Characteristics and Effects of Municipal Wastewater Discharges to the Southern California Bight - A Case Study

Alan J. Mearns
and
David R. Young

Submitted to NOAA April 1979

SCCWRP Contribution #143

TABLE OF CONTENTS

Characteristics and Effects of Municipal Wastewater Discharges to the Southern California Bight - A Case Study

Alan J. Mearns
and
David R. Young

Southern California Coastal Water Research Project
1500 E. Imperial Hwy., El Segundo, CA 90245

Submitted to the
National Oceanic and Atmospheric Administration
Marine Ecosystem Analysis (MESA) Program

April 1979

SUMMARY AND CONCLUSIONS

At present municipal wastewater discharges are the dominant source of most constituents of concern to the Southern California Bight. Effluents from these discharges are effectively diluted so that dissolved concentrations of trace materials (such as metals and chlorinated hydrocarbons) are well below levels known to cause toxic responses in marine organisms. However, because most constituents are bound to particulates, suspended matter and sediments near the outfall diffusers contain above normal concentrations of trace contaminants and organic matter.

The most serious known pollutants are the higher molecular weight chlorinated hydrocarbons, namely DDT's and PCB's. These synthetic organics have been shown to be biomagnified through the coastal marine food web leading to birds and mammals.

In contrast, trace metals do accumulate in some benthic and intertidal invertebrates (particularly molluscs) but do not undergo further food web biomagnification. Although mercury naturally undergoes bioamplification in marine food webs, available evidence indicates there is no additional mercury biomagnification due to these municipal discharges. Preliminary data indicate that other volatile and extractable chlorinated hydrocarbons, while present in relatively high concentration in sewage, do not appear to bioaccumulate through nearby marine food webs. Finally, low concentrations of benzo(a)pyrene in coastal mussels indicate that this carcinogen is not contaminating nearshore biota as a result of municipal wastewater discharges.

Thus, the higher molecular weight chlorinated hydrocarbons, mainly DDT's and PCB's, appear to be the most serious pollutants with respect to food web amplification and sea food contamination.

The response of marine communities to the municipal wastewater discharges is strongest and most obvious in benthic marco-invertebrate populations, and weakest and least obvious in plankton, fish and epibenthic invertebrate populations. The exception is at Palos Verdes where the diversity of shallow rocky subtidal kelp bed communities has been damaged by offshore discharge. This site has partially recovered possibly as a result of reduced emission of solids and DDT's.

At all major sites the main response of the benthos is in a shift from communities dominated by suspension feeding infauna to communities dominated by an abnormally high biomass of deposit-feeding invertebrates. The size of bottom areas affected by this change is directly proportional to mass emission rates of suspended solids. If future emission rates are known, this relationship can be used to forecast changes in the sizes of bottom area affected by changed communities.

Some fish and larger macroinvertebrates are more abundant and others less abundant near all discharge sites. For the smaller discharges (e.g., Point Loma and Orange County) more species are increased than are decreased. At Palos Verdes, more species are decreased than are increased.

Fin erosion is the only disease conclusively linked to wastewater discharges and it is initiated at only two of six outfall sites studied. The precise cause of the disease is not known, but high sediment and tissue concentrations of PCB's and contact with highly contaminated bottom sediments (such as occur at Palos Verdes) appear to be required.

Although we did not specifically review in this report the effects of southern California municipal discharges on dissolved oxygen or pH, numerous monitoring measurements indicate that these parameters are not significantly depressed at most sites; however, at Palos Verdes, dissolved oxygen depression approaching 10 percent below background has occasionally been reported.

Within the next five years, most of the treatment plants cited in this report will convert to partial secondary treatment. Thus, sources other than municipal waste discharges will soon dominate some chemical inputs. Research and monitoring programs should be reviewed and carefully adjusted to test forecasts and to maximize our understanding of ecological recovery rates and processes.

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

In this case study we summarize major findings obtained by the Southern California Coastal Water Research Project (SCCWRP) and others since 1971 on the fate and effects of municipal wastewater discharges to the Southern California Bight. The investigations conducted to date off the major deep ocean outfalls of the region have rather convincingly separated certain wastes of "clear concern" from others of "apparent non-concern" in well-flushed areas. However, a number of important questions remain to be answered, as described in detail in the following sections.

II. GEOGRAPHY, CIRCULATION, AND LAND USE

The Southern California Bight (Figure 1) is the open embayment of the Pacific Ocean extending from Point Conception on the north to Cabo Colnett, Baja California, on the south. The California Current roughly defines the Bight on the west. As the Bight's current system usually extends westward to the area with water depth in the order of 3,000 m, a more precise western boundary is the continental slope off southern California and northern Baja California. Within these boundaries, the Bight is approximately 500 km long and 200 km wide, covering a surface area of 100,000 sq km.

The California Current generally follows the coastline southward until it reaches the northern limit of the Southern California Bight--Point Conception. Here, the coastline turns abruptly eastward, and the flow of water departs from the coast, generally continuing in a southeastward direction. Further south, off the coast of northern Baja California, the main portion of the current turns toward the land, and the flow divides into two branches. One branch, known as the Southern California Countercurrent, turns northward and flows through the Channel Islands, forming the inshore side of the Southern California Eddy. During the spring, however, the countercurrent weakens and may even be absent. During such times, the surface flow within the Bight is to the south, (Jones, 1971).

Hendricks (1977a) has shown that nearshore surface currents in the Bight have speeds on the order of 25 cm/sec, and generally flow downcoast. In contrast, the subthermocline currents (which most affect submerged wastewater plumes), although highly variable, appear to move upcoast with a mean speed of about 3 cm/sec. If this mean flow (which was measured off San Diego) continues along the entire coast between the U.S.-Mexico border and Point Conception, it would correspond to a transit time of about 150 days.

Waters within the Bight are characterized by a warm (monthly mean temperatures between 12^{o} and 20^{o}C), well oxygenated mixed layer (20 to 30 m deep most of the year) and cooler, less-oxygenated subthermocline waters (9^{o} to 12^{o}C and 4 to 6 mg/L D.O. between depths of 50 and 200 m). The onset of strong, steady, northerly winds blowing in spring moves the warmer surface water to the west and permits colder (denser) water to upwell near the coast. This water brings up nutrients, which support heavy plankton blooms and cause the area to be one of high organic production.

The coastal plain adjacent to the Bight has an area of about 33,000 sq km and is inhabited by approximately 12 million persons, or about 5% of the Nation's population. Land use characteristic for 1970 are summarized below (SCCWRP, 1973):

Public	41.6%
Agriculture	26.6%
Residential	22.9%
Industrial	4.9%
Commercial	4.0%

Most of this population is concentrated in the Los Angeles-Orange County Basin (roughly bounded on the coast by Santa Monica and Newport Beach), with a second major urban-suburban area in San Diego County (Figure 1). The resultant municipal wastewater (1.5×10^{12} liter/yr) generally undergoes primary treatment only and then is discharged to the coastal waters through submarine outfall systems, as described in greater detail below.

Surface runoff flows to the Bight from 18 hydrologic units (SCCWRP, 1973) via more than 150 streams (excluding urban storm drains). However, most of this discharge is carried by approximately 20 major channels; the long-term near annual flow is 0.56×10^{12} liter/yr, or less than half of the municipal wastewater inputs (SCCWRP, 1973). Most of this runoff occurs as pulse inputs carried by only a few storms per year.

This Los Angeles-Orange County coast also contains the major vessel activity in the Bight. In addition to the commercial and naval vessels served by Los Angeles-Long Beach Harbor, the largest southern California anchorage, approximately 70 percent of the

35,000 recreational vessels in the Bight are sheltered in marinas of this region. A second major harbor is located in San Diego. (Most of the direct industrial discharges are situated in these two harbors.) We concluded from a 1973 Bight-wide survey that approximately 300,000 liters of antifouling paints, containing approximately 180 m tons of copper, are applied annually to vessel bottoms in southern California (Young et al. 1979a).

Thermal effluents from electrical generating stations spread along the coast represent another potential source of contamination. The 1976 discharge rate for the eight stations of Southern California Edison Company situated between Ventura and San Diego Counties was 6.8×10^{12} liters/year, roughly 70 percent of the total cooling water discharged to the Bight (Young et al., 1977a). Finally, the severe atmospheric pollution which exists in the Los Angeles-Orange County and San Diego Basins constitutes another route of pollutant inputs to the adjacent marine ecosystem.

III. MUNICIPAL WASTEWATER TREATMENT AND DISCHARGE SYSTEMS

The five largest southern California discharges account for over 95 percent of the 1.0 billion gallons of municipal sewage discharged daily (1.4×10^{12} liter/yr) into the Southern California Bight. The wastes are discharged through outfalls which range in depth from 20 to 100 m and terminate 2 to 11 kilometers from shore. The largest are those of Los Angeles County (JWPCP) and the City of Los Angeles (Hyperion Treatment Plant), which each discharge approximately 330 million gallons per day (mgd).

Approximately one-third of the Hyperion flow (100 mgd) is given secondary treatment (biological oxidation and sludge removal) but the resulting sludge is discharged via a second outfall located 11 km from shore and 3 to 4 km north of the effluent outfall. The Orange County outfall (160 mgd primary and 20 mgd secondary) discharges at a depth of approximately 60 m and about 8 km from shore in southern San Pedro Bay. The City of San Diego's Point Loma plant discharges approximately 120 mgd of primary treated effluent through a 3 km long outfall located at a depth of 60 m. The next largest outfall, from the City of Oxnard, discharges about 11 mgd of primary treated effluent through a 2 km long outfall at a depth of about 20 m. Finally, there are approximately 20 other outfalls in southern California which discharge a total of about 40 mgd through outfalls ranging in depth from 0 to 30 m. Most of the small plants chlorinate regularly, the JWPCP plant chlorinates during periods of shoreward transport, and the other three major plants rarely chlorinate.

The ocean outfalls through which the wastes are discharged are fitted with long (1000-2000 m) multiport diffusers which achieve initial dilutions of at least 100:1 (Hendricks, 1977b; Young and Jan 1975). During most of the year, when a thermocline is present, plumes remain submerged, reaching an equilibrium depth just below the thermocline.

Following initial dilution, the southern California sewage plumes tend to move along-shore and up-coast (to the northwest), along the isobath of discharge (generally 60 m) and usually opposite to the surface currents. During transit, components of the diluted effluent begin to separate; about 10 to 20 percent of the heavier particulates fall out of the plumes and onto the bottom near the discharge (Herring and Abati, 1979). Thus, bottom sediments in the fallout area around the discharges contain above-normal concentrations of trace metals, chlorinated hydrocarbons, and other contaminants attached to wastewater particulates. The fate of the remaining mass of fine particulates is largely unknown but a portion of it appears to remain suspended in the discharge area (Peterson, 1974) and perhaps many kilometers beyond. The fate of dissolved constituents is largely unknown, but ammonia is rapidly taken up by phytoplankton (Hendricks and Harding, 1974).

IV. CHARACTERISTICS OF MUNICIPAL WASTEWATERS

Wastewater monitoring programs have been conducted for many years at the five major municipal treatment plants situated along the southern California coast. With the adoption of sensitive analytical proceedures for trace analysis (such as atomic absorption spectroscopy and electron-capture gas chromatography) around 1970, reasonably reliable data on elemental and chlorinated hydrocarbon concentrations in final effluents began to be available. Tables 1 and 2 present 1977 average concentrations and associated mass emission rates for wastewater constituents of concern produced by these monitoring programs. It is important to note that most of the target trace metals and higher molecular weight chlorinated hydrocarbons (such as the DDT's and PCB 1254) have been found to be associated with the filterable ($<$ 0.4 micron) particulates in municipal wastewaters (Young et al. 1973a;

Luthy, 1973). This characteristic appears to be of major importance regarding the processes that control the dispersion and ultimate fate of such contaminants.

V. COMPARISON OF INPUTS

In 1971-72, SCCWRP surveyed inputs of various chemicals to the Bight via municipal wastewater, surface runoff, and direct industrial discharges (SCCWRP, 1973). The result for "general" constituents of interest are summarized in Table 3. Subsequently, several additional studies of trace metal and chlorinated hydrocarbon inputs were conducted (Tables 4 and 5). These data indicate that, for most substances investigated, inputs via municipal wastewater discharge far exceeded those via the other routes. As seen in Table 2, the JWPCP discharge off Palos Verdes Peninsula has been the largest single point source input for most contaminants of interest.

VI. RESULTANT DISTRIBUTIONS

Seawater

Limited studies around the largest outfall system (JWPCP) indicated that concentrations of dissolved metals (< 0.4 micron) in the wastewater plume were no more than a few times baseline levels (Young and Jan, 1975). For example, there were no significant elevations of dissolved cadmium or chromium values above median control concentrations (0.05 and 0.2 μg/liter, respectively).

In addition, median values of dissolved copper and nickel at three plume stations ranged from 0.3 - 0.6 and 0.7 - 1.2 ug/liter, respectively, compared to corresponding control values of 0.1 and 0.3 ug/liter. In contrast, the particulate fractions (> 0.4-microns) of these metals were 1 - 2 orders of magnitude above control levels (0.2 - 0.3 ug/liter), again suggesting the importance of wastewater particulates regarding the dispersion and fate of trace contaminants following discharge to the marine environment.

Although not separated into dissolved and particulate phases, DDT and PCB residues also have been measured in seawater collected in the JWPCP discharge zone. In May 1973, De Lappe and Risebrough measured concentrations of p,p'-DDE and trichlorobiphenyls up to 26 and 27 ng/liter, respectively, in seawater collected from the immediate vicinity of the outfall. In comparison, later that year they obtained concentrations that were lower by 1 - 2 orders of magnitude in seawater collected at the edge of the Bight (Risebrough et al. 1976).

Sediments

To obtain a comprehensive picture of the extent of sediment contamination caused by five major outfall systems, in 1977 SCCWRP conducted a systematic sediment survey along the 60 m contour, the approximate depth of discharge (Word and Mearns, 1979a; Word and Mearns, 1979b. Using a modified 0.1 sq m Van Veen grab, samples of bottom sediment were collected every 10 km between Point Conception and the U.S.-Mexico border (Figure 1). The upper layer (0-5 cm) was analyzed for numerous wastewater constituents; examples of the resulting distributions are presented in Figure 2. In an effort to summerize this extensive body of data for the four largest outfall systems, we have selected stations within the clear influence of the wastewater discharge; corresponding median and range values for various parameters were then calculated for each outfall zone, as well as for a large suite of control stations. The results are listed in Table 6.

These data indicate that, at least along the 60 m contour, the JWPCP discharge off Palos Verdes Peninsula has had by far the greatest impact on sediment concentrations of oxygen-demanding substances, toxic trace metals, and higher molecular weight chlorinated hydrocarbons. However, comparable levels of most of these contaminants also occur in somewhat deeper water around the terminus of the Hyperion 7-mile outfall, which discharges diluted sludge at about 100 m in Santa Monica Bay (Schafer and Bascom, 1976). Detailed summaries of sediment contamination around the major outfalls and in control regions of the Bight have been presented elsewhere (Galloway 1972; SCCWRP 1973; Young et al. 1973b; Bruland et al.1974; Hom et al. 1974; Young et al. 1975a; Young et al. 1976a; Eganhouse et al. 1976; Young et al. 1976b; Hershelman et al. 1977; Young et al. 1977b; Young and Heesen, 1978).

