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COMPARISON OF THE BENTHOS AT SEVERAL WASTEWATER DISCHARGE SITES

For several years, this Project has been accumulating data on the benthic infauna near wastewater outfalls. Only recently has enough information been obtained from all the major discharge areas to permit us to compare these data and make a preliminary, broad regional assessment. Using statistics from various sources, we have compared the benthos at five specific outfall areas for biomass, abundance, number of species, diversity, and richness. The result is a scan of some of the effects of wastewater on a 300-km section of the southern California coast. The five outfall areas (each with its own controls) are, from north to south, the Oxnard coastal shelf, Santa Monica Bay, the Palos Verdes coastal shelf, the Santa Ana River area of south San Pedro Bay, and the Point Loma coastal shelf. The comparison indicates that the major effect of the wastewaters on the benthic infauna in the outfall area is to increase the abundance of organisms and to decrease the diversity. The effect is most pronounced at the sites of the largest discharges and can be quantitatively related to the amount of wastewater discharged. However, the comparison indicates that—in addition to the localized effects of the wastewaters—there is a general increase in biomass and decrease in diversity as one approaches the Los Angeles coastal region from the north and south. The data we have assembled were produced by scientists at wastewater monitoring laboratories and at private biological laboratories as well as at our own. The use of several kinds of grab devices, two sizes of sorting screens, ships with uncertain navigational capabilities, and taxonomists of varying experience, makes us uncertain as to the preciseness of the data. However, we believe that the regional differences discussed here are so substantial that they override the inaccuracies that are doubtless contained in the data. The objective is to offer a perspective to biologists concerned with regional problems rather than to present hard data for its own sake.

METHODS

The five criteria used in the comparison are station averages in each area for:

- Biomass, the amount of living material that is retained on a 1-mm screen (or 0.5-mm screen, in the case of Oxnard); expressed in grams per square meter of bottom sediment sample.
- Abundance, the number of animals retained on a 1- or 0.5-mm screen.
- Number of species identified.
- Diversity, a measure of the relationship between the number of species and the distribution of individual animals among species in a sample. The diversity is calculated using the Shannon-Weaver index:

  $$H' = \sum_{i=1}^{S} n_i/N \, 1n \, n_i/N,$$

  where S is the number of species in the sample, n_i is the number of individuals of the ith species in the sample (i = 1, 2, 3, . . ., S), and N is the total number of individuals in the sample.
- Richness, a secondary way of estimating species variety in an attempt to account for the effect of varying sample sizes (and abundance). We calculated richness using Gleason's formula:

  $$D = (S - l)/\log_{10}N.$$

RESULTS

Table 1 summarizes the biological sampling conditions at the five sites. Table 2 presents average values, standard errors (SE) and coefficients of variation (CV) for each of the criteria for all stations in each discharge area taken during one season (summer) in 1975 or in 1974 (Oxnard). The statistics are calculated from station averages. Table 3 presents similar statistics but data from only one depth range—55 to 65 m, the depth of the four largest discharges.

As shown in Table 2, the values for each of the five characteristics chosen for this comparison differed markedly with survey area. Biomass was low at the Oxnard and Point Loma outfall sites, moderate at Orange County and in Santa Monica Bay, and high at Palos Verdes. Individual samples produced values as low as 5 g/sq m and as high as 2,000 g/sq m. Abundance showed somewhat similar (but less dramatic) trends, ranging from a low of about 1,300 animals/sq m at Point Loma to about 4,800 animals/sq m in Santa Monica Bay.

Number of species, diversity, and richness were generally high where biomass and abundance were low. For example, the average Oxnard sample (which was low in biomass and moderate in abundance) contained about 52 species and had a diversity index of 3.3 and a richness index of about 24. In contrast, samples from Santa Monica Bay and Palos Verdes (which had high values for biomass and abundance) had about one-half the number of species per sample (27 and 18, respectively) and one-half to two-thirds the diversity (2.2 and 2.0, respectively) and richness (12 and 8, respectively).

At the depth range of 55 to 65 meters (Table 3), these general trends remain, but there are some notable differences. The differences between high and low average values for biomass are increased, with Palos Verdes now showing the highest abundances. Trends in species number, diversity, and richness are not substantially changed, however.

The variability (as measured by CV) for each characteristic within each survey also shows some noteworthy trends. When all data from all stations in each discharge area are considered (Table 2), biomass and abundance are more variable (CV ranging from 49 to 115 percent for biomass, and from 39 to 114 percent for abundance) than species number, diversity, and richness (e.g., CV for species number from 18 to 44 percent). The high variability for biomass and abundance is markedly reduced when data from only one depth range is summarized (Table 3), indicating that it is important to standardize depth of sampling. Also, our previous review of data indicated that the relatively high variation at Palos Verdes was due, in part, to the occurrence of at least four or five clearly different benthic communities within the large survey grid (Smith and Greene 1976).

DISCUSSION

The general trend of these data is one of increasing biomass (but not necessarily abundance) and decreasing number of species, diversity, and richness associated with increasing amounts of discharge. The effect is most pronounced in the areas surveyed off Los Angeles, where the influence of three major municipal wastewater discharges may be compounded by other factors that also affect sediments and productivity of the benthos. These could include vessel activity, proximity to harbors, land run-off through flood control channels, or major regional differences in abundance of predatory fishes and invertebrates.

Complicating the analysis are the only partly understood effects of sampling differences at each site (such as those listed in Table 1). For example, the smaller screen size used only at Oxnard (0.5 mm versus 1.0 mm) would tend to retain more animals and more species, thus yielding higher estimates of abundance, diversity, and richness. Differences in the depth of sampler penetration and volume of sediment collected, as well as variations in water depth at sampling sites are also important variables.

