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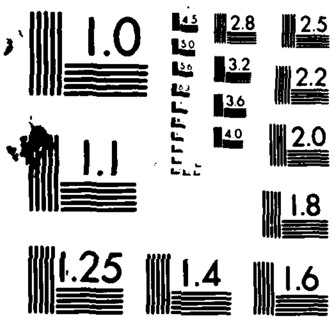

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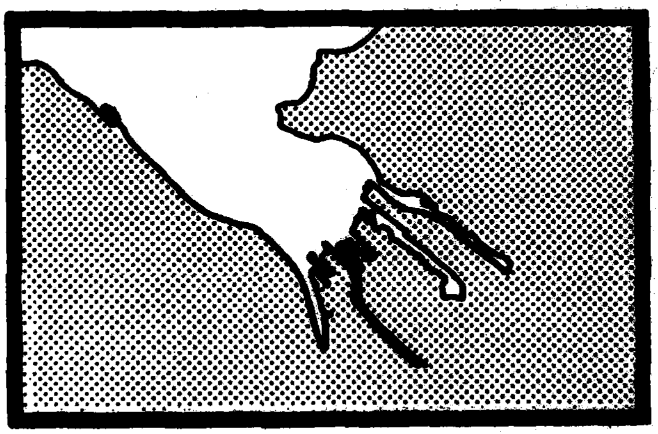
COMMENCEMENT BAY STUDY

Invertebrates



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In the 20-month period ending December 1981, Dames & Moore (Seattle) assisted by four subcontractors completed a Phase I effort to collect baseline data and provide a detailed description of the natural and human systems of the Commencement Bay area in the southern Main Basin of Puget Sound in Washington State.

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COMMENCEMENT BAY STUDIES
TECHNICAL REPORT

VOLUME IV

INVERTEBRATES

for

U.S. Army Corps of Engineers
Seattle District

December 1981

Authors:
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Dames & Moore

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1.0 INTRODUCTION

The objectives of invertebrate studies established in the Corps of Engineers Statement of Work (Section 3.4) were to:

1. Determine the exploitation level of the commercial/recreational invertebrate species (crab and shrimp).
2. Characterize the occurrence and components of the invertebrate benthic communities and their habitats.
3. Identify those species available as finfish food sources within the study area.
4. Correlate the distribution of finfish food species with habitat type and with occurrence of varied finfish species.

The Commencement Bay invertebrate study has provided additional information about benthic invertebrate communities in the vicinity of a heavily industrialized area of Puget Sound. As such, it has added to the existing data base on benthic communities and provided a point of comparison for disturbed versus undisturbed habitats.

Prior to 1970, there had been little quantitative assessment of intertidal or shallow subtidal benthos of the marine waters of northwest Washington. However, a substantial body of information had been compiled on the taxonomy, ecology, and distribution patterns of benthic species, especially intertidally. Shelford et al. (1935) divided the entire San Juan Islands intertidal and subtidal area into large regions, or "biomes." These biomes were subdivided into "associations" and "fasciations" to account for local variations (e.g., zones). Rigg and Miller (1949) conducted studies of zonation of plants and animals near Neah Bay, Washington. Stephenson and Stephenson (1961a, b) worked with zonation on cliffs and beaches near Nanaimo on Vancouver Island and fitted their results into a "universal scheme" of intertidal zonation.

Wennekins (1959) conducted a semi-quantitative (pipe-dredge) survey and catalogued general bottom types and macrofaunal assemblages throughout Puget Sound, the San Juan Islands, and the Strait of Juan de Fuca. His closest samples to Commencement Bay were the Tacoma Narrows which he classified as a "depositional channel." The first subtidal benthic studies of this period were those of Lie (1968, 1974) and Lie and Kelly (1970) who analyzed grab samples from a large number of stations in Puget Sound, the Strait of Juan de Fuca, and off the Washington coast. Their replicated sampling permitted a considerable degree of sophistication in statistical analysis of the structure of the assemblages, affinities between groups, and their relationship to physical and chemical environmental factors.

During the 1970s and continuing into the early 1980s, there has been a plethora of studies of intertidal and subtidal benthic faunal assemblages in Puget Sound and the Strait of Juan de Fuca. Many of these studies have been directed at the collection of quantitative baseline data on abundance and distribution of important species in relatively natural, undisturbed habitats.

Stratified random sampling techniques were first applied in the region by Houghton (1973) in intertidal studies at Kiket Island (Skagit Bay). Similar methods were adopted by the Washington Department of Ecology's (WDOE) Baseline Study Program (Gardner 1977) for intertidal and subtidal studies in the San Juan Islands (Nyblade 1975, 1977). Subsequently these techniques have been standardized and used in the Marine Ecosystems Analysis (MESA) program in the Strait of Juan de Fuca (Nyblade 1978) and on Whidbey Island (Weber 1979). Elements of this methodology were also employed by Houghton and Kyte (1978) in subtidal studies in the Nisqually Reach of southern Puget Sound and by Pearce et al. (1976) in intertidal studies in the same area.

A substantially different approach to sampling of benthic communities was developed by workers at the Fisheries Research Institute of the University of Washington. Benthic organisms were subdivided into infaunal and epifaunal components and a suction-type sampling device (epibenthic pump) developed to make quantitative collections of epifaunal assemblages (Miller et al. 1977, Simenstad and Kinney 1978). This technique has been used to sample benthic assemblages along the Strait of Juan de Fuca (Simenstad et al. 1980), Hood Canal (Simenstad and Kinney 1979), and was used in the Columbia River Estuary Data Development Program (CREDDP) by researchers from Dames & Moore and the Fisheries Research Institute.

Studies on the functional ecology of benthic communities are also available. Mayer (1973) studied predator-prey relationships in benthic communities in Skagit Bay while Woodin (1974) studied the abundance patterns of polychaetes in a soft-bottom habitat in the San Juan Islands. Of particular interest is the study by Nichols (1974) describing the population dynamics of three deposit-feeding benthic invertebrates in central and southern Puget Sound.

The majority of the preceding studies took place in relatively natural, undisturbed habitats. In contrast, a number of studies have been reported in recent years from areas which are industrialized or otherwise under man's influence in the greater Seattle area. The Puget Sound Interim Studies performed for METRO (Municipality of Metropolitan Seattle) focused on both the effects of sewage effluent on benthic communities near wastewater outfalls (Harman et al. 1976, 1977; Armstrong et al. 1977) and benthic community structure at Seattle beaches away from these outfalls (Armstrong et al. 1976). METRO-sponsored baseline studies describing the composition of intertidal benthic communities at Skiff Point, Bainbridge Island across from the West Point sewer outfall (Thom et al. 1979a) and at 100 subtidal sites on the eastern side of central Puget Sound (Thom et al. 1979b) have further characterized benthic communities in this region. A study done for the Port of Seattle (Leon 1980) analyzed benthic communities at Kellogg Island in the Duwamish Waterway, a site adjacent to heavy industry and within a dredged waterway. These studies, and the previously mentioned ones, create a broad background of information with which to compare the results obtained from the Commencement Bay invertebrate studies.

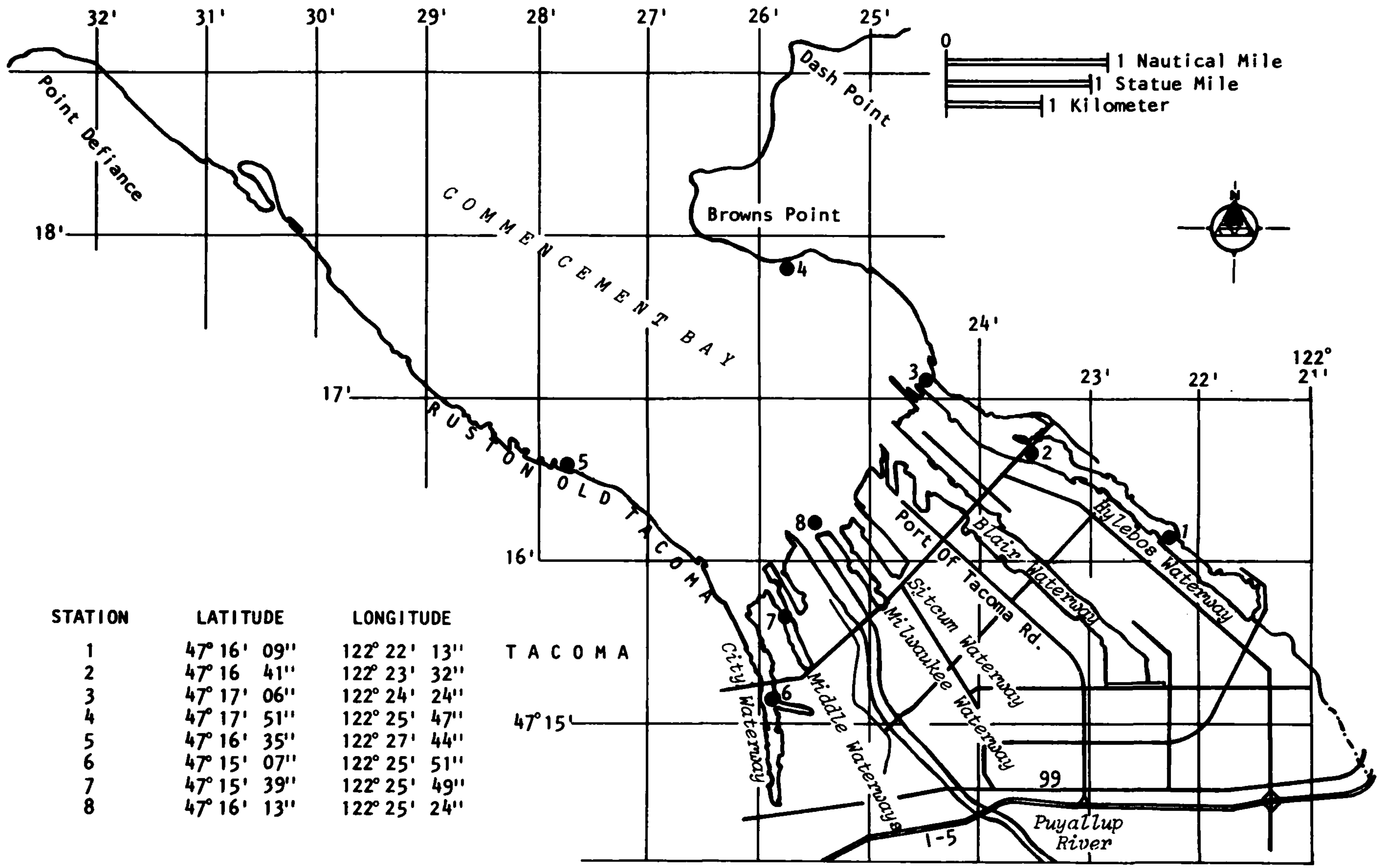
2.0 METHODS

2.1 TRANSECT LOCATION

Eight transects were established within the study area (Figure 1). These transects were chosen as representative of the majority of nearshore habitats within the study area and included locations within the waterways and in the outer bay. Intertidal sample stations at each transect included 1.8, 0.9, and 0.0 meters relative to MLLW (mean lower low water) except for Transect 8 where no 1.8 m samples were collected. Subtidal sample sites were at -2.5 m (Transects 3, 5, 6, and 7) and -10 m (Transects 1, 2, 4, and 8) relative to MLLW. Stationary landmarks on shore were used to locate the transects. Individual stations along a transect were located with the aid of a fathometer or sounding rod after correcting for the stage of the tide.

Intertidal and subtidal organisms were sampled using an epibenthic pumping system (Figure 2) consisting of a centrifugal pump drawing water and organisms through a conical, steel expander into a PVC suction hose at a rate of approximately 4 liters/second (Miller et al. 1977, Simenstad and Kinney 1978). From the pump the water passed through a flowmeter and into a steel cylinder containing two nested conical nets of mesh size 0.5 mm and 0.25 mm. Organisms were retained by the nets and concentrated in plastic net buckets. Once on station, the pump expander was lowered to the bottom. The pump was allowed to run for about 20 seconds before the nets were placed in the cylinder so that water and organisms already in the hose but not from the sample area were removed. Pumping time was approximately 60 seconds/station (equals 240 liters filtered). Large quantities of organic debris at some stations caused system clogging and reduced pumping time by as much as 50 percent. However, it is felt that the majority of organisms in the sample were collected prior to the net's clogging.

The contents of the net buckets were placed in separate glass jars and labeled according to transect, date, collection gear, mesh size, and replicate number. Equal volumes of seawater and 10-percent formalin



STATION	LATITUDE	LONGITUDE
1	47° 16' 09"	122° 22' 13"
2	47° 16 41"	122° 23' 32"
3	47° 17' 06"	122° 24' 24"
4	47° 17' 51"	122° 25' 47"
5	47° 16' 35"	122° 27' 44"
6	47° 15' 07"	122° 25' 51"
7	47° 15' 39"	122° 25' 49"
8	47° 16' 13"	122° 25' 24"

FIGURE 1 INVERTEBRATE SAMPLING STATIONS IN COMMENCEMENT BAY

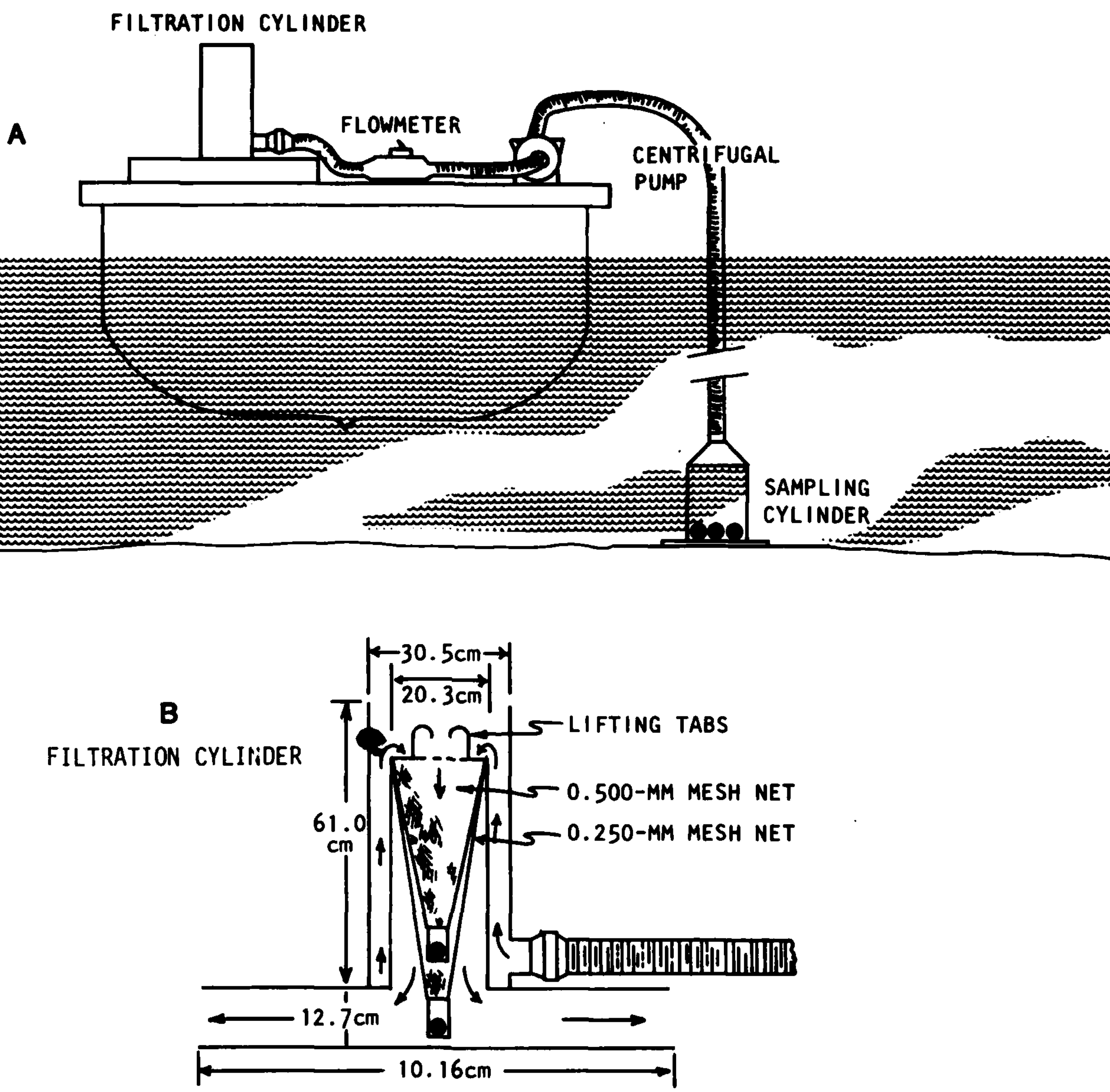


FIGURE 2

COMPONENTS OF EPIBENTHIC SUCTION-PUMP SAMPLING SYSTEM(a) AND CONSTRUCTION DETAIL OF FILTRATION CYLINDER(b)

buffered with $CaCO_3$ were then added to each jar to preserve the sample. Eight drops of Rose Bengal stain were added to each jar in the laboratory to impart a color to the organisms and thus facilitate sorting.

During April and November, two replicates were taken at each transect for each tidal level, resulting in four samples for each tidal level (two sieved at 0.5 mm and two at 0.25 mm). Due to funding limitations, only Transect 2 was sampled at each tidal level during June and August; the remaining transects were sampled at the subtidal station only.

Samples of intertidal and subtidal infauna were obtained by divers using hand-held corers (surface area = 12.5 cm^2, volume = 450 ml). These core samples were sieved at 0.5 millimeter immediately after collection, and the contents retained were preserved in equal volumes of seawater and 10-percent formalin buffered with $CaCO_3$. Rose Bengal stain was added to each jar to aid in sorting. Three core samples were taken at each transect at each tidal level. Infaunal samples were collected concurrently with epibenthic pump samples.

2.2 LABORATORY PROCEDURES

In the laboratory the contents of a jar were emptied into an enameled pan and then gently swirled so as to separate the organisms in the sample from bits of debris and heavier sand grains. Before settling could occur, this surface layer was decanted through a sieve of appropriate mesh size (0.5 mm or 0.25 mm) to retain the organisms present. This panning process was repeated 3 to 5 times per sample, which proved adequate to separate virtually all the organisms from the sediments and heavy debris.

The material retained by the sieve was gently washed into a petri dish. Major taxa were sorted into separate drops of water with the aid of a dissection microscope. Subsampling of certain samples was necessary due to the presence of extremely high numbers of certain organisms as well as the relatively high incidence of wood chips, fibers, and other organic debris. Subsampling was accomplished by placing the sample in a graduated beaker and adding water to reach a volume of 50 ml. The contents were gently agitated by hand for even distribution and a subsample drawn off with a 5-ml Henson-Stempel pipette. The organisms in the subsample were then identified and counted. Additional subsamples were taken until approximately 70 of the most numerous organisms had been counted. The numbers collected by subsampling were adjusted to reflect density in the entire sample by the formula:

$$n_1 = \frac{n_2 \times V_1}{V_2}, \text{ where}$$

n_1 = number of organisms in the sample,

n_2 = number of organisms counted in the subsample,

V_1 = total volume of sample (ml), and

V_2 = volume of subsamples (ml).

The number and types of organisms present in each sample, along with a code identifying sample origin, were recorded on forms and keypunched.

Organisms were identified to the lowest practical taxon based on existing literature and budget limitations. The majority of organisms were identified to genus and, when possible, species. Certain groups, such as Nematoda, Oligochaeta, Ostracoda, and larval crustaceans, were not identified beyond the level of class or order. Due to the amount of time required to identify genera and species of harpacticoid copepods, these animals were identified and tabulated for all stations at the order level. However, a checklist of genera and species of harpacticoid copepods was assembled for Transects 4 and 7 by Mr. Jeffrey R. Cordell, Fisheries Research Institute, University of Washington. The level of taxonomic reduction for Commencement Bay invertebrates is comparable to that of the National Oceanic and Atmospheric Administration (NOAA) Office of Marine Pollution Assessment (OMPA) Puget Sound studies.

2.3 JUVENILE SALMON AND MARINE FISH STOMACH ANALYSIS

Juvenile salmon used for stomach contents analysis were obtained from two sources: those collected by Parametrix, Inc., Dames & Moore subcontractor for COBS Task 4, Fish Studies; and samples collected by Puyallup Nation biologists during 1980. In general, only juvenile salmon collected from areas coinciding with or very near the invertebrate sampling transects were used for stomach contents analysis (Table 1). However, some salmon collected by the Puyallup Nation fisheries biologists from the Point Defiance-Ruston shoreline were included.

Fish length was measured to the nearest millimeter and the stomach removed. A longitudinal incision was made in the stomach and the contents teased into a drop of water. The contents were sorted by taxonomic group and identified as precisely as possible given their state of digestion and resulting presence or absence of key characters. Individual fish, associated stomachs, and contents were stored in labeled vials and preserved in 45 percent isopropanol.

Marine fish collected by otter trawl during the fall (October) 1980 and spring (March-April) 1981 sampling periods and retained for stomach contents analysis are shown in Table 2. The species examined were chosen using three criteria: abundance, importance, and feeding type. The fish retained for stomach content analysis were the most abundant species in the collections and several are of economic importance to sport and commercial fishermen. The fish examined constitute three feeding types (Miller et al. 1980): obligate planktivores (Pacific herring), obligate epibenthic planktivores (Pacific tomcod), and facultative benthivores (flounder and sole).

The stomach and its contents were removed and examined in a manner similar to that described for the juvenile salmon. Due to the low number of fish processed and uneven coverage of all eight invertebrate stations, only qualitative relationships between prey items and their distribution in the study area were described.

TABLE 1

JUVENILE SALMON EXAMINED FOR STOMACH CONTENTS

Species	Collection Period	Number Processed	Transects
Chinook	April 1980	23	1,2,3,8
	May 1980	18	3,7,8
	June 1980	4	3,5,6,7
Coho	April 1980	7	5
	May 1980	2	5
Pink	March 1980	2	3
	April 1980	31	2,3,4,5,6
	May 1980	12	2,4,5,upper turning basin--Hylebos Waterway
	June 1980	1	5
Chum	April 1980	25	1,2,4
	May 1980	23	2,3,4,5, Ruston Way shoreline
	June 1980	4	5, Blair Waterway, Ruston Way shoreline
Total		152	

TABLE 2

MARINE FISH EXAMINED FOR STOMACH CONTENTS

Species	Collection Period	Number Processed	Transects
Starry flounder	Fall 1980	2	3, 6
	Spring 1981	5	8, 6
Rock sole	Fall 1980	3	3, 4
	Spring 1981	5	1, 5, 7
English sole	Fall 1980	10	1, 3, 4, 6, 7
	Spring 1981	6	1, 3, 6
Flathead sole	Fall 1980	3	3
	Spring 1981	1	Milwaukee Waterway
Tomcod	Fall 1980	5	1, 2, 3
	Spring 1981	1	3
Pacific herring	Fall 1980	5	Milwaukee and Blair Waterways
Total		46	

2.4 DATA ANALYSIS

Basic distribution statistics such as number of individuals, mean, variance, and standard deviation were calculated for each sample. Measures of diversity, including species richness, Shannon-Wiener diversity index, number of moves, and number of species were also calculated for each sample. Copies of the above data for each transect and sampling period are on file with the Corps of Engineers, Seattle District, and Dames & Moore.

