CHAPTER 120

EFFECTS OF WASTEWATERS ON MARINE BIOTA

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ABSTRACT

The ocean provides enormous oapacity for dispersion and assimilation of human and natural wastes. Indsed marine ecosystsms dspend on such terrestrial sources for their nutrient supplies. It is incumbsnt on man to cause minimal disruption and, if possible, beneficial sffects from dispersing his wastss in the eea. The Southern California Bight receives the most intenss exposure to discharged sewage of any exposed region along the Pacific coast of North America. Evidenose of significantly altsred chemical and biological conditions in southsrn California have been demonstratsd. Elevated ooncentrations of csrtain metals occur in sediments nsar some large sewage outfalle. Psticide rseidues wers extremely high in sand crabs from southern California. Beds of giant kelp decreased nsar eome, but not all,sewage outfalls. Correctional measurss ars disoussed. Ecological surveys ars currsntly used to provide early warning of potential biological problems near some southern California outfalls. A survsy nsar an outfall removed from service indicatsd moet ohanges in fish and macroinvsrtebrate populations occurred within a few months after the discharge oeased.

INTRODUCTION

Ecological consequences of discharging liquid wastes to the marine environment form a complex subjsct, involving an sxtensivs literature. To restrict this discussion to reasonable space limits, I shall consider only waste disposal to the open sea. I will rely primarily on data gathered in ths southsrn California region, the arsa with which I am most familiar.

From the outset I would like to eliminate certain emotions many of us oarry with reference to liquid waste. In the nursery we are all taught that human wastss are rspulsive and should be strongly avoidsd. What is valid in the nursery may not be true for the remainder of the world. Oceanic biota utilizs and depend on many wastes of terrestrial origin. Without nutrient input from streams and rivers, life in the ssa would be greatly reduced. Precise sources of these nutrients are of little ovsrall importancs. That is, it is immaterial to a marine plant whether phosphate ions come to it from rock erosion, decay processses in soils, or releass as wastes from the bodies of man or other animals. Ws must, however, be careful to inject our nutrient subetances into the marins world in ways that do not disrupt ecosystems (i.e. avoid eutrophication problems). We must also be csrtain that the disposal operation does not significantly alter the physical and chemical environment.

The ocean is viswed as an attractive recsptacle by engineers charged with managing large volumes of liquid wastes generated by large metropolisss. The great expanse of the sea provides enormous oapacity for assimilation and dispersion. Soonsr or later most of our liquid wastes end up in the sea whether thsy are first discharged to rivers and streams or more directly placed in bays and sstuaries, or actually discharged in the ocean.

POPULATION DISTRIBUTION ALONG THE U.S. PACIFIC COAST

As a rough guide to intensity of waste generation, let us consider the distribution of human population along the Pacific United States. The combined populations of Washington, Oregon and California are about 25.5 million humans. (Statistical Abstract, 1970). About 11.3 million, or 44 percent of the three-state total, reside within "discharge distance" of the sea in the region between Ventura and San Diego (about 150 miles of coastline). More than a billion gallons of liquid wastes are discharged daily into the Southern California Bight . (1) No other region of our Pacific Coast is exposed to such an intensity of waste disposal. If marine waste disposal does affect marine biota, the Southern California Bight is a logical region for detecting and analyzing such effects.

The Southern California Bight is a major indentation in the coast just south of Point Conception (Figure 1). The seaward boundary exhibits a chain of islands lying some 25 to 50 miles offshore. The main current systems (California and Davidson Currents) usually do not affect coastal waters in southern California. Coastal currents in the regions receiving discharged wastes are sluggish and oscillatory, typically ranging up to 0.3 knots. Action from long period swell is reduced along those portions of the mainland that lie in the lee of offshore islands.

Four major outfalls account for approximately 90 percent of the sewage effluent discharged to the Southern California Bight. These facilities are operated by the City of San Diego (CSD, approximately 80 MGD), Orange County Sanitation Districts (OCSD, 135 MGD), Los Angeles County Sanitation Districts, (LACSD, 360 MGD) and the City of Los Angeles (CLA, 330 MGD) (Table 1). A number of minor municipal and industrial outfalls are scattered irregularly along the coast. Some of the minor outfalls have been studied intensively. Few, if any, ecological affects have been reported. About 90 percent of the discharged sewage effluent receives only primary treatment.

