DOC
United States Department of Commerce
National Oceanic and Atmospheric Administration
Environmental Research Laboratories
Seattle WA 98115

EPA
United States Environmental Protection Agency
Office of Environmental Engineering and Technology
Washington DC 20460

EPA-600/7-79-213
November 1979

Research and Development

The Strait of Juan de Fuca Intertidal and Subtidal Benthos

Interagency Energy/Environment R&D Program Report

THE STRAIT OF JUAN DE FUCA INTERTIDAL AND SUBTIDAL BENTHOS

Second Annual Report

Spring 1977 - Winter 1978

by

Carl F. Nyblade

University of Washington
Friday Harbor Laboratories
Friday Harbor, Washington 98250

Prepared for the MESA (Marine Ecosystems Analysis) Puget Sound Project, Seattle, Washington in partial fulfillment of

EPA Interagency Agreement No. D6-E693-EN
Program Element No. EHE625-A

EPA Project Officer: Clinton W. Hall (EPA/Washington, D.C.)
NOAA Project Officer: Howard S. Harris (NOAA/Seattle, WA)

This study was conducted
as part of the Federal
Interagency Energy/Environment
Research and Development Program

Prepared for

OFFICE OF ENERGY, MINERALS, AND INDUSTRY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

March 1979

Completion Report Submitted to
PUGET SOUND ENERGY-RELATED RESEARCH PROJECT
MARINE ECOSYSTEMS ANALYSIS PROGRAM
ENVIRONMENTAL RESEARCH LABORATORIES

by

Friday Harbor Laboratories
University of Washington
Friday Harbor, Washington 98250

This work is the result of research sponsored by the Environmental Protection Agency and administered by the Environmental Research Laboratories of the National Oceanic and Atmospheric Administration.

FOREWORD

Substantially increased petroleum tanker traffic and refining operations are anticipated in the region of northern Puget Sound and the Strait of Juan de Fuca as Alaskan crude oil production increases and as pipeline deliveries of crude from Canada to the region are terminated. This increased transport and refining activity will increase the opportunities for spills and leaks of crude oil and refined products into the marine environment. Recognizing the need for environmental information in the region, the U.S. Environmental Protection Agency has supported the Puget Sound Energy-Related Project under which studies involving biological characterizations, physical oceanography, trajectory modeling, pollutant monitoring, and fate and effects of oil have been implemented. This report has been administered by NOAA's Marine Ecosystems Analysis (MESA) Puget Sound Project office. A major part of the Project has involved a variety of biological studies intended to provide information on the characteristics of biological communities at risk to oil pollution in the region. This report presents the results of a two year field study of intertidal and shallow subtidal communities found at ten sites representative of common shoreline habitats along the Strait of Juan de Fuca. This study was conducted in consultation with representatives of the Washington State Department of Ecology.

ABSTRACT

Because of the threat of oil pollution from large scale oil shipment through the Strait of Juan de Fuca, this study was undertaken to document the pre-pollution communities in the shallow water zones along the Washington coast of the Strait of Juan de Fuca. The study objectives were to adequately describe the distribution, abundance, seasonal variations and annual variation of the intertidal and shallow subtidal benthos of this coastal area.

During the first year ten sites, representative of the range of habitats present, were sampled quarterly. Stratified random replicates were collected at each area. Strata used were high (+6'), mid (+3'), low (+0') intertidal and -5 m and -10 m. Distribution sampling at intermediate strata was conducted once. During the second year seven of the same sites were again sampled quarterly in the intertidal, while the remaining three intertidal sites and all subtidal strata were sampled once.

Over 1,000 different plant and animal species were collected during these two years, 176 of which had not previously been recorded in standard taxonomic keys for our region. The 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 (and probably productivity), followed by cobble, protected soft sediment, exposed sand, and exposed gravel habitats. Species richness values ranged from 177.5 (Tongue Pt. +0') to 1 (Dungeness Spit +6'); diversity 3.24 (North Beach Cobble +0') to 0.17 (Dungeness Spit +6'); density 56,874/m^2 (Jamestown +6') to 44/m^2 (Twin Rivers +6'); biomass 11,375 g/m^2 (Pillar Pt. +0') to < 2 g/m^2 (Dungeness +6'). Strong intertidal 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 was most often the peak for species richness, abundance, and biomass and winter most often the low. Year to year community similarity was high in the rock, cobble, and protected soft sediment areas.

An important generalization from this mass of data stood out. The rich, complex, productive communities are to be found in rock and protected soft-sediment sites. These communities were the least variable over time and are the most vulnerable to long term damage from an oil spill. These data will be useful in assessment of damage from an oil spill, especially the measures of community similarity, species richness, and diversity, since the values of these parameters change with oil pollution effects. In addition these data should have broad use in coastal zone management decisions.

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ACKNOWLEDGMENTS

The author wishes to acknowledge the generous taxonomic and support assistance of : K. Banse, P. Illg, E. Kozloff, R. Norris, R. T. Paine, R. Shimek, and D. Willows.

The diligent efforts of Louisa Norris, Tony Roth and the additional technical staff are gratefully acknowledged.

The following generously allowed access through or to their property during the course of this study: Clallam County Commissioners; Crown Zellerbach Corporation and C. B. Paulson, Forest Manager; Four Seasons Maintenance Commission; C. W. Gunstone, Jr.; D. B. McInnes; Merrill and Ring Corporation and J. Vadnais, Managing Forester; D. Moriarity; Nisqually National Wildlife Refuge, W. B. Hesselbart, Refuge Manager; M. Schiefelhein; C. Swain; Twin Rivers Investment Club; A. Webster; G. Wood.

SECTION I

INTRODUCTION

This report presents the second year results of an intertidal and shallow subtidal benthic sampling program at ten sites along the Washington State coast of the Strait of Juan de Fuca. The purpose of this program was to provide a quantitative characterization of the marine, shallow-water, bottom communities of the Strait.

In the past five years the greater Puget Sound region has seen a dramatic increase in marine crude and refined oil transport with the replacement of overland pipeline transport by large tanker transport. The possibility of Alaskan crude oil transshipment through this region to the Midwest means additional increases are possible in the near future. This tanker traffic increase also increases the risk of catastrophic and chronic oil pollution of the marine environment in this region.

Previous to 1974 virtually no quantitative data existed on the intertidal and shallow subtidal benthos of this region. The seriousness of this absence of information was two-fold. First the communities of these organisms have great recreational, ecological, and economic importance. This is especially true for the greater Puget Sound region. Hundreds of thousands of people live on or very near the shore and make use of its varied recreational activities from yachting to clam digging. These same areas are also highly productive of eelgrass and macro-algae, plants which are responsible for a very large percentage of greater Puget Sound primary production. After the economic importance of recreational uses of these communities, there is a large direct economic value based on commercial fisheries. Virtually all juvenile salmonids are dependent on intertidal and shallow water communities for food. These communities are also highly productive of commercial bottom fish and of shellfish.

The second reason an absence of quantitative data on the intertidal and shallow subtidal benthic communities of this region was so serious is the widely documented high susceptibility of these communities to damage from spilled oil (National Academy of Sciences, 1975; Malins, 1977; Wolfe, 1978). Put simply much or most oil floats and in the virtually closed greater Puget Sound basin most floating oil will come ashore (Oil on Puget Sound, 1972).

To respond to this oil pollution threat, in 1974 the Washington State Department of Ecology initiated field work for their Oil Baseline Studies. This work was largely confined to the San Juan Islands and the Rosario Strait mainland areas. In 1976 the federal government initiated field sampling along the Strait of Juan de Fuca under the EPA's Puget Sound

Energy-Related Research Project administered through NOAA's Marine Ecosystem Analysis Puget Sound Project office. This project was designed to identify the potential ecological consequences of increased petroleum transport and transfer activities anticipated for the greater Puget Sound region.

First year research components of the study reported on previously (Nyblade, 1978) 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, and quarterly determination of the vertical distribution of the organisms found at each.

In order to verify and amplify trends observed the first year and to document natural year to year variation, a second year of sampling was undertaken. Second year sampling consisted of continued quarterly determination of community composition at seven sites in the intertidal and annually at three sites intertidally and all sites subtidally. These components have permitted documentation of both seasonal and annual changes in the communities sampled.

This information is critical: to develop an understanding of the biology of the shallow water marine communities of this region, to evaluate the regional ecological importance of the various habitats, to determine the economic value of the various types of communities, and 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. Also, uses of this data base may very well involve activities quite unrelated to oil pollution, eg. damage from other pollutants, tideland utilization, siting studies--informed coastal zone management.

SECTION II

CONCLUSIONS

With the completion of this two year program of sampling along Washington's coast of the Strait of Juan de Fuca, a quantitative data set on the composition of the Strait's intertidal and shallow subtidal marine benthic communities has been established prior to any major perturbation such as a large oil spill from a tanker or submarine pipeline.

Exposed intertidal sand and gravel habitats contained relatively sparse, simple, low diversity communities dominated by worms and small crustaceans. Protected soft-sediment habitats exhibited dense, very diverse infaunal communities dominated by a vast array of polychaete species, small and large bivalves, and small and large crustaceans. Cobble and rock areas contained the richest communities with the largest standing crop biomass. Cobble and rock communities were dominated by macro-algae, herbivorous gastropods, barnacles, mussels, large and small crustaceans. Subtidal rock areas were equally rich. Communities there contained a large variety of algae, gastropods, small crustaceans, and the dominant algal grazers, sea urchins. Subtidal soft sediment areas were also species rich, but standing crop was much lower. Communities in these areas contained literally hundreds of species of polychaetes as well as a great variety of small bivalves and crustaceans.

Over 1,000 different plant and animal species were collected during the study. Second year species richness values ranged from 177.5 (Tongue Point +0') to 1 (Dungeness Spit +6'); diversity from 3.24 (North Beach Cobble +0') to 0.17 (Dungeness Spit +6'); density 56,874 /m^2 (Jamestown +6') to 44 /m^2 (Twin Rivers +6'); biomass 11,375 g/m^2 (Pillar Point +0') to < 2 g/m^2 (Dungeness +6'). Strong intertidal vertical zonation was found at all but the most exposed gravel and sand sites.

Little seasonal change in communities was documented during either of the two years of study. Surprisingly little annual change in communities was found comparing the first and second year data sets. It is clear that data variability may very well have masked real seasonal and annual changes. On the other hand major changes should be reflected in the summary parameters measured such as mean species richness, diversity, and community similarity. But little evidence was found among these parameters for seasonal or annual changes. Sanders (1978) argues forcefully for the utilization of such synthetic parameters in examining community change, rather than traditional species lists and the vast, unmanageable data set on individual species populations.

What is there specifically to be concluded about the response of the communities studied to perturbations such as an oil spill? The following summarizes these conclusions. Life span/recruitment rates are the author's best estimate from direct experience.

Increasing Damage/ Increasing Recovery Time	Habitat/Study Areas	Number of Macro-Species in Community	Life Span/ Recruitment Rates of Dominants
↓	Gravel - Dungeness Spit, Twin Rivers	few to 10's	<<1 yr.
	Sand - Kydaka Beach, North Beach Sand	10's to 20's	<1 yr. to 1 yr.
	Mud - Jamestown		
	Mixed - Beckett Point	50 to 100	1 yr. to several years
	Cobble - North Beach, Morse Creek	100's	several yrs. to decades
	Rock - Pillar Point, Tongue Point		

There finally has begun to develop a literature to support such conclusions concerning longterm damage. Torrey Canyon recovery took from 5 to 10 years and by some measures remains incomplete (Southward and Southward, 1978). Other studies of other spills for shorter periods continued to show damage after 2½ to 3 years (Sanders, 1978; Hampson and Moul, 1978) with no prediction on when recovery might be complete. Hampson and Moul have documented severe salt marsh erosion following the killing of marsh grass by oil erosion of areas that may have taken hundreds of years or longer to accumulate. The rich, complex communities of rock and protected soft-sediment areas are the most vulnerable to long term damage because they are dominated by long-lived, irregularly recruiting species. Recovery of these communities from an oil spill could take decades here.

SECTION III

RECOMMENDATIONS

A number of recommendations for further studies can be made based on the two year Strait of Juan de Fuca sampling program:

1. Further quantitative monitoring of communities at the study sites should be undertaken. Sampling methodology must be identical or compatible with previous work in order to make comparisons with previous data possible. However, for the more complex communities only a subset of the dominant species need be fully processed, the remainder of the sample being processed for long term storage only. The need for further monitoring is two-fold. First, more information is needed on normal year to year variation of these marine communities. Second, only by updating will the validity of the original data base be maintained for post-perturbation comparisons. Should an oil spill occur in 1987, use of a ten year old data base for damage assessment would be weak unless validated by long-term monitoring.
2. Studies of community recruitment dynamics, especially of the key, long-lived species of the complex rock and protected soft-bottom communities, should be undertaken. Almost nothing is known about recruitment dynamics of regional marine species, particularly the long-lived species which apparently are highly irregular in recruitment. Without a better understanding of recruitment, there can be no basis for specific predictions on the recovery of their communities from a perturbation such as an oil spill which destroys key elements of the communities.
3. A general analysis and synthesis of the greater Puget Sound shallow water marine benthos data base should be undertaken. Although sampling methodology has been similar in studies during the past five years undertaken for METRO, the Washington State Department of Ecology, and the MESA Puget Sound office, technical report data presentation has not been compatible and generally the original data has not been presented.
4. Following data synthesis a field test should be undertaken to determine the degree to which the data base can be extrapolated to areas not previously sampled.
5. Additional regional taxonomic work is desperately needed on a number of important groups: gammarid amphipods, oligochaetes, free-living nematodes, ostracods, and cumaceans - in descending order of importance. The lumping of the species of these groups into higher taxa creates great problems in data analysis and comparison. When dominant species (eg. amphipods and oligochaetes in exposed gravel areas) are not identified to species, nothing can be said about long term community change or a potential change caused by pollution.

6. Samples processed and stored must be carefully curated as long as there is any use for the data based on them. The science of taxonomy is undergoing constant change. Without recourse to the original samples no use can be made of current taxonomic information.

SECTION IV

METHODS AND MATERIALS

IV-A. Field and Laboratory Procedures

Second year procedures followed directly those of the first year (Nyblade, 1978) to guarantee comparable data sets. The purpose of this methodology was to provide data to best document the abundance, distribution, seasonal and annual variation of organisms and populations in each major habitat type present and to do this with a finite set of resources.

All ten study sites sampled during the first year were resampled during the second (Table 1, Figure 1, site maps in Appendix III). Because of problems with irregularly shifting sediment (North Beach Cobble and Twin Rivers) or limited area available to sample (Pillar Point), these three areas were only sampled once during the second year. Since during the first year subtidal areas were fully processed for only one quarter they were sampled only once during the second year.

Because tidal height/water depth has an over-riding influence on community type present within a given habitat type, the strata marked and sampled during the first year were resampled during the second to obtain comparable data. Three strata were selected for sampling in the intertidal (high +6'; mid, generally +3'; low +0') and two in the subtidal (-5m, -10m). First year distributional sampling (Nyblade, 1978), showed these levels gave full coverage of the range of organisms present over the entire tidal and shallow water range at study areas.

The number, size, and type of randomly located replicates taken at each stratum in general was identical during the second year to the first year.

They were as follows:

Rock - intertidal (Tongue Point and Pillar Point): Four 0.25 m^2 quadrats, each consisting of five 0.01 m^2 subsection scrapes and the residual 0.2 m^2 scrape.

Cobble - intertidal (North Beach and Morse Creek): Four 0.25 m^2 quadrats, each consisting of five 0.01 m^2 subsection scrapes, the residual 0.2 m^2 scrape, and the under-cobble 0.05 m^2 x 15 cm sediment core fixed and dead-sieved through 1 mm mesh; four 0.25 m^2 x 30 cm deep quadrats live-sieved through 12.5 mm mesh.

Exposed Gravel and Sand - intertidal (Dungeness Spit, Twin Rivers, North Beach, and Kydaka Point): Five quadrats of 0.05 m^2 x 15 cm deep sediment cores fixed and dead-sieved through 1 mm mesh; five of 0.25 m^2 x 30 cm live-sieved through 12.5 mm mesh.

TABLE 1. LISTING OF STUDY AREA NAMES, LOCATIONS (COORDINATES), AND INTERTIDAL 1977-78 SAMPLING DATES

Study Area- (intertidal habitat type)	Location				Intertidal Sampling Dates
1 Kydaka Point - (exposed sand)	124° 48°	22' 16'	20" 14"	W N	Apr., Jun., Oct., Feb.
2 Pillar Point - (exposed rock)	124° 48°	06' 12'	03" 51"	W N	May
3 Twin Rivers - (exposed gravel)	123° 48°	56' 09'	57" 55"	W N	May
4 Tongue Point - (exposed rock)	123° 48°	41' 09'	42" 57"	W N	May, Jun., Oct., Jan.
5 Morse Creek - (exposed cobble)	123° 48°	20' 07'	48" 09"	W N	May, Jul., Nov., Feb.
6 Dungeness Spit - (exposed gravel)	48° 123°	08' 11'	47" 12"	N W	May, Jul., Nov., Jan.
7 Jamestown - (protected sand)	48° 123°	07' 05'	51" 11"	N W	Apr., Jun., Oct., Jan.
8 Beckett Point - (protected gravel/sand)	48° 122°	04' 52'	37" 56"	N W	Apr., Jul., Oct., Jan.
9 North Beach - (exposed cobble)	48° 122°	08' 46'	36" 59"	N W	Apr.
10 North Beach - (exposed sand)	48° 122°	08' 46'	35" 51"	N W	May, Jul., Nov., Jan.

Protected Sand and Mixed - intertidal (Jamestown and Beckett Point): Two quadrats, each 0.05 m^2 x 15 cm deep, divided into 0.025m^2 x 15 cm cores, fixed and dead-sieved through 1 mm mesh; two 0.25 m^2 x 30 cm deep cores live-sieved through 12.5 mm mesh.

Rock - subtidal (Tongue Point): four quadrats, each a 0.25 m^2 scrape.

Soft-sediment - subtidal (all sites except Tongue Point): Two quadrats each a 0.1 m^2 Van Veen grab sample partitioned on the boat into equal halves.

