Changes in Macrobenthic Assemblages After Termination of Sludge Discharge into Santa Monica Bay

In the past three annual reports, we have reported on the recovery in Santa Monica Bay following termination of sludge discharge from the Hyperion Wastewater Treatment Plant 7-mile outfall. Details of the sampling design and the measurements appear in those articles. This year, we present a more detailed report on one component of the study—macrobenthic infaunal invertebrates that inhabit sediment in the bay.

Benthic infaunal organisms are probably the best indicators for ecological recovery of this area because they are resident and are not as mobile as fish and larger invertebrates. Their ability to recolonize the old sludge field will provide evidence of the progress of recovery. Additionally, the infauna are probably sampled with less bias than macroinvertebrates and fish providing a stronger basis for conclusions about recovery.

Normal rocky bottom in central Santa Monica Bay at 110m.

Materials and Methods

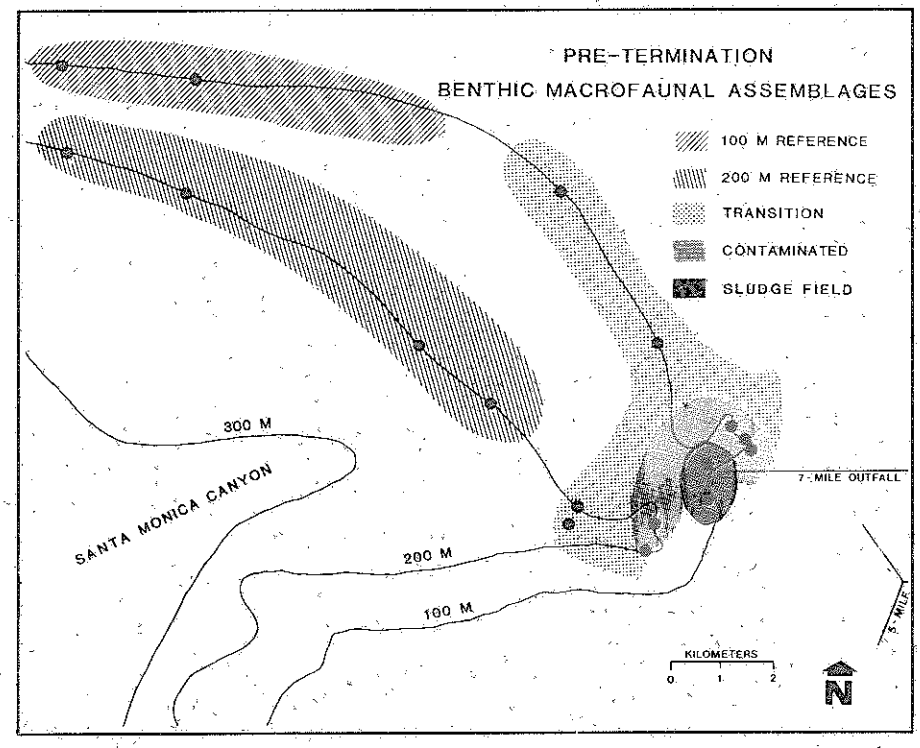
Macrobenthos was sampled from the *R/V Marine Surveyor* (City of Los Angeles) using a 0.1 m^2 chain-rigged Van Veen grab. Sites were located on the 100 and 200 m contours (Figure1).

The grab samples were washed through 1.0 and 0.5 mm

screens and fixed in formalin. In the laboratory, animals were sorted from the sediment and identified to species level where possible. In this report, we focus on the 1.0 mm fractions. The 0.5 mm fraction will be important in determining whether the observed changes are due to recruitment of juveniles or immigration of adults.

We sampled three times in the 18 months prior to termination of sludge discharge. The outfall was turned off in November 1987 and we sampled eight times since then (Figures 2-8). Preliminary (and some partial) data is presented here; further data and analyses will be presented in the final report after all analyses are completed.