ENVIRONMENTAL IMPACT OF MARINE WASTE DISPOSAL

For sewage outfalls discharging in water of adequate depth and using diffusers, changes in oceanic temperature, salinity, pH and dissolved oxygen, are nearly always negligible. Although extensive plankton blooms occur in California's waters, all evidence indicates that these are natural phenomena and nutrients from discharged wastes are a negligible stimulus (3). Potential problem areas may exist with regard to toxicants, disease, sedimentation, and induced changes in species composition. These are fields where further research is clearly indicated.

Concentrations of toxic substances in receiving waters of well-designed outfalls are low, typically below threshold levels for overt distress symptoms during short term exposures for test organisms. In recent years, however, there have been indications that subtle mechanisms in the environment are able to concentrate toxicants to levels that may be biologically damaging. Consequently any evidence that such mechanisms may be operating near a sewage outfall, is cause for concern. Wastewaters are probably not the only sources of toxic inputs. Freshwater and airborne sources must also be considered and still require considerable investigation.

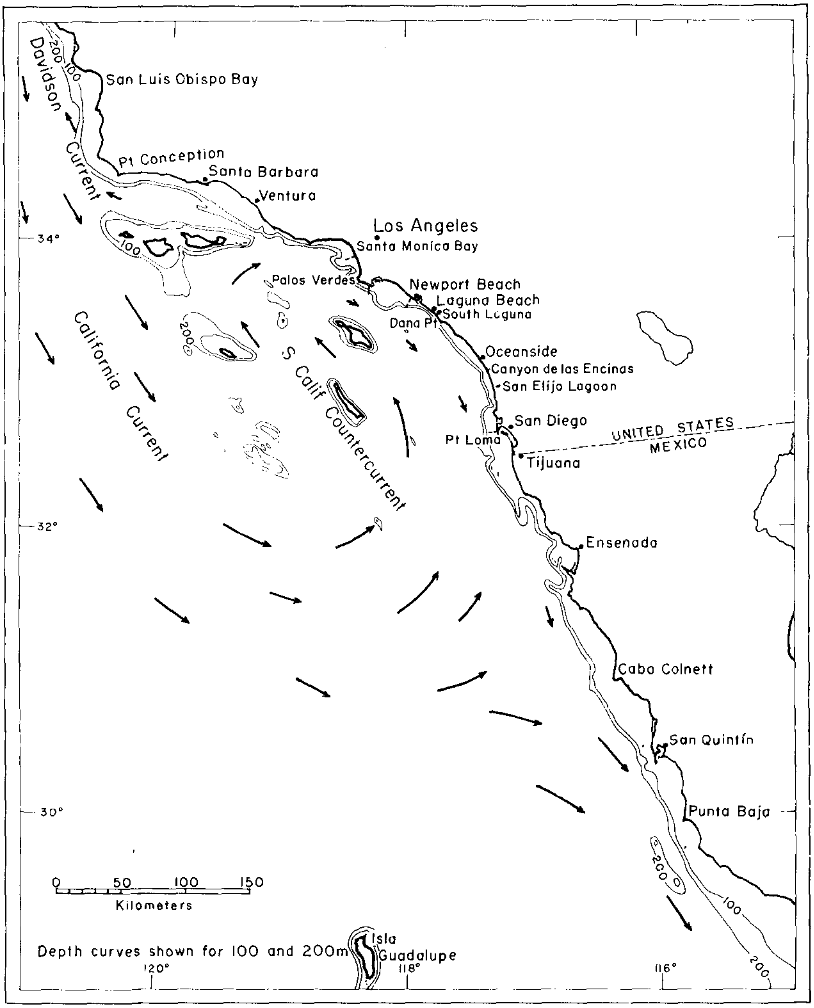

Figure 1. Chart of southern California and northern Baja California showing general current systems and their relations to the Southern California Bight, modified from Jones (2). The offshore California Current moves sluggishly most of the year but a reversal, the Davidson Current, can occur from August to November.

Table 1

Effluent volumes in millions of gallons per day versus time for four major southern California discharges. Data supplied by City of San Diego, Orange County Sanitation Districts, Los Angeles County Sanitation Districts, and City of Los Angeles.