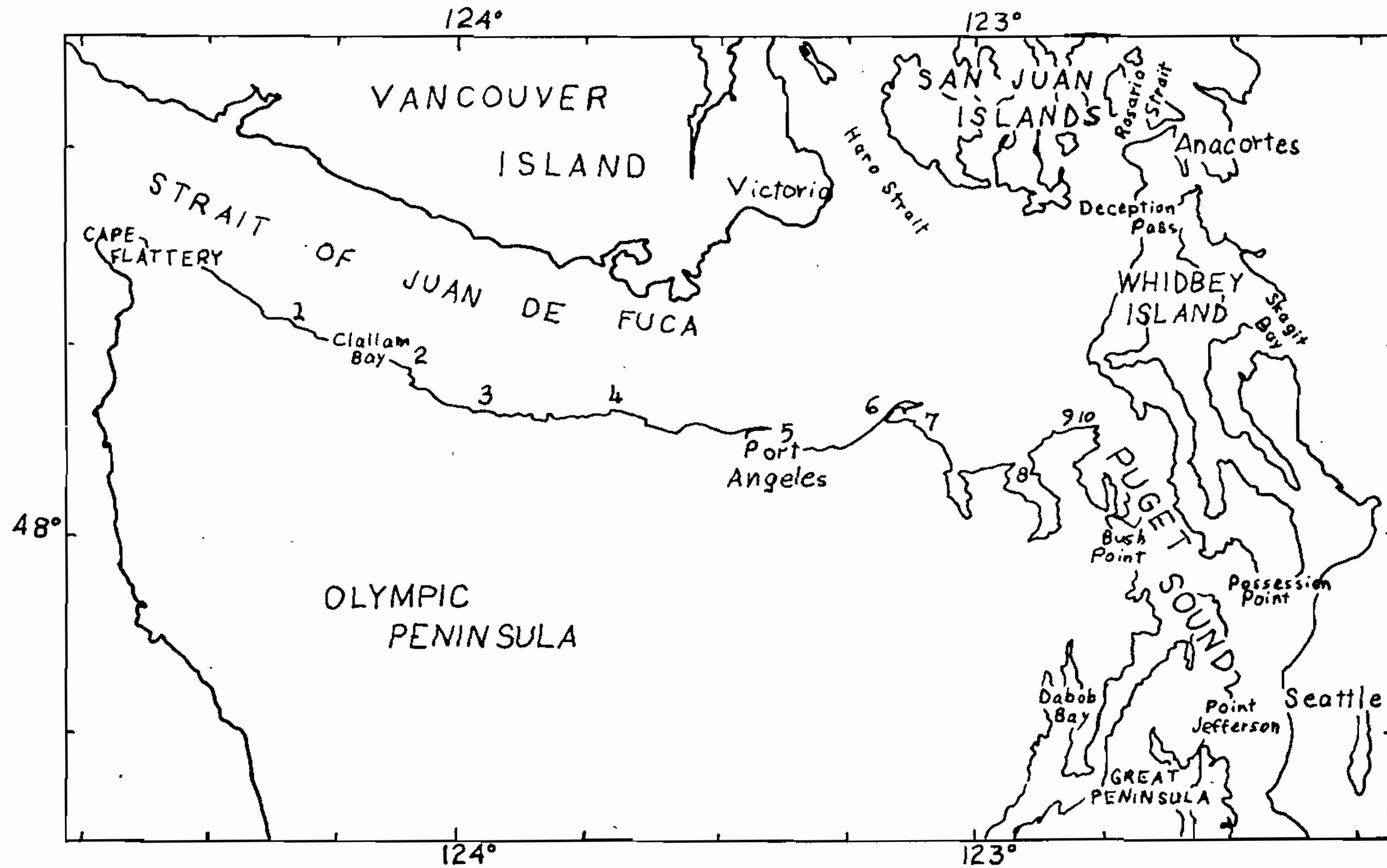

Figure 1. Map of Study Sites

In an effort to increase replicate number and hopefully to decrease sample variance at Beckett Point, Jamestown, and all soft bottom subtidal sites, the first year quadrat size was halved in the second year by sample partitioning. Instead of three replicates, four half size replicates were taken.

All samples collected during the second year program were completely processed and are stored in the Washington State Baseline Sample Repository of the University of Washington Friday Harbor Laboratories.

Highly detailed methodology descriptions, site maps, criteria for study area selection, explanations of the maps, driving directions, tidal reference point data, and details on access permissions from private and public agency land owners were presented in the first year report (Nyblade, 1978).

There are many potential sources of error in any field sample collection and their processing in the laboratory. Field errors include improperly determining quadrat boundaries, collecting the sample under water, failure to accurately count small organisms not removed. Although these mistakes generally cannot be detected once the sample has been collected, a carefully supervised and experienced field crew reduced these problems to a minimum.

Potential laboratory processing errors include improper sieving of samples, mis-counting, mis-weighting, mis-identifications, and clerical errors each time the data are transcribed. A carefully supervised, experienced staff and frequent referral to the original sample were used to minimize these sources of sampling error.

IV-B. Data Analysis

The Data Management Plan for the Puget Sound Energy-Related Research Project and MESA Puget Sound Project received from the Seattle-based 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 and Information Service. All study data are available through the E.D.I.S.

A variety of data analyses have been used in this report. Each is listed and described below. Taken together they provide a clear descriptive summary of the communities studied and enable community comparisons.

IV-B-1. Species Richness:

As in the first year report, here species richness was the total number of identification categories/study area stratum/sampling period, thus summed over the replicates. The identification categories for plants and animals include both species and higher taxonomic categories where identification to species was not possible. This total number of species found is a useful figure which summarizes one kind of community complexity but says nothing about relative abundance or numerical dominance.

IV-B-2. Diversity - H'

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. It thus provides a better measure of community complexity than species richness because it weighs the relative abundance or the evenness of constituent species spread through their community This index does not differentiate between low diversity due to low species richness or due to the overwhelming dominance 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.)

IV-B-3. Total Number:

Total number is the summed number of individuals per identification categories where individuals are counted, eg. most animals but not plants which are weighed and not counted. Especially where community biomass is low, total number gives the most useful information on overall community abundance. This is the only measure which excludes plants.

IV-B-4. Total Biomass:

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, they were totaled, added to the small real weight, and this new sum entered as a "less than" weight. This made it very clear when no meaningful community biomass information had been obtained. However, for algal rich communities, total biomass is the only realistic measure of overall community abundance. Biomass is also the first step in understanding community productivity.

IV-B-5. Similarity Index - D:

The key analysis in this second year report was the comparison of the first and second year communities at each stratum sampled. For this comparison the similarity index D (Schoener, 1968) was used.

$$D = 1 - \tfrac{1}{2} \sum_{i=1}^{n} \left| P_{x,i} - P_{y,i} \right|$$

This index gives weight to both species (identification) categories present and their abundance. The values of D range from 0.00 to 1.00, where 0.00 represents total dissimilarity from first to second year, while 1.00 means completely identical. Abundance values used (weight for algae, number for animals) were annual means or means for a comparable number of seasons. Because evolution of taxonomic knowledge from year to year may result in the same organism being called different names, artificially decreasing similarity, every effort was made to make the identification categories comparable from year one and year two. The index uses relative abundance of a species in the community from one year to the next. It is insensitive to absolute changes in abundance, as long as percentage community composition remains the same. Abundance changes, if uniform across the spectrum of community constituents, do not reflect a change in community structure. However, such changes may be of interest.

SECTION V

RESULTS

Replicate samples were successfully collected all four seasons at the seven seasonally sampled study areas and at all intertidal strata except +0' Tongue Point in the fall and winter and +0' Morse Creek in the winter. Spring sampling at Pillar Point, North Beach Cobble, Twin Rivers and all subtidal areas was successfully completed with the exception of -5m Morse Creek and -10m Twin Rivers. Bad weather/wave conditions were responsible for sample collection failures. All samples collected were completely processed and are presently stored at the Washington State Baseline Sample Repository, Friday Harbor Laboratories.

Approximately one thousand species of plants and animals were identified to species during the course of this study. Crustaceans were most numerous (280+), followed by algae (245+), annelids (220+), and molluscs (135+).

As found in the first year in general, although each stratum of each study area had a unique community, distinct substratum/exposure-associated communities were recognizable and these communities persisted from the first through the second year of sampling. 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 normalized to 1 m^2 surface area and abridged to include only the community species which are dominant by virtue of their high biomass, numerical abundance, or trophic importance. This determination of dominants is subjective. For a full listing see Appendix I. 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. Cobble and rock methodology precluded adding the 0.01 m^2 subsamples with the residual 0.2m^2 scrape for normalizing. In this case values for both sizes were normalized to 1.0 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. Cobble infaunal organisms were normalized to 1.0m^2 and added to epifaunal scrape organisms. Because large infaunal organisms were generally found only at Beckett and Jamestown, live sieve data are usually not commented on.

Special attention should be given to the fact that rock and cobble sampling methodology changed during the first year (Nyblade, 1978).

Original sampling methodology (first three quarters) involved first removing all large organisms from the 0.25 m^2 area, then taking the subsamples. This allowed recombination of normalized subsamples with the 0.25 m^2 large organism scrape, resulting in a single set of numbers for each quadrat location. Methodology for the last five sampling quarters involved removing the subsamples first; then the large organisms were removed from the remaining 0.2 m^2 area. The resulting sets of numbers are not objectively additive. To generate a single set of values for the organisms collected at each quadrat location, a species by species determination (subjective) of which subsampling value represents the best value would be necessary. This was done in order to compute first and second year community similarity. However, Appendix I gives the complete data set.

The Appendix I unabridged tables give number of replicates, means, and standard deviations in the sampled quadrat size; e.g., 0.05 m^2 x 15 cm or 0.25 m^2 (rock scrape). Cobble and rock entries are given in two or three data columns: the 0.01 m^2 scrape subsamples, the residual scrape (0.2m^2), and for cobble the sediment sample (0.05 m^2 x 15 cm deep). In Appendix I tables √ 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. 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 field parameters measured {first year (Nyblade, 1978) sediment analysis summary, water temperature, salinity, and weather} are presented in Appendix II. Where noteworthy, they are mentioned in the study area results presented below.

Tongue Point (rock)

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. No change in the physical environment was observed from year one to year two.

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 and mussels. Algal biomass was highest in spring/summer declining in the fall and winter. Seasonal patterns in the herbivores were obscured by large winter recruitment of Littorina sitkana. As in the first year barnacles showed a major recruitment between spring and summer quarter sampling. Especially noteworthy was the massive recruitment of Musculus pygmaeus between winter 1977 and spring 1977 (5200 to 68,770 / m^2) and its subsequent decline through the year.

Alaria was present in some quantity in the spring, but 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 increased in number and biomass from spring through summer declining in the fall/winter. Barnacle number peaked in the summer and then declined.

The massive barnacle and Musculus recruitment dominates the seasonal changes in diversity, total number, and biomass. Although species richness decreased from spring to summer (79 to 66), diversity increased because of the numerical dominance of Musculus in the spring.

Examination of the means and standard deviations in the Tongue Point +6' Appendix I table illustrates the spatial patchiness of the organisms in the +6' community. Still, dramatic population changes such as that of the barnacles and mussels showed through this variance. Despite the Musculus spring numerical dominance, overall community similarity between year one and two was high. (See Table 18 for all similarity values.)

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 were organisms which ate them--the herbivorous chiton (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 exception of the massive Musculus recruitment 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 occurred in descrete patches of very dense algal turf.

Table 2a. Tongue Point (rock) dominant benthic organisms from the high (+6') intertidal zone collected spring 1977 through winter 1978, expressed as number and/or biomass (g) per m . For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Phaeophyta								
Alaria spp.		17.0		0		0		<10.0
Rhodophyta								
Endocladia muricata		130.0		60.0		10.0		10.0
Gigartina papillata		217.5		96.5		23.5		1.5
Halosaccion glandiform		23.5		84.5		4.5		0.5
Iridaea spp.		17.5		302.5		63.0		2.0
Porphyra spp.		<10.0		3.5		0		3.0
Mollusca								
Gastropoda								
Collisella digitalis	260.0	48.5	370.0	45.0	290.0	44.5	290.0	29.5
C. strigatella	130.0	40.0	210.0	5.0	180.0	3.5	70.0	0.5
Littorina sitkana	520.0	10.0	2650.0	50.0	750.0	10.0	9990.0	<10.0
Siphonaria thersites	440.0	50.0	610.0	20.0	70.0	<10.0	0	
Bivalvia								
Musculus pygmaeus	68770.0	230.0	2040.0	10.0	320.0	<10.0	10.0	<10.0
Mytilus spp.	304.0	21.0	60.0	2.0	20.0	<10.0	20.0	<10.0

Table 2a. (cont.)

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Crustacea								
Cirripedia								
Balanus spp.	586.0	70.5	16790.0	641.5	4620.0	144.0	5480.0	415.0
Chthamalus dalli	3980.0	70.0	4310.0	70.0	2270.0	50.0	3610	60.0
Tanaidacea								
Pancolus californiensis	2090.0	<10.0	420.0	<10.0	510.0	<10.0	250.0	<10.0
Isopoda								
Dynamenella sheareri	3680.0	10.0	670.0	<10.0	3590.0	40.0	1990.0	<10.0
Amphipoda								
Gammaridea spp.	320.0	10.0	330.0	50.0	370.0	10.0	40	< 10.0
Insecta								
Dipteran larvae spp.	390.0	<20.0	330.0	<10.0	360.0	<30.0	150.0	<10.0
Species Richness	79		66		56		44	
Diversity, H[1]	1.50		2.79		2.75		2.54	
Total Number	89,216		29,800		14,880		13,220	
Total Biomass (g)	3,466		1,619		446		374	

Table 2b. Tongue Point (rock) dominant benthic organisms from the mid (+3') intertidal zone, collected spring 1977 through winter 1978, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Phaeophyta								
Alaria spp.		1173.5		899.5		1208.0		617.5
Rhodophyta								
Bossiella plumosa		140.0		120.0		220.0		90.0
Corallina vancouveriensis		970.0		1050.0		1060.0		250.0
Halosaccion glandiforme		6.0		55.0		969.5		227.5
Cnidaria								
Anthozoa								
Anthopleura elegantissima	30.0	<10.0	30.0	<10.0	270.0	40.0	340.0	50.0
Nematoda spp.	1460.0	<10.0	3720.0	<10.0	1300.0	<10.0	270.0	<10.0
Mollusca								
Amphineura								
Cyanoplax dentiens	30.0	< 10.0	50.0	0.5	160.0	10.0	50.0	<10.0
Gastropoda								
Barleeia haliotiphila	1500.0	<10.0	0		4250.0	<10.0	4360.0	<10.0
Collisella pelta	230.0	100.0	10.0	10.0	20.0	91.5	40.0	30.0
Notoacmaea scutum	0		10.0	<10.0	0		70.0	4.5

Table 2b. (cont.)

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Mollusca (cont.)								
Gastropoda								
Onchidella borealis	0		0		370.0	190.0	220.0	<10.0
Thais spp.	0		50.0	5.0	20.0	<20.0	20.0	<20.0
Bivalvia								
Musculus pygmaeus	1810.0	<10.0	48380.0	160.0	300.0	10.0	1080.0	<10.0
Mytilus spp.	270.0	3.0	15.0	6.0	200	61.0	80.0	1.0
Annelida								
Polychaeta								
Syllidae spp.	3110.0	<40.0	2360.0	<20.0	6840.0	<30.0	1490.0	<20.0
Oligochaeta spp.	1480.0	<10.0	6310.0	<10.0	2200	<10.0	590.0	<10.0
Crustacea								
Cirripedia								
Balanus spp.	440.0	30.0	2400.0	20.0	480.0	30.0	810.0	590.0
Tanaidacea								
Anatanais normani	270.0	<10.0	3320.0	<10.0	2490.0	<10.0	80.0	<10.0
Pancolus californiensis	640.0	<10.0	1090.0	<10.0	2260.0	<10.0	770.0	<10.0
Isopoda								
Dynamenella sheareri	4970.0	10.0	4050.0	10.0	880.0	<10.0	2000.0	<10.0

Table 2b. (cont.)

	Spr 77 #	Spr 77 wt	Sum 77 #	Sum 77 wt	Fall 77 #	Fall 77 wt	Win 78 #	Win 78 wt
Mollusca (cont.)								
Isopoda								
Idotea spp.	27.5	1.0	20.0	6.5	54.0	8.0	19.0	2.0
Amphipoda								
Gammaridea spp.	2390.0	3.0	5800.0	30.0	11250.0	70.0	2780.0	30.0
Decapoda								
Pagurus hirsutiusculus	20.0	1.0	10.0	<10.0	40.0	1.0	0	
Insecta								
Dipteran larvae spp.	1260.0	<10.0	5410.0	<10.0	410.0	<10.0	200.0	<20.0
Echinodermata								
Asteroidea								
Leptasterias hexactis	10.0	<10.0	50.0	<10.0	20.0	<10.0	0	
Holothuroidea								
Cucumaria pseudocurata	7120.0	150.0	6520.0	170.0	3150.0	140.0	1250.0	50.0
Species Richness	114		136		126		97	
Diversity, H[1]	3.15		2.79		3.08		3.14	
Total Number	30,750.0		97,740.0		45,071.5		20,500.5	
Total Biomass (g)	2984.5		3711.5		4807.0		2279.5	

Species richness was fairly constant over the year. Musculus recruitment was mainly responsible for the total number peaking in the summer. Biomass peaked in the fall, largely because Alaria, large Corallina, and Halosaccion patches were sampled. Year one/year two community similarity was high (see Table 18).

Table 2c presents the summary results of Tongue Point +0'. Wave conditions prevented sampling at this tide height in the fall and winter. 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 strucutral 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 and because surf conditions prevented fall and winter sampling.

Species richness, diversity, total number, and biomass were high both quarters. The large patch of Phyllospadix with its associated worm fauna was responsible for the lower year one/year two similarity compared to +6' and +3'.