Figure 1.
Zones of impact based on ordination and classification analyses of macrobenthic infaunal assemblages sampled during three cruises before discharge through the Hyperion 7-mile sludge outfall was terminated. Average abundances of the dominant species in each assemblage appear in Table 1.



Results and Discussion

The Benthos During Sludge Discharge

Sludge was discharged from the 7-mile outfall for 30 years. During that time, there were five identifiable macrobenthic assemblages that inhabited the sediments of the outer bay (Figure 1). They were identified with multivariate analysis. These assemblages reflected a gradient of decreasing sludge influence from the outfall to normal or reference areas.

Only a few species could live in the sludge field, and most of these were unusual or undescribed animals (Table 1). The most abundant species was a small polychaete, *Ophryotrocha* sp. C (the "C" means that it has not been formally named). Actually, there are three closely related, undescribed species in the genus. Dave Montagne (County Sanitation Districts of Los Angeles County) is preparing a scientific publication with formal descriptions and names. It is not known how they can live in these highly contaminated sediments where most other species cannot.

Surrounding the sludge field was a less contaminated area that was dominated by another polychaete, *Capitella capitata*, at densities greater than 2800/m^2. *Capitella capitata* is a cosmopolitan indicator of contamination and disturbance. Another interesting inhabitant of the contaminated zone is the gutless clam, *Solemya reidi*. It only lives in areas with hydrogen sulfide in the sediments and uses endosymbiotic bacteria to oxidize the sulfide for energy (Powell and Somero 1985). Similar metabolic strategies are used by animals that inhabit the deep-sea near geothermal vents. *Solemya reidi* did not occur in the sludge field where sulfide and contaminant levels were highest.

Farther away from the sludge field, and surrounding the contaminated zone, was a transition zone. The benthos there was more like the benthos of the reference zone. The most abundant species in the transition zone were small clams *Parvilucina tenuisculpta* and *Axinopsida serricata* (Table 1). *Parvilucina tenuisculpta* may facultatively use endosymbiotic bacteria like *Solemya reidi*. *Parvilucina tenuisculpta* grows to much larger sizes in the transition zone than in the reference zone.

The reference zone at 100 m is dominated by a small red ophiuroid, *Amphiodia urtica*. This

species is common in other reference areas along the southern California coast (Barnard and Ziesenheme 1961, Thompson *et al.* 1987). It is sensitive to sediment contamination and responds by decreases in abundance; it is not collected near sewage outfalls.

The total number of species and individuals collected per grab differ among the zones. The number of species and individuals was lowest in the sludge field and contaminated zone. The number of individuals was highest in the transition zone (Table 1). These parameters characteristically are highest at sites with intermediate disturbances and lowest near sources of contamination (Pearson and Rosenberg 1978, Swartz *et al.* 1986).