<u>Biota</u>

Elevated tissue concentrations of trace metals and higher molecular weight chlorinated hydrocarbons have been observed in a variety of marine organisms collected around (or inshore of) the major submarine outfall systems in southern California. The most dramatic example is the widespread contamination of the biota by DDT residues, caused by the massive discharge of this pesticide from the JWPCP outfalls up until the early 1970's (Anderson, 1973). Resultant levels of total DDT (mostly p,p'-DDE) in intertidal sand crabs (Emerita analoga) and mussels (Mytilus californianus) from Palos Verdes Peninsula were 2 - 3 orders of magnitude above baseline values at the edge of the Bight (Burnett, 1971; Young and Heesen 1974; Risebrough et al. 1976; Young et al. 1976c). Corresponding gradients (or contamination levels) have been reported for midwater fishes (Risebrough, 1969; Duke and Wilson 1971; MacGregor 1974; Young et al. 1975b), benthic fish and crabs (Young et al. 1976a; Young et al. 1977b) and marine birds (Anderson et al. 1975; Risebrough et al. 1976) and mammals (DeLong et al. 1973).

The severe egg shell thinning, and resultant reproductive decline, of Brown Pelicans (Pelicanus occidentalis californicus) in southern California in the early 1970's has been attributed to this DDE pollution (Risebrough et al. 1976). Young et al. 1979b) also have attributed the deaths of marine birds in the Los Angeles Zoo to high DDT residues (approximately 4 mg/wet kg) in queenfish (Seriphus politus) caught off Los Angeles and used as the exclusive diet of the birds affected. Mussle tissue concentrations of total DDT in black perch (Embiotoca jacksoni-- a popular sportfish) caught off Palos Verdes Peninsula in 1973 ranged up to 97 mg/wet kg (Young et al. 1975b), and approximately 30 percent of the seafood species collected from this discharge zone during 1975-77 exceeded the U.S. Food and Drug Administration limit of 5 mg/wet kg (Young et al., unpub. manus.)

Residues of the industrially-important polychlorinated biphenyls (PCBs) are another important class of trace synthetic organics contaminating the biota in the Bight. McDermott et al. (1978) reported median liver tissue concentrations of total PCB for Dover sole (Microstomus pacificus) collected during 1975 from the JWPCP and OCSD discharge zones of 15 and 8 mg/wet kg, respectively; corresponding muscle tissue concentrations were 0.7 and 1.1 mg/wet kg. The highest mean value obtained in the 1975-77 JWPCP seafood survey (about 2 mg/wet kg) was measured in the muscle of white croaker (Genyonemus lineatus), a water column and benthic feeder whose mean muscle tissue concentration of total DDT was 39 mg/wet kg (Young et al., unpubl. manus.).

Extensive time-series studies off the JWPCP outfall system have indicated that contamination of bottom sediments by the higher molecular-weight chlorinated hydrocarbons such as DDT's and PCB's can result in persistent contamination of benthic organisms in the region. For example, despite order of magnitude reductions in JWPCP annual mass emission rates of these two contaminants between 1972 and 1975, median levels in both bottom sediments and flatfish from the JWPCP monitoring zone decreased by only about a factor of 1.5 or less (Young et al. 1977b). Subsequent surveys suggest that the present ecological half-time of these chlorinated hydrocarbons in benthic sediments and organisms is on the order of 7-years (U.S. Congress, 1978).

In contrast to the case for DDT and PCB residues, where inputs from the JWPCP system are clearly reflected by local gradients in biological concentrations of these contaminants, levels of the known carcinogen benzo(a)pyrene are relatively low in mussels living inshore of the discharge zone (Dunn and Young,1976). The concentration for two rocky substrate stations on Palos Verdes Peninsula known to concentrate chlorinated hydrocarbons from the outfall system (Young and Heesen, 1978) were < 0.1 and 0.5 ug/wet kg, compared to values of 0.6, 1.4, and 2.3 ug/wet kg for specimens collected from rocks near the three entrances to nearby San Pedro Harbor. (Specimens from nearby pilings ranged up to 8.2 ug/ wet kg, presumably reflecting the effect of creosot applied as a wood preservative).

Numerous surveys of trace metals in various species from around major southern California municipal outfalls have shown that these submarine discharges can cause distinct elevations in metals tissue burdens of certain organisms. For example, Alexander and Young (1976) concluded that coastal intertidal mussels (Mytilus californianus) collected off the Los Angeles-Orange County Basin reflected distinct contamination of the water column by chromium, copper, and silver. This same observation was made for a subtidal bivalve mollusc, the purple-hinged rock scallop Hinnites giganteus (= H. multirugosus; Young and Jan, 1979). The three municipal outfall systems located off Los Angeles-Orange Counties accounted for the large majority of known anthropogenic inputs of these three trace metals (Young et al. 1973a). The fact that these few organisms feed by filtering particulate material from the water column, and the previously-mentioned fact that most of the metals contamination found around municipal diffusers is associated with filterable material, strengthens the hypothesis that suspended wastewater particulates are the vector for this contamination of the biota.

In addition, various invertebrate deposit feeders collected from the highly-impacted sediments around the JWPCP outfalls, also reflect the trace metals elevations, with measurable contamination factors (outfall-to-control) ranging from 2 - 10 (Young et al. 1978a; Young et al. 1978b). Unfortunately, we do not yet know to what degree such elevations of metals concentrations cause physiological, ecological, or public health problems. It should be noted that although levels of total mercury in some invertebrates collected near discharge zones are elevated a few times above normal, for neither invertebrates nor fishes have we observed a median concentration in edible tissue above the past FDA seafood standard of 0.5 mg/wet kg (deGoeij et al. 1974; Eganhouse and Young, 1976; Eganhouse et al. 1976; Eganhouse and Young 1978a; Eganhouse and Young 1978b; Young and Jan 1979).

In contrast to the situation for invertebrates, fishes living and feeding in or near the highly-impacted bottom sediments in major discharge zones have not reflected this dramatic metals contamination in their tissues (de Goeij et al. 1974; Young et al. 1978b). Although we have occasionally observed 2-3 fold elevations in outfall zone specimens, depressions of the same order are about as common (McDermott et al. 1976a; Sherwood 1979). With the exception of mercury, we have concluded that the common toxic trace metals studied to date (Ag, Cd, Cr, Cu, Ni, Pb, Zn) are not biomagnified up marine food webs in areas of trace metals contamination (Young and Mearns, 1979).

VII.ECOLOGICAL EFFECTS

During the past two decades the coastal discharge sites cited in this report have been surveyed to document the abundance, diversity, and health of marine life. Much of the work has been done by the dischargers themselves or through private and universitv contracts. Independent researchers, including those at the So.Cal. Coastal Water Research Project, have also conducted a number of regional surveys of benthic and water column life and contrasted conditions with those at distant coastal sites.

The Benthic Environment

Visual Conditions around Discharge Sites

Using submersibles, remote television, and 35 mm cameras the Coastal Water Research Project found that the Hyperion outfalls in Santa Monica Bay were colonized by a variety of large attached invertebrates including several species of gorgonians inshore of 30 meters and large anemones (*Metridium senile*) and aggregate anemones (*Corynactis* sp.) in deeper water (Allen et al. 1976). Large schools of a variety of water column feeding rockfish were common over both outfalls (including the diffusers) in deeper water and the rock ballast appeared to provide refuge for other fishes and invertebrates such as crabs and lobsters (Allen et al. 1976). Similar results have been obtained from photographic and television surveys at outfalls at Point Loma, Orange County, and Palos Verdes (SCCWRP, unpublished data). In most areas, the bottom adjacent to the pipes had a normal color and was occupied by fishes common in bottom trawls. However, television surveys near the Hyperion sludge outfall in the fall of 1976 revealed a bottom containing loosely aggregated sludge-like material with large numbers of white croaker (*Genyonemus lineatus*), northern anchovy (*Engraulis mordax*), and numerous large Pacific electric rays (*Torpedo californicus*). A grab survey revealed the area of bottom containing the loose sludge-like material was about 2 sq km in water about 100 meters deep at the head of a submarine canyon (Schafer and Bascom, 1976).

Response of the Benthic Infauna

The benthic macrofauna that normally colonizes sediments of the coastal shelf is one of the most diverse and stable communities of the open coastal zone. During 1977 and 1978, the Coastal Water Research Project conducted several large-scale, region-wide, surveys to document variations in the abundance, variety and trophic structure of benthic communities at one depth (60 m) along the entire 200 km southern California mainland shelf (Mearns and Word, 1979) and at many depths in the 100 km zone offshore of Los Angeles, Orange and southern San Diego counties (Bascom, 1979). A key element in this study was the Infaunal Trophic Index developed by biologist Jack Word (Word, 1979). The index, which ranges in values from 0 to 100, is a measure of the trophic structure of infaunal communities and utilizes numerical data from 26 abundant taxa of polychaetes, echinoderms, pelecypods, gastropods, and small crustaceans including species both sensitive to, and tolerant of, conditions near waste discharge sites. High Index values (e.g. 60-90) are indicative of a fauna dominated by suspension feeding organisms which are abundant in rural coastal areas uninfluenced by the major discharges or other sources of organic matter; lower values (0 to 60) are indicative of communities dominated by surface deposit feeding animals (30 -60) or subsurface deposit feeding animals (0-30). When used together with data or number of species, biomass (g/m^2) and some measure of organic content of surface sediments (e.g., % Volatile solids), the Index provides a useful quantitative guide to areas biologically affected by the discharges.

Background conditions

As shown in Figure 3, much of the southern California mainland shelf at a depth of 60-m was characterized by benthic communities with moderate biomass, high Infaunal Index values, and high diversity (number of species). However, near urban areas of Los Angeles, Orange, and San Diego Counties, volatile solids (Figure 2) and benthic biomass increase, and diversity and the Infaunal Trophic Index decreases. In fact, major depressions in the Index actually coincide with the four major discharges (marked on Figure 3). In addition, however, low Index values indicate that the rural coastal shelf near Point Conception is inhabited by a benthic infauna with an unusually large number of deposit-feeding animals.

In 1956-58, the Allan Hancock Foundation, University of Southern California, conducted a similar survey of the coast. Using their data, Word (1979) found that trophic structure of benthic communities at 60 m was substantially unchanged along most of the coast during the past 20 years. However, deep discharges in Santa Monica Bay, off Orange County and off Point Loma did not exist and the early data shows that infaunal trophic indicies at these sites were higher and at background levels (Word, 1979).

Using the 1977 60-m data, Word and Mearns (1979) identified 29 reference or "control" stations with which to compare the scope and magnitude of outfall effects. Overall, these data indicate that a 0.1 m^2 grab captures an average of 71 species and 423 individuals with a Shannon-Weaver index of 3.05, an Infaunal Trophic Index of 93.5 and a wet weight of 7.05 grams (Word and Mearns, 1979). Echinoderms (particularly the brittle star, Amphiodia urtica) and polychaetes dominated abundance in these "control" regions (Figure 3), but polychaetes, arthropods, and molluscs dominate species richness (Word and Mearns, 1979).

Responses to the discharges

It is evident in Figure 3 that as one approaches the epicenter of a deep water (60 m) outfall impact zone, infaunal abundance and biomass increase while the number of species and diversity generally decrease. Specific changes include a major reduction in the brittle star, Amphiodia, (Figure 3) increases, and then decreases, in several polychaetes (Tharyx sp. and

Mediomastus californiensis) and ostracods (Euphilomedes sp.) and increases in several pelycypods (notably Parvilucina tenuisculpta; Figure 3); in the areas of severe impacts (mainly at the two largest outfalls in Santa Monica Bay and off Palos Verdes) there are increases in another pelycypod (Solemya panamensis) and three polychaetes (Shistomeringus longicornis, Capitella capitata, and Armandia bioculata; Word et al. 1977). Associated with this shift, total abundance and biomass of the community can increase by as much as an order of magnitude to over 30,000 animals, weighing over 100 g/0.1 m^2 (at the Palos Verdes site). Increased biomass is partly caused by increased size of some organisms such as Parvilucina (Word et al., 1977). The total number of species drops from about 70 to less than 50 in a 0.1 m^2 sample.

The magnitude of changes in abundance, biomass, diversity, and number of species from selected stations along the 60 m contour at each discharge site is summarized in Table 7. As indicated in this table, most biological variables around the Point Loma, Orange County, and Santa Monica Bay outfalls are only slightly changed from control conditions while Palos Verdes is markedly changed. An exception is the Infaunal Trophic Index, which decreases with increasing size of discharge. Generally, however, the values indicate that the communities around the Point Loma outfall are still dominated by suspension feeding fauna (the control condition) while both deposit-feeding and suspension-feeding communities occur around the Orange County and Hyperion outfalls (values both below and above 60 occur); at Palos Verdes, most of the samples were dominated by deposit-feeding organisms.

The other interesting data appears to be the Shannon-Weaver diversities which actually show a slight increase above background at Point Loma (3.23), no change from background at Orange County (3.16), slight decrease in Santa Monica Bay (2.93) but a major decrease off Palos Verdes (2.09) (see Word and Mearns, 1979).

During 1978, the Coastal Water Research Project conducted surveys at over 300 stations between Pt. Dume and Dana Point and between La Jolla and the U.S. Mexico border at depths ranging from 10 to over 300 m in order to make detailed contours of biological conditions around the four major deep-water discharge sites (Bascom, 1979). Figure 4 shows results of contours of Infaunal Index values around the Hyperion discharge sites in Santa Monica Bay. As indicated in this figure, benthic communities dominated by surface or subsurface deposit-feeding infauna (index values below 60) surround the entire Hyperion 5-mile and 7-mile outfalls. Similar plots for the other discharge areas are given in Bascom et al. (1979). Calculations indicate bottom areas dominated by deposit-feeding benthic communities were about four sq km at Point Loma, 11 sq km at Orange County, at least 60 sq km in Santa Monica Bay (Figure 4) and over 94 sq km associated with the Palos Verdes outfall; other studies indicate there was no area around the Oxnard outfall dominated by a deposit feeding infauna. In total, then, at least 170 sq km or 4.7 percent of the 3640 sq km southern California mainland shelf (between the 20 and 200 m isobaths) is experiencing measurable change in the structure of benthic communities as a result of deep water waste discharge. As suggested by Bascom et al.(1979) about 12 sq km (or 0.3 percent), principally off Palos Verdes, is considered "degraded", i.e., very dense benthic communities dominated by sub-surface deposit feeding organisms such as the indicator polychaete, Capitella capitata.

These and earlier surveys also indicate that an area of 2 to 4 sq km at 80-100 m at the end of the Hyperion sludge outfall is occupied by a very dense, low-diversity, sub-surface deposit feeding infaunal community dominated by polychaetes (Figure 4); for example, in July and December 1974, densities ranged from 3300 to 14,500 animals/m^2 with 70 percent of the individuals represented by 1-3 species (Anon., 1977).

Fish and Macro Invertebrate Populations

Bottom fish and populations of larger macro invertebrates (crabs, shrimp, sea urchins, etc.) respond to some of the waste discharges through changes in abundance, diversity and health, but in most cases the responses are not pronounced, highly influenced by year to year natural variability and not as easily documented as those of the infauna.

Background conditions

During the 1977 60-meter survey, 28 coastal control sites, far removed from the major discharges, produced an average of 378 fish (188 of which were considered 1 year and older) of 14.5 species weighing 4.7 kg with a Shannon-Weaver diversity of 1.38 and 181 large invertebrates (prawns, crabs, urchins, starfish, etc.) of 10.5 species weighing 7.4 kg (Table 8). The catches were dominated by Pacific sanddab (Citharichthys sordidus), ridgeback prawn (Sycionia ingentis), stripetail rockfish (Sebastes saxicola), plainfin midshipman (Porichthys notatus), pink seaperch (Zalembius rosaceus), an urchin (Lytechinus anamesus), and a sea cucumber (Parastichopus californicus). Earlier (Mearns, 1974), we had concluded that the fishes noted above were normal, prominent and recurring members of the epibenthic community of the mainland shelf at these depths.