Table 2d gives the abridged results at Tongue Point -5 m and -10 m. The community at Tongue Point -5 m was dominated by algae and the urchins, Strongylocentrotus. 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) or are structurally unpalatable (the calcareous alga Calliarthron). Numerical dominance at this level was by small organisms associated with Calliarthron--Granulina, the isopods, and amphopods. The community at -10 m was also dominated by grazers (chitons, Acmaea, Lirularia, Strongylocentrotus spp.). However, suspension feeders made an appearance (Calyptraea and Spirorbis). Low -5 m year one/year two similarity is due to the larger patch of Calliarthron sampled in year two with its associated rich worm fauna. Low - 10m first and second year similarity was caused by much richer flora the second year. At both levels low similarity probably reflected patchiness, rather than major community change.

Table 2c. Tongue Point (rock) dominant benthic organisms from the low (+0') intertidal zone, collected spring 1977 through summer 1977, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spring 1977		Summer 1977	
	#	wt	#	wt
Phaeophyta				
Alaria spp.		3773.5		3104.0
Hedophyllum sessile		343.5		60.0
Rhodophyta				
Bossiella plumosa		580.0		10.0
Iridaea cordata		204.0		26.0
Odonthalia flocossa		50.0		30.0
Spermatophyta				
Phyllospadix scouleri		927.0		4359.5
Nematoda spp.	700.0	<10.0	2030.0	<10.0
Mollusca				
Amphineura				
Katharina tunicata	6.5	<0.5	20.0	140.0
Tonicella lineata	10.0	22.5	30.0	4.0
Gastropoda				
Lacuna variegata	20.0	<10.0	90.0	<10.0
Velutina laevigata	0		30.0	<10.0

Table 2c. (cont.)

	Spring 1977		Summer 1977	
	#	wt	#	wt
Mollusca (cont.)				
Bivalvia				
Hiatella arctica	50.0	10.0	20.0	<10.0
Annelida				
Polychaeta				
Capitellidae				
Capitella capitata	50.0	<10.0	1100.0	10.0
Cirratulidae				
Cirratulus cirratus	280.0	✓	40.0	< 10.0
Nereidae				
Nereis spp.	420.0	< 10.0	590.0	< 30.0
Sabellidae spp.	620.0	< 80.0	1660.0	< 50.0
Syllidae spp.	1510.0	< 70.0	2500.0	< 70.0
Terebellidae spp.	1060.0	✓	1600.0	<30.0
Oligochaeta spp.	190.0	< 10.0	2830.0	< 10.0
Crustacea				
Cirripedia				
Balanus cariosus	80.0	203.0	210.0	159.5
B. nubilus	40.0	130.5	0	

Table 2c. (cont.)

	Spring 1977 #	Spring 1977 wt	Summer 1977 #	Summer 1977 wt
Crustacea (cont.)				
Tanaidacea				
Anatanais normani	300.0	<10.0	780.0	<10.0
Isopoda				
Limnoria algarum	90.0	<10.0	80.0	<10.0
Amphipoda				
Gammaridea spp.	1320.0	<10.0	3600.0	20.0
Decapoda				
Cancer oregonensis	10.0	10.0	10.0	40.0
Oedignathus inermis	20.0	40.0	0	
Pugettia gracilis	170.0	10.0	670.0	20.0
Echinodermata				
Asteroidea				
Leptasterias hexactis	10.0	<10.0	10.0	<10.0
Species Richness	180		175	
Diversity, H[1]	2.33		2.17	
Total Number	10,470.0		28,279.5	
Total Biomass (g)	6,506.0		8,229.8	

Table 2d. Tongue Point (rock) dominant benthic organisms from the shallow (-5m, -10 m) subtidal zone, collected spring 1977, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	-5 m		-10 m	
	#	wt	#	wt
Phaeophyta				
Desmarestia viridis		10.8		17.2
Rhodophyta				
Calliarthron tuberculosum		4487.2		6.8
Mollusca				
Amphineura				
Tonicella lineata	154.8	59.2	49.2	33.6
Gastropoda				
Acmaea mitra	7.2	2.0	5.2	1.6
Amphissa columbiana	315.2	13.6	7.2	1.2
Calliostoma ligatum	524.0	117.2	2.0	0.0
Calyptraea fastigiata	0		2.0	<0.4
Fusitriton oregonensis	0		1.2	86.4
Granulina margaritula	540.0	4.0	0	
Lirularia lirulata	159.2	1.2	0	
Margarites pupillus	228.0	20.0	0	
Ocenebra lurida	53.2	7.6	0	

Table 2d. (cont.)

	-5 m		-10 m	
	#	wt	#	wt
Annelida				
Polychaeta				
Nereidae				
Nereis spp.	160.8	<0.4	7.2	<0.4
Platynereis bicanaliculata	2153.2	<0.4	62.0	<0.4
Serpulidae				
Spirorbis spp.	63.2	<0.4	2.0	<0.4
Crustacea				
Isopoda				
Ianiropsis spp.	377.2	0.0	7.2	<0.4
Munna spp.	265.2	0.0	0	
Amphipoda				
Gammaridea spp.	9348.0	12.8	120.0	1.2
Decapoda				
Cancer oregonensis	28.0	18.4	0	
Paguridae spp.	429.2	15.6	0	
Pugettia gracilis	960.0	38.0	4.0	<0.4
Echinodermata				
Echinoidea				
Strongylocentrotus droebachiensis	25.2	1116.0	16.0	701.2

Table 2d. (cont.)

	-5 m		-10 m	
	#	wt	#	wt
Echinodermata				
Echinoidea				
Strongylocentrotus franciscanus	9.2	2786.4	5.2	1723.2
Species Richness	209		94	
Species Diversity, H[1]	1.45		3.00	
Total Number	18,634		834	
Total Biomass (g)	9,160		2,988	

Pillar Point (rock, intertidal; sand, subtidal)

The intertidal at Pillar Point from +0' to +6' was solid rock. Unlike Tongue Point, the rock was an irregular conglomerate, not smooth at all. The slope varied from 45^o to 90^o. 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. Because of this fact and the very limited area available for sampling on the rock outcrop, this area was sampled only once during the second year, in the spring. 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 -5m and fine sand at -10m. Salinity in winter quarter of the first year showed some slight freshwater influence from the Pysht River, likely of no biological consequence. No major changes in the physical environment were observed over the course of the study.

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 algal barnacle matrix were small crustaceans and dipteran larvae. The similarity between the first and second year community was very high.

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, Odonthalia, 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 (limpets and chitons) and the carnivores (Thais spp.). And there were small organisms intimately dependent on the physical structuring of the dominants: nematodes, polychaetes, oligochaetes, tanaids, isopods, amphipods, and insect larvae.

Year one/year two community similarity was quite high despite considerably lower mussel and barnacle numbers.

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 especially Phyllospadix), and large barnacles were absent. Sand scouring may have been responsible for the latter. Herbivores (chitons, Lacuna, Idotea, and Pugettia) and small plant-associated animals (polychaetes, oligochaetes, tanaids, isopods, and amphipods) were also abundant. Cancer oregonensis was the only major carnivore collected.

The similarity in data sets between year one and year two was low due to the massive amounts of Phyllospadix and its associated worm fauna collected the second year. This represents patchiness, not community change.

Table 3a. Pillar Point (rock) dominant benthic organisms from the high (+6′) intertidal zone, collected spring 1977, expressed as number and/or biomass(g) per m^2. For complete data set see Appendix I.

	#	wt
Rhodophyta		
Gigartina papillata		10.0
Mollusca		
Collisella digitalis	120.0	41.0
Littorina scutulata	210.0	0.5
L. sitkana	1090.0	20.0
Crustacea		
Cirripedia		
Balanus glandula	1770.0	70.0
Chthamalus dalli	7460.0	190.0
Isopoda		
Idotea montereyensis	31.5	2.0
Amphipoda		
Gammaridea spp.	70.0	<10.0
Insecta		
Diptera larvae spp.	170.0	<10.0

Table 3a. (cont.)

	#	wt
Species Richness	42	
Diversity, H[1]	1.85	
Total Number	11,620	
Total Biomass	480	

Table 3b. Pillar Point (rock) dominant benthic organisms from the mid(+3') intertidal zone, collected spring 1977, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	#	wt
Phaeophyta		
Alaria sp.		2131.0
Hedophyllum sessile		1432.0
Rhodophyta		
Corallina vancouveriensis		20.0
Gigartina papillata		33.0
Halosaccion glandiforme		10.0
Iridaea cordata		784.0
Odonthalia floccosa		220.0
Nemertea spp.	150.0	10.0
Nematoda spp.	980.0	10.0
Mollusca		
Amphineura		
Cyanoplax dentiens	1.5	<0.5
Katharina tunicata	19.0	298.0

Table 3b. (cont.)

	#	wt
Mollusca (cont.)		
Gastropoda		
Thais spp.	20.0	<20.0
Bivalvia		
Hiatella arctica	40.0	2.0
Mytilus spp.	102.5	0.5
Annelida		
Oligochaeta spp.	140	<10.0
Polychaeta		
Sabellidae spp.	530.0	<50.0
Syllidae spp.	370.0	<40.0
Pycnogonida spp.	70.0	<50.0
Crustacea		
Cirripedia		
Balanus spp.	421.5	863.5
Tanaidacea		
Leptochelia dubia	2160.0	<10.0

Table 3b. (cont.)

	#	wt
Crustacea (cont.)		
Isopoda		
Dynamenella sheareri	550.0	<10.0
Munna chromatocephala	790.0	<10.0
Amphipoda		
Caprellidea		
Cercops compactus	290.0	<10.0
Gammaridea spp.	100.0	<10.0
Insecta		
Diptera larvae spp.	130.0	<10.0
Species Richness	131	
Diversity, H^1	2.50	
Total Number	8,994	
Total Biomass	6,317	

Table 3c. Pillar Point (rock) dominant benthic organisms from the low (+0') intertidal zone, collected spring 1977, expressed as number and/or biomass(g) per m^2. For complete data set see Appendix I.

	#	wt
Phaeophyta		
Alaria spp.		2593.5
Egregia menziesii		1621.5
Rhodophyta		
Iridaea cordata		261.0
Spermatophyta		
Phyllospadix scouleri		6119.5
Nematoda spp.	8200.0	<10.0
Mollusca		
Amphineura		
Tonicella lineata	2.5	<0.5
Gastropoda		
Lacuna variegata	20.0	<10.0
Bivalvia		
Mytilus sp. (juv.)	20.0	<10.0
Annelida		
Oligochaeta spp.	1630.0	<10.0

Table 3c. (cont)

	#	wt
Annelida (cont.)		
Polychaeta		
Arenicolidae spp.	2050.0	<10.0
Lumbrineridae		
Lumbrineris spp.	480.0	<10.0
Spionidae spp.	930.0	<50.0
Syllidae spp.	280.0	<40.0
Crustacea		
Tanaidacea		
Antanais normani	40.0	<10.0
Isopoda		
Idotea spp.	230.0	<20.0
Amphipoda		
Caprellidea		
Caprella spp.	10.0	<10.0
Gammaridea spp.	510.0	2.0
Decapoda		
Cancer oregonensis	2.5	1.5
Pugettia gracilis	10.0	13.0

Table 3c. (cont.)

	#	wt
Species Richness	124	
Diversity, H[1]	2.04	
Total Number	15,642	
Total Biomass (g)	11,375	

Table 3d gives a summary of the subtidal Pillar Point data set. The communities at -5m and -10m were similar. 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. Year one, year two similarity was surprisingly high considering the crudeness of grab sampling.

Table 3d. Pillar Point (fine-medium sand) dominant benthic organisms from the shallow (-5 m, -10 m) subtidal zone, collected spring 1977, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	-5 m		-10 m	
	#	wt	#	wt
Mollusca				
Bivalvia				
Macoma spp.	62.0	<2.0	12.0	<2.0
Mysella tumida	400.0	<2.0	96.0	<2.0
Psephidia lordi	476.0	2.0	216.0	2.0
Tellina spp.	46.0	<2.0	52.0	<2.0
Tresus capax	70.0	<2.0	36.0	<2.0
Annelida				
Polychaeta				
Capitellidae				
Capitella capitata	870.0	<2.0	66.0	<2.0
Mediomastus sp.	1830.0	<2.0	380.0	<2.0
Cirratulidae spp.	320.0	<2.0	392.0	<2.0
Orbiniidae				
Scoloplos sp.	200.0	<2.0	76.0	<2.0
Spionidae				
Prionospio steenstrupi	3000	<2.0	770.0	<2.0

Table 3d. (cont.)

	-5 m		-10 m	
	#	wt	#	wt
Crustacea Cumacea spp.	282.0	<2.0	12.0	<2.0
Tanaidacea Leptochelia dubia	366.0	<2.0	110.0	<2.0
Amphipoda Gammaridea spp.	2290.0	2.0	700.0	<2.0
Species Richness	77		86	
Diversity, H^1	2.82		3.26	
Total Number	13,814		4,426	
Total Biomass (g)	<156		<172	

North Beach Cobble (cobble)

This area was selected in 1976 as a cobble habitat although the +6' substratum consisted of coarse sand. During the first year the +0' cobble was buried in sand, and cobble was uncovered at +6'. This sediment instability made this area unsuitable for baseline population monitoring. Because of this the area was sampled only once during the second year.

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 (Exosphaeroma), an infauna detritivore (oligochaetes), and barnacles. Low similarity between year one and year two resulted from sediment instability. Spring year one found the area sand covered, while spring year two found the cobble exposed.

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

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). Year one/year two similarity was lower than for the Morse Creek +3' cobble community. A major factor in this was the much lower isopod number the second year.

Abridged results from North Beach Cobble +0' are given in Table 4c. The rich spring algal flora was dominated by Ulva, Alaria, Nereocystis, Iridaea and Pterosiphonia. Major epifaunal constituents were grazers (chitons, Lacuna, Notoacmea, and Idotea), planktivores (Balanus spp.), predators (Thais spp., Cancer spp.,) and under-rock detritivores (Exosphaeroma, gammarids). The abundant worm infauna consisted of an active predator (Hemipodus), tube-building algal grazers (Nereidae spp., Onuphis), and detritivores (oligochaetes, Malacoceros).

The richer second year algal flora was primarily responsible for the fairly low year one/year two community similarity.

Table 4a. North Beach Cobble (cobble over sand) dominant benthic organisms from the high (+6') intertidal zone, collected spring 1977, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	#	wt.
Mollusca		
Gastropoda		
Littorina scutulata	720.0	34.0
Annelida		
Oligochaeta spp.	140.0	<2.0
Polychaeta		
Nereidae		
Nereis sp.	30.0	<2.0
Crustacea		
Cirripedia		
Balanus glandula	320.0	18.0
Isopoda		
Exosphaeroma media	366.0	<2.0
Amphipoda		
Gammaridea spp.	6.0	<2.0
Species Richness	16	
Diversity, H^1	1.99	
Total Number	2,148	
Total Biomass (g)	78	

Table 4b. North Beach Cobble (cobble over sand) dominant benthic organisms from the mid (+3') intertidal zone, collected spring 1977, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	#	wt
Cnidaria		
Anthozoa		
Anthopleura elegantissima	8.5	3.0
Mollusca		
Gastropoda		
Collisella pelta	50.0	0.0
Collisella strigatella	50.0	0.5
Littorina scutulata	252.0	12.0
L. sitkana	1066.0	52.0
Thais spp.	96.0	7.5
Annelida		
Oligochaeta spp.	76.0	<2.0
Polychaeta		
Nereidae		
Nereis vexillosa	56.0	<2.0
Spionidae		
Polydora proboscidea	76.0	<2.0
Syllidae		
Syllis spp.	126.0	<2.0

Table 4b. (cont.)

	#	wt
Crustacea		
Cirripedia		
Balanus spp.	126.0	14.0
Isopoda		
Exosphaeroma media	107.0	<1.0
Gnorimosphaeroma oregonense	380.0	<2.0
Decapoda		
Hemigrapsus nudus	10.0	23.0
Insecta		
Diptera larvae spp.	20.0	<10.0
Species Richness	38	
Diversity, H^1	2.48	
Total Number	3,802	
Total Biomass	128	

Table 4c. North Beach Cobble (cobble over sand) dominant benthic organisms from the low (+0') intertidal zone, collected spring 1977, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	#	wt
Chlorophyta		
Ulva spp.		90.0
Phaeophyta		
Alaria spp.		713.0
Nereocystis luetkeana		156.5
Rhodophyta		
Gigartina papillata		45.0
Iridaea cordata		409.5
Pterosiphonia bipinnata		174.0
Mollusca		
Amphineura spp.	10.0	<2.0
Gastropoda		
Lacuna variegata	886.0	<10.0
Notoacmea scutum	16.0	<10.0
Annelida		
Oligochaeta spp.	326.0	<10.0
Polychaeta		
Glyceridae		
Hemipodus borealis	120.0	<2.0

Table 4c. (cont.)

	#	wt
Annelida		
Polychaeta		
Nereidae	50.0	<10.0
spp.		
Onuphidae		
Onuphis	100.0	<2.0
stigmatis		
Spionidae		
Malococeros	270.0	<10.0
glutaeus		
Crustacea		
Cirripedia		
Balanus	10.0	<10.0
cariosus		
Isopoda		
Exosphaeroma	30.0	<10.0
amplicauda		
E.	430.0	<10.0
media		
Idotea	1186.0	0.5
spp.		
Amphipoda		
Gammaridea	317.5	<2.0
spp.		
Decapoda		
Cancer	10.0	<10.0
spp.		
Species Richness	125	

Table 4c. (cont.)

	#	wt
Diversity, H^1	3.24	
Total Number	6,724	
Total Biomass	1,862	

Morse Creek (cobble, intertidal; gravel, subtidal)

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 +6' cobble was never uncovered, although live barnacles were recovered from buried cobble in several quadrats. Mid and low intertidal zone sediments consisted of cobble over sand. The subtidal sediment at -10 m consisted of gravel. No samples were collected at -5 m because small cobble prevented the grab from operating.

This beach had a fairly gentle slope and like North Beach only a moderate exposure to wave activity. No major changes in the physical environment were observed between the first and second year.

Table 5a presents the abridged results for Morse Creek +6'. This community was very simple, consisting of detritus feeding oligochaetes, isopods, 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 peak in summer quarter. Diversity and species richness were uniformly low. Total number generally followed the amphipods. Biomass was insignificant.