Year	San Diego	Orange County	L. A. County	L. A. City
1972			360*	329*
1971	83	135	370	336
1970	81	130	371	330
1969	84	125	373	344
1968	80	120	348	323
1967	73	114	336	317
1966	71	107	318	316
1965	63	95	302	293
1964	61	89	293	287
1963	48	82	288	283
1962	49	75	280	278
1961	48	66	274	261
1960	48	54	264	259
1959	45	52	248	262
1958	44	44	220	267
1957	43	37	195	256
1956	40	31	183	249
1955	39	24	180	244
1954	39		176	239
1953	38		154	230
1952	37		147	219
1951	32		125	193
1950	28		114	194
1949	25		104	199
1948	23		82	184
1947	21		59	178
1946	23		53	161
1945	22		52	160
1944	9.7		52	162
1943	5.2		47	148
1942			35	143
1941			34	144
1940			29	133
1939			25	130
1938			23	131
1937			20	131
1936			19	114
1935			18	113
1934			17	107
	1887			1894

*Estimate based on portion of year

Klein and Goldberg (4) have demonstrated increases in sedimentary Mercury in the vicinity of the LACSD discharge. Young (1) recently summarized all information concerning Mercury distribution in the Southern California Bight. Galloway (5) demonstrated increased levels of Zinc, Copper, Lead, Cadmium, and Chromium in sediments near the LACSD and CLA outfalls, vs. background values from distant samples. Burnett (6) examined DDT levels in sand crabs, Emerita analoga, as a function of distance from the Los Angeles region. Crabs from the Los Angeles area yielded DDT ooncentrations two orders of magnitude greater than collections from remote areas in central California.*

There is thus olear evidence that potential toxicants are being concentrated at certain locations in the Southern California Bight. Ecological consequences of these phenomena await analysis. If significant adverse effects exist, source control of toxicants may be necessary. It should be mentioned that Clendenning (7) found that short term exposures (up to 96 hours) of giant kelp tissues (Macrocystis) to 100:1 dilutions of sewage in seawater (oomposite sewage samples provided by LACSD and CSD), stimulated photosynthesis as much as 50 percent, presumably an effect from nutrients in the sewage.

Investigations of disease among organisms near sewer outfalls are presently only in preliminary phases. Collections have indicated some association of abnormal conditions among oertain fish species captured near outfalls. Abnormalities may also be found, albeit with reduoed frequencies, in the same species from areas well removed from outfalls. Thus Russell and Kotin (8) noted an 0.3 inoidence of papillomas in white croaker (Genyonemus lineatus) from Santa Monica Bay vs. none among specimens from a control area. Halstead and Young (9) desoribed a variety of afflictions in various fish species, which they believe were related to discharged wastes. The Southern California Coastal Water Research Project (10) is collecting and analyzing incidence vs. distribution data. Etiology of these diseases remains unknown. North (11) observed tumorlike growths on stipes and bladders of kelps near the San Diego outfall.

Grigg and Kiwala (12) believed that light sedimentation upon normally rocky surfaces was responsible for reduction in numbers of species that they recorded near the LACSD sewer outfall. These authors reasoned that even a thin film of sedimented material might prevent settling by microscopic planktonic larvae seeking solid rock substrate. The LACSD discharge in recent years has discharged about 500 tons daily of suspended solids (13). Although muoh of the suspended solids would not settle unless floculation occurred, the quantities liberated are very large and oomparable to the natural coastal transport of sediments in some areas. There is not evidence that sedimentation poses problems on normally sedimentary bottoms, although Carlisle (14) has suggested that distributions of fishes may ohange in such areas.

There are indications that marine waste disposal may cause significant alterations in distributions of ecologically important species. One such species is giant kelp, Macrocystis pyrifera. Giant kelp develops a treelike structure underwater. Populations of plants form a forest habitat that comprises the base of diverse and productive communities. The kelp bed assooiation provides commercial and recreational sources of fishes and shellfish. Kelp canopies are harvested and prooessed as food additives and for alginates. Kelp beds near Los Angeles and San Diego began declining in the early 1940's and were virtually nonexistent by 1960 (15). In general, the first indications

*DDT discharge by LACSD has been essentially eliminated.

of permanent large-scale disappearance occurred in those portions of the beds closest to sewage outfalls (Figure 2). Deterioration spread from this local region. During the period of decline, volumes of discharged effluent increased continually (Table 1).

Surveys in the deteriorating kelp beds typically revealed large-scale destruction of kelp holdfasts (the plant's anchoring mechanism) by swarms of grazing sea urchins. Deterioration of the Point Loma kelp bed near San Diego was halted and reversed (16) after urchin populations were brought under control (Figure 3). Pearse et al. (17) showed that urchins could absorb organics from seawater through the dermis and utilize them. Analyses by Clark (18) indicated that dissolved organic substances near the LACSD sewer outfall were significantly elevated vs. a control area. She calculated that dissolved free amino acids alone were present in sufficient concentration near the LACSD outfall to provide significant nourishment to urchins of the region. The restored kelp bed off Point Loma perhaps now benefits from nutrients discharged from the San Diego outfall. An indication is offered by the high productivity of this kelp bed. The bed's present area is considerably less than 10 percent of all kelp beds in California, yet Point Loma yields about 25 percent of the annual harvest.

