbivores by chemical noxia (Desmarestia), structurally unpalatable (the calcareous alga Calliarthron), or becoming too large to eat (Nereocystis). Numerical dominance at this level was by small organisms associated with Calliarthron--Granulina, the isopods, and amphipods. The community at -10 m was also dominated by grazers (chitons, Acmaea, Lirularia, Strongylocentrotus spp.). However, suspension feeders made an appearance (Calyptraea and Spirorbis).

Table 2e presents the results of the summer quarter vertical distribution sampling for Tongue Point in abridged form. The obviousness of the zonation of each species needs little comment. Figure 11 presents an example of this zonation for the brown alga Alaria and the red Halosaccion glandiforme. Virtually no organism failed to show a peak in number and/or biomass over a narrow tidal range. These data clearly demonstrated that +0', +3', and +6' represented an adequate coverage of the species present in the intertidal at Tongue Point.

Table 2c. Tongue Point +0 per m^2

	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Phaeophyta								
Alaria sp.		5132.0		3666.4		3534.8		844.4
Hedophyllum sessile		196.8		1516.8		190.0		17.2
Rhodophyta								
Iridaea cordata		84.4		59.6		62.0		41.2
Odonthalia floccosa		12.4		32.8		25.6		8.0
Spermatophyta								
Phyllospadix scouleri		<0.4		0		1107.2		0
Mollusca								
Amphineura								
Katharina tunicata	0		6.0	102.0	2.0	74.0	1.2	75.2
Tonicella lineata	2.0	1.2	10.0	22.0	15.2	9.2	19.2	9.2
Gastropoda								
Lacuna variegata	47.2	<0.4	288.4	0.8	19.2	0.4	35.2	<0.4
Velutina laevigata	0		14.4	<0.4	50.0	1.2	25.2	<0.4
Bivalvia								
Hiatella arctica	133.2	3.2	69.2	0.4	115.2	1.2	80.0	
Annelida								
Polychaeta								
Cirratulidae								
Cirratulus cirratus	14.0		10.0		67.2		30.0	
Nereidae								
Nereis spp.	62.4		31.2		265.2		395.2	
Sabellidae spp.	5.2		41.2		174.4		545.2	

Table 2c. Tongue Point +0 per m^2

	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Crustacea								
Cirripedia								
Balanus cariosus	60.0	231.6	88.0	298.0	116.0	110.8	65.2	18.0
Balanus nubilus	75.2	1418.8	24.0	133.6	6.0	70.0	128.0	990.8
Tanaidacea								
Anatanais normani	174.0	<0.4	150.0	<0.4	395.2	<0.4	265.2	<0.4
Isopoda								
Limnoria algarum	47.2	<0.4	130.4	<0.4	175.2	<0.4	120.0	<0.4
Amphipoda								
Gammaridea spp.	554.4	<1.6	214.4	<1.0	1979.2	4.4	1015.2	
Decapoda								
Cancer oregonensis	12.0	5.2	4.0	9.6	10.0	12.0	17.6	1.2
Oedignathus inermis	1.2	<0.4	11.2	12.8	3.2	<0.4	5.2	<0.4
Pugettia gracilis	5.2	<0.4	62.0	0.4	56.0	2.0	0	
Echinodermata								
Asteroidea								
Leptasterias hexactis	19.2	6.4	3.2	<0.4	30.8	7.6	5.2	0.4
Species Richness	209		148		138		106	
Diversity, H'	2.32		2.25		2.62		2.70	
Total Number	4052.8		2914.8		6917.6		4012.4	
Total Biomass (g)	7566.0		6019.6		5335.6		2128.4	

Table 2d. Tongue Point subtidal per m^2

	-5m #	-5m wt	-10m #	-10m wt
Phaeophyta				
Desmarestia viridis		62.0		<0.4
Nereocystis luetkana		4158.4		0
Rhodophyta				
Calliarthron tuberculosum		906.8		0.4
Mollusca				
Amphineura				
Lepidozona mertensii	0		32.0	7.6
Tonicella lineata	22.0	7.2	40.0	25.2
Gastropoda				
Acmaea mitra	8.0	8.0	21.2	12.8
Amphissa columbiana	108.0	9.2	6.8	5.2
Calliostoma ligatum	32.0	1.6	0	
Calyptraea fastigiata	0		14.8	4.0
Fusitriton oregonensis	2.0	141.6	0	
Granulina margaritula	394.0	2.8	2.8	<0.4
Lirularia lirulata	142.0	0.8	9.2	<0.4
Margarites pupillus	54.0	2.0	0	
Ocenebra lurida	18.0	1.6	1.2	<0.4
Nereidae				
Nereis pelagica	202.0		0	
Serpulidae				
Spirorbis spp.	56.0		386.8	
Crustacea				
Isopoda				
Exosphaeroma rhomburum	160.0	0.4	0	
Amphipoda				
Ampithoe sp. C	294.0	1.6	0	
Aoroides columbiae	204.0	<0.4	2.8	<0.4
Hyale frequens	206.0		0	
Photis bifurcata	454.0	0.8	0	
Photis brevipes	1960.0	2.4	0	

Table 2d. Tongue Point subtidal per m^2

	-5m		-10m	
	#	wt	#	wt
Decapoda				
Cancer oregonensis	4.0	0.4	0	
Pagurus spp.	178.0	7.2	6.4	<0.4
Pugettia gracilis	230.0	6.0	1.2	<0.4
Echinodermata				
Echinoidea				
Strongylocentrotus droebachiensis	42.0	3164.0	9.2	24.4
Strongylocentrotus franciscanus	0		4.0	684.8
Species Richness	133		59	
Species Diversity - H'	2.57		2.10	
Total Number	6004.0		603.6	
Total Biomass (g)	8538.8		778.0	

Table 2e. Tongue Point 11 July 1976 Vertical Distribution per m^2

Taxon		+0	+1	+2	+3	+4	+5	+6	+7
Phaeophyta									
Alaria sp.	wt	3666.4	2358.0	2496.8	1380.4	378.0	151.6	25.6	0
Fucus distichus	wt	0	0	0	2.0	88.0	310.0	17.6	847.6
Hedophyllum sessile	wt	1516.8	4978.8	0	0	0	0	0	0
Rhodophyta									
Antithamnion dendroideum	wt	49.2	< 0.4	0	0	0	0	< 0.4	0
Bossiella plumosa	wt	0	37.6	219.6	34.4	22.0	< 0.4	1.6	< 0.4
Corallina vancouveriensis	wt	< 0.4	32.0	893.6	29.6	576.0	4.0	24.0	< 0.4
Gigartina papillata	wt	0	0.4	4.8	18.4	34.8	170.4	60.8	12.8
Halosaccion glandiforme	wt	< 0.4	< 0.4	5.6	232.0	738.8	1499.6	73.2	0
Hymenena sp.	wt	14.0	22.8	90.8	3.6	1.6	0	2.8	0
Iridaea cordata	wt	59.6	34.8	0	0	0	0	0	0
Iridaea heterocarpa	wt	0	0	0	2.0	10.0	52.8	2.8	0
Microcladia borealis	wt	< 0.4	1.2	69.2	30.0	20.4	87.6	2.4	< 0.4
Pterosiphonia bipinnata	wt	< 0.4	0	0	0.8	< 0.4	134.8	0	0
Rhodomela larix	wt	< 0.4	0	< 0.4	0.4	0	162.0		0
Spermatophyta									
Phyllospadix scouleri	wt	0	1.6	115.2	0	0	1.2	0	0
Cnidaria									
Anthozoa									
Anthopleura	#	5.2	0	742.0	246.8	8.0	0	0	0
elegantissima	wt	< 0.4		114.4	40.4	< 0.4			
Platyhelminthes									
Turbellaria	#	0	0	0	161.2	402.0	360.0	0	0
sp.	wt				< 0.4	< 0.4	< 0.4		
Nemertea	#	32.0	10.0	88.8	142.4	14.0	80.0	2.4	6.0
sp.	wt	< 0.4	< 0.4	< 0.4	0.8	0.4	0.8	0.8	< 0.4
Nematoda	#	227.2	294.0	1178.0	646.0	42.0	10.0	38.0	0
sp.	wt	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	
Mollusca									
Amphineura									
Cyanoplax	#	2.0	4.0	50.0	45.2	162.0	12.0	1.2	0
dentiens	wt	< 0.4	< 0.4	2.8	0.4	< 0.4	0.4	< 0.4	

Table 2e. Tongue Point 11 July 1976 Vertical Distribution per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Katharina	#	6.0	16.0	54.0	9.2	0	0	0	0
tunicata	wt	25.5	480.0	166.8	20.4				
Tonicella	#	10.0	6.0	2.0	0	0	0	0	0
lineata	wt	22.0	6.4	< 0.4					
Gastropoda									
Barleeia	#	6.0	48.0	2492.0	534.0	388.0	0	4.0	0
haliotiphila		< 0.4	< 0.4	3.2	< 0.4	< 0.4		< 0.4	
Collisella	#	0	0	12.0	31.2	8.0	164.0	251.2	22.0
digitalis	wt			9.6	13.6	3.2	15.6	136.0	< 0.4
Collisella	#	5.2	2.0	116.0	68.0	92.0	58.0	3.2	0
pelta	wt	< 0.4	< 0.4	48.8	17.6	22.4	37.2	0.4	
Collisella	#	0	0	30.0	65.2	104.0	114.0	9.2	2.0
strigatella	wt			2.0	4.8	7.2	7.6	0.8	< 0.4
Lacuna	#	288.0	1148.0	1986.0	200.0	238.0	170.0	26.0	0
variegata	wt	0.8	2.8	2.8	0.4	0.8	< 0.4	< 0.4	
Littorina	#	0	0	4.0	43.2	6.0	1594.0	313.2	1730.0
sitkana	wt			< 0.4		4.0	69.6	20.0	19.6
Notoacmea	#	0	0	0	112.0	16.0	0	0	0
scutum	wt				35.6	4.8			
Onchidella	#	0	2.0	10.0	149.2	14.0	354.0	0	0
borealis	wt		< 0.4	0.4	4.0	0.8	18.4		
Thais	#	3.2	6.0	6.0	62.4	36.0	60.0	0	0
spp.	wt	4.8	< 0.4	< 0.4	22.0	34.8	104.8		
Bivalvia									
Hiatella	#	69.2	118.0	4.0	0	0	0	2.0	0
arctica	wt	0.4	0.4	< 0.4				< 0.4	
Musculus	#	5.2	60.0	814.0	201.2	172.0	2980.0	2550.0	6.0
pygmaeus	wt	< 0.4	< 0.4	2.4	0.4	0.4	16.4	2.4	< 0.4
Mytilus	#	0	0	28.0	19.2	122.0	0	0	0
edulis	wt			12.0	118.0	10.8			
Mytilus	#	89.2	518.0	968.0	408.0	2624.0	150.0	121.2	2.0
sp.(juv.)	wt	0.4	0.4	6.0	1.6	2.4	< 0.4	3.2	< 0.4

Table 2e. Tongue Point 11 July 1976 Vertical Distribution per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Annelida									
Polychaeta									
Lumbrineridae sp.	#	18.0	68.0	14.0	1.2	0	0	0	0
Sabellidae	#	41.2	12.0	28.5	14.0	0	2.0	0	0
sp.									
Syllidae									
syllis sp.	#	10.0	4.0	204.0	86.4	14.0	16.0	25.2	4.0
Oligochaetea									
sp.	#	20.0	28.0	354.0	102.0	50.0	152.0	12.0	4.0
Crustacea									
Cirripedia									
Balanus	#	88.0	158.0	108.0	2822.0	1538.0	412.0	178.0	22.0
cariosus	wt	298.0	142.0	1.2	284.8	171.6	341.2	146.4	<0.4
Balanus	#	27.2	382.0	4.0	34.0	238.0	1144.0	3150.0	244.0
glandula	wt	1.2		<0.4	3.6	2.4	11.6	78.4	47.2
Balanus	#	24.0	22.0	0	0	0	0	0	0
nubulus	wt	133.6	1.2						
Balanus	#	734.0	3340.0	2294.0	26566.0	28112.0	84434.0	6594.0	1280.0
sp.(juv.)	wt	7.6		6.0	136.4	319.6	55.6	10.8	
Chthamalus	#	0	8.0	0	50.0	0	138.0	126.0	0
dalli	wt		<0.4		<0.4		1.6		
Tanaidacea									
Anatanais	#	150.0	154.0	120.0	118.0	4.0	0	0	0
normani	wt	<0.4	<0.4	<0.4	<0.4	<0.4			
Leptochelia	#	150.0	368.0	122.0	7.2	0	0	27.2	0
dubia	wt	<0.4	<0.4	<0.4	<0.4			<0.4	
Pancolus	#	11.2	0	170.0	576.0	1302.0	1376.0	1523.2	0
californiensis		<0.4		<0.4			10.0		
Isopoda									
Cirolana	#	0	0	64.0	31.2	2.0	2644.0	0	0
harfordi	wt			<0.4	<0.4	<0.4	4.0		
Dynamenella	#	0	34.0	3712.0	1814.0	2100.0	0	782.0	0
sheareri	wt		<0.4	12.0	3.2	4.8		0.4	

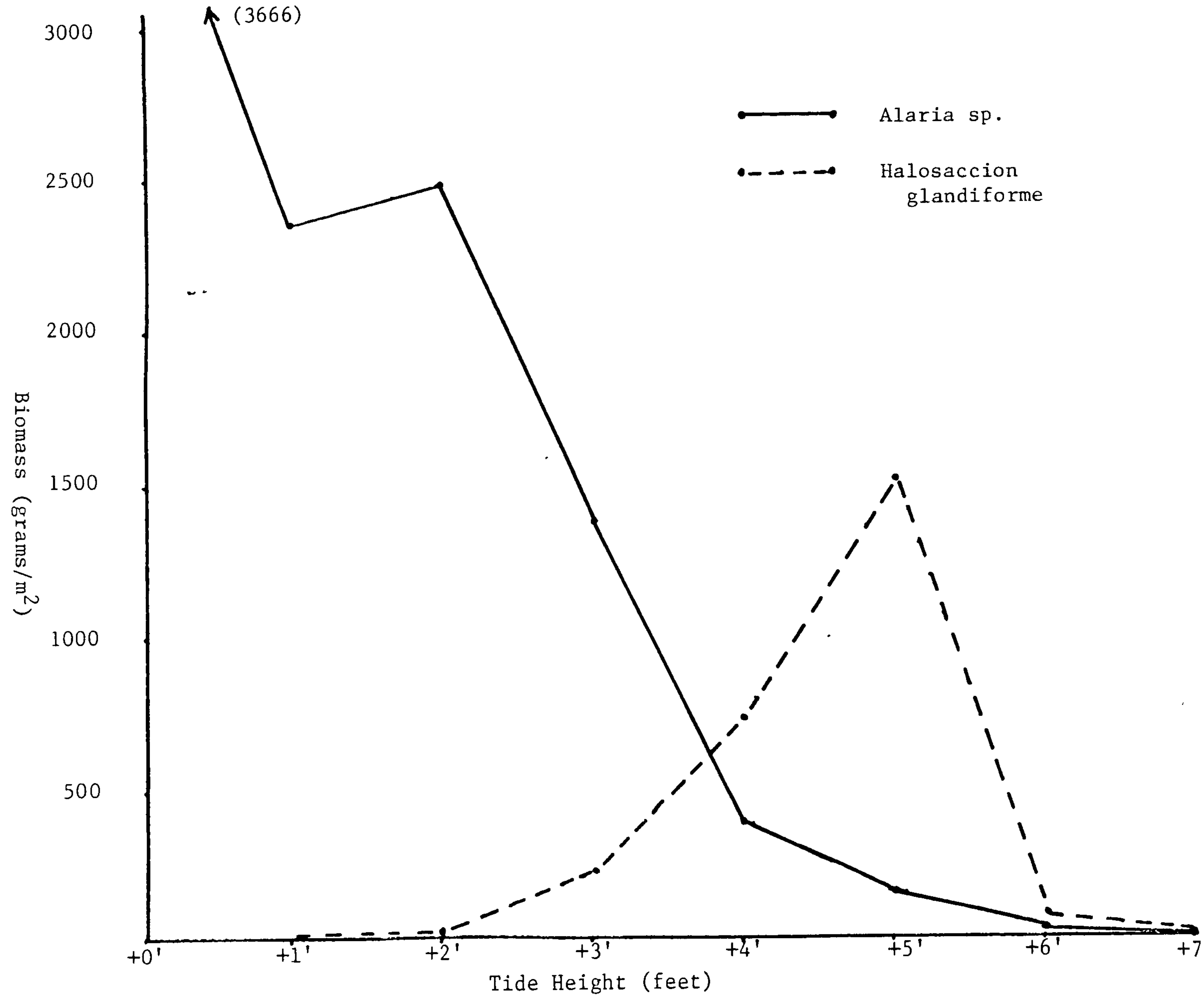
Table 2e. Tongue Point 11 July 1976 Vertical Distribution per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Idotea wosnesenskii	#	3.2	2.0	116.0	105.2	0	0	0	0
	wt		< 0.4	29.2	1.2				
Limnoria algarum	#	130.4	112.0	0	0	0	0	0	0
	wt	< 0.4	< 0.4						
Munna chromatocephala	#	20.0	44.0	38.8	7.2	58.0	10.0	2.0	0
	wt	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	
Amphipoda									
Ampithoe simulans	#	0	12.0	0	3499.2	200.0	98.0	0	0
	wt		< 0.4				< 0.4		
Cercops compactus	#	67.2	16.0	0	0	0	0	0	0
	wt	< 0.4	< 0.4						
Hyale anceps	#	0	2.0	0	390.0	106.0	38.0	40.0	0
	wt		< 0.4			< 0.4	< 0.4	< 0.4	
Oligochinus lighti	#	0	4.0		401.2	478.0	102.0	87.2	0
	wt		< 0.4				< 0.4	< 0.4	
Decapoda									
Cancer oregonensis	#	4.0	12.0	2.0	0	0	0	0	0
	wt	9.6	6.0	< 0.4					
Pagurus h. hirsutiusculus	#	0	0	42.0	24.0	2.0	2.0	0	0
	wt			5.6	32.0	1.6	< 0.4		
Pugettia gracitis	#	62.0	22.0	292.0	0	0	0	0	0
	wt	0.4	0.4	36.8					
Insecta									
Diptera spp.	#	6.0	196.0	518.0	5462.0	1900.0	892.0	233.2	30.0
	wt	< 0.4	< 0.4					< 0.4	< 0.4
Echinodermata									
Asteroidea									
Leptasterias hexactis	#	1.2	0	16.0	1.2	0	0	0	0
	wt	< 0.4		< 0.4	0.8				
Holothuroidea									
Cucumaria pseudocurata	#	0	0	730.0	3511.2	4.0	2.0	0	0
				22.0	79.2	< 0.4	< 0.4		

Table 2e. Tongue Point 11 July 1976 Vertical Distribution per m^2

	+0	+1	+2	+3	+4	+5	+6	+7
Species number	154	112	124	113	82	70	57	32
Diversity - H'	2.30	2.27	3.13	2.01	1.76	0.93	1.92	1.41
Total number	2901.2	7595.2	20407.2	50132.4	44082.0	98674.0	16606.8	3376.0
Total biomass(g)	6019.6	8247.2	4620.0	2622.0	2582.0	3306.8	829.6	931.0

Figure 11. Tongue Point, Algal Zonation



Pillar Point

The intertidal at Pillar Point from +0' to +7' was solid rock. Unlike Tongue, the rock was an irregular conglomerate, not smooth at all. The slope varied from 45° to 90°. There were no large crevices, and no pools were sampled. Seasonally, sand scouring at +0' might be significant as the rock at that level was adjacent to a sandy bottom. This site was exposed to both extreme wave action from the north and to rather continuous oceanic swells.

Subtidally, the substratum was medium and fine sand at -5 m and fine sand at -10 m.

Salinity in winter quarter showed some slight freshwater influence from the Pysht River, likely of no biological consequence.

Table 3a presents the abridged results for Pillar Point +6'. The community at this level was relatively simple and was dominated by grazers (*Collisella digitalis* and *Littorina* spp.) and by the planktivorous barnacles (*Balanus glandula* and *Chthamalus dalli*). Associated with this barnacle matrix were isopods and dipteran larvae. Pillar was sampled after the massive early May barnacle set. As a result of barnacle mortality post-set, the barnacle population, total number, and biomass showed a decline spring through fall. There might be additional fall recruitment or the increase might have been just a product of this patchy distribution. Populations of the grazers showed no dramatic seasonal pattern, in part perhaps also because of their patchy distribution. Species richness remained fairly constant and the diversity reflected the dominance of the barnacles.

Table 3b presents a summary of the +3' Pillar Point data set. The community at this level was structurally dominated by algae (*Alaria*, *Hedophyllum*, and to a lesser extent *Corallina*, *Gigartina*, and *Iridaea*), *Mytilus* spp., and barnacles (*Balanus* spp.). Two sets of organisms were associated with these structuring components. There were those which eat them, the herbivores (*Collisella* spp., *Lacuna*, and the chitons) and the carnivores (*Thais* spp., and *Cancer oregonensis*). And there were small organisms intimately dependent on their physical structuring of the dominants: nematodes, polychaetes, oligochaetes, tanaids, isopods, amphipods, and insect larvae.

With the possible exception of *Alaria*, which showed a summer biomass peak, the "seasonal change" in the population of all the structuring organisms reflected their patchiness in distribution. This patchiness also overwhelmed seasonal patterns in both the populations of associated organisms and overall total numbers and biomass. Species richness and diversity remained high and fairly constant through all four quarters.

