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CADMIUM AND MERCURY IN THE SOUTHERN CALIFORNIA BIGHT
Summary of Findings, 1971 to 1973

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U.S. Environmental Protection Agency,
National Marine Water Quality Laboratory,
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INTRODUCTION

The Southern California Coastal Water Research Project is engaged in ecological research of the Southern California Bight, the section of the coastal waters between Point Conception in southern California and Cabo Colnett, 600 km to the south in northern Baja California, Mexico (Figure 1). Approximately 5 percent of the U.S. population lives in the coastal plain of the Bight, and more than 1,000 million gallons per day (mgd) of municipal wastewater are discharged into the Bight via coastal submarine outfalls. The overall objective of the Project is to determine the ecological effects of these discharges in relation to effects of other activities of man and natural occurrences. This report summarizes my interpretation of the Project's findings to date on two wastewater constituents of immediate interest, the trace metals cadmium and mercury.

INPUTS

The average concentrations and estimated mass emission rates of cadmium and mercury in five to seven different effluents from southern California municipal wastewater treatment plants for 1971 are summarized in Table 1. Additional Project studies on mercury during 1972 and 1973, summarized in Table 2, provide insight into the extent of change in effluent concentration since 1971. Table 3 shows the percent of cadmium in wastewater effluents that is retained on 0.45-micron filters and the concentrations of cadmium on wastewater particulates from 1-week composite samples collected in summer 1971. The table also gives the cadmium concentrations found on natural marine sediments around the outfalls; the average natural concentration is 0.37 mg/dry kg. The corresponding average for mercury is 0.037 mg/dry kg.

During 1971 and 1972, the Project also studied the inputs of a number of metals (including cadmium and mercury) via storm surface runoff in four major southern California channels. Most of the trace metal concentrations appeared to be correlated with the concentration of suspended sediments and with the discharge rate (an example is shown in Figure 2). In addition, on the average, 78 percent of the cadmium in the storm runoff samples was retained on 0.45-micron filters (Young et al. 1973b).

The Project has recently measured mercury concentrations in effluents representative of major types of industries discharging directly

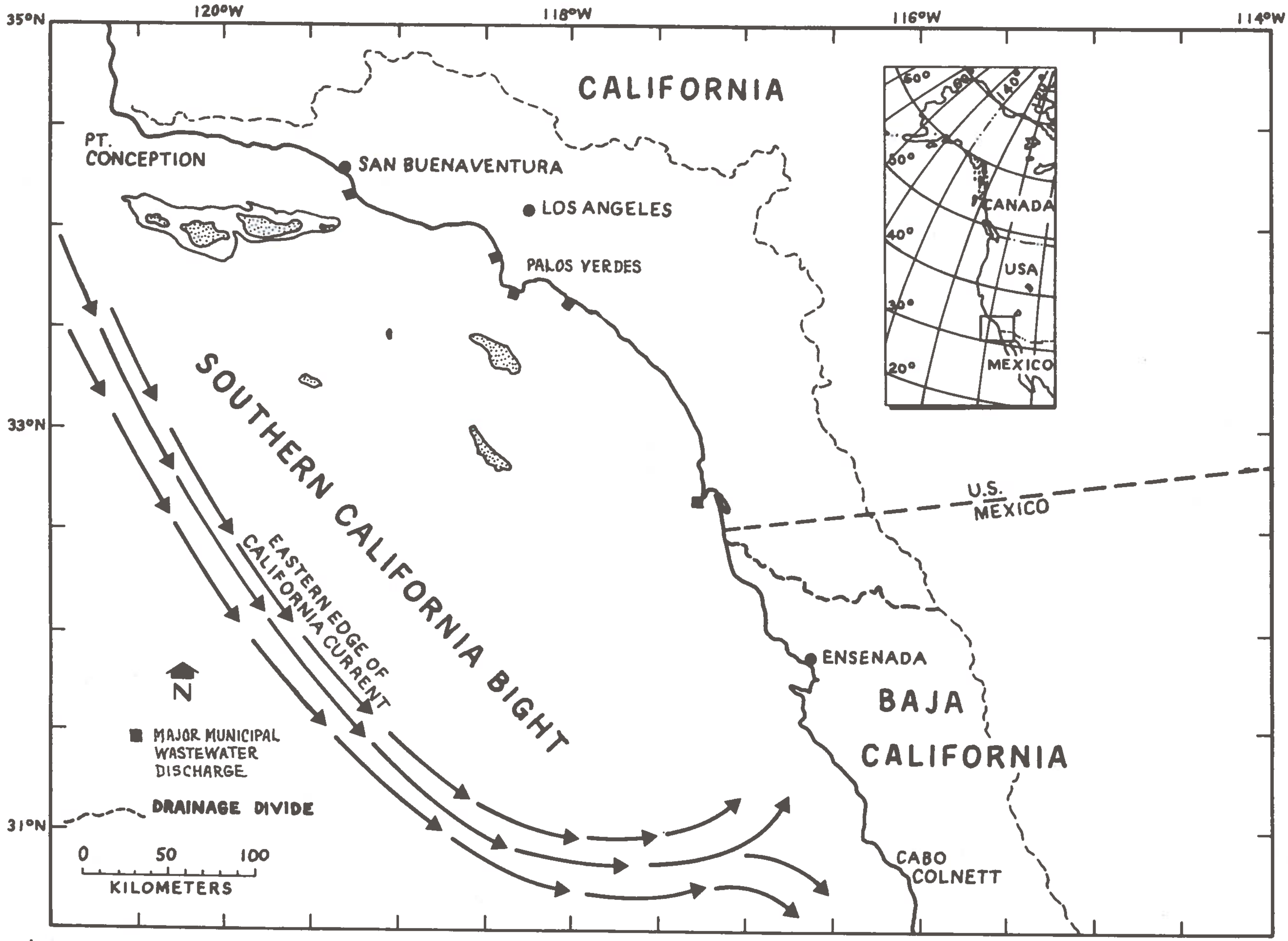

Figure 1. The Southern California Bight.

