STRUCTURE, DISTRIBUTION, AND SEASONAL DYNAMICS OF THE BENTHIC COMMUNITY IN THE UPPER NEWPORT BAY, CALIFORNIA

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ABSTRACT

The benthic community in the Upper Newport Bay was sampled at two intertidal and two subtidal depths at three stations during five assessment periods between October 1977 and January 1979. Heavy sediment deposition occurred during the 1977-1978 winter period, and the sedimentary environment was transformed from one characterized by fine sands (January 1978) to one dominated by silts (January 1979). Total density, species richness, and species diversity were generally lowest at the uppermost station (Ski Zone) and highest at the lowermost station (Shellmaker Island). Immediately following the 1977-1978 winter rainy period, total faunal density was extremely low, particularly at the Ski Zone station. However, heavy recruitment after April 1978 resulted in maximal total density values at all stations in August 1978. Species richness was highest during October 1977 and lowest in April 1978 following the heavy rainfall period. The benthic community was dominated in October 1977 by three polychaetes, *Fabricia limnicola*, *Streblospio benedicti*, and *Capitella capitata*. By August 1978, *F. limnicola* had not recruited back into the community and three additional polychaete species (*Polydora ligni*, *Pseudopolydora paucibranchiata*, and *Scolelepis acuta*) shared community dominance with *C. capitata* and *S. benedicti*. The crustaceans showed strong seasonal oscillations, being abundant in the October and August samples and occurring sparsely in the January and April samples.

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INTRODUCTION

Biological investigations in the Upper Newport Bay (summarized by Daugherty, 1978b) have been few. Even more restricted are the number of studies concerned with the soft bottom benthic community. The effects of fresh water inundation on the Upper Bay following a severe storm in March of 1938 were reported by MacGinitie (1939). Mass mortalities resulted from the storm, but many animals became reestablished more abundantly than before March. MacGinitie considered the sediments deposited from the storm waters to have created a favorable environment for benthic reestablishment. Only two qualitative studies (Barnard and Reish, 1959; Frey, et al., 1970), which were primarily taxonomic, and one quantitative study (Daugherty, 1978a) have been conducted on the soft bottom benthos in the Upper Bay. Of the 56 subtidal stations occupied by Barnard and Reish (1959) throughout Newport Bay, 21 were located in the Upper Bay. Polychaetes were identified and enumerated from 0.065 m^2 Orange-Peel Grab samples collected in January 1954. Gammaridean amphipods were analyzed from these samples, as well as from intertidal samples and piling and float scrapings taken between 1951 and 1953. From the subtidal samples taken in the Upper Bay, a total of 43 species of polychaetes and 19 species of gammarids were recorded. From an intertidal site immediately north of the Pacific Coast Highway Bridge (Fig. 1), 13 species of gammarids were collected in December 1953. Eight of these 13 species were also recorded from the subtidal samples taken in January 1954 from the Upper Bay.

A list of 216 invertebrate taxa was compiled by Frey et al. (1970) for the Upper Bay, of which 155 were not restricted to hard substrates such as pilings, floats, and boulders. Polychaetes were best represented (53 taxa), followed by the bivalves (26 taxa) and gastropods (23 taxa). The gammaridean amphipods were not identified below this higher taxonomic level, nor were the copepods, ostracods, cumaceans, leptostracans, turbellarians, nemerteans, or phoronids. Taxa were not enumerated in this study, but were assigned abundance levels of very common, common, and rare.

Results of a subtidal benthic study in 1975 and 1976 in the Upper and Lower Bay were reported by Daugherty (1978a). Three replicate samples were collected with an 0.05 m^2 Ponar Grab at each of 8 stations in mid September 1975 and late March to early April 1976. Two of these stations were located in the Upper Bay, close to two of the stations established in the present study off Shellmaker Island (off North Star Beach) and in the Ski Zone (Fig. 1). The latter station was also sampled in late February 1976. At the station off Shellmaker Island, Daugherty reported a 37% decline in number of taxa from September to March-April. At the Ski Zone station, on the other hand, the number of taxa decreased by 75% between September and February, but then increased by a factor of two in March-April. This decline in number of taxa at the Ski Zone was accompanied by a 25-fold decrease in total density between September and February. However, this decrease was followed by a 4-fold increase in March-April. At the station off Shellmaker Island, by comparison, total density decreased only slightly (a 30% reduction) between September and March-April.

In summary, the objective of the Barnard and Reish (1959) study was principally to characterize the taxonomic composition and distribution of the subtidal benthic polychaetes and gammaridean amphipods throughout Newport Bay. Daugherty (1978a) was concerned, in contrast, with characterizing the taxonomic composition and abundance (density) patterns of the entire subtidal benthic fauna at the end of summer (September) and in late winter (March-April) at a restricted number of stations (8) located in selected areas of the bay. In addition to being restricted to the Upper Bay, the present study differs from Daugherty's in that (1) an additional station was established in the Upper Bay near Big Canyon (Fig. 1), (2) each station was sampled five times over a 16-month period from October 1977 to January 1979 to enable a temporal characterization of the dynamic nature of the benthic community, and (3) each station was sampled during each assessment period at subtidal depths (midchannel and -2.5 ft) and in the intertidal zone (at Mean Lower Low Water and +2.5 ft). As in Daugherty's study, density data represented means of replicated samples.

MATERIALS AND METHODS

Sampling sites in the Upper Bay (Fig. 1) were established in October 1977 at Shellmaker Island (Station I), at the mouth of Big Canyon (Station II), and in the Ski Zone region (Station III). Sites for the determination of temperature and salinity (using an _in situ_ Beckman Model RS5-3 Salinometer) were established at midchannel depths in the vicinity of each station (Fig. 1). Five seasonal assessments were made at the three stations; 24-28 October 1977, 19-23

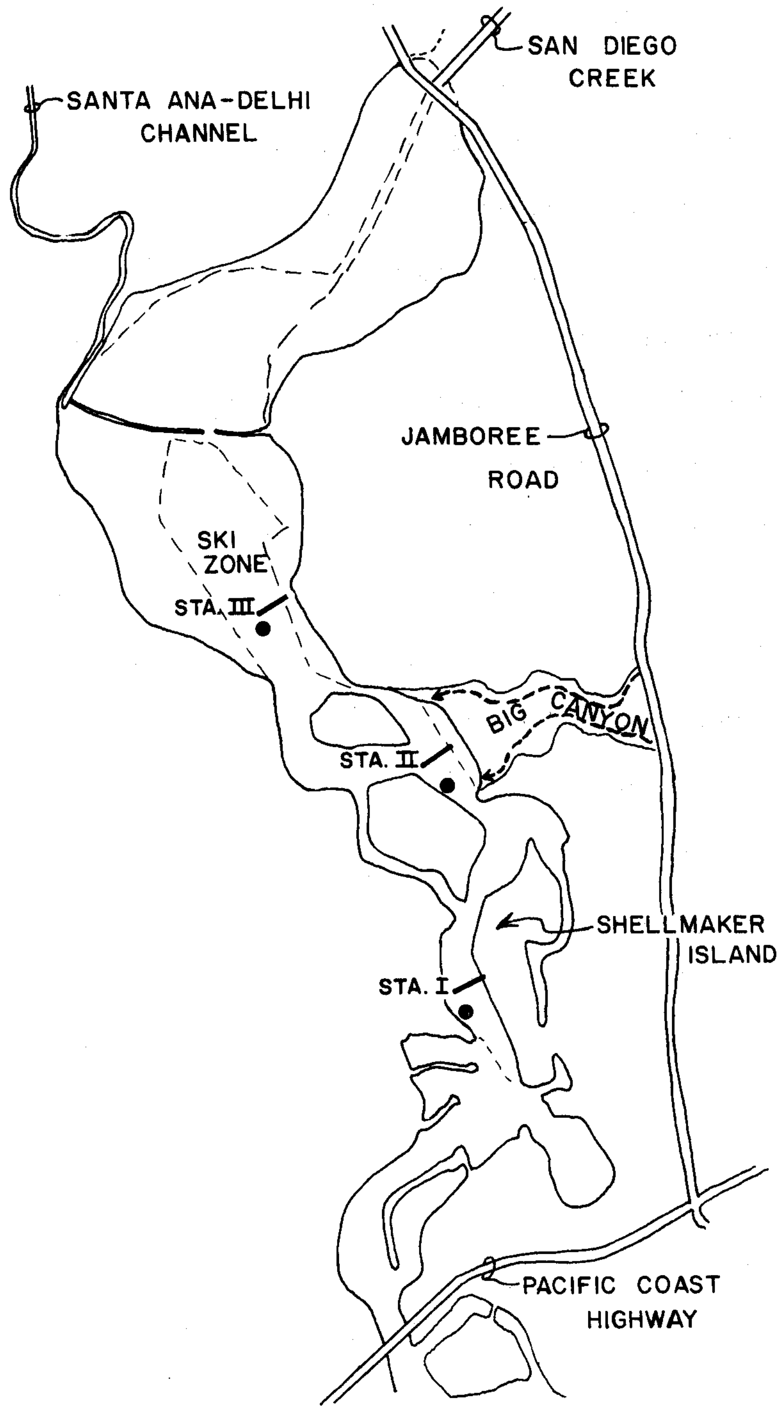


FIGURE 1. Location of sampling (lines) and hydrographic (solid circles) stations at Shellmaker Island, Big Canyon, and the Ski Zone in Upper Newport Bay.

January 1978, 1-7 April 1978, 2-5 August 1978, and 8-11 January 1979.

Duplicate benthic samples were collected at each station at approximately +2.5 ft, 0.0 (Mean Lower Low Water), -2.5 ft, and at midchannel. Sampling locations were mapped for each station during each visit with reference to fixed landmarks in order that subsequent samples could be taken in immediately adjacent, but non-overlapping locations. Midchannel and -2.5 ft sampling locations were determined from a boat by traversing the channel at each station and taking soundings to find the deepest area and the location corresponding to the -2.5 ft level.

Grab samples were taken at all depths with an Ekman-Birge Dredge (surface area = 0.04 m^2). Grab contents were washed through a bucket sieve having a mesh size of 0.6 mm. At intertidal and -2.5 ft depths, the grab was forced into the substrate by hand or foot, usually to a depth of 12 cm. Adequate samples were obtained at midchannel depths by the free fall of the grab, except at Station I where it had to be forced into the substrate by a diver. At the -2.5 ft and midchannel depths, the location of each grab sample was not predetermined, but was established haphazardly by dropping the grab off the side of the boat. Sampling locations at the 0.0 and +2.5 ft levels were positioned by running out a transect line perpendicular to the shoreline, determining the 0.0 and +2.5 ft locations on the line by standard surveying techniques, and then going to the right or left of the line by 1 or 2 m, using a coin flip to determine which of the two alternatives to follow. At the 0.0 and +2.5 ft depths, the deeper burrowing organisms were sampled by pushing a large cylindrical coring device with a surface area of 0.145 m^2 (see Seapy and Kitting, 1978) into the substrate to a depth of 40 cm. The sediments were removed by hand and washed through a bucket sieve having a mesh size of 2.0 mm. Sediments and organisms retained in the bucket sieves were transferred to quart jars and preserved in 10% buffered seawater-formalin solution. To assess the epifauna at the 0.0 and +2.5 ft levels, a 1.0 m^2 quadrat made of 2.5 cm PVC tubing was laid on the substrate and the contained area was carefully searched for invertebrates. The 1.0 m^2 quadrat was employed principally as a method to census the intertidal mudsnail Cerithidea californica. The 0.0 and +2.5 ft samples were taken by initially placing the 1.0 m^2 quadrat on the substrate and collecting the epifauna. The 0.145 m^2 corer was then positioned in the center of the 1.0 m^2 quadrat, followed by the 0.04 m^2 grab. The 0.04 m^2 grab sample was removed from the middle of the core, and then the core sample was removed. For those species enumerated from the core samples, individuals recorded from the contained grab samples were added to the core sample counts. All density data were expressed in terms of numbers of individuals per square meter.

Sediment samples were collected from each tidal level at each station using a hand-operated plexiglass coring tube, 5 cm in diameter and 20 cm in length. Samples were prepared for grain size analysis in the laboratory by treatment with a 30% solution of hydrogen peroxide to eliminate organic matter. Analysis of the sand fraction of each sample was made by the settling tube method of Emery (1938). Determination of the percent of the sample representing the silt-clay fraction was made by wet-sieving a portion of each sample through a 0.0625 mm sieve (corresponding to the grain size of 4 Ø, which separates the very fine sands from the coarse silts). The sand fraction was set aside. An aliquot (usually about 10%) of the silt-clay fraction was transferred to centrifuge tubes and spun down at 12,000 rev per min for 10 min in a Sorval RC2-B Centrifuge. The supernatent was decanted off and the sediments washed into an aluminum weighing dish. The sand and silt-clay samples were dried in an oven at 60°C. Mean grain size was determined by plotting cumulative percent composition in phi (∅) units on probability graph paper (after Inman, 1955). When the silt-clay fraction represented greater than about 60% of the sample, the mean grain size could not be accurately estimated graphically. Because the grain size distribution of the silt-clay fraction was not determined, the mean value was recorded as >4.5 ∅.

During the November 1977 and January 1978 sampling periods, sediment samples were collected for analysis of organic carbon content. These samples were frozen within 4 hrs of collection, and were kept frozen until the time of analysis, at which time they were dried in an oven at 60°C, and then pulverized in a Spex Grinder for 30 min. Subsamples were taken to determine total carbon, using an automated LECO Model WR-12 Carbon Analyzer, and inorganic carbon, by acid digestion (after Kolpack and Bell, 1968). Organic carbon content was subsequently computed as the difference between total carbon and inorganic carbon content.

Two measures of species diversity were calculated: Shannon's (Shannon and Weaver, 1962) index ($H' = \Sigma\ p_i \log p_i$), and an index of evenness ($J' = H'/\log s$) after Pielou (1969). Comparisons of community structure between the different tidal levels and stations and between assessment periods were made by computer-mediated cluster analyses, where the percent ecological distance (or dissimilarity) between the various possible station pairs was determined using the Bray-Curtis measure,

$$D = \sum_{1}^{n} |x_{1j} - x_{2j}| \;/\; \sum_{1}^{n} (x_{1j} + x_{2j});$$

where n is the number of species, and x_{1j} and x_{2j} are the densities (in numbers per m^2) of the jth species at Station 1 and at Station 2, respectively. The Bray-Curtis measure is considered (Clifford and Stevenson, 1975) to be optimal for these sorts of ecological data.

RESULTS

Hydrography

Physical-chemical properties of the waters in the Upper Bay are strongly influenced by (1) the relative isolation of these waters (exchange with waters in the Lower Bay occurs only through a narrow gap traversed by the Pacific Coast Highway; Fig. 1), and (2) by the seasonally-variable levels of fresh water runoff from the surrounding and inland watershed. A year-round inflow of fresh water, primarily from agricultural sources (Scherfig, 1979), enters the upper reaches of Newport Bay from the San Diego Creek (Fig. 1) and dominates the total fresh water flow into the bay. Secondary inputs of runoff water (Scherfig, 1979) are from the Santa Ana-Delhi Channel (principally from urban and industrial sources), Big Canyon Creek (primarily from residential sources), and two other minor points. These year-round inputs result in a reduction in the salinity of Upper Bay waters even during non-rainy periods.

The five sampling periods utilized during this study occurred at critical times relative to the unusually wet winter season of 1978 (Fig. 2), which contributed to a total annual rainfall that was equivalent to 250% that for a normal year (NOAA, 1977, 1978, 1979). The initial assessment made in October 1977 was preceded by a 6 month period during which a total of 9.1 cm of rain had fallen in the Newport Bay area (NOAA, 1978). The January 1978 visit was made late in an usually rainy month, when a total of 20.1 cm of rainfall was recorded (Fig. 2). High rainfall continued during February and March, with monthly totals of 14.2 and 18.2 cm. In April the rainfall had decreased to 3.9 cm. Thus, the third sampling period in early April came at the end of this unusually rainy winter season. During the months of May, June, and July, there was no rainfall, and the sampling period of early August took place at a time preceded by three dry months. Because of the 5.3 cm and 10.6 cm of rain recorded in September and January, respectively, the intervening period between the August 1978 and January 1979 sampling dates can be characterized as having a somewhat higher than normal total rainfall.

The pattern of seasonal input of freshwater into the Upper Bay is reflected in the salinity data collected during each of the site visits (Fig. 3). In October 1979, salinities at the three stations were high, ranging from values of 26.7 to 29.8 $^{o}/oo$ at the surface to 34.3 $^{o}/oo$ at a depth of 4 m at Station I. In January 1978, the Upper Bay waters were appreciably diluted by fresh water inflow, resulting in surface salinities ranging from 13.0 $^{o}/oo$, (Station I) to 8.1 $^{o}/oo$ (Station II). Bottom salinity at Station III was 11.2 $^{o}/oo$, while bottom salinities were 19.3 and 17.7 $^{o}/oo$ at Stations I and II, respectively, reflecting the mixing of these deeper waters with Lower Bay waters.