Areas with sparse fauna generally show extreme patchiness, and this level was no exception (see variances, Appendix I). However, despite this patchiness, year one and year two community similarity was very high.

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 structural dominants such as at Tongue and Pillar. Algal species richness was low and what algae 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, Malacoceros, Corophium, and dipteran larvae.

Species richness, diversity, and biomass were fairly constant. Numbers peaked in summer/fall. Intense barnacle recruitment occurred between spring and summer quarter sampling. The second year community was very similar to the first year.

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, Tresus, and sabellids) were also abundant. Important predators in this community were Thais spp. and Cancer spp.

Table 5a. Morse Creek (sandy gravel) dominant benthic organisms from the high (+6') intertidal zone, collected spring 1977 through winter 1978, expressed as number and/or biomass(g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Mollusca								
Gastropoda								
Littorina sitkana	60.0	<2.0	0		0		80.0	8.0
Annelida								
Oligochaeta spp.	6.0	<2.0	40.0	<2.0	10.0	<2.0	20.0	<2.0
Crustacea								
Cirripedia								
Balanus spp.	6.0	<2.0	0		110.0	6.0	406.0	12.0
Isopoda								
Gnorimosphaeroma oregonense	0		326.0	4.0	10.0	<2.0	116.0	<2.0
Amphipoda								
Gammaridea spp.	110.0	<2.0	2028.0	4.0	1106.0	<4.0	126.0	<2.0
Species Richness	8		16		7		15	
Diversity, H[1]	1.31		0.76		0.48		1.72	
Total Number	206		2,458		1,257		844	
Total Biomass (g)	<16		<36		<20		<46	

Table 5b. Morse Creek (cobble over sand) dominant benthic organisms from the mid (+3') intertidal zone, collected spring 1977 through winter 1978, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Phaeophyta								
Fucus distichus		<10.0		190.5		<10.0		3.5
Rhodophyta								
Gigartina papillata		70.0		70.0		50.0		10.0
Platyhelminthes								
Turbellaria spp.	1.5	0.5	106.0	<12.0	796.0	<12.0	986.0	<12.0
Nemertea spp.	330.0	<12.0	670.0	<12.0	356.0	<12.0	456.0	<10.0
Mollusca								
Gastropoda								
Collisella pelta	10.0	0.5	20.0	12.5	30.0	8.0	60.0	12.5
C. strigatella	20.0	<10.0	40.0	0.5	40.0	10.0	80.0	<2.5
Lacuna variegata	0		<10.0	<10.0	226.0	<12.0	36.0	<12.0
Littorina sitkana	4496.0	426.0	866.0	20.0	260.0	12.0	650.0	120.0
Bivalvia								
Mytilus spp.	10.0	<10.0	36.0	<12.0	90.0	<12.0	36.0	0.5
Annelida								
Polychaeta								
Capitellidae								
Capitella capitata	346.0	2.0	836.0	<2.0	430.0	<2.0	366.0	<12.0

Table 5b. (cont.)

	Spr 77 #	Spr 77 wt	Sum 77 #	Sum 77 wt	Fall 77 #	Fall 77 wt	Win 78 #	Win 78 wt
Annelida (cont.)								
Spionidae								
Malacoceros glutaeus	0		320.0	<2.0	1830.0	<2.0	60.0	< 2.0
Crustacea								
Cirripedia								
Balanus glandula	0		620.0	28.0	5430.0	616.0	5246.0	660.0
B. spp. (juv.)	90.0	2.0	18,930.0	516.0	50.0	< 10.0	0	
Isopoda								
Idotea wosnesenskii	14.0	7.0	36.0	20.5	136.0	20.5	21.5	10.5
Amphipoda								
Gammaridea spp.	6.0	< 2.0	66.0	<12.0	476.0	0.5	100.0	<12.0
Corophium spp.	10.0	< 10.0	1290.0	<24.0	17,590.0	10.0	2836.0	< 12.0
Decapoda								
Hemigrapsus spp.	20.0	60.5	116.0	184.5	180.0	43.5	157.0	110.0
Pagurus spp.	36.0	18.0	96.0	27.0	46.0	1.0	286.0	<27.0
Insecta								
Dipteran larvae spp.	120.0	<10.0	2,136.0	<12.0	21,200	<12.0	400.0	<12.0
Species Richness	59		76		70		64	
Diversity, H[1]	2.34		2.04		1.97		2.50	
Total Number	6,452		29,420		33,278		13,514	
Total Biomass (g)	653		1,047		916		1,088	

Table 5c. Morse Creek (cobble over sand) dominant benthic organisms from the low (+0') intertidal zone, collected spring 1977 through fall 1977, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Win 78	
	#	wt	#	wt	#	wt
Clorophyta						
Ulva spp.		13.5		117.5		10.0
Phaeophyta						
Alaria spp.		702.5		503.0		1473.5
Hedophyllum sessile		57.5		0		0
Rhodophyta						
Gigartina papillata complex		39.5		142.5		118.0
Iridaea cordata		2,397.5		1,975.0		468.0
Cnidaria						
Anthozoa						
Anthopleura elegantissima	130.0	5.0	50.0	2.5	16.0	10.0
Nemertea spp.	0		360.0	4.0	250.0	<12.0
Nematoda spp.	490.0	<12.0	536.0	<12.0	114.0	<12.0
Mollusca						
Gastropoda						
Lacuna variegata	126.0	0.5	1000.0	12.0	834.0	12.0
Notoacmea spp.	26.0	5.5	62.0	7.5	46.0	20.0

Table 5c. (cont.)

	Spr 77 #	Spr 77 wt	Sum 77 #	Sum 77 wt	Fall 77 #	Fall 77 wt
Mollusca (cont.)						
Gastropoda						
Thais spp.	3.1	0.5	0		0	
Bivalvia						
Mytilus spp.	190.0	<10.0	10.0	<10.0	0	
Protothaca staminea	6.0	<2.0	0		0	
Tresus capax	10.0	102.0	30.0	12.0	6.0	<2.0
Annelida						
Polychaeta						
Arenicolidae						
Abarenicola spp.	416.0	<12.0	62.0	<2.0	166.0	<2.0
Capitellidae						
Capitella capitata	0		1100.0	<12.0	3556.0	<12.0
Cirratulidae						
Cirratulus cirratus	1826.0	<12.0	1810.0	82.0	1380.0	<2.0
Nereidae spp.	766.0	<34.0	362.0	64.0	166.0	<28.0
Opheliidae						
Armandia brevis	0		60.0	<12.0	214.0	<2.0
Sabellidae spp.	11416.0	<62.0	7816.0	<70.0	76.0	<30.0

Table 5c. (cont.)

	Spr 77		Sum 77		Fall 77	
	#	wt	#	wt	#	wt
Annelida (cont.)						
Polychaeta						
Spionidae						
Malacoceros glutaeus	16.0	<2.0	736.0	<12.0	2286.0	<2.0
Crustacea						
Tanaidacea						
Leptochelia dubia	36.0	<12.0	36.0	<12.0	14.0	<2.0
Amphipoda						
Gammaridea spp.	916.0	12.0	1176.0	<148.0	1120.0	10.0
Decapoda						
Cancer spp.	12.5	15.5	46.0	35.0	6.0	4.0
Pugettia gracilis	40.0	<12.0	436.0	10.0	56.0	2.0
Species Richness	112		117		82	
Diversity, H^1	2.14		2.55		2.29	
Total Number	17,843		17,450		10,360	
Total Biomass (g)	3,936		3,176		2,216	

Species richness, total numbers, total biomass, and populations of most component species showed a spring/summer maximum. However, as in all rock areas, the community components were very patchy. Despite this, a comparison of the first and second year data sets showed high similarity.

Table 5d presents the subtidal abridged data set for Morse Creek. The -10 m community was dominated by detritus feeders: Macoma, capitellids, maldanids, Armandia, spionids, Exogone, most gammarids, and ophiuroids. Suspension feeders (Calyptraea, Crenella, Mysella, and Leptochelia) were also abundant at -10 m.

Species richness and diversity were very high. However the total biomass was fairly low. Year one/year two community similarity was high.

Table 5d. Morse Creek (gravel) dominant benthic organisms from the shallow (-10 m) subtidal zone, collected spring 1977, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	-10 m	
	#	wt
Phaeophyta		
Desmarestia ligulata		<2.0
Mollusca		
Gastropoda		
Amphissa columbiana	250.0	16.0
Calyptraea fastigiata	60.0	2.0
Bivalvia		
Crenella decussata	6.0	<2.0
Macoma spp.	86.0	0.0
Mysella tumida	396.0	2.0
Annelida		
Polychaeta		
Capitellidae		
Mediomastus sp.	510.0	<2.0
Maldanidae spp.	156.0	<2.0
Nereidae		
Platynereis bicanaliculata	70.0	<2.0
Opheliidae		
Armandia brevis	36.0	<2.0
Spionidae		
Malacoceros glutaeus	0	
Prionospio cirrifera	20.0	<2.0
P. steenstrupi	106.0	<2.0
Syllidae		
Exogone spp.	416.0	<2.0

Table 5d. (cont.)

	-10 m	
	#	wt
Crustacea		
Tanaidacea		
Leptochelia dubia	4806.0	2.0
Amphipoda		
Gammaridea spp.	2030.0	4.0
Decapoda		
Cancer productus	20.0	12.0
Paguridae spp.	116.0	8.0
Echinodermata		
Ophiuroidea spp.	166.0	2.0
Species Richness	127	
Species Diversity, H[1]	2.72	
Total Number	11,654	
Total Biomass (g)	<290	

Beckett Point (protected sand-gravel, intertidal; sand, subtidal)

The sediment at Beckett Point was a sandy gravel at +6', a gravel-sand mix at +3', a mdeium-fine sand with gravel at +0', fine sand at -5m, and medium to fine sand at -10m. 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. Major physical environment changes from year one to year two were not observed.

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) and isopods. The isopods and oligochaetes both showed peak numbers in fall quarter both years, perhaps correlated with fall plant die back. Year one, year two community similarity was quite high.

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, Transennella, and Tresus), detritus feeders (capitellids, oweniids, spionids, syllids, oligochaetes, isopods, amphipods, Dendraster, and Leptosynapta), and a couple of carnivores (nemerteans and Hemipodus). The bivalves were very patchy in distribution. Seasonal pattern showed a fall peak for species richness, diversity, and density. Year one/year two similarity was low, probably reflecting the patchy nature of the community rather than community change.

Table 6c gives the abridged results for Beckett Point +0'. This rich diverse community was dominated by suspension feeding bivalves (Clinocardium, Mysella, Protothaca, Transennella, and Tresus); deposit/detritus feeding worms, crustaceans, and echinoderms; and a number of carnivores (nemerteans, Nassarius, 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. Year one/year two community similarity was high.

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, hesionids, and phyllodocids). The Van Veen grab operates best in fine sediments such as at Beckett. It is not surprising that Beckett subtidal communities showed the greatest year one/year two similarity of all subtidal communities sampled since grab-caused error would be at a minimum.

Table 6a. Beckett Point (sandy gravel) dominant benthic organisms from the high (+6) intertidal zone, collected spring 1977 through winter 1978, expressed as number an/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Nematoda spp.	570.0	<2.0	172.0	<4.0	272.0	<4.0	420.0	<4.0
Annelida								
Oligochaeta spp.	580.0	<2.0	92.0	<4.0	832.0	<4.0	780.0	<4.0
Polychaeta								
Nereidae spp.	40.0	<2.0	12.0		44.0	<4.0	24.0	<8.0
Syllidae								
Syllis spp.	340.0	<2.0	140.0	<4.0	60.0	<4.0	140.0	<4.0
Crustacea								
Cirripedia								
Balanus glandula	0		112.0	28.0	480.0	168.0	432.0	168.0
Isopods								
Exosphaeroma media	10.0	<2.0	0		2452.0	16.0	80.0	<4.0
Species Richness	10		13		15		12	
Diversity, H[1]	1.43		2.04		1.44		1.69	
Total Number	1630		632		4,404		1904	
Total Biomass	<20		<68		<232		<212	

Table 6b. Beckett Point (gravel-sand) dominant benthic organisms from the mid(+3') intertidal zone, collected spring 1977 through winter 1978, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Nemertea spp.	30.0	<2.0	100.0	<4.0	212.0	<4.0	100.0	
Mollusca								
Gastropoda								
Lacuna variegata	0		172.0	0.0	3092.0	12.0	0	
Bivalvia								
Mysella tumida	20.0	<2.0	492	4.0	492	4.0	152.0	<4.0
Mytilus edulis	110.0		172.0	4.0	9012.0	20.0	460.0	<4.0
Protothaca staminea	90	<2.0	52.0	<4.0	172.0	16.0	32.0	<4.0
Transennella tantilla	60.0	<2.0	132.0	0.0	380.0	8.0	20.0	<4.0
Tresus sp.	0		6.0	292.0	90.0	26.0	10.0	40.0
Annelida								
Oligochaeta spp.	20.0	<2.0	100.0	<4.0	120.0	<4.0	152.0	<4.0
Polychaeta								
Capitellidae								
Notomastus tenuis	0		340.0	<4.0	132.0	<4.0	312.0	<4.0
Glyceridae								
Hemipodus borealis	1370.0	✓	1680.0	✓	3152.0	✓	1212.0	✓
Oweniidae								
Owenia fusiformis	190.0	<2.0	280.0	✓	8292.0	✓	1220.0	<4.0

Table 6b. (cont.)

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Annelida								
Polychaeta								
Spionidae								
Pygospio elegans	0		100.0	<4.0	188.0	<4.0	0	
Spio filicornis	0		52.0	<4.0	572.0	<4.0	0	
Spiophanes bombyx	0		0		60.0	<4.0	0	
Syllidae								
Syllis spp.	20.0	<2.0	40.0	<4.0	12.0	<4.0	0	
Crustacea								
Cirripedia								
Balanus glandula	60.0	16.0	4712.0	96.0	792.0	136.0	40.0	0.0
Isopoda								
Exosphaeroma spp.	460.0	<2.0	432.0	<8.0	1600.0	12.0	12.0	<4.0
Amphipoda								
Gammaridea sp.	40.0	<2.0	1172.0	4.0	400.0	<4.0	32.0	<4.0
Echinodermata								
Echinoidea								
Dendraster excentricus	0		40.0	<4.0	660.0	<4.0	0	
Holothuroidea								
Leptosynapta clarki	0		12.0	<4.0	80.0	4.0	0	

Table 6b. (cont.)

	Spr 77	Sum 77	Fall 77	Win 78
Species Richness	23.0	55.0	75.0	29.0
Diversity, H^1	1.89	2.20	2.73	2.15
Total Number	3,450	11,068	48,228	3,964
Total Biomass	< 54	< 836	< 532	< 184

Table 6c. Beckett Point (medium-fine sand) dominant benthic organisms from the low (+0) intertidal zone, collected spring 1977 through winter 1978, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Nemertea spp.	530.0	<2.0	860.0	✓	352.0	<4.0	480.0	<4.0
Nematoda spp.	900.0	<2.0	292.0	<4.0	8832.0	<4.0	1652.0	<4.0
Mollusca								
Gastropoda								
Lacuna variegata	80.0	<2.0	652.0	4.0	152.0	<4.0	32.0	<4.0
Nassarius mendicus	30.0	18.0	20.0	12.0	20.0	<4.0	0	
Bivalvia								
Clinocardium nuttallii	180.0	18.0	12.0	4.0	580.0	8.0	972.0	8.0
Macoma spp.	60.0	<2.0	36.0	48.0	64.0	4.0	184.0	12.0
Mysella tumida	4250.0	18.0	9772.0	16.0	19500.0	32.0	8812.0	16.0
Protothaca staminea	180.0	2.0	32.0	12.0	292.0	36.0	280.0	4.0
Transennella tantilla	490.0	2.0	1120.0	4.0	232.0	4.0	480.0	<4.0
Tresus capax	0		572.0	64.0	172.0	32.0	72.0	44.0
Annelida								
Oligochaeta spp.	220	<2.0	52.0	<4.0	1240.0	<4.0	140.0	<4.0
Polychaeta								
Capitellidae spp.	680.0	< 8.0	824.0	<8.0	1712.0	<16.0	948	<16.0

Table 6c. (cont.)

	Spr 77 #	Spr 77 wt	Sum 77 #	Sum 77 wt	Fall 77 #	Fall 77 wt	Win 78 #	Win 78 wt
Annelida								
Polychaeta								
Glyceridae								
Hemipodus borealis	940.0	<2.0	692.0	✓	480.0	<8.0	480.0	<4.0
Goniadidae								
Glycinde picta	180.0	<2.0	40	<4.0	0		200.0	<4.0
Hesionidae spp.	186.0	<4.0	232.0	<8.0	292.0		0	
Nephtyidae spp.	0		0		24.0	4.0	20.0	<4.0
Nereidae								
Platynereis bicanaliculata	250.0	<2.0	300.0	✓	1692.0	✓	1512.0	<4.0
Opheliidae								
Armandia brevis	20.0	< 2.0	60.0	< 0.0	1720.0	<4.0	740.0	<4.0
Oweniidae								
Owenia fusiformis	310.0	<2.0	1032.0	✓	1392.0	<4.0	872.0	<4.0
Phyllodocidae spp.	290.0	<10.0	484.0	<16.0	1160.0	<20.0	396.0	<16.0
Polynoidae spp.	50.0	<6.0	52.0	<8.0	64.0	8.0	64.0	<12.0
Spionidae spp.	645.0	<10.0	15236.0	<8.0	2232.0	<28.0	644.0	<24.0

Table 6c. (cont.)

