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FISH FOOD HABITS ALONG A POLLUTION GRADIENT [1]

JEFFREY N. CROSS, JAMES RONEY, and GARY S. KLEPPEL
Southern California Coastal Water Research Project
646 W. Pacific Coast Hwy.
Long Beach, California 90806

The distribution and food habits of eight species of demersal fishes were examined along a pollution gradient on the mainland shelf near Los Angeles, California. Along the gradient of increasing municipal wastewater effects: i) the diversity and richness of the benthic infauna (potential fish prey) declined, ii) the proportion of polychaetes in grab samples increased while the proportions of crustaceans and molluscs decreased, iii) the abundance, richness, and diversity of demersal fishes decreased, but while some species of fishes declined in abundance other species increased.

Changes in abundance of fishes along the pollution gradient were related to the food habits of the fishes and the distribution and abundance of their prey. The abundance of longspine combfish, *Zaniolepis latipinnis,* yellowchin sculpin, *Icelinus quadriseriatus,* California tonguefish, *Symphurus atricauda,* speckled sanddab, *Citharichthys stigmaeus,* and hornyhead turbot, *Pleuronichthys verticalis,* decreased along the gradient of increasing wastewater effects. The first four species fed primarily on benthic, epibenthic, and nektonic crustaceans, and the hornyhead turbot fed on several species of polychaetes that were rare or absent at stations strongly affected by wastewater discharge. The abundance of English sole, *Parophrys vetulus,* Dover sole, *Microstomus pacificus,* and Pacific sanddab, *Citharichthys sordidus,* increased along the pollution gradient. The proportion of polychaetes increased and the proportion of crustaceans decreased in the diet of these species along the pollution gradient.

INTRODUCTION

The distribution of fishes in polluted areas has been examined by several investigators. Bechtel and Copeland (1970) and Haedrich (1975) showed that the diversity (H ') of fishes was lower in polluted areas when compared to unpolluted areas. Bechtel and Copeland (1970) attributed this to stress eliminating the more sensitive species thereby reducing competition and allowing the more resistant species to increase in abundance. Haedrich (1975) showed that the decreased diversity of fishes in polluted estuaries was accompanied by increased faunal similarity between seasons when compared to unpolluted estuaries. He argued, to the extent that annual succession of fishes existed in unpolluted estuaries, a disturbance such as pollution would render the habitat less suitable. Annual succession would therefore decline and faunal similarity between seasons would increase.

Carlisle (1969), Allen (1977), and Mearns (1981) examined the abundance of demersal fishes in otter trawl samples from the mainland shelf in southern California. They found that some species were more abundant (enhanced) and other species were less abundant (depressed) near municipal wastewater outfalls when compared to areas some distance away. In general, the diversity of trawl-caught fishes was lower near major outfalls than in control areas (Mearns 1973, 1979; Allen 1977; Allen and Voglin 1976).

This study examines the distribution and food habits of some common nearshore demersal fishes in an area of wastewater discharge off southern California.

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The data were collected originally for a fish food habits study (Kleppel, Word and Roney 1982). Because of the lack of information about the effects of wastewater discharge on marine fish populations (Boesch 1982), the data were recast to examine the hypothesis that enhancements and depressions of fish abundance around municipal wastewater outfalls are a result of the food habits of the fishes and the altered distributions of their prey.

Study Area

The study took place in the coastal waters of the greater Los Angeles metropolitan area (Figure 1). The mainland shelf around Los Angeles has received anthropogenic domestic and industrial wastes since 1894 (Tillman and Bargman 1973). In 1981, the City of Los Angeles discharged 107.6 metric tons (mt) of suspended solids per day (39,270 mt/yr) through a 60 m deep (8.3 km long) outfall and 126.0 mt of total solids per day (46,000 mt/yr) through a 100 m deep (11.3 km long) outfall in Santa Monica Bay (Figure 1). The County of Los Angeles discharged 230.1 mt of suspended solids per day (84,000 mt/yr) through three outfalls located between 30 and 60 m on the Palos Verdes shelf (Schafer 1982) (Figure 1).