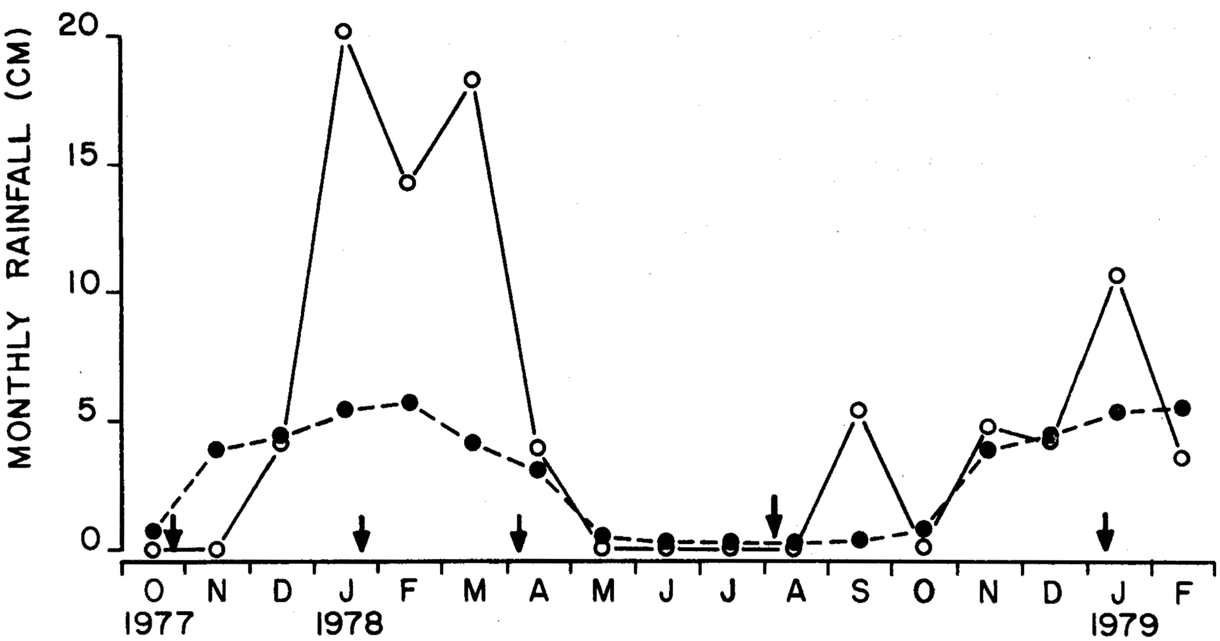


FIGURE 2. Total monthly rainfall between October 1977 and February 1979 (open circles) compared with the February 1979 (open circles) compared with the long term, mean monthly rainfall for Newport Bay (solid circles). Data from NOAA (1977-1979). The times at which the five sampling dates occurred are indicated by vertical arrows.

In April, the surface waters had extremely low salinities (ranging from 7.3 ^{o}/oo at Station I to 1.2 ^{o}/oo at Station III), while salinity increased with depth to values of 23.2 ^{o}/oo at Station II and 25.1 ^{o}/oo at Station I. Here, the increase of salinity with depth and the lowering of salinity at stations further inland produce an excellent profile of the effects of freshwater input on the hydrography of the Upper Bay. By August 1978, salinities at Stations I and II were comparable with the October 1977 values, although freshwater inflow was still influencing the water column profile at both stations and had strongly lowered the salinity at Station III. It is noteworthy that the salinity at Station III (10.3 ^{o}/oo) was determined at the time of the low tide (+2.0 ft) and one would expect that the runoff from San Diego Creek (Fig. 1) should strongly influence water properties at that time. These influences were also reflected in the lowered surface salinities at Stations II (25.4 ^{o}/oo) and I (29.2 ^{o}/oo). The January 1979 study period was preceded by a somewhat higher than normal rainfall (Fig. 2), and salinities at the three stations were quite comparable at the surface, ranging from 19.6 ^{o}/oo (Station III) to 23.1 ^{o}/oo (Station II), and increasing to 30.9 ^{o}/oo at the bottom at Station I.

Water temperatures, taken at each station during each assessment period (Fig. 4), clearly show a pattern of seasonal variability and the effects of the Upper Bay's isolation from open ocean influences. During late October 1977, temperatures ranged from 18.2 to 20.8°C, with values at any given depth being higher in progression from Stations I to III. In January 1978, temperatures had dropped to a range of 14.2 to 16.0°C, with temperatures at Station II being higher than

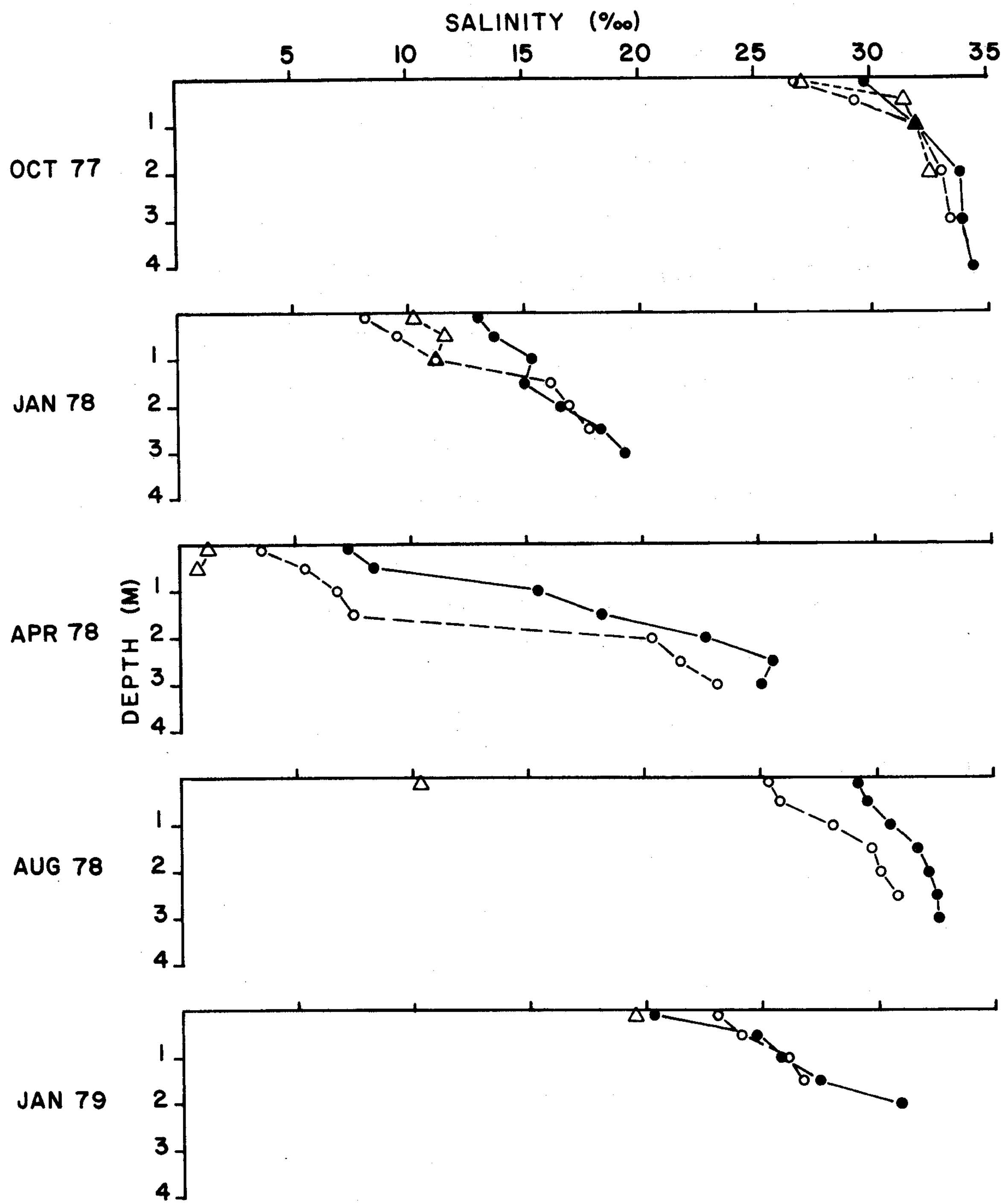


FIGURE 3. Salinity plotted as a function of depth for each of the five visits from October 1977 to January 1979 at Stations I (solid circles), II (open circles), and III (open triangles) in Upper Newport Bay.

those at Station I, and Station III being colder than Station II; probably as a result of mixing with inflowing colder fresh water. Although the waters were somewhat warmer in April 1978, a similar pattern was exhibited, with temperatures at Stations I and II (range of 16.2 to 16.7°C) being nearly identical and Station III (15.0 to 15.5°C) being influenced by colder inflowing fresh water. By August 1978, Upper Bay waters were very warm (22.3 to 35.4°C), with the effects of isolation becoming more pronounced as one progresses from Stations I to III. Temperatures at all three stations were similar in January 1979, and were about 1°C colder than those recorded in January 1978.

Sediments

The transport of sediments into the Upper Bay during the winter rainy season of 1978 was considerable. No estimates of the quantities transported into or deposited in the Upper Bay are made here, although our measurements of bottom depths at midchannel locations for each station give an indication of the magnitude of these deposits. Midchannel samples for October 1977 were taken at -9.8 ft at Station I, -7.2 ft at Station II, and -2.6 ft at Station III. By August 1978, the midchannel depths were noticeably shallower, being -7.5 ft at Station I, -5.6 ft at Station II, and +0.5 ft at Station III. These shallower depths were essentially established by April 1978, with the January 1978 period presenting intermediate depths, e.g., the depth at Station III was -1.6 ft in January.

The grain size distribution of the sediments changed noticeably over the course of the study (Table 1), with the mean particle size

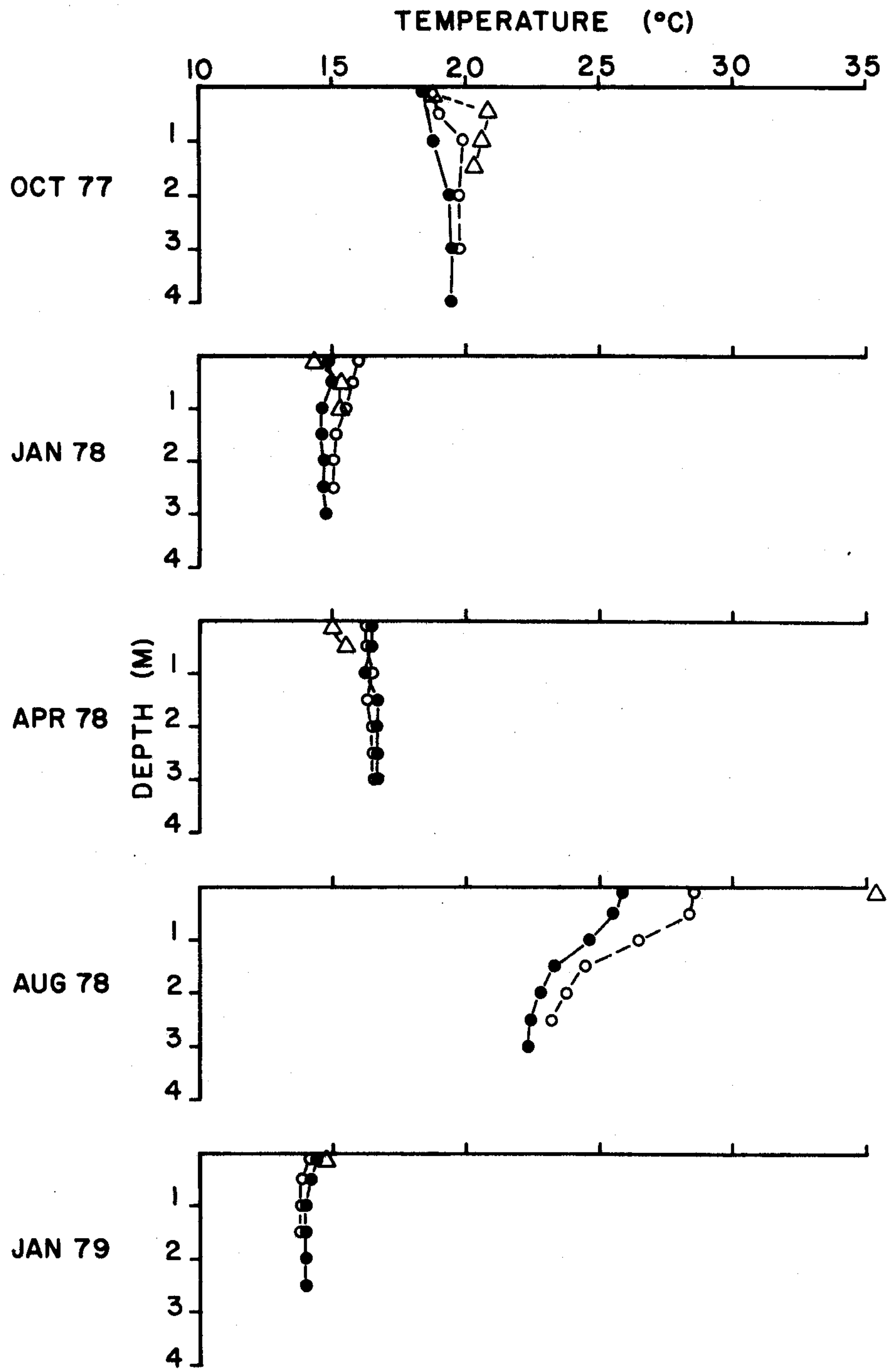


FIGURE 4. Temperature plotted as a function of depth for each of the five assessments from October 1977 to January 1979 at Stations I (solid circles), II (open circles) and III (open triangles) in the Upper Newport Bay.

shifting from predominantly fine and very fine sands (2.0 to 4.0 Ø) in January 1978 to silts (>4.0 Ø) by August 1978. In January 1979, only the +2.5 ft level at Station I had a mean grain size (3.60 Ø) that was not in the silt region of the scale. This temporal change in the increasingly fine nature of the sediments is also shown (Table 2) by the progressive increase in representation by the silt-clay fraction of the samples. In January 1978, the sediments generally possessed low percentages of silts and clays (average = 19.30%; range = 0.62 - 66.04%). By August 1978, the character of the sediments had changed markedly and the silt-clay fraction dominated in most samples, averaging 72.92%. This continued through to January 1979, when the mean percent was 81.13%, and the range of values had decreased substantially (standard deviation = 19.89 in contrast with 32.77 in August 1978). It is noteworthy that the winter rains deposited sediments by April that were finer than existed in January, while additional deposition of fine sediments or a reworking of the existing sediments resulted in a marked increase in the silt-clay fraction by August 1978, and continued to January 1979. These data imply that a substantial change in the sedimentary environment took place during the summer months, despite the fact that fresh water inflow, and hence additional sediment input, should have been at a seasonal low.

Analysis of the organic carbon content of the sediment samples from October 1977 and January 1978 (Table 3) revealed an average of 0.93 and 0.98% organic carbon, respectively, and a broad range of values (from 0.24 to 1.70%), which were generally higher in October at Station III and were lowest at Stations IIA, IIB, and IIIA during both

TABLE 1. Mean particle size (Ø) in sediment samples from stations occupied between January, 1978 and January, 1979.

	Date			
Station	Jan 78	Apr 78	Aug 78	Jan 79
IA	1.84	1.38	2.86	3.60
IB	3.05	>4.50	>4.50	>4.50
IC	2.93	>4.50	>4.50	>4.50
ID	2.19		2.98	>4.50
IIA	2.34	3.24	>4.50	4.20
IIB	2.80	3.10	>4.50	4.50
IIC	4.18	3.18	4.31	>4.50
IID	3.15	3.16	>4.50	>4.50
IIIA	2.91	4.45	>4.50	>4.50
IIIB	4.24	3.20	>4.50	
IIIC	>4.50			
IIID	3.49	3.60	>4.50	>4.50

TABLE 2. Percent silt-clay fraction in sediment samples from stations occupied between January, 1978 and January, 1979.

	Date			
Station	Jan 78	Apr 78	Aug 78	Jan 79
IA	0.62	0.09	7.81	37.64
IB	8.49	70.94	92.03	94.36
IC	4.75	68.29	94.52	92.48
ID	3.05		13.57	78.51
IIA	0.78	48.33	76.75	56.62
IIB	9.30	30.43	91.68	97.32
IIC	55.96	6.52	60.95	93.09
IID	10.14	13.28	76.81	88.83
IIIA	14.04	56.19	98.45	97.25
IIIB	53.85	18.28	91.80	
IIIC	66.04			
IIID	4.57	26.92	97.71	75.23
Mean	19.30	33.93	72.92	81.13
Standard Deviation	24.19	25.52	32.77	19.89

October and January. As the percentage of the sediment samples represented by the silt-clay fraction increases, one would expect that the organic carbon content should also increase. This relationship infers that the reduced water velocities required for deposition of the fine sediments also permits deposition of lighter particulate organic matter. Using the January 1978 data for mean particle size and percent organic carbon content of the sediments (Tables 1 and 3), a correlation coefficient of 0.42 was computed, which was not significant at the 5% level (an r value of 0.602 for 10 d.f. would have been required for significance; Rohlf and Sokal, 1969). The lack of a significant positive correlation may be related to limited variation in the physical environment sampled in the Upper Bay.

TABLE 3. Percent content of organic carbon in sediment samples from stations occupied in October, 1977 and January, 1978.

	Date	
Station	Oct 77	Jan 78
IA	0.24	0.40
IB	0.26	0.53
IC	0.70	1.12
ID	0.79	
IIA	0.52	0.44
IIB	0.71	1.70
IIC	1.33	1.47
IID		1.16
IIIA	1.58	1.25
IIIB	1.55	1.01
IIIC		1.13
IIID	1.48	0.54
Mean	0.93	0.98
Standard Deviation	0.55	0.44

Density and Diversity Patterns

The total number of individuals per m^2 at each tidal level was averaged for each station during each seasonal assessment (Fig. 5). During each assessment period, the total density was highest at Station I and lowest at Station III. Lowest densities at each station occurred during the rainy season visits of January and April 1978. Interestingly, the declines in density by nearly 15 fold at Stations II and III between October 1977 and January 1978 reflect the short-term impact of the winter rains on the isolated upper portions of the bay. Station I, which is less isolated than the other stations, experienced only a 3-fold decrease in density between October and January. However, total density at Station I declined further in April, while numbers actually increased by April at Stations II and III. Recruitment to the benthic community between the April and August censuses was heavy, resulting in higher numbers than occurred during the October 1977 sampling period, and with density increases of nearly 10 fold (Stations I and II) and 15 fold (Station III). The more "normal" winter period of 1978-1979 resulted in density decreases by January 1979 at each station that were related to the degree of isolation of each station, _i.e._, 9.4-, 5.5-, and 3.0-fold declines at Stations III, II, and I, respectively, between August 1978 and January 1979.