Table 3a. Pillar Point +6 per m^2

	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Rhodophyta								
Gigartina papillata		0.4		14.0		2.4		5.6
Mollusca								
Gastropoda								
Collisella digitalis	242.0	108.0	152.0	82.4	83.2	65.2	110.0	102.4
Littorina scutulata	216.0	7.6	417.2	33.2	176.0	12.4	430.0	18.4
Littorina sitkana	271.2	4.8	603.2	29.2	1254.0	43.6	1190.0	41.6
Crustacea								
Cirripedia								
Balanus glandula	7795.2	135.2	8708.0	207.6	2044.0	53.6	5170.0	195.6
Chthamalus dalli	17836.0	317.2	5681.2	25.2	3574.0	71.2	7925.2	216.4
Isopoda								
Dynamenella sheareri	0		1.2	<0.4	431.6		128.0	5.2
Exosphaeroma media	0		1.2	<0.4	1635.2	1.2	535.2	
Insecta								
Dipteran larvae spp.	624.8		572.0	7.6	478.0		1115.2	
Species Richness	26		28		30		38	
Diversity, H'	0.92		1.14		2.08		1.77	
Total Number	27282.0		16222.8		11656.0		18942.0	
Total Biomass (g)	639.6		442.8		377.6		725.2	

Table 3b. Pillar Point +3 per m^2

	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Phaeophyta								
Alaria spp.		1693.2		2346.0		261.6		168.0
Hedophyllum sessile		1557.2		1387.6		394.8		1723.2
Rhodophyta								
Corallina vancouveriensis		48.4		66.4		15.6		139.2
Gigartina papillata		242.0		15.6		100.4		4.4
Halosaccion glandiforme		63.2		42.4		62.4		2.8
Iridaea cordata		185.6		140.0		122.8		38.8
Odonthalia floccosa		19.2		41.2		84.8		16.4
Nemertea spp.	100.0	<0.4	175.2	<0.4	70.0	<0.4	160.0	<0.4
Nematoda spp.	882.0	<0.4	2968.0	<0.4	160.0	<0.4	3745.2	<0.4
Mollusca								
Amphineura								
Cyanoplax dentiens	32.0	0.8	6.0	<0.4	0		31.2	1.2
Katharina tunicata	38.0	496.0	12.0	164.4	8.0	125.2	28.4	607.2
Gastropoda								
Collisella pelta	60.4	14.0	9.2	<0.4	0		50.0	2.4
Lacuna variegata	91.2	1.2	529.2	8.8	206.0	0.8	60.0	<0.4
Thais spp.	60.4	60.8	25.6	<1.6	15.6	17.6	40.0	<1.2
Bivalvia								
Hiatella arctica	132.0	5.6	52.0	0.4	13.2	<0.4	505.2	9.2
Mytilus spp.	2065.2	2651.6	1526.4	11.2	714.4	62.4	2970.4	28.8
Annelida								
Polychaeta								
Sabellidae spp.	38.4		656.4		652.4		510.4	

Table 3b. Pillar Point +3 per m^2

	Spr 76		Sum 76		Fall 76		Win 77	
	#	wt	#	wt	#	wt	#	wt
Syllidae spp.	135.6		118.4		221.2		110.0	
Oligochaeta spp.	95.2		498.0		298.0		280.0	
Pycnogonida spp.	21.6		63.6		45.6		72.8	
Crustacea								
Cirripedia								
Balanus spp.	4905.2	3838.4	2218.4	294.8	885.2		2020.4	2659.0
Tanaidacea								
Leptochelia dubia	521.2	0.4	766.0		195.2	<0.4	4040.0	1.6
Isopoda								
Munna chromatocephala	104.0	<0.4	125.2	<0.4	99.2	<0.4	340.0	<0.4
Amphipoda								
Caprellidea								
Cercops compactus	21.2	<0.4	79.2	<0.4	164.0	<0.4	570.0	
Gammaridea spp.	416.4		217.6		524.0		725.2	
Decapoda								
Cancer oregonensis	6.0	12.8	5.2	<0.4	0		16.0	14.0
Insecta								
Dipteran larvae spp.	279.2	<0.4	330.0	<0.4	283.2	<0.4	510.0	<0.4
Species Richness	169		148		106		128	
Diversity, H'	3.11		3.08		3.21		2.87	
Total Number	11540.4		12330.4		6260.0		19447.2	
Total Biomass (g)	11765.6		5078.4		1408.4		5602.8	

An abridged data set for Pillar Point +0' appears in Table 3c. Two things stood out in this community. The community was totally structurally dominated by plants (Alaria, Egregia, Iridaea, and Phyllospadix), and large barnacles were absent. Sand scouring might have been responsible for the latter. Herbivores (chiton, Lacuna, Idotea, and Pugettia) and small algal-associated animals (polychaetes, oligochaetes, tanaids, isopods, and amphipods) were also abundant. Cancer oregonensis was the only major carnivore collected.

Plant patchiness obscured all seasonal patterns in species populations, total number, and total biomass. Species richness was high and fairly constant through all four quarters.

Table 3d gives a summary of the subtidal Pillar Point data set. The communities at -5 m and -10 m were similar with the exception of eel grass (Zostera) at -5 m. They were dominated by epifaunal and infaunal deposit feeders. Species richness and diversity were high at both levels. Neither density nor measured biomass were particularly high at either level. These communities run energetically on imported organics and an unknown amount fixed at the levels by the largely microscopic epiflora.

The results of the summer quarter vertical distribution sampling for Pillar Point are presented in abridged form in Table 3e. The zonation of virtually all the organisms was amply clear. Figure 12 presents the zonation of the grazing gastropods Collisella digitalis, C. pelta, Lacuna variegata, and Littorina sitkana. The three strata chosen for quarterly sampling clearly covered the species present in the intertidal at Pillar Point.

Table 3c. Pillar Point +0 per m^2

	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Phaeophyta								
Alaria spp.		3370.4		522.0		95.6		314.4
Egregia menziesii		802.0		5071.2		0		345.6
Rhodophyta								
Iridaea cordata		1052.0		180.0		185.6		10.0
Neoptilota asplenioides		71.6		70.8		0		0
Spermatophyta								
Phyllospadix scouleri		3.6		1205.6		6180.8		902.
Mollusca								
Amphineura								
Katharina tunicata	5.2	1832.0	0		0		1.2	<0.4
Mopalia spp.	15.6	47.6	0		0		8.4	37.2
Tonicella lineata	26.2	15.6	8.0	15.2	0		8.0	3.6
Gastropoda								
Lacuna variegata	68.0	<0.4	8342.0	144.0	213.2	2.8	25.2	<0.4
Bivalvia								
Mytilus sp. (juv.)	191.2	<0.4	478.0	3.2	127.2	<0.4	25.2	<0.4
Annelida								
Polychaeta								
Arenicolidae spp.	1.2		800.0		745.2		5.2	
Lumbrineridae								
Lumbrineris spp.	6.4		194.0		369.2		15.2	
Syllidae spp.	1.2		168.0		170.4		15.2	
Oligochaeta	0		654.0		3183.2		5.2	
Crustacea								
Tanaidacea								
Anatanais normani	27.2	<0.4	164.0	<0.4	276.0	<0.4	595.2	<0.4

Table 3c. Pillar Point +0 per m^2

	Spr 76		Sum 76		Fall 76		Win 77	
	#	wt	#	wt	#	wt	#	wt
Isopoda								
Idotea spp.	21.2	0.4	324.0	2.0	622.4	12.0	92.8	0.8
Amphipoda								
Caprellidea								
Caprella spp.	6.0	<0.4	16.0	<0.8	866.2	<2.4	25.2	<0.4
Gammaridea	158.8	<6.0	2028.0		2258.0		381.2	<0.8
Decapoda								
Cancer oregonensis	1.2	15.6	14.0	0.4	6.0	0.8	5.2	1.6
Pugettia gracilis	0		72	1.6	130.0	26.8	27.6	0.8
Species Richness	123		136		126		101	
Diversity, H'	1.79		2.32		2.47		2.96	
Total Number	728.8		15216.0		10678.0		2728.8	
Total Biomass (g)	7548.0		16044.0		17471.6		1943.2	

Table 3d. Pillar Point subtidal per m^2

	-5m		-10m	
	#	wt	#	wt
Spermatophyta				
Zostera marina		96.0		0
Mollusca				
Bivalvia				
Macoma spp.	23.0	<1.0	60.0	<1.0
Mysella tumida	267.0	<1.0	163.0	<1.0
Psephidia lordi	47.0	<1.0	153.0	<1.0
Tellina spp.	427.0	5.0	133.0	1.0
Annelida				
Polychaeta				
Capitellidae				
Capitella capitata	400.0		57.0	
Mediomastus sp.	1440.0		927.0	
Cirratulidae				
Tharyx multifilis	53.0		310.0	
Orbiniidae				
Scoloplos sp.	107.0		93.0	
Spionidae				
Prionospio steenstrupi	80.0		93.0	
Crustacea				
Cumacea				
Diastylis sp.	247.0	1.0	50.0	<1.0
Tanaidacea				
Leptochelia dubia	53.0	<1.0	427.0	<1.0
Amphipoda				
Paraphoxus spp.	850.0		483.0	
Protomedeia sp. A	140.0	<1.0	20.0	<1.0
Synchelidium shoemakeri	303.0	<1.0	227.0	<1.0

Table 3d. Pillar Point subtidal per m^2

	-5m		-10m	
	#	wt	#	wt
Species Richness	92		91	
Diversity	3.07		3.26	
Total Numbers	6123.0		4715.0	
Total Biomass (g)	109.0		73.0	

Table 3e. Pillar Point 9 August 1976 per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Chlorophyta									
Ulva spp.	wt	44.8	2.8	<0.4	24.0	3.6	42.0	< 0.4	< 0.4
Phaeophyta									
Alaria sp.	wt	522.0	4226.4	6015.2	2346.0	1975.6	316.0	0	0
Egregia menziesii	wt	5071.2	0	0	0	0	0	0	0
Hedophyllum sessile	wt	0	79.6	494.8	1387.6	483.2	12.8	0	0
Rhodophyta									
Corallina vancouveriensis	wt	0.8	21.2	34.4	64.8	251.6	234.4	0	0
Gigartina papillata	wt	2.4	0.4	0	15.6	23.2	144.4	14.0	16.4
Halosaccion glandiforme	wt	0	1.6	0.4	42.4	16.0	463.6	0	0
Iridaea cordata	wt	180.0	255.2	178.4	140.0	< 0.4	9.2	0	0
Iridaea heterocarpa	wt	0	0	0	15.6	92.8	22.8	0	0
Microcladia borealis	wt	< 0.4	0.8	0.4	46.0	90.8	154.4	0	0
Odonthalia floccosa	wt	24.8	18.4	70.4	41.2	30.0	196.8	0	0
Rhodoglossum californicum	wt	493.6	0	0	< 0.4	0	0	0	0
Spermatophyta									
Phyllospadix scouleri	wt	1205.6	0	0	0	0	0	0	0
Nemertea	#	60.0	4.0	2.0	175.2	130.0	84.0	0	0
spp.		< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4		
Nematoda	#	766.0	144.0	138.0	2968.0	3376.0	1224.0		2.0
spp.	wt	< 0.4	< 0.4	< 0.4			< 0.4		< 0.4
Mollusca									
Amphineura									
Cyanoplax	#	0	0	0	6.0	16.0	16.0	0	0
dentiens	wt				< 0.4	1.2			
Katharina	#	0	0	24.0	12.0	4.0	2.0	0	0
tunicata	wt			604.8	164.4	117.6	42.0		
Tonicella	#	8.0	4.0	14.0	0	0	0	0	0
lineata	wt	15.2	3.6	4.0					
Gastropoda									
Barlecia	#	0	8.0	8.0	135.2	294.0	134.0	0	0
haliotiphilia	wt		< 0.4	< 0.4	< 0.4	< 0.4	< 0.4		
Collisella	#	0	0	0	0	0	0	152.0	48.0
digitalis	wt							82.4	58.8

Table 3e. Pillar Point 9 August 1976 per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Collisella	#	2.0	0	40.0	9.2	42.0	260.0	4.0	0
pelta	wt	<0.4		< 0.4	<0.4	< 0.4	22.8	2.0	
Lacuna	#	8334.0	242.0	306.0	529.2	300.0	88.0	0	0
variegata	wt	144.0	4.4		8.8	5.6	< 0.4		
Littorina	#	0	0	0	0	0	0	417.2	102.0
scutulata	wt							33.2	4.0
Littorina	#	0	0	0	0	2.0	10.0	603.2	1250.0
sitkana	wt					< 0.4	< 0.4	29.2	58.0
Onichidella	#	0	0	0	1.2	6.0	44.0	0	0
borealis	wt				< 0.4	< 0.4	0.8		
Thais	#	0	2.0	6.0	25.6	68.0	64.0	3.2	0
spp.	wt		0.4	< 1.2	< 1.2		40.0	6.0	
Bivalvia									
Adula	#	98.0	32.0	26.0	334.0	652.0	78.0	0	0
californiensis	wt	< 0.1	< 0.1	< 0.1	2.4	1.6	< 0.4		
Hiatella	#	38.0	34.0	28.0	52.0	152.0	2.0	0	0
arctica	wt	<0.4	< 0.4	<0.4	0.4	2.0	< 0.4		
Musculus	#	0	10.0	0	45.2	30.0	224.0	0	0
pygmaeus	wt		<0.4		< 0.4	< 0.4			
Mytilus	#	0	0	0	0	0	88.0	0	0
californianus	wt						265.6		
Mytilus	#	6.0	0	0	15.2	0	506.0	27.2	0
edulis	wt	<0.4			0.8		4.8	8.4	
Mytilus	#	478.0	22.0	16.0	1511.2	3028.0	519.6	27.2	0
sp.(juv.)		3.2	<0.4	<0.4	10.4	10.0	29.6	1.6	
Annelida									
Polychaeta									
Arenicolidae spp.	#	936.0	0	8.0	490.0	154.0	4.0	0	0
Lumbrineridae									
Lumbrineris spp.	#	200.0	24.0	8.0	66.4	6.0	22.0	0	0
Nereidae									
Nereis sp.	#	58.0	42.0	10.0	3.6	32.0	2.0	0	0
Opheliidae									
Armandia brevis	#	78.0	0	0	0	0	0	0	0

Table 3e. Pillar Point 9 August 1976 per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Phyllodocidae									
Eulalia spp.	#	70.0	34.0	6.0	24.0	62.0	0	0	0
Sabellidae									
spp.	#	3.0	128.0	238.0	656.4	952.0	520.5	0	0
Spionidae									
Polydora spp.		56.0	92.0	48.0	2.0	26.0	0	0	0
Syllidae									
Syllis spp.	#	160.0	4.0	6.0	83.2	50.0	212.0	3.2	0
Oligochaeta									
spp.	#	654.0	6.0	0	498.0	352.0	592.0	2.0	0
Crustacea									
Cirripedia									
Balanus	#	50.0	96.0	218.0	678.0	7364.0	3932.0	0	0
cariosus	wt	0.4	7.2	45.6	289.6	466.8	2195.6		
Balanus	#	30.0	32.0	136.0	489.2	1296.0	9694.0	8708.0	3374.0
glandula	wt	7.2	0.8	13.6	0.8	188.4	66.0	207.6	402.0
Balanus	#	0	36.0	84.0	1.2	0	0	0	0
nubilus	wt		667.2	1575.2	0.4				
Balanus	#	200.0	686.0	714.0	1050.0	3348.0	4702.0	4.0	140.0
sp.(juv.)	wt	0.4			4.0	3.2	30.8	<0.4	<0.4
Chthamalus	#	0	0	0	2.0	40.0	16.0	5681.2	194.0
dalli	wt				<0.4	<0.4	<0.4	25.2	2.0
Cumacea									
Cumella	#	0	0	4.0	39.2	86.0	20.0	0	0
vulgaris	wt			<0.4	<0.4	<0.4	<0.4		
Tanaidacea									
Anatanais	#	164.0	344.0	422.0	45.2	2.0	28.0	0	0
normani	wt	<0.4	<0.4		<0.4	<0.4	<0.4		
Leptochelia	#	22.0	14.0	62.0	766.0	724.0	32.0	0	0
dubia	wt	<0.4	<0.4	<0.4			<0.4		
Pancolus	#	28.0	0	0	50.0	232.0	792.0	0	0
californiensis	wt	<0.4			<0.4	<0.4			

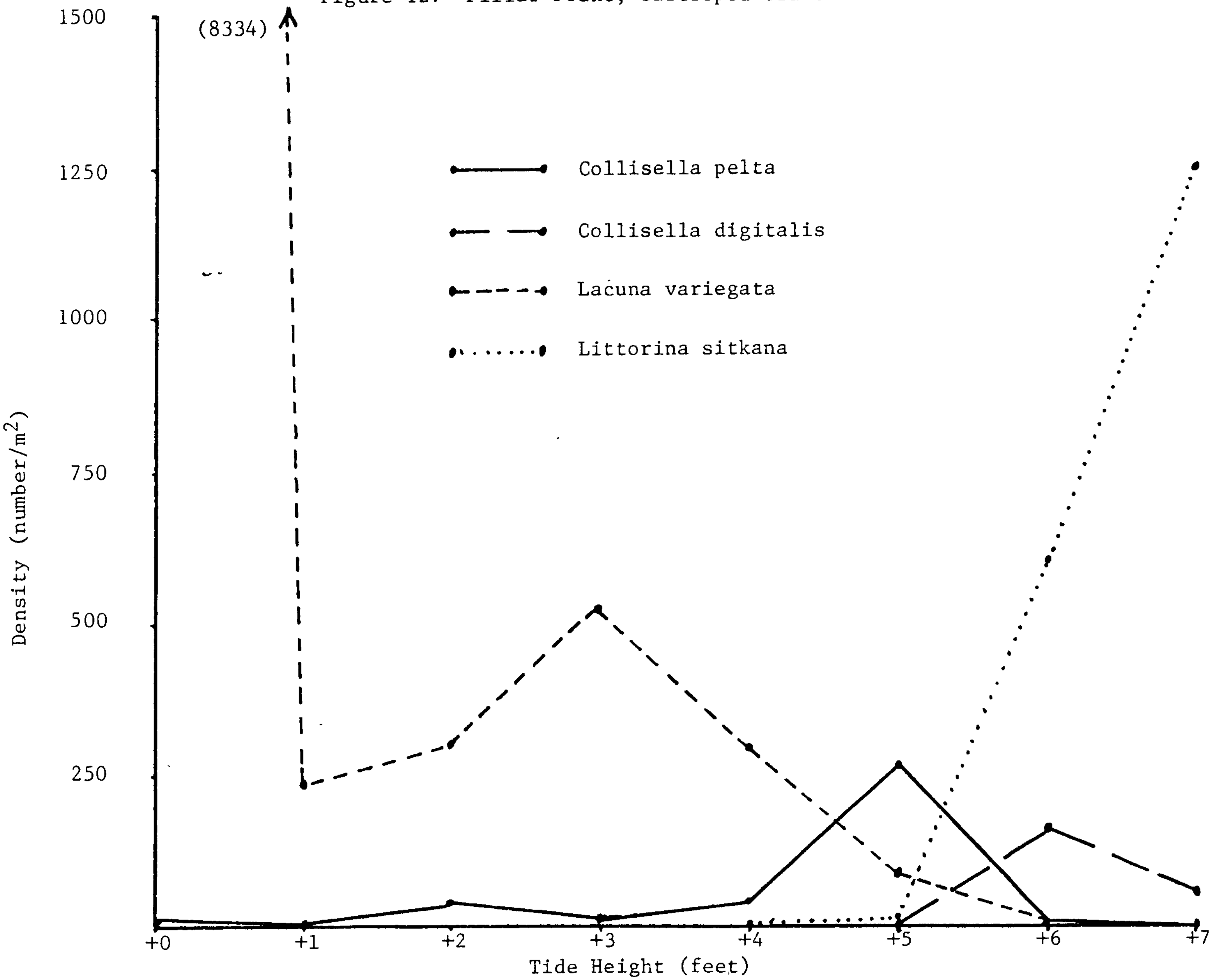
Table 3e. Pillar Point 9 August 1976 per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Isopoda									
Dynamenella	#	2.0	0	0	158.0	214.0	2920.0	1.2	0
sheareri	wt	< 0.4			< 0.4	< 0.4	5.2	< 0.4	
Munna	#	6.0	0	6.0	125.2	618.0	342.0	0	10.0
chromatocephala	wt	< 0.4		< 0.4	< 0.4	< 0.4	< 0.4		< 0.4
Amphipoda									
Calliopiella	#	80.0	0	0	0	0	0	0	0
pratti	wt	< 0.4							
Cercops	#	6.0	2.0	48.0	79.2	58.0	0	0	0
compactus	wt	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4			
Hyale	#	0	0	0	31.2	4.0	118.0	0	0
anceps	wt				< 0.4	< 0.4	< 0.4		
Hyale	#	1252.0	2.0	0	6.0	0	0	0	0
frequens	wt		< 0.4		< 0.4				
Ischyrocerus	#	84.0	0	0	0	0	0	0	0
anguipes	wt	< 0.4							
Jassa	#	98.0	8.0	0	16.0	6.0	4.0	0	0
falcata	wt	< 0.4	< 0.4		< 0.4	< 0.4	< 0.4		
Najna	#	302.0	0	2.0	14.0	0	0	0	0
consiliorum	wt	< 0.4		< 0.4	< 0.4				
Oligochinus	#	0	0	0	61.2	38.0	172.0	0	0
lighti	wt				< 0.4	< 0.4	< 0.4		
Decapoda									
Cancer	#	14.0	20.0	12.0	5.2	12.0	2.0	0	0
oregonensis	wt	0.4	39.2	45.6	< 0.4	2.0	< 0.4		
Pugettia	#	72.0	2.0	2.0	7.2	2.0	0	0	0
gracilis	wt	1.6	< 0.4	< 0.4	0.4	0.8			
Insecta									
Diptera	#	24.0	6.0	26.0	330.0	978.0	1224.0	572.0	250.0
spp.(larva)	wt	< 0.4	< 0.4	< 0.4	< 0.4			7.6	< 0.4

Table 3e. Pillar Point 9 August 1976 per m^2

	+0	+1	+2	+3	+4	+5	+6	+7
Species richness	136	91	94	153	119	104	27	16
Diversity - H'	2.49	2.13	1.93	3.13	2.83	2.69	1.14	1.17
Total number	15208.0	3422.0	3800.4	12072.8	25704.4	31288.8	16228.8	5370.0
Total biomass(g)	8069.6	4859.6	9180.4	5072.8	4155.2	6970.4	442.8	564.4

Figure 12. Pillar Point, Gastropod Grazer Zonation



North Beach Cobble

This area was selected as a cobble habitat although the +6' substratum consisted of coarse sand. During the year the +0' cobble was buried in sand, and cobble was uncovered at +6'. This sediment instability would make this area unsuitable for baseline population monitoring, except perhaps at +3'.

The beach had a fairly gentle slope and an offshore kelp bed doubtless moderated this area's exposure. There were no ocean swells at this end of the Strait and given the prevailing winds wave activity was probably fairly moderated.

North Beach subtidal will be discussed with North Beach Sand.

Table 4a presents summary data for North Beach Cobble +6'. The community present at this level was fairly simple, dominated by a grazer (Littorina scutulata), a surface detritivore (Gnorimosphaeroma), and an infauna detritivore (oligochaetes). The emergence of cobble fall-winter brought along an associated fauna of barnacles, Exosphaeroma, and gammarid amphipods. It also obscured seasonal patterns completely.

Diversity and species richness was low throughout the year. Cobble emergence greatly increased total number and total biomass.

Table 4b presents an abridged data set for North Beach Cobble +3'. This community was dominated by grazers (Collisella spp., Littorina spp., Cyanoplax), planktivores (Balanus spp.) and under-rock detritivores (Exosphaeroma, Gnorimosphaeroma, and Hemigrapsus). Macroalgae were a very minor constituent of this community, as was the infauna.