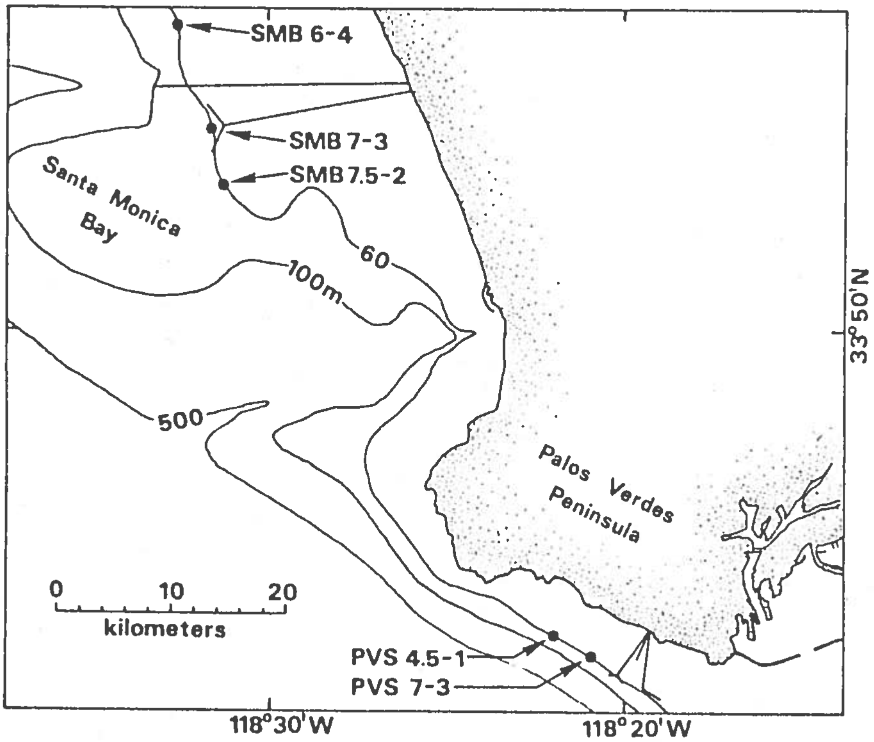

FIGURE 1. Location of sampling stations and outfalls in Santa Monica Bay (SMB) and on the Palos Verdes shelf (PVS). In SMB the outfall discharging at 60 m is the 8.3 km outfall and the outfall discharging at 100 m is the 11.3 km outfall.

MATERIALS AND METHODS

Five stations that ranged from relatively unaffected to strongly affected by wastewater discharge were selected on the 60 m isobath in Santa Monica Bay (SMB) and on the Palos Verdes shelf (PVS) from a larger array of stations sampled regularly by Los Angeles City and County Sanitation Districts. The original station numbers have been retained for continuity. The stations were sampled during the day on 27 and 28 June and again on 7 and 11 December, 1979. Two benthic grabs and one otter trawl were taken at each station.

Grabs were taken with a modified 0.1 m^2 Van Veen grab. Grab samples for infauna were sieved through a 1 mm screen and the retained contents were fixed in 5% buffered formalin aboard ship. In the lab, the grab samples were washed in freshwater and preserved in 70% ethanol. The animals were sorted and identified with a binocular microsope. Grab samples for sediment analyses were subsampled with a 2 cm deep core and the samples were frozen. Total volatile solids (TVS) was determined by drying the samples to a constant weight at 60°C, burning the samples in a muffle furnace at 500°C for 2 hours, and reweighing; the percent weight loss is TVS. Percent sand was determined by drying the samples to a constant weight at 60°C and washing them through a 63 μ USGS seive; the retained portion was dried to a constant weight, reweighed, and the percent of the sample > 62 μ was calculated.

Fishes were collected with a 7.6 m headrope otter trawl with a 3.8 cm body mesh and a 1.3 cm cod-end liner towed at 2–3 knots for 10 minutes. Fishes in the trawl samples were counted, measured (to the nearest mm board standard length), and fixed in 10% buffered formalin aboard ship. In the lab, the stomachs were removed and preserved in 70% ethanol; the contents of the stomachs were sorted and identified to the lowest taxon possible.

Diversity was calculated by the Shannon-Weiner information function:

$$H' = -\sum_{i=1}^{s} p_i \log_{10} p_i$$

where p_i is the proportion of the ith species and s is the number of species in the sample.

Percent similarity between samples was calculated by:

$$PS = 100 \sum_{i=1}^{s} \min(p_{i1}, p_{i2})$$

where p_{i1} = the proportion of species i in sample one, p_{i2} = the proportion of species i in sample two, and s = the total number of species in both samples.

The study stations were ranked in order of increasing wastewater effects based on several physical and chemical sediment parameters directly attributable to wastewater discharge (Table 1). The order was determined by ranking the stations for each parameter individually from least to most affected and then summing the ranks for each station.