Responses to discharges

Compared to the 1977 background data, two of the discharge sites (Point Loma and Orange County) produced catches that were statistically indistinguishable from background in terms of abundance but which were significantly higher in terms of diversity (Shannon-Weaver). The Orange County site also had significantly higher numbers of invertebrate species (22) than the control regions (10.5; Table 8). In Santa Monica Bay, total catch was significantly lower than in control areas, but catch of fish one-year and older was not. Also fish diversity and invertebrate abundance, number of species and biomass was significantly higher in Santa Monica Bay than at control sites.

The fourth site, Palos Verdes, produced fish catches that were significantly lower than the control sites in terms of abundance (56 fish per haul), number of species (10) and biomass in spite of an apparently normal Shannon-Weaver diversity (1.66) and normal or above normal catches of invertebrates (Table 8).

Clearly the fish fauna at this site was less abundant than background at this depth and time. Other data indicates catches can be very high and very variable at this site.

Some of these sites also differed from each other and from controls in terms of dominance and community structure. For example, Pacific sanddabs (Citharichtys sordidus) were captured in unusually low abundance at Point Loma, Santa Monica Bay, and especially Palos Verdes; similar differences were noted for stripetail rockfish (Sebastes saxicola). Inspection of the data revealed the differences were due primarily to low numbers of young of the year at these outfall sites and to a few patchy, but high catches of young of the year juveniles at several control sites off Santa Barbara. Examination of Table 9 indicates that pink sea perch (Zalembius rosaceus) and English sole (Parophrys vetulus) occurred in unusually high abundance in the Point Loma area, yellowchin sculpin (Icelinus quadriseriatus), California tonguefish (Symphurus atricauda) and speckled sanddab (Citharichthys stigmaeus) in the Orange County area and speckled sanddabs in the Santa Monica Bay area. Dover sole (Microstomus pacificus) were particularly abundant at Palos Verdes.

Examination of invertebrates revealed a similar mix of possible enhancements and depressions. For example, the urchin, Lytechinus anamesus appeared to be unusually abundant in the Point Loma trawl area but unusually reduced in Santa Monica Bay and off Palos Verdes. In contrast, the ridgeback prawn, Sycionia ingentis, appeared to occur in normal abundance at all sites except Palos Verdes where it was nearly an order of magnitude more abundant than in the control areas.

A summary of possible enhancements and depressions is shown at the bottom of Table 9 which indicates there were twice as many enhancements (4) as depressions (2) at Point Loma (the smallest discharge), five times as many at Orange County (5 and 1, respectively) but only about one-third as many at Santa Monica Bay and Palos Verdes (the largest discharge).

These results generally confirm what has been concluded from numerous earlier surveys (e.g., Mearns and Greene, 1974; Allen, 1975; and Allen and Voglin, 1976) except that fish were much more abundant at Palos Verdes in the past. Special trawls and photographic surveys has also confirmed that bottomfish and macroinvertebrates have been abundant in the 2 to 4 sq km area containing sludge or sludge-like material in Santa Monica Submarine Canyon. For example, a 20 minute trawl taken precisely through the affected area in December, 1976, produced 1279 fish dominated by Dover sole (26% percent of the catch), white croaker 24%), pink sea perch (15%), longspine combfish (*Zaniolepis latipinnis*) (14%), speckled sanddab (7.2%) and 18 other species and over 1400 invertebrates of 24 species dominated by sandstars (*Astropectin verrilli*, 51%) and ridgeback prawn (24%, Anon., 1977). Routine surveys of this site have not been conducted in recent years, but comparison with low catches in past sampling (e.g., Mearns and Greene,1974) indicate that bottomfish population are extremely variable at this site.

Diseased Fish Populations

While abundance and diversity of bottom fish appear to be only moderately changed at major discharge sites, more profound changes occur in the health of some fishes at a few sites. For example, a fin erosion disease occurs or has occurred at three of the sites but is absent at the remaining two and at control sites. In addition, bottom fish living at some of the sites have enlarged livers.

The fin erosion disease was discovered in Dover sole from the Palos Verdes Peninsula when trawls were taken there for the first time in 1969. Since then over 30 species of fish bearing eroded fins have been reported from Palos Verdes (Sherwood and Mearns, 1977). As described by Sindermann (1979) and Sherwood (1979) a similar disease has been observed in bottom fish from dumping sites in the New York Bight, an industrial waterway in Seattle, off Orange County, in deep water in Santa Monica Bay, and in Boston Harbor. Additional trawl surveys confirmed this disease was absent at Point Loma, Oxnard, and at control sites in southern California (Sherwood and Mearns, 1977, Table 10).

The diseases do not appear to be caused by infectious micro-organisms but may be related to high chlorinated hydrocarbon levels (especially PCB's) in tissues of affected fishes and to sediments highly contaminated with trace metals and chlorinated hydrocarbons (Sherwood and Mearns, 1977; Sindermann, 1979). The disease was experimentally induced in previously healthy Dover sole exposed to sediments from Palos Verdes (Sherwood and Mearns, 1977). It also affects post larval fish within one to two months after they settle out of the plankton into the Palos Verdes discharge area (Sherwood, 1979). Finally, another study suggested that affected Dover sole at the Orange County outfall were in fact migrants from Palos Verdes (McDermott-Ehrlich et al. 1977) and that the disease was probably affecting Dover sole in Santa Monica submarine canyon within a year after discharge of sludge was initiated in 1957 (Sherwood, 1979).

Together, these studies suggest that of the five discharge sites, the disease is clearly initiated at one (Palos Verdes), possibly at another (the Hyperion sludge discharge site) but not at any other site.

Liver size, color, and structure of flatfish also seem to respond to some of the waste discharges. For example, livers in Dover sole from Palos Verdes are over twice the size of control fish; fish from Orange County, Santa Monica Bay, and at a natural oil seep have livers of intermediate size (Sherwood, 1979). Several histological studies indicate livers of some fish have increased lipid vacuolation and compensatory changes in structure and organization of the tissue (Pierce et al. 1977 and Sherwood and Mearns, 1977) and laboratory experiments indicated that both Palos Verdes sediments and sediments contaminated only by PCB's caused increased liver size in Dover sole (Sherwood, 1979). The significance of this change to the fish, or its reversibility, is unknown.

Skin tumors occur in pleuronectid flatfish throughout the north Pacific but have also been implicated as responses to waste discharge (reviewed in Sindermann, 1979). However, all studies in Puget Sound and southern California have failed to show that tumor prevalence near discharge sites is any higher than at control sites (Mearns and Sherwood, 1977 and Table 10).

The Inshore Environment

Although the major southern California ocean outfalls discharge in relatively deep weater offshore, inshore waters and subtidal habits (i.e., within 1 km of shore or the 15 m isobath) are not immune to effects.

During the 1950's and 1960's, beds of giant kelp (*Macrocystis pyrifera*) decreased in size at Palos Verdes, La Jolla, Point Loma, and other coastal sites. By the late 1960's, beds were nearly extinct off Palos Verdes although elsewhere, they had partially recovered (Mearns et al., 1977). In addition, the diversity and abundance of other sea weeds, macro-invertebrates and fishes along the 15 m contour at Palos Verdes were greatly reduced and divers reported a large amount of flock or detritus on rocks in the area (Grigg and Kiwala, 1970). These conditions were attributed to a combination of factors including inshore accumulation of wastewater solids from the Palos Verdes outfalls, overgrazing by sea urchins and abnormally warm sea surface temperatures during 1957-58.

By 1973, these conditions began to reverse and by 1977-78, there were marked increases in diversity and abundance of fishes, macro-invertebrates and sea weeds at 15 m (Grigg, 1979 and Figure 5), and kelp beds had increased from a few plants to several large beds covering 1.2 sq km. Most of the recovery took place along the coast northwest and most distant from the discharges. The cause, or causes, of the decline and recovery of biological conditions at Palos Verdes are still uncertain. Kelp-transplant activity has certainly been a factor (Wilson et al. 1978). However, there has also been a long-term general increase in visibility in Santa Monica Bay during the period 1973-78 (Mearns, 1979a). As noted above, some changes have also occurred in effluent quality such as a dramatic (96 percent) decrease in DDT mass emission rate (from 21.6 metric tons in 1971 to less than 0.8 metric tons in 1977) and moderate (38 percent) decrease in suspended solids mass emission rates (from 164,000 metric tons in 1971 to 104,000 metric tons in 1978; Henry Schafer, SCCWRP, pers. comm.). Perhaps all these changes have led to improved conditions. At present, it appears that outfall-related factors are still involved in decreased biological diversity at 15 m near the discharge site itself; 6 meter depths appear to be little affected at this time (Grigg, 1979).

There is still some confusion about changes in condition of kelp beds at Point Loma. As pointed out above the decline in size of kelp canopy off Point Loma occurred prior to initiation of discharge offshore (1964) while recovery from 1964 onward coincided with both wastewater discharge and culture activity. At present, a kelp bed of substantial size (over 7.5 sq km) is centered about the base of an outfall discharging over 20,000 metric tons per year (dry weight) of suspended solids. These data indicate that deepwater discharge was not a factor causing previous loss of these kelp beds. The situation also suggests

Table. Summary of length of Palos Verdes rocky subtidal coastline (km) at the 50-ft (15 m) depth characterized by near normal "control" species diversity and by abnormal species diversity in 1969 and 1977. Adapted from Grigg, 1979 "Total Coastline in about 16.5 km "control" is a site at La Jolla sampled in 1977 (Grigg, 1979). "Diversity" means number of species of sea weeds, macro-invertebrates and fishes encountered at transects defined by Grigg (1979)

Percent within or below control species diversity	1969	1977
Diversity 10% above control	0 km	1 km
Diversity within 10% of control	0 km	9 km
Diversity 10% or lower than control	14 km	7.5 km
Diversity 20% or lower than control	12.5 km	6.0 km
Diversity 30% or lower than control	11.0 km	4.5 km
Diversity 40% or lower than control	9.5 km	0 km

that deepwater waste discharge itself at the present mass emission and effluent characteristics is not sufficient to degrade kelp beds in inshore rocky subtidal areas.

Outfalls off Orange County and Ventura and in Santa Monica Bay discharge mainly offshore of sandy beaches. With the exception of infrequent abnormal beach coliform counts (some of which are due to sources other than the offshore outfalls), the nearshore benthic biota show no responses that can be attributed to the offshore outfalls. For example, there is an area of depressed infaunal indicies inshore of the Orange County deepwater outfall, but it is isolated from the low values around the outfall itself (Bascom, 1979); our present opinion is that this inshore area has been affected by runoff from the Santa Ana River.

The Pelagic Environment

The occurrence of DDE, originating from the Palos Verdes discharge, in intertidal biota (Young et al. 1978a) and at a distant pelican breeding site (Anderson et al. 1977) confirms that materials from deep water discharge can enter the upper pelagic zone. However, other than DDE, the effects of potentially toxic materials on euphotic zone organisms is largely unknown.

Several past studies confirm that the plankton community has responded to some of the larger discharges. The Southern California Coastal Water Research Project (SCCWRP, 1973) reported that in Santa Monica Bay over a 15-year period from 1957-1970, annual variations in net-haul plankton volumes varied according to changes in the plankton abundance in the entire California current region. However, the study also found evidence that total plankton volume in the Bay was higher when the Hyperion Treatment Plant was operating a shallow water discharge than after discharge was diverted to the deep water sites offshore. Presumably, in past years, much more of the wastes were entering the mixed layer and contributing to plankton growth. However, recent evidence for stimulation of phytoplankton by nutrients (especially ammonia) from the discharges has been gathered by several workers. Throughout several seasons, Eppley et al. 1978, found consistently higher phytoplankton standing crops and productivity in Santa Monica Bay than at other sites of equivalent depth and distance from shore. In an earlier study, MacIsaac et al. (in press) found that ammonia levels in the mixed layer near both the Santa Monica Bay and Palos Verdes discharges were sufficient to enhance phytoplankton growth yet inhibit phytoplankton nitrate uptake.

Attempts to determine responses of fishery populations have so far been inconclusive. Using catch and catch and effort data compiled by the California Department of Fish and Game from 16 by 16 sq km statistical blocks, Mearns (1977) and Allen and Voglin (1977) were unable to identify geographical trends that could be conclusively attributed to proximity to the discharges. For example, in 1973 in 37 statistical areas ranging from Point Conception to the U.S.-Mexico border, the average commercial party boat coastal catch was 1.47 fish per angler hour with an accumulative average of 24.3 species per area. Seven statistical areas occupied by the five major discharge sites produced an average of 1.67 fish per angler hour (ranging from 1.25 off Point

Loma to 3.84 in Santa Monica Bay) and a cumulative average of 34 species per block (Mearns, 1977). Lack of an observable adverse response may simply be due to the large geographical areas (10 x 10 sq mi.) over which catch and effort data are summarized. However, Allen et al. 1975, using standardized fishing procedures with set lines and rod and reel, demonstrated a slightly higher catch per unit effort and variety near the Hyperion sludge outfall than at more remote sites in Santa Monica Bay. Commercial landings data did produce one important observation; seventeen statistical blocks within a 50 km radius of the three largest outfalls produced 73 percent of the 1973 southern California catch (178,000 metric tons; Allen and Voglin, 1977). Thus, most of the commercial fish landed are taken from those waters closest to the urban areas and outfalls.

Recovery and Resiliency

Changes in the health, diversity, and abundance of marine life caused by southern California coastal discharges are not necessarily permanent. During the period August 1970 through August 1972 Smith (1974) recorded biological and physical changes accompanying termination of a 15-year long discharge of primary effluent from an inshore (20 m deep) diffuser off Orange County. He also monitored changes in the benthic infauna associated with initiation of discharge of these wastes through the deeper (60 m) diffuser. Later surveys of both sites were done by the Coastal Water Research Project and the Orange County Sanitation Districts.

Following termination of shallow discharge, Smith (1974) reported rapid recovery; sediment organic carbon and total sulfide concentrations dropped to background within three months while the infauna returned to normal diversity, abundance, and community structure within one year. In addition trawl surveys indicated that fish abundances decreased by about one-half several years after termination. In contrast, changes were much slower at the new deeper site following initiation of discharge. Fish catches and the abundance and biomass of infauna increased slowly from 1969 through 1976 at stations nearest the new diffuser but the most dramatic responses occurred two to four years after discharge began; during this period, *Capitella capitata* density increased from less than $50/m^2$ to over $1000/m^2$ while the brittlestar *Amphiodia urtica* decreased from 500 to $1000/m^2$ down to less than $50/m^2$ (Mearns, in press). Also during the second through fourth years, sediment copper concentrations increased from an average background value of about 16 mg/ dry kg to slightly over 30 mg/kg. Subsequent sampling (1975-1978) suggests no further progressive increase in intensity of effects or size of affected area after 1975-76; thus, the benthic environment at this site may be in equilibrium with the input (Mearns, in press).

Unfortunately no experience exists which would allow observation of the rate of recovery from termination of deepwater (e.g. 60 m) discharge. However, several periods of sludge discharge at Point Loma (October 1964 through December 1966 and July through December 1968) were accompanied by a major increase in sediment BOD and benthic biomass and followed by a return to background sediment BOD in 3 to 4 years and return to background biomass in less than two years (Orlob, 1977). As noted earlier, there were apparently no affects of these added discharges on inshore kelp beds. In contrast, as noted above, a nearly 40 percent reduction in solids emission from Palos Verdes during the 1970's may be a factor involved in the nearly parallel recovery of rocky subtidal communities and kelp beds. These kinds of observations therefore suggest that biological responses to control of solids at deep water sites may occur within a period of several years.