DETECTING ECOLOGICAL CHANGE

It is clear that effects of sewer outfalls on marine ecosystems can be subtle, complex, and at times unpredictable. To protect biota of the Southern California Bight, regulatory agencies have defined beneficial uses to be protected that include preservation of fishes and other aquatic life. In addition, the State of California sponsored an extensive survey of the southern California continental shelf by the Allan Hancock Foundation of the University of Southern California (USC). The study's purpose was to establish background conditions to aid in evaluating future change. The investigation gathered data on water temperature, salinity, dissolved oxygen, phosphate, silicate, nitrate, pH, transparency, transmissivity, sedimentary characteristics, microplankton, sedimentary fauna, foraminifera, and intertidal algae from 1956 to 1960, occupying 732 stations (19). For several reasons, usage of the data has only been moderate. For example, different sampling and analytical techniques now in common use may not yield comparable data. Likewise data may be needed for specific locations not sampled during the USC study.

The USC and subsequent investigations (20, 21) have demonstrated the great complexity of the nearshore environment. Distributions of organisms are usually patchy, posing difficult sampling and analytical problems. Even restricted areas may support hundreds of plant and animal species, displaying great ranges of densities. Sorting and identifying organisms can be an enormous and tedious burden. Specialists are usually needed to identify the difficult groups such as Polychetes, Amphipods, Isopods, and Mollusks. Initially, monitoring programs sought to define the entire ecosystem but costs and the hopelessness of such efforts have caused a shift in emphasis. A recently designed study, conducted by OCSD, utilizes trawling to characterize fishes and macroinvertebrates. Fishes are components of a wide variety of food chains. If a significant ecological disruption developed, changes in fish populations would probably occur at a fairly early stage and provide the necessary warning of an impending problem. Southern California fishes have been studied thoroughly, so identification and sorting efforts in the OCSD monitoring program are relatively small.

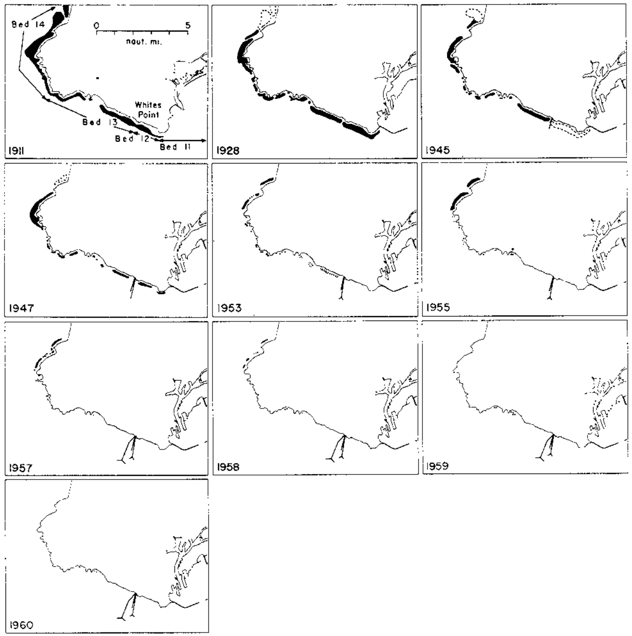

Figure 2. Historical series of charts of the Palos Verdes Peninsula showing status of kelp beds and construction of outfall system off Whites Point. Kelp beds shown as black. Data gathered from maps and aerial photos. Where a portion of the coast was missing in a series of aerial photos, the outline of kelp beds from the previous chart is shown as a dotted line. Abnormally high water temperatures from 1957 to 1959, seriously damaged existing kelp.