TABLE 1. Physical And Chemical Parameters Measured At The Study Stations in Santa Monica Bay (SMB) And On The Palos Verdes Shelf (PVS). The Stations Are Arranged In Increasing Order of Wastewater Effects (From SMB 7.5-2 to PVS 7-3) Based On Sediment Analyses. The Order Was Determined By Ranking The Stations For Each Parameter (Except Percent Sand) From Least To Most Affected And Then Summing The Ranks For Each Station.

Station	*Percent sand* ($>62\mu$)	*Total volatile solids (%)*	*5-day BOD (mg/kg)* [1]	*Total PCB (ppm)* [2]	*Cd (ppm)* [3]	*Cr (ppm)* [3]	*Zn (ppm)* [3]
SMB 7.5-2	41.1	3.2	220	.060	2.1	138	92
SMB 6-4	78.9	3.6	630	.066	2.8	73	79
SMB 7-3	39.6	3.8	910	.110	3.8	118	113
PVS 4.5-1	50.7	17.0	15,180	.880	21.0	631	713
PVS 7-3	67.5	19.8	15,500	.952	27.1	802	993

[1] Bascom (1978)
[2] R. Gossett, SCCWRP, pers. commum.
[3] SMB data from: Jan and Hershelman (1980); PVS data from: G.P. Hershelman, SCCWRP, pers. commum.

While the stations do not constitute a geographical gradient (i.e. a linear transect away from an outfall), they do constitute an effects gradient. The justification is as follows: i) The physical properties of the sediments are similar in the two areas as reflected by the proportion of the sediments $>62\mu$ (Table 1). A more extensive series of percent sand determinations was made for 60 m stations in Santa Monica Bay and on the Palos Verdes shelf by Word and Mearns (1979). The sand content of Santa Monica Bay samples ($\bar{x} = 38.9\%$, SD = 25.4, N = 13) was not significantly different from the sand content of Palos Verdes samples ($\bar{x} = 51.5\%$, SD = 20.7, N = 9) (t-test, $.20 < p < .50$); ii) The direction and speed of water currents on the mainland shelf are similar in the two areas (Hendricks 1980); iii) The composition of the infauna at the five stations ranged from assemblages nearly indistinguishable from control areas to assemblages typical of areas of high organic enrichment. (Pearson and Rosenberg 1978).

RESULTS

Grab Samples

The proportion of polychaetes in the grab samples (Table 2) was positively correlated with the gradient of increasing wastewater effects [(Spearman $r_s = .839$, $.002 > p > .005$; the June and December samples were combined because there was no systematic difference in the numbers of infaunal animals collected (sign test, $p = .50$)]. The proportion of crustaceans ($r_s = -.858$, $.002 < p < .005$) and molluscs ($r_s = -.542$, $.10 < p < .20$) were negatively correlated with the gradient of increasing wastewater effects.

The polychaete fauna was most diverse at SMB 7.5-2 and SMB 6-4 (Table 3), although few polychaetes were collected at the latter station in December (Table 2). *Capitella capitata* was the most abundant polychaete at the remaining stations (Table 3).

The crustacean fauna was most diverse at SMB 7.5-2 and SMB 6-4 (Table 3). Gammarid amphipods comprised about 50% of the crustaceans collected at SMB 7.5-2, about 5% at SMB 6-4, and less than 1% at the remaining stations. Ostracods (primarily *Euphilomedes* spp.) comprised about 90% of the crustaceans collected at SMB 6-4 and SMB 7-3, and less than 1% at the remaining stations. Crustaceans were virtually absent at PVS stations (Table 2).

TABLE 2. Percent Of Individuals In 0.1 m^2 Benthic Grab Samples In Major Infaunal Groups In June (J) And December (D); N = Total Number Of Individuals Collected.