As noted in the previous section of this report, such is not necessarily the case for specific toxic chemicals such as chlorinated hydrocarbons however. Despite source control of DDT in 1970, sediments off Palos Verdes continue to contain extremely high concentrations which are, in turn, leading to continued contamination of the benthic and water column biota at this site (Young et al. 1977b; Young and Heesen 1978). Fortunately, DDT concentrations in the Brown pelicans roosting at an offshore island (100 km distant from Palos Verdes) have decreased substantially and through 1975, reproductive success has increased (Anderson et al., 1975); reproductive success has decreased again since 1975 and low availability of prey fish is thought to be a factor (Dr. George Hunt, Univ. of Calif., Irvine, 1979, pers. comm.)

VIII. PUBLIC HEALTH

Pathogens and their Indicators

Enteric bacteria and viruses from southern California effluents occur in seawater near the discharge sites at measurable concentrations. Total coliform bacteria are most frequently monitored in effluents, surface and subsurface samples above sewage plumes, at "nearshore" stations (within 1000 feet from shore or over the 30 foot isobath, which ever is closest to shore) and at numerous "shore" stations (sampled from the beaches). Sampling is conducted daily at many beach stations, and weekly, monthly, and quarterly, at offshore surface and subthermocline stations. All of the data is available to the public but very little of it has been formally published.

Inspection of numerous data sets by us indicates that total coliform concentrations in final effluents are generally in the range of 10^7 to 10^8 per 100 ml (confirmed in Morris et al. 1976). Thus at the edge of initial dilution zones and below the thermocline, concentrations can be expected to be on the order of 10^5 to 10^6 per 100 ml. Subsequent dilution and settling reduces these subsurface concentrations to 10^2 to 10^4 per 100 ml within a few kilometers from the outfalls (confirmed in Morris et al., 1976) while the thermocline generally keeps surface water concentrations well below 10 per 100 ml. Inshore of all major discharge sites surface "nearshore" and "shore" samples (defined above) are generally below 10 per 100 ml (e.g. 75% of the time at Point Loma, Orlab, 1977) and generally meet all state bathing and shellfish standards. However, there are exceptions, particularly in winter months when runoff causes increased concentration at shore stations near drains and rivers and when loss of the thermocline and onshore winds occasionally combine to transport diluted surfacing plumes inshore. This situation is rare in Santa Monica Bay, at Point Loma, and off Orange County, but more common in the winter at Oxnard and Palos Verdes; these dischargers do chlorinate during such episodes.

An earlier study (Rittenberg, 1956) indicated that high coliform concentrations (up to 12,000 MPN/cm^2) in surface sediments around the large southern California outfalls during the years when the discharges were nearshore. Although few sediment samples have been analyzed for bacteria offshore and adjacent to the newer deepwater discharges it can be assumed that such sediments also contain high concentrations of coliform bacteria that have settled out of the plumes.

In 1974 and 1975 SCCWRP sampled pathogens in water and sediments near the Hyperion 5-mile and 7-mile outfalls (Kim, 1975). Of the two pathogens studied only salmonella was isolated in water and sediment samples along with coliform and fecal streptococcus bacteria. Salmonella were isolated in less than 8 percent of the samples containing less than 1,000 indicator bacteria (coliform or fecal streptococcus) per 100 ml. However, salmonella could be detected in 25 to 75 percent of the samples containing in excess of 1,000 fecal coliforma/100 ml, and in 38 to 100 percent of the samples containing in excess of 1,000 fecal streptococci/100 ml. Using these data, we estimate that the maximum concentration of salmonella near the plumes was about one organism in 400 ml of water (0.25/100 ml) and about one salmonella per 20,000 indicator bacteria.

In a pilot study Morris et al. (1976) detected enteric viruses in caged mussels (Mytilus californiensis) attached to buoys and deployed several miles offshore and adjacent to each of the three Los Angeles and Orange County outfalls. Like the coliform bacteria, virus concentrations (plaque forming units, PFU) were low or undetectable at the surface (average 0.01 PFU per gm of mussel tissue) but increased with depth (0.19 PFU per gm tissue at 8 to 20 m and 0.5 PFU per gram at 25 to 35 m). Since mussels concentrate bacteria and other particulates about 1,000-fold, we judge virus concentration in water adjacent to the outfalls to range from 0.00001 to 0.0005 viruses per ml or from 0.01 to 0.5 per liter with lowest concentrations occurring near the surface and away from the discharges. Additional calculations suggest that enteric virus at these sites have a deactivation rate about one-sixth that of coliform mortality (Morris et al., 1976) . Measurements of coliform bacteria die off rates in the field range from 0.1 to 2 days.

Of nine shore stations sampled, Morris et al. (1976) detected enteric viruses in only two sites - near a marina and an adjacent flood control channel. Coupled with data on coliform concentration these observations suggested runoff to be the most likely source.

Trace Chemicals

As discussed above (Section VI), the principal known public health problem from chemical pollutants in municipal wastewater effluents is the contamination of organisms by DDT residues in the JWPCP discharge zone off Palos Verdes Peninsula. Five of seventeen seafood species (approximately 30 percent) collected there during 1975-77 exceeded the U.S. Food and Drug Administration standard of 5 mg/wet kg (Young et al., unpublished manuscript), and we have repeatedly informed public regulatory agencies of these findings. Although PCB residues are easily measured in organisms collected near several large municipal outfalls, typical levels in edible tissues seldom exceed the proposed FDA standard of 2 mg/wet kg (Young et al. 1975a; McDermott et al. 1976b; Young and Heesen 1978; McDermott et al. 1978; Young et al., unpublished manuscript). Similarly, typical concentrations of total mercury in edible tissues have not been observed above the past FDA standard of 0.5 mg/wet kg for organisms collected anywhere in the Bight (Eganhouse and Young, 1976; Eganhouse and Young 1978a; Eganhouse and Young 1978b; Young and Jan 1979).

IX. PROJECTIONS

Mass emissions of materials from the major southern California discharges are not necessarily constant, in fact, during the past several years there have been slight but significant reductions in inputs of many metals, PCBs and suspended solids due both to source control programs and to major changes at several treatment plants. For example, mass emission rates of suspended solids from JWPCP into coastal waters off Palos Verdes have decreased about 38 percent between 1971 and 1978 (from 167,000 to about 102,000 MT/yr). This and other plants are now constructing facilities to further reduce emissions (including partial secondary).

Recently, the Coastal Water Research Project was asked to forecast coastal conditions that might exist during and after initiation of the new treatment schemes (U.S. Congress, 1978). To begin the forecast effort, data on projected wastewater quality was obtained from the three largest dischargers and converted to mass emission rates. The forecast period was to begin in 1983 and extend to 1985 (or longer, if required for a specific forecaster). Time series data on sediment chemistry and on variation in benthic infauna, fish populations and diseased populations were acquired and reviewed and a new mathematical model incorporating sedimentation and sediment resuspension processes was constructed are tested (Hendricks, 1979). Next, similarities and differences among the outfall sites were carefully examined to reveal possible relattionships between input variables (such as suspended solids) and size or magnitude of coastal responses (e.g., benthic biomass, see Figure 6 , relative sediment contamination, etc.). Finally, based on available information from field and laboratory tests, assumptions were made about the behavior of pollutants (e.g., there is no significant desorption of metals from particulates, coliform die-off and sedimentation rates will remain unchanged, etc.) and about cause-effect relationships (e.g., the excess benthic biomass and depressed infaunal indicies around outfalls are biostimulatory and due to the excess organic matter in solids, part of which settle around the discharge sites; fin erosion disease is a function of PCB contamination in affected fish; etc.). The net result was a collection of 10 forecasts covering a variety of subjects and each with various degress of uncertainty and specificity.

Several kinds of conclusions were reached. First, we determined that for the three dischargers, pollutant inputs for the three largest dischargers would be reduced by more than half of present (1976) levels (e.g., 50 to 70 percent depending on the material; some examples in Table 11). Next, we concluded that some environmental conditions will not change substantially either because (1) they are not caused by the discharges (e.g. incidence of skin tumors in young-of-the-year pleuronectid flatfish); (2) they are already too close to background to discern a measurable change (e.g., surface and subsurface dissolved oxygen concentrations; phytoplankton and zooplankton densities) or (3) they are naturally to variable to discern a measurable change (e.g., sport- and commercial fish landings, and again, phytoplankton and zooplankton densities). We then identified some changes that would occur in general and at all three sites. For example, coliform bacterial concentration at nearshore stations (defined above) would be reduced by one to two orders of magnitude so that present occasional excursions above State standards willoccur much less frequently in the future (unless the uncertainty that they are due to other sources is verified); total excess benthic infaunal standing crop (biomass in metric tons), will be reduced by about 90 percent (with most of the change occurring off Palos Verdes, Table 11). The size (in sq km) decrease by about 70 percent (from 73 to 22 sq km, Table 11), and the length of coastline along the 60 m isobath affected by below-background infaunal trophic indicies will decrease by 92 percent (from 80 to less than 6.5 km, Table 11). Also, sediment contamination by specific pollutants (e.g., chromium Table 11) would decrease by 50 to 80 percent (depending on the site and contaminant).

Finally, we arrived at some conclusion regarding site specific changes. Among the most important was the conclusion that rate of recovery off Palos Verdes would be extremely slow compared to other sites due mainly to very heavy past loadings of the bottom sediments and to the apparently long ecological half-life of DDT and PCB contamination in sediments and in benthic or nearshore populations (estimated to be approximately 7 years). We also concluded that the prevalence of fin erosion disease would decline but would still be affecting about 9 percent of the Palos Verdes Dover sole population in 1988; however there remain uncertainties that total PCB is indeed the only cause of the disease and that the ecological half-life is indeed on the order of 7 years at this site.

Metals contamination levels in the benthic environment, as reflected by surficial sediment concentrations, do not appear to be rapidly decreasing around the major outfall systems. Young (U.S. Congress, 1978) concluded from 1974-76 monitoring data for the JWPCP discharge that the median half-time for six metals (Cd, Cr, Cu, Ni, Pb, Zn) in sediments a few km downcurrent of the outfall diffusers was 6 years (range: 5 - 13 years). Further, it appears that sediment concentrations of metals around the Hyperion (City of Los Angeles) 7-mile sludge line remained fairly stable between 1970-71 and 1976, and that metals levels had reached a high equilibrium in sediments around the new (172) 5-mile outfall of Orange County Sanitation District (U.S. Congress, 1978). This is consistant with the fact that, in general, only second-order reductions in metals emissions have been obtained since 1971 by these major municipal wastewater systems (Schafer, 1977).

In addition to the previously published forecasts (U.S. Congress, 1978), new data (Grigg, 1979) suggests that nearshore rocky subtidal communities may have already responded and partially recovered from reduction in pollutant emissions off Palos Verdes. A recent computation (AJM) suggests that further recution in solids to the level reported in Table 1 (e.g., 20,000 MT/yr) could be sufficient to allow full recovery of kelp beds and subtidal community structure at 15 m along the Peninsula. In summary, then, it is not unlikely that some major ecological recovery will occur as a result of planned and projected treatment strategies, that they will involve mainly subtidal and benthic ecosystems.

XI. ACKNOWLEDGEMENTS

We thank all personnel of our Project and of the major municipal wastewater treatment plants discussed here who contributed to obtaining the information summarized in this paper. Contribution Number 143 of the Southern California Coastal Water Research Project.

XII. LITERATURE CITED

Alexander, G.V. and D.R. Young. 1976. Trace metals in southern California mussels. Mar. Poll. Bull. 7:7-9.

Allen, M.J. 1975. Regional variation in the structure of fish communities. In: Coastal Water Research Project Annual Report, 1975, pp. 99-102. NTIS No. PB 274467/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Allen, M.J. and R.M. Voglin. 1976. Regional and local variation of bottom fish and invertebrate populations. In: Coastal Water Research Project Annual Report, 1976, pp. 217-221. NTIS No. PB 274461/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Allen, M.J. and R.M. Voglin. 1977. Commercial fish catches. In: Coastal Water Research Project Annual Report, 1977, pp. 121-126. NTIS No. PB 274463/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Allen, M.J., J.B. Isaacs, and R.M. Voglin. 1975. Hook-and-line survey of demersal fishes in Santa Monica Bay. TM 222, Southern California Coastal Water Research Project, El Segundo, CA 90245.

Allen, M.J., H. Pecorelli, and J.Q. Word. 1976. Marine organisms around outfall pipes in Santa Monica Bay. J. Water Poll. Control Fed. 48:1881-1893.

Anderson, B.P. 1973. Trace constituents monitoring. In: Monthly Report From The Technical Services Department, County Sanitation Districts of Los Angeles County, January 1973, Whittier, CA 90601, pp. 51-62.

Anderson, D.W., J.R. Jehl, Jr., R.W. Risebrough, L.A. Woods, Jr., L.R. DeWeese, and W.G. Edgecomb. 1975. Brown pelicans: Improved reproduction off the southern California coast. Science 190:806-808.

Anderson, D.V., R.M. Jurek, and J.O. Keith. 1977. The status of brown pelicans at Anacapa Island in 1975. Calif. Fish and Game 63:4-10.

Bascom, W. 1979. Life in the bottom: San Pedro and Santa Monica Bays, Palos Verdes and Point Loma Peninsulas. In: Coastal Water Research Project Annual Report, 1978, pp. 57-80. Southern California Coastal Water Research Project, El Segundo, CA 90245.

Bascom, W., A.J. Mearns, and J.Q. Word. 1979. Establishing boundaries between normal, changed, and degraded areas. In: Coastal Water Research Project Annual Report, 1978, pp. 81-94. Southern California Coastal Water Research Project, El Segundo, CA 90245.

Bruland, K.W., K. Bertine, M. Koide, and E.D. Goldberg. 1974. History of heavy metal pollution in southern California coastal zone. Environ. Sci. Tech. 8:425-432.

Burnett, R. 1971. DDT residues: Distribution of concentrations in Emerita analoga (Stimpson) along coastal California. Science 174:606-608.

DeGoeij, J.J.M., V.P. Guinn, D.R. Young, and A.J. Mearns. 1974. Neutron activation analysis trace element studies of Dover sole liver and marine sediments. In: IAEA (Ed.), Comparative Studies of Food and Environmental Contamination, International Atomic Energy Agency, Vienna, pp. 189-200.

DeLong, R.L., W.G. Gilmartin, and J.G. Simpson. 1973. Premature births in California sea lions: Association with high organochlorine pollutant residue levels. Science 181:1168-1170.

Duke, T.W. and A.J. Wilson, Jr. 1971. Chlorinated hydrocarbons in livers of fishes from northeastern Pacific Ocean. Pestic. Monit. J. 5:228-232.

Dunn, B.P. and D.R. Young. 1976. Baseline levels of benzo(a)pyrene in southern California mussels. Mar. Poll. Bull. 7:231-234.

Eganhouse, R.P. and D.R. Young. 1976. Mercury in tissues of mussels off southern California. Mar. Poll. Bull. 7:145-147.

Eganhouse, R.P. and D.R. Young. 1978a. Total and organic mercury in benthic organisms near a major submarine wastewater outfall system. Bull. Environ. Contam. Toxicol. 19:758-766.

Eganhouse, R.P. and D.R. Young. 1978b. _In situ_ uptake of mercury by the intertidal mussel _Mytilus californianus_. Mar. Poll. Bull. 9:214-217.

Eganhouse, R.P., J.N. Johnson, D.R. Young, and D.J. McDermott. 1976. Mercury in southern California waters: Inputs, distribution and fate. TM 227, Southern California Coastal Water Research Project. NTIS No. PB 274465/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Eppley, R.W., C. Sapienza and E.H. Renger. 1978. Gradients in phytoplankton stocks and nutrients off southern California in 1974-76. Estuar. Coastal Mar. Sci. 7:291-301.

Galloway, J.N. 1972. Man's alteration of the natural geochemical cycle of selected trace metals. Ph.D. Thesis, University of California, San Diego, CA.