Table 1. Average concentrations and estimated mass emission rates of cadmium and mercury in municipal wastewater effluents, 1971.*

Discharger	Flow (mgd)	Total Suspended Solids (mg/L)	Average Conc. (mg/L) Cadmium	Mercury	Mass Emission Rate (metric ton/yr) Cadmium	Mercury
City of Oxnard	12	80	0.02	<0.001	0.3	<0.02
City of Los Angeles (Hyperion)						
Effluent	335	73	0.05	0.003	23	1.4
Sludge	5	3,000	0.23	0.10	2	0.7
Los Angeles Co.						
JWPCP	371	330	0.03	0.001	15	0.5
Terminal I.	8	120	0.01	0.001	0.1	0.01
Orange Co.	130	145	0.06	0.001**	11	0.2
City of San Diego (Pt. Loma)	90	110	0.02	<0.001	2.5	<0.1
TOTAL	951				54	2.8

*Based on data in Young et al. 1973b, tabs. 1 and 4, and Southern California Coastal Water Research Project 1973, tab. 4-4.
**Average of 22 grab samples, 15-21 June 1972.

into the Los Angeles Harbor; these are listed in Table 4. In comparison, we have found the average concentrations of mercury in numerous seawater samples from uncontaminated regions of the Bight to be approximately 0.000030 mg/L (or 30 parts per trillion). These data indicate that, relative to the municipal wastewaters, these direct industrial discharges are completely insignificant sources of mercury to the Bight.

In an attempt to obtain a rough picture of metallic inputs to the Bight, we have made best estimates of the mass emission rates via direct rainfall and vessel-related inputs and the probable upper limits of the mass emission rates via barged ocean dumping. Then, for each metal, the estimated values for the coastal inputs and their sums were compared to the estimated quantity of that metal transported through the Bight annually via ocean current

Table 2. Mercury concentrations in municipal wastewater effluents, 1972 and 1973.*

Discharger	Collection	Liquid Basis (mg/L)	Solid Basis** (mg/dry kg)
City of Oxnard	May 72	0.0004	-
	Jun 73	0.0008	6.3
	Sep 73	0.0004	1.0
City of Los Angeles (Hyperion)			
Effluent	Jun 72	0.0006	6.6
	Sep 73	0.0005	5.8
	Dec 73	0.0004	4.8
Sludge	Jun 72	0.059	9.5
	Sep 73	0.061	10.5
	Dec 73	0.038	7.9
Los Angeles Co. (JWPCP)	May 72	0.0013	4.6
	Jul 73	0.0012	4.6
	Sep 73	0.0009	4.0
Orange Co.	Jun 72	0.0010	5.8
	Jul 73	0.0015	9.1
	Sep 73	0.0009	7.4
City of San Diego (Point Loma)	Jul 72	0.0014	7.8
	Jul 73	0.0011	7.8
	Sep 73	0.0007	4.5

*Based on data to be presented in a future Project publication.
**Assuming all the mercury in the effluent is associated with the particulates; to the first order, this assumption appears to be justified by filtration experiments. For example, the average of 23 weekly composite values from 1971 monitoring data of Los Angeles County Sanitation Districts indicates that approximately 90 percent of the total mercury in JWPCP final effluent was retained on a 0.8-micron filter.

Table 3. Cadmium in wastewaters and in sediments around wastewater outfalls, 1971.

Discharger	Percent Particulate[1]	Concentration (mg/dry kg) Wastewater Particulates[1]	Natural Sediments[2]
City of Oxnard	92	115	0.20
City of Los Angeles (Hyperion)			
Effluent	88	108	0.22
Sludge	-	180	-
Los Angeles Co. (JWPCP)	95	65	0.42
Orange County	98	245	0.53
City of San Diego (Pt. Loma)	91	65	0.48
AVERAGE	93		0.37

1. Data from Young et al. 1973b, tabs. 2 and 3.
2. Data from Southern California Coastal Water Research Project 1973, tab. 6-1.

Table 4. Concentrations of mercury in effluents representative of industrial discharges into Los Angeles Harbor.

Type of Discharge	Flow (mgd)	Mercury ($mg/L \times 10^{-6}$*)
Fish Cannery		
Waste No. 1	5.55	240
Waste No. 2	3.20	140
Retort Discharge	0.12	81
Condensor Water	1.94	120
Shipyard		
Cooling Water No. 1	0.04	84
Cooling Water No. 2	0.43	86
Oil Tanker Cleandown	0.25	120
Ship Ballast No. 1	0.04	95
Ship Ballast No. 2	0.29	150
Oil Refinery		
Cooling Water	0.02	48
Power Plant		
Cooling Water	257	38
Chemical Plant		
Combined Processes	5.51	79
Average Seawater		30

*Or parts per trillion.