	Spr 77 #	Spr 77 wt	Sum 77 #	Sum 77 wt	Fall 77 #	Fall 77 wt	Win 78 #	Win 78 wt
Annelida (cont.)								
Polychaeta								
Syllidae								
Exogone spp.	720.0	<4.0	8920	<4.0	3104.0	<8.0	1600.0	<8.0
Crustacea								
Cumacea								
Cumella vulgaris	510.0	<2.0	52.0	<4.0	160.0	<4.0	32.0	<4.0
Tanaidacea								
Leptochelia dubia	9670.0	2.0	1798.0	8.0	44632.0	24.0	20372.0	8.0
Amphipoda								
Gammaridea spp.	1410.0	<2.0	3532.0	32.0	880.0	<4.0	820.0	4.0
Decapoda								
Cancer spp.	0		112.0	<8.0	12.0	<4.0	0	
Crangon nigricauda	0		12.0	<4.0	0		0	
Pagurus spp.	0		52.0	<4.0	0		0	
Echinodermata								
Echinoidea								
Dendraster excentricus	94.0	2.0	912.0	76.0	992.0	16.0	480.0	12.0
Holothuroidea								
Leptosynapta clarki	110.0	2.0	112.0	4.0	140.0	<4.0	80.0	✓

Table 6c. (cont.)

	Spr 77	Sum 77	Fall 77	Win 78
Species Richness	68	83	93	79
Diversity, H^1	2.52	2.51	2.13	2.30
Total Number	24,830	58,584	97,112	45,784
Total Biomass	< 1,226	< 2,780	< 3,080	< 2,784

Table 6d. Beckett Point (medium-fine sand) dominant benthic organisms from the shallow (-5 m, -10 m) subtidal zone, collected spring 1977, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	-5 m		-10 m	
	#	wt	#	wt
Nemertea spp.	260.0	< 2.0	400.0	< 2.0
Nematoda spp.	160.0	< 2.0	360.0	< 2.0
Mollusca				
Gastropoda				
Alvinia sp.	316.0	< 2.0	340.0	6.0
Lacuna variegata	190.0	< 2.0	66.0	< 2.0
Mitrella tuberosa	50.0	2.0	326.0	14.0
Nassarius mendicus	0		20.0	0.0
Bivalvia				
Macoma spp.	200.0	4.0	206.0	2.0
Mysella tumida	1290.0	2.0	3076.0	4.0
Tellina sp.	376.0	10.0	146.0	12.0
Annelida				
Polychaeta				
Chaetopteridae				
Mesochaetopterus taylori	36.0	< 2.0	280.0	< 2.0
Phyllochaetopterus prolifica	0		826.0	< 2.0
Spiochaetopterus costarum	110.0	< 2.0	160.0	< 2.0
Hesionidae				
Micropodarke dubia	566.0	< 2.0	950.0	< 2.0
Nereidae				
Platynereis bicanaliculata	2096.0	✓	1360.0	< 2.0
Oweniidae				
Owenia fusiformis	130.0	< 2.0	6.0	< 2.0

Table 6d. (cont.)

	-5 m		-10 m	
	#	wt	#	wt
Annelida (cont.)				
Polychaeta				
Phyllodocidae				
Eulalia sanguinea	156.0	<2.0	250.0	<2.0
Phyllodoce spp.	122.0	<2.0	912.0	<2.0
Spionidae				
Polydora socialis	76.0	<2.0	1080.0	<2.0
Prionospio steenstrupi	1630.0	<2.0	730.0	<2.0
Spiophanes berkeleyorum	10.0	<2.0	0	
Crustacea				
Tanaidacea				
Leptochelia dubia	1260.0	<2.0	316.0	<2.0
Amphipoda				
Gammaridea spp.	2976.0	2.0	3026.0	6.0
Decapoda				
Paguridae spp.	36.0	<2.0	280.0	<2.0
Species Richness	83		90	
Diversity, H[1]	2.77		3.05	
Total Number	13,416		17,542	
Total Biomass	<170		<214	

Dungeness Spit (sand-gravel)

The sediment at Dungeness Spit was sandy gravel at +6', gravel at +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 difficult to sample because of surf conditions. No noteworthy differences in the physical environment were observed between the first and second year.

Abridged results for Dungeness Spit +6', +3', and +0' are given in Tables 7a-c respectively. All three levels had a very species-poor community. In fact at +6' fall quarter absolutely no organisms were found. The only organisms found with any regularity at the three levels were deposit/detritus feeding oligochaetes and amphipods. No consistent seasonal pattern in populations appeared. The community similarity between the first and second years was high at +3, and low at +6' and 0', because of fewer oligochaetes and more amphipods found the second year. 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 -5m. The community at -10 m, although of low biomass, was fairly rich in both species and total number. The community was composed of small bivalves and deposit feeding polychaetes (capitellids, dorvilleids, spionid, and syllids, and gammarids). Year one and year two subtidal community similarity was low at both levels. This probably reflects sampling inadequacy rather than community change.

Table 7a. Dungeness Spit (sandy gravel) dominant benthic organisms from the high (+6') intertidal zone collected spring 1977 (through winter 1978), expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Annelida								
Oligochaeta spp.	4.0	< 2.0	0		0		4.0	< 2.0
Crustacea								
Amphipoda								
Gammaridea spp.	4.0	< 2.0	332.0	< 2.0	0		0	
Species richness	2		1		0		1	
Diversity - H'	0.69		0.00		0		0.00	
Total number	8		332		0		4	
Total biomass (g)	< 2		< 2		0		< 2	

Table 7b. Dungeness Spit (sandy gravel) dominant benthic organisms from the mid (+3') intertidal zone collected spring 1977 (through winter 1978), expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Annelida								
Oligochaeta spp.	4.0	<2.0	0		0		0	
Crustacea								
Amphipoda								
Gammaridea spp.	272.0	0.0	4.0	<2.0	16.0	<2.0	572.0	<2.0
Species richness	2		2		1		1	
Diversity - H'	0.08		0.56		0.00		0.00	
Total number	276		16		16		572	
Total biomass (g)	< 2		< 4		< 2		< 2	

Table 7c. Dungeness Spit (sandy gravel) dominant benthic organisms from the low (+0') intertidal zone collected spring 1977 (through winter 1978), expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Annelida								
Oligochaeta spp.	8.0	< 2.0	0		0		0	
Crustacea								
Amphipoda								
Gammaridea spp.	40.0	< 2.0	140.0	< 2.0	492.0	< 2.0	68.0	< 2.0
Species richness	3		2		5		1	
Diversity - H'	0.69		0.13		0.27		0.00	
Total number	52		144		520		68	
Total biomass (g)	< 6		< 4		< 10		< 2	

Table 7d. Dungeness Spit (medium-fine sand with gravel) dominant benthic organisms from the shallow subtidal zone collected spring 1977, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	-5 m		-10 m	
	#	wt	#	wt
Nematoda spp.	0		876.0	<2.0
Mollusca				
Bivalvia				
Crenella decussata	30.0	< 2.0	66.0	<2.0
Macoma spp.	0		52.0	<2.0
Mysella tumida	30.0	<2.0	70.0	<2.0
Psephidia lordi	40.0	<2.0	10.0	<2.0
Annelida				
Capitellidae				
Mediomastus sp.	70.0	<2.0	1060.0	0.0
Dorvilleidae				
Protodorvillea gracilis	0		456.0	<2.0
Hesionidae				
Micropodarke dubia	0		220.0	<2.0
Spionidae				
Prionospio steenstrupi	0		146.0	<2.0
Spiophanes bombyx	0		6.0	<2.0
Syllidae				
Exogone spp.	0		508.0	<2.0
Crustacea				
Tanaidacea				
Leptochelia dubia	6.0	< 2.0	240.0	<2.0

Table 7d. (Cont.)

	-5 m		-10 m	
	#	wt	#	wt
Amphipoda				
Gammaridea spp.	380.0	<2.0	560.0	<2.0
Species richness	28		136	
Diversity - H'	2.43		3.82	
Total number	858		6764	
Total biomass (g)	<56		<322	

Twin Rivers (sand-gravel)

The sediment at Twin Rivers was sandy gravel at +6', gravel at +3', gravel with fine sand at +0', gravel at -5 m. The beach had a fairly steep slope and was very exposed to both waves and ocean swells. Wave conditions prevented sampling at -10 m during the second year.

Tables 8a-c present abridged results for Twin Rivers +6', +3', and +0' respectively for the single quarter sampled. At all levels species richness, diversity, and biomass were low. The communities, such as they are, were primarily composed of deposit feeding worms and gammarid amphipods. As expected with a sparse fauna, it was extremely patchy spatially. Year one, year two similarity was high at +6' and low at +3' and +0'.

Twin Rivers -5 m subtidal abridged results are given in Table 8d. Weather conditions prevented -10 m sampling. The community was dominated by deposit feeding annelids, and crustaceans. As with most of the Van Veen samples, variance among replicates was very high and might not reflect organism patchiness. In addition there was very little similarity between first and second year samples. First year species richness was 139 compared to 28 the second year. This is most likely a reflection of poor sampling, not year to year change.

Table 8a. Twin Rivers (sand, gravel) dominant benthic organisms from the high (+6') intertidal zone collected spring 1977, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77	
	#	wt
Annelida		
Oligochaeta	32.0	<2.0
spp.		
Crustacea		
Amphipoda		
Gammaridea	8.0	<2.0
spp.		
Species richness	3	
Diversity - H'	0.76	
Total number	44	
Total biomass (g)	<6	

Table 8b. Twin Rivers (sand, gravel) dominant benthic organisms from the mid (+3') intertidal zone collected spring 1977, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77 #	Spr 77 wt
Annelida		
Oligochaeta spp.	28.0	<2.0
Crustacea		
Isopoda		
Gnorimosphaeroma oregonense	32.0	<2.0
Amphipoda		
Gammaridea spp.	576.0	<2.0
Species richness	4	
Diversity - H'	0.63	
Total number	692	
Total biomass (g)	<8	

Table 8c. Twin Rivers (sand, gravel) dominant benthic organisms from the low (+0') intertidal zone collected spring 1977, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77	
	#	wt
Annelida		
Polychaeta		
Capitellidae		
Capitella capitata	168.0	<2.0
Spionidae		
Malacocerus glutaeus	660.0	<2.0
Crustacea		
Amphipoda		
Gammaridea spp.	480.0	<2.0
Species richness	15	
Diversity - H'	1.62	
Total number	1448	
Total biomass (g)	<30	

Table 8d. Twin Rivers (gravel) dominant benthic organisms from the shallow subtidal zone collected spring 1977, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	-5m	
	#	wt
Mollusca		
Bivalvia		
Mysella tumida	6.0	<2.0
Protothaca staminea	10.0	6.0
Annelida		
Oligochaeta spp.	6.0	<2.0
Polychaeta		
Capitellidae		
Mediomastus sp.	410.0	<2.0
Cirratulidae		
Tharyx multifilis	5190.0	✓
Goniadidae		
Glycinde picta	70.0	<2.0
Nereidae		
Platynereis bicanaliculata	16.0	<2.0
Oweniidae		
Owenia fusiformis	670.0	<2.0
Spionidae		
Prionospio steenstrupi	150.0	<2.0
Crustacea		
Cumacea		
Diastylopsis sp.	1766.0	2.0

Table 8d. (Cont.)

	-5 m #	-5 m wt
Isopoda		
Gnorimosphaeroma oregonense	230.0	2.0
Amphipoda		
Gammaridea spp.	1486.0	2.0

Species richness	28
Diversity - H'	1.69
Total number	8852
Total biomass (g)	<56

North Beach Sand (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. No major changes in the physical environment were observed between the first and second year.

Abridged results for North Beach Sand +6' are given in Table 9a. The community was very low in species richness, diversity, total number of organisms, and total biomass. It was composed of deposit feeding worms and crustaceans. Species richness and total number appeared particularly depressed in the winter. The sparse fauna was of course very patchy in spatial distribution. First and second year community similarity was low.

Table 9b gives a summary data set for North Beach Sand +2'. Major components of this community were all detrital/deposit feeders (Paraonella, Eohaustorius, and Paraphoxus). The community was dominated by the fossorial amphipod Eohaustorius. Its populations peaked in the summer. Species richness, diversity, and total biomass were low and exhibited little seasonal pattern. The community was extremely similar from year one to year two.

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 and was dominated by three species: the paraonid polychaete Paraonella, the mysid Archaeomysis, and the amphipod Eohaustorius. Paraonella and Eohaustorius populations peaked in the spring. Archaeomysis showed a severe population decline in the fall/winter. This may merely indicate migration of the species out of the littoral zone during this period. As at +2' this community showed great similarity from year one to year two.

Abridged subtidal data are given in Table 9d for North Beach. Except for fewer plants at -10 m, the communities at -5 m and -10 m were quite similar. They were composed of herbivores (Lacuna and Onuphis), suspension-feeding bivalves (Clinocardium, Crenella, Mysella, Psephidia), many deposit feeding annelids and small crustaceans, and carnivores (Natica, Micropodarke, and Cancer at -5 m). Species richness, diversity, total number, and biomass were high at both levels. Year to year similarity was low, again likely due to poor sampling methodology.

Table 9a. North Beach Sand (medium-fine sand with gravel) dominant benthic organisms from the high (+6') intertidal zone collected spring 1977 (through winter 1978), expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Annelida								
Oligochaeta spp.	24.0	<2.0	0		28.0	<2.0	8.0	<2.0
Crustacea								
Amphipoda								
Gammaridea spp.	4.0	<2.0	0		0		8.0	<2.0
Species richness	10		8		6		5	
Diversity - H'	2.02		1.48		1.35		1.55	
Total number	92		156		48		28	
Total biomass (g)	<20		<18		<12		<10	

Table 9b. North Beach Sand (medium-fine sand with gravel) dominant benthic organisms from the mid (+2') intertidal zone collected spring 1977 (through winter 1978), expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Annelida								
Polychaeta								
Paraonidae								
Paraonella platybranchia	156.0	<2.0	132.0	<2.0	12.0	<2.0	36.0	<2.0
Spionidae								
Pygospio elegans	0		0		0		0	
Crustacea								
Isopoda								
Exosphaeroma media	0		0		0		2.6	<2.0
Amphipoda								
Eohaustorius spp.	2408.0	6.0	6072.0	8.0	1524.0	4.0	1988.0	2.0
Paraphoxus spp.	0		8.0	<2.0	156.0	<2.0	200.0	<2.0
Species richness	10		15		10		10	
Diversity - H'	0.33		0.26		0.70		0.66	
Total number	2600		6372		1824		2352	
Total biomass (g)	<24		<32		<28		<22	

Table 9c. North Beach Sand (medium-fine sand with gravel) dominant benthic organisms from the low (+0') intertidal zone collected spring 1977 (through winter 1978), expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Nemertea spp.	16.0	<2.0	20.0	<2.0	0		12.0	<2.0
Annelida								
Polychaeta								
Arenicolidae								
Abarenicola claparedi oceanica	64.0	<2.0	4.0	<2.0	24.0	<2.0	4.0	<2.0
Orbiniidae								
Scoloplos sp.	112.0	✓	132.0	✓	32.0	<2.0	112.0	<2.0
Paraonidae								
Paraonella platybranchia	2168.0	✓	1984.0	✓	480.0	<2.0	1448.0	<2.0
Spionidae spp.	92.0	<2.0	56.0	<2.0	124.0	<2.0	456.0	<2.0
Syllidae								
Syllis spp.	116.0	<2.0	124.0	<2.0	0		196.0	<2.0
Crustacea								
Mysidacea								
Archaeomysis grebnitzkii	16.0	<2.0	1188.0	4.0	4.0	<2.0	0	
Amphipoda								
Eohaustorius washingtonianus	2940.0	6.0	992.0	0.0	2792.0	0.0	2796.0	2.0

Table 9c. (Cont.)

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Amphipoda (cont.) Paraphoxus spp.	32.0	<2.0	16.0	<2.0	4.0	<2.0	0	
Species richness	16		21		18		19	
Diversity - H'	1.11		1.56		1.02		1.36	
Total number	5608		3692		3792		5296	
Total biomass (g)	<28		<34		<36		<38	

Table 9d. North Beach (coarse sand-gravel) dominant benthic organisms from the shallow subtidal zone collected spring 1977, expressed as number and/or biomass (g) per m². For complete data set see Appendix I.

	-5 m		-10 m	
	#	wt	#	wt
Phaeophyta				
Laminaria saccharina		1655.0		0
Pterygophora californica		9163.0		0
Rhodophyta				
Odonthalia washingtoniensis		0		0
Opuntiella californica		700.0		0
Nematoda spp.	330.0	<1.0	260.0	<2.0
Mollusca				
Gastropoda				
Lacuna variegata	940.0	5.0	40.0	<2.0
Margarites pupillus	120.0	<1.0	0	
Natica clausa	5.0	<1.0	6.0	26.0
Bivalvia				
Clinocardium nuttallii	1375.0	1.0	30.0	0.0
Crenella decussata	15.0	<1.0	646.0	2.0
Macoma sp.	0		10.0	<2.0
Mysella tumida	100.0	<1.0	0	
Psephidia lordi	105.0	<1.0	46.0	0.0
Annelida				
Oligochaeta spp.	175.0	<1.0	1250.0	<2.0

Table 9d. (Cont.)

	-5 m		-10 m	
	#	wt	#	wt
Polychaeta				
Capitellidae				
Mediomastus sp.	35.0	<1.0	6.0	<2.0
Dorvilleidae				
Protodorvillea gracilis	290.0	<1.0	30.0	<2.0
Hesionidae				
Micropodarke dubia	540.0	<1.0	416.0	<2.0
Onuphiidae				
Onuphis spp.	285.0	<1.0	10.0	<2.0
Sabellidae spp.	25.0	<1.0	0	
Spionidae				
Polydora hamata	420.0	<1.0	0	
P. pygidialis	275.0	<1.0	0	
Prionospio steenstrupi	130.0	<1.0	30.0	<2.0
Spio filicornis	90.0	<1.0	270.0	<2.0
Syllidae				
Exogone spp.	395.0	<1.0	166.0	<2.0
Archiannelida				
Polygordiidae				
Polygordius sp.	520.0	<1.0	560.0	<2.0
Crustacea				
Tanaidacea				
Leptochelia dubia	175.0	<1.0	176.0	<2.0

Table 9d. (Cont.)

	-5 m		-10 m	
	#	wt	#	wt
Isopoda				
Exosphaeroma spp.	655.0	0.0	136.0	<2.0
Amphipoda				
Gammaridea spp.	4275.0	6.0	630.0	2.0
Decapoda				
Cancer spp.	30.0	9.0	0	
Paguridae spp.	130.0	5.0	36.0	<2.0
Species richness	201		151	
Diversity - H'	1.44		3.86	
Total number	14103		7442	
Total biomass (g)	12021		1474	

Kydaka Beach (sand)

The sediment at Kydaka Beach at +6', +3', and +0' was uniformly 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 (20.1 $^{o}/oo$). No major difference was observed in the physical environment between the first and second year.