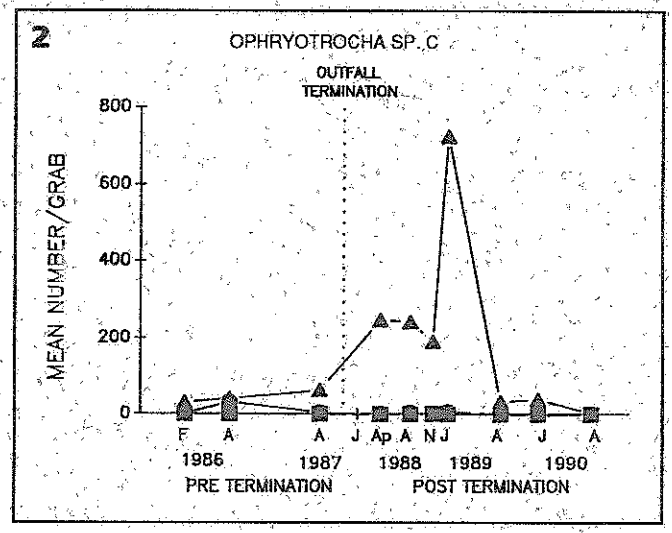
Changes in the Benthos

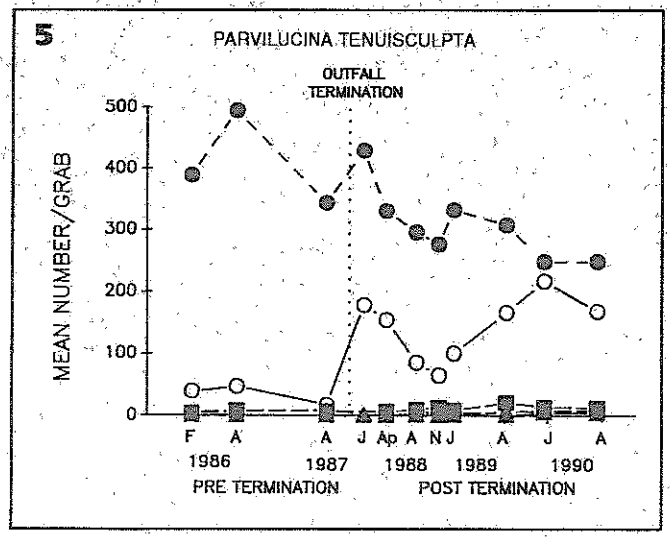
As recovery proceeds, the abundance of indicator species and other assemblage parameters in the impacted zones should become more like the reference zone. Recovery will be complete when there are no significant differences between parameters in the impacted and reference zones.

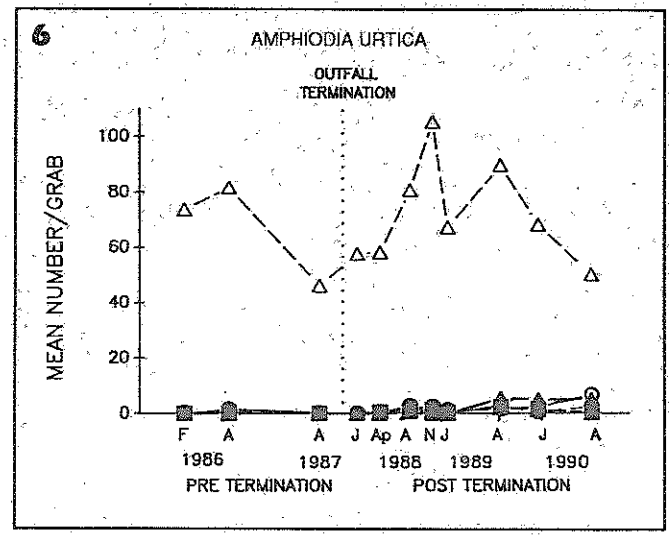
The macrofauna have changed considerably since sludge discharge was terminated. The abundance of *Ophryotrocha* sp. C increased by almost ten-fold in the sludge field, but decreased to near zero in August 1990 (Figure 2). As *Ophryotrocha* declined, the zone became dominated by *Capitella capitata*

Figures 2-8.
Recovery graphs of benthic macrofaunal indicator species and community parameters.

TRANSITION
CONTAMINATED
SLUDGE FIELD
100 METER REFERENCE
200 METER REFERENCE







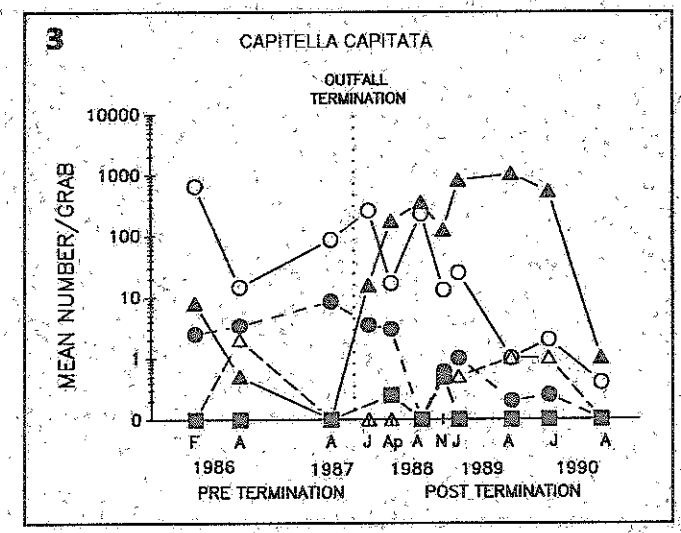
(Figure 3). At about the same time, *Solemya reidi* began to move into the sludge field (Figure 4). The abundance of *Capitella capitata* had decreased dramatically in the sludge field by the last sampling period.

