Contamination of Recreational Seafood Organisms off Southern California

Contaminant levels in marine organisms and sediments in and around Santa Monica Bay decreased from the early 1970s to the mid-1980s (MBC 1988, 1993; Mearns *et al.* 1991). However, many of the organisms analyzed were not seafood species and contaminant levels in seafood organisms had not been measured since the mid-1980s. Growing public concern about pollution in the coastal waters off Southern California prompted the Santa Monica Bay Restoration Project (SMBRP) (US Environmental Protection Agency National Estuary Program) to fund a study of chemical contamination of seafood organisms from the Santa Monica Bay area. This study would provide up-to-date information on contaminant levels in seafood organisms needed for risk assessment.

The objectives of the seafood study were to: 1) determine chlorinated hydrocarbon and trace metal concentrations in white croaker (*Genyonemus lineatus*) and yellow rock crab (*Cancer anthonyi*) collected from Santa Monica Bay, the Palos Verdes Shelf, and Dana Point (reference site), and 2) compile and review available historical data on seafood contamination in the area. A detailed account of sampling protocols, analytical methods, and results are presented in SCCWRP *et al.* (1992).

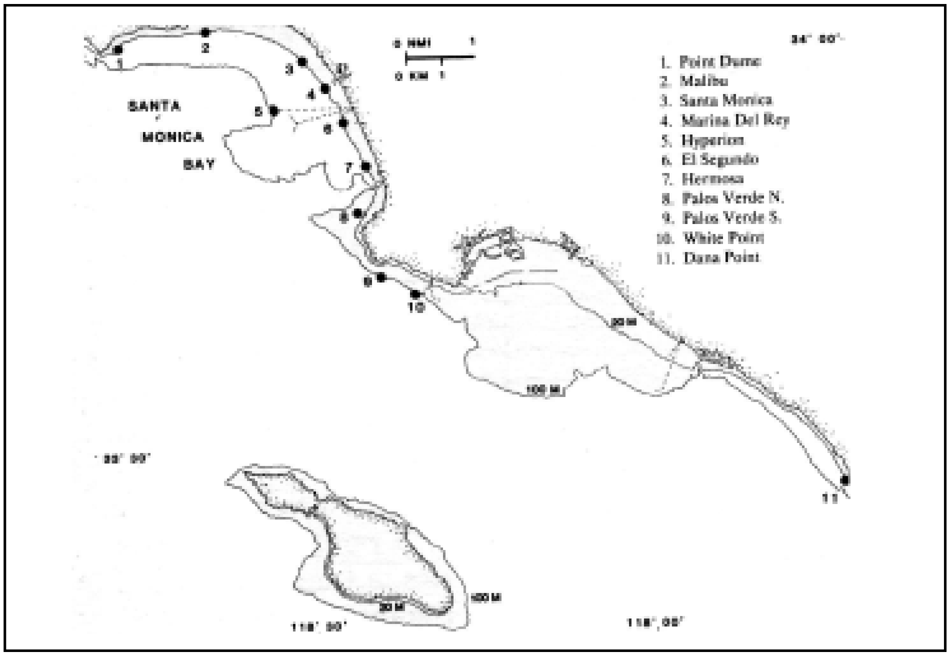
Fishermen on Cabrillo Pier.

Materials and Methods

MBC Applied Environmental Sciences developed the historical database of anthropogenic chemical contamination of the edible portion of fish and invertebrate species from Santa Monica Bay by compiling information in published and unpublished reports (primarily Risebrough 1987, Mearns *et al.* 1991, and Pollock *et al.* 1991) that covered samples collected from 1973 to 1987.

We collected new data on white croaker and yellow rock crab in September 1990 from sites in Santa Monica Bay, on the Palos Verdes Shelf, and off Dana Point (Figure 1). White croaker were collected by 7.6-m otter trawl and by angling with hook and line; yellow rock crab were collected by baited

Figure 1.
Collection stations for white croaker (*Genyonemus lineatus*) and yellow rock crab (*Cancer anthonyi*) in September 1990.



traps.

Twenty white croaker were collected from each of 11 stations and 20 yellow rock crab were collected from each of two stations. Fish and crabs were frozen on board ship and segregated into five composites of four individuals for each site in the laboratory. An equal amount of edible muscle tissue was dissected from all individuals in each composite in a MAC 10 2448 Clean Work Station. Composites were homogenized in a Brinkman polytron blender with a titanium blade and analyzed by the University of Santa Cruz Trace Organics Facility.