Station	*Polychaeta* J	*Polychaeta* D	*Crustacea* J	*Crustacea* D	*Mollusca* J	*Mollusca* D	*Echinodermata* J	*Echinodermata* D	*N* J	*N* D
SMB 7.5-2	44.9	45.7	23.4	20.2	14.8	19.2	10.2	9.5	461	569
SMB 6-4	16.8	0.1	36.9	40.3	45.3	59.0	0.2	0.6	1,328	914
SMB 7-3	51.3	72.7	13.9	10.3	34.5	16.0	0.0	0.2	798	407
PVS 4.5-1	49.0	90.0	5.2	1.0	34.4	8.6	0.0	0.1	96	807
PVS 7-3	94.8	98.1	0.7	0.0	4.5	1.3	0.0	0.0	290	1,029

Otter Trawls

Twenty-six species of fishes representing 2310 individuals were collected in 10 otter trawls (Table 4). Twenty-four species and 1163 individuals were collected in five otter trawls in June and 24 species and 1147 individuals were collected in five otter trawls in December. The number of fishes collected in the trawls was negatively correlated with the gradient of increasing wastewater effects [$r_s = -.736$, $.02 < p < .05$; the June and December samples were combined because there was no systematic difference in the number of individuals collected (sign test, $p = .50$)]. Species richness ($r_s = -.636$, $.05 < p < .10$) and diversity ($r_s = -.421$, $.20 < p < .50$) were also negatively correlated with the gradient of increasing wastewater effects. The percent similarity between June and December samples generally increased along the gradient of increasing wastewater effects and was negatively correlated with total annual diversity (calculated from combined June and December samples; $r_s = -.900$, $p = .10$).

Stomach Analyses

Eight widespread and abundant demersal fish species were selected for stomach analyses. June and December samples were combined because there were no major differences in food habits at the taxonomic level on which we were focusing and because there were no significant size differences among the predators between seasons (Mann-Whitney U-test, $p > .05$). The diets of the longspine combfish, *Zaniolepis latipinnis*, yellowchin sculpin, *Icelinus quadriseriatus*, California tonguefish, *Symphurus atricauda*, and speckled sanddab, *Citharichthys stigmaeus*, were dominated by crustaceans ($\bar{x} = 76\%$, SD = 7, N = 12) (Table 5). These fishes were common at SMB 7.5-2 and SMB 6-4, uncommon at SMB 7-3, and rare or absent at PVS 4.5-1 and PVS 7-3. The diet of the hornyhead turbot, *Pleuronichthys verticalis*, was dominated by polychaetes ($\bar{x} = 73\%$, SD = 9, N = 3) (Table 5); hornyhead turbots were collected in SMB but not on the PVS. The remaining species were collected at most stations along the gradient. The diet of the English sole, *Parophrys vetulus*, was comprised of polychaetes, nematodes, and crustaceans (Table 5). The diets of Pacific sanddab, *Citharichthys sordidus*, and Dover sole, *Microstomus pacificus*, were dominated by crustaceans in SMB ($\bar{x} = 70\%$, SD = 21, N = 5) and polychaetes on the PVS ($\bar{x} = 61\%$, SD = 8, N = 4) (Table 5).

DISCUSSION

Along the gradient of increasing wastewater effects, the infauna changed from a diverse, species-rich assemblage of crustaceans, polychaetes, and molluscs typical of control areas to a strongly dominated (by *C. capitata*), species-poor assemblage of polychaetes and molluscs typical of organically enriched areas (Pearson and Rosenberg 1978, Boesch 1982) (Table 3).

TABLE 3. Relative Abundance (%) of Dominant Organisms in 0.1 m² Benthic Grab Samples At the Study Stations by Month.