The total number of species present during each assessment (Fig. 5) was highest at Station I and lowest at Station III, except during October 1977 for Stations I and II. Species numbers decreased sharply at each station during the rainy period, from 84 in October to 24 in April at Station I, from 60 in October to 13 in April at Station

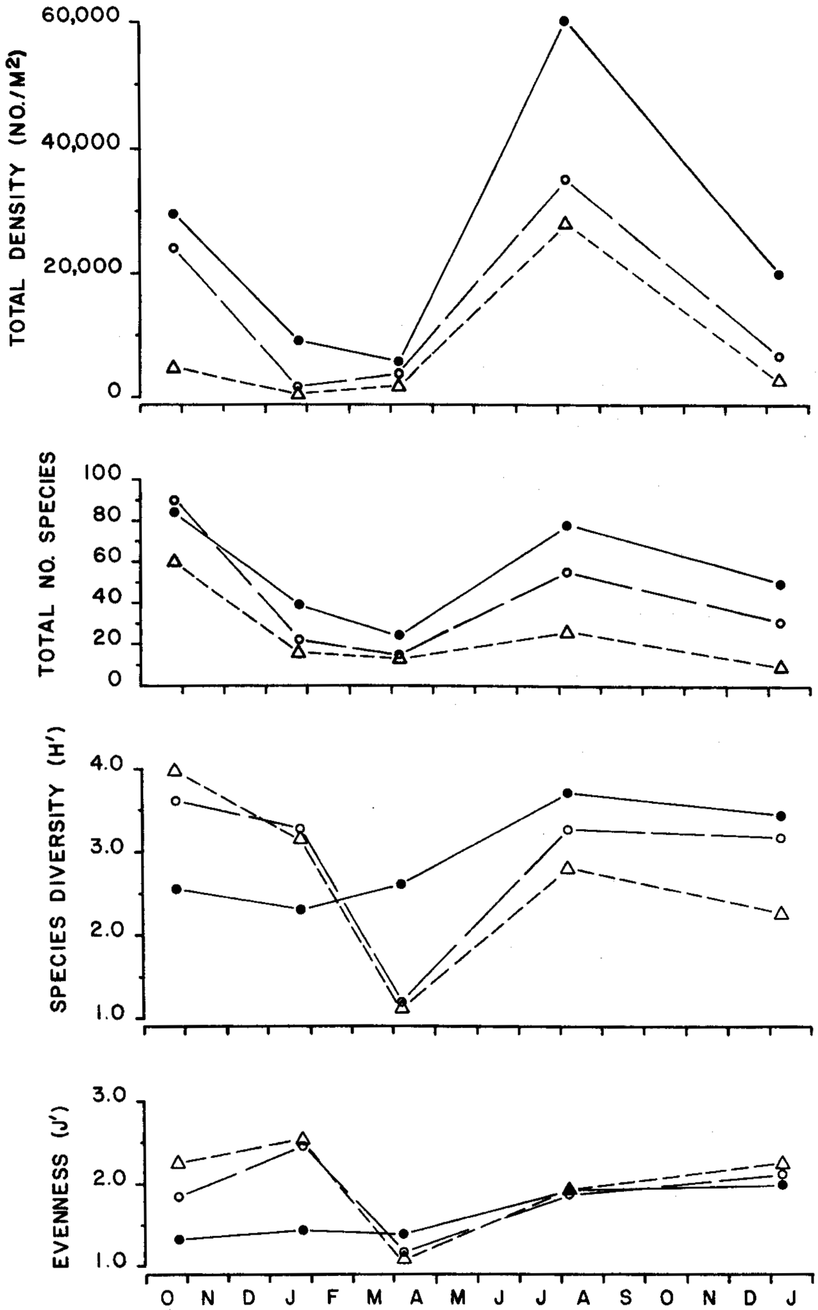


FIGURE 5. Total density, number of species, species diversity, and evenness for each of the five assessments at Stations I (solid circles), II (open circles), and III (open triangles) in the Upper Newport Bay.

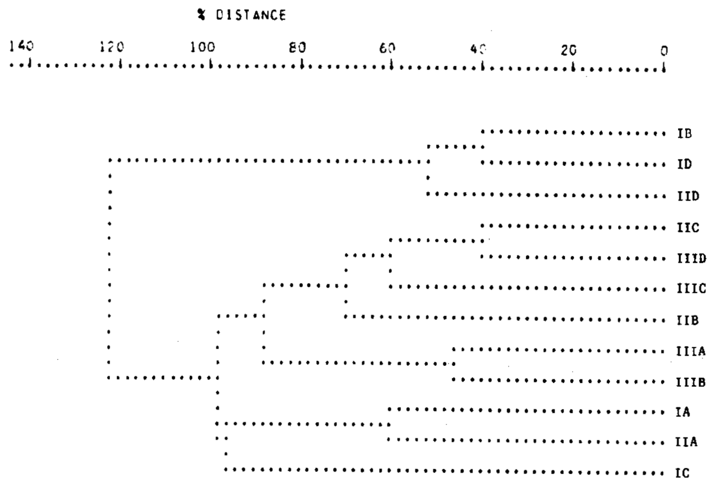
III, and with Station II showing the greatest decline, from 90 in October to 14 in April. Species numbers increased by two to four fold between April and August, but declined again by January 1979. Comparison of species numbers for the October 1977 and August 1978 assessments (Fig. 5) suggests that while Station I had nearly recovered (84 vs 78 species), neither Stations II or III (90 vs 55 species and 60 vs 26 species, respectively) had recovered appreciably following the 1978 rainy season. Comparison of species numbers between January 1978 and January 1979 indicate that although fewer species were recorded at Station III in January 1979 (18 vs 10), higher numbers occurred at Stations I and II (39 vs 50 and 22 vs 31, respectively). These data are possibly explainable by the observation that midchannel depths at the three stations did not appear to become shallower between October 1978 and January 1979. Thus, sediment deposition prior to the January 1979 sampling would appear to have been negligible, while sediment transport into the Upper Bay preceding the January 1978 assessment appears to have been substantial, and could have had smothering or burial effects on the fauna.

Using average species density data at each station, Shannon diversity index (H') values were computed (Fig. 5), which indicate parallel trends for Stations II and III, i.e., maximal diversity in October 1977 (H' = 3.62 and 3.98, respectively), followed by a decline to lows of 1.17 and 1.12 in April. After April, trends at the three stations were similar; increasing in August, and then decreasing somewhat in January 1979. Diversity changes at Station I between October and April were peculiar, with lower values than either of the other stations during October and January and a higher value in April. Since species numbers were higher (except for October 1977) at Station I, the depressed H' values for October and January 1978 can be attributed to low evenness among the species densities (Fig. 5), while Stations II and III, which had lower total densities and a higher evenness component, had higher H' values. Similarly, the reason H' was not lower at Station I in April is partially attributable to the fact that the evenness component at that station was higher than at the other two stations. In August and January 1979, J' values for the three stations were similar (Fig. 5), and the differences in H' between the stations is clearly related to (and parallels) the richness component, i.e., species numbers.

Community Structure

Cluster analyses were performed to determine station and tidal level groupings for each visit. The dendrogram obtained from analysis of the October 1977 visit (Fig. 6a) reveals the presence of two major groupings, of which the second can be further subdivided at the 90% distance level. Interpretation of these patterns is facilitated by overlaying the cluster groups on a map of the study area (Fig. 6b). The first cluster group is seen to include the midchannel samples at Stations I and II and the MLLW sample at Station I. The +2.5 ft samples at Stations I and II are also distinctive as a separate cluster group. The remaining group is large and includes the 0.0 and -2.5 ft samples at Station II and all of the Station III samples. Within this grouping, the 0.0 and +2.5 levels at Station III are distinctive from the remaining four sites shared between Station II

(a)



(b)

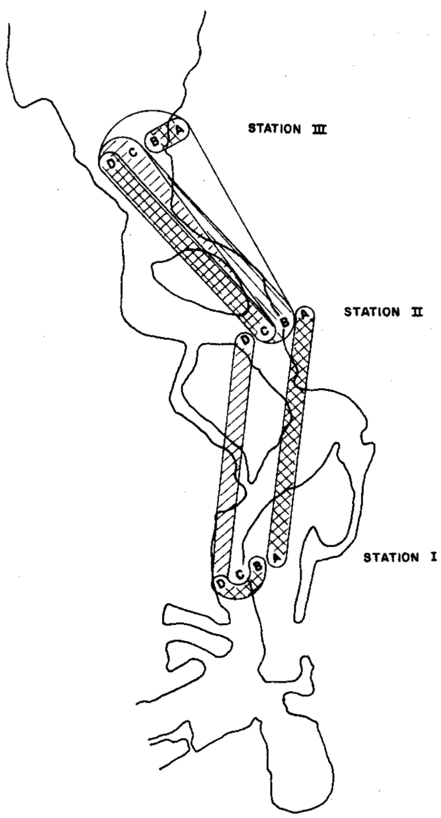
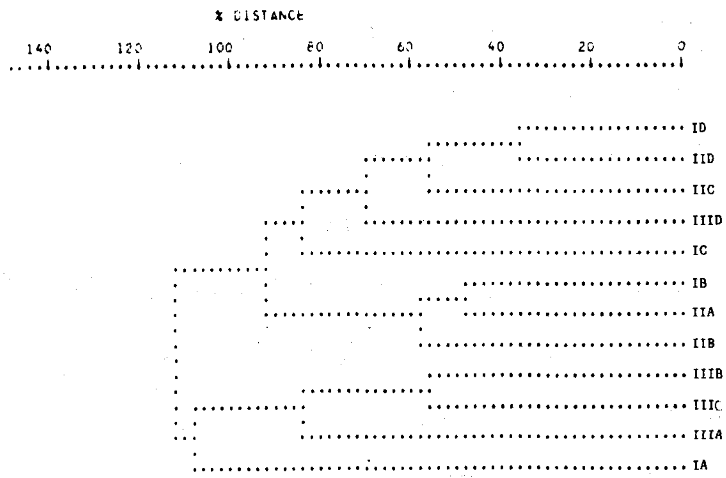


FIGURE 6. (a) Dendrogram plot of cluster analysis results for the October 1977 assessment. (b) Overlay of cluster groups on a map of the Upper Newport Bay based on the dendrogram plot.

(0.0 and -2.5 ft) and Station III (-2.5 ft and midchannel). Thus, the sites are grouped both horizontally and vertically; Stations I and II are linked at the midchannel and +2.5 ft levels, while Stations II and III are linked at 0.0 and -2.5 ft and at -2.5 ft and midchannel depths, respectively. The grouping together of the Station III samples, with their only linkage being to the -2.5 ft and 0.0 samples at Station II, reflects the relative isolation of this station. This isolation is more pronounced in January 1978 (Fig. 7), with the +2.5 ft, 0.0, and -2.5 ft samples at Station III forming a cluster group separate at the 100% distance level from the remaining large cluster group. The midchannel sample at Station III is grouped with the midchannel and -2.5 ft samples at Stations I and II. This clustering pattern is possibly a reflection of the fact that these deeper sites share an elevated salinity, while the shallower sites are differentially impacted by fresh water runoff. This would certainly agree with the observed isolation of the -2.5 ft, 0.0 ft, and +2.5 ft samples at Station III and with the vertical separation of the midchannel and -2.5 ft samples from the 0.0 and +2.5 ft samples that are linked horizontally at Stations I and II.

Results of the cluster analysis for April 1978 (Fig. 8) strongly reflect the impact of fresh water runoff on community structure. The marked drop in species diversity and abundances discussed above for the April assessment resulted in higher similarities (i.e., lower ecological distances) between site groupings in the cluster analysis. At the 60% distance level, three cluster groups are defined (Fig. 8b) as a midchannel group and as a -2.5 ft (Stations I and II) and 0.0 ft (Stations I and III) group which are linked across all three stations.

(a)



(b)

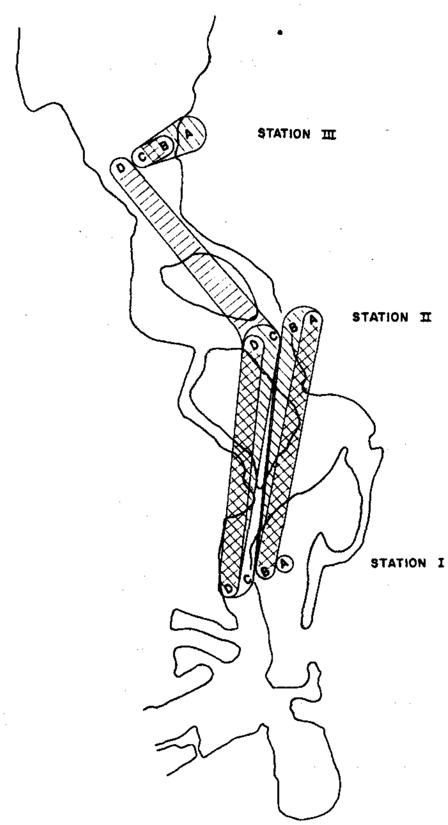


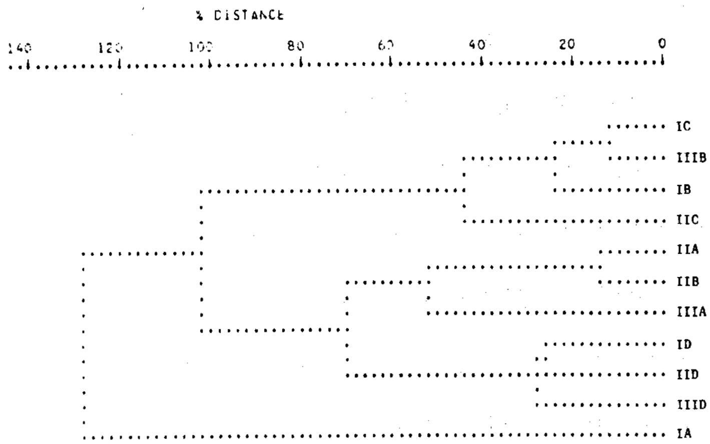
FIGURE 7. (a) Dendrogram plot of cluster analysis results for the January 1978 assessment. (b) Overlay of cluster groups on a map of the Upper Newport Bay, based on the dendrogram plot.

The shallow samples at Stations II and III clustered together, but were distinct from the +2.5 ft sample at Station I. This latter sample remained unique, as it was in the January 1978 cluster analysis.

By August 1978, species diversity and abundances had increased substantially, as noted above, and the horizontal stratification at and below the 0.0 level across all three stations was no longer present (Fig. 9). Community development at the +2.5 ft level (in the absence of rainfall) was similar at all three stations, resulting in a distinctive cluster grouping. The 0.0 and midchannel samples at Station III were quite similar (as one would predict since they were at the same vertical level after April), and were weakly linked with the midchannel sample at Station II. This cluster group was separated at the 88% distance level from a group including the 0.0 and -2.5 ft samples at Station II and the -2.5 ft and midchannel samples at Station I.

The winter rainfall period prior to the January 1979 sampling resulted in a decrease in diversity and abundance, and a rather peculiar restructuring of the site grouping pattern (Fig. 10). The +2.5 ft levels at Stations II and III clustered together, but they were not grouped with the +2.5 ft and 0.0 levels at Station I, as in August. Instead, the +2.5 ft and 0.0 samples at Station I stand alone, separated from the remaining samples. Interestingly, the midchannel sample at Station III was the most distant of all samples. The 0.0, -2.5 ft, and midchannel samples at Station II formed a discrete cluster group that was linked at the 70% distance level with the +2.5 ft samples at Stations II and III and the -2.5 ft sample of Station I. Interpretation of these clustering patterns is difficult, except to possibly point out the separations that could have arisen between the

(a)



(b)

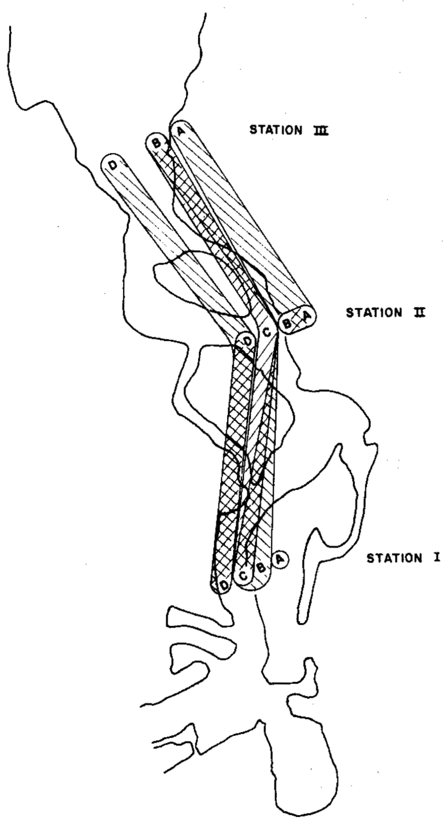
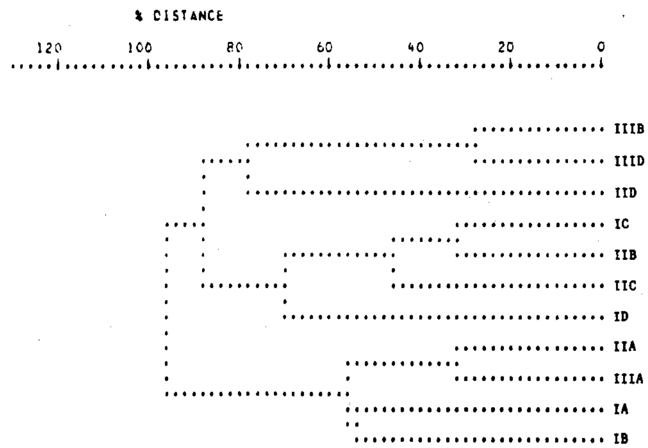


FIGURE 8. (a) Dendrogram plot of cluster analysis results for the April 1978 assessment. (b) Overlay of cluster groups on a map of the Upper Newport Bay, based on the dendrogram plot.