The major seasonal population change, reflected also in the total number and biomass was the massive recruitment of barnacles between the spring and summer sampling period. No other seasonal patterns were obvious within populations. Species richness remained fairly constant over the year.

As would be expected given the nature of the substratum in this area, the expected rock organism patchiness was even more extreme. The variance among replicates was very high (Appendix I).

Abridged results from North Beach Cobble +0' are given in Table 4c. Since this area was almost completely buried in sand between spring and summer sampling, it was most difficult to interpret the data. The fairly rich spring algal flora was pretty much gone by summer, but recovered womewhat by winter. Major epifaunal constituents were grazers (Mopalia, Lacuna, Notoacmea, and Idotea), planktivores (Balanus spp.), predators (Thais spp., Cancer spp.,) and

Table 4a. North Beach Cobble +6' per m^2

	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Mollusca								
Gastropoda								
Littorina scutulata	11.2	<0.4	135.2	4.0	85.2	6.0	1675.2	64.0
Annelida								
Polychaeta								
Nereidae								
Nereis spp.	10.0		30.0		5.2		115.2	
Oligochaeta spp.	175.2	<0.4	170.0	<0.4	61.2	<0.4	355.2	<0.4
Crustacea								
Cirripedia								
Balanus glandula	10.0	<0.4	130.0	0.4	40.0	<0.4	2235.2	196.4
Isopoda								
Exosphaeroma media	0		0		970.0	3.2	845.2	
Gnorimosphaeroma oregonense	5.2	<0.4	100.0	4.4	5.2	<0.4	161.2	0.4
Amphipoda								
Gammaridea spp.	5.2	<0.4	90.4	<1.2	870.0	11.2	0	
Species Richness	12		16		14		25	
Diversity, H'	1.50		2.12		1.23		1.77	
Total Number	282.8		726.4		2102.4		6063.6	
Total Biomass (g)	<4.8		<10.8		30.0		279.2	

Table 4b. North Beach Cobble +3' per m^2

	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 76 #	Win 76 wt
Rhodophyta								
Porphyra spp.		0		31.6		0		0
Cnidaria								
Anthozoa								
Anthopleura elegantissima	9.2	9.2	23.2	20.4	0		1.2	4.0
Mollusca								
Amphineura								
Cyanoplax dentiens	0		14.0	0.0	1.2	0.4	1.2	0.4
Gastropoda								
Collisella digitalis	0		17.2	8.0	9.2	1.2	0	
Collisella pelta	25.2	2.4	131.2	36.0	6.0	6.0	5.2	<0.4
Collisella strigatella	58.0	5.2	17.2	0.0	71.2	4.8	80.0	1.2
Littorina scutulata	534.0	28.0	201.2	14.4	177.2	17.6	280.0	20.0
Littorina sitkana	322.0	28.8	323.2	23.2	858.0	20.0	870.0	56.0
Thais spp.	12.0	16.0	44.0	68.4	11.2	11.2	48.0	39.6
Annelida								
Polychaeta								
Nereidae								
Nereis vexillosa	16.0	0.4	30.0		15.2		30.0	
Spionidae								
Polydora spp.	10.0		40.0		56.4		95.2	
Syllidae								
Syllis spp.	185.2		91.2		52.4		185.2	
Oligochaeta spp.	250.0	<0.4	95.2	<0.4	61.2	<0.4	180.0	<0.4
Crustacea								
Cirripedia								
Balanus spp.	570.4	69.6	14667.2	2088.8	4534.4	511.2	3981.6	112

Table 4b. North Beach Cobble +3' per m^2

	Spr 76 #	wt	Sum 76 #	wt	Fall 76 #	wt	Win 76 #	wt
Isopoda								
Exosphaeroma media	1685.2	8.3	686.0	4.8	2197.2	2.4	950.0	
Gnorimosphaeroma oregonense	5199.2	60.4	2660.0	29.6	637.2	7.6	3515.2	
Amphipoda								
Corophium spp.	0		57.2	<0.8	189.2	<0.4	340.0	<0.4
Decapoda								
Hemigrapsus spp.	35.2	26.6	5.2	<0.4	5.2	0.4	16.4	44.4
Insecta								
Dipteran larvae spp.	0		49.2	<0.4	163.2	<0.4	550.0	
Species Richness	49		54		43		47	
Diversity - H'	1.57		1.88		1.83		2.14	
Total Numbers	9077.2		18440.0		9456.8		11957.6	
Total Biomass	353.2		2362.0		594.0		360.8	

Table 4c. North Beach Cobble +0 per m^2

	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Chlorophyta								
Ulva spp.		158.8		61.6		14.0		6.0
Phaeophyta								
Alaria spp.		34.8		0		0		196.0
Rhodophyta								
Gigartina papillata		3.6		26.4		43.2		8.0
Pterosiphonia bipinnata		188.4		1.6		86.4		34.4
Mollusca								
Amphineura								
Mopalia spp.	0.8	47.8	0		2.0	66.4	0	
Gastropoda								
Lacuna variegata	417.2	4.8	5018.0	9.2	6485.2	19.6	865.2	0.4
Notoacmea scutum	47.2	32.8	12.0	4.0	9.2	6.4	55.2	18.8
Thais spp.	3.2	16.0	30.4	1.2	50.4	73.4	22.4	11.2
Annelida								
Polychaeta								
Glyceridae								
Hemipodus borealis	181.2		75.2		23.2		190.0	
Nereidae spp.	138.4		6.0		50.0		86.4	
Onuphidae								
Onuphis stigmatis	435.2		110.0		168.0		900.0	
Spionidae								
Malacocerus glutaeus	175.2		145.2		99.2		30.0	
Crustacea								
Cirripedia								
Balanus cariosus	38.0	54.0	67.2	1.2	285.2	115.6	1660.0	346.4
Isopoda								
Exosphaeroma amplicauda	268.0	0.4	1648.0	5.2	247.2	<0.4	610.0	1.6
Idotea spp.	608.4	5.2	70.0	<0.8	17.2	<0.4	21.2	<0.4
Amphipoda								
Gammaridea spp.	1192.8		998.8		521.2	7.2	240.4	2.0

Table 4c. North Beach Cobble +0 per m^2

	Spr 76		Sum 76		Fall 76		Win 76	
	#	wt	#	wt	#	wt	#	wt
Decapoda								
Cancer spp.	2.0	4.8	0		16.4	7.6	16.4	0.0
Pagurus spp.	54.4	20.8	0		90.4	18.0	5.2	<0.4
Species Richness	122		76		88		75	
Diversity - H'	3.5		2.13		1.47		2.64	
Total Number	5512.0		10063.2		8793.2		5993.2	
Total Biomass (g)	908.0		157.2		503.6		794.8	

under-rock detritivores (Exosphaeroma, gammarids, Pagurus spp.). The abundant infauna consisted of an active predator (Hemipodus), tube-building algal grazers (Nereidae spp., Onuphis) and a detritivore (Malacoceros).

Any seasonal changes have been confused by the sediment instability.

The summer distribution sampling for North Beach Cobble is presented in Table 4d. Shifting sediments have obviously depressed biomass and total number at +0'. Surface cobble and most of its potential fauna were absent at +6' and +7'. Some buried rock at +6' had live barnacles attached (and these were uncovered fall-winter quarters). However, within the +1' to +5' zone, faunal zonation was clear. Because of shifting sediments neither +0' nor +6' proved to be very suitable for baseline population monitoring.

Table 4d. North Beach Cobble 9 July 1976 per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Chlorophyta									
Ulva sp.	wt	61.6	5.2	9.6	0.4	< 0.4	7.2	< 0.4	< 0.4
Rhodophyta									
Gigartina papillata	wt	25.6	< 0.4	7.6	0.4	0	3.2	0	0
Cnidaria									
Anthozoa									
Anthopleura	#	11.2	14.0	0	23.2	0	14.0	0	0
elegantissima	wt	0.8	6.8		20.4		18.4		
Mollusca									
Amphineura									
Mopalia	#	0	12.0	0	0	0	0	0	0
sp.	wt		106.0						
Gastropoda									
Collisella	#	20.0	122.0	58.0	131.2	10.0	6.0	0	0
pelta	wt	2.4	12.0	46.0	36.0	< 0.4	1.2		
Lacuna	#	5018.0	2416.0	1008.0	18.0	0	1654.0	0	0
variegata	wt	9.2	9.6	3.5	< 0.4		2.8		
Littorina	#	0	0	0	201.2	340.0	1386.0	135.2	0
scutulata	wt				14.4	17.2	20.8	4.0	
Littorina	#	2.0	10.0	128.0	323.2	190.0	254.0	0	0
sitkana	wt	< 0.4	< 0.4	5.6	23.2	6.0	8.8		
Notoacmea	#	0	42.0	52.0	15.2	0	8.0	0	0
scutum	wt		22.8	17.2	5.2		4.0		
Thais	#	29.2	418.0	74.0	44.0	10.0	4.0	0	0
spp.	wt	< 0.8	81.2	36.4	68.4	< 0.4	< 0.4		
Annelida									
Polychaeta									
Glyceridae									
Hemipodus borealis	#	75.2	130.0	0	7.2	0	0	0	0
Nereidae									
Nereis spp.	#	6.0	10.0	10.0	30.0	60.0	56.0	30.0	0

Table 4d. North Beach Cobble 9 July 1976 per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Onuphidae									
Onuphis stigmatus	#	110.0	760.0	0	0	0	0	0	0
Spionidae									
Malacoceros glutaeus	#	145.2	10.0	0	0	0	0	0	0
Syllidae									
Syllis spp.	#	25.2	130.0	10.0	91.2	52.0	10.0	25.2	
Oligochaeta									
spp.	#	75.2	260.0	40.0	95.2	0	0	170.0	140.0
Crustacea									
Cirripedia									
Balanus	#	67.2	5234.0	1710.0	2946.0	1460.0	16.0	0	0
cariosus	wt	1.2	418.8	40.0	2018.8		7.2		
Balanus	#	6.0	8288.0	29252.0	6346.0	1920.0	6330.0	130.0	10.0
glandula	wt	< 0.4	192.0	439.6	70.0	20.0	426.4	0.4	< 0.4
Balanus	#	5.2	28980.0	0	5375.2	860.0	190.0	0	0
sp. (juv.)	wt	< 0.4					< 0.1		
Mysidacea									
Archaeomysis	#	465.2	10.0	0	0	0	0	0	0
grebnitzkii	wt	1.6	< 0.4						
Cumacea									
Cumella	#	1.2	52.0	0	0	0	0	0	0
vulgaris	wt	< 0.4	< 0.4						
Isopoda									
Exosphaeroma	#	118.0	1648.0	30.0	0	0	36.0	0	0
amplicauda	wt	<0.4	5.2	<0.4			<0.4		
Exosphaeroma	#	34.0	414.0	180.0	686.0	150.0	3420.0	0	0
media	wt	<0.4	<0.4	1.2	4.8	1.2	21.2		
Gnorimosphaeroma	#	75.2	24.0	5886.0	2660.0	1520.0	0	100.0	0
oregonense	wt		<0.4	66.0	29.6	20.0		4.4	
Idotea (pentidotea)	#	556.0	70.0	400.0	74.0	80.0	154.0	0	0
wosnesenskii	wt	22.0	<0.4	50.0	14.4	17.2	8.4		

Table 4d. North Beach Cobble 9 July 1976 per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Amphipoda									
Anonyx	#	100.0	190.0	30.0	0	0	0	0	0
spp.	wt	<0.8	<0.4	<0.8					
Corophium	#	0	50.0	30.0	57.2	0	0	0	0
spp.	wt		2.0	<0.4	<0.8				
Eohaustorius	#	85.2	0	0	0	0	0	0	0
washingtonianus	wt	<0.4							
Hyale rubra	#	118.0	204.0	84.0	0	0	32.0	0	0
frequens	wt	<0.4	<0.4	<0.4			<0.4		
Parallorchestes	#	55.2	0	0	0	0	2.0	0	0
ochotensis	wt	<0.4					<0.4		
Paramoera	#	0	0	0	0	0	0	75.2	0
mohri	wt							<0.4	
Paraphoxus	#	365.2	250.0	10.0	5.2	0	0	0	0
spinosus	wt			<0.4	<0.4				
Pontogeneia	#	189.2	390.0	0	0	0	0	0	0
ivanovi	wt								
Decapoda									
Hemigrapsus	#	0	0	0	5.2	10.0	24.0	0	0
nudus	wt				4.8	62.0	30.0		
Pagurus	#	17.2	52.0	8.0	6.0	0	0	0	0
spp.	wt	<0.4	<0.8	<0.8	<0.4				
Insecta									
Diptera (larvae)	#	6.0	180.0	70.0	49.2	10.0	76.0	35.2	0
spp.	wt	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	
Species Number		78	75	49	54	23	44	25	8
Diversity - H'		2.00	1.65	1.10	1.20	1.93	1.59	2.22	0.90
Total Number		8438.8	51712.0	39340.0	43548.0	6856.0	13730.0	706.4	180.0
Total biomass (g)		172.8	894.4	874.4	2366.8	81.6	554.4	<19.2	<3.2

Morse Creek

Although +6' at this area, as at North Beach Cobble, also consisted of sandy gravel over buried cobble, this area was selected for a cobble habitat. During the course of the year, the cobble was never uncovered, although live barnacles were recovered from buried cobble in several quadrats. The subtidal sediment at both -5 m and -10 m consisted of gravel plus enough small cobble to make taking a Van Veen grab difficult to impossible.

This beach had a fairly gentle slope and like North Beach only a moderate exposure to wave activity.

Table 5a presents the abridged results for Morse Creek +6'. This community was very simple, consisting of detritus feeding oligochaetes and gammarid amphipods. The barnacles were buried in the gravel and the _Littorina_ were probably drift. The oligochaetes showed no seasonal pattern. However, the amphipods showed a dramatic peak in summer quarter. Diversity and species richness were uniformly low. Total number followed the amphipods. Biomass was insignificant.

Areas with sparse fauna generally show extreme patchiness, and this level was no exception (see variances, Appendix I).

Abridged results for Morse Creek +3' are presented in Table 5b. The rock community at this area and level was basically two dimensional, with no structured dominants such as at Tongue and Pillar. Algal species richness was low and what occurred regularly (_Fucus_ and _Gigartina_) were very patchy. Gastropod grazers _Idotea_, and barnacles dominated the epifaunal community. _Hemigrapsus_ and _Pagurus_, detritivores, dominated under-rock. The infaunal community was dominated by the detritivores _Capitella_, _Corophium_, and dipteran larvae.

Species richness was fairly constant. No other seasonal patterns were clear from the data.

Table 5c gives the summary results from Morse Creek +0'. Algae (_Alaria_, _Hedophyllum_, and _Iridaea_) were the structural dominants of the epi-community. Herbivore associates included _Lacuna_, _Notoacmea_, and _Pugettia_. The infaunal community was dominated by detritivores (nematodes, _Abarenicola_, _Capitella_, _Cirratulus_, _Armandia_, spionids, _Leptochelia_ and some gammarids). However, a herbivore (_Nereis_) and suspension feeders (_Protothaca_ and sabellids) were also abundant.

Species richness, total numbers, total biomass, and populations of most component species showed a summer maximum. However, as in all rock areas, the community components were very patchy.

Table 5d presents the subtidal abridged data set for Morse Creek. Both -5 m and -10 m communities were dominated by detritus feeders:

Table 5a. Morse Creek +6 per m^2

	Spr 76		Sum 76		Fall 76		Win 77	
	#	wt	#	wt	#	wt	#	wt
Mollusca								
Gastropoda								
Littorina sitkana	60.0	1.2	14.8	5.2	5.2	<0.4	25.2	2.4
Annelida								
Oligochaeta spp.	65.2	<0.4	40.0	<0.4	25.2	<0.4	75.2	<0.4
Crustacea								
Cirripedia								
Balanus spp.	613.6	222.4	0		55.2	<0.4	10.0	1.2
Amphipoda								
spp.	95.2	<0.4	8605.2		2670.0	1.2	105.2	<0.4
Species Richness	11		5		8		10	
Diversity - H'	1.33		0.54		0.23		1.78	
Total Number	869.6		8670.0		2699.2		286.0	
Total Biomass (g)	223.6				<4.0		<6.8	

Table 5b. Morse Creek +3 per m^2

	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Phaeophyta								
Fucus distichus		0.4		10.4		9.2		2.8
Rhodophyta								
Gigartina papillata		200.0		66.8		190.0		39.2
Platyhelminthes								
Turbellaria spp.	1.2	< 0.4	0		447.2	0.4	575.2	
Nemertea spp.	70.0	< 0.4	103.2	< 0.4	273.2	< 0.4	1060.0	
Mollusca								
Gastropoda								
Collisella pelta	25.2	12.0	14.0	3.2	3.2	5.2	10.0	21.6
Collisella strigatella	19.2	2.0	2.0	0.4	16.0	1.2	8[illegible].2	2.0
Lacuna variegata	10.0	< 0.4	45.2	< 0.4	492.0	41.2	50.0	1.2
Littorina sitkana	1541.6	944.0	3918.0	72.8	4081.2	74.0	3985.[illegible]	144.0
Bivalvia								
Mytilus spp.	29.2	1.6	50.0		47.2	2.8	55.2	13.2
Annelida								
Polychaeta								
Capitellidae								
Capitella capitata	0		10.0		639.2		1760.0	
Crustacea								
Cirripedia								
Balanus glandula	809.2	121.6	12667.2	212.8	6689.2	241.6	4955.2	137.2
Balanus spp. (juv.)	7182.0		4867.2	2.4	557.2	10.4	0	
Isopoda								
Idotea wosnesenskii	7.2	0.8	215.2	28.8	283.2	14.4	30.0	8.4
Amphipoda								
Corophium spp.	20.0	0	113.2		6650.0	5.2	5395.2	
Decapoda								
Hemigrapsus spp.	78.0	263.6	62.0	136.4	21.2	20.0	21.2	50.4
Pagurus spp.	95.2	11.2	23.2	2.8	154.4	13.6	40.4	2.8
Insecta								
Dipteran larvae spp.	8.0	< 0.4	268.0		2152.0		1000.0	

Table 5b. Morse Creek +3

	Spr 76	Sum 76	Fall 76	Win 77
Species Richness	51	61	62	53
Diversity - H'	1.56	1.55	2.11	2.12
Total Number	12267.2	26251.6	26202.8	20831.6
Total Biomass	1587.2	597.2	688.8	292.0

Table 5c. Morse Creek +0 per m^2

	Spr 76		Sum 76		Fall 76		Win 76	
	#	wt	#	wt	#	wt	#	wt
Chlorophyta								
Ulva spp.		10.0		206.4		9.6		0.8
Phaeophyta								
Alaria spp.		282.8		689.2		128.8		537.0
Hedophyllum sessile		0		1176.0		0		0
Rhodophyta								
Gigartina papillata		161.6		125.6		137.6		25.2
Iridaea cordata		245.6		1058.8		290.4		157.2
Cnidaria								
Anthozoa								
Anthopleura elegantissima	25.2	5.6	8.0	10.0	30.8	14.4	6.4	8.4
Nemertea spp.	105.2	<0.4	515.2		530.0		775.2	
Nematoda spp.	57.2	<0.4	3721.2		1598.0		165.2	<0
Mollusca								
Gastropoda								
Lacuna variegata	912.0	1.6	8591.2	53.2	3014.0	17.6	805.2	5.2
Notoacmea spp.	20.0	3.6	110.4	13.6	27.6	3.6	30.4	4.0
Thais spp.	1.2	2.0	10.0	<0.8	5.2	<0.4	1.2	2.0
Bivalvia								
Mytilus spp.	171.2	2.8	252.4	2.4	45.2	<0.4	15.2	<0.4
Protothaca staminea	1.2	<0.4	22.0	<0.4	5.2	<0.4	15.2	1.2
Annelida								
Polychaeta								
Arenicolidae								
Abarenicola spp.	155.2		91.2		30.0		0	
Capitellidae								
Capitella capitata	750.0		2180.0		1760.0		1525.2	
Cirratulidae								
Cirratulus cirratus	2227.2		970.0		1760.0		1170.0	
Nereidae								
Nereis spp.	36.4		35.2		62.4		70.4	

Table 5c. Morse Creek +0 per m^2

	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 76 #	Win 76 wt
Opheliidae								
Armandia brevis	35.2		45.2		60.0		40.0	
Sabellidae spp.	78.4		557.2		2723.6		425.6	
Spionidae								
Malacoceros glutaeus	135.2		710.0		335.2		65.2	
Crustacea								
Tanaidacea								
Leptochelia dubia	8.0	<0.4	3302.0		15.2	<0.4	30.8	<0.4
Amphipoda								
Gammaridea spp.	430.0		428.4		660.4	0.4	805.2	3.2
Decapoda								
Cancer spp.	1.2	1.2	3.2	1.6	13.6	7.6	5.2	1.2
Pugettia gracilis	18.0	1.2	530.0	5.2	48.0	2.4	50.0	0.4
Species Richness	109		134		90		74	
Diversity - H'	2.80		2.68		2.47		2.62	
Total Numbers	6042.4		24892.0		13636.8		6606.0	
Total Biomass	1626.0		3648.8		653.6		805.2	

Table 5d. Morse Creek per m^2

	-5m		-10m	
	#	wt	#	wt
Phaeophyta				
Desmarestia ligulata		63.0		< 0.1
Mollusca				
Gastropoda				
Calyptraea fastigiata	0		33.0	1.0
Bivalvia				
Crenella decussata	0		290.0	1.0
Macoma spp.	27.0	< 1.0	147.0	2.0
Mysella tumida	20.0	< 1.0	243.0	< 1.0
Annelida				
Polychaeta				
Capitellidae				
Mediomastus sp.	13.0		890.0	
Maldanidae				
Euclymene sp.	7.0		300.0	
Nereidae				
Platynereis bicanaliculata	77.0		143.0	
Opheliidae				
Armandia brevis	153.0		153.0	
Spionidae				
Malacoceros glutaeus	157.0		0	
Prionospio cirrifera	13.0		133.0	
Prionospio steenstrupi	3.0		267.0	
Crustacea				
Tanaidacea				
Leptochelia dubia	450.0	< 1.0	3077.0	1.0
Amphipoda				
Melita spp.	43.0	< 1.0	0	
Paraphoxus spp.	110.0	< 1.0	0	
Decapoda				
Cancer oregonensis	0		10.0	< 1.0

Table 5d. Morse Creek per m^2

	-5m		-10m	
	#	wt	#	wt
Echinodermata				
Ophiuroidea spp.	3.0	<1.0	160.0	2.0
Species Richness	74		149	
Species Diversity H'	3.01		2.79	
Total Number	1495.0		8863.0	
Total Biomass (g)	104.0		37.0	

Macoma, capitellids, maldanids, Armandia, spionids, most gammarids, and ophiuroids. Suspension feeders (Calyptraea, Crenella, Mysella, and Leptochelia) were abundant at -10 m.