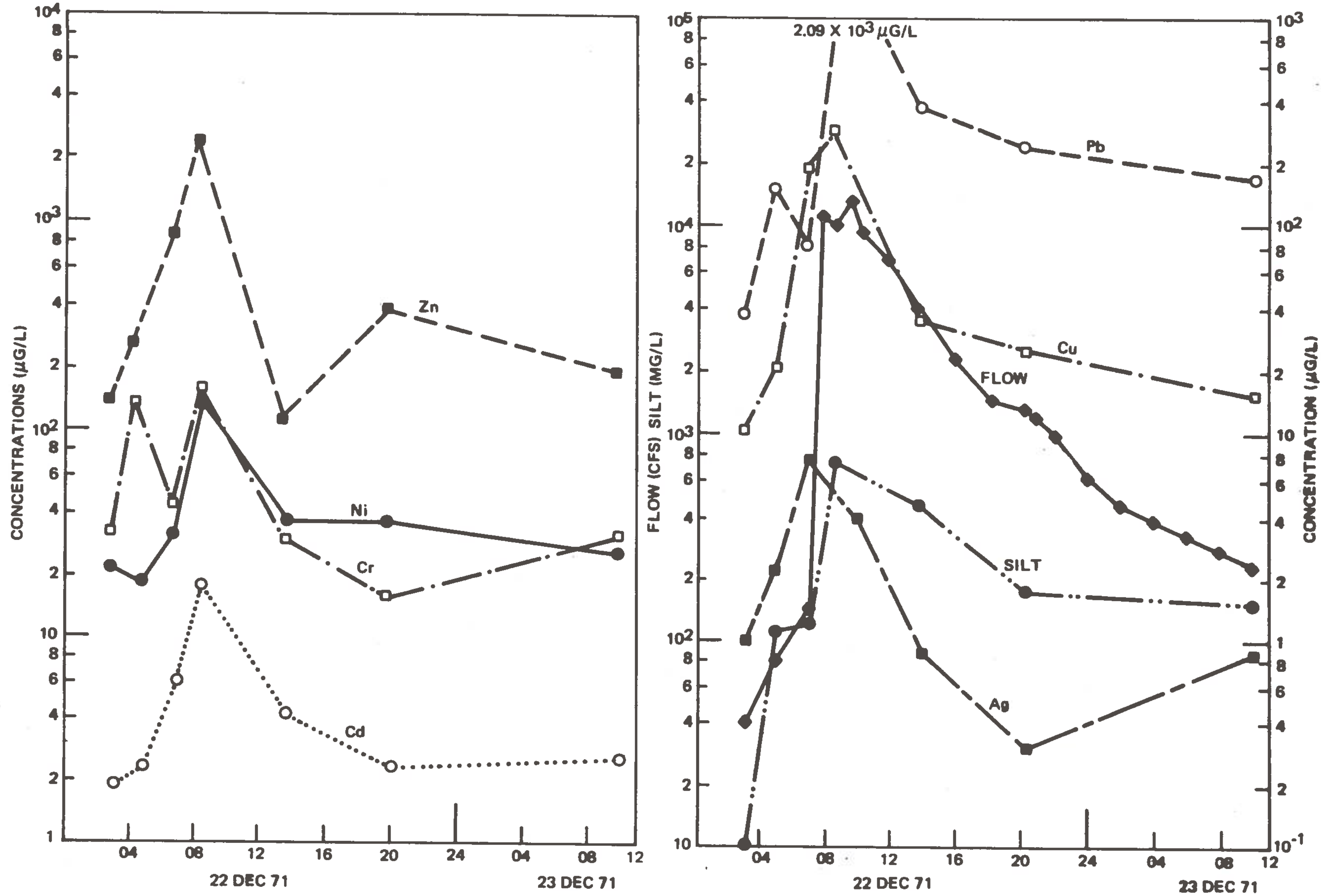

Figure 2. Concentrations of trace metals in Los Angeles River stormwaters, 22-23 Dec 71. From Southern California Coastal Water Research Project 1973, fig. 4-6.

advection (Young et al. 1973b). The 1971 results for cadmium and mercury are summarized below:

Source	Mass Emission Rate (metric tons/year) Cadmium	Mercury
Municipal wastewaters	54	3
Surface runoff	1	0.1
Direct rainfall	-	8
Vessel-related activities	0.1	4
Estimated dumping	<14	<2
Sum of coastal inputs	55-69	15-17
Ocean currents	2,000	600

This summary indicates that, at least for cadmium, municipal wastewater is by far the most important of the known anthropogenic sources to the coastal waters of the Bight. This is significant in light of the fact that approximately 85 percent of the 1,000 mgd of these wastewaters, and approximately 95 percent of the cadmium in the wastewaters, is discharged by the City of Los Angeles, Los Angeles County, and Orange County within about 30 km of the Palos Verdes Peninsula (site of the Los Angeles County (JWPCP) discharge). Thus, relative to the 600 km of coastline in the Bight, these discharges apparently constitute a semipoint source of anthropogenic cadmium to the coastal ecosystem.

BIOLOGICAL RESERVOIRS

To determine whether or not any evidence of widespread contamination of the marine biota by cadmium (or other metals) could be uncovered, the Project made extensive collections of intertidal mussels (*Mytilus californianus*) throughout the Bight during the summer of 1971. Three males and three females (4 to 6 cm in length) from each station were isolated and their digestive glands excised and analyzed by emission spectroscopy, in collaboration with George Alexander (University of California at Los Angeles). The results are illustrated in Figure 3.

The values illustrated are averages of two determinations, one for the male composite samples and one for the female; the difference between the two measurements at a station is indicated in the parentheses. These data do not show any clear pattern of enhanced cadmium concentrations at the coastal stations in Los Angeles and Orange Counties (Point Dume to Santa Ana): The average of these six values (16 mg/dry kg) is less than that of the six island values (21 mg/dry kg), and the means are not significantly differ-