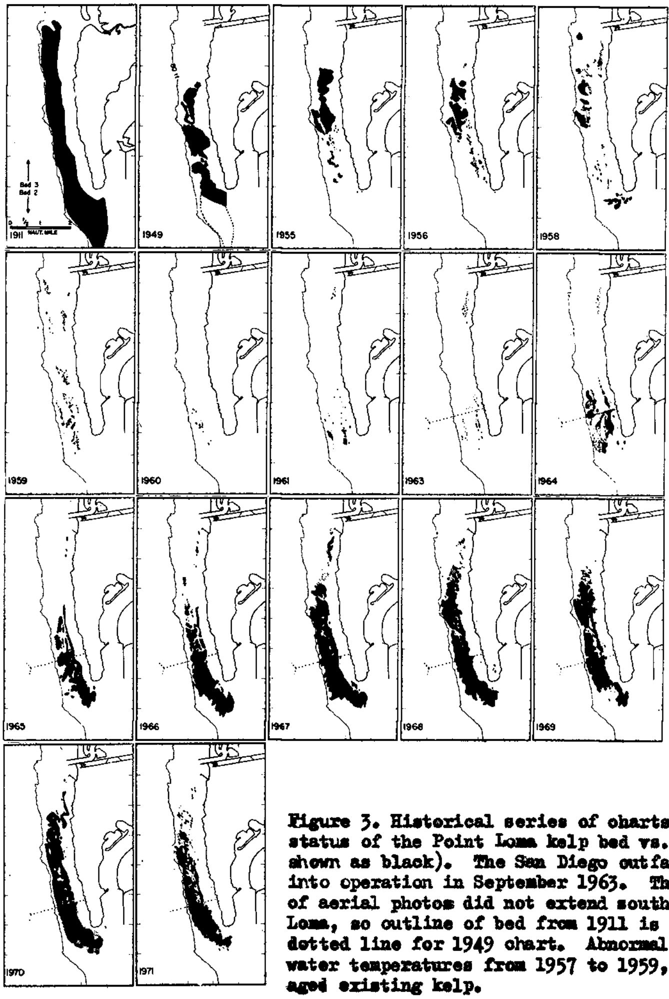

Figure 3. Historical series of charts showing status of the Point Loma kelp bed vs. time (kelp shown as black). The San Diego outfall was put into operation in September 1963. The 1949 series of aerial photos did not extend south of Point Loma, so outline of bed from 1911 is shown as dotted line for 1949 chart. Abnormally high water temperatures from 1957 to 1959, seriously damaged existing kelp.

Monitoring at the San Diego outfall presently places emphasis on sedimentary fauna. The voluminous data have been periodically analyzed by independent contractors (22,23,24). No significant adverse effects have appeared. Abundances of some groups increased substantially after discharge commenced in 1963.

Marine populations frequently undergo changes in response to natural environmental events as well as to other human activities such as fishing, accidents, construction, dredging, etc. To identify such effects it is important that control stations be included in monitoring programs.

OTHER BENTHIC STUDIES

A review paper by Gunnerson in 1961 (25) summarized most of the early literature. Relatively little biological work near Pacific coast outfalls had been published at that time. The large background survey of the Allan Hancock Foundation (19) and the first kelp studies (15) were still in progress. Since then, a number of studies (apart from routine monitoring) have sought to evaluate conditions near sewage outfalls.

Point Loma

Much additional survey and collection work off Point Loma was undertaken in 1965 by diving biologists from the Department of Fish and Game. Their study indicated a diverse and abundant fauna and flora existed on the rocky shelf inshore from the outfall and no adverse effects attributable to the discharge were observed (20). Grab samples of sediment close to the terminus did not yield sludge but species composition of the infauna suggested influence by the discharge.

San Elijo Lagoon

A 6 MGD ocean outfall near the mouth of the San Elijo Lagoon discharges domestic sewage through a diffuser at a depth of 60 feet. Biota was surveyed and described just before outfall construction in 1964 (26). The same region was resurveyed in 1969 after nearly five years of discharging had occurred (27). Of eleven species or groups observed along the sedimentary outfall transect in 1964, eight were recorded again in 1969. Missing organisms were a red alga, *Agardhiella*, a gastropod, *Acteon*, and a sea star, *Luidia*, none of which had been highly abundant. In 1969, however, the region near the outfall yielded an additional seven algal and 97 animal species not recorded from this transect in 1964. The presence of the nearby solid outfall structure was probably responsible for many but not all of the increased numbers of species. The outfall terminus yielded 105 species and varieties. Numbers of fishes were greater at the terminus than along the shallower section of the pipe that supported a lush growth of kelp (kelp is usually highly attractive to fishes).

Density of giant kelp in the area was determined by Strachan in 1969 for three established kelp beds previously studied by North in 1963-64 (28). Standing crops in 1969 had increased at all three stations by factors ranging from about double to nearly 18 times the 1964 values. Considerable marine life was noted remaining throughout the region. The richest transect was one-half mile north of the outfall and yielded nine algal, 144 invertebrate, and five fish species vs. eight algal, 118 invertebrate, and fifteen fish species in 1964. It appeared, therefore, that the outfall had produced little, if any detrimental effect. The increased abundance of giant kelp might represent a nutritional stimulus such as reported by Clendenning (7).