		Polychaeta	*Crustacea*	*Mollusca*
SMB 7.5-2	JUNE	*Glycera capitata* 15.0	Phoxocephalidae 22.2	*Parvilucina* 26.5
		Spiophanes 14.0	*Ampelisca* 16.7	*Volvulella* 26.5
		Prionospio 8.7	Callianassidae 16.7	*Axinopsida* 11.8
		Lumbrinereis 7.7	*Lepodomorpha* 13.0	*Tellina* 8.8
		Onuphis 5.3	Cylindroleberidae 5.6	*Mysella* 5.9
		Tharyx 4.8	*Photis* 3.7	*Acteocina* 5.9
		Terebellidae 4.8	Corophidae 3.7	
		Cistena californiensis 4.3	*Byblis* 2.8	
		Cossura bruena 3.9		
	DEC	Maldanidae 12.3	*Ampelisca* 41.7	*Axinopsida* 34.9
		Prionospio 10.4	Phoxocephalidae 10.4	*Parvilucina* 33.9
		Spiophanes 9.6	Callianassidae 10.4	*Volvulella* 11.9
		C. californiensis 6.9	Corophidae 7.8	*Tellina* 6.4
		Lumbrinereis 5.0	*Photis* 5.2	*Mysella* 2.8
		Phyllodocidae 4.2	*Byblis* 4.3	
		Aricidea 3.5	*Listriella* 2.6	
		Heteromastus 3.1	*Pinnixa* 2.6	
		Nothria elegans 3.1		
SMB 6.4	JUNE	*Spiophanes* 28.3	*Euphilomedes* 87.3	*Parvilucina* 78.2
		C. californiensis 13.0	Phoxocephalidae 2.7	*Axinopsida* 11.6
		Prionospio 12.6	*Ampelisca* 2.4	*Tellina* 2.7
		Cirratulidae 10.3		*Thyasira* 2.5
		Capitellidae 10.3		*Mysella* 1.8
		Euclymene delineata 5.8		
	DEC	one individual collected	*Euphilomedes* 88.6	*Parvilucina* 73.7
			Phoxocephalidae 4.1	*Axinopsida* 12.6
			Ampelisca 2.4	*Tellina* 4.9
				Thyasira 1.9
SMB 7-3	JUNE	*Capitella capitata* 87.8	*Euphilomedes* 90.1	*Parvilucina* 36.4
		Chloeia 2.9	Cylindroleberidae 2.7	*Bittium* 22.2
		Spiophanes 2.2	*Pinnixa* 2.7	*Mysella* 18.9
				Axinopsida 8.7
				Tellina 6.9
				Macoma carlottensis 4.7
	DEC	*C. capitata* 87.2	*Euphilomedes* 97.6	*Parvilucina* 61.5
		C. californiensis 4.7		*Tellina* 13.8
		Glycera capitata 2.0		*Mysella* 12.3
		Notomastus 2.0		*Axinopsida* 3.1
				M. carlottensis 3.1
PVS 4.5-1	JUNE	*C. capitata* 40.4	five individuals collected	*Mysella* 39.4
		Nereis procera 31.9		*Parvilucina* 27.3
		Hessionidae 14.9		*Acteocina* 18.2
		Notomastus 6.4		
	DEC	*C. capitata* 94.5	eight individuals collected	*Parvilucina* 37.7
		Hessionidae 2.1		*Acteocina* 20.3
		Nereis 1.4		*Kurtzia* 15.9
				Mysella 11.6
				Cylichna 8.7
PVS 7.3	JUNE	*C. capitata* 89.1	two individuals collected	*Mysella* 30.8
		Dorvilleidae 5.5		*Parvilucina* 23.1
		Nereis 4.0		*Kurtzia* 23.1
	DEC	*C. capitata* 89.4	absent	*Parvilucina* 53.8
		Dorvilleidae 5.2		*Mysella* 15.4
				Nudibranchia 15.4

TABLE 4. Summary of Otter Trawl Catches in June (J) and December (D) in Santa Monica Bay (SMB) and on the Palos Verdes Shelf (PVS). Percent Similarity is the Similarity Between June and December Samples.

Station	*SMB 7.5-2*		*SMB 6-4*		*SMB 7-3*		*PVS 4.5-1*		*PVS 7-3*	
Month	*J*	*D*	*J*	*D*	*J*	*D*	*J*	*D*	*J*	*D*
Number of individuals	614	417	289	343	31	185	114	68	88	139
Number of species	20	14	15	14	7	17	7	7	8	11
Diversity	.928	.532	.808	.859	.704	.999	.533	.644	.419	.681
Percent similarity	47.1		42.7		36.4		65.8		71.0	

The composition of the fish assemblage near the wastewater outfalls also changed over relatively short distances. Fish abundance, diversity, and species richness decreased, and the similarity between seasonal collections increased with increasing wastewater effects. Similar patterns were reported for the same area by Allen (1977) and Mearns (1979), and the diversity and similarity findings, though not significant, are in general agreement with Bechtel and Copeland (1970) and Haedrich (1975).

We suggest that changes in the composition of the benthic fish assemblages between sites are the result of changes in the composition of the infauna. Five of the eight species examined for food habits (longspine combfish, yellowchin sculpin, California tonguefish, speckled sanddab, and hornyhead turbot) accounted for a mean of 62% (SD = 14, N = 6) of the catches in SMB but only 2% (SD = 1, N = 4) of the catches on PVS. The total catch of these species in a 10 minute trawl declined from a mean of 205 (SD = 158, N = 6) in SMB to 2 (SD = 1, N = 4) on PVS. Carlisle (1969) also found that abundance of the dominant species in SMB (speckled sanddab, yellowchin sculpin, and California tonguefish) was greater at three stations away from the 8.3 km outfall when compared to three stations close to the outfall.