Tables 10a-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. Similarity in communities between year one and two was low at all three levels, doubtless due to the problems in sampling such a sparse fauna.

The summary subtidal results for Kydaka Beach appear in Table 10d. Major constituents were deposit feeding bivalves (Tellina), small suspension feeding bivalves (Mysella), deposit feeding polychaetes (capitellids and spionids) and small crustaceans (ostracods, cumaceans, and gammarid amphipods). Year one to year two community similarity was high given the limitations of grab sampling noted earlier.

Table 10a. Kydaka Beach (coarse-fine sand) dominant benthic organisms from the high (+6') intertidal zone collected spring 1977 (through winter 1978), expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Annelida								
Oligochaeta spp.	8.0	<2.0	68.0	<2.0	12.0	<2.0	8.0	<2.0
Crustacea								
Amphipoda								
Gammaridea spp.	0		44.0	<4.0	76.0	<2.0	0	
Species richness	2		6		4		2	
Diversity - H'	0.64		1.23		0.71		0.64	
Total number	12		144		96		12	
Total biomass (g)	<4		<12		<8		<4	

Table 10b. Kydaka Beach (coarse-fine sand) dominant benthic organisms from the mid (+3') intertidal zone collected spring 1977 (through winter 1978), expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Annelida								
Oligochaeta spp.	0		0		0		0	
Crustacea								
Mysidacea								
Archaeomysis grebnitzkii	4.0	<2.0	212.0	<2.0	40.0	<2.0	0	
Species richness	2		5		2		1	
Diversity - H'	0.69		0.87		0.45		0.00	
Total number	8		328		48		12	
Total biomass (g)	<4		<10		<4		<2	

Table 10 c. Kydaka Beach (coarse-fine sand) dominant benthic organisms from the low (+0') intertidal zone collected spring 1977 (through winter 1978), expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Annelida								
Polychaeta								
Nephtyidae								
Nephtys spp.	0		0		8.0	<2.0	0	
Paraonidae								
Paraonella platybranchia	0		24.0	<2.0	8.0	<2.0	0	
Crustacea								
Mysidacea								
Archaeomysis grebnitzkii	4.0	<2.0	16.0	<2.0	0		0	
Amphipoda								
Gammaridea spp.	268.0	<8.0	64.0	<4.0	0		0	
Species richness	6		5		7		1	
Diversity - H'	0.61		1.25		1.77		0.00	
Total number	272		112		56		8	
Total biomass (g)	<12		<10		<14		<2	

Table 10d. Kydaka Beach (medium-fine sand) dominant benthic organisms from the shallow subtidal zone collected spring 1977, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	-5 m		-10 m	
	#	wt	#	wt
Mollusca				
Bivalvia				
Mysella tumida	610.0	2.0	1656.0	4.0
Psephidia lordi	0		1316.0	8.0
Tellina sp.	26.0	2.0	56.0	2.0
Annelida				
Polychaeta				
Capitellidae				
Mediomastus sp.	256.0	<2.0	1670.0	0.0
Orbiniidae				
Scoloplos spp.	110.0	<2.0	50.0	0.0
Oweniidae				
Owenia fusiformis	150.0	<2.0	220.0	0.0
Spionidae				
Polydora socialis	60.0	<2.0	116.0	0.0
Prionospio steenstrupi	740.0	<2.0	3850.0	0.0
Crustacea				
Ostracoda spp.	196.0	2.0	1560.0	2.0
Cumacea				
Diastylis sp.	0		46.0	2.0
Diastylopsis sp.	476.0	2.0	6.0	0.0

Table 10d. (Cont.)

	-5 m		-10 m	
	#	wt	#	wt
Isopoda				
Edotea sublittoralis	20.0	2.0	0	
Amphipoda				
Gammaridea spp.	2076.0	4.0	2576.0	6.0
Echinodermata				
Holothuroidea				
Leptosynapta clarki	336.0	6.0	0	
Species richness	54		96	
Diversity - H'	2.55		2.83	
Total number	6230		17,410	
Total biomass (g)	<114		<222	

Jamestown (protected sand)

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. No major changes in the physical environment were noted between the first and second year.

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-fall, highest total number in winter. The patchiness of the fauna was very great (Appendix I). However, because of the overwhelming numerical dominance of oligochaetes, year one and year two similarity was total.

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, arenicolids, capitellids, paraonids, spionids, oligochaetes, gammarids, and Leptosynapta), and carnivores (Nephtys, Eteone). No clear seasonal patterns appeared in the results, although spring appears to have lowest species richness and number. First and second year community similarity was high, but densities were greater in the second year.

Table 11c presents an abridged data set for Jamestown +0'. This high density, high biomass community was quite complex. Tube-building polychaetes and crustaceans and Upogebia provided major structuring elements and dominated 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 clear community seasonal changes appeared in the results. However, many polychaetes (e.g. Platynereis) showed peak numbers in fall/winter, evidence of recruitment. Community similarity between year one and two was very high.

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. Over ten species of suspension feeding bivalves and one deposit feeder were present. Herbivores included Margarites/Lirularia, Platynereis, Onuphis, and Pugettia. Among carnivores were nemerteans, Nassarius, Natica, hesionids, and polynoids. In addition there were many deposit/detritus feeding polychaetes and small crustaceans. Replicate variance was fairly low at this area and year one to year two similarity rather high for subtidal grab-sampled communities.

Table 11a. Jamestown (sandy gravel) dominant benthic organisms from the high (+6') intertidal zone collected spring 1977 (through winter 1978), expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Nematoda spp.	60.6	<2.0	72.0	<4.0	60.0	<4.0	20.0	<4.0
Annelida Oligochaeta spp.	148,830.0	<2.0	44,332.0	<4.0	30,640.0	<4.0	1,612.0	<4.0
Crustacea Amphipoda Gammaridea spp.	650.0	<2.0	0		140.0	<4.0	80.0	<4.0
Species richness	8		4		4		14	
Diversity - H'	0.07		0.02		0.07		0.73	
Total number	150,220		44,428		30,972		1876	
Total biomass (g)	<14		<16		<16		<52	

Table 11b. Jamestown (fine sand) dominant benthic organisms from the mid (+1.4') intertidal zone collected spring 1977 (through winter 1978), expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Nematoda spp.	40.0	<2.0	412.0	<4.0	252.0	<4.0	472.0	<4.0
Mollusca								
Bivalvia								
Macoma nasuta	60.0	156.0	20.0	148.0	72.0	340.0	12.0	80.0
Transenella tantilla	1270.0	8.0	760.0	<4.0	7232.0	32.0	5280.0	<4.0
Annelida								
Polychaeta								
Arenicolidae sp.	50.0	<2.0	700.0	<4.0	7052.0	<4.0	2132.0	<4.0
Capitellidae								
Capitella capitata	870.0	<2.0	3632.0	<4.0	3012.0	4.0	1140.0	<4.0
Paraonidae								
Paraonella platybranchia	60.0	<2.0	332.0	<4.0	112.0	<4.0	52.0	<4.0
Phyllodocidae								
Eteone longa	380.0	<2.0	17,520.0	<4.0	712.0	<4.0	1352.0	<4.0
Phyllodoce maculata	20.0	<2.0	12.0	<4.0	320.0	<4.0	340.0	<4.0

Table 11b. (Cont.)

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Spionidae								
Malacoceros glutaeus	5750.0	<2.0	820.0	<4.0	11,892.0	✓	13,040.0	<4.0
Polydora kempi japonica	80.0	<2.0	1880.0	<4.0	2940.0	✓	272.0	<4.0
Pygospio elegans	820.0	<2.0	51,512.0	<4.0	2740.0	<4.0	1980.0	<4.0
Crustacea								
Tanaidacea								
Leptochelia dubia	10.0	<2.0	40.0	<4.0	600.0	<4.0	1252.0	<4.0
Amphipoda								
Gammaridea spp.	906.0	<2.0	1048.0	<20.0	1868.0	<16.0	24.0	<8.0
Echinodermata								
Holothuroidea								
Leptosynapta clarki	10.0	<2.0	0		12.0	<4.0	172.0	<4.0
Species richness	33		38		48		38	
Diversity - H'	1.87		1.19		2.02		1.90	
Total number	11,536		68,244		61,368		28,632	
Total biomass (g)	<224		<340		<704		<220	

Table 11c. Jamestown (medium sand) dominant benthic organisms from the low (+0') intertidal zone collected spring 1977 (through winter 1978), expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Nemertea spp.	50.0	<2.0	32.0	<4.0	120.0	<4.0	100.0	<4.0
Nematoda spp.	0		12.0	<4.0	60.0	<4.0	340.0	<4.0
Mollusca								
Bivalvia								
Macoma spp.	320.0	<2.0	32.0	24.0	20.0	4.0	12.0	4.0
Transennella tantilla	780.0	4.0	540.0	<4.0	2560.0	12.0	1572.0	<4.0
Annelida								
Oligochaeta spp.	11,690.0	<2.0	9532.0	<4.0	19,820.0	<4.0	27,072.0	✓
Polychaeta								
Capitellidae								
Capitella capitata	1060.0	<2.0	632.0	<4.0	2960.0	<4.0	2332.0	<4.0
Mediomastus sp.	770.0	<2.0	1500.0	<4.0	1772.0	<4.0	1312.0	<4.0
Cirratulidae spp.	410.0	<2.0	192.0	<4.0	152.0	<4.0	224.0	<4.0

Table 11c. (Cont.)

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Dorvilleidae Dorvillea rudolphi	230.0	<2.0	180.0	<4.0	380.0	<4.0	192.0	4.0
Hesionidae Ophiodromus pugettensis	60.0	<2.0	92.0	<4.0	120.0	<4.0	160.0	<4.0
Lumbrineridae Lumbrineris spp.	1210.0	<2.0	1112.0	<4.0	2044.0	76.0	1172.0	✓
Maldanidae sp. (juv.)	550.0	<2.0	312.0	<4.0	2300.0	4.0	2172.0	✓
Nereidae Platynereis bicanaliculata	10.0	<2.0	0		820.0	0.0	332.0	<4.0
Opheliidae Armandia brevis	90.0	<2.0	20.0	<4.0	212.0	<4.0	280.0	<4.0
Orbiniidae Naineris spp.	560.0	<2.0	452.0	<4.0	692.0	<4.0	716.0	✓
Phyllodocidae Eteone longa	40.0	<2.0	20.0	<4.0	12.0	<4.0	40.0	<4.0

Table 11c. (Cont.)

	Spr 77 #	Spr 77 wt	Sum 77 #	Sum 77 wt	Fall 77 #	Fall 77 wt	Win 78 #	Win 78 wt
Phyllodocidae (cont.)								
Phyllodoce maculata	40.0	<2.0	52.0	<4.0	120.0	<4.0	252.0	<4.0
Polynoidae								
Harmothoe imbricata	50.0	<2.0	380.0	<4.0	492.0	8.0	52.0	✓
Spionidae								
Malacoceros glutaeus	650.0	<2.0	600.0	<4.0	2692.0	<4.0	4052.0	✓
Syllidae								
Exogone lourei	5220.0	<4.0	2560.0	<4.0	5180.0	<4.0	3432.0	<4.0
Terebellidae								
Pista brevibranchiata	560.0	✓	512.0	<4.0	340.0	20.0	492.0	✓
Crustacea								
Tanaidacea								
Leptochelia dubia	810.0	<2.0	1492.0	<4.0	1760.0	<4.0	2080.0	<4.0
Amphipoda								
Gammaridea spp.	590.0	<2.0	452.0	<4.0	218.0	16.0	660.0	<4.0

Table 11c. (Cont.)

	Spr 77		Sum 77		Fall 77		Win 78	
	#	wt	#	wt	#	wt	#	wt
Decapoda								
Pinnixa spp.	50.0	4.0	24.0	0.0	140.0	<4.0	52.0	<4.0
Upogebia pugettensis	120.0	40.0	660.0	60.0	220.0	308.0	352.0	<4.0
Echinodermata								
Holothuroidea								
Leptosynapta clarki	220.0	<2.0	112.0	<4.0	20.0	<4.0	100.0	<4.0
Species richness	47		57		78		62	
Diversity - H'	2.36		2.42		2.48		2.10	
Total number	25,910		24,216		50,412		51,644	
Total biomass (g)	302		252		1084		20	

Table 11d. Jamestown (coarse-fine sand) dominant benthic organisms from the shallow subtidal zone collected spring 1977, expressed as number and/or biomass (g) per m^2. For complete data set see Appendix I.

	-5 m		-10 m	
	#	wt	#	wt
Nemertea spp.	96.0	<2.0	170.0	<2.0
Nematoda spp.	1336.0	<2.0	426.0	<2.0
Mollusca				
Gastropoda				
Alvinia sp.	410.0	<2.0	26.0	<2.0
Margarites/Lirularia spp.	196.0	<2.0	226.0	<2.0
Nassarius mendicus	0		6.0	<2.0
Natica clausa	0		6.0	<2.0
Bivalvia				
Cardita ventricosa	0		0	
Clinocardium nuttallii	210.0	2.0	20.0	<2.0
Crenella decussata	1366.0	2.0	86.0	<2.0
Macoma spp.	126.0	4.0	452.0	34.0
Mysella tumida	1450.0	2.0	280.0	<2.0
Psephidia lordi	210.0	<2.0	156.0	<2.0
Annelida				
Ampharetidae				
Ampharete arctica	0		240.0	<2.0
Capitellidae				
Mediomastus sp.	426.0	<2.0	796.0	<2.0
Chaetopteridae				
Phyllochaetopterus prolifica	280.0	<2.0	80.0	<2.0

Table 11d. (Cont.)

	-5 m		-10 m	
	#	wt	#	wt
Cirratulidae spp.	50.0	<2.0	646.0	<2.0
Tharyx multifilis	76.0	<2.0	136.0	<2.0
Dorvilleidae				
Protodorvillea gracilis	236.0	<2.0	56.0	<2.0
Hesionidae				
Micropodarke dubia	406.0	<2.0	636.0	<2.0
Maldanidae spp.	392.0	<2.0	290.0	<2.0
Nicomache personata	400.0	<2.0	40.0	<2.0
Nereidae				
Platynereis bicanaliculata	326.0	<2.0	176.0	<2.0
Onuphidae				
Onuphis sp.	10.0	<2.0	66.0	<2.0
Oweniidae				
Owenia fusiformis	130.0	<1.0	50.0	<2.0
Paraonidae				
Aricidea sp.	36.0	<2.0	26.0	<2.0
Polynoidae				
Harmothoe imbricata	416.0	<2.0	200.0	<2.0
Sabellidae				
Sabella media	0		270.0	<2.0

Table 11d. (Cont.)

	-5 m		-10 m	
	#	wt	#	wt
Spionidae				
Malacoceros glutaeus	10.0	<2.0	16.0	<2.0
Polydora socialis	26.0	<2.0	46.0	<2.0
Prionospio steenstrupi	146.0	<2.0	166.0	<2.0
Spiophanes bombyx	50.0	<2.0	20.0	<2.0
Syllidae				
Exogone sp.	1940.0	<2.0	826.0	<2.0
Sphaerosyllis pirifera	70.0	<2.0	20.0	<2.0
Oligochaeta spp.	270.0	<2.0	620.0	<2.0
Crustacea				
Cumacea				
Diastylis sp.	6.0	<2.0	50.0	<2.0
Tanaidacea				
Leptochelia dubia	2646.0	<2.0	1370.0	<2.0
Amphipoda				
Gammaridea spp.	1660.0	4.0	1536.0	2.0
Decapoda				
Pugettia gracilis	146.0	<2.0	30.0	<2.0
Species richness	136		156	
Diversity - H'	3.49		3.81	
Total number	17,364		12,864	
Total biomass (g)	782		76	

SECTION VI

DISCUSSION

Prior to the initiation of these studies in the spring 1976 absolutely no quantitative information existed on the shallow water benthic communities along the Washington coast of the Strait of Juan de Fuca. With the completion of this second year of sampling and sample analysis a vast storehouse of quantitative data on the full range of intertidal and shallow subtidal communities has been accumulated. Strict, clear, replicable sampling has been done. Literally hundreds of thousands of organisms attributed to over one thousand species have been processed. All processed organisms have been retained in a long-term storage repository to enable future reference.

In the following discussion first the study areas will be compared. Then seasonal and annual changes will be considered.

VI-A. Study Area Comparisons

Summary information on species richness, species diversity, density, and biomass for the intertidal and subtidal are presented on Tables 12 and 13 respectively. The intertidal values were averaged over the four sample periods for the seven areas sampled quarterly.

Second year data confirmed first year data trends. Intertidal species richness and diversity were highest in the rock sites (Tongue Point, Pillar Point), followed by cobble (North Beach, Morse Creek) and protected sediment areas (Beckett, Jamestown). They were lowest in the exposed sand (North Beach, Kydaka) and gravel (Dungeness Spit, Twin Rivers) areas.

Intertidal species richness increased with decreasing tide height in all habitats except at Pillar Point where sand scouring reduced richness at +0' (Nyblade, 1978). In the severely exposed gravel (Dungeness Spit, Twin Rivers) and sand (Kydaka) areas the very low richness showed little tidal height difference. Species diversity showed a less distinct pattern. Except in species poor areas lowest diversity was found in the high intertidal.

High diversity and species richness were found in the subtidal. Patterns among the areas or between the two depths were difficult to discern. Generally, species richness was less in the most exposed areas (Kydaka, Twin Rivers -5m, Dungeness -5m). Still, all subtidal areas were species rich compared to gravel and sand intertidal habitats. At the subtidal rock site (Tongue Point) intense grazing by sea urchins was observed at both -5m and -10m. Species richness was much lower at -10m both years, reflecting the decline in algal species number with depth in

Table 12. Intertidal summary of second year community parameters by study area - tide height. Pillar Point, North Beach Cobble, and Twin Rivers are spring 1977 data only; other areas means of four seasons (spring 1977 - winter 1978) (Tongue Point +0', spring-summer only; Morse Creek +0', spring - fall only).