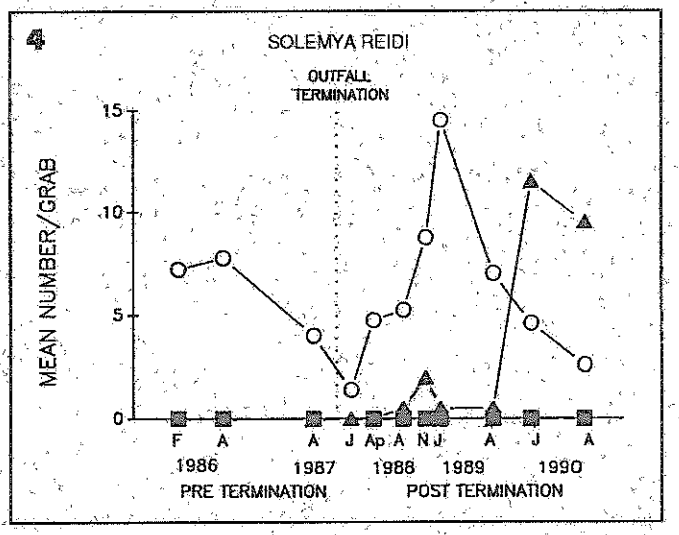
Parvilucina tenuiscultpa have steadily decreased in abundance in the transition since discharge was terminated. But they have increased in abundance in the contaminated zone as conditions improve (Figure 5). Eventually their abundance should decrease in both of these zones as reference zone organisms become established.

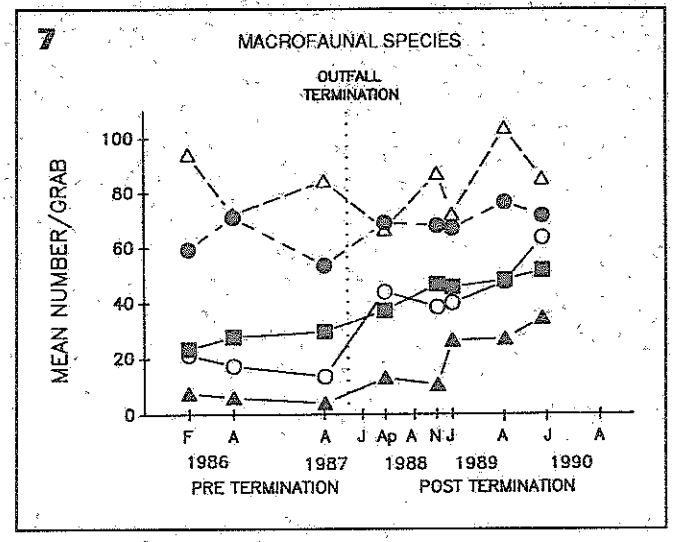
Amphiodia urtica abundances remain low in all but the reference zone (Figure 6). One promising sign is the discovery of a few juvenile ophiuroids, probably *Amphiodia urtica*, in the most recent samples from the sludge field. We do not know how long it will take for this species to recolonize the impacted zones.

Species richness has increased in the contaminated and transition zones to nearly reference levels (Figure 7). The sludge field has five times more species now than during sludge discharge. The number of individuals has also increased dramatically in the sludge field (Figure 8), mostly due to the invasion of thousands of *Capitella capitata*. As recovery proceeds, the number of individuals should increase to pre-termination transition zone levels in the sludge field and contaminated zones before decreasing to reference levels.