The invertebrate samples were grouped based on gear type used for collection; 0.25-mm epibenthic pump, 0.5-mm epibenthic pump, and 0.5-mm infaunal core, and each group analyzed separately.

The April and November collections, at all depth levels for each transect, were used to test for significant differences between transects at a given depth level. Mean values for species diversity (H'), species abundance (N), and species richness (S), were grouped by depth level for Transects 1 through 8 and analyzed using a Kruskal-Wallis test (Sokal and Rohlf 1969), a nonparametric method of evaluating the probability that two or more groups come from the same population. Seasonal effects between April and November collections were analyzed by calculating a Mann-Whitney U statistic (Sokal and Rohlf 1969) for April versus November mean values for H', N, and S within a given depth level.

Patterns in species composition were evaluated with cluster analysis techniques (Clifford and Stephenson 1975). These techniques use group averaging methods to construct dendrograms illustrating station and species groupings within the study area. Based on the results of the cluster analysis, we have attempted to provide a detailed description of the invertebrate assemblages present in order to characterize the occurrence and components of the invertebrate benthic communities in the study area.

3.0 RESULTS AND DISCUSSION

3.1 EXPLOITATION LEVEL OF THE COMMERCIAL/RECREATIONAL INVERTEBRATE SPECIES

3.1.1 Review of Data

There is currently no commercial fishing activity for shrimp or crab within the Commencement Bay study area, although shrimp were commercially fished years ago within Commencement Bay and surrounding regions (Bumgarner 1981). The most recent commercial shrimp fishing in south Puget Sound took place in Carr Inlet but has been closed since 1978 due to a severe decline in shrimp stocks (Bumgarner 1981). Within Puget Sound there is no commercial fishing for crabs south of Point Madison, and Dungeness crab population levels are low south of Bainbridge Island according to recent Washington Department of Fisheries sampling programs (Bumgarner 1981).

Recreational fishing for crab (primarily Dungeness, Cancer magister, and rock crab, Cancer productus) occurs within the study area; however, quantitative catch data are limited. A draft report published by the Pierce County Health Department (Noviello 1981) states that crabs are taken predominately along the Browns Point to Hylebos Waterway shoreline, in Blair Waterway, and in City Waterway. Creel surveys at the above areas (10 visits to each between July 1 and September 11, 1981) revealed that 79 fishermen caught 104 crabs, while surveys at the Old Town dock and Point Defiance showed no crabs taken among 202 fishermen during the same time period (Noviello 1981). Observations made by Puyallup Tribal Fisheries Division biologists also confirm a sport harvest of crab within City Waterway, Blair Waterway, Hylebos Waterway, and along the Marine View Drive shoreline to Browns Point (Miyamoto 1981).

Recreational shrimp fishing within the study area is primarily directed toward two species. Fishermen have been seen using shrimp pots in Blair Waterway and Hylebos Waterway seaward of 11th Street (Miyamoto 1981), presumably to catch the coonstripe shrimp, Pandalus danae, for human consumption. Also, digging of ghost shrimp, Callianassa spp., for use as fish bait has been observed at three intertidal mudflat areas: at the mouth of Hylebos Waterway, near the 11th Street Bridge over Hylebos Waterway, and in Middle Waterway (Miyamoto 1981).

Existing population estimates for recreationally important crab and shrimp species within the study area are mostly qualitative. Nakatani et al. (1973) observed two Dungeness crabs among piling remnants on one of four transects which divers swam southeast of the ASARCO smelter. Large numbers of coonstripe shrimp were observed inhabiting submerged lumber mill debris at depths of 5 to 25 feet below MLLW and ghost shrimp burrows were observed at shallower depths (Nakatani et al. 1973). Another diving survey along the Ruston Way shoreline (Salo et al. 1980) covered five transects from near Commencement Park to just southeast of the ASARCO smelter. Coonstripe shrimp were observed on submerged logs and tires along four of the transects and Dungeness crabs were observed in small pockets of eelgrass along two of the transects (Salo et al. 1980). Salo and McComas (1980) report the results of a diving survey at eight transects within and at the mouth of Milwaukee Waterway. Large numbers of coonstripe shrimp were observed colonizing submerged logs in the interior of the waterway and Dungeness crabs were observed on all diving transects except two (Salo and McComas 1980). A total of 18 Dungeness crabs were collected by Parametrix, Inc. biologists while trawling for bottomfish (Schadt 1981). The majority of these were caught during October 1980 near the mouth of Hylebos Waterway.

Malins et al. (1980) provide quantitative catch data for several shellfish species in the study area. Individual trawl stations were pooled by geographic area to calculate seasonal and annual total catch values from four locations: Browns Point, Hylebos (the entire waterway), waterways (Blair, Sitcum, Puyallup, and City Waterways), and southwest Commencement Bay (three stations along Ruston Way shoreline). Catch values for Dungeness crab were highest during spring sampling in Hylebos and waterway locations with one station (unidentified) within each location yielding approximately three crabs (Malins et al. 1980). One Dungeness crab was taken at a single station in Hylebos the other three sampling periods, while two were taken at a waterway station during winter. No Dungeness crabs were taken at Browns Point and at southwest Commencement Bay stations. No rock crab were taken at any stations in Commencement Bay.

Two shrimp species of recreational importance were taken by trawls in Commencement Bay: coonstripe shrimp, Pandalus danae, and pink shrimp, Pandalus jordani (Malins et al. 1980). Hylebos Waterway stations had the largest catches in the study area. Winter and spring catches of pink shrimp were very low; the summer catch was approximately 80 shrimp and the fall catch was approximately 160 shrimp. Coonstripe shrimp were taken year-round in Hylebos with catch values of approximately 25 shrimp in winter, 10 in spring, 40 in summer, and a high of 50 in fall. Other sampling areas in Commencement Bay had considerably less shrimp. Approximately 20 coonstripe shrimp were taken in fall and winter from waterway stations and none were caught at Browns Point and southwest Commencement Bay stations. The only other area yielding pink shrimp was Browns Point where approximately 20 were taken during the fall.

3.1.2 Summary and Conclusions

There currently is no commercial fishing in the study area for crab and shrimp and present population levels of these species are probably too low to support a viable commercial fishing activity. Recreational fishing for crab and shrimp is common within the study area. The number of recreational fishermen interviewed by Noviello (1981) appears to indicate a fairly high level of exploitation, though no breakdown of numbers of fishermen seeking fish versus shellfish was provided. Recreational fishing pressure could be predicted to increase in the future. Access to shoreline fishing areas and concern about contamination of the catch from industrial pollution are probably the major factors limiting the number of recreational fishermen seeking shellfish in the study area.

From the data that exist it is apparent that the Marine View Drive shoreline from Browns Point to, and including, Hylebos Waterway and City Waterway are the most popular crab and shrimp fishing areas. Observations of fishing activity are numerous but catch data are limited. More information in the form of creel surveys and catch per unit effort data are required to determine the actual exploitation level of these species.

The coonstripe shrimp's habit of seasonally colonizing submerged logs, pilings, and wood debris in nearshore areas (Butler 1980) and its reported abundance in the study area in these habitats (Nakatani et al. 1973, Salo et al. 1980, Salo and McComas 1980) makes it a potential species for increased recreational fishing effort. These types of habitats are probably fairly common in nearshore areas of Commencement Bay but may not be generally accessible to the fisherman.

3.2 QUALITATIVE CHARACTERISTICS OF TRANSECTS

Observations were made by divers during the collection of samples on the general bottom characteristics of each transect. These observations, coupled with laboratory observations of sediments and associated debris in the epibenthic and infaunal samples, helped to characterize the occurrence of varied habitat type along the transects sampled. Table 3 summarizes these observations.

Transect 1, near the head of Hylebos Waterway, contained considerable slag throughout the intertidal region over a bottom of gravel and cobble with some fine sand. The subtidal sediments were soft with a large amount of loose organic debris forming a surface layer. Mysids were commonly observed on top of the sediments at the -10-m station.

Intertidal areas at Transect 2, Hylebos Waterway at the 11th Street Bridge, were composed of soft mud with a high clay and sand content. The subtidal station at -10 m was fairly hard-packed sand. The 0.9-m and 0.0-m stations contained high amounts of an organic debris surface layer.

Transect 3, at the mouth of Hylebos Waterway, had a predominantly sandy bottom at all stations with a gently sloping gradient out to the edge of the dredged channel. There were very low amounts of organic debris present at all tidal levels along this transect.

Transect 4, east of Browns Point below the Cliff House Restaurant, contained gravel at the beach level gradually changing to cobble in the mid- to low intertidal regions. The -10-m station consisted of a mixture

TABLE 3

QUALITATIVE CHARACTERISTICS OF INVERTEBRATE SAMPLING STATIONS BASED ON DIVER AND LABORATORY OBSERVATIONS

Transect	Tidal Elevation	Mud	Sand-Gravel	Organic Debris[a] High	Organic Debris[a] Medium	Organic Debris[a] Low
1	1.8 m		X		X	
	0.9 m		X		X	
	0.0 m		X	X		X
	-10 m	X				
2	1.8 m	X			X	
	0.9 m	X		X		
	0.0 m	X		X		
	-10 m		X			X
3	1.8 m		X			X
	0.9 m		X			X
	0.0 m		X			X
	-2.5 m		X			X
4	1.8 m		X			X
	0.9 m		X			X
	0.0 m		X			X
	-10 m	X				X
5	1.8 m		X			X
	0.9 m		X		X	
	0.0 m		X		X	
	-2.5 m	X	X	X		
6	1.8 m		X			X
	0.9 m	X	X			X
	0.0 m	X	X		X	
	-2.5 m	X	X	X		
7	1.8 m		X			X
	0.9 m		X			X
	0.0 m	X		X		
	-2.5 m	X		X		
8	0.9 m		X	X		
	0.0 m		X	X		
	-10 m	X		X		

(a) Organic debris consisted primarily of wood fibers and chips. Amount present determined on the basis of $\geq$50 percent by volume = high; $\geq$10 percent, $<$50 percent by volume = medium; and $<$10 percent by volume = low.

of silt, sand, and mud mixed with shell fragments. All levels had a fairly low level of organic debris on the surface layer. Transect 4 contained an abundance of laminarians and red algae on rocks from about 0.0 m down to the -10-m station. Attached marine life, including barnacles, mussels, and anemones were abundant. Several species of starfish were observed here.

The intertidal area at Transect 5, on Ruston Way at Commencement Park, was composed of sand, gravel, and smooth pebbles. The 0.0-m level down to -2.5 m contained a mixture of sand and silt with a large amount of organic material in a surface layer. A whitish, odoriferous material was consistently observed on top of the sediments at the -2.5-m station. This was probably *Beggiatoa* sp., a bacterium noted by Salo et al. (1980) during a diving survey at this site.

Transect 6, in City Waterway at the mouth of Wheeler-Osgood Waterway, had a very soft, mucky bottom at all levels composed of fine sand and mud with some coarser material. Medium to high amounts of organic debris were present as a surface layer at the 0.0- and -2.5-m stations. The top 15 cm of the bottom sediments were very soft with a more firm material underneath.

Transect 7, in Middle Waterway adjacent to Foss Marine Tug and Barge, had sandy high intertidal areas with some cobble and gravel. The 0.0- and -2.5-m stations were very soft, with approximately 15 cm of sediments and organic material with a gel-like consistency, black in color, and having a diatom film. Several flatfish species were consistently observed at this transect.

Transect 8, at the mouth of the Puyallup River between the river and Milwaukee Waterway, had high intertidal levels composed mainly of sand. The 1.8-m station was covered by riprap and inaccessible to sampling. Clam siphons and mud shrimp burrows are very abundant between the 0.9-m and 0.0-m levels. The subtidal station, -10-m, was composed of very soft, blackish sediments with a large amount of organic material present as a surface layer.

3.3 BENTHIC AND EPIBENTHIC INVERTEBRATE COMMUNITIES

3.3.1 Species Composition

Approximately 229 taxa of benthic and epibenthic invertebrates (Table 4) were identified from the 588 samples collected and processed. The majority of the taxa were polychaetes (31 percent), copepods (16.6 percent), gammarid amphipods (16.1 percent), and bivalve molluscs (6.9 percent). These percentages are partly biased by level of identification of harpacticoid copepods (only samples from Stations 4 and 7 were identified to genus).

Polychaetous annelids were most abundant in the mud-shell sediments at the -10-m station of Transect 4. At each sampling period this station contained the highest number of polychaete species. Stations 1/-10 m, 5/-2.5 m, 7/-2.5 m, and 8/-10 m also contained fairly high numbers of polychaetes. The intertidal stations at Transect 2 (1.8-, 0.9-, 0.0-m) and all the 1.8-m stations in general had the lowest abundance of polychaetes throughout the study area. Within the polychaeta, the family Spionidae contained the highest number of species (Table 4). The Cirratulidae, Glyceridae, Lumbrineridae, Phyllodocidae, and Syllidae were also represented by several species. Polychaetes were occasionally within organic debris sucked up by the epibenthic pump. Polychaetes collected in this manner were counted and identified to family, but were not entered into the epibenthic analysis since they are primarily infaunal organisms.

Copepods dominated the epibenthic pump samples sieved at 0.25 mm and were about equally split between the orders Calanoida and Harpacticoida. In the 0.25-mm epibenthic pumps the planktonic calanoid genera *Pseudocalanus*, *Microcalanus*, and *Eurytemora* were widely distributed at all stations during the spring and summer months while *Paracalanus* and the cyclopoid *Corycaeus* were most abundant in the November samples. *Aetidius armatus* and *Calanus* sp. were the only calanoid copepods commonly encountered at all locations in the 0.5-mm epibenthic pumps, primarily in the April collections. Harpacticoid copepods were not identified

TABLE 4

TAXONOMIC COMPOSITION AND OCCURRENCE OF INVERTEBRATES COLLECTED IN COMMENCEMENT BAY

Taxa	Epibenthic Pump	Infaunal Core
Hydrozoa		
Hydroida (polyp)		+
Scyphozoa		
Scyphozoan medusae	+	
Nemertea		+
Nematoda	+	+
Turbellaria		
Polycladida		+
Gastropoda		+
Acmaeidae		+
Collisella sp.		+
Mitrella sp.		+
Polinices sp.		+
Bivalvia		
Bivalvia sp. juv.		+
Axinopsida sp. juv.		+
Clinocardium sp.		+
Clinocardium californiense		+
Cryptomya californica		+
Mytilus edulis	+	+
Macoma sp.		+
Macoma balthica		+
Macoma calcarea		+
Macoma nasuta		+
Macoma obliqua		+
Protothaca sp.		+
Solen sicarius		+
Tellina sp.		+
Tellina modesta		+
Transenella tantilla	+	+
Polychaeta		
Ampharetidae		
Amphicteis sp.		+
Arenicolidae sp.		+
Capitellidae		
Barantolla americana		+
Capitella capitata		+
Cirratulidae sp.		+
Chaetozone setosa		+
Cauleriella alata		+
Cirratulus cirratus		+
Cirratulus spectabilis		+
Tharyx sp.		+
Tharyx secundus		+
Cossuridae		
Cossura soyeri		+

TABLE 4 (Continued)

Taxa	Epibenthic Pump	Infaunal Core
Dorvilleidae		
Dorvillea annulata		+
Glyceridae sp.		+
Glycera sp.		+
Glycera americana		+
Glycera capitata		+
Goniadidae		
Glycinde picta		+
Hesionidae		
Gyptis brevipalpa		+
Micropodarke dubia		
Ophiodromus pugettensis		+
Lumbrineridae sp.		+
Lumbrineris sp.		+
Lumbrineris luti		+
Lumbrineris pallida		+
Lumbrineris zonata		+
Magelonidae		
Magelona japonica		+
Maldanidae sp.		+
Nephtyidae		
Nephtys cornuta franciscana		+
Nephtys ferruginea		+
Nereidae sp.		+
Nereis sp.		+
Nereis procera		+
Platynereis bicanaliculata		+
Onuphidae		
Diopatra ornata		+
Opheliidae sp.		+
Armandia brevis		+
Ophelina acuminata		+
Orbiniidae sp.		+
Scoloplos acmeceps		+
Oweniidae sp.		+
Pectinariidae		+
Pectinaria granulata		
Phyllodocidae		+
Eteone longa		+
Eulalia sanguinea		+
Phyllodoce sp.		+
Phyllodoce groenlandica		+
Phyllodoce maculata		+
Polynoidae sp.		
Harmothoe lunulata		+
Lepidonotus squamatus		+

TABLE 4 (Continued)

Taxa	Epibenthic Pump	Infaunal Core
Sabellidae		
Chone duneri		+
Manayunkia aestuarina		+
Sigalionidae		
Pholoe minuata		+
Spionidae sp.		+
Polydora sp.		+
Polydora brachycephala		+
Polydora kempi japonica		+
Polydora ligni		+
Polydora proboscidea		+
Polydora pugettensis		+
Prionospio cirrifera		+
Prionospio steenstrupi		+
Pygospio elegans		+
Streblospio benedicti		+
Syllidae sp.		+
Exogone sp.		+
Sphaerosyllis brandhorsti		+
Syllis heterochaeta		+
Syllis hyalina		+
Terebellidae sp.		+
Polycirrus sp.		+
Oligochaeta		+
Araneae		
Halacaridae	+	
Arthropoda		
Ostracoda		
Myodocopa	+	+
Podocopa	+	+
Copepoda		
Calanoida sp.	+	+
Acartia clausi	+	
Acartia longiremis	+	
Aetidius sp.	+	
Aetidius armatus	+	
Calanus sp.	+	+
Calanus pacificus	+	
Eurytemora affinis	+	
Microcalanus sp.	+	
Paracalanus sp.	+	
Pseudocalanus sp.	+	+
Scolecithricella minor	+	
Tortanus discaudatus	+	
Cyclopoida sp.	+	+
Corycaeus anglicus	+	+
Cyclopina sp.	+	

TABLE 4 (Continued)

Taxa	Epibenthic Pump	Infaunal Core
Cyclops bicuspidatus thomasi	+	
Hemicyclops subadhaerens	+	
Oithona similis	+	
Harpacticoida	+	+
Acrenhydrosoma perplexum	+	
Bulbamphiascus sp.	+	
Dactylopodia sp.	+	
Dactylopodia vulgaris inornata	+	
Halectinosoma sp.	+	
Harpacticus sp.	+	
Harpacticus uniremis	+	
Heterolaophonte discophora	+	
Heterolaophonte longisetigera	+	
Huntemannia jadensis	+	
Leimia vaga	+	
Microarthridion littorale	+	
Normanella sp.	+	
Parathalestris californica	+	
Rhynchothalestris helgolandica	+	
Stenhelia (*Stenhelia*) *peniculata*	+	
Tisbe spp.	+	
Typhlamphiascus pectinifer	+	
Zaus sp.	+	
Copepoda copepodite	+	+
Copepoda nauplii	+	+
Cirripedia		
Balanus sp.		+
Balanus glandula		+
Balanomorpha nauplii	+	
Balanomorpha cyprids		+
Leptostraca		
Nebalia pugettensis	+	
Mysidacea sp.	+	
Acanthomysis sp.	+	
Acanthomysis davisi	+	
Acanthomysis macropsis	+	
Holmsiella anomala	+	
Cumacea sp.	+	+
Bathycuma sp.	+	
Cumella vulgaris	+	+
Eudorella sp.	+	+
Eudorellopsis sp.	+	
Lamprops sp.	+	+
Leptocuma sp.	+	
Leptostylis sp.	+	+

TABLE 4 (Continued)

Taxa	Epibenthic Pump	Infaunal Core
Tanaidacea sp.	+	+
Anatanais normani	+	
Leptochelia savignyi	+	+
Pancolus californiensis	+	+
Pseudotanais oculatus	+	+
Isopoda sp.	+	
Bopyridae	+	
Gnorimosphaeroma oregonensis		+
Munna sp.	+	+
Gammaridea sp.	+	
Aoroides columbiae	+	+
Allorchestes angusta	+	+
Ampeliscidae	+	
Ampithoe sp.		+
Calliopiidae	+	
Calliopius sp.	+	
Calliopius cf. *laeviusculus*		+
Corophium sp.	+	+
Eogammarus sp.	+	
Eogammarus confervicolus		+
Eusirus sp.	+	
Guernea sp.	+	+
Heterophoxus oculatus		+
Hyale sp.	+	
Hyale anceps	+	+
Hyale plumulosa		+
Ischyrocerus sp.	+	
Lysiannassiadae		+
Monoculoides sp.	+	
Orchestia traskiana		+
Orchomene sp.	+	+
Orchomene cf. *pinguis*	+	
Paracalliopiella pratti	+	
Paramoera sp.		+
Paramoera mohri	+	+
Paraphoxus sp.	+	
Parapleustes sp.	+	
Photis sp.	+	+
Photis bifurcata		+
Phoxocephalidae	+	
Pleustidae		+
Pleusirus sp.	+	
Pleustes sp.	+	
Pleusymtes sp.	+	+
Synchelidium shoemakeri	+	+
Westwoodilla caecula	+	+
Hyperiidea sp.	+	
Parathemisto pacifica	+	

TABLE 4 (Continued)

Taxa	Epibenthic Pump	Infaunal Core
Caridea sp.		+
Caridea larvae	+	
Caridea megalops	+	
Euphausiacea larvae	+	
Hippolytidae	+	
Eualus fabricii		+
Heptacarpus stimpsoni	+	
Callianassidae		
Callianassa californiensis		+
Anomura		
Anomuran zoea	+	
Brachyura		
Brachyuran zoea	+	+
Cancer magister		+
Grapsidae sp.		+
Hemigrapsus oregonensis		+
Lithodidae	+	
Pinnotheridae		+
Pinnixa occidentalis		+
Telmessus cheiragonus		+
Echinodermata		
Ophiuroidea juv.	+	+
Vertebrata		
Larval fish	+	+

all transects, at all stations, in both infaunal cores and epibenthic pumps. In terms of abundance, harpacticoids dominated all other epibenthic crustacea in the 0.25-mm epibenthic pumps. Transects having greatest abundance were 7 (all levels) and 8 (all levels). Transects 1/-10 m, 2/1.8 m, 3/0.9 m, 4/0.0 m, 5/0.9, 0.0, -2.5 m, and 6/0.0, -2.5 m also contained high densities. Stations having greatest harpacticoid abundance correspond fairly well with stations containing large amounts of an organic surface layer (Table 3). Some harpacticoids feed on bacteria and detritus (Barnes 1974), which is probably very abundant in the organic debris, and this could partly explain why they are so abundant at these stations. One harpacticoid species, Bulbamphiascus, was also reported by Simenstad and Cordell (1980) from City Waterway. They further stated that this species had previously never been found in epibenthic zooplankton assemblages from Pacifc Northwest estuaries.