Organochlorine pesticides and PCBs (Aroclors, DDTs, DDMU, HCH, HCB, and chlordane; see Appendix for abbreviations and definitions) were analyzed by high resolution gas chromatography on a Hewlett-Packard 5890A GC with a ^{63}Ni electron capture detector by a modified version of EPA method 8080; detection limits were 0.05 ppb wet weight. Polychlorinated dibenzo-*p*-dioxin (PCDD) and polychlorinated dibenzofurans (PCDF) were analyzed by high resolution gas chromatography-high resolution mass spectrometry using EPA method 8290; detection limits ranged from 0.15 to 4.3 pptr wet weight. Selenium was analyzed by a modified EPA method 7741 on a Varian Spectra 30 Atomic Absorption Spectrophotometer; detection limits were 20 ppb wet weight. Lead was analyzed by a modified EPA method 7421 on a deuterium corrected PE 5000 Graphite Furnace Atomic Absorption Spectrophotometer; detection limits were 2 ppb wet weight.

The data were summarized by arithmetic means, standard deviations, and ranges. Concentration differences among animals from the sites in 1990 were tested by analysis of variance (white croaker) and t-tests (yellow rock crab). The data were tested for homogeneity of variances using Box-Andersen, Tukey jackknife, and Levine median tests. If variances were not homogeneous, the data were transformed using log, natural log, reciprocal, or square root transformations as appropriate.

A t-test was used to detect changes in contaminant levels of white croaker collected in 1987 (Pollock *et al.* 1991) and in 1990. Comparisons of total PCBs were based on Aroclors 1254 and 1260 because Aroclor 1242 was not quantified in the 1987 study. Method detection limits in the 1987 study were 38 ppb for DDT and 50 ppb for PCBs, but data were presented below these limits. Uncensored data were used in the t-tests comparing 1987 and 1990 data to avoid data truncation problems resulting from censoring data below method detection limits. However, we examined the effect of censoring DDT and PCB data below the method detection limits on the mean,

Figure 2.

Mean concentrations of total PCB (sum of Aroclors 1242, 1254, and 1260) in composites (five per site) of white croaker (*Genyonemus lineatus*) collected from coastal Southern California in September 1990.

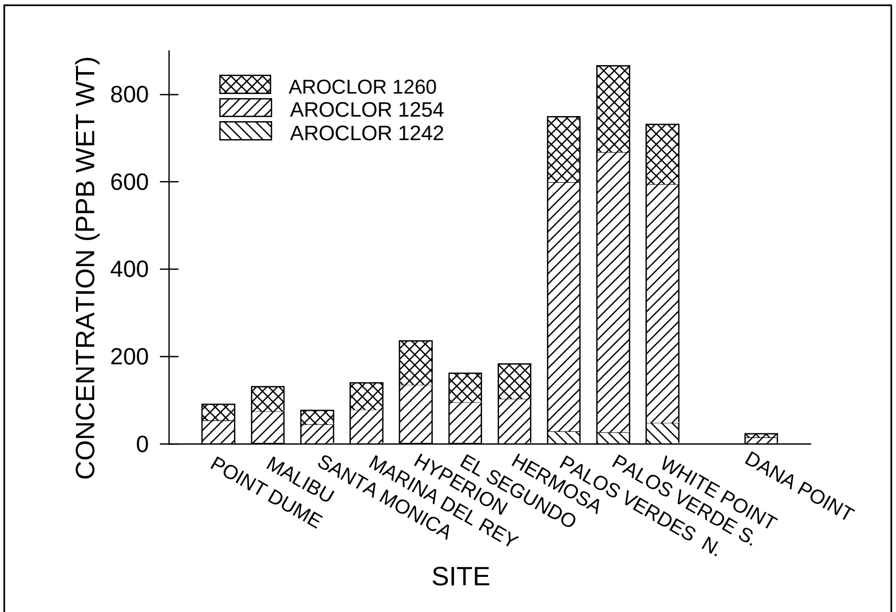
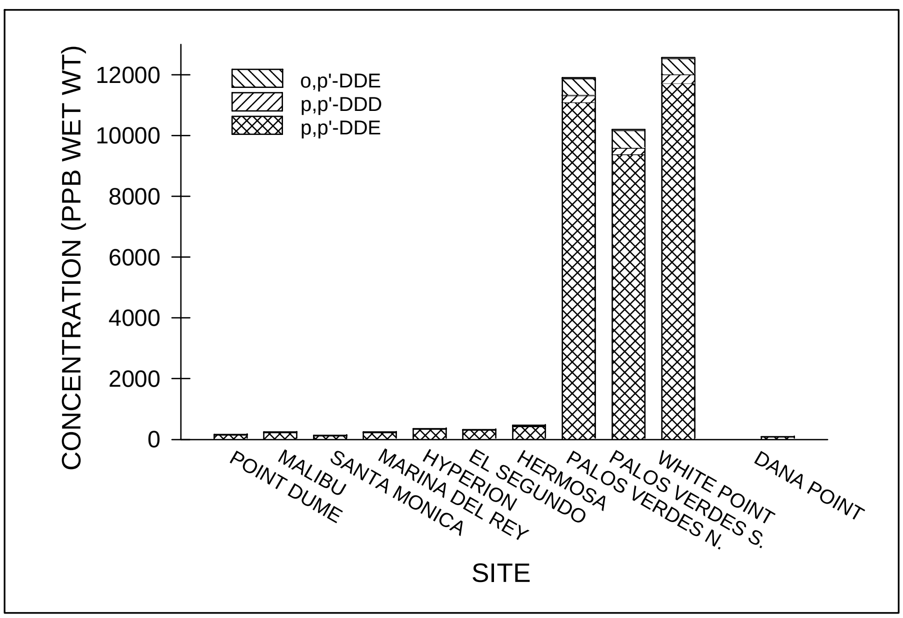