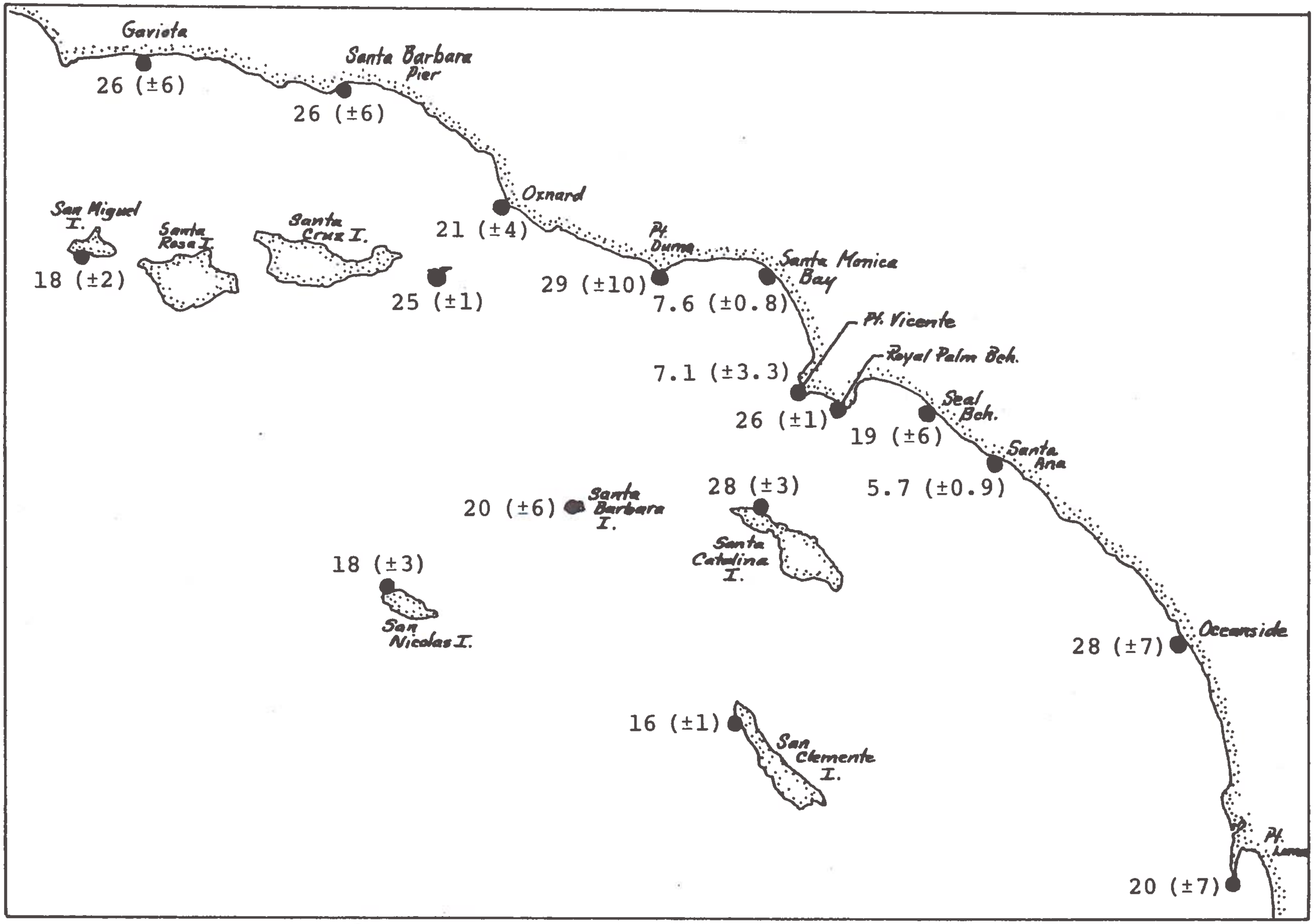

Figure 3. Concentrations (mg/dry kg) of cadmium in digestive glands of *Mytilus californianus*, 1971. Numbers in parentheses are standard errors.

ent. In contrast, this same species showed dramatic gradients of DDT compounds, with concentrations decreasing by two orders of magnitude away from the Palos Verdes Peninsula, the location of the dominant DDT input (via JWPCP effluent) to the Bight (Figure 4). Thus, although the mussel specimens had clearly been exposed to anthropogenic inputs from the vicinity of the Peninsula, with enhanced DDT levels indicating a response for 100 km or more in most directions, there is no evidence of a corresponding widespread contamination of the intertidal biota by cadmium.

Mercury was not measured in these samples. However, the Project's research has revealed an enrichment of this metal in one fraction of the ecosystem far removed from the centralized inputs near Los Angeles. Figure 5 illustrates an approximate doubling of total mercury over baseline levels in dated varved sediments collected from the anaerobic Santa Barbara Basin (approximately 100 km northwest of Palos Verdes). Increased concentrations begin to occur around 1900, long before the construction of major ocean outfalls. In contrast, the data on cadmium (Figure 6) from this basin provide no convincing evidence of recent enrichment: The average of the five measurements for the five youngest layers (deposited between 1942 and 1962) was 2.6 mg/dry kg; a corresponding average for the five oldest layers, covering the period 1835 to 1858, was 3.5 mg/dry kg. Again, the means are not significantly different.

Detailed Project surveys of the sediments around the submarine discharges of the City of Los Angeles (Hyperion 7-mile "sludge" line) and Los Angeles County Sanitation Districts (JWPCP Whites Point outfall system) revealed strong horizontal and vertical gradients of both cadmium and mercury, as illustrated in Figures 7 through 9. Surface layer concentrations of both metals within 1 km of the northernmost outfall off Whites Point were up to 100 times natural levels. Nevertheless, specimens of a flatfish (Dover sole, Microstomus pacificus) trawled from this vicinity, and known by their high DDT concentrations and incidence of fin erosion to have lived on the contaminated sediments, showed no significant enrichment over baseline concentrations of cadmium or mercury in their liver tissue (Table 5).

SUMMARY

The following conclusions about cadmium and mercury in the Southern California Bight are drawn from the findings discussed above:

1. Municipal wastewaters are important sources of both cadmium and mercury to the coastal ecosystem. Despite specific efforts to reduce emission of mercury, analyses of six major effluents during 1971-73 do not reveal any large reductions in concentrations on a regional scale during that interval.