Canyon de lae Encinas

Department of Fish and Game divers oonducted background (1962) and post-discharge surveye near the small (2.2 MGD) sewer outfall off Canyon de las Enoinas to note any changes caused by the operation. Principal ohangee involved increased abundances of sea anemonies, hermit crabe, sand stars, and white urchins (29). Diversities and abundances of speoies colonizing the outfall structure were considered normal for the age of the "reef". Overall, no adverse influences of outfall operation were noted.

Pre- and post-disoharge studies were conducted on kelp beds near Canyon de las Encinas (30, 31). Parameters measured were kelp abundance, plant size, growth rate, mortality, and reproduction as evidenced by abundance of juveniles. No adverse effects were found. The beds have remained luxuriant (as indicated by surface canopiee) up to the present.

Central Orange County

Three small (6MGD) outfalls discharge in nearshore waters at depths from 30 to 80 feet at Laguna Beach, South Laguna, and Dana Point in central Orange County. Distances between adjacent outfalle varies from $2\frac{1}{2}$ to 5 miles. The region was surveyed by Andereon and North (32), comparing conditions near the outfalls to control areas two or more miles away from discharge sites. Quantitative eampling indicated concentrations of a worm, Pherusa, and a sea star, Astropecten, were reduced near the Laguna Beach outfall while another worm, Diopatra, was much more abundant (values highly eignificant) near the Laguna Beach and South Laguna outfalls. Diversity was greatly reduced near the Dana Point outfall and its control etation compared to the other eites. Recent construction of a harbor in the Dana Point area may have affected biota at thie outfall and its control station.

Orange County Outfall

Diving biologiete from the Department of Fish and Game surveyed biota near the Orange County Sanitation Districts discharge off the Santa Ana River in early 1965. A nearby artificial reef was also inspected. Numbers and kinds of sedimentary fauna appeared normal as did communities encrusting moet of the outfall structure (33). The last 100 feet of outfall pipe displayed reduced speciee diversity and there were indications of impoveriehment on the artificial reef. The general biological impact of the diecharge was nonetheless coneidered emall. Thie outfall has been retained on a standby basie since March 1971 and the new 4 mile pipe carriee effluent to a much deeper discharge eite. A decrease in sedimentary sulfide levels was observed near the old outfall after diecharge operations ceased (10).

PLANKTONIC STUDIES

Gunnereon (25) stated that "evidence for greater production of marine plankton in the vicinity of sewage-effluent dischargee is strong", citing studies from Florida, Oslo Fjord, and the Mediterranean as support. This conclusion has since been verified for southern California waters by Tibby et al. (34;

see also 19). These workers found an initial depression of phytoplankton productivity as sewage and seawater became mixed near the Orange County outfall. After about eight hours a substantial increase in carbon-14 uptake was noted, lasting about two hours. No correlations were found between productivity and concentrations of phosphate, silicate and ammonia. Stevenson and Grady (35) usually found increases in planktonic concentrations near outfall "boils". Occasionally the effect could be traced to a 12,000 foot distance. These authors did not believe that effluent mixtures caused plankton "blooms" (marked concentration increases) but they surmised that discharged nutrients might enhance bloom intensities. Gunnerson (25) could find no convincing evidence that the subtle fertilization effects of sewage could lead to dense plankton bloom or eutrophication in open coastal waters although such effects may occur in semi-enclosed situations. Tibby _et al._ concurred (19). Comparing microplankton counts from 59 stations near outfalls, with counts from all 800 stations surveyed, the Allan Hancock Foundation was unable to find any differences among numbers of dinoflagellates recovered, but reported a significantly greater mean value for diatoms from the outfall stations (differences in means were 2.9 times the standard error). Influences on individual species were not determined.