Grigg, R.W. 1979. Long-term changes in rocky bottom communities off Palos Verdes. In: Coastal Water Research Project Annual Report, 1978, pp. 157-184. Southern California Coastal Water Research Project, El Segundo, CA 90245.

Grigg, R.W. and R.S. Kiwala. 1970. Some ecological effects of discharged wastes on marine life. Calif. Fish and Game, 56:145-155.

Henricks, T.J. 1977a. Coastal currents. In: Coastal Water Research Project Annual Report, 1977, pp.53-62. NTIS No. PB 274463/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Hendricks, T.J. 1977b. *In situ* measurements of initial dilution. In: Coastal Water Research Project Annual Report, 1977, pp. 41-51. NTIS No. PB 274463/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Hendricks, T.J. 1979. Forecasting changes in sediments near outfalls. In: Coastal Water Research Project Annual Report, 1978, pp. 127-143. Southern California Coastal Water Research Project, El Segundo, CA 90245.

Hendricks, T.J. and J.M. Harding. 1974. The dispersion and possible biological uptake of ammonia in a wastefield, Point Loma, May 1972. TM 210. Southern California Coastal Water Research Project, El Segundo, CA 90245.

Herring, J.R. and A.L. Abati. 1979. Effluent particle dispersion. In: Coastal Water Research Project Annual Report, 1978, pp. 113-125. Southern California Coastal Water Research Project, El Segundo, CA 90245.

Hershelman, G.P., T.-K. Jan, and H.A. Schafer. 1977. Pollutants in sediments off Palos Verdes. In: Coastal Water Research Project Annual Report, 1977, pp. 63-68. NTIS No. PB 274463/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Hom, W., R.W. Risebrough, A. Soutar, and D.R. Young. 1974. Deposition of DDE and polychlorinated biphenyls in dated sediments of the Santa Barbara Basin. Science 184:1197-1199.

Jones, J.H. 1971. General circulation and water characteristics in the Southern California Bight. TR 101. Southern California Coastal Water Research Project, El Segundo, CA 90245.

Luthy, R.F., Jr. 1972. Trace constituents monitoring. In: Monthly Report From The Technical Services Department, County Sanitation Districts of Los Angeles County, February 1972, Whittier, CA 90601, pp. 76-83.

MacGregor, J.W. 1974. Changes in the amount and proportions of DDT and its metabolites, DDE and DDD, in the marine environment of southern California, 1949-1972. Fish. Bull. 72:275-293.

MacIsaac, J.J., R.C. Dugdale, S.A. Huntsman, and H.L. Conway. The effect of sewage on uptake of inorganic nitrogen and carbon by natural populations of marine phytoplankton. J. Mar. Res. 37:in press.

McDermott, D.J., D.R. Young, and T.C. Heesen. 1976b. PCB contamination of southern California marine organisms. In: Proceedings of the National Conference on Polychlorinated Biphenyls, 19-21 November 1975, Chicago, IL, pp. 209-217. EPA Report 560/6-75-004.

McDermott-Ehrlich, D., D.R. Young, and T.C. Heesen. 1978. DDT and PCB in flatfish around southern California municipal outfalls. Chemosphere 6:453-461.

McDermott, D.J., G.V. Alexander, D.R. Young and A.J. Mearns. 1976a. Metal contamination of flatfish around a large submarine outfall. J. Water Poll. Control Fed. 48:1913-1918.

McDermott-Ehrlich, D., M.J. Sherwood, T.C. Heesen, D.R. Young, and A.J. Mearns. 1977. Chlorinated hydrocarbons in Dover sole, Microstomus pacificus: Local migrations and fin erosion. Fish. Bull. 75: 513-517.

Mearns, A.J. 1977. Coastal gradients in sportfish catches. In: Coastal Water Research Project Annual Report, 1977, pp. 127-132. NTIS No. PB 274463/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Mearns, A.J. 1979a. Variations in coastal physical and biological conditions, 1969-1978. In: Coastal Water Research Project Annual Report, 1978, pp. 147-156. Southern California Coastal Water Research Project, El Segundo, CA 90245.

Mearns, A.J. 1979b. Effects of municipal discharges on open coastal ecosystems. In: R.A. Geyer (Ed.), Studies in Marine Environmental Pollution. Elsevier Publishing Co., in press.

Mearns, A.J. and C.S. Greene (Eds.) 1974. A comparative trawl survey of three areas of heavy waste discharge. TM 215. Southern California Coastal Water Research Project, El Segundo, CA 90245.

Mearns, A.J., D.A. Hanan, and L. Harris. 1977. Recovery of kelp forest off Palos Verdes. In: Coastal Water Research Project Annual Report, 1977, pp. 99-108. NTIS No. PB 274463/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Morris, R.L., A.J. Mearns, and J. Kim. 1976. Viruses and bacteria in coastal waters and shellfish. In: Coastal Water Research Project Annual Report, 1976, pp. 97-103. NTIS No. PB 274461/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Orlob, G.T. 1977. Impacts of domestic wastewater discharge on the ocean environment of Point Loma, California, a review of ocean monitoring by the City of San Diego, January 1975 through April 1976. RMA 6160. A Report to the State Water Resources Control Board from Resource Management Associates, Lafayette, CA 94549.

Peterson, L.L. 1974. The propagation of sunlight and the size distribution of suspended particles in a municipally polluted ocean water. Ph.D. Thesis, California Institute of Technology, Pasadena, CA.

Pierce, K.V., B. McCain, and M.J. Sherwood. 1977. Histology of liver tissue from Dover sole. In: Coastal Water Research Project Annual Report, 1977, pp. 207-212. NTIS No. PB 274463/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Risebrough, R.W. 1969. Chlorinated hydrocarbons in marine ecosystems. In: M.W. Miller and G.G. Berg (Eds.), Chemical fallout, current research on persistent pesticides, Charles C. Thomas, Springfield, IL, pp. 5-23.

Risebrough, R.W., B.W. de Lappe, and W. Walker, II. 1976. Transfer of higher molecular weight chlorinated hydrocarbons to the marine environment. In: H.L. Windom and R.A. Duce (Eds.),Marine Pollutant Transfer, D.C. Heath and Co., Lexington, MA., pp. 261-321.

Rittenberg, S.C. 1956. Studies on coliform bacteria discharged from the Hyperion outfall, final bacteriological report. A Report to Hyperion Engineers, Inc. from the Allan Hancock Foundation, University of Southern California, Los Angeles, CA 90007.

SCCWRP. 1973. The ecology of the Southern California Bight: Implications for water quality management. TR 104, Southern California Coastal Water Research Project. NTIS No. PB 274462/AS, U.S.Dept. of Commerce, Springfield, VA 22161.

Schafer, H.A. 1977. Characteristics of municipal wastewater discharges, 1976. In: Coastal Water Research Project Annual Report, 1977, pp. 19-23. NTIS No. PB 274463/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Schafer, H.A. 1979. Characteristics of municipal wastewater discharges, 1977. In: Coastal Water Research Project Annual Report, 1978, pp. 97-101. Southern California Coastal Water Research Project, El Segundo, CA 90245.

Schafer, H.A. and W. Bascom. 1976. Sludge in Santa Monica Bay. In: Coastal Water Research Project Annual Report, 1976, pp. 77-82. NTIS No. PB 274461/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Sherwood, M.J. 1977. Fin erosion disease and liver chemistry: Los Angeles and Seattle. In: Coastal Water Research Project Annual Report, 1977, pp. 213-219. NTIS No. PB 274463/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Sherwood, M.J. 1979. The fin erosion syndrome. In: Coastal Water Research Project Annual Report, 1978, pp. 203-221. Southern California Coastal Water Research Project, El Segundo, CA 90245.

Sherwood, M.J. and A.J. Mearns. 1977. Environmental significance of fin erosion in southern California demersal fishes. Annals N.Y. Acad. Sci. 298:177-189.

Sinderman, C.J. 1979. Pollution-associated diseases and abnormalities of fish and shellfish: A review. Fish. Bull. 76:717-749.

Smith, G.B. 1974. Some effects of sewage discharge to the marine environment. Ph.D. Thesis. Scripps Institution of Oceanography, University of California, San Diego, CA.

U.S. Congress. 1978. Modification of secondary treatment requirements for discharges into marine waters. Hearings before the Subcommittee on Water Resources of the Committee on Public Works and Transportation, House of Representatives, 95th Congress, Second Session, May 24-25, 1978, pp. 133-218. Report 95-54, U.S. Government Printing Office, Washington, D.C.

Wilson, K.C., P.L. Haaker, and D.A. Hanan. 1978. Kelp restoration in southern California. In: Marine Plant Biomass of the Pacific Northwest Coast, Oregon State University Press, Corvallis, OR, pp. 183-202.

Word, J.Q. 1979. The Infaunal Trophic Index. In: Coastal Water Research Project Annual Report, 1978, pp. 19-39. Southern California Coastal Water Research Project, El Segundo, CA 90245.

Word, J.Q. and A.J. Mearns. 1979a. The 60-meter control survey. In: Coastal Water Research Project Annual Report, 1978, pp. 41-56. Southern California Coastal Water Research Project, El Segundo, CA 90245.

Word, J.Q. and A.J. Mearns. 1979b. The 60-meter control survey off southern California. TM 229. Southern California Coastal Water Research Project, El Segundo, CA 90245. Manuscript in preparation.

Word, J.Q., B.L. Myers, and A.J. Mearns. 1977. Animals that are indicators of marine pollution. In: Coastal Water Research Project Annaul Report, 1977, pp. 199-206. NTIS No. 274463/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Young, D.R. and T.C. Heesen. 1974. Inputs and distributions of chlorinated hydrocarbons in three southern California harbors. TM 212, Southern California Coastal Water Research Project. NTIS No. PB 275412/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Young, D.R. and T.C. Heesen. 1978. DDTs, PCBs, and chlorinated benzenes in the marine ecosystem off southern California. In: R.L. Jolley, H. Gorchev, and D.H. Hamilton, Jr., (Eds.), Water Chlorination: Environmental Impact and Health Effects, Vol. 2, pp. 267-290. Ann Arbor Science Publishers, Ann Arbor, MI.

Young, D.R. and T.-K. Jan. 1975. Trace metals in nearshore seawater. In: Coastal Water Research Project Annual Report, 1975, pp. 143-146. NTIS No. PB 274467/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Young, D.R. and T.-K. Jan. 1979. Trace metal contamination of the rock scallop, Hinnites giganteus, near a large southern California municipal outfall. Fish. Bull. 76:936-939.

Young, D.R. and A.J. Mearns. 1979. Pollutant flow through food webs. In: Coastal Water Research Project Annual Report, 1978, pp. 185-202. Southern California Coastal Water Research Project, El Segundo, CA 90245.

Young, D.R., G.V. Alexander, and D. McDermott-Ehrlich. 1979a. Vessel related contamination of southern California harbors by copper and other trace metals. Mar. Poll. Bull. 10:50-56.

Young, D.R., T.C. Heesen, and D.J. McDermott. 1976b. An offshore biomonitoring system for chlorinated hydrocarbons. Mar. Poll. Bull. 7:156-159.

Young, D.R., T.-K. Jan, and T.C. Heesen. 1978a. Cycling of trace metal and chlorinated hydrocarbon wastes in the Southern California Bight. In: M.L. Wiley (Ed.), Estuarine Interactions, pp. 481-496, Academic Press, N.Y.

Young, D.R., T.-K. Jan, and M.D. Moore. 1977a. Metals in power plant cooling water discharges. In: Coastal Water Research Project Annual Report, 1977, pp. 25-31. NTIS No. PB 274463/AS, U.S. Dept. of Commerce, Springfield, VA 22161.

Young, D.R., D.J. McDermott, and T.C. Heesen. 1976a. DDT in sediment and organisms around southern California outfalls. J. Water Poll. Control Fed. 48:1919-1928.

Young, D.R., D.J. McDermott, and T.C. Heesen. 1976b. Marine inputs of polychlorinated biphenyls off southern California. In: Proceedings of the National Conference on Polychlorinated Biphenyls, 19-21 November 1975. Chicago, IL, pp. 199-208. EPA Report 560/6-75-004.

Young, D.R., D. McDermott-Ehrlich, and T.C. Heesen. 1977b. Sediments as sources of DDT and PCB. Mar. Poll. Bull. 8:254-257.

Young, D.R., C.S. Young, and G.E. Hlavka. 1973a. Sources of trace metals from highly-urbanized southern California to the adjacent marine ecosystem. In: Cycling and Control of Metals, pp. 21-39. U.S. Environmental Protection Agency, National Environmental Research Center, Cincinnati, OH.

Young, D.R., T.C. Heesen, G.N. Esra, and E.B. Howard, 1979b. DDE-contaminated fish off Los Angeles are suspected cause in deaths of captive marine birds. Bull. Environ. Contam. and Toxicol. 21:584-590.

Young, D.R., T.C. Heesen, M.D. Moore, and D. McDermott-Ehrlich. DDT and PCB contamination of seafood off Los Angeles, California. Unpublished manuscript.

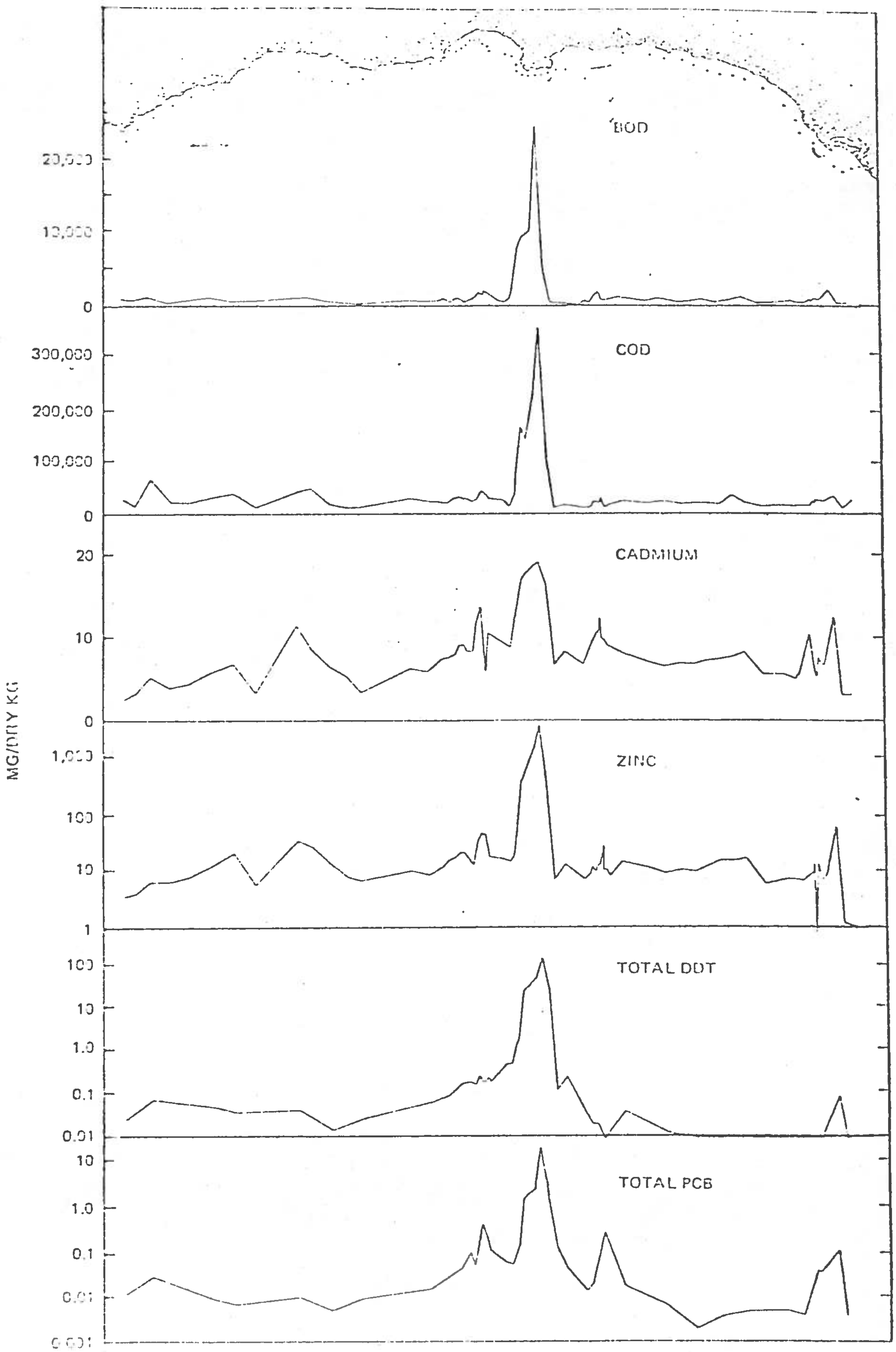
Young, D.R., J.N. Johnson, A. Soutar, and J.D. Isaacs. 1973 b. Mercury concentrations in dated varved marine sediments collected off southern California. Nature 244:273-275.