2. Approximately 90 percent of the cadmium and mercury in municipal wastewaters appears to be associated with the filterable fraction of the effluent. The concentrations of cadmium on the

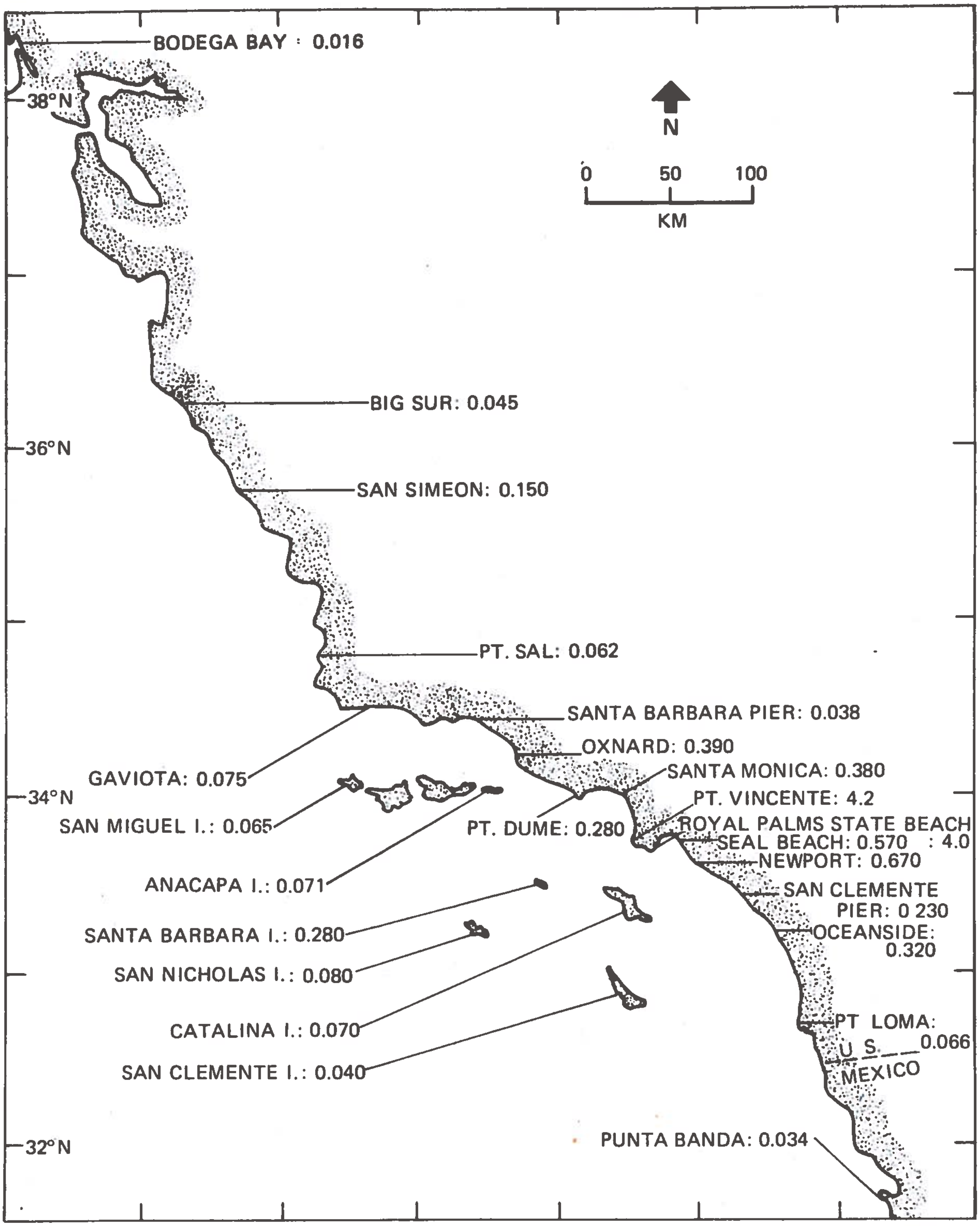

Figure 4. Concentrations (mg/wet kg) of total DDT in whole soft tissues of *Mytilus californianus*, 1971. From Southern California Coastal Water Research Project 1973, fig. 8-16.

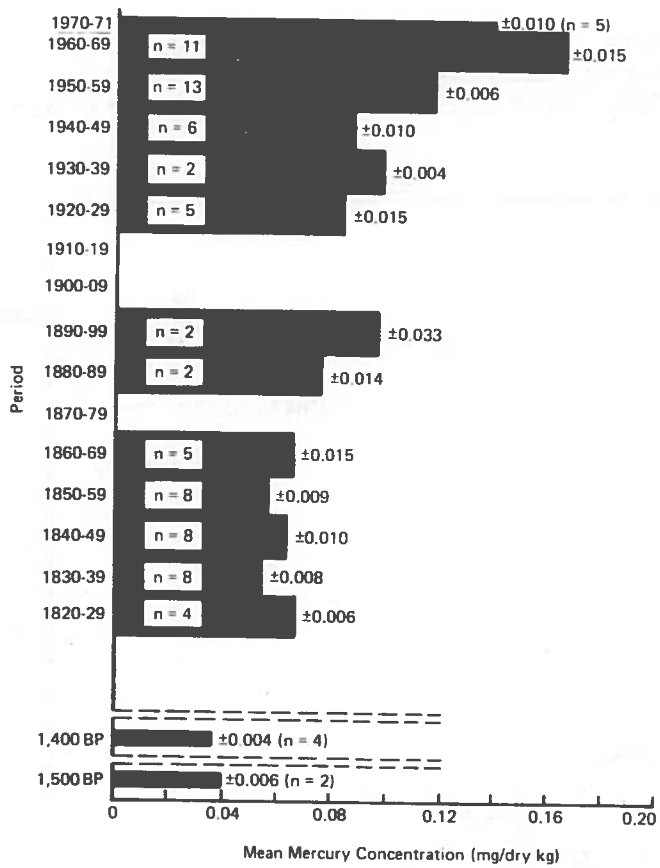

Figure 5 (above). Mean concentrations of mercury in dated varved sediments from Santa Barbara Basin. Number to right of bar indicates standard error. From Young et al. 1973a, fig. 1.