(a)



(b)

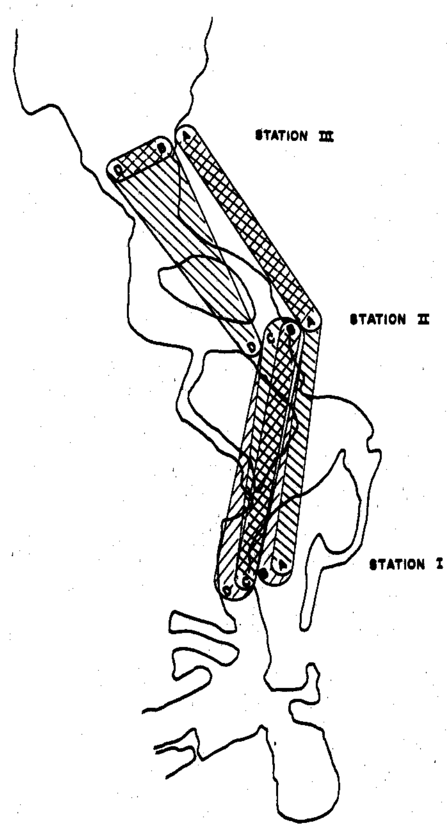
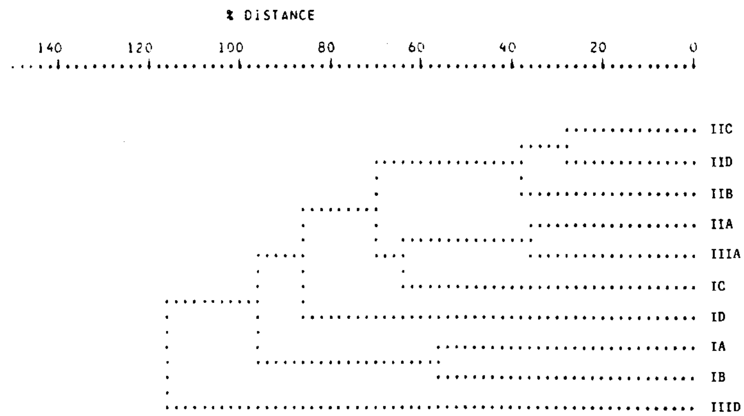


FIGURE 9. (a) Dendrogram plot of cluster analysis results for the August 1978 assessment. (b) Overlay of cluster groups on a map of the Upper Newport Bay, based on the dendrogram plot.

different stations as a result of differential fresh water impaction.

To determine the degree to which samples collected during the five assessment periods differed from each other, a cluster analysis was run using the combined data from all visits (Fig. 11). The April 1978 samples were separated completely, with the exception of Station IA, from the other assessment periods at the 194% distance level. It is noteworthy that the April period exhibited the lowest diversity and total abundances of all five visits (see above) and that one might expect to find that these samples would be dissimilar from those obtained during other visits. The August 1978 assessment also clustered out separately (at the 176% distance level). The uniqueness of these samples would appear to be related to the fact that the community structure established by August was largely derived from larval settlement into the depauperate community existing four months earlier. The remaining samples fell into two large and one small cluster group. The two January periods showed the greatest cluster integrity. Seven of 12 samples from January 1978 clustered together, while 6 of 10 samples from January 1979 were grouped. It is noteworthy that the October 1977 samples showed the weakest identity as a distinctive sampling period. October samples appeared to have their highest similarities with the January 1978 samples, which one would predict since the community structure underwent a decrease in species densities and diversity (richness) between October and January, yet retained basic compositional features, particularly as regards the common species that were not negatively impacted by the winter conditions. By April, community structure was strongly altered, with the samples

(a)



(b)

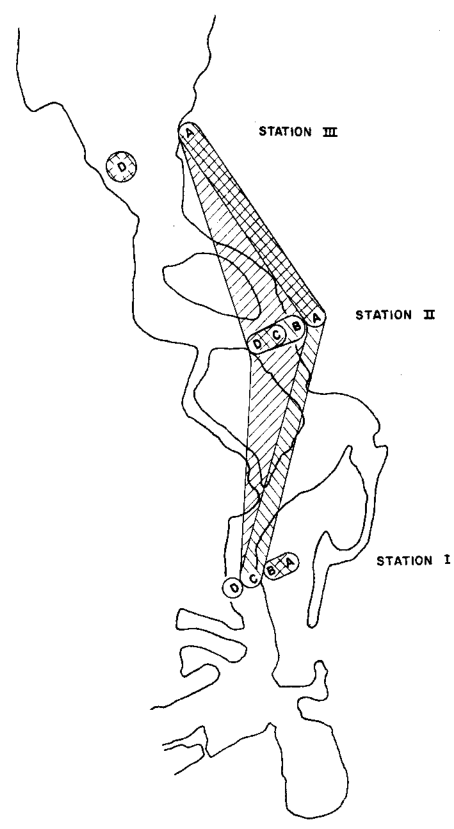


FIGURE 10. (a) Dendrogram plot of cluster analysis results for the January 1979 assessment. (b) Overlay of cluster groups on a map of the Upper Newport Bay, based on the dendrogram plot.

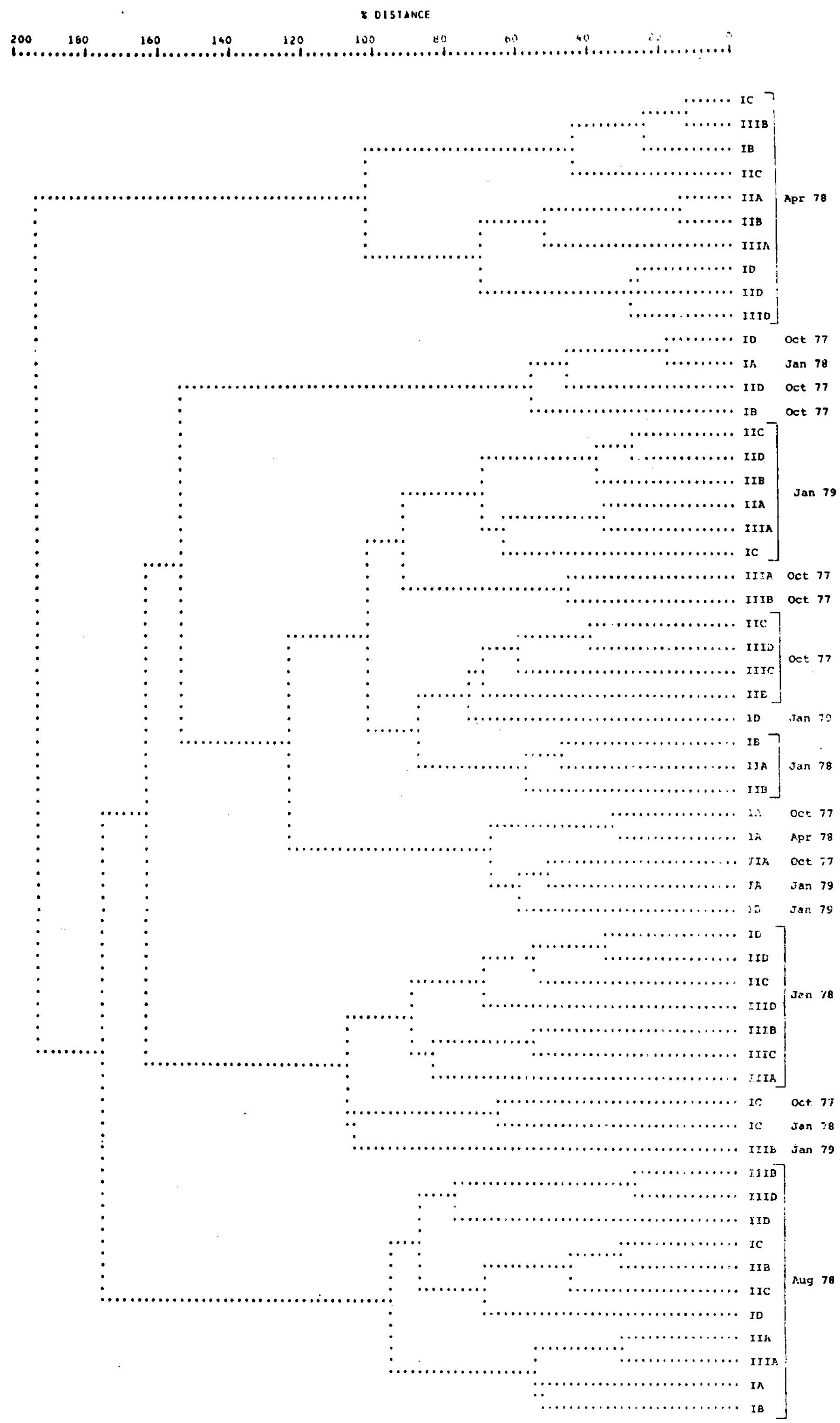


FIGURE 11. Dendrogram plot of cluster analysis results for all five assessment periods.

becoming structurally simpler and, thus, different from those obtained during the other assessment periods.

Species Distributions and Abundances

Density data for the sampled species and taxa are given in Appendices I-V as averaged and paired replicate values by tidal level and station. The most numerically-important taxonomic group during each of the five assessments was the polychaete worms. In October 1977, 49 species of polychaetes were recorded (Appendix I) with a total mean density (i.e., the sum of the mean densities of each species at each station, averaged for all three stations) of 15,891 individuals per m^2. Total mean polychaete density per station was highest at Station I (28,750/m^2), followed by Station II (16,908/m^2) and Station III (2,016/m^2). At Station I, 97% of the specimens collected were polychaetes, while at Stations II and III the polychaetes were also the dominant taxon, but were not as proportionately important, representing 70% and 44%, respectively, of the fauna. The polychaete species with the highest mean densities (averaged over all samples) were the sabellid <u>Fabricia limnicola</u> (7,402/m^2), the spinoid <u>Streblospio benedicti</u> (2,853/m^2), and the capitellid <u>Capitella capitata</u> (2,139/m^2). Two oligochaetes, <u>Peloscolex</u> sp. A and <u>Peloscolex</u> sp. B, contributed mean densities of 964/m^2 and 666/m^2, respectively. Although represented by 19 species, the molluscan densities were low, with the exceptions of <u>Acteocina inculta</u> (mean of 209/m^2) and <u>Tagelus</u> spp. juveniles (mean of 304/m^2). It is noteworthy that the juvenile <u>Tagelus</u> had selectively settled in the upper portion of the bay, as evidenced by the high mean density of $886/m^2$ at Station III compared with $26/m^2$ at Station II and $1/m^2$ at Station I. Settlement of *Tagelus* spp. at Station III was essentially limited to the +2.5 ft ($2,481/m^2$) and 0.0 ft ($1,054/m^2$) levels. Adult *Tagelus* were represented at these intertidal levels only by a low density ($17.5/m^2$) of *T. californianus* at +2.5 ft. However, *Tagelus* did not survive the following winter period, as their densities were greatly reduced by January (Appendix II), and they were gone from Station II and III (except at IIA) by April (Appendix III). In October 1977, the crustaceans were represented by 28 taxa (Appendix I), of which 15 were amphipods. Although the amphipods were not numerically important, *Mayerella acanthopoda* averaged 159 individuals/m^2 and was quite abundant ($1,138/m^2$) at Station IID. Among the remaining crustaceans, only the cumacean *Oxyurostylis pacifica* was common, with a mean density of $144/m^2$ and with individuals present at all tidal levels and stations.

Between October 1977 and January 1978, substantial declines had occurred (Appendix II) in species richness (from 117 to 46 taxa) and abundance (from a total mean density of $19,444/m^2$ to $3,620/m^2$). As in October, the polychaetes were the most numerous taxon in January, representing an average of 55% (ranging from 88% at Station I to 37% at Station III) of the individuals sampled and 20 of the 47 taxa recorded. The most abundant species, in terms of mean density, were *Fabricia limnicola* ($1,916/m^2$), *Capitella capitata* ($368/m^2$), and *Streblospio benedicti* ($204/m^2$). Although these three species were also the numerical dominants in October, their mean densities were markedly lower, ranging from a 4-fold reduction of *F. limnicola* to a

14-fold decline for S. benedicti. Overall, decreases in abundance by the polychaetes were most pronounced at Stations II (a 26-fold decline, from a total mean density of $16,908/m^2$ in October to $661/m^2$ in January) and III (a 19-fold decrease, from a total mean density of $2,016/m^2$ in October to $107/m^2$ in January). Both species of oligochaetes that were abundant in October were present in January, but in quite reduced numbers. Peloscolex sp. A had decreased from a mean density of $964/m^2$ to $109/m^2$, while Peloscolex sp. B had declined from $666/m^2$ to $169/m^2$. The mollusks decreased in numbers of taxa from 19 in October to 11 in January, with only one species, Acteocina inculta, showing moderate densities (mean of $235/m^2$). The crustaceans underwent a dramatic decline in both numbers of taxa (from 28 to 6) and abundance (from a total mean density of $645/m^2$ to $9/m^2$). The crustaceans were only infrequently collected in January (occurring in 6% of the samples), and their maximal density was only $12.5/m^2$.

Between January and April 1978, during the heavy winter rainfall period (Fig. 2), the total number of taxa decreased from 46 to 27 (Appendix III). The total mean density, however, increased slightly (from $3,620/m^2$ to $3,760/m^2$). As in October and January, most of the faunal abundance was attributable to the polychaetes, which accounted for 89, 82, 85% of the fauna (in terms of total mean density) at Stations I, II, and III, respectively. While the total mean polychaete density decreased at Station I (from $7,913/m^2$ to $5,167/m^2$), it increased at Stations II (from $661/m^2$ to $2,942/m^2$) and III (from $107/m^2$ to $1,618/m^2$). Interestingly, two of the three dominant polychaete species during October and January were only abundant at the +2.5 ft level at Station I in April. Streblospio benedicti had an average density at this station of $6,438/m^2$, while Capitella capitata had an average density here of $2,438/m^2$. The third species, Fabricia limnicola, had been wiped out entirely, with the exception of a single individual collected in a midchannel sample at Station III. These three species were replaced numerically by the spionid Polydora ligni, which had mean densities at Stations I, II, and III of $2,038/m^2$, $2,797/m^2$, and $1,578/m^2$, respectively. Another spionid, Polydora nuchalis was important at the +2.5 ft level at Station I, having an average density of $1,650/m^2$. The oligochaete fauna changed in an interesting manner. Peloscolex sp. A declined from a mean density of $109/m^2$ in January to $48/m^2$ in April. Peloscolex sp. B decreased from a mean density of $169/m^2$ in January to its absence from Stations I and II and a mean density of $38/m^2$ at Station III in April. The unidentified oligochaete sp. A increased slightly from a mean density of $41/m^2$ to $53/m^2$, while the unidentified obligochaete sp. B, which was not recorded during October or January, had mean densities of $200/m^2$ and $535/m^2$ at Stations I and II, respectively, and was absent from Station III in April. The number of molluscan species decreased from 11 in January to 6 in April, with only Acteocina inculta occurring in noteworthy numbers at Station I (mean of $285/m^2$). The crustaceans decreased from 6 to 2 taxa, with these two taxa occurring sparsely.

The absence of rainfall during the four month period between the April and August assessments was correlated, as noted above, with the increase in diversity and abundance of the benthic community. The total mean density for the fauna in August (Appendix IV) was maximal for the entire study period, and averaged $41,310/m^2$, with a range of $60,317/m^2$ at Station I to $20,041/m^2$ at Station III. The high total densities at each station were largely attributable to the polychaetes (73, 80, and 84% of the total mean densities at Stations I, II, and III, respectively). Five species of polychaetes comprised 90% of the total mean polychaete density; Polydora ligni ($8,047/m^2$), Capitella capitata ($7,906/m^2$), Pseudopolydora paucibranchiata ($5,783/m^2$), Streblospio benedicti ($5,106/m^2$) and Scolelepis acuta ($2,123/m^2$). The cluster analysis results for all assessments (Fig. 11) indicated the uniqueness of the August samples, and is reflected here in the changed pattern of polychaete species dominance. Comparisons with the October 1977 data (Appendix I) indicate a substantial decline by the sabellid Fabricia limnicola. It was the most numerous species in October ($7,402/m^2$), but in August 1978 it was only present at Station I, at a mean density of $1,522/m^2$, with most individuals occurring +2.5 ft. The most abundant species in August, Polydora ligni, had a mean density of $182/m^2$ in October, which is 1/44 of its mean density in August. Similarly, Scolelepis acuta had a mean density of $69/m^2$ in October, which was 1/31 of its August density. Among the oligochaetes, the two species of Peloscolex (spp. A and B) that dominated in October were of secondary importance in August to two species (unidentified sp. B and Peloscolex sp. C) that were not recorded in October. The nematodes had a mean density of $789/m^2$ in August, but were absent in October. Phoronis pallida was in low abundance at deeper levels in October (total mean density of $48/m^2$), while in August its mean density was nearly six times greater ($269/m^2$), with greatest numbers at the 0.0 ft level. Acteocina inculta remained the only abundant mollusk, although its densities were much higher (mean of $1,992/m^2$) than at any other time. This density value represents a 19-fold increase over April, and is nearly ten times the mean October value of $209/m^2$. The crustaceans recovered dramatically from the April assessment period, when only two species were recorded in low densities. In August, 14 crustacean taxa occurred only at Stations I and II, with 4 exceptions. The amphipod *Mayerella acanthopoda* had the highest densities (means of 5,141, 2,135, and $9/m^2$ at Stations I, II, and III). The cumacean, *Oxyurostylis pacifica*, was next in abundance, with mean densities of 1,379, 157, and $0/m^2$ at Stations I, II, and III. In overview, the April and August data on the crustaceans suggest the hypothesis that this group is highly sensitive to stressful winter conditions.