Longspine combfish, yellowchin sculpin, California tonguefish, and speckled sanddab fed predominately on benthic, epibenthic, and nektonic crustaceans (Table 5), animals that were rare or absent at stations strongly affected by wastewater discharge (Table 3). Several studies demonstrated that yellowchin sculpin (Allen 1982), California tonguefish (Telders 1981), and longspine combfish (Hume, Gunnerson and Imel 1962; Allen 1982) consume polychaetes. However, some of the specimens examined in these studies were collected on the Palos Verdes shelf or in Santa Monica Bay, large portions of which are affected by wastewater discharges. Johnson and Adams (1970) showed that the diets of longspine combfish (N = 104) collected between Point Hueneme and Santa Barbara were dominated by crustaceans, but that polychaetes occurred in about 20% of the stomachs.

The hornyhead turbot fed primarily on spionid and ampharetid polychaetes (Table 5) that were rare or absent at stations strongly affected by wastewater discharge (Table 3). Allen (1982) also found that spionids and ampharetids dominated the diets of hornyhead turbots.

The remaining species examined for food habits (English sole, Pacific sanddab, and Dover sole) accounted for a mean of 14% (SD = 11, N = 4) of fishes captured in SMB and 54% (SD = 32, N = 4) of the fishes captured on PVS. Total catch of these fishes increased from a mean of 39 (SD = 28, N = 6) in SMB to 57 (SD = 38, N = 4) on PVS; the difference is not significant (Mann-Whitney U-test, p = .305). The proportion of polychaetes in English sole stomachs increased and the proportion of pelecypods and crustaceans decreased from SMB to PVS (Table 5). The proportion of polychaetes in the diets of Dover

TABLE 5. Stomach Contents of Selected Demersal Fishes. Data Presented as Mean Percent Numbers. Mean Board Standard Length (mm), One Standard Deviation (SD), and Sample Size (N) at Bottom of Table. Mysid/Eupha = Mysidacea/Euphausiacea.

	Longspine combfish					*Yellowchin sculpin*					*California tonguefish*				
	SMB 7.5-2	*SMB 6-4*	*SMB 7-3*	*PVS 4.5-1*	*PVS 7-3*	*SMB 7.5-2*	*SMB 6-4*	*SMB 7-3*	*PVS 4.5-1*	*PVS 7-3*	*SMB 7.5-2*	*SMB 6-4*	*SMB 7-3*	*PVS 4.5-1*	*PVS 7-3*
Nematoda	12	17	24		78	9	7	9		80	4	11	11		65
Polychaeta															
Ampharetidae															
Amphictenidae															
Capitellidae					8					40		3	3		
Dorvilleidae					61					40					
Onuphidae															
Spionidae															
Mollusca											2		4		
Gastropoda													2		
Bivalvia											2		2		
Crustacea	81	79	64		18	77	87	66		20	83	82	72		11
Ostracoda		10				12	6	7				7	5		
Mysid/Eupha	54					4		8							
Cumacea		6					4				7	9	6		
Tanaidacea		6									16	5			
Isopoda		11	11					4		20			14		
Gammaridea	15	38	32			30	51	26			45	54	38		11
Decapoda			11					6				4			
Osteichthyes	7					9		21			4		8		
MM	137	140	146		139	58	52	63		60	129	132	139		120
SD	25	9	4		1	5	21	6		0	10	8	11		0
N	9	25	10	0	2	20	23	15	0	1	17	20	15	0	1

TABLE 5. Stomach Contents of Selected Demersal Fishes. Data Presented as Mean Percent Numbers. Mean Board Standard Length (mm), One Standard Deviation (SD), and Sample Size (n) at Bottom of Table. Mysid/Eupha = Mysidacea/Euphausiacea.—Continued