Study Area		Mean Species Richness	Mean Diversity	Mean Total Density (#/m^2)	Mean Total Biomass (g/m^2)
Tongue Point	+6'	61.3	2.40	36,779	1476
(rock)	+3'	118.3	3.04	48,516	3446
	+0'	177.5	2.25	19,375	7368
Pillar Point	+6'	42	1.85	11,620	480
(rock)	+3'	131	2.50	8,994	6317
	+0'	124	2.04	15,642	11375
North Beach Cobble	+6'	16	1.99	2148	78
(cobble over sand)	+3'	38	2.48	3802	128
	+0'	125	3.24	6724	1862
Morse Creek	+6'	11.5	1.07	1191	<30
(cobble over sand)	+3'	67.3	2.21	20,666	926
	+0'	103.7	2.33	15,218	3109
Beckett Point	+6'	12.5	1.65	2143	<133
(protected	+3'	45.3	2.24	16,678	<402
gravel-sand)	+0'	80.8	2.37	56,578	<2468
Dungeness Spit	+6'	1	0.17	86	<2
(exposed gravel-	+3'	1.5	0.16	220	<3
sand)	+0'	2.8	0.27	196	<6
Twin Rivers	+6'	3	0.76	44	<6
(exposed gravel-	+3'	4	0.63	692	<8
sand)	+0'	15	1.62	1448	<30
North Beach Sand	+6'	7.3	1.60	81	<15
(semi-exposed	+2'	10.5	0.49	3287	<27
sand)	+0'	18.5	1.26	4597	<34

Table 12. (Cont.)

Study Area		Mean Species Richness	Mean Diversity	Mean Total Density (#/m^2)	Mean Total Biomass (g/m^2)
Kydaka Beach (exposed sand)	+6'	3.5	0.81	66	<7
	+3'	2.5	0.50	99	<5
	+0'	4.8	0.91	112	<10
Jamestown (protected sand)	+6'	7.5	0.22	56,874	<25
	+1.4'	38.2	1.75	42,445	<372
	+0'	60.3	2.34	38,046	<115

Table 13. Subtidal summary of second year community parameters by study area - depth. All parameters are for June 1977.

Study Area		Species Richness	Diversity H'	Total Density (#/m^2)	Total Biomass (g/m^2)
Tongue Point	-5 m	209	1.45	18,635	9160
(rock)	-10 m	94	3.00	834	2988
Pillar Point	-5 m	77	2.82	13,814	<156
(sand)	-10 m	86	3.26	4426	<172
Morse Creek (cobble-gravel)	-10 m	127	2.72	11,654	<290
Beckett Point	-5 m	83	2.77	13,416	<170
(sand)	-10 m	90	3.05	17,542	<214
Dungeness Spit	-5 m	28	2.43	858	<56
(sand-gravel)	-10 m	136	3.82	6764	<322
Twin Rivers (gravel)	-5 m	28	1.69	8852	<56
North Beach	-5 m	201	1.44	14,103	12,021
(cobble-gravel-sand)	-10 m	151	3.86	7442	1474
Kydaka Beach	-5 m	54	2.55	6230	<114
(sand)	-10 m	96	2.83	17,410	<222
Jamestown	-5 m	136	3.49	17,364	782
(sand)	-10 m	156	3.81	12,864	76

part but also a decline in polychaete and small crustacean species. This latter would imply that more or larger sediment pockets were sampled at -5m compared to -10m.

The above illustrates the difficulty of determining causes for observed patterns from the data alone. A very large number of factors, both real and sampling induced, could produce the observed patterns in species richness. Fortunately poor sampling is more likely to obscure patterns than create them. Of the patterns mentioned above it is clear that two factors are primarily responsible. First is the type of substratum. Rock supports the richest marine communities in this region. Second and virtually of equal importance is exposure to wave and current activity. Exposed rock communities are much richer than those from protected rock areas. The opposite exposure effect is found for soft sediment areas. Exposed soft sediment areas support very species poor communities, while the communities found in protected soft sediment areas may approach the richness of protected rock communities. (See Figure 4.)

Intertidal abundance and biomass followed fairly closely species richness patterns with highest values at the rock, cobble, and protected soft sediment areas. Patterns at these areas relative to tidal height were more complex. Biomass increased with decreasing tide height. No clear pattern in abundance was observed. In gravel and sand areas, low biomass precluded determination of tide height patterns. Density was usually lowest at the highest tide height.

For subtidal areas lowest densities occurred at exposed Dungeness -5m and Tongue Point -10m. In general, biomass decreased with increasing depth, due largely to decreased plant biomass with depth.

It is also possible to rank all study sites by biomass or standing crop and from this to make inferences about productivity and energy flow in the community. Rock habitats usually had by far the greatest standing crop with as much as 11.4 kg/m^2 found in this study. The 12.0 kg/m^2 found at North Beach -5m was mostly due to a single large Pterogophora; very large algae are not adquately sampled by the methodology employed in this study. Cobble areas were next in standing crop, although protected 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 protected sediment systems is impossible without detailed rate studies.

The first year report (Nyblade, 1978) gave a detailed analysis of study area and tidal level similarities. Second year data confirmed first year patterns. Rock, cobble, and gravel intertidal areas were similar to each other. Subtidal areas of similar sediment type showed high community similarity. Low similarity was found between communities at high, mid, and low tidal height at given study sites. Appendix II Tables 1 - 10 give the cumulative two year species list for each study site with the tidal height/depth range indicated for each species. Examination of these tables reinforces the patterns observed above.

In last years report a brief comparison was made between the Strait study sites and some San Juan Island DOE study sites. It would be very desirable to be able to expand on that to compare all study sites sampled by comparable methodology in the greater Puget Sound basin in the past five years. It would be valuable to know if regional faunal/floral trends exist within this larger area.

The number of sites sampled is now quite large with METRO sites from Puget Sound, DOE sites from San Juan Island and the Rosario Strait mainland area, and NOAA sites from Whidbey Island. To obtain the necessary original data and put it into a uniform format would be both very time consuming and expensive, putting regional comparisons beyond the scope of this report. (See Recommendations.)

Site to site trends in replicate variability would be of interest and would be possible using a similarity index. This would require extensive computer analysis and proved to be beyond the scope of this report.

VI-B. Seasonal Changes

Tables 14, 15, and 16 summarize seasonal changes many of which were noted area by area in the Results. Table 14 gives a summary of species richness seasonal changes. In 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 (Tongue +3, +0; Pillar +0). There was also often a winter depression in species richness at gravel and sand sites, species poor areas. Such winter depressions may be due to annual algal die-off and storm disturbance.

A summary of seasonal change in community density is presented in Table 15. Seasonal patterns were not particulary clear. However, more areas had their highest densities in the summer and lowest in the winter than during the other three quarters.

Seasonal change in biomass (Table 16) was not obvious. No meaningful biomass information was obtained from the low biomass areas, a majority of sites, giving a much shorter table than Table 14 and 15. Algae dominated the biomass at higher biomass areas. The patchiness of large algae distribution masked any seasonal trends.

Except for species which had a discrete period of massive recruitment (Balanus, Musculus, Platynereis), seasonal population changes of individual species were often not apparent. Reasons for this may be several. First, there may have been little population change over the year. The species may be long-lived or the individuals of a species may be replaced at the same rate as mortality. Inadequacy of the sampling methodology to adequately

Table 14. Second year (1977-78) seasonal change in species richness by study area - tide height. Asterisk indicates seasonal peak.

Study Area		Spring	Summer	Fall	Winter
Tongue Point	+6′	79*	66	56	44
(rock)	+3′	114	136*	126	97
	+0′	180	175	–	–
Morse Creek	+6′	8	16*	7	15
(cobble over	+3′	59	76*	70	64
sand)	+0′	112	117*	82	–
Beckett Point	+6′	10	13	15*	12
(protected	+3′	23	55	74*	29
gravel-sand)	+0′	68	83	93*	79
Dungeness Spit	+6′	2*	1	0	1
(exposed gravel-	+3′	2*	2*	1	1
sand)	+0′	3	2	5*	1
North Beach Sand	+6′	10*	8	6	5
(semi-exposed	+2′	9	13*	10	10
sand)	+0′	16	21*	18	19
Kydaka Beach	+6′	2	6*	4	2
(exposed sand)	+3′	2	5*	2	1
	+0′	6	5	7*	1
Jamestown	+6′	8	4	4	14*
(protected sand)	+1.4′	33	36	46*	38
	+0′	47	57	76*	61

Table 15. Second year (1977-78) seasonal change in density by study area - tide height. Asterisk indicates seasonal peak.

Study Area		Spring	Summer	Fall	Winter
Tongue Point	+6'	89,216*	29,800	14,880	13,220
(rock)	+3'	30,750	97,740*	45,072	20,501
	+0'	10,470	28,280	–	–
Morse Creek	+6'	206	2,458*	1,257	844
(cobble over	+3'	6,452	29,420	33,278*	13,514
sand)	+0'	17,843*	17,450	10,360	–
Beckett Point	+6'	1,630	632	4,404*	1,904
(protected	+3'	3,450	11,068	48,228*	3,964
gravel-sand)	+0'	24,830	58,584	97,112*	45,784
Dungeness Spit	+6'	8	332*	0	4
(exposed gravel-	+3'	276	16	16	572*
sand)	+0'	52	144	520*	68
North Beach Sand	+6'	92	156*	48	28
(semi-exposed	+2'	2,600	6,372*	1,824	2,352
sand)	+0'	5,608*	3,692	3,792	5,296
Kydaka Beach	+6'	12	144*	96	12
(exposed sand)	+3'	8	328*	48	12
	+0'	272*	112	56	8
Jamestown	+6'	150,220*	44,428	30,972	1,876
(protected sand)	+1.4'	11,536	68,244*	61,368	28,632
	+0'	25,910	24,216	50,412	51,644*

Table 16. Second year (1977-78) seasonal change in biomass by study area - tide height where significant biomass was measured. Asterisk indicates seasonal peak.

Study Area		Spring	Summer	Fall	Winter
Tongue Point (rock)	+6'	3466*	1619	446	374
	+3'	2985	3712	4807*	2280
	+0'	6506	8230	—	—
Morse Creek (cobble over sand)	+3'	653	1047	916	1088*
	+0'	3936*	3176	2216	—
Jamestown (protected sand)	+0'	302	252	1084*	20

reflect real population change may be another reason. The methodology used was designed to optimally describe the communities present, not necessarily to provide population information on component species useful for examining seasonal population change.

It is satisfying to note that the general composition or structure of the communities sampled remained stable at most areas sampled in terms of the dominant species and their general order of abundance. Community composition remained stable over the seasons sampled and between the first year and second, as discussed in the next section.

VI-C. Annual Changes

An essential goal of the second year program was to document changes from first year results. Observed changes may be due to real or extrinsic factors or may be the result of poor sampling design. Once changes are clearly determined to be due to extrinsic factors, speculation on what factor or factors produced the change becomes possible. One factor may be only the normal biological variation in an otherwise stable community, its biological noise. The community may not be stable. It may be undergoing slow directional change, because of its early successional stage or long-term changes in the physical environment. It may not be a stable community at all, representing just a single time frame of random change.

First year/second year comparisons of species richness, diversity, abundance, and biomass are presented in summary form for all sites in Table 17. Species richness and diversity showed very little year to year change especially in the richer intertidal sites. Figures 2 and 3 present graphically the relationship between richness/diversity and year one/year two percentage change in these parameters. The more complex the communities, the lower the year to year change in these parameters. Larger subtidal changes may be only a product of sampling error. Abundances also show surprisingly little change, generally much less than a factor of ten, and biomass changes are even less. An exception is North Beach -5m where much algae was collected the second year, probably a sampling problem caused by collecting larger cobble in the second year in this apparently heterogeneous area.

Table 18 presents a summary of the values for community similarity between the first and second year. These were mentioned in the Results. Community similarity in the intertidal from the first to second year was greatest at the rock, stable cobble, and protected soft bottom areas, all areas with rich, complex communities. This year to year constancy in overall community composition was an especially noteworthy result when one considers sampling problems due to organism patchiness and the irregular recruitment of some important individual component species. Figures 4 and 5 graphically present the relationship between sediment type, community complexity, and year to year community constancy. In general, species richness increases with increasing sediment particle size. The complex communities associated with rock/cobble and protected sediments show less year to year community change than the simpler exposed gravel and sand communities, with the exception of a few simple communities where taxonomic lumping may create artificially high community constancy.

Table 17. Comparison of first and second year summary community parameters. Asterisk: Pillar Point, North Beach Cobble, Twin Rivers comparison of spring 1976 with spring 1977; Tongue Point +0' spring-summer 1976 with spring-summer 1977; Morse Creek +0' spring-fall 1976 with spring-fall 1977.

Study Area	Stratum	Mean Species Richness		Mean Diversity H'		Mean Total Abundance (#/m²)		Mean Total Biomass* (g/m²)	
		'76-'77	'77-'78	'76-'77	'77-'78	'76-'77	'77-'78	'76-'77	'77-'78
Tongue Point	+6'	47.3	61.3	2.2	2.4	18,109	36,779	928	1,476
	+3'	103.3	118.3	2.6	3.0	28,371	48,516	2,575	3,446
	*+0'	150.3	177.5	2.5	2.3	4,474	19,375	5,262	7,368
	-5m	133	209	2.6	1.5	6,004	18,635	8,539	9,160
	-10m	59	94	2.1	3.0	604	834	778	2,988
Pillar Point	*+6'	26	42	0.9	1.9	27,282	11,620	640	480
	+3'	169	131	3.1	2.5	11,540	8,994	11,766	6,317
	+0'	123	124	1.8	2.0	729	15,642	7,548	11,375
	-5m	92	77	3.1	2.8	6,123	13,814	-	-
	-10m	91	86	3.3	3.3	4,715	4,426	-	-
North Beach Cobble	*+6'	12	16	1.5	2.0	283	2,148	-	78
	+3'	49	38	1.6	2.5	9,077	3,802	353	128
	+0'	122	125	3.5	3.2	5,512	6,724	908	1,862
Morse Creek	+6'	8.5	11.5	1.1	1.1	3,131	1,191	-	-
	+3'	56.8	67.3	1.8	2.2	21,388	20,666	791	926
	*+0'	101.8	103.7	2.6	2.3	12,794	15,218	1,683	3,109
	-5m	74		3.0		1,495		-	-
	-10m	149	127	2.8	2.7	8,863	11,654	-	-
Beckett Pt.	+6'	17.3	12.5	1.8	1.7	1,713	2,143	-	-
	+3'	40.0	45.3	2.0	2.2	4,716	16,678	-	-
	+0'	80.3	80.8	2.1	2.4	34,102	56,578	-	-
	-5m	101	83	2.9	2.8	15,522	13,416	-	-
	-10m	132	90	3.1	3.1	18,122	17,542	-	-
Dungeness Spit	+6'	4.0	1.0	1.0	0.2	60	86	-	-
	+3'	3.0	1.5	0.7	0.2	150	220	-	-
	+0'	3.3	2.8	0.8	0.3	97	196	-	-
	-5m	30	28	2.4	2.4	283	858	-	-
	-10m	90	136	3.0	3.8	3,828	6,764	-	-

Table 17. (Cont.)

Study Area	Stratum	Mean Species Richness		Mean Diversity H'		Mean Total Abundance (#/m2)		Mean Total Biomass* (g/m2)	
		'76-'77	'77-'78	'76-'77	'77-'78	'76-'77	'77-'78	'76-'77	'77-'78
Twin Rivers	*+6'	3	3	0.3	0.8	184	44	-	-
	+3'	5	4	0.6	0.6	332	692	-	-
	+0'	10	15	0.9	1.6	420	1,448	-	-
	-5m	139	28	3.5	1.7	5,282	8,852	-	-
	-10m	65	-	2.1	-	6,093	-	-	-
North Beach Sand	+6'	7.8	7.3	1.1	1.6	221	81	-	-
	+2'	10.8	10.5	0.7	0.5	3,521	3,287	-	-
	+0'	14.8	18.5	1.0	1.3	4,223	4,597	-	-
	-5m	163	201	3.6	1.4	9,303	14,103	390	12,021
	-10m	109	151	3.1	3.9	5,881	7,442	62	1,474
Kydaka Beach	+6'	3.3	3.5	0.8	0.8	175	66	-	-
	+3'	4.8	2.5	0.5	0.5	443	99	-	-
	+0'	6.3	4.8	1.5	0.9	42	112	-	-
	-5m	51	54	3.0	2.6	2,300	6,230	-	-
	-10m	53	96	2.9	2.8	4,568	17,410	-	-
Jamestown	+6'	6.8	7.5	0.1	0.2	22,319	56,874	-	-
	+1.4'	30.0	38.2	1.9	1.8	11,579	42,445	-	-
	+0'	64.0	60.3	2.2	2.3	56,076	38,046	-	-
	-5m	174	136	3.5	3.5	21,712	17,364	266	782
	-10m	144	156	3.2	3.8	20,747	12,864	106	76

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* Blanks occur where community biomass for first, second or both years was low and uncertain due to the large numbers of <0.1 g. weights.

Table 18. Community similarity between year one and year two by study area - tide height. Similarity values range from 0.00, no similarity, to 1.00, total similarity. Blanks occur where two years of data were not obtained. Values for Pillar Point, North Beach Cobble, Twin Rivers are based on spring 1976 and spring 1977 only; Tongue Point +0' spring-summer 1976 and spring-summer 1977; Morse Creek +0' spring-fall 1976 with spring-fall 1977 only.