As recovery has progressed,







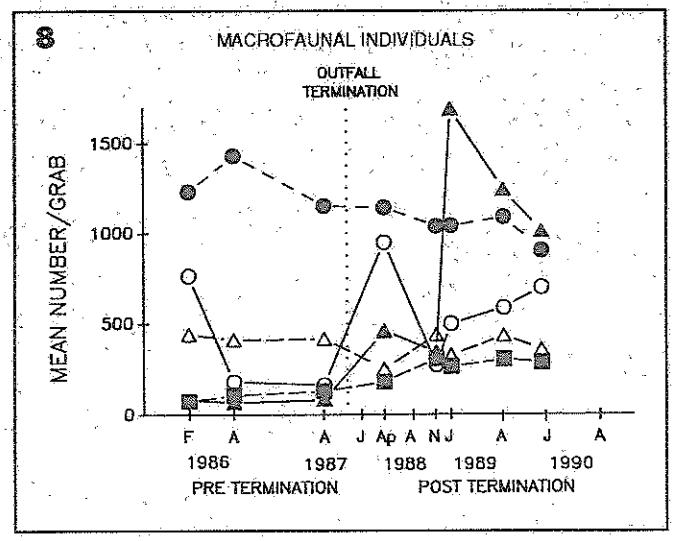


Table 1.

Average abundances (mean number/m²) of the most common and abundant benthic macrofauna collected in each zone of impact, or assemblage, as identified by classification analysis; based on three pre-termination cruises.

Species	Taxon[a]	100 m Reference (n=7)	Transition (n=13)	200 m Reference (n=12)	Contaminated (n=13)	Sludge Field (n=6)
Amphiodia urtica	e	640	3	0	5	0
Spiophanes missionensis	p	366	165	5	0	0
Mediomastus sp.	p	163	62	7	2	2
Spiophanes fimbriata	p	437	203	78	0	0
Melinna heterodonta	p	0	8	48	0	0
Axinopsida serricata	m	151	3481	309	3	0
Decamastus gracilis	p	6	847	5	0	0
Paraprionospio pinnata	p	23	93	67	4	0
Parvilucina tenuisculpta	m	76	3996	62	349	0
Tellina carpenteri	m	43	975	20	81	2
Capitella capitata	p	6	47	0	2818	28
Sigambra tentaculata	p	0	3	0	158	3
Solemya reidi	m	0	0	0	64	0
Ophryotrocha sp. B	p	0	0	0	25	8
Ophryotrocha sp. A	p	0	0	0	49	223
Ophryotrocha sp. C	p	0	0	0	81	450
Orchomene anaquela	c	0	0	0	0	8
Mean No. Species per grab		84	62	27	18	6
Mean No. Individ. per m²		1197	12808	1026	3082	760
Mean Biomass (wet g) per m²	119	369	120	200	26	