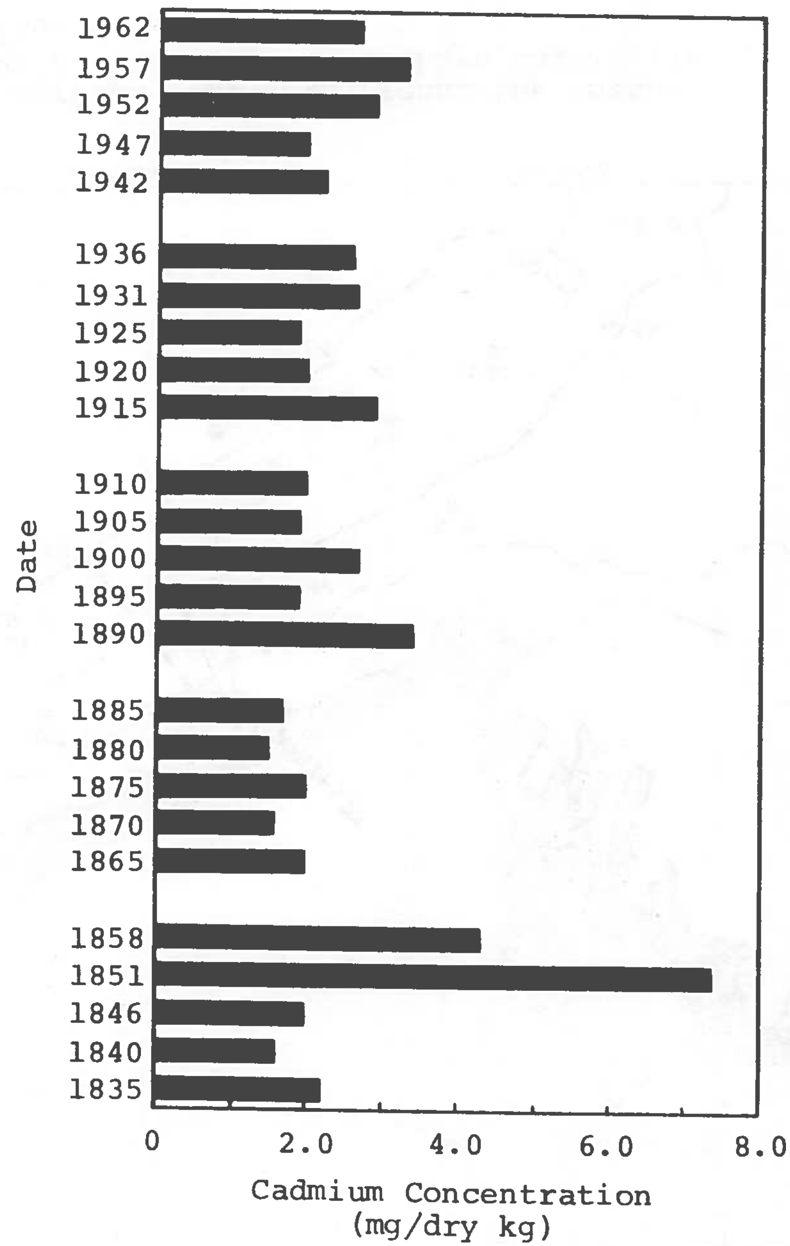

Figure 6 (right). Concentrations of cadmium in dated varved sediments from Santa Barbara Basin. Study by Dr. James Galloway, reported in Southern California Coastal Water Research Project 1973, tab. 6-5.

