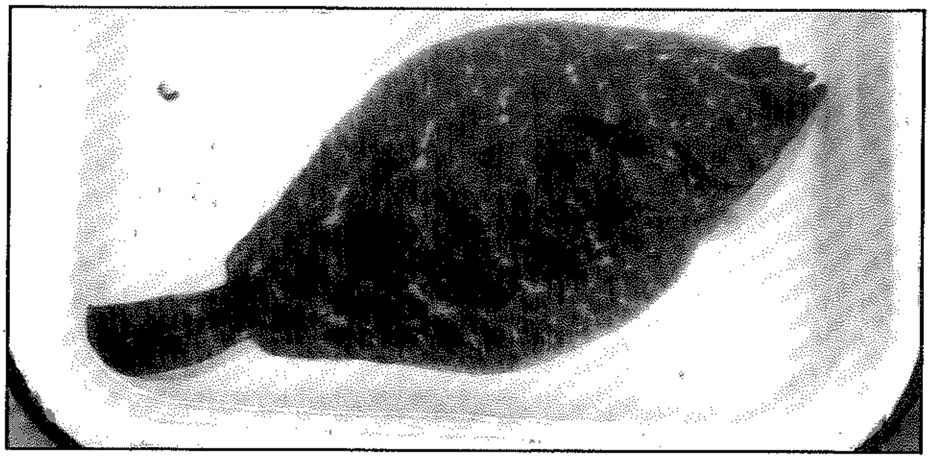
Response of Dover Sole to Termination of Sludge Discharge in Santa Monica Bay

Dover sole *(Microstomus pacificus)* commonly occur on the upper slope off Southern California at depths to about 1000 m (Allen and Mearns 1976). Most of the fish migrate into shallow water in summer related to feeding and back into deep water in the winter for reproduction (Hagerman 1952).

Dover sole are more abundant near municipal wastewater outfalls and the incidence of fin erosion and epidermal tumors is also higher in these areas (Cross 1985, 1986). Fish in contaminated areas may be more susceptible to these diseases due to elevated body burdens of contaminants, which may interfere with the immune system of the fish.

A major dietary component of Dover sole is polychaetes, especially *Capitella* spp. (Pearcy and Hancock 1978). The high levels of total organic carbon (TOC) in the sediments near the Joint Water Pollution Control Plant (Los Angeles County) outfall support high abundances of deposit feeding polychaetes like *Capitella*, and this probably supports the higher abundance of Dover sole in these areas (Cross *et al.* 1985).

The Hyperion sewage treatment plant terminated discharge of solid waste into the Santa Monica Bay in November 1987. Termination of sludge discharge caused changes in the biology of the macrofauna in the area near the outfall (Thompson 1991). The objective of this study was to examine changes in the abundance of Dover sole as a result of termination of sludge discharge.



Dover sole

Materials and Methods

Biologists from the Environmental Monitoring Division (City of Los Angeles) and SCCWRP collected fish at 12 stations in Santa Monica Bay from July 1986 to August 1990. Fish were collected by dragging a 7.6 m otter trawl for 10 min along a depth isobath at approximately 2 knots. Trawls were made during the summer (Jul-Aug) and winter (Jan-Feb) at two stations at 100 m and two stations at 200 m in each of three zones; there were no trawl collections in winter 1987. Fish were counted, measured (standard length) to the nearest centimeter, and examined for diseases (fin erosion and tumors). The catch was weighed to the nearest 0.1 kg by species.

Raw abundance data were not normally distributed and variances increased with increased means. Log transformation of abundance produced a normal distribution with homogeneous variances. The transformed data were analyzed by analysis of variance for effects of depth (100 and 200 m), season (winter and summer), location relative to the outfall (reference, transition, and contaminated zones), and pre- and post-sludge discharge. Disease incidence and sediment TOC data were transformed with the arcsin. The transformed TOC data were analyzed by analysis of variance for effects of depth, season, location relative to the outfall, and pre- and post-sludge discharge.

Three zones differing in the effect of sludge discharge were identified by benthic macrofauna assemblages: contaminated, transition, and reference. Sediment and infauna samples were collected using a modified Van Veen grab with an area of 0.1 m^2 along the 100 m and 200 m isobaths; two stations at each depth were located in each zone (Thompson 1991).

Results

The abundance of Dover sole in the trawls was significantly affected by season, distance of collection from the outfall (zone), and termination of sludge discharge (Table 1). Dover sole were generally more abundant in the summer (Table 2). Dover sole were most abundant in the contaminated zone near the outfall, least abundant in the reference zone, and intermediate in abundance in the transition zone. The abundance of Dover sole declined after the termination of sludge discharge. There was no significant difference in abundance of fish at 100 m and 200 m.

Epidermal tumors and fin erosion occurred in 5% of all Dover sole collected and the proportion of disease decreased with distance from the sludge outfall (Table 3). The highest incidence of disease occurred among fish collected on the 100 m isobath in the contaminated zone. There was little or no disease among fish collected in the reference and transition zones, although they were significantly different from each other.