Gammarid amphipods were most abundant in the infaunal samples. No species showed any overall dominance; however Corophium was probably the most common gammarid collected. Transects 7 (all levels) and 5/-2.5 m contained the highest diversity of gammarids during April, June, and August. Gammarids were still present in the November collections but at reduced levels. The majority of the gammarid species collected have been identified by Staude (1980) as deposit feeders, burrowing into the sediments and feeding on detritus.

The bivalve molluscs were represented by 15 species, including 5 species of Macoma (Table 4). Bivalves were generally most abundant at the low intertidal to subtidal levels of transects having sandy bottoms; such as Transects 3 and 5. Transects with sandy substrates in the mid to high intertidal levels, Transects 7 and 8, also contained relatively higher numbers of bivalves. The bivalves collected were generally small (<2 cm) and the larger specimens often had soft, pliable shells.

Other invertebrate groups that were less abundant but still represented by several species included Cumacea (7 species), Mysidacea (4 species), and Tanaidacea (4 species) (Table 4). The Nematoda and Oligochaeta were often very abundant in the benthic sediments. Because these groups were not identified to a lower level, it is possible that they are represented by a large number of species within the study area.

3.3.2 Infauna Analysis

Mean values for species richness (S, number of taxa) in infaunal samples ranged from 0 in several samples in which animals were absent to 19 species in a sample from the -10-m station on Transect 4 in June. Total species per station ranged from 1 at the 0.9-m station on Transect 2 in June to 30 at the -2.5-m station on Transect 5 in June. The total number of species per station averaged 11.8 $\pm$ 17.1 for all stations sampled. Average species richness was highest at the -10-m station on Transect 4 and lowest was at the 0.9-m station on Transect 5 (Table 5). The total number of taxa identifed was 153 (Table 4).

Species richness generally differed significantly between the transects when compared within each depth level (Table 6). Generally, Transects 4 and 7 had highest richness and Transect 5 had lowest richness. Exceptions to this pattern occurred at the 0.0- and -2.5-m stations (Table 5).

Species richness increased with increasing depth throughout the study area (Table 5; $p<0.01$, Kruskal-Wallis test). Thus, lowest richness usually was encountered at the upper stations at each transect. Variability among stations at a given level was high, however, as pointed out above.

Species richness values showed no significant seasonal pattern. Comparisons were made separately for each level between sample sets collected in April and November (Table 7). The probability that the samples from April and November represented the same statistical population (same biological assemblages) ranged from 13 to 31 percent.

Abundance values (N) ranged from 0 in several samples in which animals were absent to 1,496 individuals (predominantly Oligochaetes) in a sample from the 1.8-m station on Transect 5 in November. Total individuals per station ranged from 4,306 at that same station to 1 at the 0.9-m station on Transect 2 in June. The mean number of individuals per station, averaged for all periods sampled, ranged from 11.5 at the 0.0-m station on Transect 5 to 536.0 at the 0.9-m station on Transect 4 (Table 5).

TABLE 5

POOLED MEAN VALUES OF H', N, AND S FOR ALL INFAUNAL STATIONS ALONG EACH TRANSECT

Tidal Elevation (m)	Transect 1	2	3	4	5	6	7	8
H'								
1.8	0.94	1.24	1.01	0.45	0.12	0.93	1.28	--
0.9	0.80	1.31	1.27	0.65	0.19	0.80	1.88	1.86
0.0	1.40	1.36	1.87	1.19	1.62	1.27	1.51	1.66
-2.5	--	--	2.15	--	2.22	1.52	2.32	--
-10.0	1.40	1.68	--	2.12	--	--	--	1.77
N								
1.8	157.5	74.5	38.5	207.5	2190.0	61.0	372.5	--
0.9	201.0	34.0	54.0	536.0	101.5	169.5	135.5	16.0
0.0	106.5	61.5	58.0	206.0	11.5	130.5	61.0	81.0
-2.5	--	--	57.3	--	106.8	96.8	69.5	--
-10.0	232.2	32.7	--	147.0	--	--	--	158.5
S								
1.8	7.5	7.0	6.0	5.5	3.0	3.5	10.0	--
0.9	7.0	5.0	6.5	8.5	2.5	6.5	11.5	8.0
0.0	8.0	5.5	14.0	10.0	7.0	11.0	9.0	13.0
-2.5	--	--	15.8	--	20.5	13.3	19.5	--
-10.0	12.3	9.3	--	22.3	--	--	--	18.5

TABLE 6

INFAUNAL CORE SAMPLES: PROBABILITIES OF SIGNIFICANT DIFFERENCES AMONG TRANSECTS AT A GIVEN DEPTH LEVEL (KRUSKAL-WALLIS TEST)

April and November 1980

Tidal Elevation (m)	Numerical Parameters H'	S	N	Accept or Reject Null Hypothesis
1.8	p<0.01	p<0.01	p<0.01	Reject for all
0.9	p<0.001	p<0.01	p<0.01	Reject for all
0.0	p>0.20	p>0.10	p<0.02	Accept for S and H', reject for N
-2.5	p>0.10	p>0.30	p>0.30	Accept for all
-10.0	p<0.02	p<0.01	p<0.05	Reject for all

TABLE 7

INFAUNAL CORE SAMPLES: PROBABILITIES OF SIGNIFICANT DIFFERENCES AMONG TRANSECTS AT A GIVEN DEPTH LEVEL (MANN-WHITNEY U-TEST)

April and November 1980

Tidal Elevation (m)	Numerical Parameters H'	S	N	Accept or Reject Null Hypothesis
1.8	p>0.27	p>0.23	p>0.27	Accept for all categories
0.9	p>0.19	p>0.44	p>0.30	
0.0	p>0.31	p>0.45	p>0.28	
-2.5	p>0.13	p>0.14	P>0.23	
-10.0	p>0.23	p>0.21	p>0.21	

Abundance differed significantly among transects when compared within each depth level at all except the -2.5-m station (Table 6). Lower abundances usually occurred at Transects 2 and 3 and higher abundances at Transect 4.

Abundance varied considerably among the stations on each transect but no consistent depth pattern was apparent (Table 5, p>0.7). General increases in abundance with decreasing elevation were observed on Transects 1, 2, and 8, but decreases over a similar elevation gradient were observed on Transects 4, 5, and 7.

Abundance also exhibited no significant seasonal pattern between sample sets collected in April and November (Table 7). The probability that the samples from April and November represented the same biological assemblage ranged from 14 to >45 percent.

Species diversity values (H') ranged from 0.0 in 19 samples in which animals were either lacking or were all of one species to 2.52 in a sample from the -2.5-m level on Transect 7. H' for pooled station data ranged from 0.0 at the 0.9-m station on Transect 2 in June (only a single specimen was contained in the three replicates collected) to 2.69 at the -2.5-m station on Transect 7 in August. Average pooled H' ranged from 0.12 at the 1.8-m station on Transect 5 to 2.32 at the -2.5-m station on Transect 7 (Table 5).

H' varied significantly among transects at the 1.8-, 0.9-, and -10-m stations, but not at the 0.0- and -2.5-m stations (Table 6). Generally, species diversity values were higher on Transects 3 and 7 and lower on Transect 5 (Table 5).

H' was also significantly higher at lower elevations throughout the study area (Table 5; $p<0.01$). Thus, lower diversity values usually were encountered at the higher intertidal stations and higher values at the lower elevations on a specific transect. However, as pointed out above, variability within transects at a given station was high.

Species diversity also did not exhibit significant seasonal patterns. The probability that the samples from April and November represented the same biological assemblage ranged from 21 to 30 percent (Table 7).

A pattern of increasing species abundance and richness with increasing depth was also observed in benthic communities at Skiff Point, Bainbridge Island (Thom et al. 1979a), and in the Duwamish Waterway (Leon 1980). Thom et al. (1979a) reported the highest species diversity and abundance values in low littoral cobble and cobble-boulder habitats in the Bainbridge Island study area. Meyer and Vogel (1978) found harpacticoid density was higher at lower intertidal stations in Hylebos Waterway while gammarids and cumaceans showed an opposite trend. In Commencement Bay, higher species diversity values were associated with Transect 4 at the low intertidal and subtidal stations, an area of cobble and sand/mud substrates. At both Commencement Bay and Bainbridge Island polychaetes were the most abundant and diverse group in cobble areas. Malins et al. (1980) report lowest species richness values for benthic infauna in Commencement Bay at the lower turning basin in Hylebos Waterway and the highest values near Browns Point.

The components of the benthic communities near Kellogg Island in the Duwamish Waterway (Leon 1980) are very similar to those of Commencement Bay. Polychaetes dominated intertidal and subtidal core samples in terms of abundance and diversity, with the sabellid Manyunkia aestuarina and the spionids Polydora, Pseudopolydora, and Pygospio the most abundant (Leon 1980). The cirratulids Cirratulus sp. and Tharyx sp. were very abundant subtidally. These species were all abundant in the Commencement Bay study area.

Major differences exist between the benthic communities in Commencement Bay and other less disturbed habitats in Puget Sound. Except for Transect 4, there was a general absence of larger invertebrate fauna according to diver observations at the transects studied. In contrast, an abundance of these forms (sea stars, anemones, gastropods) was observed in nearshore habitats at Nisqually Delta (Wissemann et al. 1977, Houghton and Kyte 1978) and Bainbridge Island (Thom et al. 1979a). Substrate differences probably account for some of this variation since rock/cobble substrates are generally lacking in the study area. However, there clearly are other factors operating to limit the occurrence of these forms on the mud and sand habitats in Commencement Bay.

Classification analyses of infaunal species and station groups were run for the April and November sampling periods. Results for April show five major species groups (Figure 3) and three major station groups (Figure 4). Species Groups I and II (Figure 3, Table 8) are primarily composed of polychaetes and bivalves and are most commonly found within Group A stations (Figure 4, Table 8). Group A stations account for all but one (3/-2.5) of the subtidal stations. Species Groups I and II can be considered as characteristic assemblages of the subtidal stations in the study area. Differences in distribution between Species Groups I and II seem to be the main reason for their classification as two groups rather than one. Group I occurs at most of the stations in Group A (Table 8) while Species Group II is most common subtidally at Transects 5, 7, and 8 (Table 8). Species Group III (Figure 3, Table 8) contains both infaunal polychaetes such as Capitella capitata and Manayunkia aestuariana and epibenthic crustaceans such as harpacticoid copepods, Corophium, Cumella vulgaris, and Pancolus californiensis. Nematoda, Oligochaeta, and Harpacticoida are distributed over all the station groups (Table 8) and this is probably due to their level of taxonomic identification in this study. Had they been identified further, to the generic level for example, it is possible that these taxa would show a different pattern of classification. The remaining species in Group III

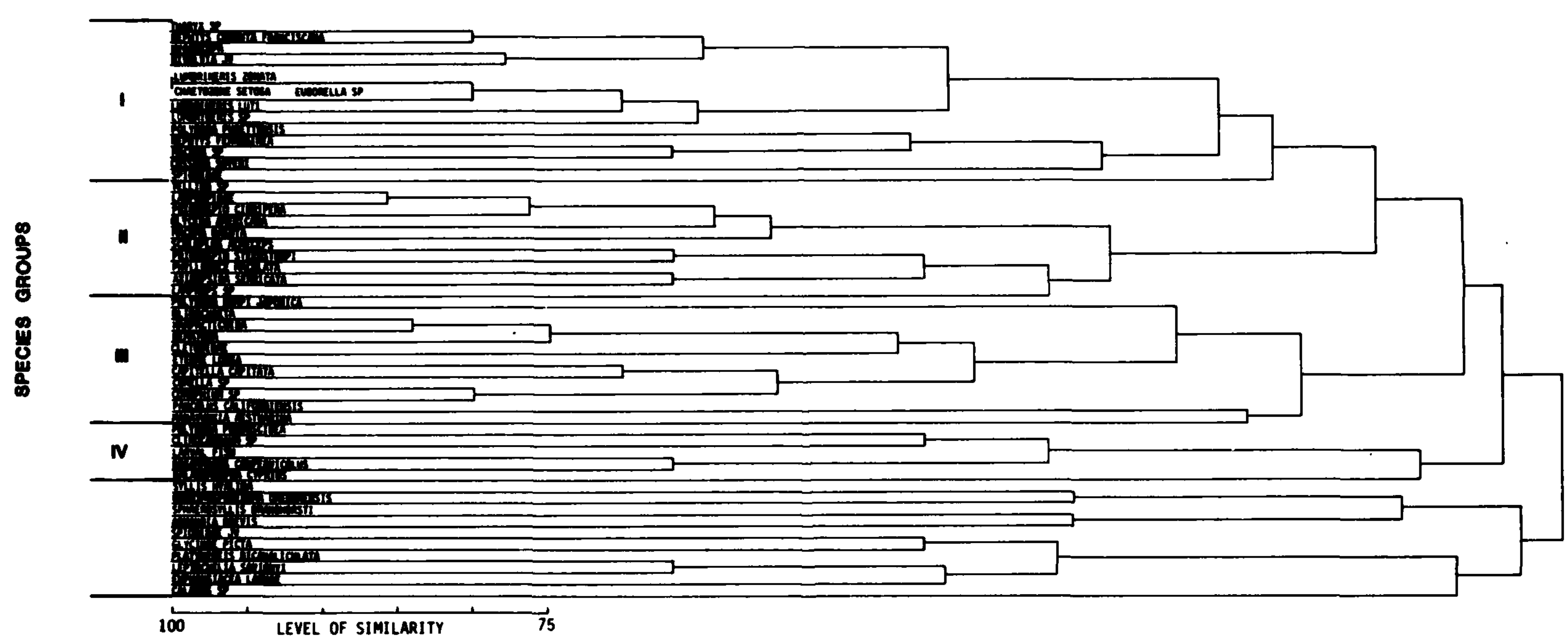


FIGURE 3
DENDROGRAM OF SPECIES GROUPINGS
FOR APRIL, 1980 INFAUNAL SAMPLES

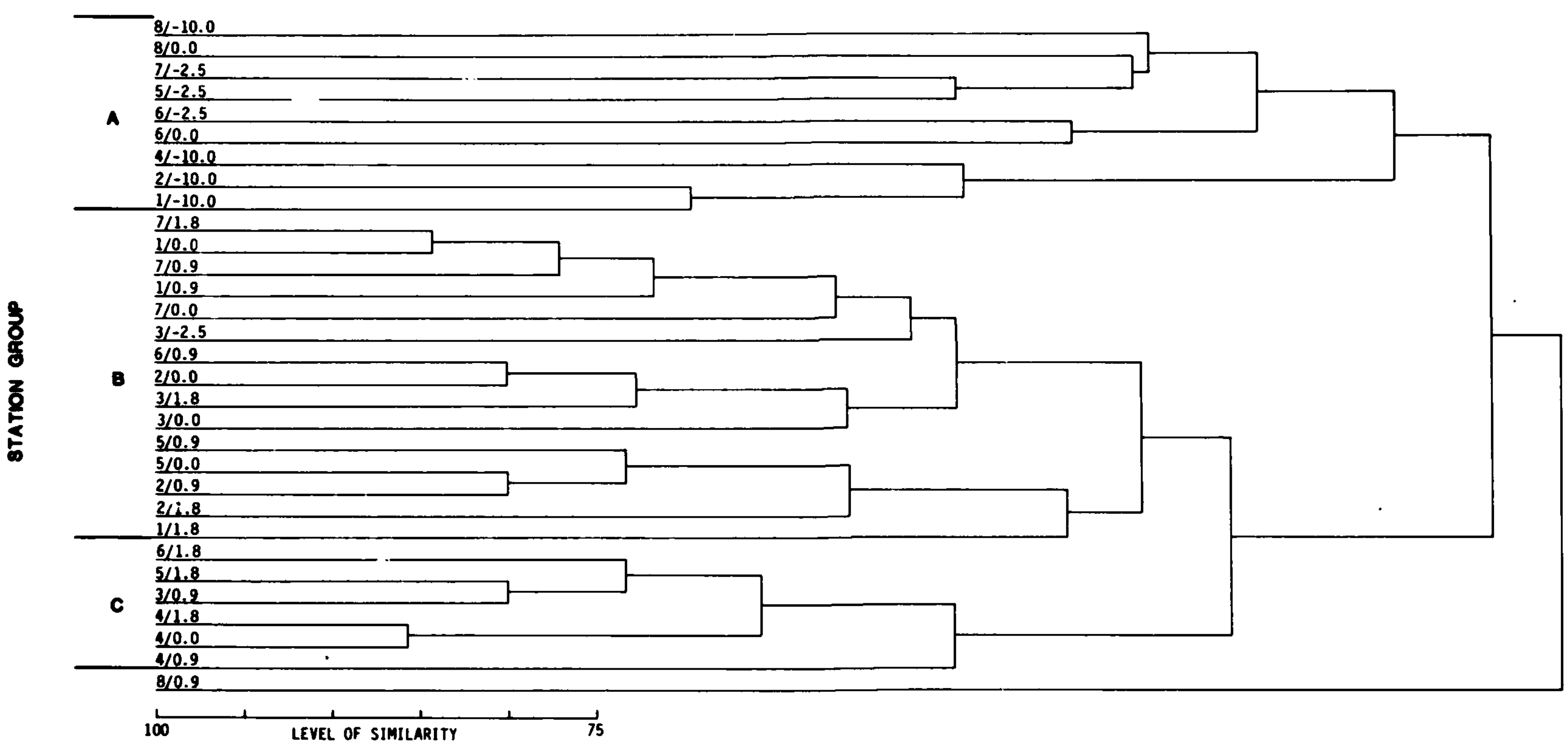


FIGURE 4
DENDROGRAM OF STATION GROUPINGS
FOR APRIL, 1980 INFAUNAL SAMPLES

TABLE 8

TWO-WAY TABLE OF COINCIDENCE SHOWING RELATIONSHIPS AMONG
INFAUNAL STATION AND SPECIES GROUPS FROM COMMENCEMENT BAY, APRIL 1980

		Station Groups																														
		A									B															C						
		8/ -10	8/ 0.0	7/ -2.6	5/ -2.5	6/ -2.5	6/ 0.0	4/ -10	2/ -10	1/ -10	7/ 1.8	1/ 0.0	7/ 0.9	1/ 0.9	7/ 0.0	3/ -2.5	6/ 0.9	2/ 0.0	3/ 1.8	3/ 0.0	5/ 0.9	5/ 0.0	2 0.9	2/ 1.8	1/ 1.8	6/ 1.8	5/ 1.8	3/ 0.9	4/ 1.8	4/ 0.0	4/ 0.9	8/ 0.9
Group I	Tharyx sp.	0.6		1.0				2.3	1.3	7.0																						
	Nephtys cornuta franciscana	4.0		0.6			0.6		1.3	2.3																						
	Myodocopa			0.3	5.0		1.3	4.6	0.6	0.6					0.33																	
	Bivalvia jv.	2.6	2.3	1.0	7.6	0.6	0.3	0.3	1.3	1.0					1.3																	0.6
	Lumbrineris zonata							1.0	0.6	0.3																						
	Chaetozone setosa							0.6	3.6	0.6																						
	Eudorella sp.							0.3	0.3																							
	Lumbrineris luti							1.3		1.0																						
	Lumbrineris sp.								0.3	1.3																						
	Polydora pugettensis	2.3						0.3																								
	Nephtys ferruginea	2.3	0.3	0.6	1.0			0.6									0.3			1.3												
	Macoma sp.	2.0	1.6			0.3		1.3												0.3												
	Cossura soyeri	7.6	0.3							0.3														0.6								
	Spionidae							0.3																								
Group II	Tellina sp.	0.3		0.6	1.0											0.6			1.0													
	Lampropidae			0.3	1.0											0.6																
	Prionospio cirrifera	0.6			1.3											0.3																
	Glycera americana		0.6	0.6	1.0								0.3			1.0																
	Macoma nasuta				0.3											2.6																0.3
	Scoloplos acmeceps		0.3		1.0																											
	Prionospio steenstrupi		0.3		0.6		0.3	1.3																								
	Phyllodoce maculata				0.3			0.3																								
	Axinopsida serricata			1.0	0.3			0.3		13																						
	Lamprops sp.				0.3										0.3																	
Group III	Polydora kempi japonica												1.6			0.6				0.3						25.0	23.0	4.0	72.0	4.6	57.0	2.0
	Oligochaeta	5.6	31.0	0.3	0.67	26.0	4.6	[illegible]			105.0	7.3	7.6	50.0	2.3	8.3	30.0	1.0	11.0	7.6	59.0	0.67	1.0	27.0	4.6							
	Harpacticoida	0.3	1.3	14.0	1.3	6.3	2.3		0.3	0.6	47.0	2.0	25.0	19.0	20.0	0.6	2.3	2.0	0.3	0.3	0.3	0.3	2.6	0.6	0.3	5.0	1.3	0.3	8.3	5.6	11.0	
	Nematoda	1.3				3.0	6.6	9.3			0.3	4.3	7.6	0.3	1.3	0.6	13.0	0.6	0.6	2.3			0.6	3.0				7.6				
	Cletodidae										1.3	1.0	2.0			0.6	0.6	0.3	1.3	1.6												
	Eteone longa									0.3	6.0	[illegible]	0.3	1.0	0.3	0.3			0.3	0.3					0.3							
	Capitella capitata										3.3	0.3	5.0			0.3				0.6												
	Cumella vulgaris		1.3					0.3			0.3	0.3	13.0	0.3	4.3	0.3																
	Corophium spp.		8.3					0.3			2.0		7.0	0.6																		
	Pancolus californiensis			1.0							1.0			0.3											0.3							
	Manayunkia aestuarina			0.6		3.0			0.3		1.6	1.6			0.3																	
Group IV	Polydora proboscidea		1.3	0.3		3.0																			0.6							
	Clinocardium sp.		0.3	0.3		4.0										0.3																
	Larval fish		0.3																													0.3
	Eogammarus confervicolus		0.3								1.6							0.3														1.3
	Balanomorpha cyprids	0.3																													0.3	0.3
Group V	Syllis hyalina						1.0																						0.3		1.3	
	Gnorimosphaeroma oregonensis																												0.3	0.3		
	Sphaerosyllis brandhorsti						0.3																	0.3	0.3							
	Armandia brevis						0.3		0.3																							
	Spionidae jv.					0.3																				0.3						
	Glycinde picta					0.3														0.3												
	Platynereis bicanaliculata			0.3		2.0	0.6																								0.3	
	Leptochelia savignyi					1.3	7.3																									0.3
	Euphausiacea larvae			0.3		0.3																										
	Calanus sp.			0.3																												

were most commonly found in Group B stations, especially 7/1.8, 0.9, 0.0 and 1/0.9, 0.0 (Table 8). Species Groups IV and V (Figure 3, Table 8) are rather loosely related, limited in distribution, and are termed groups mainly for convenience. Species Groups IV and V contain neritic, epibenthic, and infaunal species that show no clearly defined pattern of distribution over the stations. Classification of stations into groups (Figure 4) appears to be correlated with tidal level as well as species distribution. Station Group A is predominantly subtidal, Group B contains mainly 0.0-m and 0.9-m stations (lower intertidal) while Station Group C contains 1.8-, 0.9-, and one 0.0-m station (Figure 4).