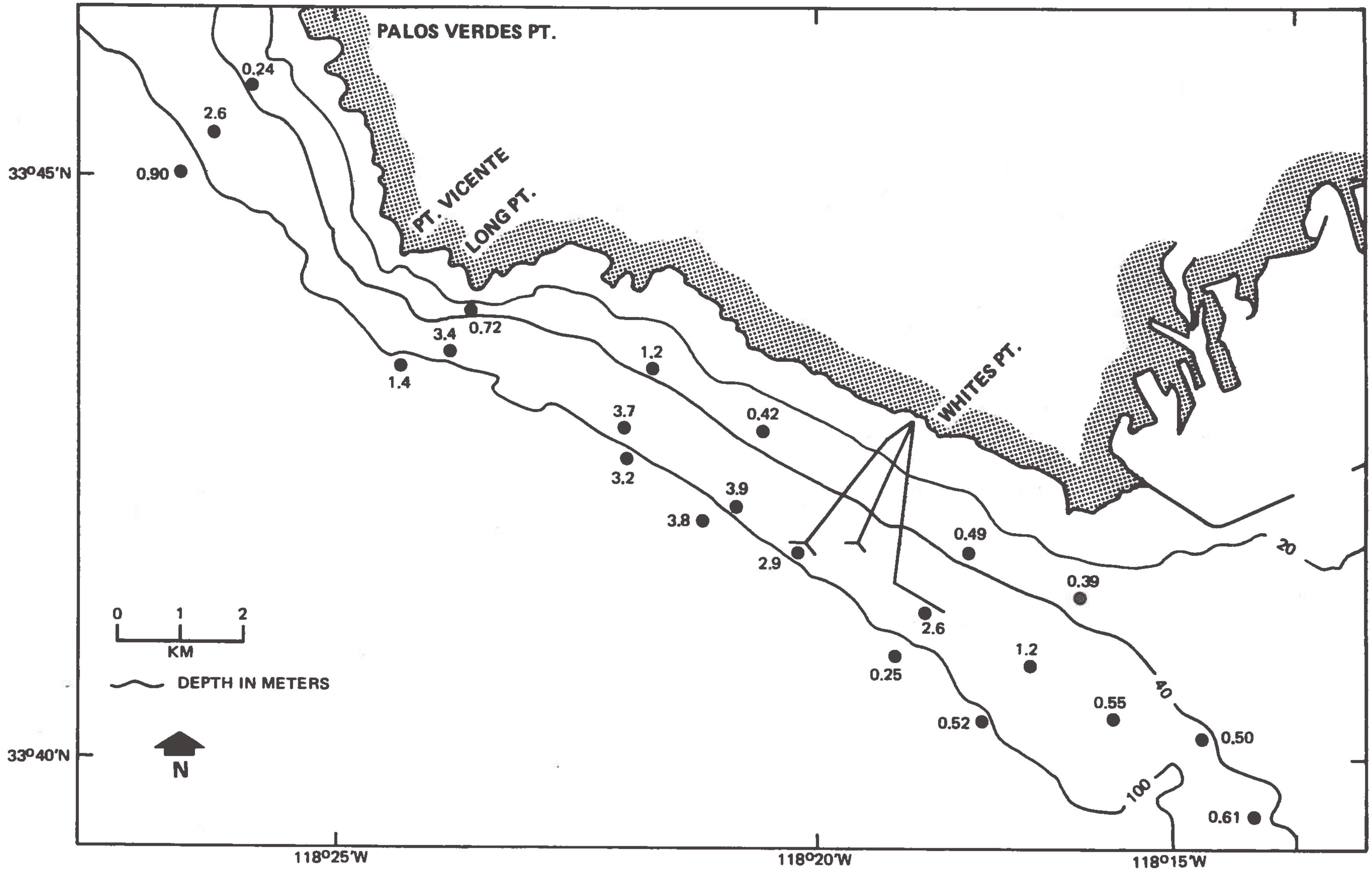

Figure 7. Mercury concentrations (mg/dry kg) in surface sediments around the Whites Point outfall system (Phleger cores, June 1972). From Southern California Coastal Water Research Project 1973, fig. 6-4.

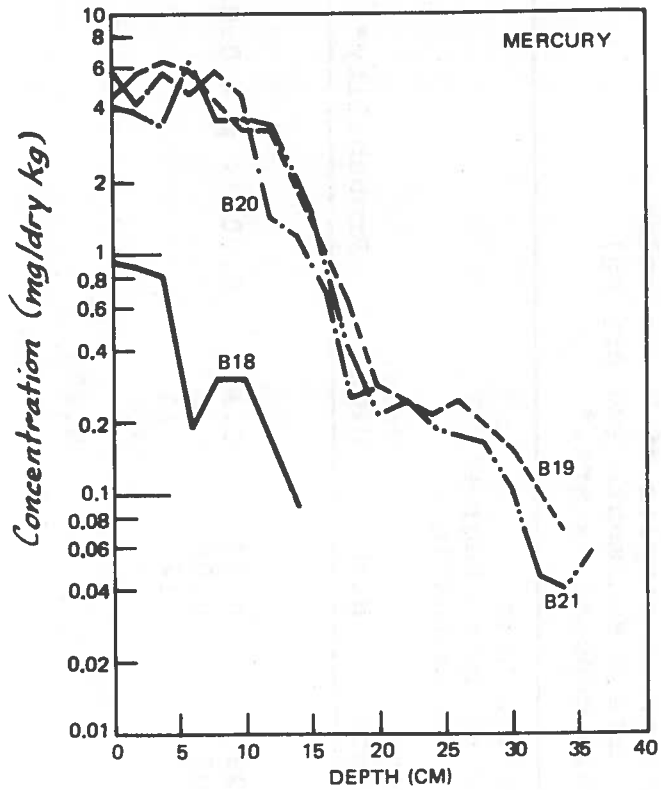

Figure 8. Vertical profiles of mercury concentrations in sediments collected northwest of the Whites Point outfall system (box cores, July 1971). From Southern California Coastal Water Research Project 1973, fig. 6-5.