Another complicating factor may be the unique distributions of certain species, such as the echiuroid *Listriolobus petodes*, which dominates biomass at some sampling sites off Palos Verdes (over 1,500 g/sq m at some localities) but is considerably less common elsewhere (except in a bed between Ventura and Santa Barbara). However, when information on this animal is deleted from the body of data, the general patterns of biomass, abundance, and diversity remain the same, although the magnitude of biomass differences among the sites is reduced.

Some of the regional differences described above also remained when the "control" transects for each area were analyzed separately and compared. This supports the suggestion that large-scale regional effects, possibly independent of the outfalls, exist in our coastal area. We hope to verify these patterns by some kind of a large-scale selective sampling survey, employing one set of methods at these five sites and at locations in between. Confirmation of such trends could have important implications. For example, in the future, it may be important to pay more careful attention to the selection of "control" sites, the standardization of sampling methods and data analysis, and the consideration of sources of nutrients and pollutants other than wastewater discharges that may change the abundance and diversity of the coastal benthos.

Meanwhile, we hope these preliminary conclusions will stimulate new thinking about the benthos and the meaning of benthic survey data.

REFERENCES

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Table 1. Summary of benthic biological sampling conditions at five southern California wastewater discharge sites, summer 1974 and 1975.

	Oxnard	Santa Monica Bay	Palos Verdes	Orange* County	Point Loma
Description of Discharge					
• Depth (m)	16	60 & 100	60 & 65	56	61
• Distance from shore (km)	1.5	8 & 11	2.6 & 3.6	7.3	3.5
• 1975 flow (mgd)	9.5	349	341	175	109
• 1975 total suspended solids (metric tons/yr)	2,181	110,180	130,966	33,396	18,725
Benthic Sampling					
• Date of sampling	Jul 74	Jul 75	Aug 75	Jul 75	Jul 75
• No. of stations (No. of replicates)	19(3)	23(4)	40(4)	35(1-3)	18(3)
• Approximate size of survey grid (sq km)	20	214	60	15	18
• Depth range (m)	12-60	20-170	10-310	13-180	20-80
• Frequency of sampling (times/yr)	4	2	2	1	2
• Grab device	Shipek	Shipek	Shipek	Van Veen	Petersen
• Grab area (sq m)	0.04	0.04	0.04	0.108	0.121
• Screen size (mm)	0.5	1.0	1.0	0.5/1.0	1.0

*Survey conducted by the Coastal Water Research Project (Greene 1976).

Table 2. Summary of sampling statistics from surveys of all benthic stations sampled in the five southern California discharge sites, summer 1974 and 1975.

	Oxnard Coastal Shelf	Santa Monica Bay	Palos Verdes Shelf	Southern San Pedro Bay	Point Loma Coastal Shelf
Biomass (g/sq m)					
Mean ± std. error	9.3 ± 1.3	141.3 ± 23.8	439.4 ± 80.2	61.8 ± 7.6	20.2 ± 2.6
CV* (%)	60.9	80.7	115.4	72.4	49.3
Abundance (No./sq m)					
Mean ± std. error	3,560 ± 316	4,766 ± 1,129	3,963 ± 551	4,251 ± 347	1,290 ± 140
CV (%)	38.7	113.6	87.9	48.3	42.0
Species (No./sample)					
Mean ± std. error	51.8 ± 2.4	26.7 ± 2.0	18.1 ± 1.3	57.7 ± 2.0	41.9 ± 1.9
CV (%)	17.7	35.6	44.4	20.3	17.6
Diversity (H')					
Mean ± std. error	3.3 ± 0.07	2.22 ± 0.15	1.96 ± 0.10	2.69 ± 0.07	2.91 ± 0.12
CV (%)	9.2	32.8	32.3	15.4	16.0
Richness (D)					
Mean ± std. error	23.7 ± 0.80	12.0 ± 0.94	7.89 ± 0.53	21.5 ± 0.69	19.0 ± 1.1
CV (%)	14.7	37.7	42.4	19.0	22.5

*Coefficient of variation.

Table 3. Summary of sampling statistics from surveys of benthic stations located between 55 and 60 meters at five southern California discharge sites.

	Oxnard Coastal Shelf	Santa Monica Bay	Palos Verdes Shelf	Southern San Pedro Bay	Point Loma Coastal Shelf
Biomass (g/sq m)					
Mean ± std. error	11.8 ± 3.90	153.0 ± 41.9	917.6 ± 213.3	69.1 ± 15.3	27.8 ± 2.9
CV* (%)	67.8	67.1	73.4	66.3	27.5
Abundance (No./sq m)					
Mean ± std. error	3,092 ± 450	4,021 ± 620	6,624 ± 1,210	5,709 ± 675	1,469 ± 137
CV (%)	29.1	37.7	57.7	35.5	24.7
Species (No./sample)					
Mean ± std. error	48.6 ± 4.30	24.3 ± 1.8	21.0 ± 1.3	63.8 ± 3.7	42.4 ± 1.8
CV (%)	17.7	17.7	23.6	17.4	11.2
Diversity (H')					
Mean ± std. error	3.4 ± 0.10	2.21 ± 0.14	1.79 ± 0.10	2.69 ± 0.15	2.96 ± 0.17
CV (%)	5.9	15.0	34.1	16.7	15.2
Richness (D)					
Mean ± std. error	22.9 ± 1.43	10.8 ± 0.85	8.39 ± 0.49	23.0 ± 1.5	18.5 ± 0.87
CV (%)	12.2	19.3	18.6	19.6	12.4

*Coefficient of variation.