Clendenning and Sweezey (36) believed that there may have been an association between sewage effluent and cryptomonads in San Diego Bay. The City of San Diego conducted surface to 20 foot depth plankton tows for five years near their Point Loma outfall (a discharge that rarely, if ever, extends to within 20 feet of the surface). A total of 80 groups that included 35 species were segregated during processing. Several species may have responded to the Point Loma discharge (_Ceratium dens_, _Ceratium furca_, and _Noctiluca_ sp. may have increased temporarily, _Skeletonema costatum_ and _Oxytoxum_ sp. may have increased, particularly during a period of sludge discharge). Overall, however, it was concluded that influences on planktonic communities were negligible (22,23). This study was certainly the most detailed effort and the most carefully analyzed work of its kind ever conducted on the Pacific coast. As a result, the Regional Water Quality Control Board was convinced that the San Diego discharge was not influencing planktonic communities significantly and the City was allowed to discontinue this exceedingly costly program.

The problems associated with conducting meaningful plankton studies have plagued almost every survey that has examined this type of community near outfalls. Species identification requires highly specialized and painstaking efforts from collection to identification (37). Personnel with necessary skills are often unavailable. The City of San Diego studies were hampered by high turnover rates among technical personnel. Abundance variations even for a single species can be enormous, sometimes spanning five or six orders of magnitude during a single collection series. Vertical migrations, tendencies to form stratified distributions under certain (usually unknown) conditions, horizontal transport by currents, and other factors introduce transients leading to profound abundance fluctuations within hours or even minutes.

In designing dispersal characteristics for a proposed ocean outfall for the City of San Francisco, bioassays were conducted on common marine animals to determine toxicity thresholds (38). The most sensitive species proved to be larvae of the bay shrimp (_Crago nigrocauda_) and of the market crab (_Cancer magister_).

STUDIES NEAR A DISCONTINUED DISCHARGE

An interesting study has been conducted by Marine Biological Consultants, funded by the County Sanitation Districts of Orange County (39). Trawling was used to define any macrofaunal changes following cessation of discharge from the District's Ocean Outfall No. 1. The outfall had been operating since 1954 and dispersed about 135 MGD of primarily treated effluent from a diffuser at a depth of approximately 55 feet. This system was removed from operation in March 1971 and thereafter effluent was dispersed from a newly-constructed outfall at a depth of 195 feet about three miles south from the former site of discharge.

The trawling studies involved quarterly collections using a 24 foot otter board trawl with a 1½ inch mesh body and a ½ inch mesh liner in the cod end. Each trawl occupied ten minutes of bottom fishing time. Collections were made at depths of about 50 feet, approximately 100 yards west of the outfall. Similar trawls were conducted at a control station of comparable depth and substrate, about four miles easterly. Studies ran continuously from August 1969 to the present (i.e. comprising twelve collection series).

The collections yielded a total of 75 invertebrate and 65 fish species. The outfall site produced 42 invertebrate and 52 fish species while the control yielded 61 invertebrates and 44 fishes. Most species appeared so sporadically that no relation to cessation of the discharge could be established. Among those species recovered fairly frequently and/or abundantly, 20 appeared to be relatively indifferent to the presence or absence of the discharge, nine showed tendencies to be less frequent near the outfall station before March 1971. Three species displayed reduced frequencies and/or abundances at the outfall station after March 1971 (i.e. there may have been some attraction by the discharge for these species: Table 2). Total species recovered per trawl fluctuated widely but after March 1971, values remained consistently high at both stations.

The data were thus fairly conclusive and revealing for certain species. When changes occurred, they usually appeared shortly after the discharge ceased. Obviously trawling is a highly selective operation, recovering primarily larger epibenthic invertebrates and intermediate-sized fishes. Even so, the data are useful in demonstrating character and rapidity of the changes involved.

CORRECTIONAL MEASURES

In-depth discussion of correctional measures is far beyond the scope of this paper. Needs for correction may become apparent from in situ observations gathered by monitoring programs or from external sources - generally research conducted elsewhere on problems aggravated by special circumstances. Correction, if needed, may take several forms including increased waste treatment effort, source control, or in certain cases, legislative action. Decisions are often costly and consequences far-reaching. Obviously both society and the environment benefit most if decisions are not made in a hysterical atmosphere.

Table 2

Summary of trawling studies comparing the Orange County Sanitation Districts Ocean Outfall No. 1 with a control area about 4 miles away. Sewage disposal at this outfall was terminated in March 1971. Numbers represent individuals recovered per ten minute trawl. Data from Marine Biological Consultants (39). Num = numerous; P = present.