Species richness and diversity were very high. However, the total biomass was fairly low. Sample variance (see Appendix I) demonstrate clearly how unsatisfactory the Van Veen sampler in this type of area.

The results of the summer distribution sampling at Morse Creek are presented on Table 5e. As in the two rock areas, virtually all organisms showed clear vertical zonation. Species richness, diversity and total biomass all increased with decreasing tide height. The three levels sampled quarterly provided complete coverage of the dominant species.

Table 5e. Morse Creek 27 July 1976 per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Chlorophyta									
Spongomorpha coalita	wt	58.8	1.2	0.8	1.2	1.2	0	0	0
Ulva sp.	wt	206.4	463.2	293.6	2.0	<0.4	0	0	0
Phaeophyta									
Alaria sp.	wt	689.2	0	0	0	0	0	0	0
Hedophyllum sessile	wt	1176.0	0	0	0	0	0	0	0
Laminaria saccharina	wt	62.4	0	0	0	0	0	0	0
Rhodophyta									
Corallina vancouveriensis	wt	60.8	0	0	0	0	0	0	0
Gigartina papillata	wt	125.6	388.8	324.4	66.8	15.6	0	0	0
Iridaea cordata	wt	1058.8	292.0	0	0	0	0	0	0
Cnidaria									
Anthozoa									
Anthozoa	#	8.0	140.0	10.0	0	0	0	0	0
elegantissima	wt	10.0	19.2						
Nematoda	#	3721.2	38.0	216.0	190.0	380.0	290.0	0	10.0
spp.	wt		<0.4	<0.4	<0.4	<0.4	<0.4		<0.4
Nemertea	#	515.2	210.0	460.0	103.2	72.0	0	0	13.2
spp.	wt				<0.4	<0.8			<0.4
Mollusca									
Amphineura									
Cyanoplax	#	1.2	10.0	2.0	0	0	0	0	0
dentiens	wt	<0.4	<0.4	<0.4					
Gastropoda									
Collisella	#	16.0	110.0	10.0	14.0	0	0	0	0
pelta	wt	2.4	1.6	<0.4	3.2				
Lacuna	#	8591.2	5458.0	1006.0	45.2	102.0	20.0	0	0
variegata	wt	64.0	52.8	5.6	<0.4	<0.4	<0.4		
Littorina	#	3.2	54.0	5250.0	3918.0	4064.0	190.0	14.8	0
sitkana	wt	<0.1	<0.1	11.5	72.8	300.4	18.0	5.2	
Notoacmea	#	90.4	332.0	112.0	11.2	4.0	0	0	0
spp.	wt	12.4	11.6	13.2	14.8	2.8			
Thais	#	10.0	0	0	0	0	0	0	0
spp.	wt	<0.8							

Table 5e. Morse Creek 27 July 1976 per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Bivalvia									
Adula	#	138.0	30.0	2.0	10.0	0	0	0	0
californiensis	wt	0.4	< 0.4	< 0.4	< 0.4				
Hiatella	#	125.2	42.0	0	0	0	0	0	0
arctica	wt	20.4	5.2						
Mya	#	29.2	20.0	0	0	0	0	0	0
arenaria	wt	6.0	< 0.4						
Mysella	#	65.2	70.0	10.0	5.2	0	0	0	0
tumida	wt		< 0.1	< 0.1	< 0.1				
Mytilus	#	252.4	42.0	54.0	50.0	108.0	20.0	0	0
spp.	wt	2.4	0.4	2.0	< 1.2	18.4	10.0		
Annelida									
Polychaeta									
Capitellidae									
Capitella capitata	#	2180.0	1100.4	370.0	10.0	0	0	0	0
Cirratulidae									
Cirratulus cirratus	#	970.0	664.0	140.0	5.2	0	0	0	0
Nereidae									
Platynereis bicanaliculata	#	245.2	10.0	0	5.2	0	0	0	0
Opheliidae									
Armandia brevis	#	45.2	2.0	0	5.2	0	0	0	0
Sabellidae									
spp.	#	657.2	70.0	0	0	0	0	0	0
Spionidae									
Malococerus glutaeus	#	710.0	170.0	30.0	0	0	0	0	0
Syllidae									
Syllis sp.	#	35.2	10.0	0	2.0	512.0	0	10.0	20.0
Oligochaeta									
spp.	#	430.0	10.0	0	10.0	2.0	340.0	40.0	300.0

Table 5e. Morse Creek 27 July 1976 per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Crustacea									
Cirripedia									
Balanus	#	167.2	0	856.0	55.2	770.0	0	0	0
cariosus	wt	24.8		14.8	8.0	684.4			
Balanus	#	1.2	2.0	0	0	0	0	0	0
nubilus	wt	1.2	<0.4						
Balanus	#	16.0	90.0	364.0	4867.2	2888.0	0	0	0
sp. (juv.)	wt	0.8	1.2		2.4	10.4			
Tanaidacea									
Leptochelia	#	3302.0	28.0	0	0	2.0	0	0	0
dubia	wt		<0.4			<0.4			
Isopoda									
Exosphaeroma	#	0	148.0	0	0	0	0	0	0
amplicauda	wt		<0.1						
Gnorimosphaeroma	#	5.2	120.0	6330.0	3305.0	1006.0	0	0	0
oregonense	wt	<0.4	<0.4	35.6	29.2	16.0			
Idotea	#	30.4	852.0	316.0	1.2	0	0	0	0
spp.	wt	3.2	56.8	5.2	<0.4				
Amphipoda									
Gammaridea	#	428.4	1118.0	6332.0	124.4	10.0	2430.0	8605.2	50.0
spp.	wt			1.6	<0.8	<0.4			<0.4
Decapoda									
Cancer	#	3.2	0	0	0	0	0	0	0
spp.	wt	1.6							
Hemigrapsus	#	0.	0	2.0	62.0	92.0	0	0	0
nudus	wt			28.8	136.4	44.4			
Pagurus	#	29.2	80.0	126.0	23.2	20.0	0	0	0
spp.	wt	<0.4	0.4		2.8	4.8			
Pugettia	#	530.0	186.0	0	0	0	0	0	0
gracilis	wt	5.2	1.2						
Telmessus	#	21.2	0	0	0	0	0	0	0
cheiragonus	wt	0.4							

Table 5e. Morse Creek 27 July 1976 per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Insecta Diptera spp.	#	379.2	338.0	4444.0	268.0	320.0	0	0	0
	wt	< 0.4	< 0.4		< 0.4	< 0.4			
Species Richness		149	70	51	62	41	9	5	6
Diversity - H'		2.69	2.49	2.25	1.52	1.37	1.00	0.54	0.92
Total Number		24820.0	11924.4	29870.4	26056.4	27378.0	3370.0	8670.0	403.2
Total Weight (g)		4067.2	1313.2	895.6	568.4	416.0	42.0	5.2	< 2.4

Beckett Point

The sediment at Beckett Point was a sandy gravel at +6', a gravel-sand mix at +3', a medium-fine sand with gravel at +0', fine sand at -5 m, and medium to fine sand at -10 m. The study area was completely protected inside Discovery Bay. The beach slope was fairly steep, and tidal action probably was mainly responsible for the fairly coarse sediment at the study site in the intertidal. The salinity showed no freshwater influence.

Table 6a presents the summary data from +6' at Beckett Point. The community had two components, planktivorous epifaunal Balanus, responsible for most of the total biomass, and detritus feeding worms (nematodes, syllids, and oligochaetes). Seasonal patterns in this low diversity, low biomass community were not particularly clear. The syllids and oligochaetes both showed peak numbers in fall quarter.

An abridged data set for Beckett Point +3' is presented in Table 6b. The community at this level was dominated by suspension feeding bivalves (Mysella, Mytilus, Protothaca, Saxidomus, Transennella, and Tresus), detritus feeders (capitellids, oweniids, spionids, syllids, oligochaetes, isopods, amphipods, and Leptosynapta), and a couple of carnivores (nemerteans and Hemipodus). The bivalves were very patchy in distribution. Seasonal patterns were not clear. Species richness remained fairly constant. Total number showed a summer peak. Biomass was dominated by the irregularly occurring large bivalves and barnacles.

Table 6c gives the abridged results for Beckett Point +0'. This rich, diverse community was dominated by suspension feeding bivalves (Clinocarium, Mysella, Protothaca, Transennella, and Tresus); deposit/detritus feeding worms, crustaceans, and echinoderms; and a number of carnivores (nemerteans, Nassarius, Polinices, Hemipodus, Glycinde, hesionids, nephtyids, phyllodocids, polynoids, Cancer, and Crangon).

The majority of species and the total number peaked strongly in the fall. Species richness and diversity remained fairly constant through the year. Biomass was subject to irregularly occurring large bivalve and gastropods.

Abridged subtidal results for Beckett Point are presented in Table 6d. The very rich, diverse communities at -5 m and -10 m at Beckett were very similar. The communities were dominated by deposit feeders: nematodes, Macoma, Tellina, oweniids, spionids, tanaids, and amphipods. There were a few suspension feeders (Mysella, chaetopterids) and carnivores (Nassarius, Natica, hesionids, and Cancer). High variance was likely to be more the result of the Van Veen grab methodology than real patchiness.

Table 6a. Beckett Point +6.0' per m^2

	Spr 76		Sum 76		Fall 76		Win 77	
	#	wt	#	wt	#	wt	#	wt
Nematoda								
spp.	320	< 2.0	540	< 2.0	266	< 2.0	280	< 2.0
Annelida								
Polychaeta								
Nereidae								
spp.	40		20		48		28	
Syllidae								
Syllis spp.	146		170		600		80	
Oligochaeta								
spp.	440		370		774		354	
Crustacea								
Cirripedia								
Balanus glandula	114	20.0	190	208.0	174	30.0	226	58.0
Species Richness	12		14		23		20	
Diversity - H'	1.57		1.73		2.02		1.70	
Total Number	1110		1480		2988		1274	
Total Biomass (g)	22		212		54		94	

Table 6b. Beckett Point +3.0' per m^2

	Spr 76		Sum 76		Fall 76		Win 77	
	#	wt	#	wt	#	wt	#	wt
Nemertea								
spp.	20	< 2.0	146	< 2.0	86	< 2.0	66	< 2.0
Mollusca								
Gastropoda								
Lacuna variegata	0		14	< 2.0	74	< 2.0	14	< 2.0
Bivalvia								
Mysella tumida	114	< 2.0	20	< 2.0	80	< 2.0	74	< 2.0
Mytilus edulis	20	4.0	6	< 2.0	166	18.0	34	< 2.0
Protothaca staminea	6	40.0	6	60.0	14	62.0	30	< 2.0
Saxidomus giganteus	0		6	826.0	6	1336.0	0	
Transennella tantilla	26	< 2.0	0		20	< 2.0	100	< 2.0
Tresus spp.	20	620.0	0		0		0	
Annelida								
Polychaeta								
Capitellidae								
Notomastus tenuis	406		606		206		426	
Glyceridae								
Hemipodus borealis	2780		2346		3280		866	
Oweniidae								
Owenia fusiformis	26		6		66		154	
Spionidae								
Spio filicornis	0		40		126		0	
Spiophanes bombyx	366		6		14		6	
Syllidae								
Syllis spp.	94		14		46		0	
Oligochaeta								
spp.	120		74		34		34	
Crustacea								
Cirripedia								
Balanus glandula	414	222.0	526	134.0	0		6	< 2.0
Isopoda								
Exosphaeroma spp.	6	< 2.0	306	8.0	160	< 4.0	280	< 2.0

Table 6b. Beckett Point +3.0' per m^2

	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Amphipoda spp.	6	< 2.0	1514	6.0	0		646	6.0
Echinodermata								
Holothuroidea								
Leptosynapta clarki	86	2.0	14	< 2.0	34	< 2.0	0	
Species Richness	37		44		40		39	
Diversity - H'	1.86		2.00		1.60		2.35	
Total Number	5024		5982		4800		3056	
Total Biomass (g)	892		1048		1450		146	

Table 6c. Beckett Point +0.0' per m^2

	Spr 76		Sum 76		Fall 76		Win 77	
	#	wt	#	wt	#	wt	#	wt
Nemertea								
spp.	126	< 2.0	286	< 2.0	1712		754	
Nematoda								
spp.	54	< 2.0	6746	< 2.0	3352	< 2.0	846	< 2.0
Mollusca								
Gastropoda								
Lacuna variegata	0		1606	12.0	1986	10.0	374	< 2.0
Nassarius mendicus	14	4.0	34	16.0	6	6.0	14	< 2.0
Polinices lewisii	0		0		0		6	1270
Bivalvia								
Clinocardium nuttallii	0		6	< 2.0	646	12.0	634	30.0
Macoma spp.	86	< 2.0	52	6.0	146	< 2.0	14	< 2.0
Mysella tumida	254	2.0	2334	4.0	3454	14.0	5740	10.0
Protothaca staminea	26	6.0	26	< 2.0	54	12.0	20	6.0
Traysennella tantilla	20	< 2.0	1514	2.0	634	14.0	546	< 2.0
Tresus capax	0		34	8.0	46	10.0	14	42.0
Annelida								
Polychaeta								
Capitellidae spp.	114		286		546		352	
Glyceridae								
Hemipodus borealis	580		86		766		746	
Goniadidae								
Glycinde picta	74		46		440		266	
Hesionidae spp.	40		166		3452		1126	
Nephtyidae spp.	20		12		32		20	
Nereidae								
Platynereis bicanaliculata	114		240		15854		7800	
Opheliidae								
Armandia brevis	6		0		2060		334	

Table 6c. Beckett Point +0.0' per m^2

	Spr 76		Sum 76		Fall 76		Win 77	
	#	wt	#	wt	#	wt	#	wt
Oweniidae								
Owenia fusiformis	220		834		24		1020	
Phyllodocidae spp.	28		52		1926		1048	
Polynoidae spp.	28		54		154		48	
Spionidae spp.	368		2058		3140		1552	
Syllidae								
Exogone spp.	20		360		1160		380	
Oligochaeta								
spp.	174		74		360		194	
Crustacea								
Cumacea								
Cumella vulgaris	0		0		300	< 2.0	660	< 2.0
Tanaidacea								
Leptochelia dubia	40	< 2.0	4994		13966		7694	
Amphipoda								
spp.	80	< 8.0	1112	< 4.0	6812	20.0	7012	8.0
Decapoda								
Cancer productus	0		0		14	2.0	0	
Crangon nigracaula	0		26	< 2.0	0		0	
Pagurus spp.	14	6.0	106	< 2.0	20	< 2.0	6	< 2.0
Echinodermata								
Echinoidea								
Dendraster excentricus	40	4.0	800	20.0	300	10.0	746	8.0
Holothuroidea								
Leptosynapta clarki	66	4.0	166	18.0	114	< 2.0	46	< 2.0
Species Richness	68		71		99		83	
Diversity - H'	3.37		2.64		2.73		2.72	
Total Number	3332		25060		66048		41968	
Total Biomass (g)	74		264		140		1384	

Table 6d. Beckett Point per m^2

	-5m		-10m	
	#	wt	#	wt
Nemertea spp.	147.0	<1.0	203.0	
Nematoda spp.	1143.0	<1.0	1067.0	
Mollusca				
Gastropoda				
Alvinia sp.	333.0	<1.0	177.0	<1.0
Mitrella tuberosa	418.0	20.0	347.0	19.0
Nassarius mendicus	0		3.0	1.0
Natica clausa	0		3.0	1.0
Bivalvia				
Macoma spp.	823.0	4.0	733.0	13.0
Mysella tumida	1073.0	1.0	3677.0	3.0
Tellina sp.	310.0	4.0	150.0	4.0
Annelida				
Polychaeta				
Chaetopteridae				
Mesochaetopterus taylori	13.0		420.0	
Hesionidae				
Micropodarke dubia	553.0		817.0	
Nereidae				
Platynereis bicanaliculata	2967.0		1260.0	
Oweniidae				
Owenia fusiformis	1253.0		230.0	
Spionidae				
Polydora socialis	17.0		520.0	
Prionospio steenstrupi	533.0		503.0	
Spiophanes berkeleyorum	13.0		170.0	
Crustacea				
Tanaidacea				
Leptochelia dubia	4080.0	3.0	3323.0	2.0
Amphipoda				
Gammaridea				
Ampelisca pugetica	27.0	<1.0	363.0	

Table 6d. Beckett Point per m^2

	-5m		-10m	
	#	wt	#	wt
Aoroides columbiae	220.0	<1.0	160.0	<1.0
Paraphoxus spp.	780.0		773.0	
Photis brevipes	157.0	<1.0	60.0	<1.0
Podoceropsis inaequistylus	183.0	<1.0	83.0	<1.0
Protomedia sp. A	30.0	<1.0	200.0	
Decapoda				
Cancer gracilis	7.0	11.0	20.0	7.0
Species Richness	101		132	
Diversity - H'	2.91		3.11	
Total number	15522.0		18122.0	
Total biomass	50.0		55.0	

Distributional sampling results for the Beckett Point intertidal are presented in Table 6e. Virtually all organisms showed the same sharp vertical zonation as found in the rocky intertidal. Figure 13 presents the zonation of three tube-building polychaetes: *Hemipodus borealis*, a carnivore on micro-crustaceans; *Platynereis bicanaliculata*, a herbivore on macro-algae; and detritus feeding *Syllis* spp. The three levels sampled quarterly gave complete coverage of the dominant species. Species richness generally decreased with tidal height. Total number and biomass showed a less clear vertical pattern.

Table 6e. Beckett Point 12 July 1976 per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Spermatophyta									
Zostera marina	wt	156.0	0	0	0	0	0	0	0
Nemertea	#	286.0	3010.0	220.0	146.0	20.0	160.0	10.0	10.0
spp.	wt	< 2.0		< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Nematoda	#	6746.0	1980.0	20.0	26.0	0	0	540.0	60.0
spp.	wt	< 2.0	< 2.0	< 2.0	< 2.0			< 2.0	< 2.0
Mollusca									
Gastropoda									
Lacuna	#	1606.0	2960.0	610.0	14.0	0	0	0	0
variegata	wt	12.0	8.0	< 2.0	< 2.0				
Nassarius	#	34.0	10.0	0	0	0	0	0	0
mendicus	wt	16.0	< 2.0						
Bivalvia									
Clinocardium	#	6.0	60.0	0	0	0	0	0	0
nuttallii	wt	0.0	76.0						
Macoma	#	52.0	60.0	30.0	0	0	0	0	0
spp.	wt	6.0	22.0	< 2.0					
Mysella	#	2334.0	7390.0	330.0	20.0	20.0	0	0	0
tumida	wt	4.0	44.0	8.0	< 2.0	< 2.0			
Protothaca	#	26.0	230.0	0	6.0	0	14.0	2.0	0
staminea	wt	< 2.0	298.0		60.0		< 2.0	< 2.0	
Saxidomus	#	0	30.0	0	6.0	0	0	0	0
giganteus	wt		10.0		826.0				
Tellina	#	126.0	190.0	0	0	0	0	0	0
spp.	wt	2.0	4.0						
Transennella	#	1414.0	4250.0	50.0	0	10.0	0	0	10.0
tantilla	wt	2.0	12.0	< 2.0		< 2.0			< 2.0
Tresus	#	34.0	860.0	10.0	0	0	0	0	0
capax	wt	8.0	124.0	190.0					
Annelida									
Polychaeta									
Capitellidae									
Mediomastus sp.	#	214.0	860.0	10.0	0	0	0	0	0
Notomastus tenuis	#	26.0	1220.0	910.0	606.0	410.0	0	0	0

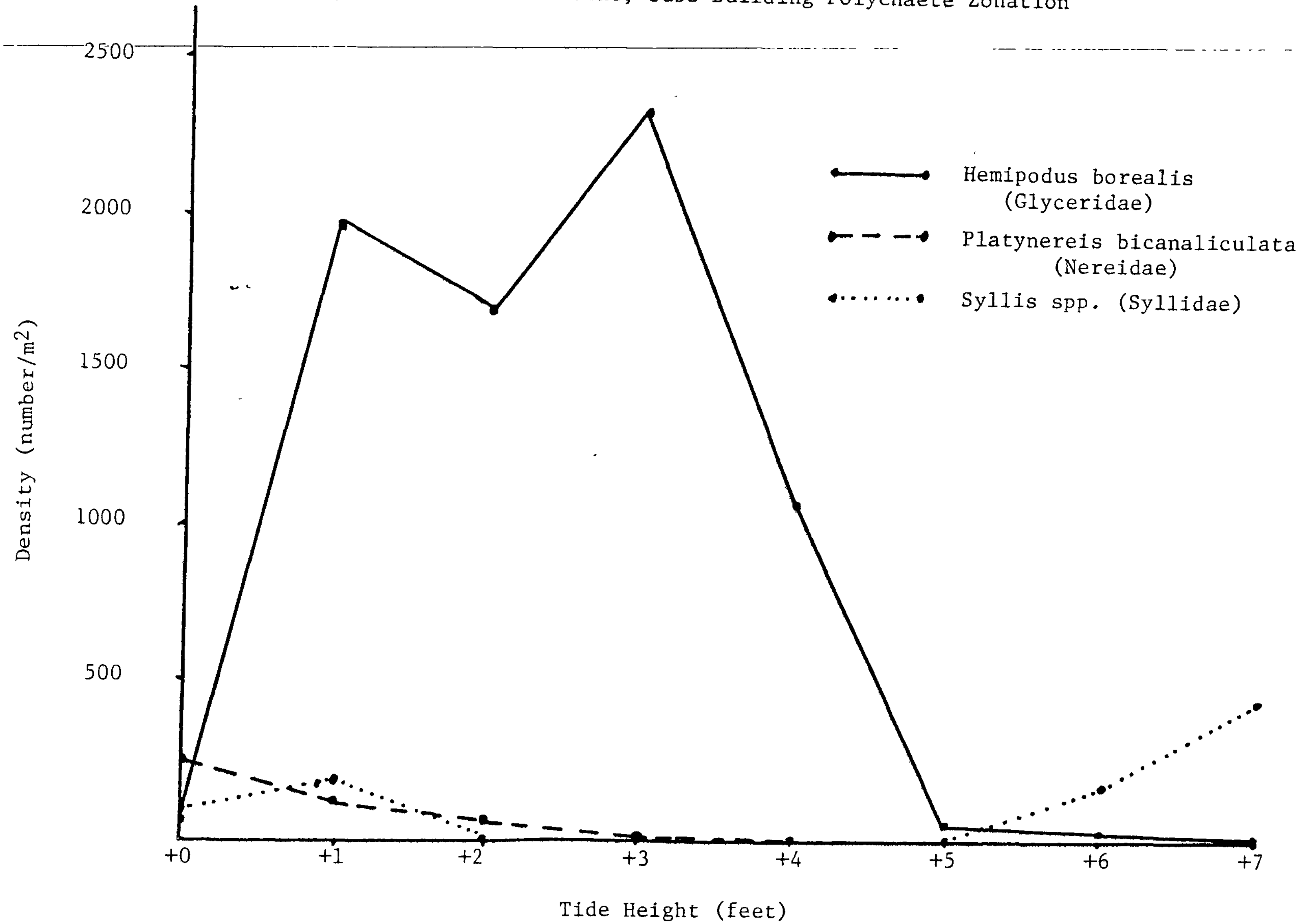
Table 6e. Beckett Point 12 July 1976 per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Chaetopteridae									
Mesochaetopterus taylori	#	146.0	240.0	10.0	0	0	0	0	0
Cirratulidae									
Tharyx multifilis	#	0	780.0	0	6.0	0	0	0	0
Dorvilleidae									
Protodorvillea gracilis	#	40.0	620.0	0	40.0	0	0	0	0
Glyceridae									
Hemipodus borealis	#	86.0	1970.0	1710.0	2346.0	1080.0	50.0	10.0	0
Nereidae									
Platynereis bicanaliculata	#	240.0	120.0	50.0	6.0	0	0	10.0	0
Oivuphidae									
Onuphis spp.	#		1110.0	30.0	34.0	0	0	0	0
Opheliidae									
Armandia brevis	#	34.0	550.0	80.0	0	0	0	0	0
Oweniidae									
Owenia fusiformis	#	834.0	1130.0	50.0	6.0	0	0	0	0
Phyllodocidae									
Phyllodoce maculata	#	26.0	680.0	0	0	0	0	0	0
Spionidae									
Malacoceros glutaeus	#	0	610.0	70.0	0	0	0	0	0
Polydora socialis	#	106.0	6520.0	2240.0	0	0	0	0	0
Prionospio steenstrupi	#	6.0	660.0	530.0	0	0	0	0	0
Pygospio elegans	#	506.0	320.0	1260.0	26.0	0	10.0	0	0
Spio filicornis	#	186.0	5080.0	1540.0	40.0	0	0	0	0
Spiophanes bombyx	#	1060.0	370.0	190.0	6.0	0	0	0	0
Syllidae									
Exogone lourei	#	360.0	2380.0	0	0	0	0	0	0
Syllis spp.	#	66.0	170.0	0	14.0	10.0	10.0	170.0	440.0
Oligochaeta									
spp.	#	14.0	530.0	0	74.0	230.0	590.0	370.0	100.0
Crustacea									
Cirripedia									
Balanus	#	0	0	530.0	346.0	40.0	300.0	190.0	20.0
glandula	wt			72.0	134.0	18.0	130.0	205.0	2.0