Discussion

The seasonal patterns of Dover sole abundance observed in this study are consistent with the seasonal migration patterns of Dover sole reported by others (Hagerman 1952, Cross 1985, Hunter *et al.* 1990). The higher abundance of Dover sole, and the increased prevalence of fin erosion and epidermal tumors, in the contaminated zone near the sludge outfall is similar to the pattern observed among fish collected near the municipal wastewater outfalls on the Palos Verdes Shelf (Cross 1985, 1986). Of the nearly 60 species collected on the Palos Verdes Shelf, Dover sole were the most susceptible to tumors and fin erosion (Cross 1985).

The decrease in Dover sole abundance and disease prevalence after termination of solid waste discharge indicates that benthic conditions are improving near the outfall. The decline in fish abundance may be related to decreased organic content and prey abundance in the sediments. The abundance of Dover sole was correlated with the organic carbon content of the sediments. The concentrations of TOC in surface sediment was significantly higher near the outfall and declined somewhat after termination of solid waste discharge (Table 4). The abundance of polychaetes in grab samples was also correlated with TOC ($r=0.214$, $n=95$, $0.02<p<0.05$). Sediments with high organic content support large populations of deposit feeders such as polychaetes, which are the main prey item of Dover sole (Gabriel and Pearcy 1981, Cross *et al.* 1985).

Further evidence for the link between Dover sole abundance, sediment organic content, and polychaete abundance was observed during an anomalous incident. During the summer of 1989, the abundance of fish at the contaminated stations declined well below abundances recorded in previous summers. By the summer of 1990, abundances had returned to pre-1989 levels. In the summer of 1989, sediment TOC levels and polychaete abundances decreased, and the sand content of the sediments increased, at canyon stations close to the sludge outfall. High down-canyon currents were also measured during this period. These currents may have been responsible for increased levels of sand and decreased levels of TOC in the contaminated zone. Burial of the high organic sediments by shelf sediments entrained in the high currents, or resuspension of the organic material, may have increased the amount of sand and decreased the number of

Table 1

Analysis of variance of Dover sole abundance (log transformed number per 10 min trawl). Main effects are before and after termination of sludge discharge (pre/post), season (winter and summer), zone (contaminated, transition, and reference), and depth of collection (100 and 200 m). Interactions were not significant ($p>0.05$); N = 108, R^2 = 0.585. SS = sum of squares, DF = degrees of freedom, MS = mean square, F = MS main effect/MS error, P = probability.

Source	SS	DF	MS	F	P
Pre/Post	0.676	1	0.676	4.108	0.046
Season	0.773	1	0.773	4.696	0.033
Zone	11.373	2	5.686	34.552	0.000
Depth	0.241	1	0.241	1.466	0.229
Error	13.824	84	0.165		

polychaetes. Reduced prey availability may account for the decline in the number of Dover sole collected. By the winter of 1990, the characteristics of the sediments had returned to pre-1989 conditions and the relative abundances of Dover sole and their prey species increased to former levels.

Conclusions

Termination of sludge discharge has significantly changed the marine environment in the area of the sludge outfall in Santa Monica Bay. The decreased incidence of disease in the Dover sole population is a positive sign of improving conditions. This trend of improvement will likely continue in the future.

Table 2

Dover sole abundance (number/10 min trawl) in the contaminated, transition, and reference zones in winter and summer collections before and after sludge discharge termination (pre and post) in Santa Monica Bay. Data from the 100 and 200 m stations combined. N = number of trawls in each zone, SD = standard deviation.

			Contaminated		Transition		Reference	
		N	Mean	SD	Mean	SD	Mean	SD
Pre	Winter	4	62.5	70.1	48.3	40.4	10.8	11.8
	Summer	8	101.6	66.7	41.1	31.5	6.3	4.6
Post	Winter	12	36.2	29.0	21.2	23.4	4.8	5.1
	Summer	12	83.7	74.6	25.8	24.6	13.3	10.8

Table 3

Summary of incidence of epidermal tumors and fin erosion in the contaminated, transition, and reference zones, during winter and summer, before (pre) and after (post) termination of sludge discharge in Santa Monica Bay. Data from the 100 and 200 m stations combined. N = number of trawls in each zone, SD = standard deviation.

			Contaminated		Transition		Reference	
		N	Mean	SD	Mean	SD	Mean	SD
Pre	Winter	4	12.8	20.9	0.5	1.0	0	
	Summer	8	10.1	9.0	0.3	0.7	0	
Post	Winter	12	2.5	3.6	0.1	0.3	0.1	0.3
	Summer	12	2.4	3.7	0.3	0.6	0.3	0.6

Table 4

Summary of sediment total organic carbon (%TOC) content in the contaminated, transition, and reference zones, during winter and summer, before (pre) and after (post) termination of sludge discharge in Santa Monica Bay. Data from the 100 and 200 m stations combined. N = number of trawls in each zone, SD = standard deviation.

			Contaminated		Transition		Reference	
		N	Mean	SD	Mean	SD	Mean	SD
Pre	Winter	4	2.9	1.4	1.9	1.1	1.2	0.3
	Summer	8	2.7	1.1	1.9	1.2	1.2	0.2
Post	Winter	12	2.8	1.4	1.8	1.1	1.1	0.4
	Summer	12	2.2	1.2	1.7	1.2	1.2	0.2

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