The rainfall pattern between August 1978 and January 1979 was more typical of a normal year (Fig. 2) than that preceding the January 1978 assessment. Similarly, the decline in numbers of species and total mean density that occurred by the January 1979 assessment period was not as pronounced (Fig. 5). The total mean density of the fauna decreased by about four fold from $41,310/m^2$ in August to $9,823/m^2$ in January 1979 (Appendix V). A large proportion of this decrease is attributable to the polychaetes, which declined substantially and represented a lower percentage of the total faunal density than in August, ranging from 55% at Station I to 61% at Station II. The impact of freshwater runoff on density decreases by the polychaetes was especially evident at Station III, where total mean density dropped from $23,397/m^2$ in August to $1,726/m^2$ in January. The polychaetes at Station III belonged to 6 species, and all were collected at the +2.5 ft level (Appendix V). However, the only abundant species at this tidal level were the spionids Streblospio benedicti (2,000/m^2) and Polydora nuchalis (1,275/m^2). Total mean density of the polychaetes was greatest at Station I (10,986/m^2), with Station II (3,959/m^2) being closer to Station III (1,726/m^2). In terms of mean density, Streblospio benedicti was the most abundant species (2,024/m^2), followed by Capitella capitata (1,052/m^2), Fabricia limnicola (972/m^2), Polydora nuchalis (538/m^2), P. socialis (339/m^2), and P. ligni (134/m^2). The last species declined substantially, since it was the most abundant species (8,047/m^2) in August 1978. Fabricia limnicola was particularly noteworthy because it occurred in high numbers at the +2.5 ft and 0.0 ft levels at Station I (9,225/m^2 and 2,350/m^2, respectively), but infrequently elsewhere. This distribution pattern reflects recruitment at these levels at Station I and sparsely elsewhere, since F. limnicola occurred only at Station I at the +2.5 ft (5,500/m^2) and 0.0 ft (538/m^2) levels in August 1978 (Appendix IV). Polydora socialis and P. ligni were also maximally abundant at the +2.5 ft level at Station I (2,500/m^2 and 1,150/m^2, respectively), while a third species of Polydora, P. nuchalis showed high densities at the +2.5 level at all three stations. The nematodes increased by 3 fold over August 1978 to a mean density of 2,361/m^2, with an extraordinarily high density of 15,863/m^2 being recorded at the +2.5 ft level at Station I. Among the oligochaetes, Peloscolex sp. C declined slightly from a mean density of 395/m^2 in August to 266/m^2 in January, while Peloscolex sp. A increased from 138/m^2 to 382/m^2. As before, the only abundant mollusk was Acteocina inculta, but it had declined from a mean density of 1,992/m^2 in August to 804/m^2 in January. The crustaceans declined sharply (as in January,

1978) and were represented by only four taxa that occurred sparsely, although the harpacticoid copepods had a mean density of $47.5/m^2$, but were recorded only at Stations I and II.

DISCUSSION

The 21 subtidal stations occupied by Barnard and Reish (1959) in the Upper Bay provided taxonomic and abundance data which can be compared with the present results. Of the 19 subtidal gammarid taxa, which provided a combined mean density of $643.4/m^2$, only one of these species (Corophium acherusicum) was recorded in low numbers ($2.1/m^2$) during January 1978 from the subtidal samples of the present study. Barnard and Reish reported 13 species of intertidal gammarids of unknown densities from December 1953. Of these species, none were recorded in the present study, which might be related to the fact that the intertidal collections of Barnard and Reish were made just to the north of the Pacific Coast Highway Bridge, in an area of rapid, tidal-induced currents (Wehner, 1978) and, presumably, coarse sediments. By contrast, the nearest station in the present study (Station I) was located on Shellmaker Island (Fig. 1), where tidal currents are less (Wehner, 1978) and finer sediments most likely occur. In January 1954, a total of 43 subtidal polychaete taxa were identified by Barnard and Reish from the Upper Bay, which contributed a total mean density of $1,055.8/m^2$ (Table 4). In the present study, the subtidal polychaete taxa numbered only 12 in January 1978, with a total mean density of $519.0/m^2$, and numbered 16 in January 1979, with a total mean density of $2,265.7/m^2$ (Table 4). Of the 43 polychaete taxa

TABLE 4. Comparisons of mean densities of polychaete species collected from the Upper Bay in January 1954 by Barnard and Reish (1959) with subtidal samples from the present study in January of 1978 and 1979.

	Mean Density (No./m^2)		
Species	Jan 1954	Jan 1978	Jan 1979
Capitella capitata	-	68.8	800.0
Cossura candida	3.7	343.8	-
Exogone uniformis	-	-	31.3
Fabricia limnicola	17.6	8.3	3.1
Haploscoloplos elongatus	147.3	14.6	-
Lumbrineris minima	30.8	6.3	3.1
Marphysa sp.	-	-	71.9
Mediomastus ambiseta	-	31.3	46.9
Mediomastus californiensis	-	22.9	-
Neanthes arenaceodentata	-	2.1	75.0
Notomastus (C.) tenuis	-	2.1	-
Polydora ligni	-	-	40.6
Polydora nuchalis	-	-	18.8
Polydora socialis	-	-	137.5
Polydora websteri	-	-	25.0
Polydora sp.	-	4.2	-
Pseudopolydora paucibranchiata	73.3	-	9.4
Schistomeringos rudolphi	-	-	12.5
Scolelepis acuta	18.3	-	87.5
Streblospio benedicti	0.7	10.4	900.0
Tharyx monilaris	-	-	3.1
Tharyx parvus	20.5	4.2	-
Other taxa (35)	743.6		
Total	1,055.8	519.0	2,265.7

identified by Barnard and Reish, only 8 species were recorded from the subtidal samples of January 1978 and January 1979. In the present study, 6 taxa (in January 1978) and 11 taxa (in January 1979) were present that were not identified by Barnard and Reish.

The decrease in species richness of gammarid and polychaete taxa discussed above was pronounced between the January samplings in 1954 and in the present study. The urbanization and development of the region surrounding the Upper Bay and its watershed have resulted in water quality conditions heavily influenced by man's activities. Agricultural, industrial, and urban sources all contribute (Scherfig, 1979) to an inflow of waters that enter the Upper Bay year round. These inputs must certainly all be of a much greater magnitude than in 1954, and could reasonably be expected to contribute to a decline in water quality and to the observed reduction in species richness.

One approach that has been used to characterize environmental quality has been the definition of indicator species of polychaete worms (Reish, 1959). Based on a study of Los Angeles and Long Beach Harbors, Reish considered three species to be characteristic of healthy bottoms, of which two were recorded from the Upper Bay by Barnard and Reish (1959) and in the present study (Table 5). He considered three species to be characteristic of semi-healthy bottoms, of which only one (Pseudopolydora paucibranchiata) was present in the Upper Bay in January of 1954 and in the present study. One species, Capitella capitata, was considered to be indicative of unhealthy or polluted bottoms (Table 5). Using Reish's (1959) criteria, one can characterize the Upper Bay in January 1954 as moderately healthy to healthy, while in 1977-1979 it would have to be considered unhealthy or semi-healthy based on the high densities of C. capitata and P. paucibranchiata, especially in August 1978. Although its densities declined in the winter, C. capitata remained an important component of the benthic community throughout the present study. By contrast, C. capitata was not recorded from the Upper Bay in January 1954. Data from the subtidal stations in January 1954 and in the present study for two of the species considered by Reish (1959) to be indicative of a healthy benthos are most interesting. In January 1954, Cossura candida was recorded in low densities in the Upper Bay, while in the present study it occurred in moderate numbers in October 1977 and January 1978, but plummeted to low numbers in April 1978. It did not recruit into the community by August 1978, and was not recorded subtidally in January 1979. Tharyx parvus also appears to be sensitive to reduced salinities and/or sedimentary influx associated with winter periods, as it declined from moderate densities in October 1977 to low numbers in January 1978, after which it was not recorded subtidally.

Recently, the broad application of Capitella capitata as a indicator of polluted waters has come under attack (reviewed by Daugherty, 1978a). Reish (1979) has stated that indicator species should not be used to define the degree of pollution in estuarine areas where stresses on benthic communities associated with winter periods of fresh water influx would favor the establishment of opportunistic species. Capitella capitata, which has a short life history and is capable of reproducing throughout the year, would be

TABLE 5. Comparison of mean densities of polychaete species indicative of different levels of environmental quality (after Reish, 1959) from subtidal samples collected during January 1954 in the Upper Bay by Barnard and Reish (1959) and during October 1977 to January 1979 in the present study.

	Mean Density (No./m^2)					
Species	Jan 1954	Oct 1977	Jan 1978	April 1978	Aug 1978	Jan 1979
Cossura candida (1)	4.1	138.3	343.8	9.4	9.4	-
Tharyx parvus (1)	22.7	156.3	4.2	-	-	-
Pseudopolydora paucibranchiata (2)	81.0	50.0	-	240.6	3,906.3	9.4
Capitella capitata (3)	-	412.5	68.8	106.3	1,125.0	800.0

(1) Characteristic of healthy bottoms
(2) Characteristic of semi-healthy bottoms
(3) Characteristic of unhealthy (polluted) bottoms

expected to be an important community component in the estuarine environment (Reish, 1979). The decline of Cossura candida and Tharyx parvus, coupled with the persistence of C. capitata during the period of the present study conform with the analysis of Reish (1979).

Bottom samples collected by Daugherty (1978a) in the late summer of 1975 and winter of 1976 from Newport Bay revealed substantial seasonal decreases in abundance and diversity (Table 6). Seasonal change was most dramatic at the Ski Zone station, where there were sharp declines between September and February in both the number of taxa (from 57 to 14) and in total faunal density (from $24,313/m^2$ to $960/m^2$). By March-April, the number of taxa (28) and total density ($3,860/m^2$) increased, however. That this increase took place during the month of March is peculiar. The Newport Bay area received 3.3 cm of rainfall this month, while the total rainfall from the summer of 1975 to the end of February 1976 was only 6.7 cm (NOAA, 1975, 1976). If anything, one would have expected a further decline over February values. Instead, 14 additional polychaete taxa appeared between the samplings in February and March-April, and noteworthy increases occurred in the mean densities of three species (Table 7); Polydora ligni (from 33 to $1,598/m^2$), Mayerella acanthopoda (from 0 to $280/m^2$), and Capitella capitata (from 47 to $240/m^2$). Interestingly, a similar pattern of winter decline, followed by a late winter increase, is seen in the midchannel sample data from the Ski Zone (Station IIID) in 1977-1978 (Table 6). Total density and number of taxa were not nearly as high in October 1977 ($3,391/m^2$ and 31 taxa) as in September 1975 ($24,313/m^2$ and 57 taxa), but there was still a substantial decrease (by 77%) in number of taxa and an 83% decline

TABLE 6. Comparison of total mean density and numbers of taxa from mid-channel stations off Shellmaker Island and in the Ski Zone sampled by Daugherty (1978a) in 1975-1976 and from the present study in 1977-1979.

Location and Date		Total Density (No./m^2)	No. Taxa(1)
SKI ZONE STATIONS			
Sep	1975	24,313	57
Feb	1976	960	14
Mar-Apr	1976	3,860	28
Oct	1977	3,391	31
Jan	1978	566	7
Apr	1978	1,863	8
Aug	1978	25,343	17
Jan	1979	163	3
SHELLMAKER ISLAND STATIONS			
Sep	1975	33,127	88
Feb	1976	-	-
Mar-Apr	1976	23,093	55
Oct	1977	30,294	54
Jan	1978	1,407	14
Apr	1978	2,275	9
Aug	1978	35,350	50
Jan	1979	2,126	18

(1) Nemertean taxa were combined as a single taxonomic entity from the present study to be consistent with Daugherty (1978a).

in total density between October 1977 and January 1978. In contrast with the observed increase in number of taxa and density between February and March-April in 1976 (Table 6), the increase between January and April of 1978 only represented an addition of one taxon and the establishment of one polychaete species (Polydora ligni at 1,463/m^2), which was not recorded in the January sample (Table 7). It is noteworthy that Capitella capitata, which had increased from 47 to 240/m^2 between February and March-April 1976, declined from 250/m^2 in January 1978 to 0/m^2 in April 1978 (Table 7).

A comparison may also be made between the present August 1978 data and the September 1975 data of Daugherty (1978a) from the mid-channel station in the Ski Zone (Table 6). Following the unusually heavy rainfall of the 1977-1978 winter, the benthic community in April 1978 was depauperate, and was represented (if Polydora ligni is excluded) by a total density of only 375/m^2 and 7 taxa. Community recovery between April and August was characterized by a phenomenal increase in total density to 25,343/m^2; a value which is comparable to the total density of 24,313/m^2 recorded in September 1975. In contrast with the September 1975 sampling, only 17 taxa were recorded in August 1978 (Table 6), of which five polychaete species contributed 83% of the total density (Table 7). Four of these five species (Scolelepis acuta, Streblospio benedicti, Polydora ligni, and Capitella capitata) were also the numerical dominants in September 1975, comprising 78% of the total density. The major difference between the two sampling periods, then, is the presence of a much higher number of taxa in lower densities in September 1975 (Table 7). This result could possibly be explained if there were a much lower

Table 7. Mean densities of selected species from midchannel samples in the Ski Zone and off Shellmaker Island in 1975-1976 (Daugherty, 1978a) and 1977-1979 (this study).

Location and Species	Date							
	Sep 75	Feb 76	Mar-Apr 76	Oct 77	Jan 78	Apr 78	Aug 78	Jan 79
SKI ZONE MIDCHANNEL STATION								
Polychaeta:								
Capitella capitata	1,400	77	240	438	250	0	7,763	0
Euchone limnicola	53	0	0	25	0	0	0	0
Exogone lourei	220	0	40	0	0	0	0	0
Fabricia limnicola	6	0	0	38	0	13	0	0
Polydora ligni	4,180	33	1,598	100	0	1,463	4,563	0
Pseudopolydora paucibranchiata	0	0	167	0	0	0	1,468	0
Scolelepis acuta	8,993	0	0	163	0	0	4,963	0
Scoloplos acmeceps	0	0	0	0	0	0	0	0
Streblospio benedicti	4,287	7	13	150	0	0	3,600	0
Mollusca:								
Acteocina inculta	587	0	0	113	0	0	425	50
Protothaca staminea	0	0	0	0	0	0	0	0
Arthropoda:								
Corophium acherusicum	0	0	7	0	0	0	38	0
Leptochelia dubia	33	7	0	13	0	0	0	0
Mayerella acanthopoda	653	0	280	25	0	0	25	0
Oxyurostylis pacifica	680	7	20	88	0	0	0	0
Rudilemboides stenopropodus	153	7	0	50	0	0	0	0
Phoronida:								
Phoronis pallida	193	0	7	25	0	0	188	25
SHELLMAKER ISLAND MIDCHANNEL STATION								
Polychaeta:								
Capitella capitata	20		0	0	13	100	350	25
Euchone limnicola	47		0	138	0	0	7,663	0
Exogone lourei	520		273	88	0	0	0	0
Fabricia limnicola	8,393		16,707	25,263	0	0	0	0
Polydora ligni	53		0	50	0	1,525	2,338	113
Pseudopolydora paucibranchiata	893		0	25	0	525	2,713	0
Scolelepis acuta	13		0	0	0	0	663	38
Scoloplos acmeceps	1,443		280	0	0	0	38	0
Streblospio benedicti	160		73	1,275	0	0	275	538
Mollusca:								
Acteocina inculta	0		20	0	13	0	50	138
Protothaca staminea	240		27	147	38	0	88	28
Arthropoda:								
Corophium acherusicum	880		33	0	0	0	63	0
Leptochelia dubia	920		53	13	0	0	0	0
Mayerella acanthopoda	1,013		1,647	338	0	0	6,563	0
Oxyurostylis pacifica	13		40	250	0	0	4,900	0
Rudilemboides stenopropodus	780		127	100	0	0	13	0
Phoronida:								
Phoronis pallida	0		0	38	113	0	175	13

rainfall in the winter period preceding the September 1975 sampling and if a large-scale dieback of an existing diverse community did not occur. The winter rainfall data for these two periods support this scenario. During the 1974-1975 winter, a total of 32 cm of rainfall was recorded (NOAA, 1974, 1975). This amount is somewhat above that for a "normal" year (Fig. 2) when the winter rainfall totals 28 cm, but is much lower than the total of 60.5 cm recorded for the winter of 1977-1978. One final observation regarding the midchannel community in the Ski Zone is that the community characterized by low species richness and high density which existed in August 1978 was short lived. By January 1979, only 3 of the 17 taxa present in August remained, and total density had dropped from 25,343/m^2 to 163/m^2 (Table 6). This decline can be correlated with an early winter total of 18.8 cm that preceded the January sampling date.

The midchannel community off Shellmaker Island was shown by Daugherty (1978a) to have a higher number of taxa and total density than the Ski Zone Station (Table 6). This result agrees with data from these two stations on all sampling dates in the present study (Table 6). Declines in species richness (by 38%) and total density (by 30%) between September 1975 and March-April 1976 were less pronounced than at the Ski Zone Station. The differences discussed above in winter rainfall between 1975-1976 and 1977-1978 are reflected in the greater decreases in number of taxa (by 83%) and total density (93%) between October 1977 and April 1978. The curious increase in total density between January and April 1978 noted above in the Ski Zone also occurred at the Shellmaker Island station. This increase was also largely attributable to the polychaete Polydora ligni

(Table 7), which had densities of $0/m^2$ in January and $1,525/m^2$ in April. The Shellmaker Island station recovered dramatically by August 1978 to a total density of $35,350/m^2$, contributed by 50 taxa. Community structure at this station was similar to that at the Ski Zone in August 1978, in that a high percentage of the total density (68%) was contributed by only five species (Table 7). As in 1977-1978, the community declined sharply by January 1979, although species richness did not decrease as drastically. Four of the five most abundant species in August (Euchone limnicola, Leptochelia dubia, Mayerella acanthopoda and Pseudopolydora paucibranchiata) were gone completely in January. This result mirrors the disappearance of the five most abundant species in the Ski Zone by January, as discussed above. It is noteworthy that Fabricia limnicola, which was by far the most abundant species in October 1977 at the midchannel station off Shellmaker Island, was never recorded from that station after that date (Table 7).