Young, D.R., D.J. McDermott, T.C. Heesen, and D.A. Hotchkiss. 1975b. DDT residues in bottom sediments, crabs, and flatfish off southern California submarine outfalls, Calif. Water Poll. Control Assoc. Bull. 12:62-66.

Young, D.R., D.J. McDermott, T.C. Heesen, and T.-K. Jan. 1975a. Pollutant inputs and distributions off southern California. In: T.M. Church (Ed.), Marine Chemistry in the Coastal Environment, pp. 424-439. American Chemical Society, Washington, D.C.

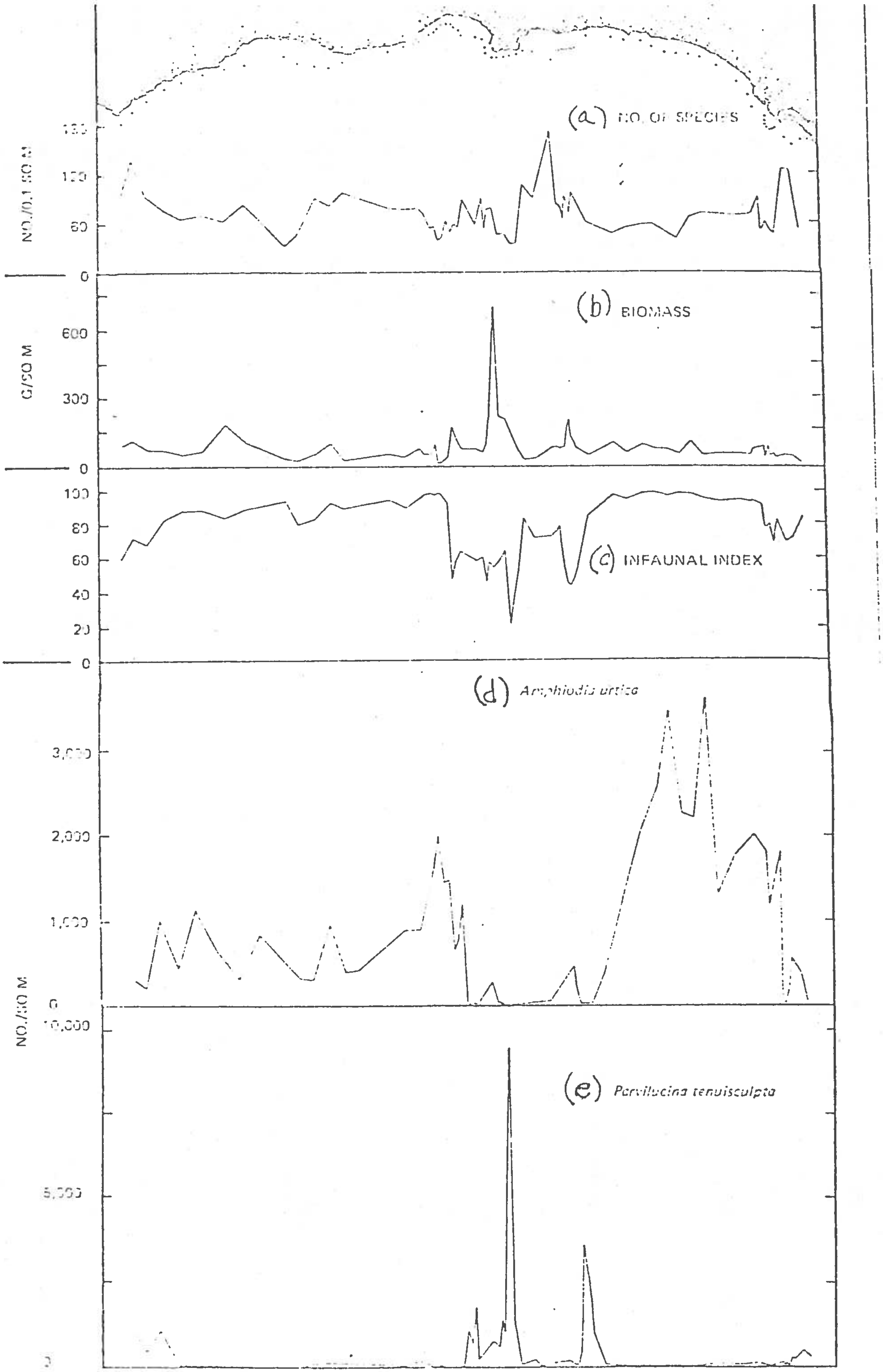
Young, D.R., M.D. Moore, G.V. Alexander, T.-K. Jan, D. McDermott-Ehrlich, R.P. Eganhouse, and G.P. Hershelman. 1978b. Trace metals in seafoods around southern California municipal outfalls. Publication No. 60, California State Water Resources Control Board, Sacramento, CA 95814.

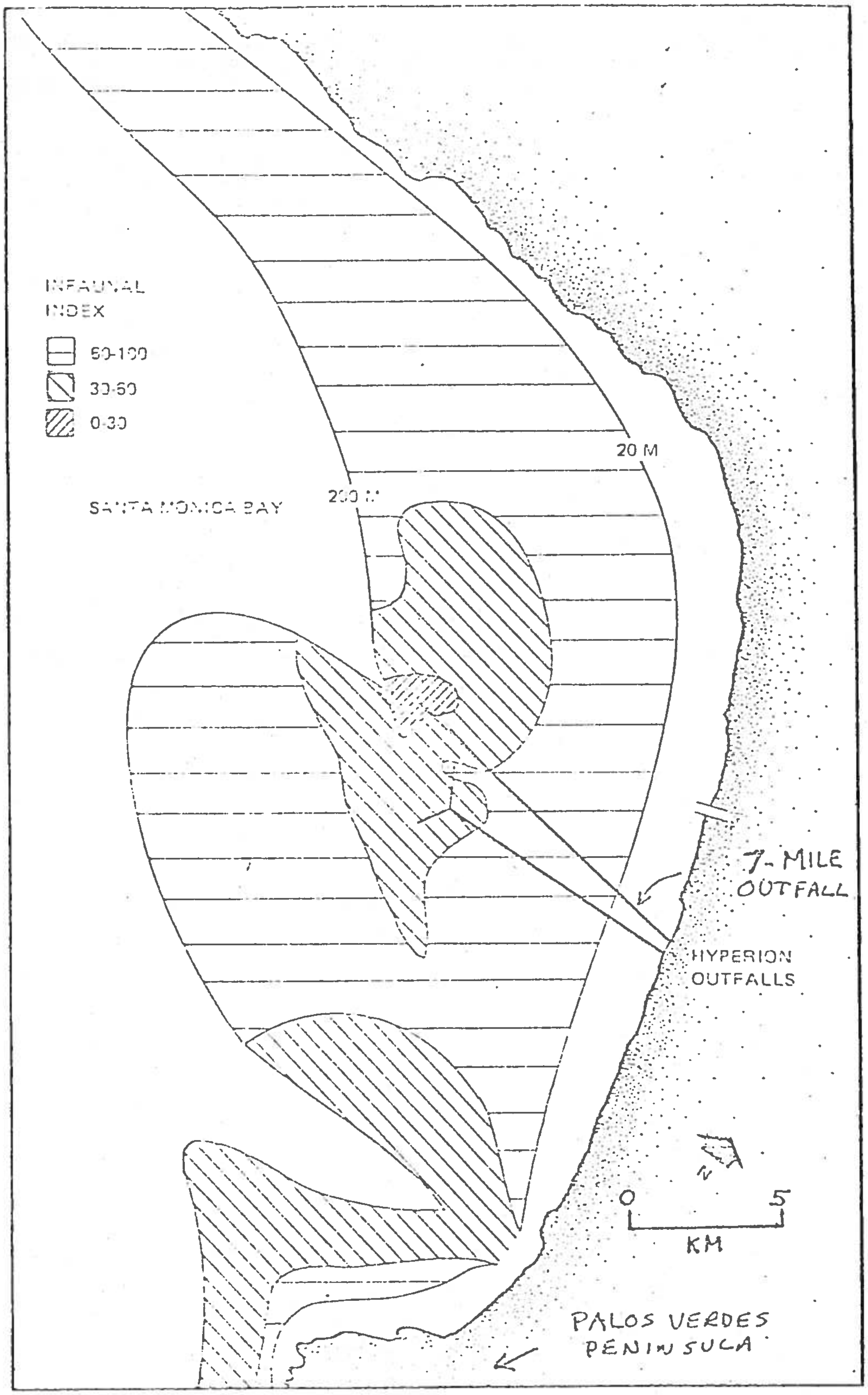
Figure 2. Variations in concentrations of six materials in surface sediments from 77 stations along the 60-meter isobath, spring and summer 1977. Large peak is centered about the Palos Verdes discharge area. Some secondary peaks in 5-day BOD, cadmium, zinc, and total PCB are centered about the other major discharges but there are also secondary peaks elsewhere. Major DDT source is from Palos Verdes outfalls. From Word and Mearns, 1979.



BOD
20,000
10,000
0
COD
300,000
200,000
100,000
0
CADMIUM
20
10
0
ZINC
1,000
100
10
1
TOTAL DDT
100
10
1.0
0.1
0.01
TOTAL PCB
10
1.0
0.1
0.01
0.001
MG/DRY KG

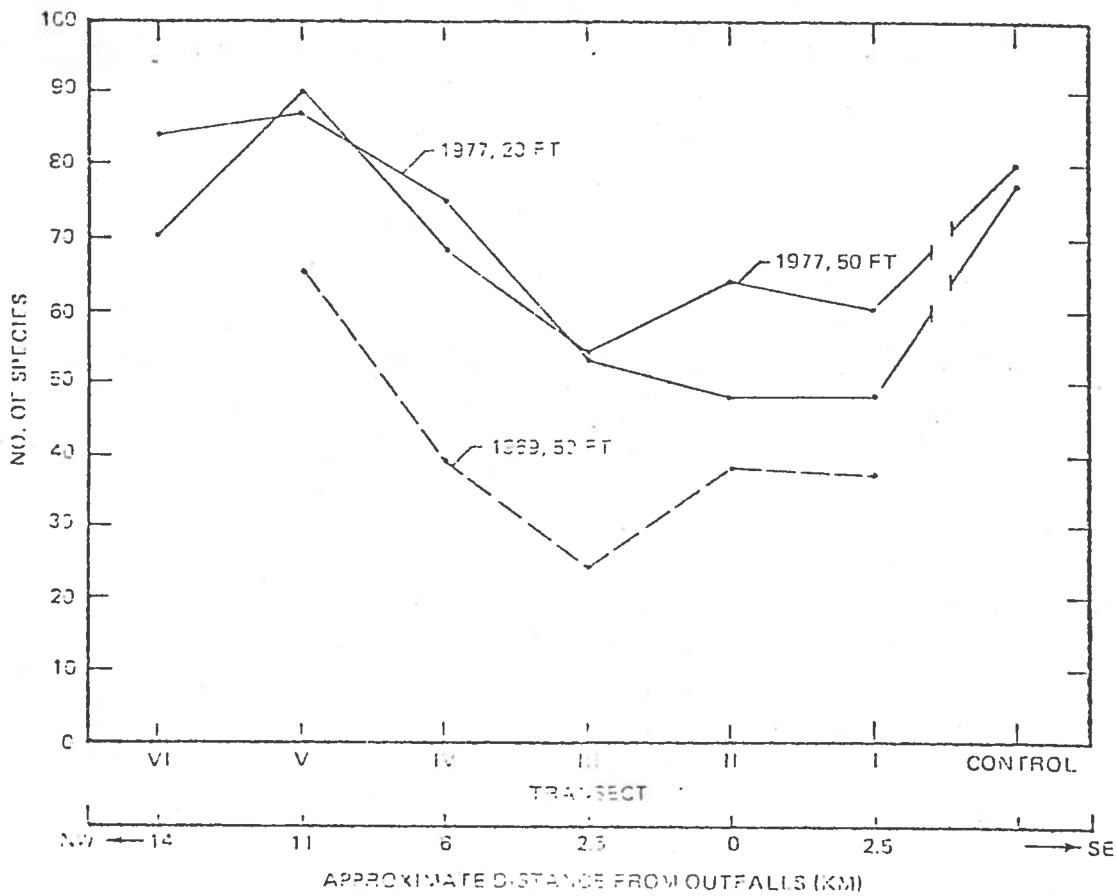
Figure 3. Variations in benthic infaunal communities along the 60-meter isobath of the southern California mainland shelf. Some peaks in (a) number of species, (b) biomass, and (c) infaunal index correspond with major discharge sites (·); abundance of (d) the normally conspicuous brittlestar, Amphiodia urtica is high along most of the coast, but reduced in the Los Angeles-Orange County area and near the U.S.-Mexico border. In contrast, abundance of (e) the bivalve, Parvilucina tenuisculpta is low along most of the coast, but very high at the four major discharge sites, and moderately abundant at Point Conception. After Word and Mearns, 1979.