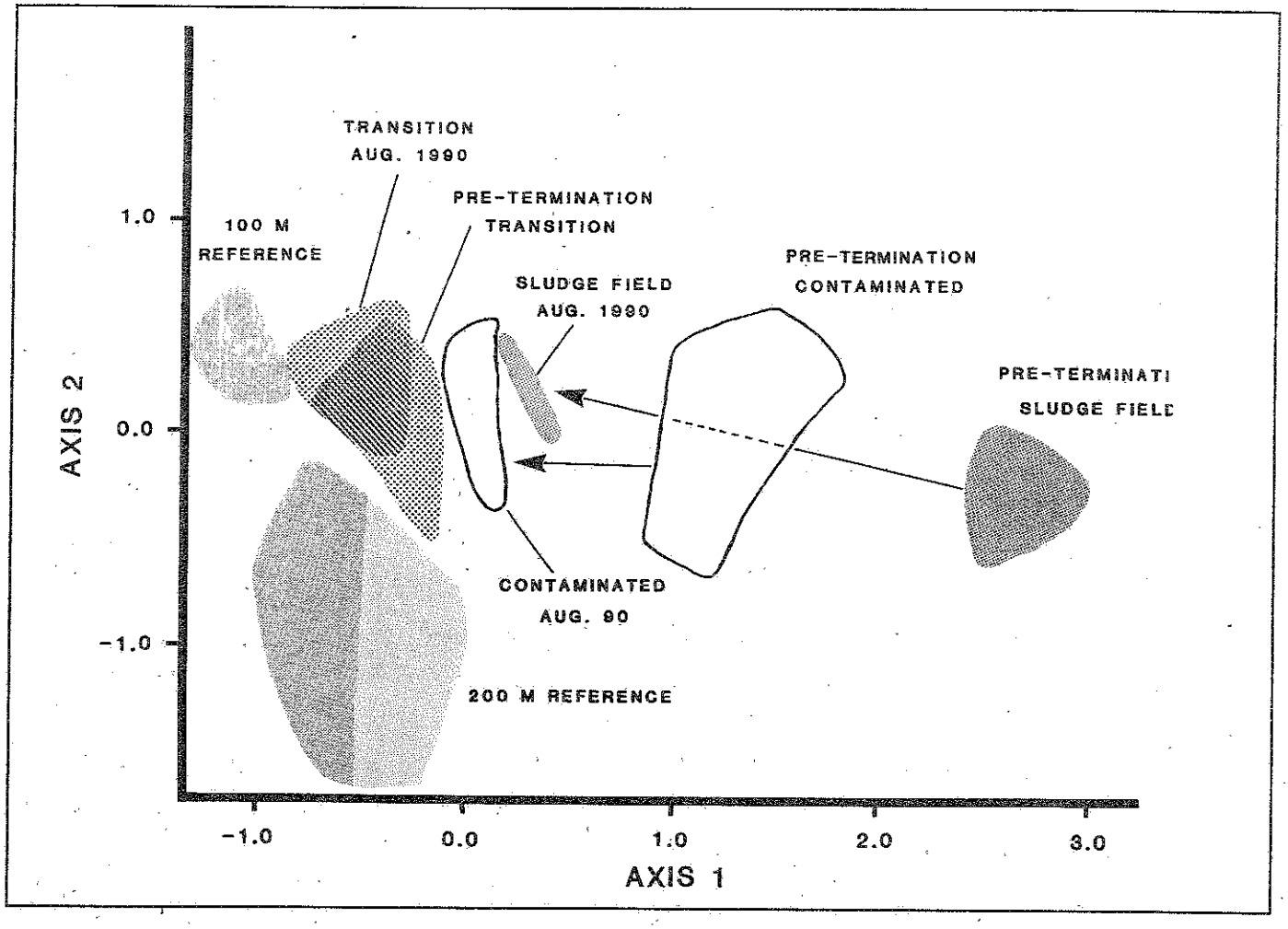
[a]e=echinoderm, p=polychaete, m=mollusc, c=crustacean

macrobenthic assemblages in the transition, contaminated, and sludge zones have become more like assemblages in the adjacent, less contaminated zones (Figure 9). The ordination scores of assemblages from the impacted zones are moving through ordination space towards the reference zones. Eventually, scores from the impacted zones should become similar to those of the reference zone at the same depth.

Along with the biological changes, numerous changes have occurred in the sediments, which are presumably causing the biological changes. Concentrations of organic material, hydrogen sulfide, trace metals, and chlorinated and petroleum hydrocarbons have declined in the sediment, but at different rates. We do not know which sediment component(s) is driving the biological changes. More rigorous analyses of the data may help understand these relationships.

None of the macrofaunal measurements indicate that recovery has occurred in the contaminated zone or the sludge field. The City's Environmental Monitoring Division will continue to sample some of these sites in the future. We do not know how long it will take for the macrobenthic fauna in the sludge field and contaminated zones to completely recover. ■

Figure 9.
Recovery of benthic macrofaunal assemblages. Ordination analysis (Smith et al. 1988) was used to compare the scores of the pre-termination assemblages with scores of post-termination cruises. Scores of the sludge field have moved towards scores of the reference zone in the ordination space.



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