Results for November show five major species groupings (Figure 5) and three major station groupings (Figure 6). As in April, November stations are grouped primarily by depth. Species Group I (Figure 5) is composed of benthic, infaunal species that are primarily found in subtidal stations (Station Group A, Figure 6 and Table 9). Species Group II (Figure 5) is a mixture of infaunal and epibenthic forms (harpacticoids, cumaceans, oligochaetes, polychaetes) with a distribution throughout all stations, but most common in Station Group B (Figure 6, Table 9). Species Group III (Figure 5, Table 9) primarily contains polychaetes with three species of epibenthic crustaceans and one bivalve. This group is distributed within Station Group A and is most common at 4/-10 and 5/-2.5 (Table 9). Species Group IV is a collection of four polychaete species and one tanaid that is characteristic of Station 2/1.8 in Station Group B (Table 9) with patchy occurrence elsewhere. Species Group V (Figure 5) is a collection of typically epibenthic species occurring at 4/0.0, 0.9, and 1.8 (Table 9). These stations at Transect 4 were the only ones in the study area with rock/cobble substrates that had growths of barnacles and mussels. Station Group C includes several pairs of stations from 1.8-m to -2.5-m with limited affinity to other stations.

A comparison of April and November results (Tables 8 and 9) shows that Station Group A remains the same in both months except for 8/0.0 and 6/0.0 dropping out of the November group. Station Group B in both months are fairly similar, containing a mixture of intertidal stations that generally tend to be lower intertidal although more high intertidal stations are added to the November grouping than in April. Species

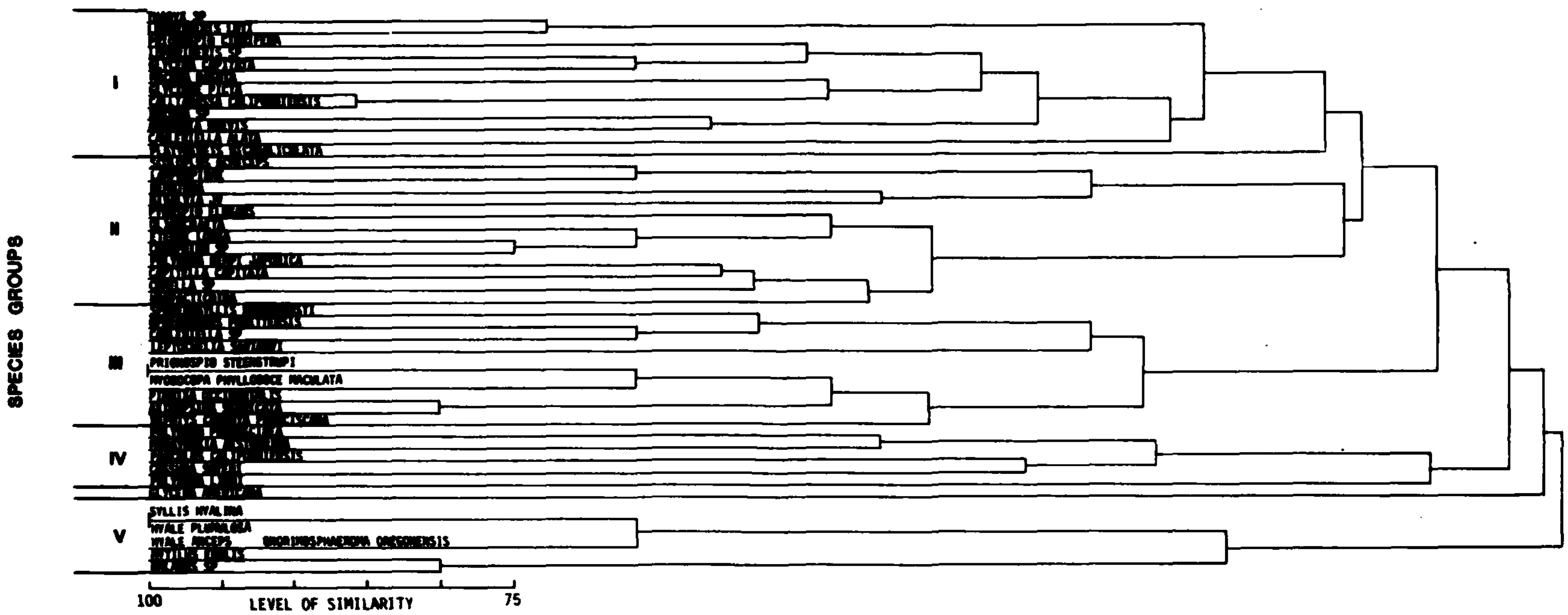


FIGURE 5
DENDROGRAM OF SPECIES GROUPINGS
FOR NOVEMBER, 1980 INFAUNAL SAMPLES

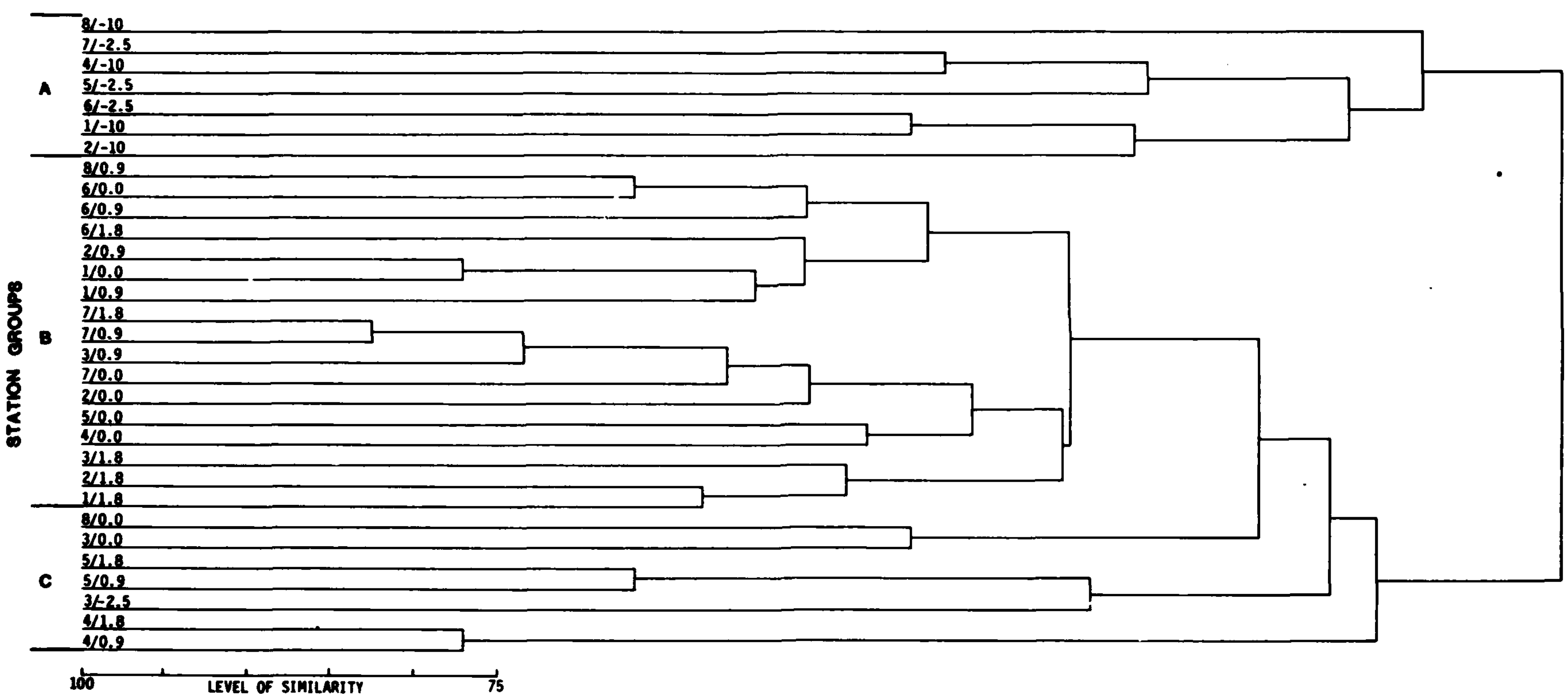


FIGURE 6
DENDROGRAM OF STATION GROUPINGS
FOR NOVEMBER, 1980 INFAUNAL SAMPLES

TABLE 9

TWO-WAY TABLE OF COINCIDENCE SHOWING RELATIONSHIPS AMONG INFAUNAL STATION AND SPECIES GROUPS FROM COMMENCEMENT BAY, NOVEMBER 1980

		Station Groups: A							B																	C						
		8/ -10	7/ -2.5	4/ -.4	5/ -2.5	6/ -2.5	1/ -10	2/ -10	8/ 0.9	6/ 0.0	6/ 0.9	6/ 1.8	2/ 0.9	1/ 0.0	1/ 0.9	7/ 1.8	7/ 0.9	3/ 0.9	7/ 0.0	2/ 0.0	5 0.0	4/ 0.0	3/ 1.8	2/ 1.8	1/ 1.8	8/ 0.0	3/ 0.0	5/ 1.8	5/ 0.9	3/ -2.5	4/ 1.8	4/ 0.9
Group I	Tharyx sp.		1.0	1.6			10.0	0.67																		0.3						
	Lumbrineris luti		0.3	1.0			0.3																							0.3		
	Prionospio cirrifera		4.6	3.0				1.0																0.3		0.3	1.0			0.3		
	Lumbrineris sp.			0.3																							0.3					
	Glycera capitata		0.67	0.3					0.3																		0.3					
	Macoma nasuta									0.3	0.3															0.3	0.3					
	Glycinde picta																				0.3					0.67	0.3					
	Callianassa californiensis	0.3																			0.67					1.0	0.3					
	Macoma spp.	6.3		1.6					0.3	0.3											0.3						1.0					
	Armandia brevis		0.3	0.3	0.6				0.3	1.3											1.6	0.6										
	Cauleriella alata						0.3																				0.3					
	Platynereis bicanaliculata		0.3							2.3																						
Group II	Scoloplos acmeceps		0.3																0.3							0.67						
	Lampropidae																		0.3							0.67				0.3		
	Nematoda											3.3					3.3		0.3													
	Bivalvia jv.		1.6	2.0	1.0												0.3		0.3													
	Pygospio elegans								0.3	0.3	0.6	2.3	1.3	1.0	0.67										4.0		0.67					
	Oligochaeta						153.0		0.67	53.0	9.0	1.6	3.0	30.0	47.0	30.0	2.6	6.6	3.0			9.6	6.0	2.0	82.0		9.6	999.0	6.6	1.3	51.0	244.0
	Eteone longa								0.6	0.3	2.3			0.3		3.6	1.6	1.3	1.3	03	0.3	0.3	0.3	0.6	0.3	0.3						0.3
	Corophium sp.				12.0				0.3	1.6	52.0	3.0	4.6	16.0	9.0	28.0	5.6	2.6		10.0	0.67	1.3		3.6	7.3							
	Polydora kempi japonica								1.3							4.6	3.3	0.6	2.3	3.6						0.3	4.0					
	Capitella capitata		0.6						1.0				3.3	2.6		6.0	0.3		1.0	1.5	0.3	0.6	3.0			3.0	0.3		0.6	0.3		
	Cumella vulgaris												0.6	2.0	0.6	1.6	0.3	2.3	0.3		0.3						0.6					
	Harpacticoida															1.0	0.6	0.3			1.0	0.6	0.3		0.3		2.3				1.0	
Group III	Sphaerosyllis brandhorsti				0.3																									1.0		
	Ophiodromus pugettensis				0.3					0.6																						
	Cauleriella sp.				0.3																											
	Leptochelia savignyi		0.6		4.0																	0.6										
	Prionospio steenstrupi			11.0	6.0		0.3																									
	Myodocopa			3.6	1.6		0.6																									
	Phyllodoce maculata			0.3	1.0													1.0														
	Pinnixa occidentalis	0.3		0.3																												
	Axinopsida serricata	1.0		0.6	0.3																											
	Nephtys cornuta franciscana	1.6			0.3		0.3																									
Group IV	Polydora proboscidea										0.3													5.6								
	Manayunkia aestuarina												5.0											0.3								
	Pancolus californiensis														1.6									2.3	0.3							
	Cossura soyeri	6.0		0.3			1.6																0.3	1.6	1.0							
	Polydora ligni										0.3			0.6																		
	Glycera americana																	0.3		0.3												
Group V	Syllis hyalina																														1.3	0.6
	[illegible] alguulosa																														1.3	3.6
	[illegible] sp.																														1.3	19.0
	Gnorimosphaeroma oregonensis																					2.3									0.6	12.0
	Mytilus edulis													0.3								4.3										2.6
	Balanus sp.													2.0								1.0										

Group II, April (Figure 3) and Species Group III, November (Figure 5) are essentially the same and both are found within most of the stations (Tables 8 and 9). A major difference between April and November results is the absence of harpacticoids, nematodes, and oligochaetes at subtidal stations in November (Station Group A, Table 9) while they were present in April.

Thom et al. (1979b) performed cluster analysis on intertidal benthic samples from Bainbridge Island. Sample sites were grouped primarily by tidal height and secondarily by habitats within a tidal height. Based on the secondary grouping by habitat, Thom et al. (1979b) concluded that substrate type is a more important factor than tidal height in structuring the benthic community. Analysis of the benthic infaunal communities in this study supports this conclusion. Based on the qualitative station substrate characteristics shown in Table 3, it appears that infaunal station subgroupings are related to substrate type and the amount of organic debris present. A more detailed analysis of physical and chemical substrate characteristics correlated with station and species groupings would be required to quantify this apparent relationship.

3.3.3 0.25-mm Epibenthic Pump Analysis

Species richness values (S) in the 0.25-mm epibenthic pump samples varied from 1 at several stations to 19 taxa identified at the 0.9-m station of Transect 1 during April. Mean values of species richness (Table 10) ranged from 3.25 at the 1.8-m station of Transect 3 to 12.0 at the 0.9-m station of Transect 1. Total number of taxa identified in all epibenthic pump samples was 89 (Table 4).

Species richness values were extremely variable within transects and depth levels. Increasing species richness with increasing depth was not apparent for the 0.25-mm epibenthic pump samples. Transect 3 showed this pattern, but Transects 1, 2, and 6 showed an opposite trend and Transects 4, 5, and 8 had relatively similar species richness values at all depth levels. A significant difference in species richness between transects was detected at the -2.5-m station ($p<0.05$, Kruskal-Wallis test), no significant differences were detected at any other depth levels (Table 11). Transects 6 and 7 had the lower species richness values at -2.5 m while Transects 3 and 5 had the higher ones.

TABLE 10

POOLED MEAN VALUES OF H', N, AND S FOR ALL 0.25-MM EPIBENTHIC PUMP STATIONS ALONG EACH TRANSECT

Tidal Elevation (m)	Transect 1	2	3	4	5	6	7	8
H'								
1.8	1.70	1.65	0.81	1.39	1.47	1.72	1.05	--
0.9	1.74	1.63	0.87	1.42	1.51	1.64	0.93	1.19
0.0	1.54	1.30	0.97	0.83	0.95	0.69	0.94	1.38
-2.5	--	--	1.35	--	1.10	0.94	0.94	--
-10.0	1.11	1.15	--	1.45	--	--	--	0.44
N								
1.8	114.0	95.0	39.5	49.7	46.0	35.2	266.7	--
0.9	125.2	52.9	109.0	105.7	249.2	38.7	522.0	18.75
0.0	133.5	119.5	44.0	296.0	285.5	87.7	123.7	76.75
-2.5	--	--	83.7	--	579.1	137.5	222.1	--
-10.0	194.5	124.5	--	163.5	--	--	--	1277.0
S								
1.8	9.0	10.0	3.25	6.5	6.75	7.75	5.0	--
0.9	12.0	8.25	5.5	7.0	8.0	7.25	7.0	5.0
0.0	6.5	5.9	4.0	6.5	6.25	4.75	7.25	5.75
-2.5	--	--	8.25	--	7.25	5.63	5.62	--
-10.0	5.87	6.1	--	8.1	--	--	--	4.0

TABLE 11

0.25-MM EPIBENTHIC PUMP: PROBABILITIES OF SIGNIFICANT DIFFERENCES AMONG TRANSECTS AT A GIVEN DEPTH LEVEL (KRUSKAL-WALLIS TEST)

April and November 1980

Tidal Elevation (m)	Numerical Parameters H'	S	N	Accept or Reject Null Hypothesis
1.8	p>0.05	p>0.5	p>0.1	Accept for all
0.9	p>0.1	p>0.1	p>0.9	Accept for all
0.0	p>0.5	p>0.5	p>0.9	Accept for all
-2.5	p<0.05	p>0.5	p<0.05	Accept for N, reject for H', S
-10.0	p<0.05	p>0.5	p>0.5	Accept for N, S, reject for H'

Significant seasonal differences in species richness between transects were detected at all tidal levels except 0.9 m (Table 12), $p<0.005$ to 0.025, Mann-Whitney test).

TABLE 12

0.25-MM EPIBENTHIC PUMP: PROBABILITIES OF SIGNIFICANT DIFFERENCES AMONG TRANSECTS AT A GIVEN DEPTH LEVEL (MANN-WHITNEY U-TEST)

April and November 1980

Tidal Elevation (m)	Numerical Parameters H'	S	N	Accept or Reject Null Hypothesis
1.8	p<0.025	p<0.001	p<0.005	Reject for all
0.9	p<0.05	p>0.05	p>0.05	Accept for N, S, reject for H'
0.0	p<0.005	p<0.025	p<0.005	Reject for all
-2.5	p<0.01	p<0.025	p<0.025	Reject for all
-10.0	p<0.025	p<0.025	p<0.025	Reject for all

Species diversity values (H') show considerable variation both within transects and depth levels (Table 10). The -10-m station of Transect 8 had the lowest mean species diversity value while the 0.9-m station of Transect 1 had the highest mean value. Mean values for species diversity were generally higher in the 0.25-mm epibenthic pump samples than in the 0.5-mm epibenthic pump samples at similar transects and depth levels (Tables 10 and 15).

Significant differences in species diversity values for all transects were detected at the -2.5- and -10-m stations (Table 11, $p<0.05$, Kruskal-Wallis test). Transects 6 and 7 had the lowest values at the -2.5-m station while Transects 3 and 5 had highest values. Transects 2 and 8 had lowest species diversity values at the -10-m station while Transects 1 and 4 had highest values.

Seasonal effects in species diversity for all transects between April and November were present at all depth levels (Table 12, $p<0.005$ to 0.05, Mann-Whitney test).

Species abundance values (N) ranged from 4 organisms collected in several samples to 4,130 organisms (99.75 percent harpacticoid copepods) collected at the -10-m station of Transect 8 in June. Mean species abundance values (Table 10) suggest a pattern of increasing abundance with increasing depth; however, considerable variation exists and this trend is not evident at all transects.

No significant difference in species abundance values for all transects was found at any tidal level (Table 11, Kruskal-Wallis test). However, significant seasonal effects for all transects between April and November were detected at the 1.8-, 0.0-, -2.5-, and -10-m stations (Table 12, $p<0.001$ to 0.25, Mann-Whitney test). No significant difference was detected at the 0.9-m station.