The seasonal declines in abundance and species richness recorded in the present study and by Daugherty (1978a) have been correlated above with differences in rainfall patterns between 1974 and 1979, and, by inference, with the hypothetical yearly differences in the degree and duration of salinity reduction. Sediment deposition surely is also important, but has not been quantified. Further, biotic factors have been essentially ignored in this discussion, as we have no data to indicate their magnitudes. The impact of predation on the benthic community must be a very important factor which varies both seasonally and annually. A variety of fishes feed on the benthos in the Upper Bay, and their predatory impact varies in magnitude as the composition and abundance of the fish community changes (M. Horn, personal communication). The role of shorebird predation on the intertidal benthic community has been shown by M. Quammen (cited by Couffer and Couffer, 1978) to be strongly seasonal and significant. Migratory shorebirds usually arrive in the Upper Bay by October and feed actively on the intertidal flats until about June. Using exclosure cages, Quammen found that by late winter, shorebird feeding accounted for a reduction in polychaete densities by about 50%. Spring recruitment by the polychaetes, however, more than made up for these winter losses, and she recorded high polychaete densities both inside and outside the exclosure cages by June.

SUMMARY

1. The benthic community at intertidal (+2.5 ft and MLLW) and subtidal (-2.5 ft and midchannel) depths was sampled at three stations (at Shellmaker Island, Big Canyon, and the Ski Zone) in the Upper Newport Bay during five assessment periods between October 1977 and January 1979.

2. Fresh water flow into the Upper Bay occurs year-round, and results in reduced salinities, as evidenced by the depressed surface salinities recorded in October 1977 and August 1978. During the winter periods, salinities were further reduced, especially during the winter season of 1977-1978, which was characterized by extremely high rainfall during January to March 1978 and by low salinities, which were documented during the late January and early April assessments.

3. Water temperatures in the Upper Bay were highest during the late summer assessments (October 1977 and August 1978) and lowest during the January 1978 and 1979 assessments, with thermal stratification only occurring in August 1978.

4. Sediment transport and deposition in the Upper Bay was considerable during the 1977-1978 winter, particularly in the Ski Zone where an estimated 3 ft of sediments accumulated in the midchannel region that raised the bottom depth from -2.5 ft to +0.5 ft. During the course of the study, the mean grain size of the sediments changed from fine and very fine sands in January 1978 to silts by August 1978. This temporal change was reflected in the increase in representation by the silt-clay fraction from a mean of 19.3% in January 1978 to 81.1% in January 1979.

5. Organic carbon content of the sediments averaged 0.93% in October 1977 and 0.98% in January 1978, with the highest values (to 1.70%) occurring in the Ski Zone in October and the lowest values (0.24 and 0.26%) being obtained at +2.5 ft and MLLW at Shellmaker Island in October.

6. Total density of the benthic community was highest at Shellmaker Island and lowest at the Ski Zone during each assessment period. Lowest seasonal densities were recorded during the January and April 1978 assessments. These winter declines in total density were most pronounced in the Ski Zone. Heavy recruitment after April 1978 resulted in total densities during August 1978 that were considerably higher than in October 1977.

7. Total numbers of species (species richness) was highest (with one exception) at Shellmaker Island and lowest at the Ski Zone during each assessment. This relationship also held true for species diversity (H') after January 1978. During October 1977 and January 1978 species evenness at Shellmaker Island was lower than at the other two sites, resulting in lowered diversity (H') values. Species richness was highest at each site in October 1977 and dropped off dramatically to seasonal low values in April 1978. Both richness and species diversity recovered substantially by August 1978, followed by a moderate decline by January 1979.

8. Cluster analyses were used to reveal patterns of community structure. In October 1977 both horizontal and vertical groupings by stations and depths were determined, with the Shellmaker Island and Big Canyon stations being linked at midchannel depths and at +2.5 ft, while the Big Canyon and Ski Zone stations were linked at midchannel and -2.5 ft depths. By January, the Ski Zone station was isolated from the other stations except at midchannel, at which depth all three stations were linked. The midchannel and -2.5 ft depths at Big Canyon and Shellmaker Island were linked horizontally, as were the intertidal levels, excepting +2.5 ft at Shellmaker Island. Further isolation of the intertidal levels at the Ski Zone was not seen in April, however, as horizontal linkages occurred between the depth levels at the three stations, suggesting strong vertical separations resulting from verical differences in the impact of the fresh water influx into the Upper Bay. By August, a pattern basically like that of October 1977 was observed.

9. Cluster analysis using all stations and depths for all five assessment periods revealed the unique character of samples from April when the community exhibited very low total densities and species richness, and August, when a new community had developed that was characterized by high total densities and altered species dominances. The January assessments exhibited fairly strong integrity, while the October sampling showed the weakest identity as a distinctive assessment period.

10. The most numerically-important taxonomic group during each of the assessments was the polychaete worms. In October 1977 highest polychaete densities were determined for Fabricia limnicola, Streblospio benedicti, and Capitella capitata. These same three species also were most abundant in January 1978, although in much reduced numbers. Further declines had occurred by April with F. limnicola almost disappearing completely, and with Polydora ligni becoming the numerical dominant. By August the sample dominance had changed markedly from October 1977, with P. ligni, C. capitata, Pseudopolydora paucibranchiata, S. benedicti, and Scolelepis acuta being most abundant. The crustaceans, which occurred only sparsely in January and April, recovered strongly by August with high abundances of Mayerella acanthopoda and Oxyurostylis pacifica being recorded at Shellmaker Island and Big Canyon. In January 1979, dominance patterns shifted as total densities dropped off sharply, with the most abundant species being S. benedicti, C. capitata, F. limnicola (in high numbers only in the intertidal zone at Shellmaker Island), Polydora nuchalis, Polydora socialis, and P. ligni. As in January 1978, the crustaceans declined sharply.

LITERATURE CITED

Barnard, J. L., and D. J. Reish. 1959. Ecology of Amphipoda and Polychaeta of Newport Bay, California. Allan Hancock Foundation Publ., Occ. Paper No. 21. 106p.

Clifford, H. T., and W. Stephenson. 1975. An introduction to numerical classification. Academic Press, New York. 229p.

Couffer, J., and M. Couffer. 1978. Saltmarsh summer. Putnam's Sons, New York.

Daugherty, S. J. 1978a. Benthic ecology, p. 129-192. In: Orange County Human Services Agency, Water Quality Control Section. Environmnental Studies in Newport Bay. Env. Health Div. Rept., June 1978.

_______. 1978b. Annotated bibliography, p. 193-215. In: Orange County Human Services Agency, Water Quality Control Section. Environmental studies in Newport Bay. Env. Health Div. Rept., June 1978.

Emery, K. O., 1938. A rapid method for the mechanical analysis of sands. J. Sediment. Petrol. 8:105-111.

Frey, H. W., R. F. Hein, and J. L. Spruill. 1970. Report on the natural resources of Upper Newport Bay and recommendations concerning the bay's development. Calif. Dept. Fish and Game, Coastal Wetland Ser. No. 1. 68 p.

Inman, D. L. 1952. Measures for describing the size distribution of sediments. J. Sediment. Petrol. 22:125-145.

Kolpack, R. L., and S. A. Bell. 1968. Gasometric determination of carbon in sediments by hydroxide absorber. J. Sediment. Petrol. 38:617-620.

MacGinitie, G. E. 1939. Some effects of freshwater on the fauna of a marine harbor, Amer. Midl. Nat. 21:681-686.

NOAA. 1974-1979. Climatological data. California. Environmental Data and Information Service, National Oceanic and Atmospheric Administration, U. S. Dept. Commerce. Vols. 78-83.

Pielou, E. C. 1969. An introduction to mathematical ecology. Wiley-Interscience, New York. 286 p.

Rohlf, F. J., and R. R. Sokal. 1969. Statistical Tables. Freeman and Co., San Francisco. 253 p.

Scherfig, J. 1979. First annual report on Task 2-3 to the Newport Irvine Wastewater Management Agency. Univ. Calif. Irvine Water Resources Lab. 165 p.

Seapy, R. R., and C. L. Kitting. 1978. Spatial structure of an intertidal assemblage on a sheltered sandy beach. Mar. Biol. 46:137-145.

Shannon, C. E., and W. Weaver. 1962. The mathematical theory of communication. Univ. Illinois Press, Urbana. 117p.

Wehner, M. P. 1978. Hydraulics, p. 7-19. In: Orange County Human Services Agency, Water Quality Control Section. Environmental Studies in Newport Bay. Env. Health Div. Rept., June 1978.

Appendix I. Densities (numbers per square meter) of invertebrates from samples collected from the Upper Newport Bay in October 1977. Beneath each mean density value, the densities for the two replicates are given in parenthesis.

	Station											
Species	IA	IB	IC	ID	IIA	IIB	IIC	IID	IIIA	IIIB	IIIC	IIID
POLYCHAETA												
Armandia bioculata				25 (50/0)								
Boccardia proboscidea	50 (0/100)											
Boccardia uncata	25 (50/0)	1200 (1800/600)	25 (50/0)	12.5 (0/25)	375 (150/600)	125 (50/200)	37.5 (0/75)	12.5 (0/25)				
Brania sp.				137.5 (200/75)								
Capitella capitata	450 (600/300)	837.5 (1500/175)	125 (150/100)		7800 (1800/13800	575 (200/950)	675 (850/500)	925 (1325/525)	312.5 (300/325)	437.5 (375/500)	312.5 (325/300)	437.5 (75/800)
Cossura candida			187.5 (975/600)	67.5 (75/50)		37.5 (0/75)	87.5 (100/75)	387.5 (450/325)			12.5 (25/0)	75 (25/125)
Diopatra ornata												12.5 (0/25)
Dorvillea atlantica				12.5 (0/25)				12.5 (0/25)				
Euchone limnicola		100 (200/0)	137.5 (200/75)	137.5 (150/125)			37.5 (75/0)	212.5 (225/200)				25 (0/50)
Eumida bifoliata	12.5 (0/25)	150 (200/100)	67.5 (75/50)	12.5 (0/25)		25 (25/25)		167.5 (150/175)				
Exogone gemmifera				25 (0/50)								
Exogone lourei	275 (250/300)	400 (700/100)	75 (75/75)	87.5 (150/25)	87.5 (0/175)	100 (0/200)	75 (75/75)	600 (50/1150)				
Exogone uniformis					25 (0/50)							
Exogone sp.							12.5 (25/0)	50 (100/0)				
Exogonella sp.				37.5 (25/50)			12.5 (25/0)					
Fabricia limnicola	1175 (1600/750)	39687.5 (73,000/6375)	637.5 (475/800)	25262.5 (24,250/26,275)	6312.5 (4275/8350)	37.5 (50/25)	37.5 (75/0)	15612.5 (16,200/15,025)	25 (50/0)			37.5 (0/75)
Haploscoloplos elongatus			425 (475/375)	237.5 (375/200)			67.5 (50/75)	75 (100/50)				12.5 (0/25)
Harmothoe lunulata												12.5 (0/25)
Lumbrineris minima			112.5 (100/125)	225 (175/275				25 (0/50)				50 (0/100)
Marphysa sanguinea		12.5 (0/25)				12.5 (0/25)						
Mediomastus acutus				12.5 (0/25)	50 (0/100)							
Mediomastus ambiseta		187.5 (300/75)	63.5 (125/0)	50 (25/75)		12.5 (0/25)	112.5 (75/150)	137.5 (200/75				25 (0/50)
Mediomastus californiensis		162.5 (300/25)	225 (375/75)	462.5 (525/400)		25 (0/50)	75 (100/50)	112.5 (125/100)				12.5 (0/25)
Neanthes arenaceodentata	12.5 (25/0)	2250 (3500/1000)	37.5 (75/0)			25 (50/0)	12.5 (0/25)	12.5 (25/0)				12.5 (25/0)
Pista alta			12.5 (0/25)	50 (25/75)								
Polydora ligni	187.5 (125/250)	900 (1400/400)	12.5 (25/0)	50 (50/50)	225 (550/0)	187.5 (75/300)	87.5 (75/100)	250 (75/425)		125 (25/225)	50 (25/75)	100 (25/175

Appendix I (continued)

Species	Station IA	IB	IC	ID	IIA	IIB	IIC	IID	IIIA	IIIB	IIIC	IIID
Polydora nuchalis	300 (425/ 175)	200 (0/400)	12.5 (25/0)	87.5 (100/75)	2125 (2250/ 2000)	125 (75/175)	62.5 (25/100)	12.5 (0/25)	1625 (325/ 2925)	287.5 (325/ 250)	25 (50/0)	62.5 (25/100)
Polydora socialis	25 (50/0)	10550 (16,500/ 4600)			1200 (0/2400)			87.5 (50/125)				12.5 (0/25)
Polydora websteri				12.5 (25/0)	25 (50/0)							
Polydora sp.		100 (0/200)		112.5 (75/150)	50 (0/100)				62.5 (0/125)			
Polyophthalmus pictus		75 (100/50)						25 (0/50)				
Pseudomalacoceros sp. A		200 (0/400)	37.5 (75/0)	50 (75/25)	1475 (550/ 2400)	3050 (1175/ 4925)	1025 (1000/ 1050)	12.5 (0/25)	25 (0/50)	775 (725/ 825)	187.5 (250/ 125)	37.5 (75/0)
Pseudomalacoceros sp. B			12.5 (25/0)									
Pseudopolydora paucibranchiata			150 (200/100)	25 (0/50)		37.5 (25/50)	25 (0/50)	100 (75/125)	25 (0/50)	12.5 (0/25)		
Prionospio cirrifera						87.5 (25/150)	25 (0/50)					
Prionospio heterobranchia newportensis		25 (0/50)	25 (0/50)	12.5 (25/0)			37.5 (50/25)	12.5 (25/0)				
Rhynchospio arenincola	25 (25/25)											
Sabellidae sp. A				12.5 (0/25)								
Schistomeringos rudulphi	12.5 (25/0)											
Scolelepis acuta	62.5 (100/25)	600 (1200/0)										162.5 (0/325)
Scoloplos acmeceps		375 (700/50)	50 (50/50)				12.5 (25/0)					
Spio filicornis	37.5 (50/25)				50 (0/100)							
Spiophanes missionensis				12.5 (25/0)								
Streblospio benedicti	8225 (14400/ 2050)	475 (900/50)	225 (375/75)	1275 (1400/ 1150)	18300 (1350/ 35250)	1575 (800/ 2350)	337.5 (500/ 175)	1187.5 (1025/ 1350)	1225 (300/ 2150)	1237.5 (1425/ 1050)	25 (25/25)	150 (75/225)
Terebellidae sp.				12.5 (0/25)								
Tharyx monilaris				12.5 (0/25)								
Tharyx parvus		62.5 (100/25)	912.5 (1450/ 375)	12.5 (25/0)				12.5 (25/0)				
Tharyx sp.		12.5 (0/25)		12.5 (25/0)								
Typosyllis aciculata				37.5 (0/75)								
OLIGOCHAETA												
Peloscolex sp. A	300 (400/ 200)	2000 (4000/0)	37.5 (75/0)	162.5 (50/ 275)	2750 (200/ 5300)	1200 (350/ 2050)	900 (1425/ 375)	4862.5 (2550/ 7175)	50 (0/100)		500 (150/ 850)	800 (1575/ 25)
Peloscolex sp. B		150 (0/300)	12.5 (25/0)	61.5 (75/50)	2850 (0/ 5700)	1325 (500/ 2125)	162.5 (0/325)	3200 (0/ 6400)	12.5 (0/25)	212.5 (425/0)		
Unid. sp. A					125 (0/250)		337.5 (0/675)	2462.5 (4500/ 425)				900 (0/1800)
NEMERTINA												
Unid sp. A			50 (100/0)	100 (100/ 100)	12.5 (0/25)	62.5 (75/50)		250 (175/ 325)	12.5 (0/25		12.5 (25/0)	25 (50/0)

Appendix I (continued)

Species	Station IA	IB	IC	ID	IIA	IIB	IIC	IID	IIIA	IIIB	IIIC	IIID
Unid. sp. B	25 (50/0)	25 (50/0)	12.5 (25/0)	37.5 (50/25)	25 (0/50)	75 (75/75)	112.5 (225/0)	112.5 (75/50)	12.5 (0/25)	87.5 (125/50)	500 (50/50)	50 (100/0)
Unid. sp. E					12.5 (25/0)						12.5 (0/25)	
Unid. sp. F							12.5 (25/0)			12.5 (0/25)		
TURBELLARIA												
Unid. spp.					162.5 (0/325)							
CNIDARIA: HYDROZOA												
Corymorpha palma	0.5 (0/1)					2.5 (1/4)	0.5 (1/0)					
CNIDARIA: ANTHOZOA												
Halcampa crypta?	37.5 (75/0)	12.5 (25/0)	62.5 (125/0)	137.5 (100/ 175	12,5 (25/0)		12.5 (0/25)	87.5 (75/100)	37.5 (75/0)			
Halcampa decemtentaculata									25 (50/0)			
Actiniaria sp. A								12.5 (25/0)				
Actiniaria sp. B					100 (0/200)							
SIPUNCULIDA												
Unid. sp. A										50 (75/25)		
ECHINODERMATA: HOLOTHUROIDEA												
Leptosynapta albicans								62.5 (125/0)				
Unid. sp. A									12.5 (0/25)			
Unid. sp. B				61.5 (50/75)	75 (150/0)			112.5 (100/ 125)			12.5 (0/25)	25 (50/0)
Unid. *Apoda* sp.								25 (0/50)				
ECHINODERMATA: OPHIUROIDEA												
Amphipholis squamata				37.5 (0/75)								
PHORONIDA												
Phoronis pallida			12.5 (25/0)	37.5 (75/0)		425 (475/ 375)	37.5 (75/0)	1025 (2050/ 0)			37.5 (25/50)	25 (50/0)
MOLLUSCA: GASTROPODA												
Acteocina inculta	175 (175/ 175)	487.5 (825/ 150)	37.5 (0/75)		600 (250/ 950)	600 (250/ 950)	150 (275/ 25)	225 (100/ 350)	100 (150/50)	12.5 (0/25)		112.5 (225/0)
Assiminea californica						12.5 (25/0)			12.5 (0/25)			
Bulla gouldiana	1 (2/0)	14.5 (16/13)										
Caecum californicum							12.5 (25/0)					
Cerithidea californica	0.5 (1/0)				30 (30/30)	0.5 (1/0)			63.5 (29/98)	6 (5/7)		
Haminoea vesicula	1 (0/2)	2.5 (2/3)					1 (2/0)		0.5 (0/1)	1 (0/2)		
Olivella baetica				7 (7/-)								
MOLLUSCA: BIVALVIA												
Adula diegensis	3.5 (7/0)					3.5 (0/7)						
Chione californiensis	10.5 (21/0)			7 (7/-)		3.5 (7/0)			3.5 (0/7)	3.5 (0/7)		