Study Area	Habitat Type	Tide Height +6'	+3'	+0'	-5m	-10m
Tongue Point	rock	0.56	0.61	0.49	0.31	0.08
Pillar Point	rock intertidal; sand subtidal	0.80	0.67	0.36	0.57	0.54
North Beach Cobble	cobble over sand	0.17	0.47	0.33	-	-
Morse Creek	cobble over sand	0.79	0.68	0.52	-	0.61
Beckett Point	protected gravel-sand	0.76	0.37	0.56	0.58	0.65
Dungeness Spit	exposed gravel-sand	0.24	0.83	0.21	0.30	0.34
Twin Rivers	exposed gravel-sand	0.79	0.09	0.12	0.21	-
North Beach Sand	semi-exposed sand intertidal; sand-gravel-cobble-subtidal	0.28	(+2') 0.96	0.79	0.08	0.42
Kydaka Beach	exposed sand	0.12	0.26	0.32	0.55	0.39
Jamestown	protected sand	1.00	(+1.4') 0.61	0.79	0.42	0.48

Generalizations in the subtidal are more of a problem because of the obvious inadequacy of the Van Veen grab sampling methodology. In sediment where the grab worked the best, year to year similarity was high. It is possible that most subtidal communities would show the community constancy found intertidally in rock and protected fine sediment areas if adequately sampled.

Comments on annual changes of dominant species in the various communities studied were made in the Results Section. In the exposed gravel and sand habitats populations changed greatly from year one to year two, i.e., community similarity was low. This might be only a sampling artifact due to the difficulty of sampling a sparse often aggregated fauna. However, great population oscillations may as likely be a real characteristic of these areas. In the habitats with more complex communities, some species populations changed greatly from year to year. However, the majority remained fairly stable from year one to year two.

In summary then, should one of the study sites be visited five or ten years from now, the same basic community should be found. Species composition, richness, and diversity should remain very similar, with perhaps slightly greater changes in overall abundance and biomass.

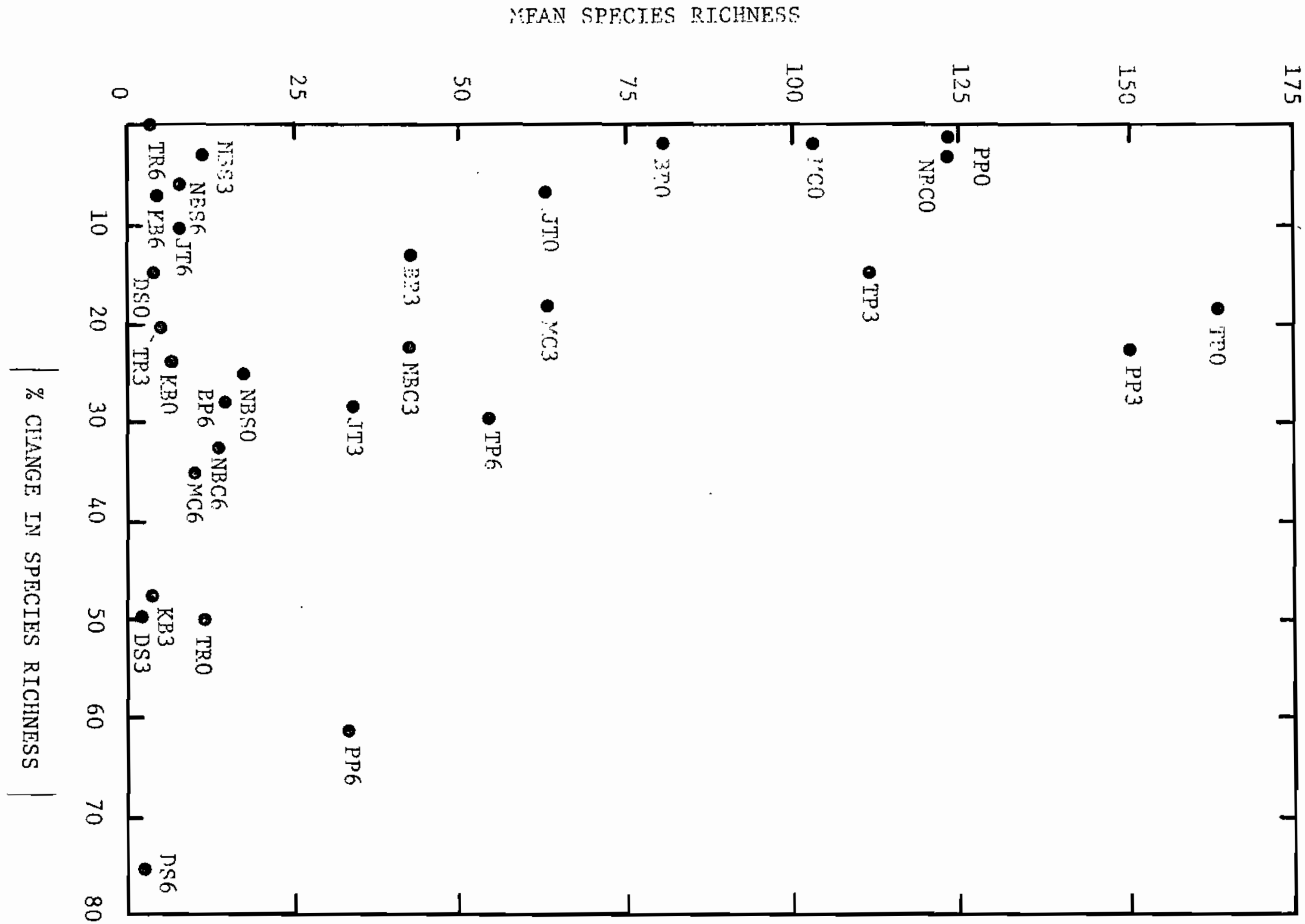

Figure 2. Intertidal species richness (mean of the first and second years) by study area - tide height compared with the percentage change in species richness between the first and second years. BP6 = Beckett Point +6', BP3 = Beckett Point +3', BP0 = Beckett Point +0'; DS6, DS3, DS0 = Dungeness Spit +6', +3', +0'; JT6, JT3, JT0 = Jamestown +6', +1.4', +0'; KB6, KB3, KB0 = Kydaka Beach +6', +3', +0'; MC6, MC3, MC0 = Morse Creek +6', +3', +0'; NBC6, NBC3, NBC0 = North Beach Cobble +6', +3', +0'; NBS6, NBS3, NBS0 = North Beach Sand +6', +2', +0'; PP6, PP3, PP0 = Pillar Point +6', +3', +0'; TP6, TP3, TP0 = Tongue Point +6', +3', +0'; TR6, TR3, TR0 = Twin Rivers +6', +3', +0'.

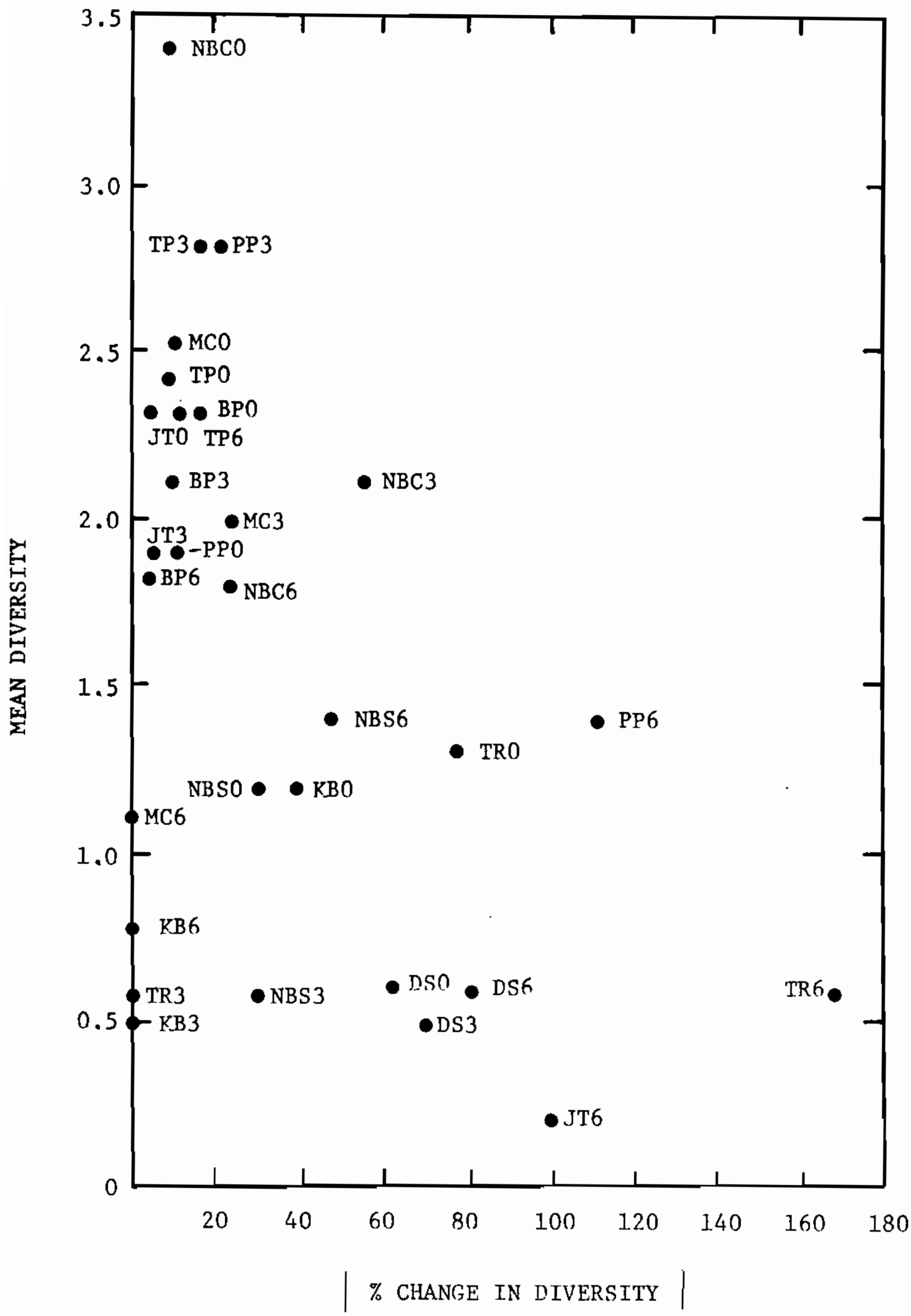

Figure 3. Intertidal diversity (mean of the first and second years) by study area - tide height compared with the percentage change in diversity between the first and second years. For study area abbreviations (e.g., BP6), see Figure 2.

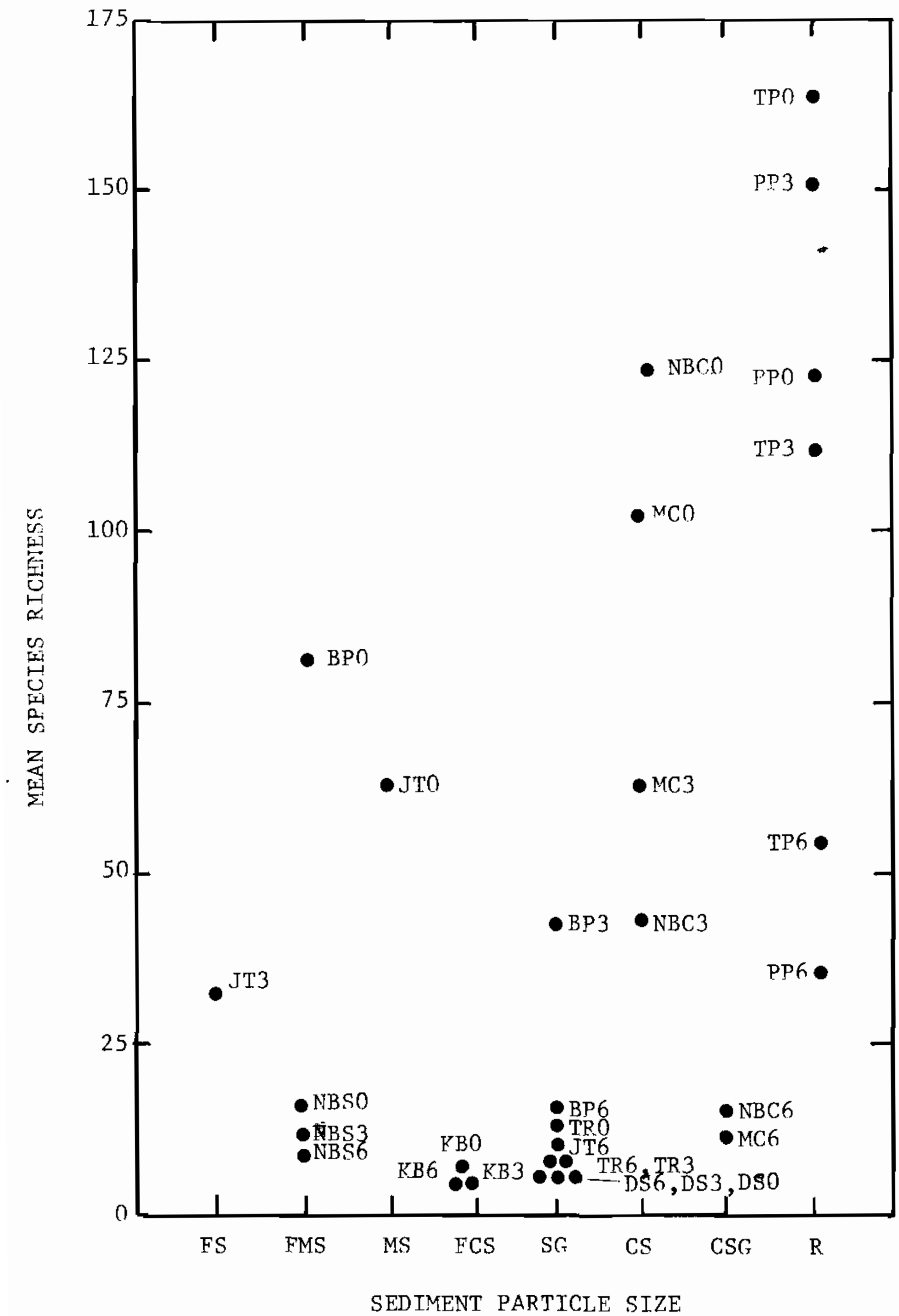

Figure 4. Intertidal species richness (mean of the first and second years) by study area - tide height compared with sediment particle size. For study area abbreviations (e.g., BP6), see Figure 2. FS = fine sand, FMS = fine-medium sand, MS = medium sand, FCS = fine-coarse sand, SG = sand and gravel, CS = cobble and sand, CSG = cobble, sand and gravel, R = rock.

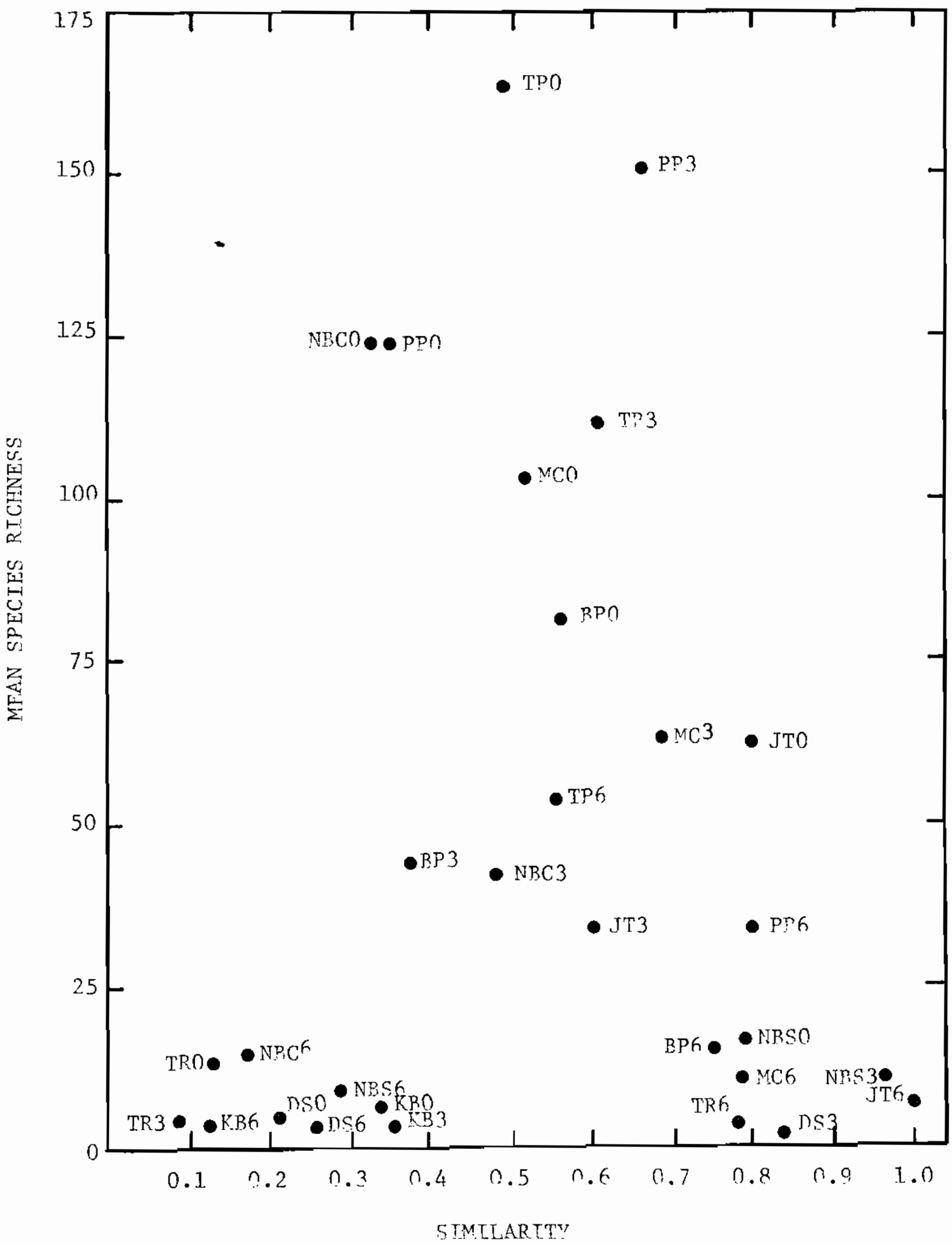

Figure 5. Intertidal species richness (mean of the first and second years) by study area - tide height compared with the similarity of communities between the first and second years. Values for similarities range from 0.0 (no similarity) to 1.0 (total similarity). For study area abbreviations (e.g., BP6), see Figure 2.

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GPO 697-148