Classification results for April 0.25-mm epibenthic pump samples are shown in Figures 7 and 8 and Table 13. Five major species groups were apparent (Figure 7), although Groups I, II, IV, and V contained 3 or less species having limited distribution at stations throughout the study area (Table 13). Species Group III contains 18 species, 12 of which are neritic calanoid copepods or crustacean larvae. This group is actually composed of several smaller subgroups that are joined together at increasingly lower levels of similarity to form the larger group. One subgroup contains Pseudocalanus, Microcalanus, Corycaeus, Calanus, Harpacticoida, Balanomorpha nauplii and cyprids, and copepod nauplii (Figure 7). All of these species are widely distributed throughout the study area (Table 13) and except for harpacticoid copepods, the species are primarily neritic and characteristic of the water column in general rather than specific stations. This accounts for their widespread distribution. The other species comprising Group III are a mixture of neritic and epibenthic organisms that are mainly distributed within Station Group B. The station groupings for April (Figure 8, Table 13) show no consistent pattern that can be related to depth or substrate type; each group contains intertidal as well as subtidal stations. Subgrouping within the main groups tends to join nearby stations at similar tidal elevations. For example, within Group C the stations at 2/1.8, 1/1.8, 1/0.9, and 2/0.9 are joined at a level of similarity

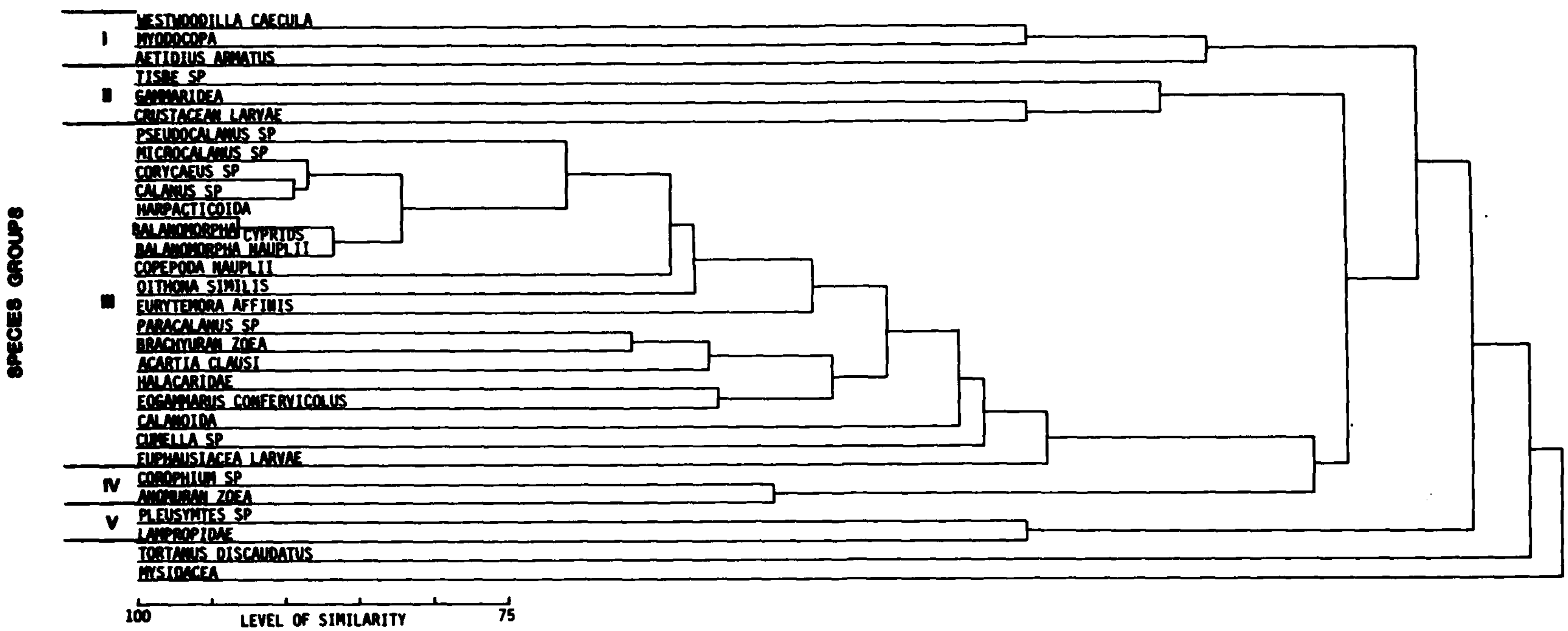


FIGURE 7
DENDROGRAM OF SPECIES GROUPINGS FOR APRIL, 1980 0.25-mm EPIBENTHIC PUMP SAMPLES

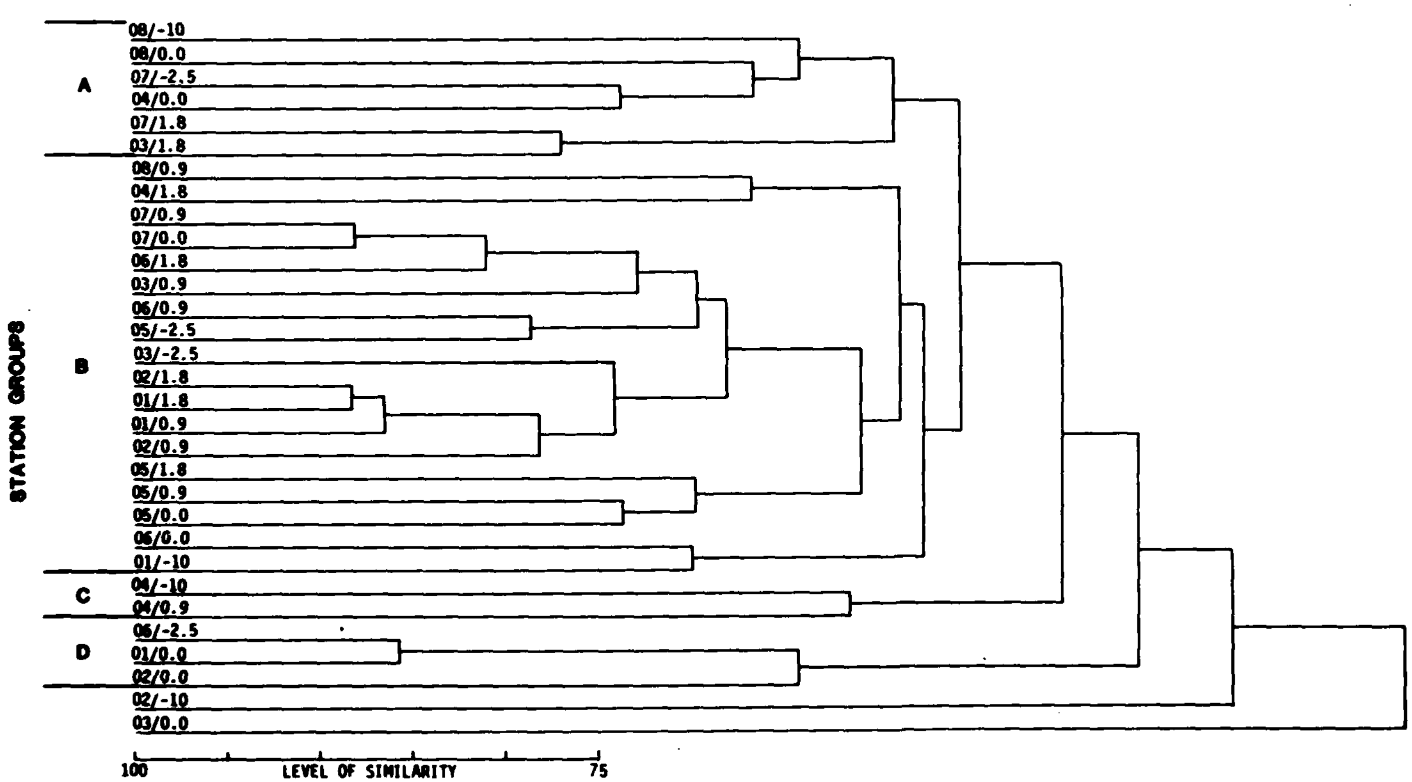


FIGURE 8
DENDROGRAM OF STATION GROUPINGS FOR
APRIL, 1980 0.25-mm EPIBENTHIC PUMP SAMPLES

TABLE 13

TWO-WAY TABLE OF COINCIDENCE SHOWING RELATIONSHIPS AMONG 0.25-MM EPIBENTHIC PUMP STATION AND SPECIES GROUPS FROM COMMENCEMENT BAY, APRIL 1980

		Station Groups																														
		A						B																		C		D				
		8/ -10	8/ 0.0	7/ -2.5	4/ 0.0	7/ 1.8	3/ 1.8	8/ 0.9	4/ 1.8	7/ 0.9	7/ 0.0	6/ 1.8	3/ 0.9	6/ 0.9	5/ -2.5	3/ -2.5	2/ 1.8	1/ 1.8	1/ 0.9	2/ 0.9	5/ 1.8	5/ 0.9	5/ 0.0	6/ 0.0	1/ -10	4/ -10	4/ 0.9	6/ -2.5	1/ 0.0	2/ 0.0	2/ -10	3/ 0.0
Group I	Westwoodilla caecula														2.0																	
	Myodocopa														3.5	1.5										20.0					3.5	
	Actidius armatus													0.5	2.0						1.0	2.5	0.5									
Group II	Tisbe sp.																		0.5	0.5			0.5							10.0		
	Gammaridea							0.5	2.0											0.5		30.0										
	Crustacean larvae																			1.0												
Group III	Pseudocalanus sp.	10.0			10.0			0.5		2.5		0.5		1.0		5.0	3.5	4.0	3.0	5.0	1.0	2.0	1.0	0.5	32.0			0.5	0.5	5.0		
	Microcalanus sp			2.0	5.0	25.0	0.5	0.5	85.0	77.0	2.0	5.0	6.5	125.0	66.0	13.0	41.0	3.5	5.0	9.5	30.0	49.0	58.0	5.5	2.5	10.0	15.0					
	Corycaeus sp.	10.0	4.5	5.0	10.0			0.5	12.0	27.0	23.0	8.5	0.5	6.5	3.5	5.5	2.5	0.5	2.0	3.0	9.0	8.5	2.5	4.0		10.0	40.0					
	Calanus sp.	5.0	0.5	1.5	15.0	15.0	0.5	0.5	3.5	72.0	5.0	11.0	6.0	5.5	10.0	1.5	14.0	2.0	7.0	5.0	4.5	1.0	1.0			5.0				5.0		
	Harpacticoida	65.0	100.0	505.0	265.0	455.0	49.0	2.0	6.0	505.0	106.0	9.5	166.0	12.0	114.0	52.0	109.0	27.0	51.0	44.0	9.0	195.0	454.0	37.0	96.0	115.0	35.0	303.0	50.0	67.0	45.0	63.0
	Balanomorpha cyprids	30.0	2.0	19.0	25.0	5.0	1.0		26.0	17.0	2.0	0.5	9.0	4.0	2.0	2.0	5.0	14.0	12.0	1.5	17.0	85.0	7.5	5.0			32.0	4.0		0.5	12.0	0.5
	Balanomorpha nauplii	10.0	11.0	13.0	5.0	15.0	10.0		17.0	17.0	2.0	6.0	0.5	3.5	2.0	9.0	13.0	24.0	35.0	11.0				1.5	20.0			0.5	55.0	15.0	37.0	
	Copepoda nauplii	5.0								10.0	3.0	7.0	1.0	7.0	2.0		5.0	6.0	5.0					1.5	1.0	5.0	5.0	10.0	10.0			
	Oithona similis						5.0			5.0	0.5	2.0		0.5	2.0	0.5	4.5	6.[illegible]	1.0		1.0	1.0			5.0							
	Eurytemora affinis									12.0	4.0	1.0		1.5				35.0	4.5	3.0	0.5							2.0	30.0	31.0		
	Paracalanus sp.															1.0	0.5	11.5	2.5		1.0						5.0				1.5	
	Brachyuran zoea													0.5	5.5	1.5	1.5	0.5	8.0	1.5											2.0	
	Acartia clausi								0.5				0.5	0.5		2.0	3.0	49.0	34.0	2.0	2.0				142.0			0.5	80.0			
	Halacaridae					5.0		0.5	1.0	27.0	1.0		1.0		2.0	2.0	5.0	1.0	1.0	2.0		3.5									1.5	
	Eogammarus confervicolus						0.5	0.5	1.0		0.5						1.0	5.0	1.5	1.5					2.5							
	Calanoida								0.5					2.0	2.0			12.5	0.5			4.0		5.0	2.5						155.0	
	Cumella vulgaris		1.0	2.0						115.0	3.0		6.5				1.0	0.5		0.5				6.5	2.5							
	Euphausiacea larvae				15.0			0.5	8.0								3.5		0.5		1.0				5.0		7.5					
Group IV	Corophium spp.	5.0		5.0													1.0		2.0													5.0
	Anomuran zoea	5.0																	0.5													
Group V	Pleusymtes sp.			1.5	15.0											1.0																
	Lampropidae			5.0							0.5																					
	Tortanus discaudatus											0.5	5.0																			
	Mysidacea		5.0																										5.0			

greater than 75 percent and stations at 5/1.8, 5/0.9, and 5/0.0 are joined at a level of similarity greater than 70 percent (Figure 8).

November classification results showed two large species groups and two smaller groups (Figure 9). Species Group I contains epibenthic crustaceans such as gammarid amphipods, tanaids, cumaceans, and isopods as well as neritic organisms such as calanoid copepods (Figure 9). Species in this group are infrequent in the study area but all are found at 4/-10 (Table 14). Pseudocalanus, Paracalanus, Harpacticoida, Corycaeus, and Oithona similis form a subgroup in Group II (Figure 9) that is widely distributed throughout all stations in the study area (Table 14). Species Group III contains the ostracod order Myodocopa and the amphipod Eogammarus confervicolus. Species Group IV consists of the gammarids Parathemisto pacifica and Allorchestes angusta (Figure 9) which are found only at intertidal stations on Transect 5 (Table 14). Station Group A (Figure 10) contains a mixture of intertidal and subtidal stations that are characterized by Species Groups I and IV. Station Group B (Figure 10) contains the intertidal stations (1.8-, 0.9-, and 0.0-m) of Transects 1, 6, and 7 and is characterized by species of Group II (Table 14). Qualitative similarities exist between Transects 1, 6, and 7 in Group B; all are well inside waterways and have substrates of soft mud with large amounts of organic debris. Cumella, Corophium, and Eogammarus (Species Group II, Table 14) are most common within these stations and are known to prefer the type of habitat these stations have. Since the other species in Group II are primarily neritic and distributed over all stations, these three epibenthic crustaceans are probably more characteristic of the habitat type at Transects 1, 6, and 7 than the rest of the species in Group II. Station 1/-10 also is placed in Station Group B (Figure 10) but it should be noted that this station joins the group at a much lower level of similarity than do the others. Station Group C (Figure 10) contains the 0.9-, 0.0-, and -10-m levels of Transect 4 which seem to be characterized by Species Group I.

Considerable variation exists between the April and November classification results. However, Species Group III from April (Figure 7) and Species Group II from November (Figure 9) contain many of the same

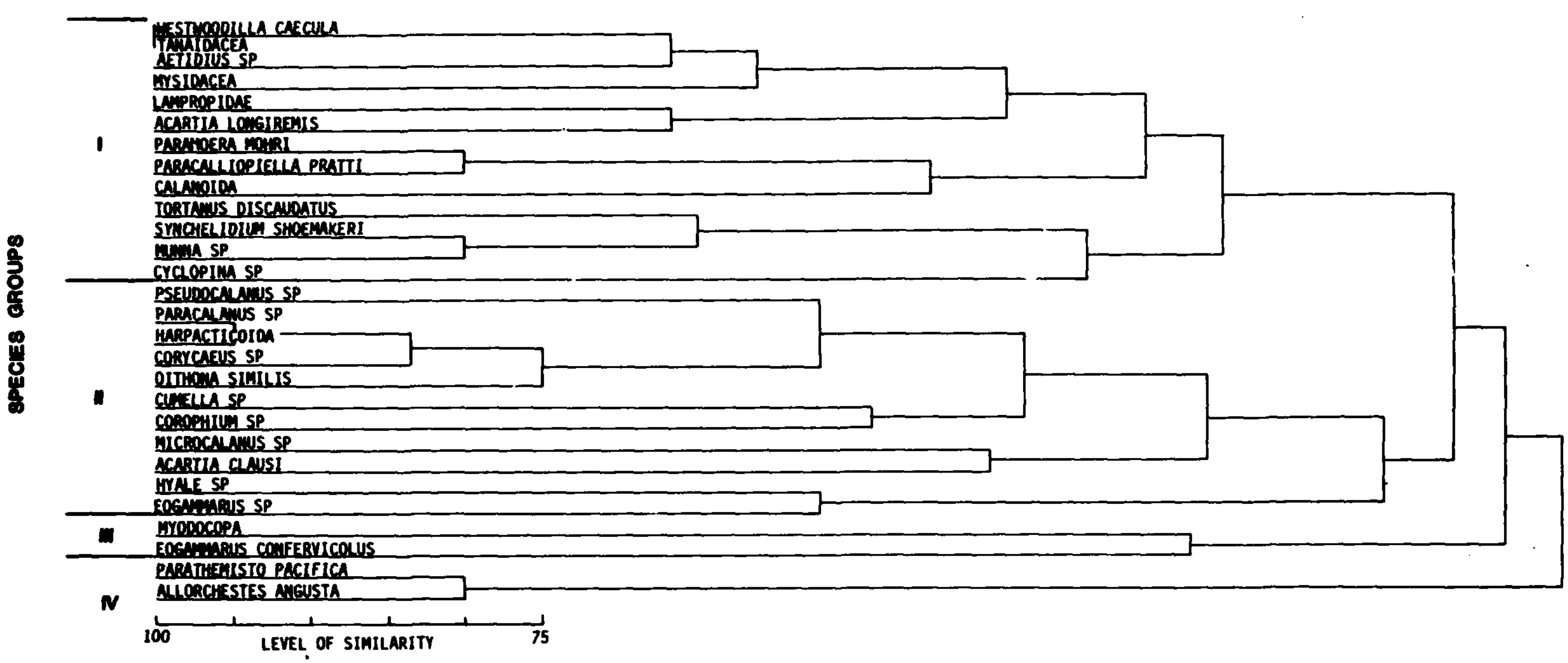


FIGURE 9
DENDROGRAM OF SPECIES GROUPINGS FOR
NOVEMBER, 1980 0.25-mm EPIBENTHIC PUMP SAMPLES

TABLE 14

TWO-WAY TABLE OF COINCIDENCE SHOWING RELATIONSHIPS AMONG 0.25-MM EPIBENTHIC PUMP STATION AND SPECIES GROUPS FROM COMMENCEMENT BAY, NOVEMBER 1980

Station Groups

		A																
		8/ -10	6/ -2.5	2/ 0.0	3/ -2.5	3/ 0.0	8/ 0.0	5/ 1.0	5/ 0.9	5/ 0.0	5/ -2.5	8/ 0.9	3/ 0.9	4/ 1.0	3/ 1.0	2/ 1.0	2/ 0.9	7/ -2.5
Group I	Westwoodilla caecula																	
	Tanaidacea																	
	Aetidius sp.							0.5										
	Mysidacea																	
	Lampropidae									0.5								
	Acartia longiremis				0.5					0.5								
	Paramoera mohri					0.5	0.5							1.0				
	Paracalliopiella pratti						0.5											
	Calanoida						1.0											
	Tortanus discaudatus										0.5							
	Synchelidium shoemakeri										1.0							
	Munna sp.										1.5							
	Cyclopina sp.		1.0		0.5	0.5					4.0							
Group II	Pseudocalanus sp.	0.5	0.5	0.5	1.5		0.5		1.0	2.0	2.0	0.5						1.5
	Paracalanus sp.	72.0	0.5	5.0	21.0	4.5	15.0	4.5	17.0	7.0	7.0	12.0	2.5	2.0	1.5	3.0	2.0	8.0
	Harpacticoida	0.5	4.5	0.5	71.0	1.0	1.5	1.0	12.0	23.0	13.0	5.5	14.0	8.0	9.0	3.5	3.5	
	Corycaeus sp.	13.5	0.5	3.5	7.5	4.5	3.5	6.0	41.0	3.5	21.0	8.0	2.5	1.5	1.5	1.5	3.5	2.5
	Oithona similis	20	0.5	0.5	0.5	1.5	3.0	1.0	26.0	0.5	4.0							
	Cumella vulgaris									0.5	2.0	0.5	2.0					
	Corophium spp.															2.0	0.5	
	Microcalanus sp.								2.0	0.5	4.0							
	Acartia clausi																	
	Hyale sp.																	
	Eogammarus sp.																	
Group III	Myodocopa				5.0												0.5	
	Eogammarus confervicolus	0.5																
Group IV	Parathemisto pacifica								0.5	0.5								
	Allorchestes angusta							1.0	16.0	7.0								

		B										C			
		7/ 1.0	6/ 1.0	6/ 0.0	6/ 0.9	1/ 1.0	1/ 0.9	1/ 0.0	7/ 0.9	7/ 0.0	1/ -10	4/ -10	4/ 0.9	4/ 0.0	2/ -10
Group I	Westwoodilla caecula											1.0			
	Tanaidacea											0.5			
	Aetidius sp.											1.0			
	Mysidacea											1.0	1.0		
	Lampropidae									0.5		3.0			
	Acartia longiremis											0.5			
	Paramoera mohri											33.0	9.5	1.0	
	Paracalliopiella pratti											4.5	6.0	0.5	
	Calanoida										2.5	0.5			
	Tortanus discaudatus										0.5				
	Synchelidium shoemakeri										1.0	0.5			
	Munna sp.											0.5			
	Cyclopina sp.											0.5	0.5		
Group II	Pseudocalanus sp.											1.0			5.0
	Paracalanus sp.	2.0	3.0	0.5	2.0	5.0	4.0	3.0		2.5	41.0	28.0	5.0	3.0	55.0
	Harpacticoida	3.0	5.0	5.0	6.5	12.0	14.9	9.0	138.0	10.0	6.0	46.0	44.0	204.0	
	Corycaeus sp.	2.0	7.5		3.5							14.0		7.0	
	Oithona similis	0.5	0.5	0.5	4.0	0.5	1.0	0.5			0.5	5.5			
	Cumella vulgaris	0.5	0.5	0.5			2.0	6.5	10.0	0.5			0.5		0.5
	Corophium spp.	5.0	1.0	2.0	3.0	3.0	7.0	6.0	5.0	0.5	0.5	0.5			
	Microcalanus sp.					0.5	0.5				1.0	1.0		0.5	
	Acartia clausi					2.0	2.0	1.0			22.0				5.0
	Hyale sp.						0.5						3.0	0.5	
	Eogammarus sp.		0.5				1.0	0.5					0.5		
Group III	Myodocopa							0.5			20.0				
	Eogammarus confervicolus										1.0				
Group IV	Parathemisto pacifica														
	Allorchestes angusta														

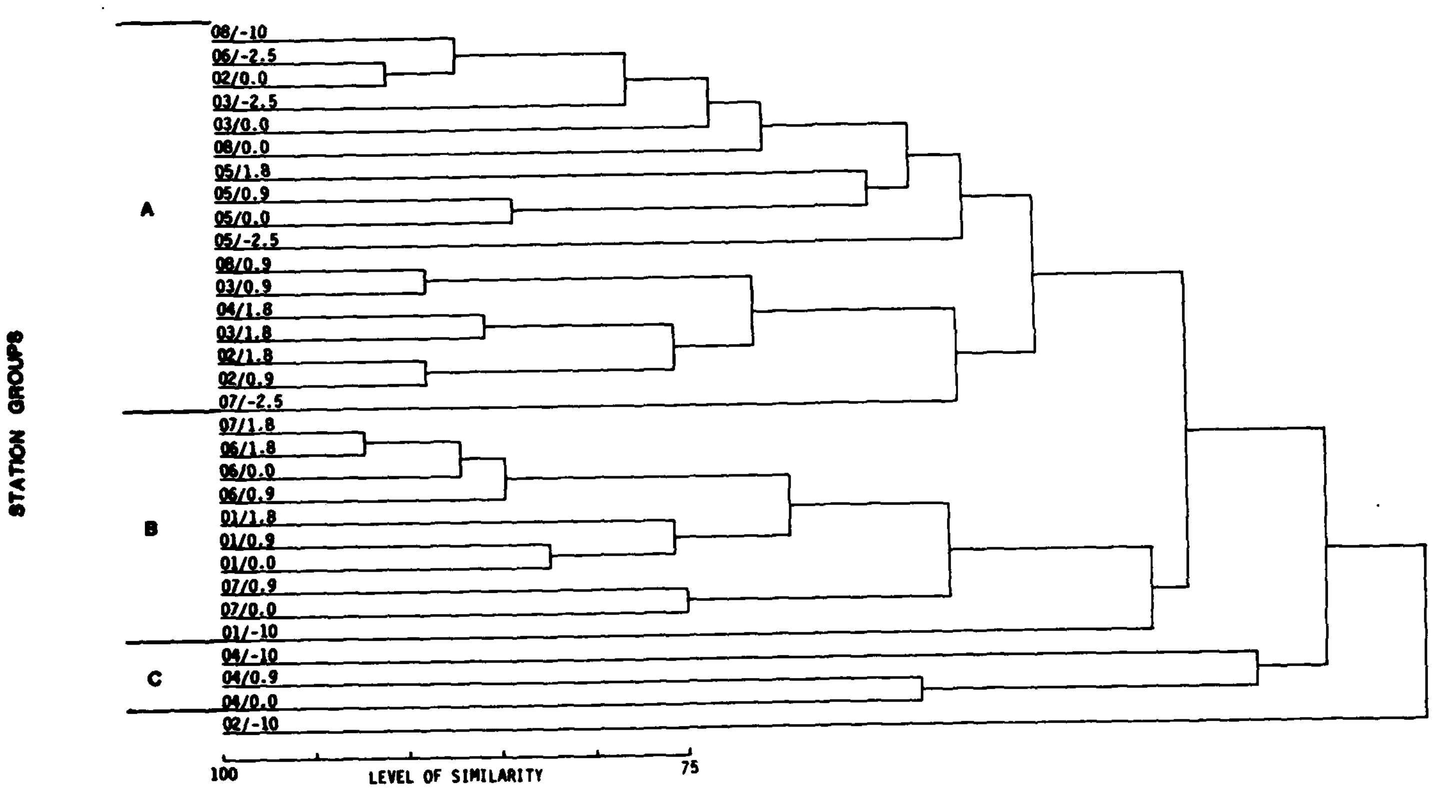


FIGURE 10
DENDROGRAM OF STATION GROUPINGS FOR
NOVEMBER, 1980 0.25-mm EPIBENTHIC PUMP SAMPLES

neritic copepod species that are widely distributed throughout the study area. The main difference between the two groups is the absence of larval crustaceans in November. Station groups were generally inconsistent between April and November except that Group C from April (Figure 8) and Group C from November (Figure 10) contained stations from Transect 4.