Table 6e. Beckett Point 12 July 1976 per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Cumacea									
Cumella	#	0	600.0	10.0	14.0	0	0	0	0
vulgaris	wt		< 2.0	< 2.0	2.0				
Tanaidacea									
Leptochelia	#	4994.0	13220.0	150.0	6.0	0	0	10.0	0
dubia	wt	2.0	6.0	< 2.0	< 0.2			< 2.0	
Isopoda									
Exosphaeroma	#	0	690.0	110.0	160.0	0	0	0	0
amplicauda	wt		2.0	2.0	4.0				
Amphipoda									
Gammaridea	#	606.0	650.0	860.0	1510.0	20.0	80.0	120.0	60.0
spp.	wt	< 2.0	< 2.0	< 2.0	6.0	< 2.0	< 2.0	< 2.0	< 2.0
Corophium	#	506.0	630.0	50.0	0	0	0	0	0
spp.	wt	< 2.0	< 2.0	< 2.0					
Decapoda									
Pugettia	#	120.0	680.0	270.0	0	0	0	0	0
gracilis	wt	18.0	8.0	2.0					
Upogebia	#	0	340.0	20.0	6.0	20.0	0	0	0
pugettensis	wt	12.0	< 2.0	< 2.0	< 2.0				
Echinodermata									
Echinoidea									
Dendraster	#	800.0	2140.0	40.0	0	0	0	0	0
excentricus	wt	2.0	36.0	4.0					
Holothuroidea									
Leptosynapta	#	166.0	300.0	50.0	14.0	0	0	0	0
clarki	wt	6.0							
Species Number		70	88	48	44	15	15	15	8
Diversity - H'		2.63	3.15	3.09	2.00	1.22	2.03	1.51	1.27
Total numbers		24994.0	68866.0	13600.0	5988.0	1560.0	1414.0	1472.0	710.0
Total Biomass (g)									

Figure 13. Beckett Point, Tube-Building Polychaete Zonation



Dungeness Spit

The sediment at Dungeness Spit was sandy gravel at +6', gravel +3', fine sand with gravel at +0', medium to fine sand with gravel at -5 m and medium sand with gravel at -10 m. The intertidal had a moderate slope and was extremely exposed to severe wave action. It was the only area east of Port Angeles which proved very difficult to sample because of surf conditions.

Abridged results for Dungeness Spit +6', +3', and +0' are given in Tables 7a-c respectively. All three levels had a very sparse, species-poor community. In fact at each level one quarter during the year absolutely no organisms were found. The only organisms found with any regularity at the three levels were deposit/detritus feeding oligochaetes and amphipods. Fall and winter quarters had the sparsest fauna. However, it would hardly be accurate to say populations, species richness, diversity, total number or biomass peaked in the spring or summer. As expected with such a sparse fauna, patchiness was extreme (see Appendix I).

Subtidal summary results for Dungeness Spit are presented on Table 7d. Fauna was still extremely sparse at -5 m, with no single species found in all three replicates. The community at -10 m, although of low biomass, was fairly rich in both species and total number. The community was composed of small suspension feeding bivalves (*Crenella*, *Mysella*, and *Psephidia*) and deposit feeding polychaetes (capitellids, dorvilleids, and spionids) and gammarids.

Table 7e presents results of the vertical distribution sampling at Dungeness Spit. There was clearly no vertical zonation among the sparse fauna. The levels sampled quarterly were as good as any in documenting Dungeness fauna. There were no tidal height patterns in species number, diversity, total number, or biomass.

Table Dungeness Spit per m^2

7a. +6.0'	Spr 76 #	wt	Sum 76 #	wt	Fall 76 #	wt	Win 77 #	wt
Annelida-Oligochaeta spp.	72	<2.0	6	<2.0	4	<2.0	0	
Crustacea-Amphipoda spp.	8	<2.0	30	<2.0	4	<2.0	0	
Species Richness	4		6		2		0	
Diversity, H	0.88		1.50		0.69		0	
Total Number	112		60		8		0	
Total Biomass (g)	<8.0		<12.0		<4.0		0	

7b. +3.0'	Spr 76 #	wt	Sum 76 #	wt	Fall 76 #	wt	Win 77 #	wt
Annelida-Oligochaeta spp.	20	<2.0	6	<2.0	4	<2.0	0	
Crustacea-Amphipoda spp.	24	<2.0	320	<2.0	20	<2.0	0	
Species Richness	3		4		2		0	
Diversity, H^1	1.09		0.49		0.45		0	
Total Number	60		366		24		0	
Total Biomass (g)	<6.0		<8.0		<4.0		0	

Table Dungeness Spit per m^2

7c. +0.0'	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Annelida-Oligochaeta spp.	200	<2.0	0		0		4	<2.0
Crustacea-Amphipoda spp.	48	<2.0	6	<2.0	0		0	
Species Richness	7		2		0		1	
Diversity, H^1	0.90		0.69		0		0	
Total Number	274		12		0		4	
Total Biomass (g)	<14.0		<4.0		0		<2.0	

Table 7d. Dungeness Spit per m^2

	-5m		-10m	
	#	wt	#	wt
Mollusca				
Bivalvia				
Crenella decussata	0		320.0	<1.0
Macoma spp.	0		17.0	2.0
Mysella tumida	0		630.0	1.0
Psephidia lordi	0		883.0	8.0
Annelida				
Polychaeta				
Capitellidae				
Mediomastus sp.	0		207.0	
Dorvilleidae				
Protodorvillea gracilis	0		93.0	
Spionidae				
Prionospio steenstrupi	0		123.0	
Spiophanes bombyx	0		383.0	
Crustacea				
Amphipoda				
Corophium	0		120.0	<1.0
Melita desdichada	10.0	<1.0	80.0	<1.0
Paraphoxus spp.	17.0	<1.0	67.0	<1.0
Species Richness	30		90	
Diversity - H'	2.44		2.97	
Total Number	283.0		3828.0	
Total biomass (g)	<30.0		<135.0	

Table 7e. Dungeness Spit 25 July 1976 per m^2

Tide Height		+0	+1	+2	+3	+4	+5	+6	+7
Platyhelminthes									
Turbellaria	#	0	10.0	100.0	30.0	0	0	6.0	0
spp.	wt		<2.0	<2.0	<2.0			<2.0	
Annelida									
Oligochaeta sp.	#	0	0	0	6.0	10.0	20.0	6.0	10.0
Crustacea									
Amphipoda	#	6.0	30.0	1990.0	320.0	20.0	210.0	30.0	80.0
sp.	wt	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Species Number		2	2	2	4	3	2	6	2
Diversity - H'		0.69	0.56	0.19	0.49	1.04	0.30	1.50	0.35
Total Number		12.0	40.0	2090.0	366.0	40.0	230.0	60.0	40.0
Total biomass (g)		<4.0	<4.0	<4.0	<8.0	<6.0	<4.0	<12.0	<4.0

Twin Rivers

The sediment at Twin Rivers was sandy gravel at +6', gravel at +3', gravel with fine sand at +0', gravel at -5 m and very fine sand and mud at -10 m. In fact, Twin Rivers -10 m had the finest sediment encountered in the study. The beach had a fairly steep slope and was very exposed to both waves and ocean swells. The lowest salinity in the study (21.5 ‰) was found in spring quarter at Twin Rivers.

Tables 8 a-c present abridged results for Twin Rivers +6', +3', and +0' respectively. At all levels species richness, diversity, and biomass were low. The communities, such as they are, were primarily composed of deposit feeding oligochaetes and gammarid amphipods. No seasonal patterns were apparent. As expected with a sparse fauna, it was extremely patchy spatially.

Twin Rivers subtidal abridged results are given in Table 8d. Despite sediment and depth differences, the communities at -5 m and -10 m were quite similar, rich in species and number, and low in biomass. The communities were dominated by suspension feeding bivalves (*Mysella*, *Protothaca*, *Psephidia*), deposit feeding bivalves (*Macoma*), deposit feeding annelids, and crustaceans. In addition, at -5 m there were herbivores (*Lacuna*, *Platynereis*, and *Pugettia*) and carnivores (*Glycinde* and *Cancer*). As with most of the Van Veen samples, variance among replicates was very high and might not reflect organism patchiness.

Table 8e presents the vertical distribution results in abridged form from Twin Rivers. Except for oligochaetes, there was no clear vertical zonation among the species. There was no tide height pattern in species number, diversity, or biomass. The three seasonal levels sampled were obviously as good as any other three.

Table 8a. Twin Rivers per m^2

+6.0'	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Annelida								
Oligochaeta spp.	172	<2.0	206	<2.0	80	<2.0	256	<2.0
Crustacea								
Amphipoda spp.	12	<2.0	76	<2.0	4	<2.0	40	<2.0
Species Richness	3		4		3		2	
Diversity - H'	0.28		0.84		0.37		0.40	
Total Number	184		304		88		296	
Total Biomass (g)	<6.0		<8.0		<6.0		<4.0	

Table 8b.

+3.0'	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Annelida								
Oligochaeta spp.	280	<2.0	866	<2.0	516	<2.0	208	<2.0
Crustacea								
Isopoda								
Gnorimosphaeroma oregonense	4	<2.0	130	<2.0	4	<2.0	0	
Amphipoda spp.	12	<2.0	66	<2.0	44	<2.0	4	<2.0
Species Richness	5		3		6		3	
Diversity - H'	0.62		0.60		0.44		0.47	
Total Number	332		1062		580		244	
Total Biomass (g)	<10.0		<6.0		<12.0		<6.0	

Table 8c. Twin Rivers per m^2

+0.0'	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Annelida								
Polychaeta								
Spionidae								
Malacocerus glutaeus	32	<2.0	50	<2.0	4	<2.0	16	<2.0
Oligochaeta spp.	336	<2.0	40	<2.0	176	<2.0	164	<2.0
Crustacea								
Amphipoda spp.	0		286	<2.0	4	<2.0	240	<2.0
Species Richness	10		6		4		4	
Diversity - H'	0.88		1.04		0.31		0.86	
Total Number	420		412		188		424	
Total Biomass (g)	<20.0		<12.0		<8.0		<8.0	

Table 8d. Twin Rivers per m^2

	-5m		-10m	
	#	wt	#	wt
Mollusca				
Gastropoda				
Lacuna variegata	127.0	<1.0	0	
Bivalvia				
Macoma spp.	153.0	1.0	17.0	<1.0
Mysella tumida	133.0	<1.0	37.0	<1.0
Protothaca staminea	80.0	2.0	0	
Psephidia lordii	10.0	<1.0	540.0	2.0
Annelida				
Oligochaeta spp.	403.0		393.0	
Polychaeta				
Capitellidae				
Mediomastus sp.	327.0		1330.0	
Cirratulidae				
Tharyx multifilis	67.0		2540.0	
Goniadidae				
Glycinde picta	50.0		123.0	
Nereidae				
Platynereis bicanaliculata	153.0		20.0	
Oweniidae				
Owenia fusiformis	217.0		77.0	
Spionidae				
Prionospio steenstrupi	3.0		163.0	
Crustacea				
Cumacea				
Diastylis sp.	213.0	<1.0	80.0	<1.0
Amphipoda				
Ischyrocerus anguipes	1060.0		0	
Melita desdichada	113.0	<1.0	0	
Paraphoxus spp.	313.0	<1.0	27.0	<1.0
Synchelidium rectipalmum	157.0	<1.0	0	
Tiron biocellata	110.0	<1.0	0	

Table 8d. Twin Rivers per m^2

	-5m #	-5m wt	-10m #	-10m wt
Decapoda				
Callianassidae sp. (juv.)	193.0	<1.0	3.0	<1.0
Cancer gracilis	30.0	4.0	0	
Cancer oregonensis	3.0	2.0	0	
Pugettia gracilis	170.0	1.0	0	
Species Richness	139		65	
Diversity - H'	3.47		2.14	
Total Number	5282.0		6093.0	
Total Biomass (g)	19.0		9.0	

Table 8e. Twin Rivers 28 July 1976 per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Annelida									
Oligochaeta spp.	#	40.0	20.0	80.0	866.0	790.0	360.0	206.0	50.0
Crustacea									
Isopoda									
Gnorimosphaeroma	#	10.0	10.0	0	130.0	20.0	0	16.0	0
oregonense	wt	<2.0	<2.0		<2.0	<2.0		<2.0	
Amphipoda									
Gammaridea	#	286.0	10.0	30.0	66.0	100.0	40.0	76.0	70.0
spp.	wt	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Species number		7	4	2	4	3	2	4	2
Diversity -H'		1.04	1.33	0.59	0.63	0.45	0.33	0.84	0.68
Total number		438.0	50.0	110.0	1068.0	910.0	400.0	304.0	120.0
Total biomass(g)		< 14.0	< 8.0	< 4.0	< 8.0	< 6.0	< 4.0	< 8.0	< 4.0

North Beach Sand

The sediment at +6' was sand with gravel, at +2' medium to fine sand with gravel, at +0' medium to very fine sand, at -5 m medium to coarse sand, and at -10 m sand and gravel. The mid-tide height of +2' was selected instead of +3' to stay out of the more gravelly upper intertidal. North Beach Sand had a moderately sloped beach and moderate exposure, as North Beach Cobble.

Abridged results for North Beach Sand are given in Table 9a. The community at +6' was very low in species richness, diversity, total number of organisms, and total biomass. It was composed of deposit feeding oligochaetes and amphipods. These exhibited no seasonal population pattern. Species richness and total number appeared particularly depressed in the winter. The fauna was of course very patchy in spatial distribution.

Table 9b gives a summary data set for North Beach Sand +2'. Major components of this community were all detrital/deposit feeders and included Paraonella, Exosphaeroma, Eohaustorius, and Paraphoxus. Populations appeared to peak in the summer or fall. Species richness, diversity, and total biomass were low and exhibited no seasonal pattern.

Table 9c presents the abridged results for North Beach Sand +0'. This low diversity, low biomass community was comprised almost totally of deposit/detrital feeding polychaetes and crustaceans plus carnivorous nemerteans. Seasonal patterns in populations were not clear, probably as a result of the difficulty of accurately sampling such patchily distributed organisms.

Abridged subtidal data are given in Table 9d for North Beach. Except for the lack of abundant plants at -10 m, the communities at -5 m and -10 m were quite similar. They were composed of herbivores (Lacuna, Lirularia, Onuphis, and Pugettia), small suspension-feeding bivalves (Crenella, Mysella, Psephidia), deposit feeding bivalves (Macoma), many deposit feeding annelids and small crustaceans, and carnivores (Nassarius, Natica at -5 m, Micropodarke, and Cancer). Species richness, diversity, and total number were high at both levels.

Abridged vertical distribution results for the North Beach Sand intertidal are presented in Table 9e. Vertical zonation of North Beach Sand organisms was clear from these results. The three seasonal levels sampled adequately covered the dominant component species. No clear vertical pattern in species number or diversity was evident. Total number was higher from +0' to +2' than at +3' to +7'.

Table North Beach Sand per m^2

9a. +6.0'	Spr 76 #	wt	Sum 76 #	wt	Fall 76 #	wt	Win 77 #	wt
Annelida-Oligochaeta								
spp.	348	<2.0	160	<2.0	0		0	
Crustacea-Amphipoda								
spp.	0		20	<2.0	124	<2.0	8	<2.0
Species Richness	8		9		10		3	
Diversity, H	1.03		0.98		1.33		1.04	
Total Number	484		208		176		16	
Total Biomass (g)	<16		<18		<20		<6	

9b. +2.0'	Spr 76 #	wt	Sum 76 #	wt	Fall 76 #	wt	Win 77 #	wt
Annelida-Polychaeta								
Paraonidae								
Paraonella platybranchia	184	<2.0	304	<2.0	16	<2.0	88	<2.0
Crustacea								
Isopoda								
Exosphaeroma media	4	<2.0	16	<2.0	84	<2.0	12	<2.0
Amphipoda								
Eohaustorius washingtonianus	5048	14.0	6320	14.0	876	<2.0	608	<2.0
Paraphoxus spp.	0		6	<2.0	68	<2.0	68	<2.0

Table______________________ North Beach Sand per m^2

9b. +2.0'	Spr 76 #	wt	Sum 76 #	wt	Fall 76 #	wt	Win 77 #	wt
Species Richness	12		11		7		13	
Diversity, H[1]	0.30		0.27		0.82		1.30	
Total Number	5348		6694		1116		924	
Total Biomass (g)	<24		<22		<14		<26	

9c. +0.0'	Spr 76 #	wt	Sum 76 #	wt	Fall 76 #	wt	Win 77 #	wt
Nemertea spp.	76	<2.0	12	<2.0	80	<2.0	16	<2.0
Annelida-Polychaeta								
Arenicolidae								
Abarenicola claparedi oceanica	48	<2.0	0		24	<2.0	28	<2.0
Orbiniidae								
Scoloplos sp.	232	<2.0	80	<2.0	24	<2.0	16	<2.0
Paraonidae								
Paraonella platybranchia	988	<2.0	836	<2.0	408	<2.0	464	<2.0
Spionidae spp.	0		16	<2.0	20	<2.0	24	<2.0
Syllidae								
Syllis sp.	28	<2.0	120	<2.0	48	<2.0	24	<2.0
Crustacea								
Mysidacea								
grebnitzkii	792	4.0	76	<2.0	0		12	<2.0

Table 9c. North Beach Sand +0.0' per m^2

	Spr 76		Sum 76		Fall 76		Win 77	
	#	wt	#	wt	#	wt	#	wt
Amphipoda								
Eohaustorius washingtonianus	5112	14.0	1064	2.0	2776	6.0	3112	10.0
Paraphoxus spp.	16	<2.0	28	<2.0	20	<2.0	44	<2.0
Species Richness	8		15		18		18	
Diversity, H	0.99		1.36		0.84		0.76	
Total Number	7300		2296		3478		3816	
Total Biomass (g)	18		<30		<36		<36	

Table 9d. North Beach per m^2

	-5m		-10m	
	#	wt	#	wt
Phaeophyta				
Agarum cribrosum		77.0		0
Rhodophyta				
Odonthalia washingtoniensis		63.0		0
Spermatophyta				
Zostera marina		168.0		0
Mollusca				
Gastropoda				
Lacuna variegata	197.0	<1.0	27.0	<1.0
Lirularia lirulata	100.0	<1.0	20.0	1.0
Nassarius mendicus	7.0	<1.0	3.0	<1.0
Natica clausa	3.0	<1.0	0	
Bivalvia				
Crenella decussata	940.0	3.0	1513.0	<1.0
Macoma spp.	83.0	1.0	23.0	<1.0
Mysella tumida	460.0	1.0	93.0	<1.0
Psephidia lordi	417.0	1.0	50.0	<1.0
Annelida				
Polychaeta				
Capitellidae				
Mediomastus sp.	37.0		117.0	
Dorvilleidae				
Protodorvillea gracilis	250.0		177.0	
Hesionidae				
Micropodarke dubia	570.0		250.0	
Onuphidae				
Onuphis spp.	720.0		3.0	
Spionidae				
Prionospio steenstrupi	0		93.0	
Syllidae				
Exogone lourei	407.0		3.0	

Table 9d. North Beach per m^2

	-5m		-10m	
	#	wt	#	wt
Oligochaeta spp.	63.0		1120.0	
Crustacea				
Tanaidacea				
Leptochelia dubia	1667.0	1.0	0	
Isopoda				
Exosphaeroma amplicauda	253.0	<1.0	0	
Amphipoda				
Pontogeneia rostrata	180.0	<1.0	40.0	<1.0
Protomedeia sp. A	157.0	<1.0	0	
Decapoda				
Cancer oregonensis	3.0	<1.0	10.0	3.0
Pugettia gracilis	93.0	1.0	17.0	<1.0
Species Richness	163		109	
Species Diversity - H'	3.55		3.05	
Total Number	9303.0		5881.0	
Total biomass (g)	390.0		62.0	

Table 9e. North Beach Sand 26 July 1976 per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Annelida									
Polychaeta									
Paraonidae									
Paraonella platybranchia	#	836.0	260.0	304.0	0	0	0	0	0
Syllidae									
Syllis sp.	#	120.0	10.0	6.0	0	0	0	0	0
Oligochaeta spp.	#	0	0	0	80.0	50.0	150.0	160.0	200.0
Crustacea									
Mysidacea									
Archaeomysis	#	76.0	10.0	0	10.0	0	0	0	0
grebnitzkii	wt	< 2.0	< 2.0		< 2.0				
Isopoda									
Exosphaeroma	#	0	0	16.0	80.0	10.0	360.0	0	0
media	wt			< 2.0	< 2.0	< 2.0	< 2.0		
Gnorimosphaeroma	#	0	0	0	270.0	10.0	0	0	0
oregonense	wt				< 2.0	< 2.0			
Amphipoda									
Eohaustorius	#	1064.0	3190.0	6320.0	10.0	0	0	4.0	0
washingtonianus	wt	2.0	6.0	14.0	< 2.0			< 2.0	
Paraphoxus	#	28.0	0	6.0	0	0	0	0	0
spp.	wt	< 8.0		< 2.0					
Species number		18	9	11	10	7	4	9	4
Diversity - H'		1.40	0.44	0.27	1.58	1.64	0.77	0.98	0.82
Total number		1192.0	3550.0	6712.0	530.0	150.0	530.0	208.0	270.0
Total biomass		< 38.0	< 24.0	< 36.0	< 20.0	< 14.0	< 8.0	< 18.0	< 8.0

Kydaka Beach

The sediment at Kydaka Beach at +6', +3', and +0' was uniform by very coarse to fine sand, at -5 m medium to fine sand, and at -10 m fine sand. The beach slope was moderately steep and the area was exposed to extremely violent wave and ocean swell action. Salinity during winter quarter sampling was quite low (25.6 ‰).