(a) NO. OF SPECIES
NO./0.1 SQ M
(b) BIOMASS
G/SQ M
(c) INFAUNAL INDEX
(d) Amphiodia urtica
NO./SQ M
(e) Parvilucina tenuisculpta



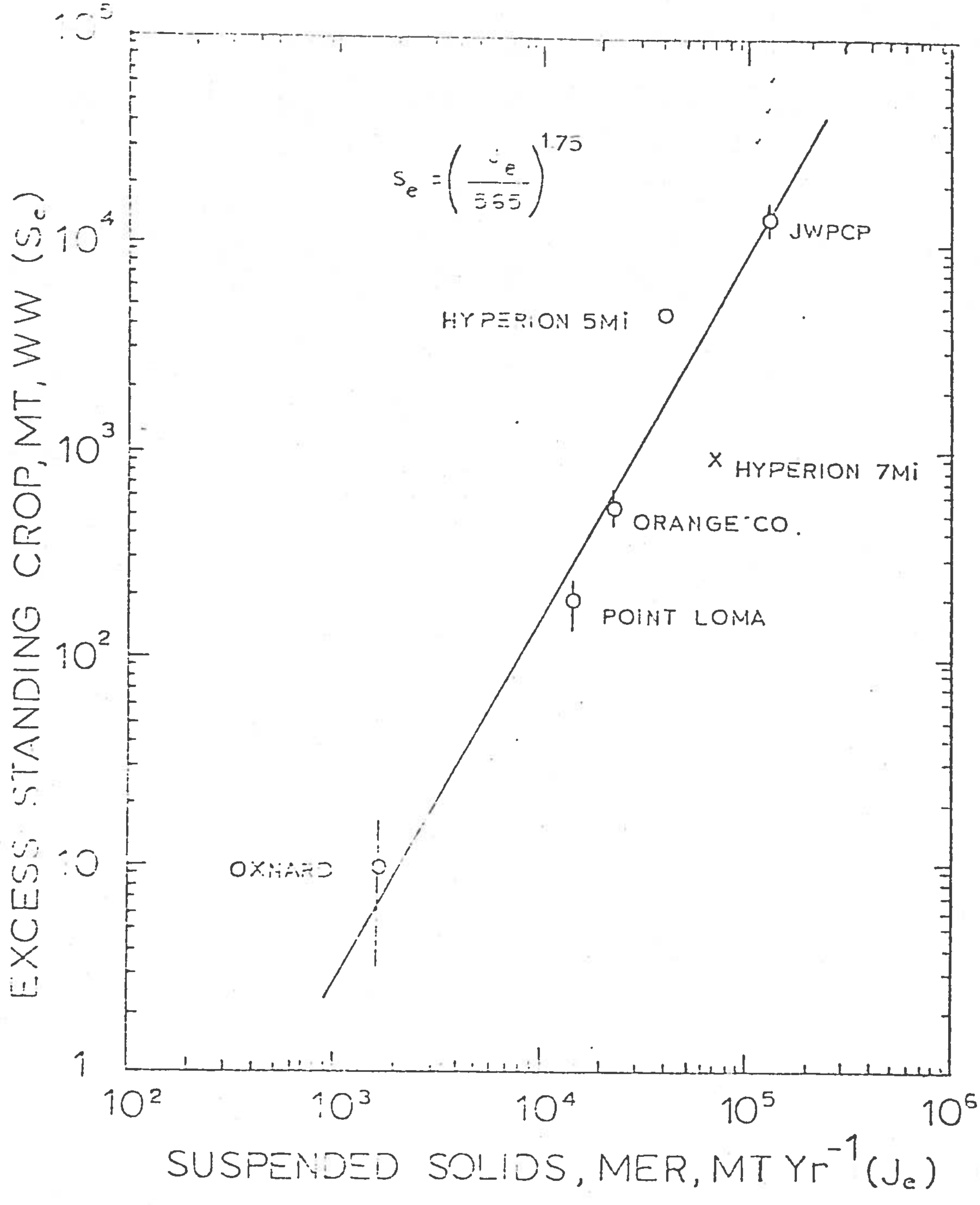
INFAUNAL
INDEX
60-100
30-60
0-30
20 M
200 M
SANTA MONICA BAY
7-MILE
OUTFALL
HYPERION
OUTFALLS
N
0
5
KM
PALOS VERDES
PENINSULA

Figure 5. Total number of algae, invertebrate and fish species observed at stations off Palos Verdes and La Jolla (control) in 1969 and 1977. From Grigg, 1979.



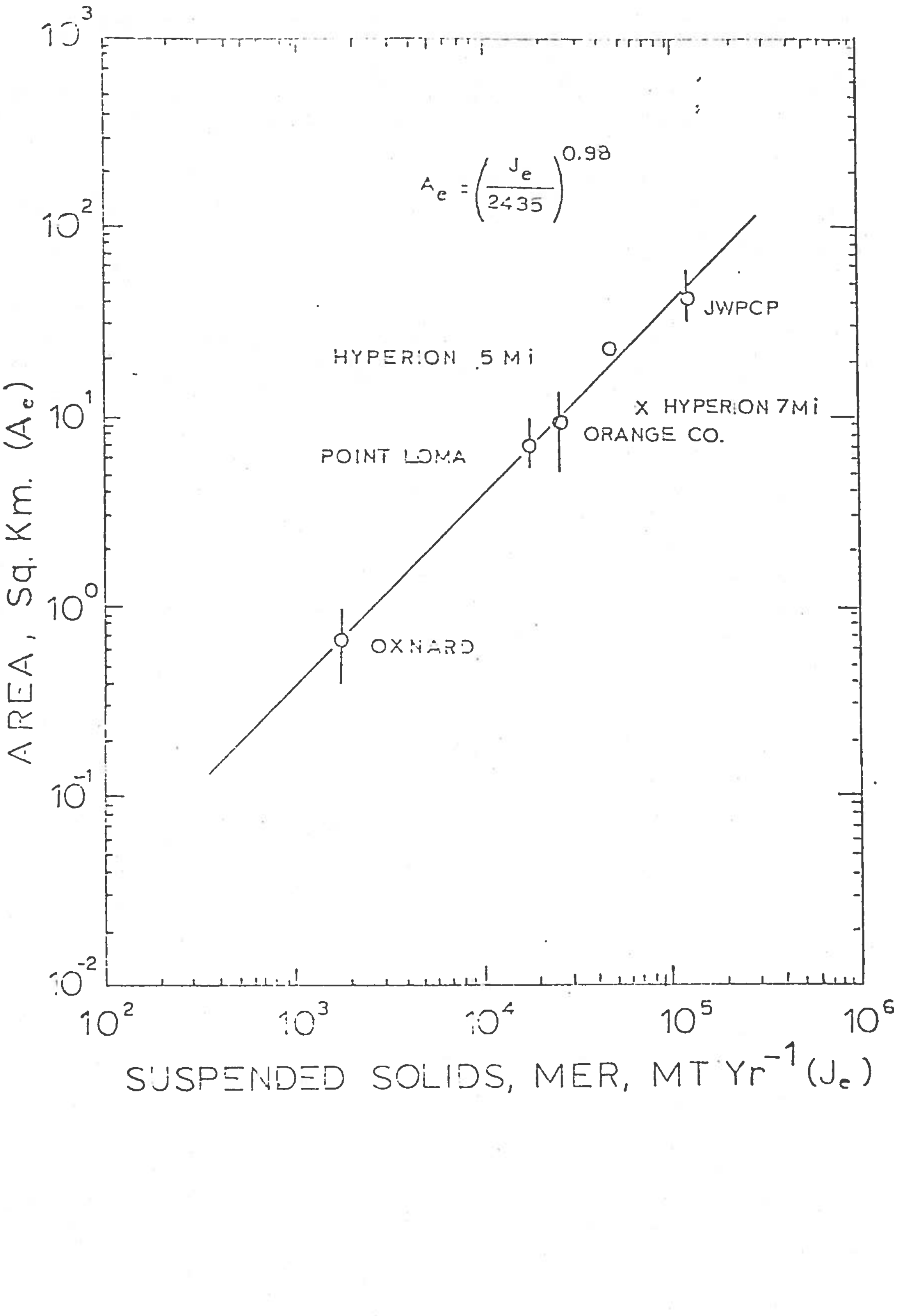
NO. OF SPECIES
100
90
80
70
60
50
40
30
20
10
0
1977, 20 FT
1977, 50 FT
1969, 50 FT
VI
V
IV
III
II
I
CONTROL
TRANSECT
NW
14
11
6
2.5
0
2.5
SE
APPROXIMATE DISTANCE FROM OUTFALLS (KM)

Figure 6. Relationship between suspended solids mass emission rates (Je) and excess standing crop of benthic infauna (Se) at six southern California ocean discharge sites. Open circle and bar represents median and range of estimates of standing crop; x represents standing crop near the Hyperion 7-mile sludge outfall (excluded from regression line).



$S_e = \left(\frac{J_e}{565}\right)^{1.75}$
JWPCP
HYPERION 5Mi
X HYPERION 7Mi
ORANGE CO.
POINT LOMA
OXNARD
EXCESS STANDING CROP, MT, WW (S_e)
1
10
10^2
10^3
10^4
10^5
10^2
10^3
10^4
10^5
10^6
SUSPENDED SOLIDS, MER, MT Yr^{-1} (J_e)

Figure 7. Relationship between suspended solids mass emission rates (Cs) and area occupied by excess standing crop (Ae) at six southern California ocean discharge sites. Open circle and bar represents median and range of estimates of area; x represents estimate of size of affected area near the Hyperion 7-mile sludge outfall (excluded from regression line).



$A_e = \left(\frac{J_e}{2435}\right)^{0.98}$
HYPERION 5 Mi
X HYPERION 7Mi
JWPCP
ORANGE CO.
POINT LOMA
OXNARD
AREA, Sq. Km. (A_e)
SUSPENDED SOLIDS, MER, MT Yr^{-1} (J_e)
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^2
10^3
10^4
10^5
10^6

Table 1. Average concentrations of general constituents, trace metals, and chlorinated hydrocarbons in the final effluent of municipal waste dischargers, 1977 (ND means "no data"). (From Schafer, 1979).

	JWPCP	Hyperion 5-mile	Hyperion 7-mile	Orange County	Point Loma	Oxnard
Flow						
mgd	335	319	4.6	180	116	11.2
liters/day x 10^6	1,268	1,207	17.4	681	439	42.39
General constituents (mg/liter)						
Total suspended solids	220	62	8,100[a]	132	123	98.0
5-day BOD	220	145	ND	197	167	258
Oil and grease	46.1	19	584	42	33.4	23.3
Ammonia nitrogen	39.0	17.2	259	36	23.8	20.5
Total phosphate—P	13.0	7.6	189	ND	ND	ND
Detergent (MBAS)	6.3	4.2	ND	ND	4.0	ND
Cyanide (CN)	0.24	0.14	0.70	0.11	0.05	0.03
Phenols	3.3	0.06	0.56	0.12	0.19	0.15
Trace metals (mg/liter)						
Silver	0.008	0.03	1.59	0.01	0.017	0.009
Arsenic	0.009	0.01	0.20	0.06	0.013	0.006
Cadmium	0.025	0.02	1.30	0.04	0.017	0.009
Chromium	0.38	0.13	12.8	0.18	0.055	0.025
Copper	0.25	0.20	15.5	0.32	0.125	0.125
Mercury	0.001	0.021	0.132	0.0005	0.001	0.0015
Nickel	0.24	0.18	4.1	0.13	0.08	0.210
Lead	0.19	0.03	2.15	0.09	0.08	0.050
Selenium	0.016	0.01	1.68	ND	ND	ND
Zinc	0.84	0.32	23.0	0.40	0.17	0.18
Chlorinated hydrocarbons (µg/liter)						
Discharger values[b]						
Total DDT	1.53	0.20	3.55	0.05	ND	ND
Total PCB	1.81	2.13	35.4	0.73	ND	ND
Total identifiable chlorinated hydrocarbons					2.3	
Project values[c]						
Total DDT	1.58	0.02	1.1	0.02	0.13	0.05
Total PCB	0.68	0.15	16	4.0	0.52	0.05

a. Total solids, suspended and dissolved.

b. Based on analysis of one grab sample per month, except for JWPCP total DDT value, which was based on analysis of 52 weekly composite sample.

c. Based on analysis of two 1-week composite samples.

Table 2. Mass emission rates of general constituents, trace metals, and chlorinated hydrocarbons in final effluent of municipal wastewater dischargers, 1977 (ND means "no data"). (From Schafer, 1979).

	JWPCP	Hyperion 5-mile	Hyperion 7-mile	Orange County	Point Loma	Oxnard
Flow						
gallons/yr x 10^9	335	319	4.6	180	116	11.2
liters/yr x 10^9	462.8	441	6.36	247	160	15.47
General constituents (metric tons/year)						
Total suspended solids	102,000	27,300	51,500[a]	33,300	20,500	1,500
5-day BOD	102,000	63,900	ND	47,900	26,700	3,900
Oil and grease	21,300	8,080	3,700	10,100	5,340	360
Ammonia nitrogen	18,000	7,590	1,650	9,830	3,810	317
Total phosphate—P	5,500	3,350	1,200	ND	ND	ND
Detergent (MBAS)	2,900	1,850	ND	ND	640	ND
Cyanide (CN)	111	61.7	4.4	29	<8	0.5
Phenols	1,530	26.5	3.56	24.7	31.5	2.40
Trace metals (metric tons/year)						
Silver	3.70	13.25	12.0	2.47	2.7	0.14
Arsenic	4.16	4.41	1.27	ND	2.1	0.03
Cadmium	11.6	8.82	8.27	10.9	2.7	0.14
Chromium	176	57.3	81.4	42.0	8.8	0.39
Copper	116	83	98.6	81.5	20	1.95
Mercury	0.462	0.926	0.84	0.37	0.16	0.023
Nickel	111	79.4	26.1	32.1	12.8	3.25
Lead	87.8	13.2	13.7	23.4	12.8	0.77
Selenium	7.39	4.4	10.7	ND	ND	ND
Zinc	388	141	178	101	27	1.7
Chlorinated hydrocarbons (kg/yr)						
Discharger values[b]						
Total DDT	730	83	23	14.1		ND
Total PCB	838	939	226	180		ND
Total identifiable chlorinated hydrocarbons					364	
Project values[c]						
Total DDT	730	8.8	7	6	21	0.8
Total PCB	314	67	103	926	83	0.8

a. Total solids, suspended and dissolved.

b. Based on analysis of one grab sample per month, except for JWPCP total DDT value, which was based on analysis of 52 weekly composite samples.

c. Based on analysis of two 1-week composite samples.

Table 4. Estimated annual inputs (m ton/yr) of trace metals to the Bight[4] (after Young et al. 1973, 1978a).

	Municipal wastewater 1976	Dry fallout[1] 1975	Storm runoff 1971-72	Storm runoff 1972-73[2]	Thermal discharge[3] 1977
Ag	20	0.06	1.1	2.6	--
Cd	45	0.84	1.2	2.8	0.3
Cr	593	6.6	25	60	0.6
Cu	507	31	18	42	2.1
Hg	2.6	--	--	0.43	--
Ni	307	12	17	41	0.7
Pb	190	240	90	210	0.8
Zn	1,060	150	101	240	1.8

1 = 100 km x 100 km off L.A. - Orange Co. Basin

2 = Extrapolating flow-weighted results from 1971-72 storm survey (abormally dry year)

3 = Southern California Edison cooling water (6.8×10^{12} l/yr)

4 = Approx. 180 m tons/yr Cu used in vessel antifouling paints.

Table 5. Estimated annual inputs (m ton/yr) of chlorinated hydrocarbons to the Bight (after Young and Heesen, 1978; Young, unpubl.)

		kg/yr			
Route	Year	Total DDT	Dieldrin	1242 PCB	1254 PCB
Muni. Wastewat.[1]	1972	6,490	100	≥ 19,200	≥ 260
Muni. Wastewat.	1973	3,920	≤ 280	≥ 1,900	1,510
Muni. Wastewat.	1974	1,580	95	4,270	1,020
Muni. Wastewat.	1975	1,270	--	2,400	680
Muni. Wastewat.	1976	940	--	2,220	590
Muni. Wastewat.	1977	770	--	1,260	300
Harbor Indust.	1973-74	40	10	≤ 70	30
Antifoul. Paint	1973	$<$ 1	--	$<$ 1	$<$ 1
Surf. Runoff	1971-72	100	20	100-170	90-110
Surf. Runoff	1972-73	320	65	0-550	250-280
Aerial Fallout[2]	1973-74	1,400	--	--	1,100
Ocean Currents	1973	≤ 7,000	--	--	≤ 4,000

1 = 1971 JWPCP discharge of total DDT: 21,600 kg

2 = Inner coastal zone: 400 km x 50 km

Table 6. Concentrations (medians and ranges) of selected general constituents, trace metals, and chlorinated hydrocarbons in sediments from 29 "control" sites and four outfall sites on the southern California mainland shelf. All data from the 60-m isobath sampled between Point Conception and the U.S.-Mexico border, 1977 (Word and Mearns, 1979). Concentrations based on dry weight.