3.3.4 0.5-mm Epibenthic Pump Analysis

Species richness values (S) in the 0.5-mm epibenthic pump samples varied from 0 at stations lacking animals to 16 species at the -10-m station of Transect 4 in April. Mean values of species richness (Table 15) ranged from 0.25 at the 0.9-m station of Transect 6 to 6.0 at the 0.0-m station of Transect 1. The total number of taxa identified in all epibenthic pump samples was 89 (Table 4).

Species richness values generally increased with increasing depth level (Table 15); lower values usually occurred at high intertidal stations while higher values were found at low intertidal and subtidal stations. Transects 1, 4, 5, and 7 generally had higher species richness values while Transects 2, 3, and 6 had lower ones. No significant differences in species richness were found within the 1.8-, 0.0-, -2.5-, and -10-m stations at all transects (Table 16). Significant differences were found within the 0.9-m stations ($p<0.05$, Kruskal-Wallis test). Variation between and within transects is high. Significant seasonal differences in species richness between April and November were detected at all stations (Table 17, $p<0.001$, Mann-Whitney U-test).

Species diversity (H') varied considerably by transect and depth level (Table 15). Stations at mid to lower intertidal and subtidal levels generally had the higher values for species diversity. Species diversity at the 1.8-m stations was consistently lower (Table 15). Transects 1, 4, and 5 had relatively higher species diversity at all stations. A comparison of species diversity values across tidal levels for all transects (Table 16) showed that no significant differences exist at any level except 1.8-m ($p<0.05$, Kruskal-Wallis test). At the 1.8-m station, Transects 2, 3, 5, and 6 had very low diversity values compared to 1 and 4.

TABLE 15

POOLED MEAN VALUES OF H', N, AND S FOR ALL 0.5-MM EPIBENTHIC PUMP STATIONS ALONG EACH TRANSECT

Tidal Elevation (m)	Transect 1	2	3	4	5	6	7	8
H'								
1.8	0.60	0.17	0.0	0.95	0.09	0.17	0.33	--
0.9	1.21	0.34	0.17	1.35	0.66	0.0	0.9	0.27
0.0	1.38	0.31	0.17	1.29	0.87	0.57	0.34	0.44
-2.5	--	--	0.71	--	1.28	0.55	0.77	--
-10.0	1.05	0.79	--	1.09	--	--	--	0.71
N								
1.8	6.25	2.25	1.5	5.25	2.75	0.75	8.75	--
0.9	9.5	1.5	1.75	13.5	16.0	0.25	14.75	1.25
0.0	17.5	10.62	2.25	25.25	4.25	4.25	3.0	1.75
-2.5	--	--	12.0	--	20.87	5.25	19.0	--
-10.0	11.5	5.62	--	18.0	--	--	--	57.12
S								
1.8	2.5	1.0	0.75	2.75	1.0	0.75	2.0	--
0.9	4.0	1.5	1.0	5.25	3.25	0.25	3.75	1.25
0.0	6.0	1.87	1.0	5.0	2.75	2.25	3.0	1.25
-2.5	--	--	3.12	--	5.87	2.13	2.87	--
-10.0	3.25	2.75	--	5.62	--	--	--	3.87

TABLE 16

0.5-MM EPIBENTHIC PUMP: PROBABILITIES OF SIGNIFICANT DIFFERENCES AMONG TRANSECTS AT A GIVEN DEPTH LEVEL (KRUSKAL-WALLIS TEST)

April and November 1980

Tidal Elevation (m)	Numerical Parameters H'	S	N	Accept or Reject Null Hypothesis
1.8	p<0.05	p>0.1	p>0.1	Accept for N,S, reject for H'
0.9	p>0.05	p<0.025	p<0.05	Accept for H', reject for N, S
0.0	p>0.1	p<0.05	p>0.1	Accept for H', N, reject for S
-2.5	p>0.5	p>0.5	p<0.1	Accept for all
-10.0	p>0.1	p>0.1	p>0.1	Accept for all

TABLE 17

0.5-MM EPIBENTHIC PUMP: PROBABILITIES OF SIGNIFICANT DIFFERENCES AMONG TRANSECTS AT A GIVEN DEPTH LEVEL (MANN-WHITNEY U-TEST)

April and November 1980

Tidal Elevation (m)	Numerical Paramete. H'	S	N	Accept or Reject Null Hypothesis
1.8	p<0.01	p<0.001	p<0.001	Reject for all
0.9	p<0.01	p<0.005	p<0.001	Reject for all
0.0	p>0.05	p<0.001	p>0.1	Accept for H', N, reject for S
-2.5	p>0.1	p<0.025	p>0.1	Accept for H', N, reject for S
-10.0	p>0.1	p<0.025	p>0.1	Accept for H', N, reject for S

An examination of seasonal variation (April versus November) within depth levels for all transects revealed that significant differences in species diversity occurred at the 1.8- and 0.9-m stations (Table 17, $p<0.01$, Mann-Whitney test). Lower intertidal and subtidal stations for all transects had sufficiently similar species diversity values to assume that the existing biological assemblages came from the same statistical population.

Abundance of organisms (N) ranged from 0 at stations lacking animals to 410 for a sample from the -10-m station of Transect 8 in June. The animals in this sample were primarily harpacticoid copepods, not normally retained by a 0.5-mm sieve. In this sample a large amount of organic debris containing harpacticoids was retained on the sieve, accounting for the high count. Compared to 0.25-mm epibenthic pump and infaunal samples, 0.5-mm epibenthic pump samples had generally lower abundance values (Tables 15, 10, and 5).

Examination of abundance values between transects at specific elevations indicated that significant differences in abundance occurred at the 0.9-m station (Table 16). Transects 2, 6, and 8 had the lower abundance values at the 0.9-m station while Transects 2, 3, 6, and 8 had the lower abundance values at the 0.0-m station. Seasonal effects in species abundance were evident at the 1.8- and 0.9-m stations between April and November (Table 17). No significant differences were detected at the other tidal levels.

Classification analysis of April 0.5-mm epibenthic pump samples resulted in five major species groups (Figure 11). Group I contains the gammarids Westwoodilla caecula and Orchomene, the cumaceans Leptostylis and Eudorella, and the cumacean family Lampropidae (mostly females or immature specimens). These epibenthic crustaceans are found individually at the subtidal stations of Transects 1, 5, 6, and 7 and as a group at 4/-10 (Table 18). Species Group II is a mixture of neritic and epibenthic crustaceans found at most of the stations in the study area (Table 18). Species Group III (Figure 11) contains two neritic organisms with very limited distribution. Species Group IV (Figure 11) contains four epibenthic crustaceans that are found as a group at 4/0.9 and 4/0.0 (Table 18). Species Group V (Figure 11) contains a mysid, a gammarid, and a harpacticoid copepod family. Eogammarus conervicolus and Acanthomyis davisi both are found at 7/0.0 and 8/0.0 within Station Group C (Table 18) but are uncommon elsewhere in the study area. April stations tended to form groups based on tidal level but considerable variation was present (Figure 12). Group ~ (Figure 12) is not a true group, but rather a collection of nonrelated subgroups that is called a group for convenience.

The results of the November species classification showed two major species groups (Figure 13). Both groups contain neritic and epibenthic organisms. Group I is found mainly within Station Group A (Figure 14, Table 19) at subtidal stations. Species Group II is most common in Station Group C which contains mostly intertidal stations (Figure 14, Table 19). Species Group III contains Eogammarus confervicolus and Calanoida (Figure 13) and is very limited in its occurrence in the study area (Table 19). November stations showed a stronger tendency to form groups based on tidal level than did April stations (Figure 14).

3.3.5 Discussion

A qualitative comparison between 0.25- and 0.5-mm epibenthic pump cluster analyses suggests that the 0.25-mm samples had a consistently higher number and diversity of species. In addition, several of these species were sufficiently abundant over all stations to represent a characteristic assemblage within the study area. A comparison of the

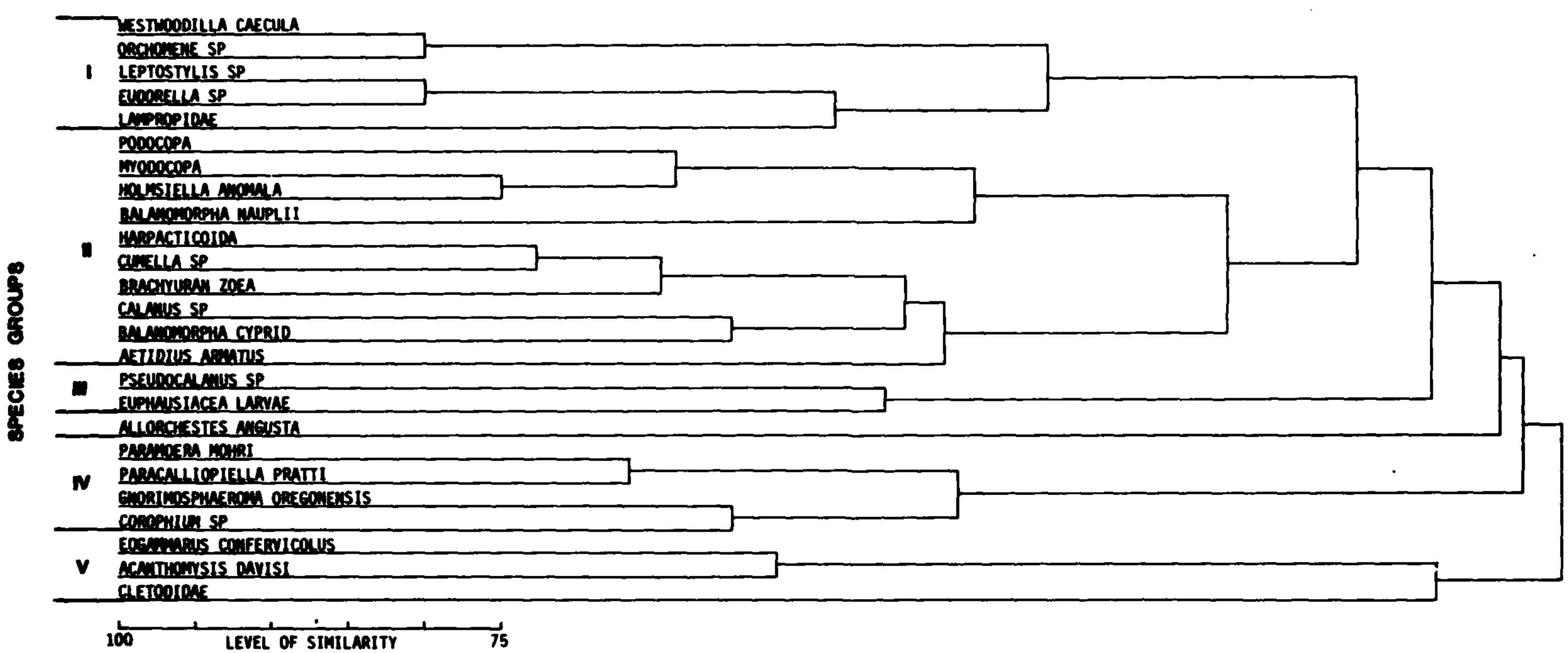


FIGURE 11
DENDROGRAM OF SPECIES GROUPINGS FOR
APRIL, 1980 0.5-mm EPIBENTHIC PUMP SAMPLES

TABLE 18

TWO-WAY TABLE OF COINCIDENCE SHOWING RELATIONSHIPS AMONG 0.5-MM EPIBENTHIC PUMP STATION AND SPECIES GROUPS FROM COMMENCEMENT BAY, APRIL 1980

	Station Groups	A							B																C						
		8/ -10	2/ -10	1/ -10	6/ 1.8	6/ 0.0	5/ -2.5	5/ 0.9	7/ -2.5	3/ 0.0	2/ 0.9	7/ 0.9	1/ 0.9	1/ 1.8	1/ 0.0	6/ -2.5	7/ 1.8	2/ 1.8	2/ 0.0	4/ -10	4/ 1.8	3/ -2.5	4/ 0.9	4/ 0.0	5/ 0.0	3/ 0.9	8/ 0.0	7/ 0.0	8/ 0.9	3/ 1.8	5/ 1.8
Group I	Westwoodilla caecula						0.5									0.5				3.5											
	Orchomene sp.						1.0													1.0											
	Leptostylis sp.			0.5																2.0											
	Eudorella sp.			2.0					2.5											3.0											
	Lampropidae							0.5	1.0											10.0											
Group II	Podocopa	0.5	0.5	0.5		0.5	0.5	1.5																	0.5						
	Myodocopa		2.0	1.0			3.0															1.5									
	Holmesiella anomala		0.5	1.5			1.0	0.5																							
	Balanomorpha nauplii		0.5		0.5	0.5	0.5	1.0							1.0						2.0	1.0		0.5			1.5				
	Harpacticoida				0.5	2.0	4.5	0.5	165.0	0.5	1.0	5.5	3.5	1.0	5.5	1.5	12.5	5.0	0.5	0.5				1.0				0.5			
	Cumella vulgaris			1.0		4.0	4.0		7.0	3.0	0.5	7.5	0.5	0.5	0.5	0.5			2.0						2.0	0.5		2.5			
	Brachyura zoea	5.0	2.5	2.0	0.5	1.0	8.0	0.5			0.5	0.5	2.5	0.5	2.5	0.5	1.0					0.5			0.5						
	Calanus sp.	0.5	1.0	1.5								2.0	1.0	2.0	1.5		2.0	0.5	0.5	2.0	1.5	1.0	1.5	1.0							
	Balanomorpha cyprids								0.5	0.5	0.5	1.0	2.5	1.5	1.5					1.5	3.0	1.0	11.5	4.5					0.5	2.5	0.5
	Aetideus armatus	0.5					1.5	13.0				0.5	0.5							0.5			2.0	1.0	2.5						4.5
Group III	Pseudocalanus sp.	0.5											1.0																		
	Euphausiacea larvae	0.5					0.5																								
	Allorchestes angusta							2.5																							
Group IV	Paramoera mohri																							7.0							
	Paracalliopiella pratti																						1.0	3.0							
	Gnorimosphaeroma oregonensis													6.0	3.5							0.5	1.0	4.5							
	Corophium spp.														0.5				0.5				0.0	1.0						0.5	
Group V	Anisogammarus confervicolus											0.5			0.5										0.5		0.5	1.5			
	Acanthomysis davisi																										1.5	0.5			
	Cletodidae																									2.5					

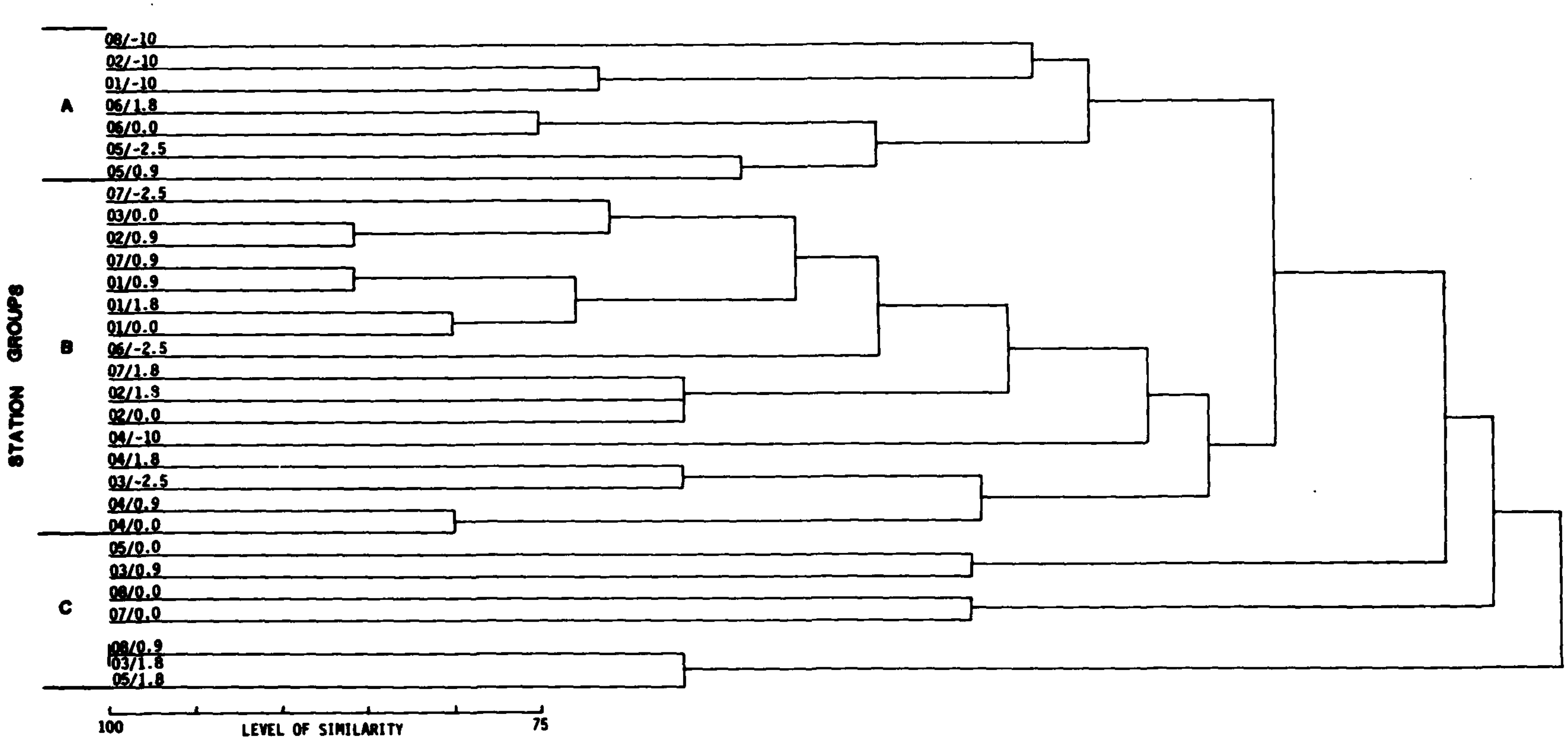


FIGURE 12
DENDROGRAM OF STATION GROUPINGS FOR APRIL, 1980 0.5-mm EPIBENTHIC PUMP SAMPLES

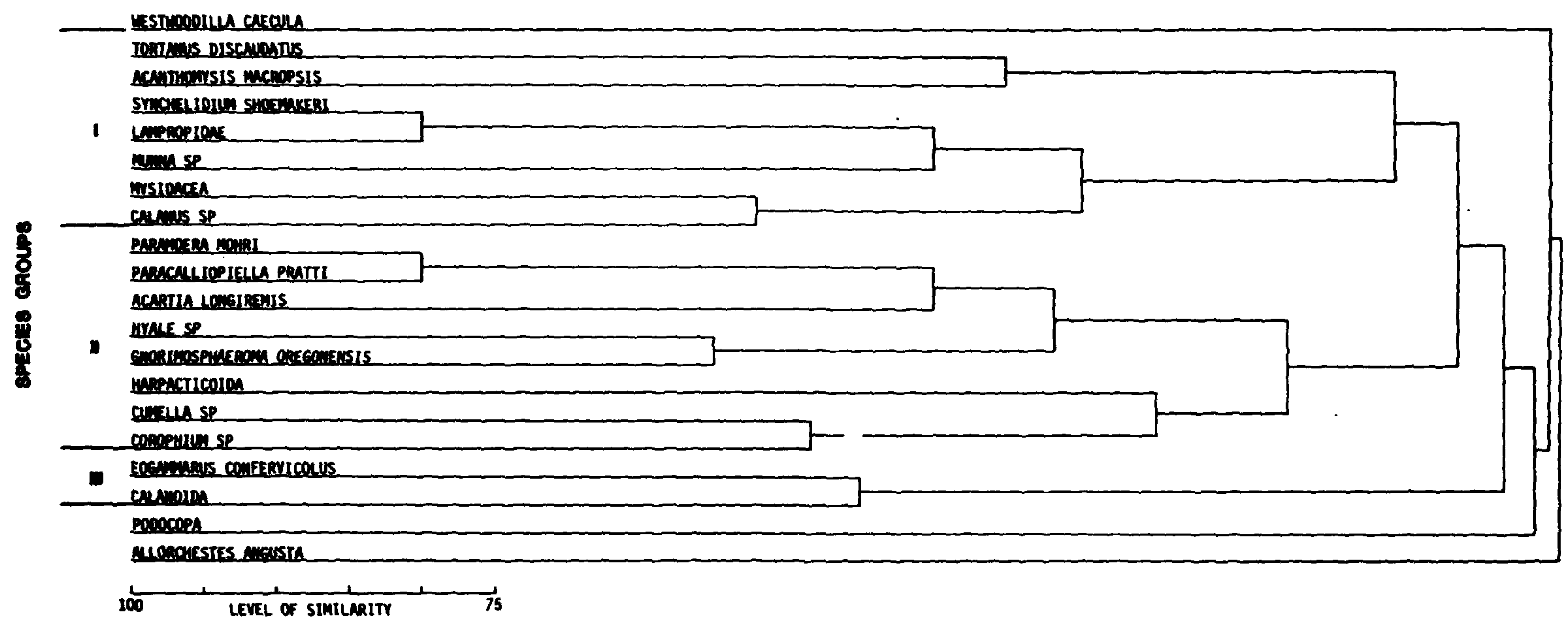


FIGURE 13
DENDROGRAM OF SPECIES GROUPINGS FOR NOVEMBER, 1980 0.5-mm EPIBENTHIC PUMP SAMPLES

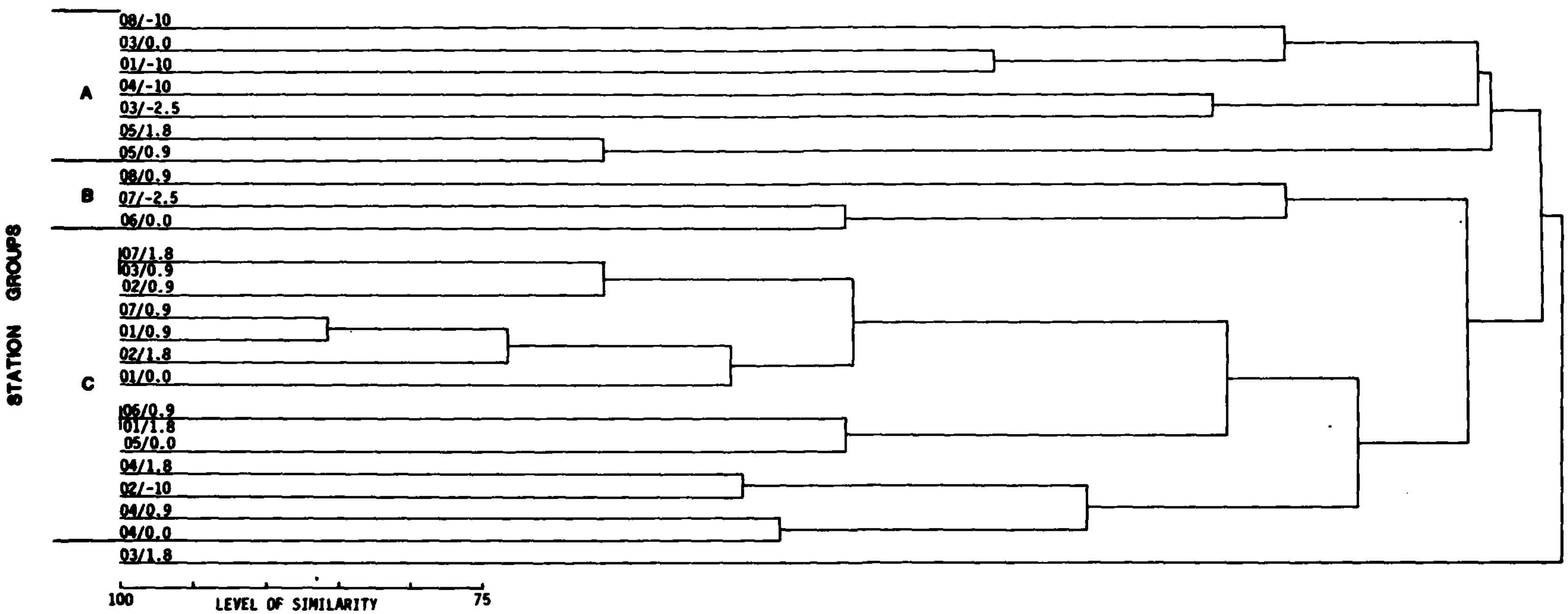


FIGURE 14
DENDROGRAM OF STATION GROUPINGS FOR
NOVEMBER, 1980 0.5-mm EPIBENTHIC PUMP SAMPLES

TABLE 19

TWO-WAY TABLE OF COINCIDENCE SHOWING RELATIONSHIPS AMONG 0.5-MM EPIBENTHIC PUMP STATION AND SPECIES GROUPS FROM COMMENCEMENT BAY, NOVEMBER 1980