Tables 10 a-c present abridged results for Kydaka Beach +6', +3', and +0' respectively. The very low diversity, low total number, low biomass communities were fairly similar at all three levels. Deposit/detrital feeders dominate (oligochaetes, gammarids, *Archaeomysis*). A carnivore (*Nephtys*) occurred at +0'. No clear seasonal patterns emerged, probably because of the difficulty of accurately sampling such a sparse fauna. Winter did appear to be a depressed time for total number.

The summary subtidal results for Kydaka Beach appear in Table 10d. The communities at -5 m and -10 m were quite similar. Major constituents were deposit feeding bivalves (*Tellina*), small suspension feeding bivalves (*Mysella*), deposit feeding polychaetes (*Scoloplos* and *Polydora*) and small crustaceans (*Diastylis*, *Edotea*, and gammarid amphipods). Patchiness at the levels appears to be low from the low variance of replicates.

Vertical distribution results for Kydaka Beach are presented on Table 10e. No clear vertical zonation appeared in the results. No vertical pattern in species richness, diversity, total number, or biomass appeared. The three levels sampled seasonally were obviously as good as any.

Table 10a. Kydaka Beach Organisms per 1.0 m^2 x 15 cm deep

+6.0'	17 Apr 76 #	wt	10 July 76 #	wt	25 Oct 76 #	wt	19 Jan 77 #	wt
Annelida								
Oligochaeta spp.	512	<2.0	8	<2.0	12	<2.0	4	<2.0
Crustacea								
Amphipoda spp.	0		0		108	<2.0	4	<2.0
Species Richness	2		6		2		3	
Diversity - H'	0.05		1.58		0.33		1.04	
Total Number	516		48		120		16	
Total Biomass (g)	<4.0		<12.0		<4.0		<6.0	

Table 10b.

+3.0'	17 Apr 76 #	wt	10 July 76 #	wt	25 Oct 76 #	wt	19 Jan 77 #	wt
Annelida								
Oligochaeta spp.	1204	<2.0	32	<2.0	16	<2.0	8	<2.0
Crustacea								
Mysidacea								
Archaeomysis grebnitzkii	16	<2.0	436	<2.0	0		0	
Species Richness	2		13		2		2	
Diversity - H'	0.07		0.78		0.50		0.64	
Total Number	1220		520		20		12	
Total Biomass (g)	<4.0		<26.0		<4.0		<4.0	

Table 10c. Kydaka Beach Organisms per 1.0 m^2 x 15 cm deep

+0.0'	17 Apr 76 #	wt	10 July 76 #	wt	25 Oct 76 #	wt	19 Jan 77 #	wt
Annelida								
Polychaeta								
Nephtyidae								
Nephtys spp.	4	<2.0	4	<2.0	4	<2.0	4	<2.0
Crustacea								
Mysidacea								
Archaeomysis grebnitzkii	36	<2.0	4	<2.0	0		0	
Amphipoda spp.	8	<2.0	8	<2.0	12	<2.0	4	<2.0
Species Richness	7		11		4		3	
Diversity - H'	1.39		2.37		1.17		0.95	
Total Number	60		48		40		20	
Total Biomass (g)	<14.0		<22.0		<6.0		<6.0	

Table 10d. Kydaka Beach per m^2

	-5m		-10m	
	#	wt	#	wt
Mollusca				
Bivalvia				
Mysella tumida	277.0	<1.0	327.0	<1.0
Tellina sp.	77.0	1.0	83.0	1.0
Annelida				
Polychaeta				
Orbiniidae				
Scoloplos spp.	27.0		67.0	
Spionidae				
Polydora socialis	30.0		70.0	
Crustacea				
Cumacea				
Diastylis sp.	197.0	<1.0	500.0	1.0
Isopoda				
Edotea sublittoralis	60.0	<1.0	0	
Amphipoda				
Atylus levidensus	0		163.0	<1.0
Paraphoxus spp.	470.0	<1.0	530.0	<1.0
Photis brevipes	203.0	<1.0	667.0	1.0
Protomedeia sp. A	3.0	<1.0	103.0	<1.0
Synchelidium shoemakeri	77.0	<1.0	187.0	<1.0
Species Richness	51		53	
Diversity - H'	2.98		2.92	
Total Numbers	2300.0		4568.0	
Total Biomass (g)	<53.0		<54.0	

Table 10e. Kydaka Beach per m^2

		+0	+1	+2	+3	+4	+5	+6	+7
Annelida									
Oligochaeta	#	4	10	10	32	0	10	8	10
Crustacea									
Mysidacea									
Archeomysis grebnitzkii	#	4	30	270	436	10	0	8	0
	wt	< 2	< 2	< 2	< 2	< 2		< 2	
Species Richness		11	7	3	14	3	3	6	3
Diversity - H'		2.37	1.83	0.30	0.80	1.04	1.04	1.64	1.10
Total number		48	100	290	520	40	40	48	30
Total biomass(g)		< 11.0	< 7.0	< 3.0	< 14.0	< 3.0	< 3.0	< 6.0	< 3.0

Jamestown

The Jamestown sediment was sandy gravel at +6', fine sand at +1.4', medium sand at +0', coarse to medium sand at -5 m, and coarse to fine sand at -10 m. The +1.4' level was selected to avoid the upper intertidal gravel. The beach was fairly well protected by Dungeness Spit. Its slope was very gradual and was the widest beach sampled. The only explanation for the anomalous salinity fall quarter (10.4 ‰) was that a rain water puddle was sampled.

Table 11a presents the summary results of Jamestown +6'. This low diversity community was composed predominantly of deposit feeders (nematodes, oligochaetes, and gammarid amphipods). Lowest species richness occurred in the summer, highest total number in winter-spring. The patchiness of the fauna was very great (Appendix I).

Abridged results for Jamestown +1.4' are presented in Table 11b. The major components of this community were a small suspension-feeding bivalve (Transennella), a deposit feeding bivalve (Macoma), other deposit feeders (nematodes, capitellids, paraonids, spionids, oligochaetes, gammarids, and Leptosynapta), and carnivores (Nephtys, Eteone, and Crangon). No clear seasonal patterns appeared in the results. The summer sample was rather anomalous.

Table 11c presents an abridged data set for Jamestown +0'. This high diversity, high biomass community was quite complex. Zostera, tube-building polychaetes and crustaceans, and Upogebia provided major structuring elements and dominate the community. Most of the worms, Macoma, small crustaceans, and Leptosynapta were deposit/detritus feeders. Carnivores included nemerteans, hesionids, phyllodocids, and polynoids. A small, suspension-feeding bivalve (Transennella) was also abundant. No major seasonal changes appeared in the results.

Subtidal results for Jamestown are presented in abridged form in Table 11d. The communities of these two levels, -5 m and -10 m, were quite similar. Both were very species rich, diverse, and had a high total number. Zostera distinguishes -5 m from -10 m. Five species of suspension feeding bivalves and one deposit feeder were present. Herbivores included Lirularia, Platynereis, Onuphis, and Pugettia. Among carnivores were nemerteans, Nassarius, Natica, hesionids, polynoids, and Cancer. In addition there were many deposit/detritus feeding polychaetes and small crustaceans. Replicate variance was fairly low at this area.

Table 11e gives the abridged results for the vertical distribution sampling at Jamestown. As in all areas with a diverse and abundant intertidal fauna vertical zonation of virtually all species was striking. Figure 14 gives the zonation for the detrivorous freely-burrowing oligochaetes and tube-building Leptochelia dubia.

Table 11a. Jamestown +6.0' per m^2

	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Nematoda spp.	54	<2.0	40	<2.0	0		46	<2.0
Annelida Oligochaeta spp.	29340		12280		10006		36966	
Crustacea Amphipoda spp.	6	<2.0	0		314	<2.0	26	<2.0
Species Richness	6		2		10		9	
Diversity, H'	0.02		0.02		0.18		0.04	
Total Number	29426		12320		10366		37164	
Total Biomass (g)	<12.0		<4.0		<20.0		<18.0	

Table 11b. Jamestown +1.4' per m^2

	Spr 76		Sum 76		Fall 76		Win 77	
	#	wt	#	wt	#	wt	#	wt
Nematoda spp.	6	<2.0	0		580	<2.0	366	<2.0
Mollusca								
Bivalvia								
Macoma nasuta	26	30.0	20	8.0	0		26	80.0
Transennella tantilla	700	6.0	346	<2.0	586		2086	6.0
Annelida								
Polychaeta								
Capitellidae								
Capitella capitata	857		674		480		1574	
Nephtyidae								
Nephtys spp.	80		134		154		60	
Paranoidae								
Paraonella platybranchia	480		700		1134		134	
Phyllodocidae								
Eteone longa	120		120		726		606	
Spionidae								
Malacoceros glutaeus	366		560		740		3874	
Pygospio elegans	100		800		3146		3140	
Oligochaeta spp.	266		154		20		1286	
Crustacea								
Amphipoda								
Gammaridea spp.	32	<2.0	2240		3086		1480	<4.0
Decapoda								
Crangon nigracauda	0		0		34	14.0	66	<2.0
Echinodermata								
Holothuroidea								
Leptosynapta clarki	14	<2.0	46		66	4.0	1326	32.0

Table 11b. Jamestown +1.4' per m^2

	Spr 76		Sum 76		Fall 76		Win 77	
	#	wt	#	wt	#	wt	#	wt
Species Richness	28		35		43		38	
Diversity - H'	2.28		2.4		2.48		2.50	
Total Number	3362		6788		12328		18046	
Total Biomass (g)	<56		<70		<86		<76	

Table 11c. Jamestown +0.0' per m^2

	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Spermatophyta								
Zostera marina		518.0		18.0		1026.0		0
Nemertea								
spp.	86	2.0	114	<2.0	106	<2.0	126	<2.0
Nematoda								
spp.	120	<2.0	114	<2.0	1386	<2.0	14	<2.0
Mollusca-Bivalvia								
Macoma spp.	34	38.0	20	10.0	26	<2.0	20	18.0
Transennella tantilla	0		120	<2.0	0		3374	6.0
Annelida								
Polychaeta								
Capitellidae								
Capitella capitata	9806		7340		12814		2714	
Mediomastus sp.	234		514		800		1600	
Cirratulidae								
Cirratulus cirratus	3154		14		2626		14	
Dorvilleidae								
Dorvillea rudolphi	1180		254		400		300	
Hesionidae								
Ophiodromus pugettensis	154		54		0		134	
Lumbrineridae								
Lumbrineris spp.	600		1306		694		1400	
Maldanidae								
spp.	1220		1654		980		2280	
Nereidae								
Platynereis bicanaliculata	1054		20		4800		434	

Table 11c. Jamestown +0.0' per m^2

	Spr 76 #	Spr 76 wt	Sum 76 #	Sum 76 wt	Fall 76 #	Fall 76 wt	Win 77 #	Win 77 wt
Opheliidae								
Armandia brevis	226		6		154		194	
Orbiniidae								
Naineris uncinata	126		206		100		760	
Phyllodocidae								
Etone longa	20		86		100		336	
Phyllodoce maculata	366		126		60		194	
Polynoidae								
Harmothoe imbricata	114		754		166		294	
Spionidae								
Malacoceros glutaeus	3174		1706		1466		3294	
Syllidae								
Exogone lourei	4414		4066		2106		2146	
Terebellidae								
Pista brevibranchiata	386		574		726		1120	
Oligochaeta								
spp.	36514		13694		27894		20626	
Crustacea								
Tanaidacea								
Leptochelia dubia	3986		9120		1194		3500	
Amphipoda								
spp.	1546	<2.0	820	<2.0	1254	<2.0	1356	<2.0
Decapoda								
Pinnixa spp.	134	14.0	106	2.0	92	8.0	60	<2.0
Upogebia pugettensis	166	128.0	770	138.0	114	76.0	146	184.0
Echinodermata								
Holothuroidea								
Leptosynapta clarki	0		26	<2.0	412		226	

Table 11c. Jamestown +0.0' per m^2

	Spr 76		Sum 76		Fall 76		Win 77	
	#	wt	#	wt	#	wt	#	wt
Species Richness	88*		51		57		60	
Diversity, H'	2.00		2.16		2.05		2.39	
Total Number	69558		43970		61976		48800	
Total Biomass (g)	710		228		1112		212	

* 73 if amphipod species are lumped as in summer-winter

Table 11d. Jamestown subtidal per m^2

	-5m		-10m	
	#	wt	#	wt
Spermatophyta				
Zostera marina		19.0		0
Nemertea spp.	503.0		260.0	1.0
Nematoda spp.	560.0	<1.0	353.0	<1.0
Mollusca				
Gastropoda				
Lirularia lirulata	130.0	<1.0	37.0	<1.0
Nassarius mendicus	0		3.0	<1.0
Natica clausa	170.0	4.0	33.0	3.0
Bivalvia				
Cardita ventricosa	200.0	5.0	7.0	
Clinocardium nuttallii	67.0	4.0	17.0	3.0
Crenella decussata	4007.0	14.0	3660.0	12.0
Macoma spp.	203.0	25.0	43.0	12.0
Mysella tumida	2630.0	3.0	1203.0	1.0
Psephidia lordi	1083.0	6.0	2737.0	13.0
Annelida				
Polychaeta				
Capitellidae				
Mediomastus sp.	2550.0		1030.0	
Chaetopteridae				
Phyllochaetopterus prolifica	40.0		433.0	
Cirratulidae				
Tharyx multifilis	190.0		213.0	
Dorvilleidae				
Protodorvillea gracilis	740.0		240.0	
Hesionidae				
Micropodarke dubia	697.0		240.0	
Maldanidae				
Euclymene sp.	193.0		63.0	

Table 11d. Jamestown subtidal per m^2

	-5m		-10m	
	#	wt	#	wt
Nereidae				
Platynereis bicanaliculata	333.0		427.0	
Onuphidae				
Onuphis stigmatis	63.0		143.0	
Oweniidae				
Owenia fusiformis	313.0		330.0	
Paraonidae				
Aricidea sp.	237.0		220.0	
Polynoidae				
Harmothoe imbricata	160.0		213.0	
Sabellidae				
Sabella media	50.0		523.0	
Spionidae				
Malacocerus glutaeus	137.0		293.0	
Polydora socialis	300.0		360.0	
Prionospio steenstrupi	17.0		553.0	
Spiophanes bombyx	263.0		277.0	
Syllidae				
Exogone lourei	800.0		473.0	
Sphaerosyllis pirifera	283.0		43.0	
Crustacea				
Cumacea				
Diastylis sp.	100.0	<1.0	47.0	<1.0
Tanaidacea				
Leptochelia dubia	1920.0		2867.0	2.0
Amphipoda				
Paraphoxus spp.	114.0	<1.0	167.0	<1.0
Decapoda				
Cancer gracilis	10.0	15.0		
Pugettia gracilis	3.0	<1.0	147.0	1.0

Table 11d. Jamestown subtidal per m^2

	-5m		-10m	
	#	wt	#	wt
Species Richness	174		144	
Diversity - H'	3.50		3.24	
Total Numbers	21712.0		20747.0	
Total Biomass (g)	266.0		106.0	

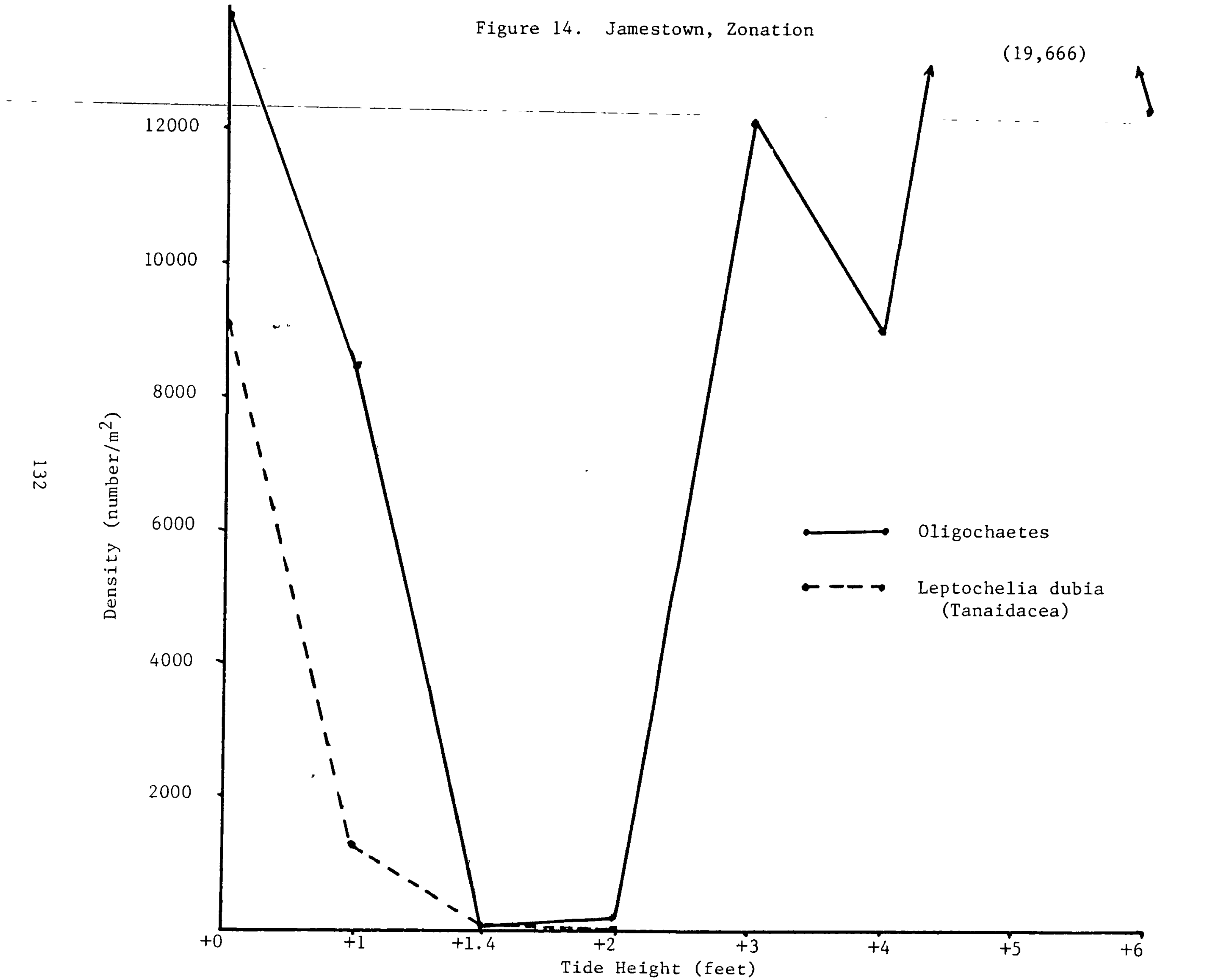
Table 11e. Jamestown per m^2

		+0	+1	+1.4	+2	+3	+4	+5	+6
Mollusca									
Bivalvia									
Transennella tantilla	#	120	140	346	0	0	20	0	0
	wt	< 2	< 2	0			< 2		
Annelida									
Polychaeta									
Capitellidae									
Capitella capitata	#	7340	680	674	350	0	0	0	0
Dorvilleidae									
Dorvillea rudolphi	#	254	70	0	0	0	0	0	0
Lumbrineridae									
Lumbrineris spp.	#	1306	2240	6	10	0	0	0	0
Maldanidae									
Axiothella rubrocincta	#	654	210	0	0	0	0	0	0
Euclymene sp.	#	814	280	0	0	0	0	0	0
Nephtyidae									
Nephtys spp.	#	6	10	134	0	0	0	0	0
Orbinidae									
Naineris uncinata	#	206	230	0	0	0	0	0	0
Paraonidae									
Paraonella platybranchia	#	0	10	700	0	0	0	0	0
Phyllodocidae									
Eteone spp.	#	86	60	120	70	0	0	0	0
Phyllodoce maculata	#	126	50	0	0	0	0	0	0
Polynoidae									
Harmothoe imbricata	#	754	280	0	0	0	0	0	0
Spionidae									
Malacoceros glutaeus	#	1706	910	560	10	0	0	0	0
Pygospio elegans	#	0	0	800	0	0	6	0	0
Syllidae									
Exogone lourei	#	14	0	0	0	0	0	0	0
Terebellidae									
Pista brevibranchiata	#	574	300	0	0	0	0	0	0
Oligochaeta spp.	#	13694	8510	154	190	12120	9026	19666	12280

Table 11e. Jamestown per m^2

		+0	+1	+1.4	+2	+3	+4	+5	+6
Crustacea									
Tanaidacea									
Leptochelia dubia	#	9120	1270	40	0	0	0	0	0
	wt	12	< 2	< 2					
Amphipoda	#	820	80	2240	18580	100	6	20	0
Gammaridea		< 2	< 2	< 2		< 2	< 2	< 2	
Decapoda									
Telmessus cheiragonus	#	6	0	0	0	0	0	0	0
	wt	42							
Upogebia pugetterisis	#	770	150	0	0	0	0	0	0
	wt	138	168						
Echinodermata									
Holothuroidea									
Leptosynapta clarki	#	26	110	46	0	0	0	0	0
	wt	< 2	< 2	< 2					
Species Richness		51	47	35	20	11	7	4	2
Diversity - H'		2.16	2.40	2.40	0.32	0.28	0.07	0.02	0.02
Total Number		43974	22945	6788	19620	12578	9112	19706	12320
Total biomass(g)		228.0	184.0	8.0	18.0	< 22.0	< 14.0	< 8.0	< 4.0

Figure 14. Jamestown, Zonation



Generally at Jamestown species richness, diversity, total number, and biomass decreased with increasing tidal height. These results were very clear justification for the selection of +0', +1.4' and +6' for seasonal sampling. These three levels gave the best possible coverage of the intertidal species at Jamestown.