Appendix I (continued)

Species	Station IA	IB	IC	ID	IIA	IIB	IIC	IID	IIIA	IIIB	IIIC	IIID
Chione fluctifraga					3.5 (7/0)				3.5 (0/7)			
Cryptomya californica					3.5 (7/0)							
Laevicardium sub-striatum										3.5 (7/0)		
Macoma nasuta		49 (42/56)	3.5 (7/0)			7 (7/7)	3.5 (0/7)					
Mytilus edulis		0.5 (1/0)										
Protothaca staminea	38.5 (49/28)	28 (28/28)	3.5 (7/0)	147 (147/-)	3.5 (7/0)				14 (28/0)			
Solen rosaceus				14 (14/-)				7 (7/7)		3.5 (0/7)		
Tagelus californianus	21 (0/42)				28 (35/21)				17.5 (0/35)			
Tagelus subteres		17.5 (14/21)	10.5 (21/0)	21 (21/-)	7 (0/14)	28 (35/21)					7 (7/7)	21 (21/21)
Tagelus spp.(juv.)			3.5 (0/7)		80.5 (77/84)	7 (0/14)		14 (14/14)	2481 (3262/ 1701)	1053.5 (980/ 1127)		7 (14/0)
Theora lubrica				7 (7/-)		38.5 (49/98)		3.5 (0/7)				
CRUSTACEA: ISOPODA												
Dynamenella sheareri	12.5 (0/25)				37.5 (50/25)	12.5 (25/0)						
Dynamenella sp.			12.5 (50/0)		75 (0/150)	12.5 (0/25)			12.5 (0/25)			
Sphaeromatidae sp.	12.5 (25/0)									12.5 (0/25)		
CRUSTACEA: TANAIDACEA												
Leptochelia dubia		25 (50/0)	25 (50/0)	12.5 (25/0)	62.5 (0/125)		25 (0/50)	50 (75/25)		150 (150/150)		12.5 (25/0)
CRUSTACEA: MYSIDACEA												
Unid. sp.					25 (0/50)							
CRUSTACEA: ANOMURA												
Callianassa californiensis	7 (7/7)	35 (28/42)										
CRUSTACEA: BRACHYURA												
Hemigrapsus oregonensis	25 (0/50)		12.5 (0/25)		62.5 (100/25)				12.5 (25/0)			
Mysis larva					25 (25/25)							
CRUSTACEA: AMPHIPODA												
Acuminodeutopus heteruropus						12.5 (0/25)					12.5 (0/25)	
Ampithoe pollex	12.5 (25/0)				12.5 (0/25)							
Ampithoe sp.	12.5 (25/0)			25 (0/50)	37.5 (25/50)	50 (25/75)	12.5 (0/25)	12.5 (25/0)	25 (50/0)	225 (75/375)		
Caprella equilibra								12.5 (25/0)				
Corophium acherusicum					50 (50/50)					37.5 (50/25)		
Corophium baconi					12.5 (0/25)							
Corophium sp.						12.5 (0/25)						12.5 (25/0)
Mayerella acanthopoda	12.5 (25/0)		50 (75/25)	337.5 (200/ 475)		87.5 (25/150)	75 (100/50)	1137.5 (600/ 1675)	25 (0/50)	75 (125/25)	87.5 (125/25)	25 (50/0)
Microdeutopus schmitti				12.5 (25/0)								

Appendix I (continued)

Species	Station IA	IB	IC	ID	IIA	IIB	IIC	IID	IIIA	IIIB	IIIC	IIID
Monoculodes sp.			37.5 (75/0)	87.5 (25/150)		12.5 (0/25)		87.5 (50/125)			12.5 (0/25)	
Pontogeneia sp.					137.5 (25/350)	50 (0/100)				25 (0/50)	50 (100/0)	
Rudilemboides steopropodus				100 (75/125)	12.5 (0/25)	112.5 (150/75)	25 (0/50)	600 (550/650)		25 (50/0)	12.5 (0/25)	50 (75/25)
Tritella pilimana								50 (75/25)				
Tritella sp.								12.5 (25/0)				
Unid. sp. A	12.5 (25/0)						25 (50/0)					
PYCNOGONIDA												
Anaplodactylus erectus			12.5 (50/0)	25 (0/50)				12.5 (25/0)			12.5 (0/25)	
CRUSTACEA: COPEPODA												
Calanoida spp.					237.5 (75/400)	25 (0/50)				12.5 (25/0)		
Harpacticoida spp.				12.5 (0/25)	462.5 (225/700)	25 (25/25)		12.5 (0/25)	237.5 (175/300)	62.5 (25/100)		
CRUSTACEA: CUMACEA												
Cumella sp.						12.5 (0/25)		12.5 (25/0)				
Oxyurostylis pacifica	12.5 (0/25)	50 (75/25)	37.5 (50/25)	250 (50/450)	37.5 (50/25)	262.5 (225/300)	50 (100/0)	350 (175/525)	25 (50/0)	100 (175/25)	462.5 (375/550)	87.5 (125/50)

Appendix II. Densities (numbers per square meter) of invertebrates from samples collected from the Upper Newport Bay in January 1978. Beneath each mean density value, the densities of the two replicates are given in parenthesis.

	Station											
Species	IA	IB	IC	ID	IIA	IIB	IIC	IID	IIIA	IIIB	IIIC	IIID
POLYCHAETA												
Capitella capitata	2337.5 (1425/ 3250)	512.5 (950/ 125)	25 (25/25)	12.5 (25/0)	462.5 (75/850)	612.5 (25/ 1200)	100 (75/125)	25 (0/50)	67.5 (100/25)	12.5 (25/0)		250 (200/ 300)
Cossura candida			1462.5 (2175/ 750)	225 (300/ 150)		12.5 (0/25)	112.5 (25/200)	262.5 (500/25)				
Exogone lourei	12.5 (0/25)	75 (150/0)										
Fabricia limnicola	22,175 (14,850/ 29,500	525 (1000/ 50)	50 (75/25)		225 (300/150)				12.5 (25/0)			
Haploscoloplos elongatus		12.5 (25/0)	87.5 (175/0)									
Lumbrineris minima			12.5 (0/25)	12.5 (25/0)				12.5 (0/25)				
Marphysa sp.					12.5 (25/0)							
Mediomastus ambiseta		325 (525/ 125)	112.5 (25/200)	25 (25/25)	12.5 (0/25)		12.5 (0/25)	37.5 (25/50)				
Mediomastus californiensis						12.5 (0/25)	87.5 (50/125)	50 (0/100)				
Neanthes arenaceodentata	25 (25/25)		12.5 (0/25)									
Notomastus (C.) tenuis	362.5 (150/ 575	50 (0/100)	12.5 (25/0)									
Polydora ligni	87.5 (100/75)											
Polydora nuchalis	387.5 (400/ 375)				275 (0/550)				50 (75/25)			
Polydora socialis	200 (0/400)											
Polydora websteri	275 (75/475)											
Polydora sp.			25 (0/50)						12.5 (25/0)			
Prionospio heterobranchia newportensis	25 (0/50)											
Scolelepis acuta					12.5 (0/25)							
Streblospio benedicti	1962.5 (2025/ 1900)	150 (300/0)	37.5 (50/25)		200 (0/400)	50 (25/75)		25 (25/25)	25 (50/0)			
Tharyx parvus		25 (0/50)					12.5 (0/25)	12.5 (0/25)				
OLIGOCHAETA												
Peloscolex sp. A	25 (25/25)	225 (300/ 150)	187.5 (175/ 200)	125 (150/ 100)	137.5 (50/225)	225 (325/ 125)	50 (50/50)	112.5 (50/175)		50 (75/25)	37.5 (25/50)	125 (100/ 150)
Peloscolex sp. B	137.5 (25/250)	800 (1450/ 150)	162.5 (250/75)	75 (100/50)	125 (0/250)	375 (450/ 300)	162.5 (125/ 200)	100 (25/175)		37.5 (50/25)	12.5 (0/25)	37.5 (75/0)
Peloscolex sp. C		37.5 (0/75)										
Unid. sp. A	125 (100/ 150)				25 (0/50)	87.5 (125/50)	62.5 (75/50)	12.5 (0/25)	25 (0/50)	25 (50/0)		125 (0/250)
NEMERTINA												
Unid. Sp. A		62.5 (125/0)										
Unid. sp. B	12.5 (0/25)		37.5 (50/25)									

Appendix II (continued)

Species	Station IA	IB	IC	ID	IIA	IIB	IIC	IID	IIIA	IIIB	IIIC	IIID
NEMATODA												
Unid. spp.				737.5 (1450/25)		12.5 (25/0)						
CNIDARIA : ANTHOZOA												
Halcampa crypta?			12.5 (25/0)									
PHORONIDA												
Phoronis pallida				112.5 (50/175)								
MOLLUSCA: GASTROPODA												
Aeteocina inculta	175 (175/ 175)	687.5 (700/ 675)	12.5 (25/0)	12.5 (0/25)	1300 (350/ 2250)	187.5 (250/ 125)	37.5 (50/25)	337.5 (125/ 450)	12.5 (0/25)	37.5 (25/50)	12.5 (25/0)	
Assiminea californica				12.5 (0/25)				12.5 (0/25)	37.5 (50/25)			12.5 (25/0)
Cerithidea californica											0.5 (0/1)	
Haminoea vesicula	0.5 (0/1)											
MOLLUSCA: BIVALVIA												
Chione californiensis	7 (0/14)			3.5 (7/0)								
Chione fluctifraga	3.5 (7/0)								3.5 (7/0)			
Geukensia demissa									3.5 (0/7)			
Macoma nasuta		7 (14/0)		3.5 (7/0)	7 (7/7)	7 (0/14)		3.5 (0/7)				
Protothaca staminea	151 (126/ 196)	38.5 (49/28)		37.5 (21/56)	31.5 (28/35)							
Tagelus californianus					17.5 (14/21)							
Tagelus subteres		7 (7/7)										
Tagelus spp. (juv.)	63 (70/56)		3.5 (7/0)		91 (56/126)	35 (42/28)		3.5 (0/7)	28 (7/49)	45.5 (56/35)	7 (7/7)	3.5 (7/0)
CRUSTACEA: COPEPODA												
Calanoida sp.											12.5 (0/25)	
Cyclopoida sp.							12.5 (25/0)					12.5 (0/25)
CRUSTACEA: CUMACEA												
Oxyurostylis pacifica		12.5 (25/0)										
CRUSTACEA: AMPHIPODA												
Corophium acherusicum			12.5 (0/25)							12.5 (0/25)		
Tritella pilimana										12.5 (0/25)		
CRUSTACEA: BRACHYURA												
Hemigrapsus oregonensis				12.5 (0/25)						12.5 (25/0)		

Appendix III. Densities (numbers per square meter) of invertebrates from samples collected from the Upper Newport Bay in April 1978. Beneath each mean density value, the densities of the two replicates are given in parenthesis.

Species	Station IA	IB	IC	ID	IIA	IIB	IIC	IID	IIIA	IIIB	IIID
POLYCHAETA											
Boccardia proboscidea	25 (0/50)										
Boccardia uncata	12.5 (25/0)										
Capitella capitata	2437.5 (3800/ 1075)	50 (0/100)	175 (325/25)	100 (100/ 100)	175 (175/ 175)		62.5 (125/0)	87.5 (125/50)	67.5 (75/50)		
Cossura candida			37.5 (50/25)								
Fabricia limnicola											12.5 (0/25)
Marphysa sp.				12.5 (0/25)							
Polydora ligni	362.5 (525/ 200)	3112.5 (2450/ 3775)	4150 (6350/ 1950)	1525 (1225/ 1825)	725 (700/ 750)	850 (1175/ 525)	7475 (11000/ 3950)	2137.5 (1875/ 2400)	675 (1050/ 300)	4175 (3875/ 4475)	1462.5 (1050/ 1815)
Polydora nuchalis	1650 (1250/ 2050)				12.5 (0/25)				12.5 (0/25)		12.5 (0/25)
Polydora sp.	262.5 (100/425)		12.5 (0/25)								
Pseudopolydora paucibranchiata		475 (400/ 550)	225 (300/ 150)	525 (575/ 475)	12.5 (0/25)		162.5 (300/25)	50 (100/0)			
Spio sp.			25 (50.0)					12.5 (25/0)			
Streblospio benedicti	6437.5 (9500/ 3375)	50 (0/100)							12.5 (25/0)		
OLIGOCHAETA											
Peloscolex sp. A	50 (75/25)	61.5 (75/50)	12.5 (0/25)	37.5 (25/0)		25 (50/0)	12.5 (25/0)		100 (75/125)	62.5 (0/125)	112.5 (100/125)
Peloscolex sp. B									62.5 (50/75)		50 (75/25)
Peloscolex sp. C			50 (25/75)	12.5 (25/0)	25 (0/50)	62.5 (50/75)	75 (100/50)	50 (100/0)		12.5 (25/0)	
Unid. sp. A	25 (0/50)	75 (25/125)	25 (50/0)		75 (100/50)	75 (100/50)	12.5 (0/25)		12.5 (25/0)	125 (75/175)	125 (125/125)
Unid. sp. B	300 (0/600)	250 (50/450)	225 (400/50)	25 (50/0)	787.5 (850/ 725)	650 (500/ 800)	687.5 (1200/ 175)	12.5 (25/0)			
NEMERTINA											
Unid. sp. B		12.5 (0/25)						12.5 (25/0)			
PHORONIDA											
Phoronis pallida						12.5 (25/0)	37.5 (0/75)				
MOLLUSCA: GASTROPODA											
Acteocina inculta	612.5 (225/ 1000)	287.5 (275/ 300)	237.5 (450/25)		12.5 (25/0)				12.5 (25/0)		
Assiminea californica						12.5 (25/0)			25 (25/25)	25 (50/0)	
Nudibranchia sp. A			12.5 (25/0)							12.5 (25/0)	62.5 (50/75)

Appendix III (continued)

Species	Station IA	IB	IC	ID	IIA	IIB	IIC	IID	IIIA	IIIB	IIID
MOLLUSCA: BIVALVIA											
Cooperella subdiaphana				12.5 (25/0)							
Protothaca staminea	7 (7/7)										
Tagelus subteres	31.5 (7/56)										
Tagelus sp. (juv.)	49 (70/28)		3.5 (7/0)		3.5 (0/7)						
CRUSTACEA: COPEPODA											
Calanoida spp.				25 (0/50)						12.5 (0/25)	25 (25/25)
CRUSTACEA: AMPHIPODA											
Corophium acherusicum		12.5 (0/25)									

Appendix IV. Densities (numbers per square meter) of invertebrates from samples collected from the Upper Newport Bay in August 1978. Beneath each mean density value, the densities of the two replicates are given in parenthesis.