Species	Station	8/19/69	11/29/69	2/20/70	5/26/70	8/19/70	12/9/70	2/16/71	5/25/71	8/19/71	12/10/71	2/11/72	5/12/72
						INDIFFERENT SPECIES							
Polinices draconis	Outfall		1							1		1	
	Control												
Balanus concavus pacificus	O			Num.				1			P		
	C		10	1	36			4		P	3		
Cancer anthonyi	O			5				2	1		1	1	
	C				3					1			1
Cancer gracilis	O	4	3	39	8	3		9	15		2	8	2
	C				2		1		7	16			
Crago nigromaculata	O	12	86	76	13	2		43	227	35	33	51	12
	C		2	1	5			14	82	4	7	2	5
Lironeca vulgaris	O		7	2	4	1		73	24	75	2	4	
	C		13	3	28			118	46	29	P	3	54
Astropecten verrilli	O	7	7	38	22	6		24	7	41	34	20	67
	C		49	6	12			64	3	24	18	158	9
Pisaster brevispinus	O	2	3	5	2			8	1	9	2	5	9
	C						2		3		1		
Citharicthys sordidus	O			16	25			19	2				2
	C			135				1352	37		19	20	56
Citharicthys stigmaeus	O	38	69		18	45		543	449	300	287		99
	C		30			64			796	979	310	405	448
Embiotoca jacksoni	O	2			1		14		15	9		11	2
	C												
Engraulis mordax	O	1034	4	18		77		36				2	
	C												
Hyperprosopon argenteum	O	2	2				2		2	6		4	
	C												
Microstomus pacificus	O				14			1	12				
	C				9			1	1	28			10
Phanerodon furcatus	O	14	15	8	17		11	17	28	33	4	5	1
	C			7	2			1	7	8			3
Pleuronicthys verticalis	O	1				1	4		4	1	4	9	
	C		1	4	1		3	2	2	7	5	11	7
Sebastes semicinctus	O							156	4				
	C					2			8		1	1	
Seriphus politus	O	577	36	75	34	8			1			248	
	C								1				
Symphurus atricauda	O	9	4	12	5	4	3	12	6	13	14	5	
	C			5	3		7	10	10	27	26	16	16
Zalembius rosaceus	O				1			5	16			15	
	C							1	22			1	34

Table 2 (continued)

Species	Station	8/19/69	11/29/69	2/20/70	5/26/70	8/19/70	12/9/70	2/16/71	5/25/71	8/19/71	12/10/71	2/11/72	5/12/72
							SPECIES THAT INCREASED						
	Outfall								1			2	1
Flabellinopsis iodinea	Control			1				2	3			1	8
	O								6			1	3
Petalaster foliata	C		5	11							2	3	1
	O										2		2
Hippoglossina stomata	C		1		11		3	5	2	5	6	2	10
	O							2		6	1	1	1
Hypsopsetta guttulata	C										2		1
	O	1			1		2	2		5	3	15	1
Paralicthys californica	C						3			2	3	3	3
	O				1	4			8		1	4	7
Parophrys vetulus	C		1		3	1	3	1		9	6	12	32
	O								4	1		2	3
Pleuronicthys coenosus	C		4	2		2			3				4
	O						2		7	15		7	3
Pleuronicthys decurrens	C						3	5	157	29	17	1	7
	O						2	4	8		4		7
Scorpaena guttata	C			1				2	1	4	2		11
							SPECIES THAT DECREASED						
	O	26	190	16	15	142		33	36	7		11	
Cymatogaster aggregata	C			38	7	4			9				3
	O	1024	160	293	455	578	254	100	6	11		32	
Genyonemus lineatus	C									2			2
	O	55		1		1	3						
Palometa simillima	C												
Species per trawl	O	22	18	24	21	14	17	29	35	28	23	35	25
	C	-	16	23	26	7	15	27	38	36	37	32	33

CONCLUSION

It is evident that marine waste disposal can and has produced significant changes among nearshore ecosystems in the Southern California Bight. This does not mean that deterioration has been complete or irreversible. The majority of the Southern California coastline still displays healthy, productive, and diverse marine communities. A major adverse effect, deterioration of the important kelp bed association, can be corrected, if given adequate effort. Clearly there is need for improvement and continued learning. I am optimistic that a time will come when we will know enough about ecological effects of marine sewage disposal to indeed be able reliably to fertilize and benefit the sea with our discarded nutrient materials.

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ACKNOWLEDGEMENTS

It is a pleasure to acknowledge help and suggestions on the manuscript from personnel of the Bureau of Sanitation, City of Los Angeles; Sanitation Districts of Los Angsles County; Sanitation Districts of Orange County; Department of Watsr Utilities, City of San Diego; and Marine Biological Consultants, Inc. The manuscript was typed by Barbara H. Britten. Laurencs G. Jones prepared the drawings.