IV. DISCUSSION

IV-A. Study Area Comparisons

Tables 12 and 13 present summary information on species richness, species diversity, density, and biomass for the intertidal and subtidal respectively. The intertidal values were averaged over the four sample periods.

Species richness and diversity were highest in the rocky intertidal followed by cobble and protected finer sediment areas (Beckett and Jamestown). They were lowest in the exposed sand and gravel areas. An inadequate number of similar habitats were sampled to detect any east-west trends along the Strait. Of the paired sand habitats, North Beach Sand was more species-rich than Kydaka, but it was also less exposed. Because of the role of exposure and the absence of a rock study area east of Port Angeles or a cobble area west, no statement can be made concerning open coast versus Puget Sound affinities. In terms of only rock fauna and flora, Puget Sound is merely a depauperate version of the open coast, containing no unique or endemic species. The existing data base is inadequate to make any similar generalizations about soft-bottom intertidal and shallow subtidal open coast versus Puget Sound systems.

In all habitats except species-poor Dungeness Spit, species richness increased with decreasing tide height in the intertidal. Except for species-poor gravel and sand areas, species diversity showed a similar pattern. No consistent patterns in species richness and diversity were evident comparing -5m to -10m.

Subtidal diversity and species richness were high. Patterns among the areas were difficult to discern. Generally, species richness was less in the most exposed areas (Kydaka, Dungeness -5m). Tongue Point -10m had low species richness because of intense urchin grazing. Still, all subtidal areas were species rich compared to gravel and sand intertidal habitats.

In the intertidal, total density and biomass followed fairly closely species richness patterns with highest values at the rock, cobble, and protected finer sediment areas. Patterns at these areas relative to tidal height were more complex. Biomass except at Beckett increased with decreasing tide height. The bivalve biomass at Beckett caused biomass to peak in the mid-intertidal. In the rock and cobble areas, high barnacle numbers caused a peak in density at +3'. In gravel and sand areas, low biomass prevented detection of tide height patterns. In the exposed areas (Dungeness, Twin Rivers, Kydaka), density peaked in the mid-intertidal. At the more protected North Beach area, density increased with decreasing tide height.

A number of patterns were evident for density and biomass at the subtidal areas. Lowest densities occurred at exposed Dungeness -5m

Table 12 Intertidal Summary Table

Study Area		Mean Species Richness	Mean Diversity H'	Mean Total Density ($\#/m^2$)	Mean Total Biomass (g/m^2)
Tongue Point	+6	47.3	2.20	18,109	927.6
	+3	103.3	2.6	28,371	2,574.9
	+0	150.3	2.5	4,474	5,262.4
Pillar Point	+6	30.5	1.5	18,526	546.3
	+3	137.8	3.1	12,395	5,963.8
	+0	121.5	2.4	7,338	10,751.7
North Beach Cobble	+6	16.8	1.7	2,294	81.2
	+3	48.3	1.9	12,233	917.5
	+0	90.3	2.4	7,590	590.9
Morse Creek	+6	8.5	1.1	3,131	78.1
	+3	56.8	1.8	21,388	791.3
	+0	101.8	2.6	12,794	1,683.4
Beckett Point	+6	17.3	1.8	1,713	95.5
	+3	40.0	2.0	4,716	884.0
	+0	80.3	2.1	34,102	465.5
Dungeness Spit	+6	4.0	1.02	60	<8.0
	+3	3.0	0.68	150	<6.0
	+0	3.3	0.8	97	<6.7
Twin Rivers	+6	3.0	0.47	218	<6.0
	+3	4.3	0.53	555	<8.5
	+0	6.0	0.77	361	<12.0
North Beach Sand	+6	7.8	1.1	221	<15.0
	+2	10.8	0.67	3,521	<21.5
	+0	14.8	0.99	4,223	<30.0
Kydaka Beach	+6	3.3	0.75	175	<6.5
	+3	4.8	0.5	443	<9.5
	+0	6.3	1.47	42	<12.0
Jamestown	+6	6.8	0.07	22,319	<13.5
	+1.4	30.0	1.87	11,579	<60.0
	+0	64.0	2.2	56,076	565.5

Table 13 Subtidal Summary Table

Study Area		Species Richness	Diversity H'	Total Density (#/m^2)	Total Biomass (g/m^2)
Tongue Point	- 5m	133	2.57	6,004	8,539
	-10m	59	2.10	604	778
Pillar Point	- 5m	92	3.07	6,123	109
	-10m	91	3.26	4,715	73
Morse Creek	- 5m	74	3.01	1,495	104
	-10m	149	2.79	8,863	37
Beckett Point	- 5m	101	2.91	15,522	50
	-10m	132	3.11	18,122	55
Dungeness Spit	- 5m	30	2.44	283	<30
	-10m	90	2.97	3,828	<135
Twin Rivers	- 5m	139	3.47	5,282	19
	-10m	65	2.14	6,093	9
North Beach	- 5m	163	3.55	9,303	390
	-10m	109	3.05	5,881	62
Kydaka Beach	- 5m	51	2.98	2,300	<53
	-10m	53	2.92	4,568	<54
Jamestown	- 5m	174	3.50	21,712	266
	-10m	144	3.24	20,747	106

and heavily grazed Tongue Point -10m. Highest densities were found in the most protected areas, Beckett Point and Jamestown. In general, biomass decreased with increasing depth. Since, algae contributed the bulk of subtidal biomass, this would be explained by decreasing light intensity with increasing depth.

Figures 15 and 16 present in matrix format the community composition comparisons using the percentage of species in common as the measure of similarity. The set of numbers used in the matrix calculations are given in Appendix I, Tables 11 and 12. An explanation of the method of computation was given in Methods and Materials.

Despite the volume of numbers the intertidal matrix only served to confirm the obvious. The rock and cobble areas were similar to each other. The gravel areas were similar to each other. No other areas showed a great deal of similarity (greater than 50%). Noteworthy was the lack of similarity of the two sand areas, Kydaka and North Beach Sand. Also of interest was the general lack of great similarity between tide heights at given study sites or at different sites of the same or similar habitat type, again reinforcing the validity of original tide height strata for sampling.

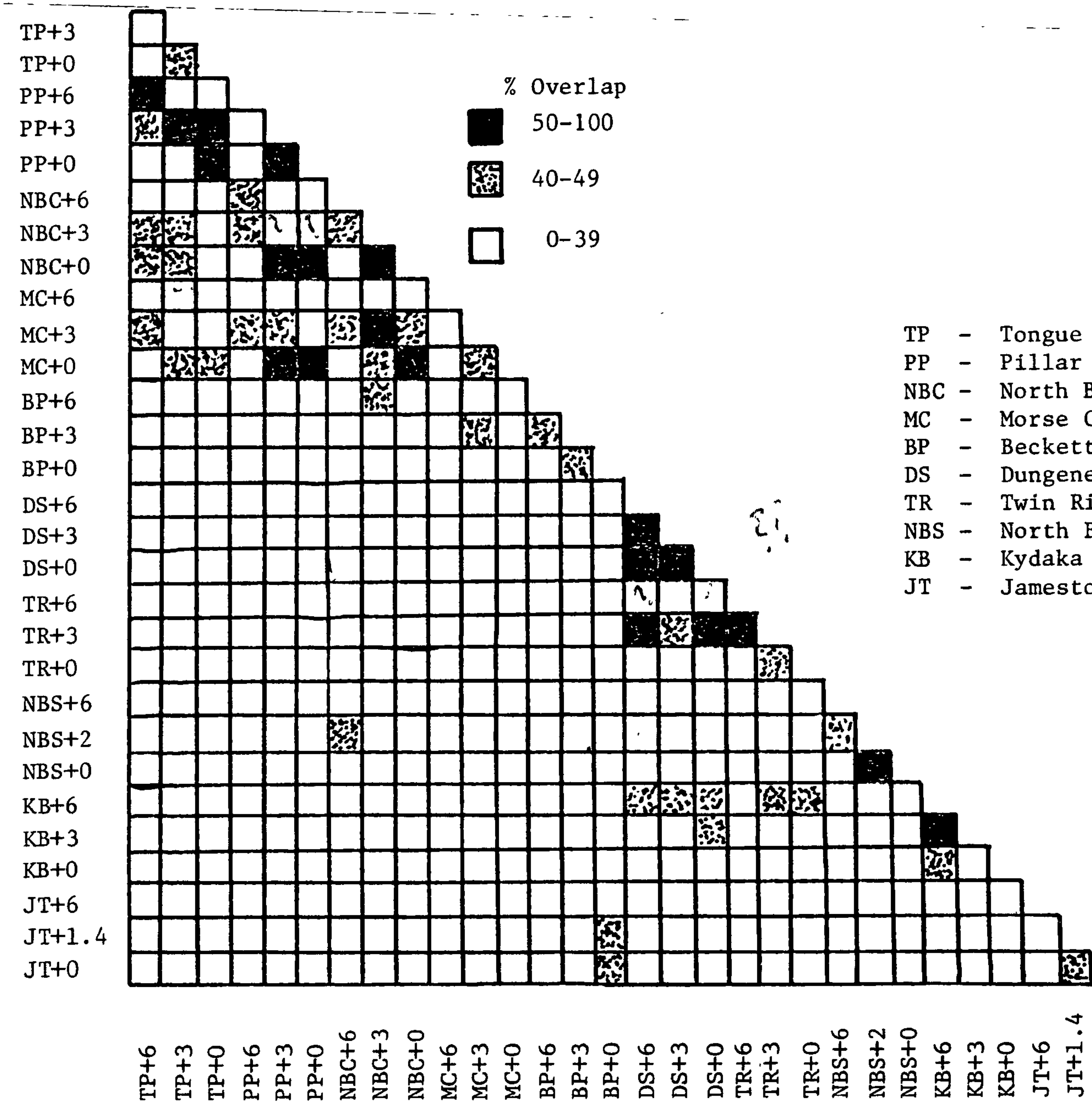
The subtidal similarity matrix was of more interest because, other than sediment analysis, nothing else was known about the areas physically. Examination of the matrix revealed that little else need be known. Except for rock (Tongue Point) depth (-5m vs -10m) had little effect on community composition. At all other areas except Dungeness Spit and Twin Rivers -5m/-10m, overlap was greater than 40%. Extreme exposure most likely explains the low -5m/-10m overlap at Dungeness Spit despite similar sediment and at Twin Rivers the sediment at -5m and -10m are radically different.

These areas are arranged by sediment below:

Gravel	Coarse Sand	Sand	Mud
North Beach -10	North Beach -5	Beckett Pt -5 & -10	Twin Rivers -10
Morse Creek -5 & -10	Jamestown -5 & -10	Pillar Pt -5 & -10	
Dungeness -5 & -10		Kydaka -5 & -10	
Twin Rivers -5			

All cases of high overlap or similarity occurred within these four categories or between adjacent categories. Therefore, sediment characteristics appeared to play an overriding role in Strait of Juan de Fuca shallow subtidal benthic soft-bottom community composition. Twin Rivers -10m, which was located off the mouth of two rivers, was a fine sediment trap and may be dismissed as anomalous. So it would appear that along the Strait there were only two basic shallow subtidal soft-bottom habitat types: gravel and sand. However, these were not discrete but form a continuum from coarse to finer sediment type.

Figure 15. Intertidal Community Composition Comparison Matrix



TP - Tongue Point - rock
PP - Pillar Point - rock
NBC - North Beach - cobble
MC - Morse Creek - cobble
BP - Beckett Point - mixed
DS - Dungeness Spit - gravel/sand
TR - Twin Rivers - gravel/sand
NBS - North Beach - sand
KB - Kydaka Beach - sand
JT - Jamestown - sand/mud

Figure 16. Subtidal Community Composition
Comparison Matrix

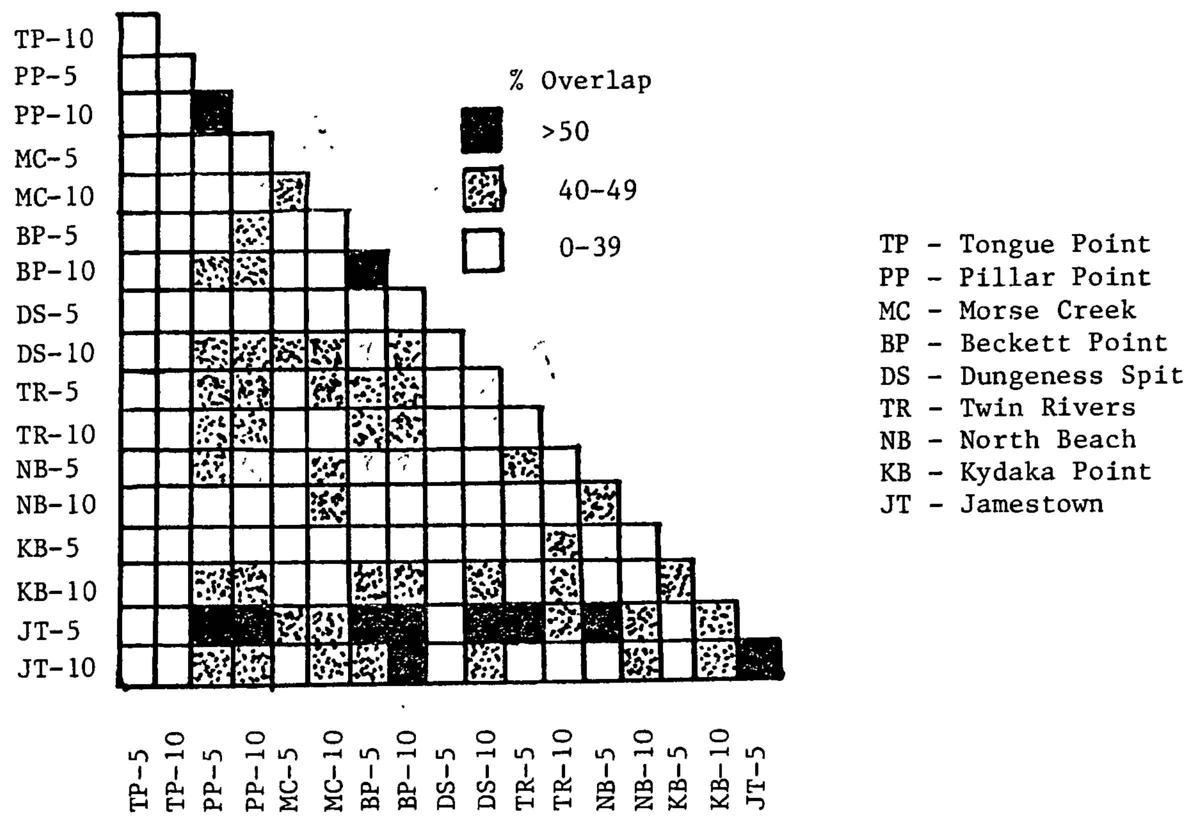


Table 14 presents study area community composition broken down by the number of species in the major taxon groups of algae, molluscs, annelids, crustaceans, and miscellaneous (all other phyla). From these data, it is clear that annelids and crustaceans were major community components at all study sites. Algal species were a major component only at the rock and cobble areas, especially numerous at the +3' and +0' levels. Molluscs were abundant at Beckett Point and Jamestown, primarily as infauna in the finer sediments there. They were also abundant at rock and cobble areas, primarily as epifauna. Molluscs were essentially absent at gravel and sand areas.

It is also possible to rank study sites by biomass or standing crop and from this to make inferences about productivity and energy flow in the community. Rock habitats had by far the greatest standing crop with as much as 17.5 kg/m^2 found in this study. Cobble areas were next in standing crop, although fine sediment areas at some levels where large bivalves and crustaceans were abundant also had a large standing crop. In rock and cobble areas a large percentage of the standing crop was benthic macro-algae (and some eelgrass), the major primary producers in these communities. Therefore, areas with little or no macro-algae such as the gravel and sand habitats would have low productivity. Energy flow in these communities would be based on importation from drift or the plankton. Although turnover rates are unknown, it is hard to imagine they are high enough to raise the energy flow and indirect productivity of these sparsely populated gravel and sand communities to the level of those of rock, cobble, or fine sediment communities. Ranking energy flow and net productivity in the rock, cobble, and fine sediment systems is impossible without detailed rate studies.

In summary then, a comparison of the study areas sampled has revealed discrete communities. The type of community found appeared to be a function of the sediment type/exposure and tide height of the given area-stratum.

Having now made study area comparisons along the Strait of Juan de Fuca, a brief comparison with San Juan Island study areas would be of interest. Since the San Juan Island study area reports did not include comparable data presentation for diversity, abundance, biomass, or community composition, only species richness was compared. Since comparable subtidal sampling was not done in the San Juan studies, only intertidal areas can be compared. Table 15 gives a summary comparison of species richness for San Juan Island areas Spring 1975 with Strait areas Spring 1976. Soft-bottom habitats are quite comparable in richness. Comparing rock areas, however, Cantilever Pier, San Juan Island was dramatically less rich than Tongue or Pillar. No simple explanation for this is apparent. Since rock communities recruit largely from the plankton and the bulk of rock organisms propagules originate on the open coast, greater Puget Sound might be considered an island with an impoverished fauna because of recruitment problems. Another hypothesis is predation. Physical factors in the Strait limit predation (including herbivory) and permit a three dimensional community to form. On San Juan Island physical factors do not limit the effectiveness of predators, and rock communities

Table 14. Community Composition by Major Taxon Groups

	Tongue Point			Pillar Point			North Beach Cobble			Morse Creek			Beckett Point		
	+6'	+3'	+0'	+6'	+3'	+0'	+6'	+3'	+0'	+6'	+3'	+0'	+6'	+3'	+0'
Spr 76															
Algae	18	40	84	11	60	55	0	16	55	0	17	36	0	0	2
Molluscs	7	30	31	7	30	17	3	9	14	1	8	11	3	12	8
Annelids	0	17	38	2	26	11	4	9	26	4	7	21	5	19	39
Crustaceans	8	46	56	5	43	33	4	13	28	5	14	36	2	4	10
Misc.	2	14	23	1	22	14	1	2	5	1	5	8	3	3	9
Total	35	147	222	26	184	130	12	49	128	11	51	112	13	38	68
Sum 76															
Algae	24	44	43	12	60	49	10	12	19	0	21	46	0	3	1
Molluscs	11	24	33	9	24	15	2	16	13	1	14	29	1	9	12
Annelids	3	13	32	2	33	33	5	6	17	2	14	20	7	18	41
Crustaceans	16	31	43	6*	45	60	5	16	29	2*	13*	34*	4*	11*	11*
Misc.	5	14	15	1	12	20	3	6	5	0	5	15	2	3	6
Total	59	126	166	30	174	177	25	56	83	5	67	154	14	44	71
Fall 76															
Algae	18	37	30	12	48	49	0	0	21	0	14	21	0	0	0
Molluscs	14	27	18	8	20	13	6	15	18	2	18	16	9	10	20
Annelids	4	7	33	4	16	30	3	9	27	2	16	26	5	20	62
Crustaceans	10*	25*	24*	14*	25*	42*	4*	16*	21*	3*	14*	23*	6*	6*	16*
Misc.	3	13	11	6	14	15	3	4	5	1	5	12	3	5	6
Total	49	109	116	44	123	149	16	44	92	8	67	98	23	41	104
Win 77															
Algae	25	37	39	13	41	41	0	3	23	0	3	14	0	0	0
Molluscs	13	18	11	9	26	16	10	15	13	4	17	15	9	12	16
Annelids	4	7	24	2	21	13	5	11	20	2	14	21	7	18	48
Crustaceans	9*	16*	24*	9*	26*	24*	6	12*	16*	3*	14*	15*	3	5*	11*
Misc.	4	12	8	5	14	7	4	6	3	1	5	9	1	4	8
Total	55	90	106	38	128	101	25	47	75	10	53	74	20	39	83

* Amphipods not identified to species

Table 14., continued

	Dungeness Spit			Twin Rivers			North Beach Sand			Kydaka Beach			Jamestown		
	+6'	+3'	+0'	+6'	+3'	+0'	+6'	+3'	+0'	+6'	+3'	+0'	+6'	+3'	+0'
Spr 76															
Algae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Molluscs	0	0	0	0	0	0	0	0	0	0	0	1	0	3	7
Annelids	1	1	3	2	2	7	5	8	4	1	1	3	3	18	44
Crustaceans	3	1	2	2	1	0	0	3	3	1	1	3	2	6	25
Misc.	0	1	2	0	1	2	3	1	0	0	0	0	1	2	10
Total	4	3	7	4	4	9	8	12	7	2	2	7	6	29	93
Sum 76															
Algae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Molluscs	0	0	0	0	1	0	0	1	1	0	0	0	0	4	5
Annelids	2	1	1	1	1	4	3	5	8	3	7	6	1	23	31
Crustaceans	1	1	1	3	2	2	5	4	7	2	5	4	0	6	9*
Misc.	3	2	0	0	0	1	1	1	2	1	1	1	1	2	5
Total	6	4	2	4	4	7	9	11	18	6	13	11	2	35	51
Fall 76															
Algae	0	0	0	0	0	0	0	0	0	0	0	0	7	3	2
Molluscs	0	0	0	0	0	1	0	0	0	0	0	0	0	1	4
Annelids	2	2	0	1	4	3	3	2	8	2	2	3	1	26	40
Crustaceans	1	1*	0	1	2*	1	1*	3*	6*	1*	1	1*	1*	11*	13*
Misc.	0	0	0	1	1	0	0	0	4	0	0	0	1	3	5
Total	3	3	0	3	7	5	4	5	18	3	3	4	10	44	64
Win 77															
Algae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Molluscs	0	0	0	0	0	0	1	2	0	0	0	0	2	4	4
Annelids	0	0	1	1	1	3	0	5	10	1	2	2	2	23	39
Crustaceans	0	0	0	1*	1	1*	2	6	6*	2	0	1	2*	7*	9*
Misc.	0	0	0	0	1	0	0	1	2	0	0	0	3	4	6
Total	0	0	1	2	3	4	3	14	18	3	2	3	9	38	60

* Amphipods not identified to species

Table 15. San Juan Island Comparison (Mean Species Richness High, Mid, and Low Intertidal)

	Spring 1975 San Juan Island	Spring 1976 Strait of Juan de Fuca
Rock	34.0	131.7, 118.0
Gravel	5.3, 12.3	4.7, 8.3
Sand	13.3	8.7, 3.7
Mixed	35.0	39.0
Mud	32.7	44.0

typically lack a third dimension which greatly reduces habitat for a large number of species requiring space in that third dimension.