Location	Control Sites		Point Loma		Orange County		Santa Monica Bay		Palos Verde	
No. Stations	29		10		10		9		7	
	$\bar{m}$	Range	$\bar{m}$	Range	$\bar{m}$	Range	$\bar{m}$	Range	$\bar{m}$	Range
General Constituents										
5-day BOD, mg kg^{-1}	636	266-1020	754	407-2180	927	499-1930	817	486-1850	7780	943-25,0
Volatile solids	2.8	1.8-3.8	2.8	1.9-4.7	2.5	1.9-3.0	3.2	2.4-3.9	17	5.0-27
Acid solids sulfides mg kg^{-1}	0.01	<0.007-0.07	0.03	0.005-0.32	0.04	0.01-0.11	0.04	0.01-0.20	0.67	0.03-1.6
Trace Metals mg kg^{-1}										
Chromium	22	6.5-43	23	4.4-28	37	33-63	74	54-146	680	86-1320
Copper	8.3	2.8-31	10	2.8-62	27	18-56	22	17-192	289	33-782
Lead	6.1	2.7-12	6.2	3.1-43	22	15-36	16	11-40	162	25-537
Zinc	42	9.8-62	41	9.8-155	47	39-88	68	58-143	526	57-2100
Chlorinated Hydrocarbons mg kg^{-1}										
Phenols[1]	0.007		No Data		0.076	0.015-0.440	No Data		No Data	
Chlorinated Benzenes[2]	No Data		No Data		No Data		No Data		0.36	
Total DDTs	0.007	<0.001-0.09	0.001	0.001-0.08	0.018	0.003-0.019	0.17	0.15-0.50	25	1.3-180
Total PCBs	<0.002	<0.002-0.04	0.037	0.004-0.14	0.063	0.020-0.25	0.12	0.060-0.51	2.1	0.11-11

1 = Data taken by Orange County Sanitation Districts, October 1974-June 1975, pers. comm.
2 = One station near outfall diffusers; from Young and Heesen, 1978.

Table 7. Summary of conditions of the benthic infauna at a series of stations (N) along the 60-m isobath at four major discharge sites and at 29 coastal control sites, all sampled by 0.1 m^2 Van Veen grab during 1977. Values are medians and ranges. No stations taken at Oxnard dicharge zone.

	Controls	Point Loma	Orange County	Santa Monica	Palos Verdes
No. Samples	29	10	9	9	7
Abundance No.m^{-2}	4167 (910-12130)	3550 (1860-8330)	5530 (3960-10780)	3670 (1980-12590)	8560 (2810-30570)
Biomass g m^{-2}	70.5 (28-112)	52 (43-94)	89 (76-218)	87 (15-135)	207 (77-707)
No. Species No. 0.1 m^2	73 (32-167)	67 (47-125)	80 (65-96)	59 (38-90)	47 (36-78)
Infaunal Trophic Index[1]	93 (83-98)	77 (69-94)	54 (44-79)	63 (48-99)	54.8 (21-64.4)
Shannon-Weaver Diversity	3.17 (2.19-4.16)	3.23 (3.09-3.94)	3.16 (2.52-4.16)	2.93 (1.54-3.31)	2.09 (1.34-3.30)
5-Day BOD mg kg^{-1},wet	632 (266-1017)	754 (407-2175)	927 (499-1931)	817 (486-1850)	7781 (943-25048)

1 = Values > 60 dominated by suspension feeding fauna, < 60 > 30 by surface deposit-feeding fauna and < 30 by subsurface deposit feeding fauna such as *Capitella capitata*; see Word, 1979.

Table 8. Summary of catch statistics for fishes and invertebrates collected in 10-minute on-bottom time otter trawls along the 60-m isobath. 28 coastal control sites and four waste discharge sites on the southern California mainland shelf, spring-summer, 1977. See Word and Mearns, 1979.

	Controls[1]	Point Loma[2]	Orange County[2]	Santa Monica[2]	Palos Verdes[2]
N	28	5	3	7	7
FISH					
Abundance (no./tow)					
All Fish	378 (186-623)	232 (114-593)	523 (236-917)	151** (17-393)	56** (26-352)
Less Recruits[3]	188 (109-291)	190 (114-370)	172 (104-757)	100 (17-340)	34** (25-145)
No. Species/tow	14.5 (12-16)	17 (14-21)	16 (14-16)	16 (4-23)	10** (7-15)
Biomass (kg)/tow	4.7 (3.2-7.9)	6.3 (4-16.5)	6.2 (2.5-14.8)	3.6 (1.5-14.8)	2.5* (0.8-4.9)
Shannon-Weaver Diversity	1.38 (1.22-1.57)	1.73** (1.63-2.45)	1.87** (1.02-1.94)	1.83** (1.21-2.08)	1.66 (0.83-1.96)
INVERTEBRATES					
Abundance (No./tow)	181 (90-351)	313 (110-3640(	167 (112-190)	488** (225-638)	286 (25-843)
No. Species/tow	10.5 (7-14)	11 (9-16)	22** (22-26)	15** (8-20)	11 (9-32)
Biomass (kg)/tow	7.4 (2.5-12.5)	1.17 (0.8-6.0)	7.4 (2.1-16.7)	7.9** (3.1-23.1)	18.9** (4.9-21.3)

1 = Median and 95% confidence limits.
2 = Medians and ranges
3 = Recently settled post-larval young of the year occurred in patches along the coast; this statistic excludes these.
** =

Table 9. Summary of median catch per 10 min. otter trawl tow for 18 species of bottom fish and invertebrates at control sites (n=28) and four discharge sites along the 60-m isobath of the southern California mainland shelf, 1977 (see Word and Mearns, 1979).

No. Samples	Control 28	Point Loma 5	Orange County 6	Santa Monica 7	Palos Verdes 7
FISHES					
Pacific sanddab	124 (80-209)	57**	89	36**	1**
Stripetail rockfish	27 (10-177)	1*	6*	20	7*
Plainfin midshipman	21 (2-40)	3	18	7	3*
Pink seaperch	9.5 (5-15)	21*	7.5	1**	0**
Dover sole	4.5 (2-7)	8	10.5	7	13*
Bigmouth sole	1 (0-3)	3	2	0*	0*
Yellowchin sculpin	5.5 (3-15)	1	65**	2	0**
Longspine combfish	2 (0-12)	0	7.5	3	0**
California tonguefish	2 (1-4)	5	8*	< 1*	1**
English sole	2 (1-5)	12 +	8.5	1	0
Speckled sanddab	< 1 (0- 1)	0	130**	19**	0
INVERTEBRATES					
<u>Lytechinus anamesus</u>	9.5 (3-162)	218*	26	0*	0**
<u>Parastichopus californicus</u>	6 (2-15)	2	22*	12	0**
<u>Astropectin verrilli</u>	<1 (0-9)	2	1	27**	0
<u>Luidia foliata</u>	3 (1-6)	1*	9	1*	0**
<u>Sycionia ingentis</u>	24 (16-98)	15	32	149	228*
<u>Mursia quadichaudi</u>	<1 (0-<1)	0	2.5**	0	1*
<u>Pleurobrachaea californica</u>	<1 (0-1)	0	1.5*	0	3**
No. Enhancement		4	5	2	4
No. Depressions		2	1	6	11
Ratio Enhancements/ Depressions		2.0	5.0	0.3	0.4

+ = 0.2 > p > .1 DIFFERENT FROM CONTROL VALUE.
* = 0.1 > p > .05 "
**= p < .05 "

Table 10. Prevalence of fin erosion and skin tumors in Dover sole collected in trawls taken along the 60-m isobath between Point Conception and the U.S. Mexico Border, summer, 1977. Samples grouped to increase regional sample sizes.

	Pt. Conception to Point Dume	Santa Monica Bay	Palos Verdes	Southern San Pedro Bay	Laguna Beach to Pt. La Jolla	Point Loma
No. Trawls	(13)	(8)	(7)	(3)	(12)	(3)
Dover sole Total No.	120	53	201	36	66	81
Catch/haul	9.2	6.6	28.7	12.0	5.5	27.0
No. with Fin Erosion (%)	0	0	63 (31%)	0	0	0
No. ≤ 120 mm SL[1]	90	16	147	15	18	58
No. with tumors (%)	3 (3.3%)	1 (6.2%)	3 (2.0%)	1 (6.7%)	0	1 (1.7%)

1 = Disease is initiated in young of the year and decreases in prevalence with age; size limitation (≤ 120 mm SL) includes mainly 1976-77 year class.

Table 11. Summary of some existing (1976) and predicted conditions in effluent mass emission rates, benthic infauna and sediment chemistry associated with expected changes in effluent quality from the three largest southern California discharges (in U.S. Congress, 1978).

			Hyperion				OCSD		Total	
			5-mile		7-mile					
	1976	1983-88	1976	1983-88	1976	1983-88	1976	1983-88	1967	1983-
Flow (MGD)	353	275	359	365	4.1	4.0	182	215	898.1	859
Sus. Solids MT/yr x 10^3	138.9	19.9	38.3	15.1	56.2	58.0	32.3	9.94	265.7	102.
Chromium MT/yr	370	50	95	23	66	96	48	8.5	579	177.
PCB kg/yr	1300	170	110	120	120	120	990	660	2520	1070
Excess Standing Crop. MT	13390	600	4660	1000	NC	NC	550	110	18600	1710
Area affected by ESC, sq km	41	8	23	10	NC	NC	9.1	4	73.1	22
Distance to Background Infaunal Index (km)	48	5*	24	1	NC	NC	8	< 0.5	80	< 6.
Chromium affected area ppm	1050	220	100	25*	570	NC	17	8.2	NA	NA

* = Greater than 20 yrs, or post 1983 equilibrium.
NA= Not applicable

Table 12. Summary of ecological and public health effects at each of five major southern California discharge sites.

	Oxnard	Point Loma	Orange County	Santa Monica 5-mile	Santa Monica 7-mile	Palos Verdes
A. Flow, MGD	11.2	116	180	319	4.6	335
B. Sus. Solids MT/yr MT/yr x 10^3	1.52	20.5	32.8	59.7	26.9	102.0
C. Sediment Contam.						
1. Metals	1	2	2	2-3	10-100	10-100
2. CHC's	1	5	10	50	100	100 - 1,000
D. Ecosystem Response						
1. Area (sq km) of excess biomass	1	8	9.1	23		41
2. Area (sq km)						
2a. Infaunal Index 60	0	4	11	60		94
2b. Infaunal Index 30	0	0	0	2-4		11
3. Bottom fish & shellfish (ratio enhanced/depressed species)	1 (est.)	2	5	0.3		0.4
4. Fin rot initiated? (EROSION)	No	No	No	No	Poss.	Yes
5. Nearshore Diversity affected?	No	No	No	No	No	Yes (8 km)
E. Public Health Response						
1. Nearshore Coliform Standards exceeded?[1]	Occ.	No	Occ.	Occ.	-	Occ.
2. Seafood contamination?						
a. Metals, Fish?[2]	No	No	No	No	No	No
b. Metals, Shellfish?[2]	ND	Yes	Yes	Yes	Yes	Yes
c. DDT[3]	No	No	No	No	No	Yes
d. PCBs[4]	No	No	No	No	Occ.	Occ.
e. Hg[5]	No	No	No	No	No	No

* = Problem

1 = May not be due to discharge 2 = No Standards 3 = >5 ppm 4 = >2 ppm 5 =>0.5 pp

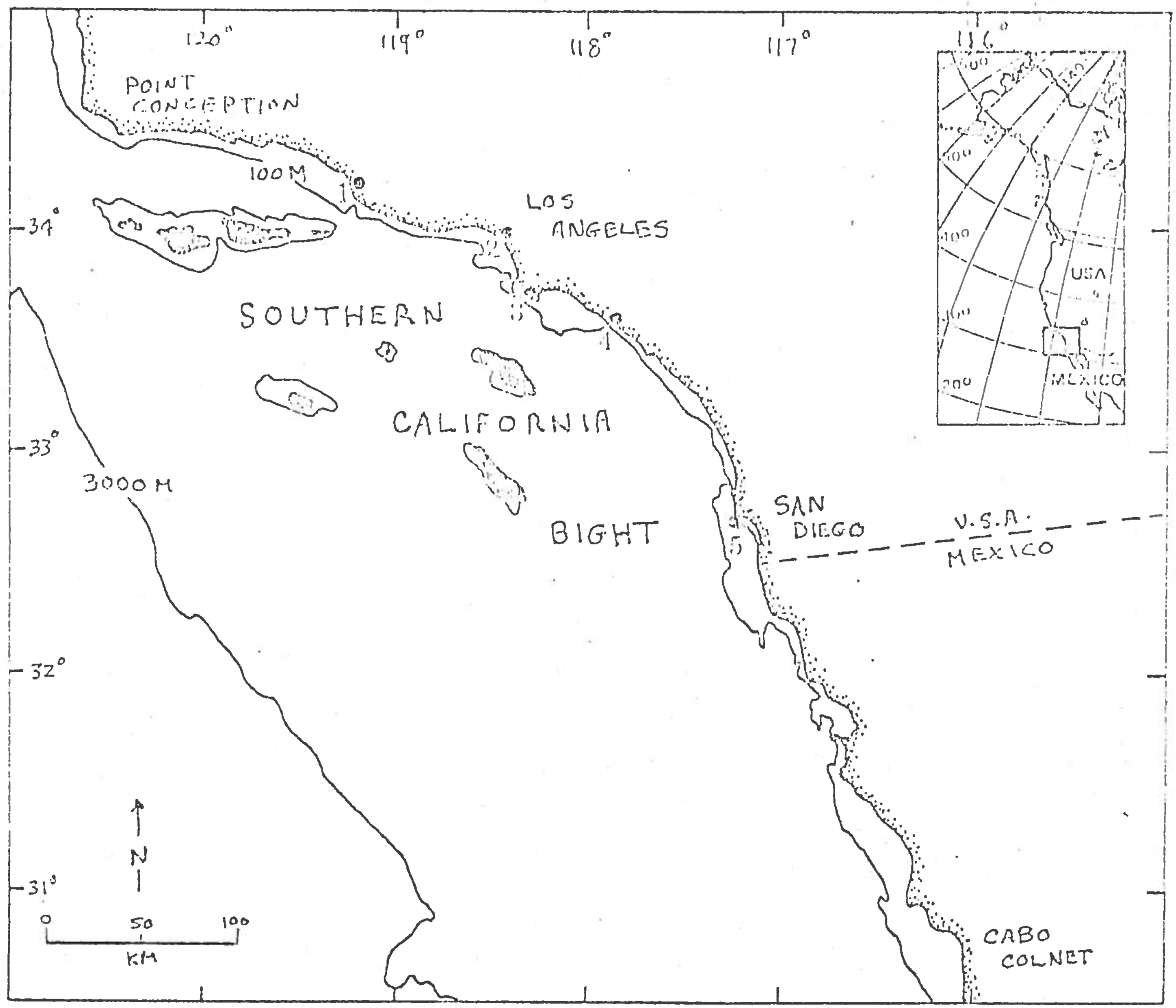

120°
119°
118°
117°
116°
POINT CONCEPTION
100 M
LOS ANGELES
SOUTHERN
CALIFORNIA
BIGHT
SAN DIEGO
U.S.A.
MEXICO
3000 M
34°
33°
32°
31°
N
0
50
100
KM
CABO COLNET
USA
MEXICO

Figure 1. The Southern California Bight and the adjacent coastal basin. Major municipal wastewater dischargers are (1) City of Oxnard, (2) City of Los Angeles (Hyperion Treatment Plant) in Santa Monica Bay, (3) Joint Water Pollution Control Plant (JWPCP) off Palos Verdes, (4) Orange County Sanitation Districts in southern San Pedro Bay, and (5) City of San Diego, Point Loma Treatment Plant. Note 100 m isobath occurs within 5-10 km from shore.