	Station										
Species	IA	IB	IC	ID	IIA	IIB	IIC	IID	IIIA	IIIB	IIID
POLYCHAETA											
Boccardia proboscidea	250 (250/ 250)										
Boccardia uncata	125 (150/ 100)	137.5 (125/ 150)	212.5 (325/ 100)	37.5 (50/25)	75 (0/150)	12.5 (0/25)	12.5 (25/0)				
Capitella capitata	16,125 (16,400/ 15,850)	11,175 (10,125/ 12,225)	2712.5 (900/ 4525)	350 (275/ 425)	20,862.5 (21,700/ 20,025)	5887.5 (4725/ 7050)	862.5 (1000/ 725)	575 (225/ 925)	15,187.5 (14,975/ 15,400)	4287.5 (5775/ 2800)	7762.5 (8350/ 7175)
Cossura candida				37.5 (0/75)							
Euchone limnicola		12.5 (25/0)	962.5 (400/ 1525)	7662.5 (10,625/ 4700)		175 (75/275)	1362.5 (1600/ 1125)				
Eumida bifoliata				12.5 (0/25)							
Exogone uniformis	575 (450/ 700)	300 (250/ 350)	12.5 (25/0)								
Fabricia limnicola	5550 (3200/ 7900)	537.5 (525/ 550)									
Glycera americana		12.5 (25/0)		12.5 (25/0)							
Haploscoloplos elongatus		25 (0/50)	37.5 (25/50)	212.5 (200/ 225)		13.5 (0/25)	25 (50/0)				
Harmothoe lunulata	25 (50/0)										
Lumbrineris minima		12.5 (25/0)		25 (0/50)							
Marphysa sanguinea								12.5 (25/0)			
Marphysa sp.	25 (0/50)		150 (75/225)	50 (75/25)		12.5 (0/25)	212.5 (175/ 250)				
Mediomastus acutus				50 (0/100)							
Mediomastus ambiseta		437.5 (475/ 400)	25 (25/25)	275 (350/ 200)	12.5 (25/0)		12.5 (25/0)		62.5 (25/100)		187.5 (175/ 200)
Mediomastus californiensis		12.5 (25/0)									
Megaloma pigmentum		12.5 (0/25)									
Nephtys californiensis			25 (25/25)	25 (25/25)			12.5 (25/0)				
Notomastus (*C.*) *tenuis*	137.5 (75/200)	37.5 (50/25)	12.5 (0/25)								
Pherusa capulata		12.5 (0/25)									
Pista alta				12.5 (0/25)							
Polydora ligni	12,350 (12,450 12,250)	4187.5 (4050/ 4325)	9425 (7450/ 11,400)	2337.5 (2300/ 2375)	16,300 (16,550/ 16,050)	5375 (4625/ 6125)	14,687.5 (12,125/ 17,250)	1062.5 (275/ 1850)	13,950 (14,000/ 13,900)	4612.5 (2450/ 6775)	4562.5 (5675/ 3450)
Polydora nuchalis	875 (900/ 850)	137.5 (225/50)	187.5 (175/ 200)		2912.5 (3250/ 2575)	350 (450/ 250)	125 (25/225)	50 (0/100)	1987.5 (1975/ 2000)	450 (200/ 700)	975 (1000/ 950)

Appendix IV (continued)

Species	IA	IB	IC	ID	IIA	IIB	IIC	IID	IIIA	IIIB	IIID
	Station										
Polydora socialis	2950 (1200/ 4700)	1412.5 (1200/ 1625)	50 (75/25)	12.5 (25/0)	37.5 (50/25)	187.5 (200/ 175)	1100 (25/2175)		12.5 (25/0)		362.5 (725/0)
Polyophthalmus pictus	37.5 (0/75)	100 (25/175)	225 (450/0)			12.5 (25/0)					
Pseudopolydora paucibranchiata	24,325 (6000/ 42,650)	6712.5 (5475/ 7950)	9087.5 (6175/ 12,000)	2712.5 (3925/ 1500)	11,500 (13,600/ 9400)	9275 (7300/ 11,250)	3787.5 (3275/ 4300)	37.5 (75/0)	525 (550/ 500)	1575 (750/ 2400)	1467.5 (1450/ 1475)
Prionospio cirrifera		25 (50/0)	12.5 (25/0)	25 (25/25)			12.5 (25/0)				
Prionospio heterobranchia newportensis		37.5 (50/25)	37.5 (25/50)	50 (75/25)							
Rhynchospio arenincola			137.5 (0/275)	67.5 (75/50)			225 (300/ 150)		12.5 (0/25)	12.5 (25/0)	25 (50/0)
Schistomeringos rudulphi		12.5 (25/0)		25 (25/25)			12.5 (25/0)				
Scolelepis acuta	312.5 (150/ 475)	375 (500/ 250)	1712.5 (700/ 2725)	662.5 (925/ 400)	2350 (1700/ 650)	3125 (3775/ 2475)	2800 (3100/ 2500)	1800 (550/ 3050)	1812.5 (1400/ 2225)	2475 (775/ 4175)	4962.5 (5725/ 4200)
Scoloplos acmeceps		12.5 (0/25)	12.5 (0/25)	37.5 (75/0)							
Scoloplos nr. acmeceps		12.5 (25/0)									
Spiophanes missionensis	25 (0/50)			62.5 (125/0)							
Sthenelanella uniformis							12.5 (0/25)				
Streblospio benedicti	37500 (28750/ 46250)	9500 (9550/ 9450)	512.5 (175/ 850)	275 (350/ 200)	3200 (4475/ 1925)	3162.5 (3500/ 2825)	850 (900/ 800)	237.5 (275/ 200)	687.5 (475/ 900)	725 (300/ 1150)	3600 (4175/ 3025)
Tharyx monilaris				12.5 (25/0)							
OLIGOCHAETA											
Peloscolex sp. A	125 (250/0)	412.5 (825/0)		237.5 (25/450)	875 (1750/0)						
Peloscolex sp. B	25 (0/50)	1850 (2500/ 1200)	12.5 (25/0)	100 (0/200)	3075 (6150/0)						
Peloscolex sp. C		1587.5 (2000/ 1175)			512.5 (1025/0)	250 (250/ 250)			1662.5 (625/ 2700)	62.5 (50/75)	62.5 (125/0)
Unid. sp. B	6225 (3425/ 9025)	25 (0/50)		25 (0/50)	200 (0/400)	425 (425/ 425)	167.5 (175/ 150)		3325 (1650/ 5000)	1750 (2275/ 1225)	87.5 (175/0)
Unid. sp. C		1187.5 (1625/ 750)	37.5 (75/0)		400 (700/ 100)						
NEMERTINA											
Unid. sp. A					12.5 (25/0)		12.5 (0/25)				
Unid. sp. B		78.5 (75/100)	37.5 (75/0	37.5 (0/75)		67.5 (75/50)					
Unid. sp. C							12.5 (0/25)				
Unid. sp. E		12.5 (0/25)			12.5 (0/25)						
Unid. sp. F		125 (125/ 125)	50 (25/75)	75 (125/25)		37.5 (75/0)			12.5 (0/25)		

Appendix IV (continued)

Species	Station IA	IB	IC	ID	IIA	IIB	IIC	IID	IIIA	IIIB	IIID
NEMATODA											
Unid. spp.	12.5 (0/25)	250 (425/75)	12.5 (0/25)	5512.5 (0/11025)		175 (175/175)	225 (50/400)		1562.5 (175/2950)	300 (425/175)	600 (1000/200)
TURBELLARIA											
Unid. spp.	225 (75/375)								725 (325/1125)	12.5 (0/25)	
CNIDARIA: ANTHOZOA											
Halcampa crypta?		12.5 (0/25)	137.5 (25/250)	312.5 (425/200)		50 (50/50)	50 (75/25)			12.5 (0/25)	
Halcampa decemtentaculata	12.5 (25/0)										
Actiniaria sp. A				12.5 (25/0)							
Actiniaria sp. B					37.5 (25/50)						
SIPUNCULIDA											
Unid. sp. A	375 (0/750)										
Unid. sp. B		37.5 (0/75)			12.5 (0/25)						
ECHINODERMATA: HOLOTHUROIDEA											
Unid. sp. B					12.5 (25/0)						
Unid. Apoda sp.			12.5 (25/0)								
PHORONIDA											
Phoronis pallida	125 (25/225)	412.5 (800/825)	975 (1050/900)	175 (300/50)	100 (75/125)	300 (350/250)	537.5 (700/375)	212.5 (275/150)	50 (50/50)	37.5 (25/50)	187.5 (250/125)
TUNICATA: ASCIDIACEA											
Molgula manhattensis			12.5 (0/25)								
MOLLUSCA: GASTROPODA											
Acteocina inculta	3262.5 (2975/3550)	9787.5 (8825/10750)	37.5 (0/75)	50 (50/50)	3475 (3600/3350)	2537.5 (2500/2575)	662.5 (975/350)	50 (25/75)	2112.5 (650/3575)	487.5 (350/625)	425 (450/400)
Assiminea californica	12.5 (25/0)										
Barleeia subtenuis								12.5 (0/25)	62.5 (0/125)		12.5 (0/25)
Cerithidea californica	1.5 (3/0)								0.5 (0/1)		
Nudibranchia sp. A			12.5 (25/0)			12.5 (0/25)	50 (0/100)				
MOLLUSCA: BIVALVIA											
Chione fluctifraga	3.5 (7/0)				7 (7/7)						
Diplodonta orbellus							3.5 (7/0)				
Macoma nasuta		38.5 (42/35)	10.5 (21/0)	37.5 (42/35)		28 (35/21)	10.5 (7/14)				
Protothaca staminea	21 (21/21)	10.5 (7/14)		87.5 (56/119)	3.5 (7/0)		7 (7/7)				
Solen rosaceus		10.5 (7/14)	3.5 (7/0)	3.5 (0/7)		3.5 (0/7)	7 (14/0)	3.5 (7/0)			

Appendix IV (continued)

Species	Station									
	IA	IB	IC	ID	IIA	IIB	IIC	IID	IIIA	IIIB	IIID

Species	IA	IB	IC	ID	IIA	IIB	IIC	IID	IIIA	IIIB	IIID
Tagelus californianus	3.5 (7/0)				374.5 (315/434)	10.5 (21/0)			7 (7/7)		
Tagelus subteres	10.5 (21/0)	3.5 (0/7)	3.5 (0/7)	17.5 (14/21)	54 (84/35)	10.5 (0/21)	3.5 (0/7)		3.5 (7/0)		
Tagelus spp. (juv.)	42 (56/28)	21 (28/14)		7 (7/7)	3.5 (7/0)	14 (7/21)			7 (0/14)		
Theora lubrica			248.5 (175/322)	766.5 (994/539)		14 (7/21)	3.5 (7/0)		3.5 (0/7)		
PYCNOGONIDA											
Anaplodactylus erectus				37.5 (75/0)							
CRUSTACEA: COPEPODA											
Harpacticoida spp.					37.5 (25/50)	100 (100/100)	12.5 (25/0)				
CRUSTACEA: CUMACEA											
Oxyurostylis pacifica	12.5 (25/0)	312.5 (275/350)	287.5 (0/575)	4900 (6700/3100)		12.5 (25/0)	250 (425/75)	362.5 (75/650)			
CRUSTACEA: AMPHIPODA											
Caprella equilibra			75 (0/150)	1075 (825/1325)		12.5 (25/0)	25 (0/50)				
Caprella sp.		12.5 (25/0)	25 (0/50)	25 (0/50)							
Corophium acherusicum	200 (350/50)	12.5 (0/25)	12.5 (0/25)	62.5 (25/100)	25 (50/0)	75 (125/25)	150 (125/175)	50 (0/100)			37.5 (25/50)
Corophium sp.		25 (0/50)	50 (0/100)	150 (25/275)		37.5 (50/25)	62.5 (0/125)				
Mayerella acanthopoda		7612.5 (9900/5325)	6387.5 (200/12575)	6562.5 (8075/5050)	137.5 (275/0)	302.5 (1950/4100)	14787.5 (8375/21200)	587.5 (50/1125)	12.5 (25/0)		25 (50/0)
Monoculodes sp.				25 (50/0)							
Pontogeneia sp.	12.5 (0/25)	725 (1025/225)	37.5 (0/75)		1212.5 (2400/25)	1512.5 (1425/1600)	50 (0/100)		12.5 (25/0)		
Rudilemboides stenopropodus				12.5 (0/25)							
Tritella pilimana		62.5 (100/25)									
CRUSTACEA: BRACHYURA											
Hemigrapsus oregonensis		12.5 (25/0)	12.5 (25/0)								
Mysis larva						87.5 (125/50)					

Appendix V. Densities (numbers per square meter) of invertebrates from samples collected from the Upper Newport Bay in January 1979. Beneath each mean density value, the densities of the two replicates are given in parenthesis.

	Station									
	IA	IB	IC	ID	IIA	IIB	IIC	IID	IIIA	IIID
POLYCHAETA										
<u>Boccardia proboscidea</u>	25 (0/50)									
<u>Boccardia uncata</u>	437.5 (300/575)	112.5 (200/25)				12.5 (0/25)				
<u>Capitella capitata</u>	3300 (3600/ 3000)	3200 (5150/ 1250)	625 (725/ 525)	25 (25/25)	1275 (1525/ 1025)	1412.5 (1625/ 1200)	937.5 (925/ 950)	1612.5 (1325/ 1900)	112.5 (25/200)	
<u>Cossura candida</u>		12.5 (25/0)								
<u>Exogone uniformis</u>	50 (50/50)	937.5 (1725/150)	112.5 (225/0)					12.5 (25/0)		
<u>Fabricia limnicola</u>	9225 (9875/ 8575)	2350 (4125/ 575)	12.5 (25/0)						37.5 (75/10)	
<u>Glycera americana</u>		12.5 (0/25)								
<u>Lumbrineris minima</u>			12.5 (0/25)							
<u>Marphysa</u> sp.			50 (100/0)	225 (200/ 250)	87.5 (25/150)	12.5 (25/0)	12.5 (0/25)			
<u>Mediomastus ambiseta</u>	25 (25/25)	250 (275/225)	100 (200/0)	37.5 (25/50)			50 (25/75)			
<u>Neanthes arenaceodentata</u>	12.5 (0/25)	250 (325/ 175)	300 (325/ 275)						12.5 (0/25)	
<u>Notomastus</u> (<u>C</u>.) <u>tenuis</u>	75 (25/125)	25 (25/25)				12.5 (0/25)				
<u>Polydora ligni</u>	1150 (1450/ 850)	262.5 (350/ 175)	12.5 (25/0)	112.5 (125/ 100)		25 (50/0)	25 (0/50)	12.5 (25/0)		
<u>Polydora nuchalis</u>	1412.5 (1825/ 1000)	212.5 (250/ 175)	50 (100/0)		1950 (875/ 3025)	250 (250/ 250)	25 (25/25)		1275 (1575/ 975)	
<u>Polydora socialis</u>	2500 (2375/ 2625)	825 (925/ 725)			12.5 (25/0)	175 (225/ 125)	537.5 (750/ 325)	12.5 (25/0)		
<u>Polydora websteri</u>	625 (825/ 425)	25 (0/50)	12.5 (0/25)	87.5 (50/125)		12.5 (0/25)				
<u>Pseudopolydora paucibranchiata</u>	650 (850/ 450)	250 (450/50)	12.5 (0/25)		12.5 (0/25)	50 (25/75)	25 (25/25)			
<u>Prionospio cirrifera</u>		12.5 (25/0)				12.5 (0/25)				
<u>Schistomeringos rudulphi</u>		25 (25/25)	50 (50/50)							
<u>Scolelepis acuta</u>		262.5 (425/ 100)	62.5 (100/25)	37.5 (75/0)	12.5 (25/0)	37.5 (75/0)	87.5 (25/150)	162.5 (275/50)	12.5 (0/25)	
<u>Scoloplos acmeceps</u>		37.5 (75/0)								
<u>Streblospio benedicti</u>	7912.5 (8750/ 7075)	4150 (6225/ 2075)	750 (775/ 725)	537.5 (625/ 450)	1275 (675/ 1875)	3350 (4000/ 2700)	950 (1000/ 900)	1362.5 (1650/ 1075)	2000 (1975/ 2025)	

Appendix V (continued)

Species	IA	IB	IC	ID	IIA	IIB	IIC	IID	IIIA	IIID
					Station					
Tharyx monilaris	37.5 (0/75)	37.5 (75/0)					12.5 (25/0)			
Tharyx sp.	12.5 (25/0)									
OLIGOCHAETA										
Peloscolex sp. A	112.5 (150/75)	1437.5 (2075/ 800)	812.5 (1125/ 500)	575 (475/ 700)	1150 (350/ 1950)	237.5 (350/ 125)	112.5 (100/ 125)	137.5 (250/25)		
Peloscolex sp. B	37.5 (50/25)	162.5 (225/100)	50 (50/50)		75 (150/0)					
Peloscolex sp. C	1512.5 (1175/ 1850)	387.5 (550/ 225)	12.5 (25/0)		712.5 (700/ 725)	212.5 (200/ 225)	12.5 (25/0)	12.5 (25/0)	75 (75/75)	87.5 (50/125)
Unid. sp. B	400 (525/ 275)	62.5 (100/25)	75 (75/75)							
Unid. sp. C			275 (425/ 125)	100 (0/200)		37.5 (75/0)				
NEMERTINA										
Unid. sp. A			62.5 (50/75)							
Unid. sp. B		25 (50/0)								
Unid. sp. E		12.5 (0/25)								
Unid. sp. F		12.5 (25/0)	25 (25/25)							
NEMATODA										
Unid. spp.	15862.5 (20050/ 11675	2312.5 (3725/ 900)	4400 (3350/ 5450)	100 (50/150)	1375 (1875/ 875)	450 (700/ 200)	462.5 (850/75)	237.5 (475/0)	1562.5 (3125/0)	
CNIDARIA: ANTHOZOA										
Halcampa crypta?		12.5 (25/0)	62.5 (50/75)	25 (25/25)						
Haliplanella luciae				37.5 (75/0)						
PHORONIDA										
Phoronis pallida		287.5 (400/ 175)	475 (275/ 675)	12.5 (25/0)		525 (625/ 425)	625 (750/ 500)	300 (350/ 250)		25 (25/25)
MOLLUSCA: GASTROPODA										
Acteocina inculta	387.5 (375/ 400)	4712.5 (5300/ 4125)	212.5 (225/ 400)	137.5 (200/75)	425 (550/ 300)	1300 (1325/ 1275)	437.5 (400/ 475)	575 (750/ 400)	675 (350/ 1000)	50 (50/50)
Barleeia subtenuis		100 (175/25)								
MOLLUSCA: BIVALVIA										
Chione californiensis	3.5 (7/0)				7 (7/7)					
Chione fluctifraga	3.5 (0/7)									

Appendix V *(continued)*

Species	Station: IA	IB	IC	ID	IIA	IIB	IIC	IID	IIIA	IIID
Macoma nasuta		14 (0/28)	7 (7/7)			7 (14/0)				
Protothaca staminea	38.5 (56/21)	3.5 (0/7)	7 (7/7)	28 (28/28)	7 (14/0)					
Tagelus californianus	94.5 (133/56)	7 (0/14)	10.5 (14/7)	7 (7/7)	220.5 (441/0)					
Tagelus subteres		17.5 (0/35)	3.5 (0/7)	3.5 (0/7)						
Tagelus spp. (juv.)		3.5 (7/0)	12.5 (25/0)			3.5 (7/0)				
Theora lubrica		10.5 (14/7)	312.5 (225/ 400)	37.5 (25/50)			37.5 (0/75)			
PYCNOGONIDA										
Anaplodactylus erectus			25 (25/25)							
CRUSTACEA: COPEPODA										
Harpacticoida spp.	125 (150/ 100)	37.5 (75/0)	75 (75/75)		212.5 (275/ 150)	25 (50/0)				
CRUSTACEA: CUMACEA										
Oxyurostylis pacifica							12.5 (0/25)			
CRUSTACEA: AMPHIPODA										
Corophium acherusicum	12.5 (0/25)				12.5 (0/25)	12.5 (0/25)				