Despite this rock habitat difference, there does appear to be enough general community similarity among areas of the same type habitats based largely on sediment characteristics to provide a basis for extrapolation to sites never sampled. Exposed gravel and sand areas have a depauperate but characteristic fauna. Even with the more complex communities found in rock, cobble, and fine sediment areas, there appears a reasonable degree of community similarity among sites sampled to date. There is a need to make more quantitative statements of the degree of similarity among sites of a given habitat type studied to date in the various greater Puget Sound baseline studies. However, because of the non-compatible format of the available data base, such regional type habitat comparisons proved beyond the scope of this report.

IV-B. Seasonal Changes

Specific changes were noted area by area in the Results and are summarized in Tables 16, 17 and 18. Some general patterns may be discerned. In virtually all areas with a high species richness, species richness remained high through the year, with some areas showing a slight decline in richness in the winter (Table 16). In species-poor areas, there was often a winter depression in species richness. This was probably due to exposure to severe winter storm disturbance.

Table 17 presents a summary of seasonal change in community abundance. Although the same seasonal pattern was not found for all levels at all sites, more areas had their highest abundance in the summer and lowest in the winter than during the other three quarters.

Seasonal change in biomass was most difficult to get a handle on (Table 18). No useful biomass information was obtained from the low biomass areas. In high biomass areas, changes, if they occurred, were generally masked by the "patchiness" of biomass; i.e., the patchiness of those large species which contribute overwhelmingly to a quadrat's biomass.

Seasonal population changes of individual species were often not clear, except for species which had a discrete period of massive recruitment (for example Balanus in early May 1976). This may have been due to the population being stable in number over the year; i.e., long-lived species or species whose individuals are replaced at about the same rate as mortality. Another reason may have been that the population was simply not adequately sampled for providing an accurate measure of population size, because the species was patchily distributed relative to the sampling methodology employed. This was a particular problem in rock, cobble, and gravel areas. In these areas, increasing quadrat size or number would produce little improvement. Because of the extreme patchiness, essentially the entire study area would have to be sampled.

Table 16.

Seasonal Change: Species Richness

		Spring	Summer	Fall*	Winter*
Tongue Point	+6'	35	56	43	55
	+3'	116	103	104	90
	+0'	209	148	138	106
Pillar Point	+6'	26	28	30	38
	+3'	169	148	106	128
	+0'	123	136	126	101
North Beach, Cobble	+6'	12	16	14	25
	+3'	49	54	43	47
	+0'	122	76	88	75
Morse Creek	+6'	11	5	8	10
	+3'	51	61	62	53
	+0'	109	134	90	74
Beckett Point	+6'	12	14	23	20
	+3'	37	44	40	39
	+0'	68	71	99	83
Dungeness Spit	+6'	4	6	2	0
	+3'	3	4	2	0
	+0'	7	2	0	1
Twin Rivers	+6'	3	4	3	2
	+3'	5	3	6	3
	+0'	10	6	4	4
North Beach, Sand	+6'	8	9	10	3
	+3'	12	11	7	13
	+0'	8	15	18	18
Kydaka Beach	+6'	2	6	2	3
	+3'	2	13	2	2
	+0'	7	11	4	3
Jamestown	+6'	6	2	10	9
	+3'	28	35	43	38
	+0'	88	51	57	60

*Amphipods not identified to species

Table 17.

Seasonal Change: Density (#/m^2)

		Spring	Summer	Fall	Winter
Tongue Point	+6'	496	15,994	36,995	18,950
	+3'	29,324	49,499	23,198	11,464
	+0'	4,052	2,915	6,918	4,012
Pillar Point	+6'	27,282	16,223	11,656	18,942
	+3'	11,540	12,330	6,260	19,447
	+0'	729	15,216	10,678	2,729
North Beach, Cobble	+6'	283	726	2,102	6,064
	+3'	9,077	18,440	9,457	11,958
	+0'	5,512	10,063	8,793	5,993
Morse Creek	+6'	870	8,670	2,699	286
	+3'	12,267	26,252	26,203	20,832
	+0'	6,042	24,892	13,637	6,606
Beckett Point	+6'	1,110	1,480	2,988	1,274
	+3'	5,024	5,982	4,800	3,056
	+0'	3,332	25,060	66,048	41,968
Dungeness Point	+6'	112	60	8	0
	+3'	60	366	24	0
	+0'	274	12	0	4
Twin Rivers	+6'	184	304	88	296
	+3'	332	1,062	580	244
	+0'	420	412	188	424
North Beach, Sand	+6'	484	208	176	16
	+3'	5,348	6,694	1,116	924
	+0'	7,300	2,296	3,478	3,816
Kydaka Beach	+6'	516	48	120	16
	+3'	1,220	520	20	12
	+0'	60	48	40	20
Jamestown	+6'	29,426	12,320	10,366	37,164
	+3'	3,362	6,788	12,328	18,046
	+0'	69,558	43,970	61,976	48,800

Table 18.

Seasonal Change: Biomass (g/m^2)

		Spring	Summer	Fall	Winter
Tongue Point	+6'	328	830	1,588	965
	+3'	2,468	2,314	3,876	1,641
	+0'	7,566	6,020	5,336	2,128
Pillar Point	+6'	640	443	378	725
	+3'	11,766	5,078	1,408	5,603
	+0'	7,548	16,044	17,472	1,943
North Beach, Cobble	+6'	-	-	-	-
	+3'	353	2,362	594	361
	+0'	908	157	504	795
Morse Creek	+6'	-	-	-	-
	+3'	1,587	597	689	292
	+0'	1,626	3,649	654	805
Beckett Point	+6'	22	212	54	94
	+3'	892	1,048	1,450	146
	+0'	74	264	140	1,384
Jamestown	+6'	-	-	-	-
	+1.4'	-	-	-	-
	+0'	710	228	1,112	212

In contrast to this problem, the general composition of communities, the dominant component species and their general order of abundance, was stable at most intertidal areas sampled. In terms of monitoring change over time or after a perturbation, rather than concentrating on the community's individual species population sizes, a better tool would be a measure of community composition over time. A number of overlap or similarity indices could prove most appropriate in measuring community change in baseline studies.

IV-C. Annual Changes

A critical component of any baseline monitoring is a determination of year-to-year changes in population abundances and community composition. Since this report is based on only one year of sampling, the question of annual change cannot be addressed. However, a second year of sampling has been completed, and annual changes will be discussed in a second year report.

IV-D. Response to Perturbations

Oil is only one of a host of natural and man-caused agents which may negatively impact intertidal and shallow subtidal communities. Their actions, however, fall in two classes: non-selective destruction (e.g., log damage, crude oil smothering) killing everything in a given area and selective destruction (e.g., a bout of low, but not too low, salinity or refined oil poisoning). Community response to each of these classes is quite different. Sterilization of an area merely opens it up for recolonization. A similar community in the short term may or may not reestablish itself , dependent on recruitment dynamics of component species. We know virtually nothing about recruitment dynamics of benthic marine organisms in this region.

Selective removal of organisms from a community will have major or minor impacts dependent on what is impacted. Elimination of an important predator in a system or of a species primarily responsible for the bio-physical structuring of the community could have devastating community repercussions. Recovery would depend on recruitment dynamics and could take decades after a single episode. Removal of a minor community component selectively by definition would have little impact. From this, it follows that the more complex systems represented by rock and fine sediment infaunal communities may be more vulnerable to lasting damage, because of the many long-lived species with unpredictable recruitment in these systems, than the simpler communities found in gravel and sand.

From all this, it is possible to rank the systems studied according to probable severity of impact from an oil spill. First at a given area from +7' to -10m the greater impact will be at the higher strata because of increased physical contact with the pollutant. In terms of habitat type-benthic community, those dominated by epifauna and epiflora will be more vulnerable than those dominated by infauna, again a function of contact with the oil. Finally, those systems whose key component species are long-lived and have unpredictable recruitment year to year, will be more damaged than those comprised of short-lived species. The ranking below results from such considerations.

Increasing Damage	Habitat Type	Strait Study Areas	Tide Height
↓	Gravel	Dungeness Spit	-10m
		Twin Rivers	
	Sand	Kydaka Beach	-5m
		North Beach Sand	
	Mud	Jamestown	0'
	Mixed	Beckett Point	
	Cobble	North Beach Cobble	+3'
		Morse Creek	
	Rock	Pillar Point	+6'
		Tongue Point	

In terms of seasonal vulnerability, Spring-Summer would be the period of greatest damage because of recruitment during this period and the high standing crop.

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VI. REFERENCES

In addition to those references cited in the text, the following list includes the major taxonomic works consulted for species identification.

Abbott, I.A., and G.J. Hollenberg. 1975. Marine Algae of California. Stanford University Press. 832 pp.

Alderman, A.L. 1936. Some new and little known amphipods of California. Univ. Calif. Pub. Zool. 41: 53-74.

Armstrong, J.W., C.P. Staude, R.M. Thom, and K.K. Chew. 1976. Habitats and relative abundances of the intertidal macrofauna at five Puget Sound beaches in the Seattle area. Syesis 9: 277-290.

Banse, K. 1956. Beiträge zur Kenntnis der Gattungen Fabricia, Manayunkia und Fabriciola. Zool. Jahrb. (Systematik) 84: 415-438.

Banse, K. 1971. Redescription of some species of Chone Kröyer and Euchone Malmgren, and three new species. Fisheries Bulletin 70 (2): 459-495.

Banse, K., and K.D. Hobson. 1968. Proc. U.S. Nat. Mus. 125: 1-53.

Banse, K., and K.D. Hobson. 1974. Benthic errantiate polychaetes of British Columbia and Washington. Bulletin Fish. Res. Bd. Canada 185:x, 1-111.

Barnard, J.L. 1952. Some Amphipoda from central California, Wasmann J. Biol. 10: 9-36.

Barnard, J.L. 1954a. Marine Amphipoda of Oregon. Oregon State Monographs, Studies in Zoology No. 8: 1-103.

Barnard, J.L. 1954b. Amphipoda of the family Ampeliscidae collected in the eastern Pacific Ocean by the "Velero III" and "Velero IV". Allan Hancock Pacific Exped. 18 (1): 1-137.

Barnard, J.L. 1959. Estuarine Amphipoda, in: Ecology of Amphipoda and Polychaeta of Newport Bay, California. Allan Hancock Found. Pub., Occ. Pap. 21: 1-106.

Barnard, J.L. 1960. The amphipod family Phoxocephalidae in the eastern Pacific Ocean, with analyses of other species and notes for a revision of the family. Allan Hancock Pacific Exped. 18: 175-368.

Barnard, J.L. 1962a. Benthic marine Amphipoda of southern California: families Aoridae, Photidae, Ischyroceridea, Corophiidae, Podoceridae. Pacific Naturalist 3 (1): 1-72.

Barnard, J.L. 1962b. Benthic marine Amphipoda of southern California: families Tironidae to Gammaridae. Pacific Naturalist 3 (2): 74-115.

Barnard, J.L. 1962c. Benthic marine Amphipoda of southern California: Families Amphilochidae, Leucothoidae, Stenothoidae, Argissidae, Hyalidae. Pac. Nat. 3: 116-163.

Barnard, J.L. 1964. Marine Amphipoda of Bahia de San Quintin, Baja California. Pac. Nat. 4: 55-139.

Barnard, J.L. 1965. Marine Amphipoda of the family Ampithoidae from southern California. Proc. U.S. Nat. Mus. 118 (3522): 1-46.

Barnard, J.L. 1969a. Gammaridean Amphipoda of the rocky intertidal of California: Monterey Bay to La Jolla. Bull. U.S. Nat. Mus. 258: 1-230.

Barnard, J.L. 1969b. The families and genera of marine gammaridean Amphipoda. Bull. U.S. Nat. Mus. 271: 1-535.

Barnard, J.L. 1971. Gammaridean Amphipoda from a deep-sea transect off Oregon. Smithsonian Contributions Zoology 61: 1-86.

Barnard, J.L. 1975. Identification of gammaridean amphipods. In: R. I. Smith and J.T. Carlton (eds.) Light's Manual: Intertidal Invertebrates of the Central California Coast. U. Calif. Press, Los Angeles, California pp. 314-352.

Barnard, J.L., and R.R. Given. 1960. Common pleustid amphipods of southern California, with a projected revision of the family Pac. Natl. 1 (17): 37-48.

Barnard, J.L., and D.J. Reish, 1959. Ecology of Amphipoda and Polychaeta of Newport Bay, California. Allan Hancock Found. Pubs. Occas. Paper No. 21, 106 p.

Benedict, James E. 1897. A revision of the genus Synidotea. Proc. Acad. Nat. Sci. Phil. 49: 389-404.

Bosworth, W.S. 1973. Three new species of Eohaustorius (Amphipoda, Haustoriidae) from the Oregon coast. Crustaceana 25 (3): 253-260.

Bousfield, E.L. 1958. Fresh-water amphipod crustaceans of glaciated North America. Canadian Field Naturalist 72 (2): 55-113.

Bousfield, E.L. 1973. Shallow Water Gammaridean Amphipoda of New England. Cornell University Press, 312 p.

Bousfield, E.L. 1961. New records of beach hoppers (Crustacea: Amphipoda) from the coast of California. Nat. Mus. Canada., Contr. Zool., Bull. 172: 1-12.

Chevreux, E., and L. Fage. 1925. Amphipodes. Faune de France 9, 488 p.

Day, J.H. 1967. A Monograph of the Polychaeta of Southern Africa. Part 1, (Errantia); Part 2, (Sedentaria). British Museum of Natural History, London.

Dow, Thomas G. 1958. Description of a new isopod from California, Exosphaeroma inornata. Bull. So. Cal. Acad. Sci. 57: 93-97.

Fee, A.R. 1926. The Isopoda of Departure Bay and vicinity with descriptions of new species, variations and colour notes. Contrib. Can. Biol. Fish. N.S. 3 (2): 13-47.

George, Robert Y., and Jarl-Ove Stromberg. 1968. Some new species and records of marine isopods from San Juan Archipelago, Washington, U.S.A., Crustaceana 14: 225-254.

Gurjanova, E. 1938. Amphipoda Gammaroidea of Siaukhu Bay and Sudzukhe Bay (Japan Sea). Dalnevostochnii Filial Vladivostok Gidrobiologicheskii Ekspeditsii na Iaponskoe More. Akad. Nauk, Leningrad, Trudy. 1: 241-404 (in Russian with English summary).

Gurjanova, E. 1951. Bokoplavy morej SSSR i sopredel' nykh vod (Amphipoda-Gammaridea). Opred. po. Faune SSSR Akad. Nauk SSSR 41: 1029 (in Russian).

Hartman, O. 1968. Atlas of the Errantiate Polychaetous Annelids from California. Allan Hancock Foundation, Los Angeles, Calif.

Hartman, O. 1969. Atlas of the Sedentariate Polychaetous Annelids from California. Allan Hancock Foundation, Los Angeles, Calif. pp. 1-812.

Hatch, M.H. 1947. The Chelifera and Isopoda of Washington and adjacent regions. Univ. Wash. Publ. Biol., 10: 155-274.

Hitchcock, C.L., and A. Cronquist. 1973. Flora of the Pacific Northwest. Univ. of Washington Press, Seattle, xix-730 p.

Hurley, D.E. 1963. Amphipoda of the family Lysianassidae from the west coast of North and Central America. Allan Hancock Found. Pub., Occ. Pap. 25: 1-160.

Kozloff, E.N. 1974. Keys to the Main Invertebrate of Puget Sound, the San Juan Archipelago, and Adjacent Regions. Univ. Wash. Press, Seattle, pp. X, 1-226.

McCain, J.C. 1969. A new species of caprellid (Crustacea: Amphipoda) from Oregon. Proc. Biol. Soc. Wash. 82: 507-510.

Maloney, J.O. 1933. Two new species of isopod crustaceans from California. Jour. Wash. Acad. Sci. 23 (3): 144-147.

Menzies, Robert J. 1950a. Notes on California isopods of the genus Armadilloniscus, with the description of Armadilloniscus coronapapitalis n. sp. Proc. Cal. Acad. Sci. (4) 26 (13): 467-481.

Menzies, Robert J. 1950b. The taxonomy, ecology, and distribution of northern California isopods of the genus Idothea with the description of a new species. Wasmann Jour. Biol. 8: 155-195.

Menzies, Robert J. 1951a. New marine isopods, chiefly from California, with notes on related forms. Proc. U.S. Nat. Mus. 101: 105-156.

Menzies, Robert J. 1952. Some marine asellote isopods from northern California, with descriptions of nine new species. Proc. U.S. Nat. Mus. 102: 117-159.

Menzies, Robert J. 1954. A review of the systematics and ecology of the genus Exosphaeroma with description of a new genus, a new species, and a new subspecies (Crustacea: Isopoda, Sphaeromatidae). Amer. Mus. Novit. No. 1683, 24 p.

Menzies, Robert J. 1957. The marine borer family Limnoriidae (Crustacea, Isopoda). Bull. Mar. Sci. Gulf and Caribbean 7 (2): 101-200.

Menzies, Robert J., and J. Laurens Barnard. 1959. Marine Isopoda on coastal shelf bottoms of Southern California: Systematics and ecology. Pac. Nat. 1 (11): 3-35.

Menzies, Robert J., and Milton A. Miller. 1972. Systematics and zoogeography of the genus Synidotea (Crustacea: Isopoda). Smithsonian Contrib. Zool. No. 102, 33 p.

Menzies, Robert J., and Jean Petit. 1956. A new genus and species of marine asellote isopod, Caecianiropsis psammophila from California. Proc. U.S. Nat. Mus. 106 (3376): 441-446.

Menzies, Robert J., and R.J. Waidzunas. 1948. Post embryonic growth changes in the isopod Pentidotea resecata (Stimpson), with remarks on their taxonomic significance. Biol. Bull. 95: 107-113.

Miller, Milton A. 1938. Comparative ecological studies on the terrestrial isopod Crustacea of the San Francisco Bay region. Univ. Cal. Pub. Zool. 43: 113-142.

Mills, E.L. 1961. Amphipod crustaceans of the Pacific coast of Canada, I. Family Atylidae. Bull. Nat. Mus. Canada 172: 13-33.

Mills, E.L. 1962. Amphipod crustaceans of the Pacific coast of Canada, II. Family Oedicerotidae. Nat. Hist. Papers, Nat. Mus. Canada. 15: 1-21.

Otte, G. 1975. A laboratory key for the identification of Corophium species (Amphipoda, Corophiidae) of British Columbia. Environ. Canada. Fish. Mar. Serv. Tech. Rep. No. 519, 19 p.

Pielou, E.C. 1975. Ecological Diversity. John Wiley and Sons, Inc. New York, 165 p.

Richardson, Harriet. 1905. Monograph on the isopods of North America. Bull. U.S. Nat. Mus. 54: iii-727.

Richardson, Harriet. 1906. Descriptions of new isopod crustaceans of the family Sphaeromatidae. Proc. U.S. Nat. Mus. 31: 1-22.

Sars, G.O. 1895. Amphipoda. An Account of the Crustacea of Norway, 711 p. + 240 pl.

Sars, G.O. 1899. Isopoda. An Account of the Crustacea of Norway with Short Descriptions and Figures of All the Species. Bergea Museum 2: 1-270.

Scagel, R.F. 1966. Marine Algae of British Columbia and Northern Washington. Part 1: Chlorophyceae (Green Algae). Nat. Mus. Canada Bull. No. 207. Ottawa, Ont. viii-257 p.

Schultz, George A. 1969. The Marine Isopod Crustaceans. Wm C. Brown Co. Pub., Dubuque, Iowa.

Sexton, E.W., and D.M. Reid. 1951. The life-history of the multiform species Jassa falcata (Montagu) (Crustacea Amphipoda) with a review of the bibliography of the species. J. Limn. Soc. London 42 Zool: 29-91.

Shoemaker, C.R. 1930. The Amphipoda of the Cheticamp Expedition of 1917. Contr. Canadian Biol. Fish., n.s. 5 (10): 219-359.

Shoemaker, C.R. 1949. The amphipod genus Corophium on the west coast of America. J. Wash. Acad. Sci. 39 (2): 66-82.

Shoemaker, C.R. 1964. Seven new amphipods from the west coast of North America with notes on some unusual species. Proc. U.S. Nat. Mus. 115: 391-430.

Smith, R.I., and J.T. Carlton, eds. 1975. Light's Manual: Intertidal Invertebrates of the Central California Coast. Univ. Calif. Press, Berkely, p. xviii, 1-716.

Stafford, Blanche E. 1912. Studies in Laguna Isopoda. First Ann. Rep. Mar. Lab., Pomona Coll. 1: 118-133.

Stafford, Blanche E. 1913. Studies in Laguna Beach Isopoda II and IIb. Pomona Coll. Jour. Ent. Zool. 5 (3): 161-172, 182-188.

Stebbing, T.R.R. 1906. Amphipoda I: Gammaridea. Das Tierreich 21: 1-806.

Steel, D.H., and P. Brunel. 1968. Amphipoda of the Atlantic and Arctic coasts of North America: Anonyx (Lysianassidae). J. Fish. Res. Bd. Canada 25 (5): 943-1060.

Thorsteinson, E.D. 1941. New or noteworthy amphipods from the north Pacific coast. U. Washington Pub. Oceanogra. 4: 53-94.

Ushakov, P.V. 1955. (Polychaete worms of the far-eastern seas of the USSR) Opredeliteli po. faune SSSR, 56. 444 p. (in Russian).

Vagners, J., and Paul Mar, eds. 1972. Oil on Puget Sound. Univ. of Wash. Sea Grant Publication. Seattle, Washington. 629 p.

Van Name, Willard G. 1936. The American land and fresh-water isopod Crustacea. Bull. Amer. Mus. Nat. Hist. 71: 1-535.

Van Name, Willard G. 1940. The American land and fresh-water isopod Crustacea (supplement). Bull. Amer. Mus. Nat. Hist. 77: 109-142.

Van Name, Willard G. 1942. The American land and fresh-water isopod Crustacea (supplement). Bull. Amer. Mus. Nat. Hist. 80: 299-329.

Widdowson, T.B. 1973. The marine algae of British Columbia and northern Washington: revised list and keys. Part I. Phaeophyceae (brown algae). Syesis, 6: 81-96, fig. 1-5.

Widdowson, T.B. 1974. Part II. Rhodophyceae (red algae). Syesis, 7: 143-186, fig. 1-8.

Woodin, S.A., C.F. Nyblade, and F.-S. Chia. 1972. Effect of diesel oil spill on invertebrates. Mar. Pollution Bull. 3 (9): 139-142.

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