	Hornyhead turbot					*English sole*					*Pacific sanddab*				
	SMB 7.5-2	*SMB 6-4*	*SMB 7-3*	*PVS 4.5-1*	*PVS 7-3*	*SMB 7.5-2*	*SMB 6-4*	*SMB 7-3*	*PVS 4.5-1*	*PVS 7-3*	*SMB 7.5-2*	*SMB 6-4*	*SMB 7-3*	*PVS 4.5-1*	*PVS 7-3*
Nematoda		5	14				28	22		39		4		4	9
Polychaeta	63	77	79				33	41		61	15	27	34	49	60
Ampharetidae	23	5	16					23							
Amphictenidae							28	15							
Capitellidae														11	3
Dorvilleidae														8	20
Onuphidae	30	9													
Spionidae		40	47				4					3			
Mollusca							19	23				6		13	
Gastropoda								4				6			
Bivalvia							19	18							
Crustacea	36	16					18	5			60	45	63	16	19
Ostracoda							4					20	21		
Mysid/Eupha											41		2		
Cumacea															
Tanaidacea															
Isopoda															
Gammaridea	36	13					10				5		20		5
Decapoda															
Osteichthyes											22			7	
MM	134	128	140				232	215		151	80	80	94	117	112
SD	75	29	50				34	18		48	8	37	11	24	27
N	4	20	10	0	0	0	16	7	0	6	20	20	11	19	20

	Speckled sanddab					Dover sole				
	SMB 7.5-2	*SMB 6-4*	*SMB 7-3*	*PVS 4.5-1*	*PVS 7-3*	*SMB 7.5-2*	*SMB 6-4*	*SMB 7-3*	*PVS 4.5-1*	*PVS 7-3*
Nematoda										
Polychaeta	14	20	21			3		2	66	67
Ampharetidae										
Amphictenidae										
Capitellidae			6						9	3
Dorvilleidae									49	38
Onuphidae										
Spionidae										
Mollusca								4		
Gastropoda										
Bivalvia										
Crustacea	76	78	67			91		93	20	23
Ostracoda		15	23					26		
Mysid/Eupha	42									
Cumacea		4				6				18
Tanaidacea						4				
Isopoda			7					7		
Gammaridea	7	33	30			76		52	9	
Decapoda									6	
Osteichthyes	12		4							
MM	71	74	85			134		114	115	97
SD	6	8	10			21		16	38	11
N	20	20	14	0	0	9	0	8	11	19

sole and Pacific sanddab increased and the proportion of crustaceans decreased from SMB to PVS (Table 5). English and Dover soles are general infaunal predators with preferences for polychaetes (Kravitz *et al.* 1977, Pearcy and Hancock 1978, Gabriel and Pearcy 1981, Allen 1982). Pearcy and Hancock (1978) found a positive correlation between the standing crop of Dover sole and the standing crop of their preferred prey and stated that "... Dover sole are versatile predators, changing their diets opportunistically in response to changes of prey availability." That Pacific sanddab behaved in the same way is surprising; it has a symmetrical mouth that is more adapted to seizing swimming prey (Yazdani 1969) and feeds primarily on pelagic crustaceans and fishes (Kravitz *et al.* 1977; Pearcy and Hancock 1978).

The results of this study are consistent with the hypothesis that depressions in the abundance of some species of fishes in areas strongly affected by wastewater discharge are caused by lack of suitable prey and increases in the abundance of other species in areas strongly affected by wastewater discharge are caused by an abundance of suitable prey and flexible food habits. Södergen (1976) concluded that the decline in abundance of *Salmo salar* in a river in Sweden receiving heavy metal wastes was largely the result of a decline in abundance of their preferred invertebrate prey which was adversely affected by the metal pollution.

While the data collected in this study are suggestive, several alternative hypotheses cannot be discounted. Changes in the distribution and abundance of some fish species around the outfalls could be the result of: i) habitat modifications (low dissolved oxygen, high hydrogen sulfide and contaminant concentrations) that affect behavior or physiology (e.g. interference with chemoreception, toxic effects, etc.) or, ii) altered biological interactions (changes in abundance of competitors, predators, or preferred prey) that reduce the suitability of the environment.

LITERATURE CITED

Allen, M. J. 1977. Pollution related alterations of southern California demersal fish communities. Cal-Neva Wildl. Trans. 1977:103–107.

Allen, M. J. 1982. Functional structure of soft-bottom fish communities of the southern California shelf. Ph.D. dissertation, Univ. Calif., San Diego, 577 p.

Allen, M. J. and R. Voglin. 1976. Regional and local variations of bottom fish and invertebrate populations. Pages 217–221 *in* W. Bascom ed. Coastal Water Research Project Annual Report, 1976. Southern California Coastal Water Research Project, El Segundo.

Bascom, W. 1978. Life in the bottom. Pages 57–80 *in* W. Bascom ed. Coastal Water Research Project Annual Report, 1978. Southern California Coastal Water Research Project, El Segundo.