		Station Groups																								
		A							B			C														
		8/ -10	3/ 0.0	1/ -10	4/ -10	3/ -2.5	5/ 1.8	5/ 0.9	8/ 0.9	7/ -2.5	6/ 0.0	7/ 1.8	3/ 0.9	2/ 0.9	7/ 0.9	1/ 0.9	2/ 1.8	1/ 0.0	6/ 0.9	1/ 1.8	5/ 0.0	4/ 1.8	2/ -10	4/ 0.9	4/ 0.0	3/ 1.8
	Westwoodilla caecula				1.5																					
Group I	*Tortanus discaudatus*	0.5		0.5																						
	Acanthomysis macropsis		0.5	0.5																				0.5		
	Synchelidium shoemakeri				0.5	0.5															0.5					
	Lampropidae					2.5															0.5					
	Munna sp.					0.5				0.5																
	Mysidacea			0.5		0.5																0.5	0.5			
	Calanus sp.			1.0		0.5		1.0																		
Group II	*Paramoera mohri*																							0.5	19.0	
	Paracalliopiella pratti					0.5																		3.5	6.0	
	Acartia longiremis																							0.5		0.5
	Hyale sp.																	0.5				1.5		2.9		
	Gnorimosphaeroma oregonensis													0.5		2.0		1.5				1.5	0.5	1.5	1.0	
	Harpacticoida									0.5	0.5				1.0	1.0									0.5	
	Cumella vulgaris														3.5	3.5	0.5	11.5	0.5	0.5	0.5					
	Corophium spp.											1.0	0.5	0.5	1.0	1.0	1.5	1.0						0.5		
Group III	*Eogammarus confervicolus*								1.0									1.5								
	Calanoida								0.5	2.5																
	Podocopa																						0.5			
	Allorchestes angusta						0.5	10.5																		

infaunal and epibenthic results suggests that the infaunal communities are more stable and less subject to seasonal shifts in abundance. Infaunal stations also were more clearly grouped by tidal height than the epibenthic stations. This could be expected since epibenthic organisms are considerably more mobile than infaunal organisms. They have the ability to move into and through various nearshore habitats and may be characteristic of water masses as well as substrate types. This could account for some of the variability seen in epibenthic station groupings as opposed to the relatively well defined depth-related station groupings of the infauna.

Several recent studies have used an epibenthic pump to sample epifaunal communities in Puget Sound and the Columbia River estuary. Mean density estimates reported (totaled over all stations) include 23,302 to 29,948 organisms/m^3 in Hood Canal (Simenstad et al. 1980), 50,039 organisms/m^3 in the Strait of Juan de Fuca (Simenstad et al. 1979), and approximately 102,819 organisms/m^3 in the Columbia River estuary (Houghton et al. 1981). Comparison of these estimates with that obtained for Commencement Bay (8,878 organisms/m^3) show that these other areas have significantly higher densities. Some of the discrepancy can be explained by noting that a minimum mesh size of 0.209 mm or 0.130 mm was used in the other studies compared to 0.250 mm in Commencement Bay. This slightly smaller mesh would be expected to retain higher numbers of crustacean larvae and eggs. Also, all organisms collected were used in the density estimates of the three previously cited studies while only true epibenthic forms were used in the Commencement Bay estimate. However, even with these differences in methodology taken into account, the density estimate for Commencement Bay would probably double at most, and still be below densities reported elsewhere.

Habitat differences probably account for much of the variation in density noted. Several of the sample sites in Hood Canal and the Strait of Juan de Fuca were eelgrass beds (Simenstad et al. 1979, 1980) containing extremely high densities of harpacticoid copepods and gammarid amphipods. High density and species diversity of gammarid amphipods were noted at Transect 4 in Commencement Bay where attached macro-algae provides good habitat. Other transects were relatively poor in gammarid amphipod diversity, Corophium being the only genus present with any regularity or abundance. Harpacticoid copepods were most abundant at stations with high amounts of organic debris, such as 07/-2.5 and 08/-10, but bare sand or mud stations were relatively poor in harpacticoids.

The majority of sites sampled by Simenstad et al. (1979, 1980) are relatively unaffected by significant pollution. The degree to which industrialization of the study area and release of pollutants into the waterways and bay influences species composition and abundance is difficult to assess. Certainly the low density estimates of epibenthic and infaunal organisms in the study area compared with less disturbed habitats in Puget Sound suggests that something beyond differences in habitat type is influencing the invertebrate communities in Commencement Bay. Simenstad and Cordell (1980) reported a low diversity but high standing stock of epibenthic invertebrates from the eastern end of City Waterway, noting that this situation is characteristic of organically enriched or polluted habitats. Several of the 0.25-mm epibenthic pump transects sampled in this study (Transect 1 for example) had stations with low species diversity (as measured by both H' and S) yet relatively high abundance values (Table 10). These low diversity values accompanied by high abundance values may be an indication of pollutants stressing the epibenthic communities in these areas.

3.4 JUVENILE SALMON STOMACH CONTENT ANALYSIS

3.4.1 Chinook

A total of 45 juvenile chinook salmon from three sampling periods (April, May, June) was examined for stomach contents (Table 20). Fish collected during April 1980 appeared to have been feeding primarily on harpacticoid copepods (81 percent of total number of prey items) and secondarily on terrestrial insects (15 percent of total number). The remaining prey items identified included epibenthic organisms such as gammarid amphipods and neritic organisms such as barnacle and copepod nauplii.

Fish collected during May 1980 were larger than the April sample, generally falling into a range between 51 and 100 mm. Harpacticoid

TABLE 20

PREY TAXA COMPOSITION: JUVENILE CHINOOK SALMON IN COMMENCEMENT BAY[a]

Sample Period/Prey	Fish Length Interval <50 mm	51-100 mm	>100 mm
April 1980	n = 21	n = 2[b]	
Harpacticoida	423 (81.0%)		
Insect larvae	44 (8.4%)		
Diptera	19 (3.6%)		
Insect unid.	15 (2.8%)		
Corophium sp.	10 (1.9%)		
Balanomorpha nauplii	5 (0.9%)		
Gammaridea	2 (0.3%)		
Copepod nauplii	2 (0.3%)		
Eogammarus confervicolus	1 (0.19%)		
Aranea	1 (0.19%)		
May 1980	n = 1	n = 17	
Harpacticoida		120 (61.8%)	
Brachyuran zoea		25 (12.8%)	
Diptera		15 (7.7%)	
Mysidacea	1 (100%)	15 (7.7%)	
Insect larvae		8 (4.1%)	
Cumacea		3 (1.5%)	
Calanoida		3 (1.5%)	
Gammaridea		3 (1.5%)	
Corophium sp.		1 (0.5%)	
Insecta unid.		1 (0.5%)	
June 1980		n = 4	
Harpacticoida		190 (43.7%)	
Diptera		123 (28.3%)	
Gammaridea		82 (18.9%)	
Cumella sp.		7 (1.6%)	
Mysidacea		5 (1.1%)	
Aranea		5 (1.1%)	
Insect larvae		4 (0.9%)	
Brachyuran zoea		4 (0.9%)	
Hymenoptera		3 (0.7%)	
Callianassa sp.		3 (0.7%)	
Corophium sp.		2 (0.5%)	
Formicidae		2 (0.5%)	
Balanomorpha cyprids		1 (0.2%)	
Lithodidae		1 (0.2%)	
Bivalvia		1 (0.2%)	
Calanoida		1 (0.2%)	

(a) Data based on total number and percent contribution of beach seine catch in 1980 (all stations pooled).
(b) Both fish had empty stomachs.

copepods were the primary prey item in terms of abundance, though at a lower percentage than found in the April samples (Table 20). Neritic organisms including brachyuran zoea, terrestrial insects, and calanoid copepods contributed 26 percent of the total number of prey items.

Fish collected during June 1980 (51-100 mm length) still fed extensively on harpacticoid copepods (43 percent of total, Table 20) though terrestrial insects and neritic organisms (32.6 percent of total) and gammarid amphipods (19.4 percent of total) were taken in increasingly larger proportions than during April and May.

Fresh et al. (1979) found that juvenile chinook salmon collected in the Nisqually Reach of southern Puget Sound fed primarily on epibenthic crustacea and to a lesser degree on neritic prey. In the Duwamish River estuary, Meyer et al. (1981) also obtained results suggesting that smaller fish eat a larger proportion of epibenthic prey than do larger fish, which eat more neritic prey. In addition, gammarid amphipods such as Corophium were found most frequently in stomachs of fish sampled at nearshore locations and terrestrial, drift insects were found more frequently in fish collected at upstream locations (Meyer et al. 1981). The results obtained from juvenile chinook collected in Commencement Bay also showed a trend toward increasing use of neritic prey with increasing fish length. Epibenthic organisms were abundant in juvenile chinook stomachs from all three sample periods. This may be explained by the fact that all samples analyzed were collected by beach seining in nearshore areas where epibenthic organisms are most common.

A recent sampling effort in Commencement Bay between May and September 1979 by Meyer et al. (unpublished preliminary report) resulted in the collection and stomach content analysis of 32 juvenile chinook salmon (mean length = 77.5 mm). Crustacean larvae, drift insects, and gammarid amphipods contributed significantly to the diet of chinook in terms of both numbers and biomass. Harpacticoid copepods comprised only 2.5 percent of the total number of organisms identified. These results generally agree with the findings of this study. Table 20 shows the increasing importance of neritic prey and decreasing importance of harpacticoid copepods as the season progresses. The low number of harpacticoids reported by Meyer et al. (unpublished) is somewhat puzzling since our results from June show harpacticoids still made up 43 percent of the total number of organisms.

3.4.2 Coho

Only nine juvenile coho salmon were collected and analyzed for stomach contents (Table 21). Samples collected during April 1980 in the 51- to 100-mm size range fed upon both epibenthic (cumaceans and mysids, 7 percent) and neritic prey (brachyuran zoea and juvenile fish, 92 percent). Coho larger than 100 mm showed the same pattern except that juvenile fish comprised the largest percentage of prey items taken (58 percent). A slightly wider variety of prey taxa was also identified in the larger coho, but this is probably due to a larger sample size for this length interval.

Two juvenile coho were collected and analyzed from May 1980, one each from the 51-100 mm and greater than 100 mm length interval. The smaller coho had fed primarily on brachyuran zoea (92 percent of total) while the larger coho contained two gammarid amphipods, *Eogammarus confervicolus*.

Neritic prey such as larval crustaceans and juvenile fish made up the bulk of the prey items taken by juvenile coho. Other studies (Fresh et al. 1979, Meyer et al. 1981) indicate that juvenile coho salmon have a very diverse prey spectra that emphasizes epibenthic organisms, especially harpacticoid copepods and mysids. Meyer et a' (1981) found that epibenthic crustacea are most important in coho diets during their early period of outmigration, with terrestrial insects becoming more important later. Also, coho less than 129 mm in length consumed a significant proportion of juvenile fish (Meyer et al. 1981). Both these results agree with the information obtained in this study.

TABLE 21

PREY TAXA COMPOSITION: JUVENILE COHO SALMON IN COMMENCEMENT BAY[a]

Sample Period/Prey	Fish Length Interval <50 mm	51-100 mm	>100 mm
April 1980		n = 2	n = 5
Brachyuran zoea		20 (75.0%)	35 (29.9%)
Juvenile fish		5 (18.5%)	69 (58.9%)
Cumacea		1 (3.7%)	
Mysidacea		1 (3.7%)	3 (2.5%)
Gammaridea			5 (4.3%)
Isopoda			2 (1.7%)
Diptera			1 (0.8%)
Cyclopoida			1 (0.8%)
Aranea			1 (0.8%)
May 1980		n = 1	n = 1
Brachyuran zoea		52 (92.8%)	
Balanomorpha cyprids		4 (7.2%)	
Eogammarus confervicolus			2 (100%)

(a) Data based on total number and percent contribution of beach seine catch in 1980 (all stations pooled).

3.4.3 Pink

A total of 46 juvenile pink salmon from 4 sampling periods (March, April, May, June) was analyzed for stomach contents (Table 22). Pink salmon collected during March, April, and May contained harpacticoid copepods in the greatest abundance (100, 94, and 92 percent, respectively). Other epibenthic organisms identified in the April collection included gammarid amphipods (2 percent by abundance), mysids (1 percent), and cumaceans, barnacle cyprids, ostracods, and tanaids (all less than 1 percent). Neritic organisms such as brachyuran zoea, calanoid copepods, hyperiid amphipods, and crustacean and drift insect larvae accounted for only 0.9 percent of the total number of prey items.

Pink salmon collected during May contained harpacticoid copepods in the highest abundance (92 percent). Dipterans and calanoid copepods were the next most abundant prey items at 3 percent and 2.9 percent, respectively. The remainder of the prey items were primarily epibenthic organisms consisting of the same taxa identified in the April collection.

TABLE 22

PREY TAXA COMPOSITION: JUVENILE PINK SALMON IN COMMENCEMENT BAY[a]

Sample Period/Prey	Fish Length Interval <50 mm	Fish Length Interval 51-100 mm	Fish Length Interval >100 mm
March 1980	n = 2		
Harpacticoida	32 (100.0%)		
April 1980	n = 31		
Harpacticoida	987 (94.1%)		
Gammaridea	13 (1.2%)		
Mysidacea	12 (1.1%)		
Corophium sp.	9 (0.8%)		
Cumacea	8 (0.7%)		
Balanomorpha cyprids	4 (0.4%)		
Myodocopa	4 (0.4%)		
Brachyuran zoea	3 (0.3%)		
Calanoida	2 (0.2%)		
Tanaidacea	2 (0.2%)		
Hyperiidea	2 (0.2%)		
Crustacea larvae	1 (0.1%)		
Insect larvae	1 (0.1%)		
May 1980	n = 12		
Harpacticoida	956 (92.4%)		
Diptera	31 (3.0%)		
Calanoida	30 (2.9%)		
Gammaridea	3 (0.3%)		
Cumella sp.	3 (0.3%)		
Mysidaceda	3 (0.3%)		
Corophium sp.	2 (0.2%)		
Brachyuran zoea	2 (0.2%)		
Insect larvae	2 (0.2%)		
Nebalia pugettensis	1 (0.1%)		
Balanomorpha cyprids	1 (0.1%)		
June 1980	n = 1		
Calanoida	48 (59.2%)		
Diptera	30 (37.0%)		
Mysidacea	2 (2.5%)		
Gammaridea	1 (1.2%)		

(a) Data based on total number and percent contribution of beach seine catch in 1980 (all stations pooled).

All pinks collected during March, April, and May were less than 50 mm in length. The June collection, however, contained 1 pink greater than 50 mm and its prey spectrum differed considerably from the smaller pinks collected earlier in the season. Calanoid copepods and dipterans comprised the bulk of the prey items (96 percent). Epibenthic organisms (mysids and gammarid amphipods) made up the remaining 4 percent.

The results obtained for juvenile pink salmon from Commencement Bay agree with those reported by Fresh et al. (1979) for Nisqually Reach. Harpacticoid copepods were most important as prey items during the early period of pink salmon outmigration with decreasing importance as the season progressed. Calanoid copepods and crustacean larvae were most important later in the season as fish grew larger and moved offshore to feed (Fresh et al. 1979).

One reason harpacticoid copepods are so predominant as prey items in the samples analyzed is that the samples were collected by beach seining. Fish caught had probably been feeding in nearshore intertidal regions of the study area where harpacticoid copepods numerically dominate. Fresh et al. (1979) showed that significant differences existed between prey spectra of beach seine versus purse seine caught pink salmon. Beach seine caught fish contained primarily harpacticoid copepods and other epibenthic organisms while purse seine caught fish contained primarily neritic organisms such as calanoid copepods.

Miller et al. (1980) classified juvenile pink salmon as obligate planktivores based on results obtained in the Strait of Juan de Fuca. Pink salmon were characteristically caught in townet collections and prey items were generally neritic organisms. The lack of harpacticoid copepods in the diet of pink salmon from the Strait of Juan de Fuca may reflect a shift to offshore feeding in the surface layer of water since harpacticoids were found to be abundant in the habitats sampled.

A comparison of prey items from juvenile pink salmon collected at outer bay stations versus inner bay stations in Commencement Bay (Table 23) shows that neritic organisms comprised a larger percent

TABLE 23

PERCENT CONTRIBUTION OF EPIBENTHIC AND NERITIC PREY ITEMS TO DIET OF JUVENILE PINK SALMON AT INNER VS. OUTER BAY STATIONS

Location (Stations)	Prey Items	Percent Contribution
Inner Bay (1, 2, 3, 6, 7, 8)	Epibenthic	99.1
	Neritic	0.9
Outer Bay (4, 5)	Epibenthic	75.5
	Neritic	24.5

contribution at outer bay stations. An explanation for this is that neritic prey items (calanoid copepods, crustacean larvae, terrestrial insects) may be more abundant at outer bay sites because of the steeper intertidal gradients present.

3.4.4 Chum

A total of 51 juvenile chum salmon from three sampling periods (April, May, June) was analyzed. Prey items for chum collected during April and May were primarily harpacticoid copepods and gammarid amphipods (Table 24). Fish of two size classes (<50 mm, 51-100 mm) were present during these months and the larger size class showed an increased percentage of gammarid amphipods in their diet (27 percent total vs. 3 percent total). Drift insects and their larvae comprised about 17 percent of the total organisms consumed during April and May while neritic organisms such as calanoid copepods and crustacean larvae were present in very small numbers.

The June sample of juvenile chum contained only fish in the 51-100 mm size class. Harpacticoid copepods, gammarid amphipods, and mysids comprised about 48 percent of the total prey items. Drift insects and their larvae made up approximately 30 percent of the total and calanoid copepods and crustacean larvae accounted for the remaining 22 percent. Apparently, as the outmigration season progresses and fish size increases, chum salmon tend to feed more in open waters and less in nearshore areas as shown by the increase in percentage of neritic prey items and decrease

TABLE 24

PREY TAXA COMPOSITION: JUVENILE CHUM SALMON IN COMMENCEMENT BAY[a]

Sample Period/Prey	Fish Length Interval <50 mm	51-100 mm	>100 mm
April 1980	n = 23	n = 1	
Harpacticoida	1,108 (94.8%)	109 (99.1%)	
Diptera	28 (2.4%)		
Gammaridea	9 (0.7%)		
Brachyuran zoea	6 (0.5%)	1 (0.9%)	
Insecta	5 (0.4%)		
Insect larvae	4 (0.3%)		
Mysidacea	2 (0.2%)		
Aranea	2 (0.2%)		
Copepoda nauplii	1 (0.1%)		
Cumacea	1 (0.1%)		
Anatanais normani	1 (0.1%)		
Calanoida	1 (0.1%)		
May 1980	n = 21	n = 2	
Harpacticoida	1,283 (87.3%)	26 (22.6%)	
Diptera	60 (4.1%)	10 (8.7%)	
Gammaridea	43 (2.9%)	32 (27.8%)	
Calanoida	41 (2.8%)	16 (13.9%)	
Insect larvae	10 (0 7%)	18 (15.6%)	
Mysidacea	9 (0.6%)		
Corophium sp.	8 (0.5%)		
Eogammarus confervicolus	6 (0.4%)		
Insecta	3 (0.2%)		
Cumacea	3 (0.2%)	1 (0.8%)	
Balanomorpha cyprids	1 (0.06%)		
Formicidae	1 (0.06%)		
Aranea	1 (0.06%)		
Fish eggs		4 (3.4%)	
Brachyuran zoea		1 (0.8%)	
Ampharetidae		7 (6.1%)	
June 1980		n = 4	
Harpacticoida		55 (31.2%)	
Diptera		50 (28.4%)	
Calanoida		28 (15.9%)	
Gammaridea		25 (14.2%)	
Brachyuran zoea		11 (6.2%)	
Mysidacea		4 (2.3%)	
Insect larvae		3 (1.7%)	

(a) Data based on total number and percent contribution of beach seine catch in 1980 (all stations pooled).

in percentage of epibenthic prey items. Similar results were obtained by Meyer et al. (1981) in the Duwamish River estuary, Simenstad et al. (1980) in Hood Canal, and Meyer et al. (unpublished) in Commencement Bay.