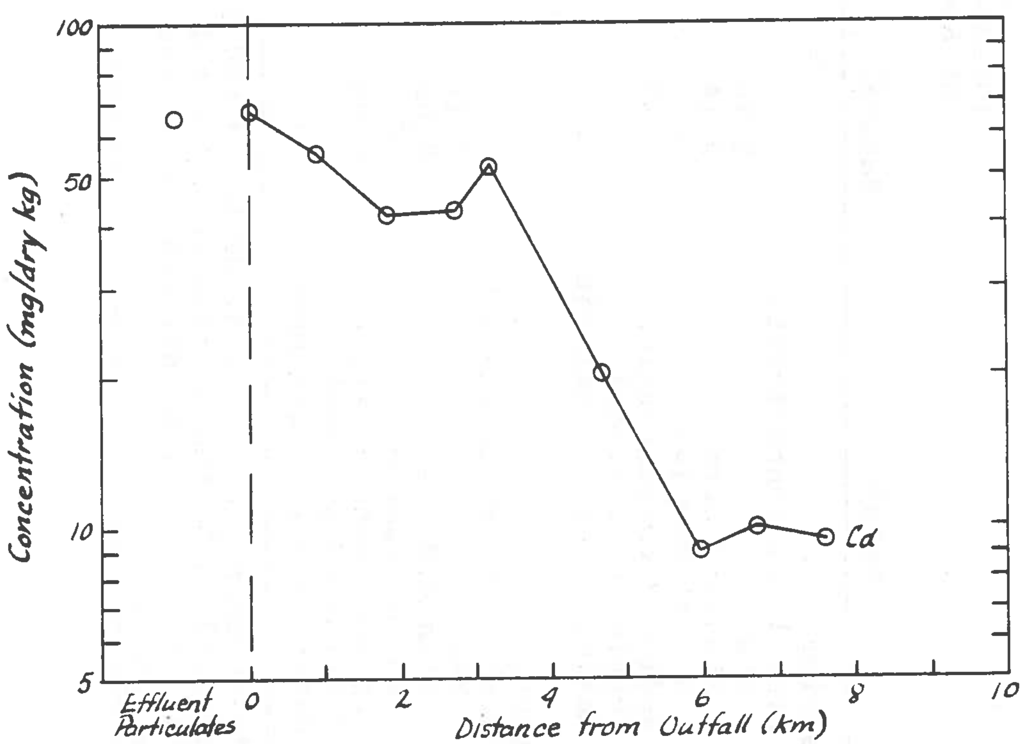

Figure 9. Distribution of cadmium in surface sediments along the 100-m depth contour to the northwest of the 90-in. outfall off Whites Point. From Hendricks and Young 1974.

Table 5. Cadmium and mercury concentrations in samples of Dover sole liver tissue (mg/wet kg) and surface sediments (mg/dry kg) collected in southern California coastal waters.*

Metal	Collection Site (Grouped According to Degree of Sediment Contamination): Natural	Intermediate	High	Very High	Probability**
Cadmium					
Fish liver concentration					
Mean	0.58	0.29	0.33	0.19	$0.001 < p < 0.01$
Standard error	0.14	0.03	0.08	0.03	
No. of samples	6	9	12	11	
Sediment concentration (estimated average)	0.37	-	-	59	
Ratio, liver to sediment	2	-	-	0.003	
Mercury					
Fish liver concentration					
Mean	0.11	0.14	0.19	0.11	$p > 0.30$
Standard error	0.02	0.01	0.03	0.007	
No. of samples	6	9	12	12	
Sediment concentration (estimated average)	0.04	-	-	3.4	
Ratio, liver to sediment	3	-	-	0.03	

*Measurements by J. J. M. de Goeij and V. P. Guinn, University of California, Irvine, reported in Southern California Coastal Water Research Project 1973, tab. 7-12.
**Probability (p) of differences in means for "natural" and "very high" areas occurring by chance.

effluent particulates are generally two orders of magnitude greater than natural concentrations on ocean bottom sediments at the submarine discharge sites.

3. Although surface runoff is a relatively minor source of cadmium and mercury to the Bight, contributing less than 5 percent the amount introduced via submarine municipal discharges, a correlation between concentrations of suspended sediment and most trace metals was observed in storm flow samples. On the average, 78 percent of the cadmium in these samples was retained on a 0.45-micron filter.

4. Effluents representative of major types of industries discharging directly into the Los Angeles Harbor generally were found to contain only small concentrations of mercury. The highest level observed was eight times the average concentration measured in seawater (0.000030 mg/L, or 30 parts per trillion), but the flows were such that direct industrial discharge of mercury appears to be insignificant relative to inputs via municipal wastewaters.

5. More than three-fourths of the cadmium estimated to enter the waters of the Bight annually from the adjacent coastal plain is carried via municipal wastewaters. Most of this 54 metric tons per year is carried via the major submarine discharges within about 30 km of Palos Verdes Peninsula off Los Angeles, making this area a semipoint source of cadmium to the Bight.

6. However, there is no evidence of regional contamination of the nearshore biota with cadmium from the municipal wastewater discharges off Los Angeles and Orange Counties. On the average, intertidal mussels of the Los Angeles/Orange County Basin contained no higher cadmium concentrations in their digestive glands than did specimens from six sparsely populated islands in the Bight, 30 to 100 km off the coast.

7. There is some evidence of regional contamination of the ocean bottom sediments of the Bight by mercury (but not cadmium). This enrichment appears to have begun about 1900, and sediments deposited between 1942 and 1962 in the Santa Barbara Basin (relatively far removed from specific mercury sources) contain about twice the mercury concentrations found in sediments deposited between 1835 and 1858.

8. In contrast, ocean bottom sediments around discharges from the Los Angeles City and Los Angeles County submarine outfalls contain cadmium and mercury concentrations up to 100 times natural levels. Despite this, flatfish trawled from these areas, and believed from independent evidence to have inhabited these contaminated sediments, showed no accumulation of either cadmium or mercury above natural levels in their liver tissue.

REFERENCES

de Goeij, J. J. M., V. P. Guinn, and D. R. Young. 1972. Activation analysis trace-element studies of marine biological samples. Trans. Amer. Nucl. Soc. 15:642.

de Goeij, J. J. M., V. P. Guinn, D. R. Young, and A. J. Mearns. 1974. Activation analysis trace element studies of Dover sole liver and marine sediments. In Comparative studies of food and environmental contamination, proceedings of an IAEA/FAO/WHO symposium, 27-31 August 1973, Otaniemi, Finland. Intl. Atomic Energy Agency, Vienna.

Hendricks, T. J., and D. R. Young. 1974. Modeling the fates of metals in ocean-discharged wastewaters. Rept. TM 208, Southern California Coastal Water Research Project, El Segundo, Calif.

Southern California Coastal Water Research Project. 1973. The ecology of the Southern California Bight: Implications for water quality management. Rept. TR 104, So. Calif. Coastal Water Res. Proj., El Segundo, Calif.

Young, D. R., J. N. Johnson, A. Soutar, and J. D. Isaacs. 1973a. Mercury concentrations in dated varved marine sediments collected off southern California. Nature 244:273-4.

Young, D. R., C. S. Young, and G. E. Hlavka. 1973b. Sources of trace metals from highly urbanized southern California to the adjacent marine ecosystem. In Cycling and control of metals, Natl. Environ. Res. Center, Cincinnati, Ohio.