Bechtel, T. J. and B. J. Copeland. 1970. Fish species diversity indices as indicators of pollution in Galveston Bay, Texas. Contrib. Mar. Sci. 15:103–132.

Boesch, D. F. 1982. Ecosystem consequences of alterations of benthic community structure and function in the New York Bight region. Pages 543–568 *in* G. F. Mayer ed. Ecological Stress and the New York Bight: Science and Management. Estuarine Research Foundation, Columbia, South Carolina.

Carlisle, J. G., Jr. 1969. Results of a six-year trawl study in an area of heavy waste discharge: Santa Monica Bay, California. Calif. Fish Game, 55:26–46.

Gabriel, W. L. and W. G. Pearcy. 1981. Feeding selectivity of Dover sole, *Microstomus pacificus*, off Oregon. Fish. Bull. 79:749–763.

Haedrich, R. L. 1975. Diversity and overlap as measures of environmental quality. Wat. Res. 9:945–952.

Hendricks, T. J. 1980. Currents in the Los Angeles area. Pages 243–256 *in* W. Bascom ed. Coastal Water Research Project Biennial Report, 1979–1980. Southern California Coastal Water Research Project, Long Beach.

Hume, N. B., C. G. Gunnerson, and C. E. Imel. 1962. Characteristics and effects of Hyperion effluent. J. Water Pollut. Contr. Fed. 34:15–35.

Jan, T. and G. P. Hershelman. 1980. Trace metals in surface sediments of Santa Monica Bay. Pages 171–180 *in* W. Bascom ed. Coastal Water Research Project Biennial Report, 1979–1980. Southern California Coastal Water Research Project, Long Beach.

Johnson, C. R. and J. P. Adams. 1970. Biology of *Zaniolepis latipinnis* (Zaniolepidae) in relation to vertical distribution. Copeia, (1970) 769–771.

Kleppel, G. S., J. Q. Word, and J. Roney. 1980. Demersal fish feeding in Santa Monica Bay and off Palos Verdes. Pages 309–318 *in* W. Bascom ed. Coastal Water Research Project Biennial Report, 1979–1980. Southern California Coastal Research Project, Long Beach.

Kravitz, M. J., W. G. Pearcy, and M. P. Guin. 1977. Food of five species of co-occurring flatfishes on Oregon's continental shelf. Fish. Bull. 74:984–990.

Mearns, A. J. 1973. Southern California's inshore demersal fishes: Diversity, distribution and disease as responses to environmental quality. Calif. Coop. Oceanic Fish. Investig. Repts. 17:141–148.

Mearns, A. J. 1979. Responses of coastal fishes and invertebrates to wastewater discharges. Prog. Wat. Tech. 4:19–32.

Mearns, A. J. 1981. Effects of municipal discharges on open coastal ecosystems. Pages 25–66 *in* P. A. Geyer ed. Man and environmental pollution. Elsevier, Amsterdam.

Pearcy, W. G. and D. Hancock. 1978. Feeding habits of Dover sole, *Microstomus pacificus;* rex sole, *Glyptocephalus zachirus;* slender sole, *Lyposetta exilis;* and Pacific sanddab, *Citharichthys sordidus,* in a region of diverse sediments and bathymetry off Oregon. Fish. Bull. 76:641–651.

Pearson, T. H. and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr. mar. Biol. Rev. 16:299–311.

Schafer, H. A. 1982. Characteristics of municipal wastewater. Pages 11–15 *in* W. Bascom ed. Coastal Water Research Project Biennial Report, 1981–1982. Southern California Coastal Water Research Project, Long Beach.

Sodergen, S. 1976. Ecological effects of heavy metal discharge in a salmon river. Rept. Instit. Freshwater Research Drottningholm. No. 55:91–131.

Telders, E. L. 1981. Feeding periodicity and diet of the California tonguefish, *Symphurus atricauda* (Pisces: Cynoglossidae). Thesis, Calif. State Univ., Long Beach, 49 p.

Tillman, D. C. and R. D. Bargman. 1973. Report on waste discharges to the ocean, Part 1. Dept. Publ. Works, City of Los Angeles, 336 p.

Word, J. Q. and A. J. Mearns. 1979. 60-meter control survey off southern California. Southern California Coastal Water Research Project, Long Beach. Tech. Mem. 229., 58 p.

Yazadani, G. M. 1969. Adaptations in the jaws of flatfish (Pleuronectiformes). J. Zool. (Lond.) 149:181–222.