Miller et al. (1980) classified juvenile chum salmon as obligate epibenthic planktivores in the Strait of Juan de Fuca. Principal prey items identified included harpacticoid copepods, gammarid amphipods, isopods, mysids, cumaceans, shrimp, and calanoid copepods (Miller et al. 1980).

A comparison of prey items taken at inner bay stations (1, 2, 3, 6, 7, 8) versus outer bay stations (4, 5) revealed that neritic prey items (calanoid copepods, insects, crustacean larvae) contributed a higher percentage of total abundance at outer bay stations than at inner bay stations (Table 25). Samples were collected by beach seine at all sites, and the differences observed can be explained by the steeper intertidal gradients at the outer bay stations resulting in greater availability of neritic prey.

TABLE 25

PERCENT CONTRIBUTION OF EPIBENTHIC AND NERITIC PREY ITEMS TO DIET OF JUVENILE CHUM SALMON AT INNER VS. OUTER BAY STATIONS

Location (Stations)	Prey Items	Percent Contribution
Inner Bay (2, 3, Blair Waterway)	Epibenthic	96.8
	Neritic	3.2
Outer Bay (4, 5, Point Defiance-Ruston)	Epibenthic	75.4
	Neritic	24.6

3.4.5 Summary of Salmonid Stomach Analysis

The results obtained from stomach content analysis of juvenile salmonids show that epibenthic organisms (harpacticoid copepods, gammarid amphipods, cumaceans, isopods) are important prey items during the residency time of juvenile salmonids within the study area. Harpacticoid copepods dominated the prey spectra of all salmon species in terms of abundance. This should not be taken to mean that harpacticoids are the most important prey items since biomass estimates of harpacticoids as prey items (Fresh et al. 1979, Simenstad et al. 1980, Miller et al. 1980, Meyer et al. 1981) indicate their percent contribution to the total biomass of prey is much less than their percent contribution to total abundance. Other epibenthic organisms, especially gammarid amphipods, contribute relatively greater percentages to the total biomass despite being numerically less abundant.

Meyer et al. (unpublished) found that harpacticoid copepods were dominant prey items of juvenile chinook from Commencement Bay in terms of both abundance and biomass. Harpacticoid copepods were consistently the most abundant organisms collected in the epibenthic pump samples, especially at the inner bay stations (1, 2, 3, 6, 7, 8). Their numerical dominance of the epibenthic biota probably explains why they also outnumber all other prey items taken by juvenile salmonids and in some cases (Meyer et al. unpublished) contribute the largest percentage of the biomass of prey items.

Another possible explanation for the numerical dominance of harpacticoid copepods in the fish examined is that the majority of these fish were small (<50 mm). Several studies (Fresh et al. 1979, Simenstad et al. 1980, Meyer et al. 1981) have shown and our data support that harpacticoids are more important as food items in smaller fish. As the fish grows it begins feeding in offshore areas on neritic prey rather than in nearshore, intertidal habitats. Examination of Tables 20, 21, 22, and 24 reveals that in juvenile salmonids larger than 50 mm harpacticoid copepods contribute a smaller percentage of total abundance than they did in fish less than 50 mm in length. Other prey items, especially neritic organisms, are taken more frequently by the larger fish.

3.5 MARINE FISH STOMACH CONTENT ANALYSIS

Of the 46 fish stomachs examined, 10 (21 percent) had empty stomachs, resulting in a sample size of 36 fish. This number is not large enough to allow comprehensive, quantitative results for prey items of resident marine fish in the study area. However, the data do lend insight into feeding patterns within the study area.

The flatfish examined (starry flounder, English sole, rock sole, and flathead sole) showed a strong preference for benthic invertebrates as prey items (Tables 26 through 29). Polychaetous worms, bivalves, and gammarid amphipods were the most abundant prey items taken. The data agree well with results presented by Miller et al. (1980) who classified these fish as faculative benthivores; organisms having a prey spectrum including both benthic and epibenthic species. Prey composition was quite variable both within and between species and the percentage occurrence values were affected by this in several samples. For instance, English sole collected during spring 1981 (Table 27) showed that 75 percent of the prey items of the four fish with material in their stomachs were oligochaetes, while actually all the oligochaetes were in the stomach of one fish. The same can be said for the high percentage of *Corophium* in rock sole stomachs from spring 1981 (Table 26); all these organisms were in the stomach of one fish. Some variation in dominant prey species taken with time would be expected to occur as the prey species present fluctuate in abundance and distribution (Miller et al. 1980). However, this variation would probably be within taxonomic groups and those that are important in the fish sampled (polychaetes, bivalves, gammarid amphipods) should continue to be heavily exploited over time.

Rock sole collected during fall 1980 showed a large percentage of polychaetes as food items (Table 26) while spring 1981 samples show a shift to epibenthic crustacea, especially the gammarid amphipod *Corophium*. Fresh et al. (1980) report a similar shift in rock sole diet from September to November samples. Some of the shift in prey items can be explained by noting that epibenthic crustaeans are more abundant at Stations 1 and 7 where spring 1981 collections were made.

TABLE 26

PREY ITEMS OF ROCK SOLE COLLECTED IN COMMENCEMENT BAY DURING FALL 1980 AND SPRING 1981 (POOLED VALUES)

FALL 1980
Species (number): Rock sole (3)
Mean length (range): 134 mm (124-143 mm)
Stations: 3, 4

Prey Item	Total Number	% Occurrence
Polychaeta unid.	8	30.7
Armandia brevis	3	11.5
Capitella capitata	1	3.8
Lumbrineris sp.	2	7.6
Phyllodocidae	1	3.8
Prionospio steenstrupi	2	7.6
Spionidae	1	3.8
Cancer sp.	5	19.2
Brachyura unid.	3	11.5

SPRING 1981
Species (number): Rock sole (5)[a]
Mean length (range): 114 mm (85-163 mm)
Stations: 1, 5, 7

Prey Item	Total Number	% Occurrence
Armandia brevis	1	0.8
Capitella capitata	3	2.4
Etone longa	1	0.8
Nereidae	1	0.8
Bivalvia unid.	2	1.6
Bivalve siphons	8	6.8
Balanomorpha cyprids	1	0.8
Harpacticoida	1	0.8
Leptochelia savignyi	2	1.6
Gnorimosphaeroma oregonensis	1	0.8
Corophium sp.	96	82.0

(a) Two fish had empty stomachs.

TABLE 27

PREY ITEMS OF ENGLISH SOLE COLLECTED IN COMMENCEMENT BAY DURING FALL 1980 AND SPRING 1981 (POOLED VALUES)

FALL 1980
Species (number): English sole (10)[a]
Mean length (range): 177 mm (115-236 mm)
Stations: 1, 3, 4, 6, 7

Prey Item	Total Number	% Occurrence
Polychaeta unid.	21	9.1
Ampharetidae	6	2.6
Armandia brevis	48	20.9
Capitella capitata	42	18.3
Cossura soyeri	32	1.3
Cirratulidae	16	6.9
Eteone longa	3	1.3
Glycera sp.	1	0.4
Maldanidae	2	0.8
Polydora sp.	1	0.4
Prionospio sp.	1	0.4
Prionospio steenstrupi	4	1.7
Spionidae	1	0.4
Bivalvia juv.	22	9.5
Bivalve siphons	31	13.4
Ostracoda	2	0.8
Harpacticoida	1	0.4
Lampropidae	1	0.4
Leptochelia savignyi	1	0.4
Gammaridea unid.	3	1.3
Corophium sp.	2	0.8
Westwoodilla caecula	2	0.8
Crangon sp.	15	6.5
Ophiuroidea juv.	1	0.4

SPRING 1981
Species (number): English sole (6)[b]
Mean length (range): 174 mm (93-280 mm)
Stations: 1, 3, 6

Prey Item	Total Number	% Occurrence
Nemertea	2	0.8
Polychaeta unid.	14	5.9
Armandia brevis	3	1.2
Capitella capitata	6	2.5
Cirratulidae	1	0.4
Eteone longa	1	0.4
Platynereis bicanaliculata	4	1.6
Prionospio steenstrupi	1	0.4
Oligochaeta	170	72.0
Leptochelia savignyi	28	11.8
Pseudotanais oculatus	2	0.8
Corophium sp.	2	0.8
Upogebia pugettensis	1	0.4
Insect larvae	1	0.4

(a) One fish had an empty stomach.
(b) Two fish had empty stomachs.

TABLE 28

PREY ITEMS OF STARRY FLOUNDER COLLECTED IN COMMENCEMENT BAY DURING FALL 1980 AND SPRING 1981 (POOLED VALUES)

FALL 1980
Species (number): Starry Flounder (2)
Mean length (range): 218 mm (191-245 mm)
Stations: 3, 6

Prey Item	Total Number	% Occurrence
Bivalvia juv. (prob. *Macoma* sp.)	6	75.0
Myodocopa	1	12.5
Glycinde picta	1	12.5

SPRING 1981
Species (number): Starry Flounder (5)
Mean length (range): 193 mm (106-246 mm)
Stations: 6, 8

Prey Item	Total Number	% Occurrence
Gammaridea unid.	13	31.7
Corophium sp.	6	14.6
Eogammarus confervicolus	3	7.3
Bivalve siphons	11	26.8
Capitella capitata	4	9.7
Eteone longa	1	2.4
Insect larvae	3	7.3

TABLE 29

PREY ITEMS OF FLATHEAD SOLE COLLECTED IN COMMENCEMENT BAY DURING FALL 1980 AND SPRING 1981 (POOLED VALUES)

FALL 1980
Species (number): Flathead Sole (3)[(a)]
Mean length (range): 162 mm (155-167 mm)
Station: 3
Fall 1980

Prey Item	Total Number	% Occurrence
Crangon sp.	8	100

SPRING 1981
Species (number): Flathead Sole (1)
Mean length (range): 230 mm (--)
Station: Milwaukee Waterway

Prey Item	Total Number	% Occurrence
Crangon sp.	4	100

(a) One fish had an empty stomach.

Polychaetous worms were the most abundant prey items in the English sole examined, except for 1 fish from spring 1980 that contained 170 oligochaetes (Table 27). English sole in the Nisqually Reach were also found to contain polychaetes as the dominant prey item (Fresh et al. 1980).

Bivalves, bivalve siphons, and gammarid amphipods comprised the majority of prey items identified in starry flounder (Table 28). Fresh et al. (1980) found a similar composition of prey items in starry flounder from Nisqually Reach. The small number of specimens collected prevents a quantitative comparison between sample periods; however, it appears that epibenthic crustacea became more important as prey items during the spring, while benthic organisms were most important during the fall. Seasonal fluctuations in abundance of epibenthic crustacea (high in spring-summer, low in fall-winter) probably contribute to the observed shift in prey items.

Pacific tomcod, Microgadus proximus, have been classified as obligate epibenthic planktivores (Miller et al. 1980), feeding exclusively on epibenthic organisms. Fresh et al. (1980) obtained results showing that tomcod in the Nisqually Reach area of south Puget Sound had prey spectra composed primarily of epibenthic organisms. Prey items identified in tomcod collected within the study area (Table 30) are primarily epibenthic, consisting mainly of ostracods (>60 percent) and crangonid and hippolytid shrimp (>20 percent). The number of tomcod analyzed (6) was too low to make quantitative comparisons between sample periods; however, Miller et al. (1980) reported considerable annual and between-habitat variability in prey composition of tomcod from the Strait of Juan de Fuca. The prey spectrum of tomcod is probably influenced by the makeup of the epibenthic biota in any particular habitat.

The Pacific herring, Clupea harengus pallasi, is an obligate planktivore (Miller et al. 1980) feeding exclusively on neritic organisms within the water column. Of the five specimens collected in the study area, four had empty stomachs and the fifth contained one cyclopoid copepod (Table 31). The small sample size and lack of prey items in the stomachs preclude an analysis of prey items within the study area.

TABLE 30

PREY ITEMS OF PACIFIC TOMCOD COLLECTED IN COMMENCEMENT BAY DURING FALL 1980 AND SPRING 1981 (POOLED VALUES)

FALL 1980
Species (number): Pacific Tomcod (5)
Mean length (range): 124 mm (88-195 mm)
Stations: 1, 2, 3

Prey Item	Total Number	% Occurrence
Myodocopa	27	61.3
Crangon sp.	11	25.0
Hippolytidae	2	4.5
Cancer sp.	2	4.5
Caridea unid.	2	4.5

SPRING 1981
Species (number): Pacific Tomcod (1)
Mean length (range): 83 mm (--)
Stations: Between Blair and Hylebos Waterway

Prey Item	Total Number	% Occurrence
Podocopa	81	67.5
Calanoida	30	25.0
Balanomorpha cyprids	4	3.3
Crangonidae	5	4.1

TABLE 31

PREY ITEMS OF PACIFIC HERRING COLLECTED IN COMMENCEMENT BAY DURING FALL 1980 (POOLED VALUES)

FALL 1980
Species (number): Pacific Herring (5)[a]
Mean length (range): 83 mm (69-100 mm)
Stations: Blair Waterway, Milwaukee Waterway

Prey Item	Total Number	% Occurrence
Corycaeus sp.	1	100

(a) Four fish had empty stomachs.

3.6 DISTRIBUTION OF FINFISH FOOD SPECIES, HABITAT TYPE, AND OCCURRENCE OF FINFISH SPECIES

3.6.1 Juvenile Salmon

Harpacticoid copepods were the most abundant prey item taken by all juvenile salmon species (except coho) and were also very abundant in, and often the dominant component of, nearshore habitats sampled by epibenthic pump (0.25-mm fraction). Harpacticoids were present at virtually every station (Tables 13-14), but were most abundant at subtidal stations of Transects 5 (June and August), 6 (April), 7 (April), and 8 (April, June, and August) and intertidally at Transects 5 and 8 in April. These stations have fairly similar subtidal bottom types, sandy muds with a large amount of organic debris forming a surface layer (Table 3). Though the intertidal stations of Transects 5 and 8 were primarily sandy they still contained large amounts of organic debris on the surface. Since harpacticoids consume detritus and/or its associated bacterial flora for food, it is not surprising to find the highest densities of harpacticoids in the study area in habitats containing large amounts of organic debris.

Juvenile salmonids from all transects contained harpacticoids; however, the highest mean values of harpacticoids as prey items in juvenile chum, chinook, and pink salmon occurred at Transects 2, 3, and 4. Other transects where harpacticoids were consumed in abundance by individual species were Transect 8 by chinook juveniles, Transect 5 by chum juveniles, and by chum at a Puyallup Nation beach seine site off Ruston Way near the ASARCO, Inc. smelter. It is interesting to note that Transects 2, 3, and 4 had the most feeding on harpacticoids by salmonids while Transects 5, 6, 7, and 8 had the highest densities of harpacticoids.

The nearshore sediments in the study area are generally classified as sandy silts and silty sands (see Sediment Studies Technical Report) with Transects 1 through 7 characterized by the former type. Transect 8, the Puyallup River mouth, contains a mixture of sands and silts distributed in random patches. The waterways that receive regular maintenance dredging would tend to have basically sandy bottoms with silty layers accumulating between dredging events. Waterways not regularly dredged and with low flushing rates could be expected to have greater accumulations of silty material. Based on this, it is likely that soft bottom habitats with organic debris surface layers, such as those found at Transects 5 through 8, are found elsewhere in the study area in nearshore regions not subject to regular channel dredging, flushing by tides and currents, or scouring by wave activity. These areas could also be predicted to have correspondingly high densities of harpacticoid copepods.

Gammarid amphipods, especially Corophium spp., were a common prey item of juvenile salmonids in the study area. While not consumed in the numbers that harpacticoid copepods were, their significantly larger biomass compared to harpacticoids makes them a prey item of major importance. Gammarid amphipods were collected at all transects although they were most abundant in a pattern similar to harpacticoids; subtidal stations at Transects 5 through 8. Gammarids were also very abundant and showed the greatest species diversity at Transect 4. Gammarid amphipods occupy a number of different trophic levels including detritivores, herbivores on macroalgae, carnivores, suspension feeders, and commensals (Simenstad et al. 1979). Preferred habitat type thus varies by a species' trophic level and food source. The majority of gammarid species collected in the study area are classified as detritivores, so habitats favorable to harpacticoid copepods (soft bottoms with lots of organic debris) might also be favorable to detritivorous gammarid amphipods.

Stomach content analysis results showed considerable variation between pink, chum, and chinook salmon in terms of the number of gammarid amphipods consumed. Generally, juvenile chum and chinook contained more gammarids than did pinks. Transects, 3, 4, 5, and 7 were the locations where gammarids were most abundant in the fish examined.

Calanoid copepods and drifting, terrestrial insects were also major prey items taken by juvenile salmonids. Calanoid copepods were collected at all epibenthic pump stations and were generally most abundant in April and June. Transects along Hylebos Waterway to Browns Point (1 through 4) and Commencement Park (5) had higher mean densities of calanoid copepods at both intertidal and subtidal stations than did the other transects (6, 7, and 8). Calanoid copepods are neritic organisms and should be thought of as components of the water column rather than any particular bottom type. Higher densities at Transects 3, 4, and 5 are probably related to steeper gradients or nearby deeper water at these stations compared to Transects 6, 7, and to some degree 8. Drift insects enter Commencement Bay from many sources. They may be washed in from the creeks flowing into the bay or by the Puyallup River. They can be windblown from upland areas or nearshore terrestrial vegetation and deposited on the water surface.

Both calanoid copepods and drift insects were taken in increasing numbers by juvenile salmon collected at transects with nearby deep water such as Transects 3, 4, and 5. Based on the suspected pattern of out-migration through the study area (see Fish Studies Technical Report), juvenile salmon would reach these areas toward the end of their residency after spending an initial time period within the waterways. They would have grown during this time and might be at the stage in their development when the shift to feeding on neritic prey occurs. Thus, the observed shift to calanoid copepods, drift insects, and other neritic prey may be more related to the developmental stage of the predator rather than prey availability. As an example, calanoid copepods were abundant at Transects 1 and 2, both intertidally and subtidally, during April and June but did not occur as prey items in the stomachs of juvenile salmonids from these areas. The primary prey items were harpacticoid copepods, indicating the fish were still bottom oriented in their feeding behavior.

Before a correlation can be made between the distributions of juvenile salmonids and their prey items, some limitations of the data base must be discussed. It was not possible to obtain stomach samples from all nearshore areas visited by outmigrating juvenile salmonids. The fish selected for stomach content analysis were usually those collected near an invertebrate transect and one or more of the salmon species present in the study area were often not collected at that transect. This necessitated pooling the data by species to give a representative sample for each salmonid species. Also, the assumption was made that the fish had been feeding in the area where they were collected and had not just recently arrived from somewhere else. Finally, epibenthic prey items are not stationary. They are mobile and move vertically and horizontally through nearshore areas in response to physical and biological factors.

Catch per unit effort (cpue) statistics for juvenile chinook salmon were relatively high at all beach seine stations during May and June but were highest at the mouth of the Puyallup River (see Fish Studies Technical Report). Juvenile pink cpue was highest at beach seine Stations 2, 4, 5, and 8 during April. Juvenile chum cpue was highest at beach seine Stations 2 and 4 in April and Stations 4 and 6 in June. These cpue data agree somewhat with the abundance data for harpacticoid copepods. Harpacticoids were most abundant at invertebrate Transects 5 through 8 and less abundant, although still dominant overall, at Transects 1 through 4. Puyallup Tribal Fisheries Division beach seine data for 1980 (unpublished) showed higher overall cpue values for chinook salmon in City Waterway than in Hylebos Waterway. These results show a good apparent correlation between prey item distribution (harpacticoids) and juvenile salmonid distribution.

Since harpacticoid copepods were numerically dominant at most stations sampled and also were the most abundant prey item taken by juvenile salmonids, it is obvious that they are an important component of nearshore epibenthic communities. Soft mud habitats with an organic debris surface layer that support harpacticoid populations are probably important feeding areas for juvenile salmonids during their early period of outmigration through the study area. As the juvenile salmonids grow and move to outer bay regions, neritic prey items become more important.

3.6.2 Marine Fish

Prey items taken by flatfish (Tables 26-29) were primarily benthic, infaunal organisms although epibenthic crustaceans were also consumed. The infaunal species taken were primarily polychaetes and bivalves.

Stomach contents and prey species present at a particular site agreed fairly well although the percentage taken was often different from that prey species' percent occurrence, indicating feeding selectivity by the fish. Miller et al. (1980) reported high between-habitat variability in the diet of juvenile English sole in the Strait of Juan de Fuca and concluded that although a few prey taxa may be important to the diet of a species, the proportional contributions among the prey taxa vary considerably between habitats.

English sole, rock sole, and flathead sole were slightly more abundant in the waterways than along the outer bay shoreline. These waterways have also been shown to contain populations of the prey items preferred by these fish. However, since these fish species are somewhat opportunistic in terms of foraging strategy, it is difficult to draw comparisons between their abundance patterns and those of their prey species. The nearshore regions of the study area are definitely used for feeding by marine fish but more information needs to be gathered to determine the importance of specific prey items on a seasonal and between-habitat basis.

4.0 CONCLUSIONS

A number of conclusions about the invertebrate communities in Commencement Bay can be made based on the results of this study.

1. Recreational fishing for shrimp and crab is widespread in the study area, although data on shellfish populations and catch statistics are generally lacking. Commercial fishing for shrimp and crab does not occur within the study area.

2. Approximately 229 taxa were identified in the study area. The species present have also been reported from other areas of central and southern Puget Sound. One harpacticoid species was identified that had not been found in other areas of Puget Sound.

3. Transects sampled show a general trend of increasing species diversity, abundance, and richness values with increasing depth.

4. Seasonal effects in species diversity, abundance, and richness were observed in the epibenthic populations but were absent in the infaunal populations.

5. Infaunal stations form groups mainly by depth level while epibenthic stations show no obvious pattern of station grouping by depth.

6. Juvenile salmonids feed extensively on epibenthic crustaceans (especially harpacticoid copepods) in nearshore environments during their period of outmigration through the study area. A shift to neritic organisms is seen in larger fish at outer bay collection sites.

7. Marine fish feed on a wide variety of benthic, infaunal invertebrates in the study area. A strong correlation was observed between stomach contents of a fish from a particular station and the infaunal organisms present at that station.

8. A positive correlation exists between harpacticoid copepod distribution and high catch values of juvenile salmonids. Soft mud habitats with an organic debris surface layer support high densities of harpacticoids and are probably important feeding areas for juvenile salmonids.

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