Figure 3.

Mean concentrations of total DDT (sum of DDT, DDE, and DDD) in composites (five per site) of white croaker (*Genyonemus lineatus*) collected from coastal Southern California in September 1990.



standard deviations, and confidence limits of 1987 and 1990 data.

Results

Spatial Distribution in 1990

White croaker from the Palos Verdes Shelf (at sites Palos Verdes North, Palos Verdes South, and White Point; Figure 1) had significantly higher levels of PCB, DDT, DDMU, HCH, HCB, and chlordane than elsewhere (Figures 2 and 3; Table 1). In 1990, PCDDs were detected at quite low concentrations (<1 pptr) in white croaker tissue from Malibu and El Segundo. Tetrachloro dibenzo-*p*-dioxin isomers were detected at Malibu and El Segundo, and heptachloro dibenzo-*p*-dioxin isomers were detected at Malibu. Total PCDFs were detected in all composites. Concentrations ranged from 12 to 27 pptr in Santa Monica Bay and the Palos Verdes Shelf, but were <1 pptr at Dana Point.

Yellow rock crab from the Palos Verdes Shelf (White Point) had significantly higher concentrations of PCBs, DDT, and HCB than those from Dana Point, but yellow rock crab from Dana Point had significantly higher levels of HCH, chlordane, and selenium (Figures 4 and 5; Table 2).

On the Palos Verdes Shelf, white croaker had concentrations of DDT that were three orders of magnitude, and concentrations of PCBs that

Table 1.

Results of ANOVA and Student-Newman-Keuls (SNK) analyses on contaminant levels in edible muscle tissue of white croaker *(Genyonemus Lineatus)* from Southern California in September 1990. Number of samples per site=5; all ANOVA p<0.0005. Horizontal SNK Lines connect values that are not significantly different.

CONTAMINANT	MEAN CONCENTRATION (PPB) BY SITE [a]										
	DP	SM	PD	M	MDR	ES	HB	H	WP	PVN	PVS
PCB	23	77	90	131	139	162	183	235	731	749	866
	DP	SM	PD	MDR	M	ES	H	HB	PVS	PVN	WP
DDT	87	137	159	248	246	325	357	461	10,255	11,904	12,574
	DP	SM	PD	MDR	ES	M	H	HB	PVS	PVN	WP
DDMU	4	10	10	14	15	17	17	36	768	807	849
	H	ES	HB	MDR	SM	DP	PD	M	PVN	WP	PVS
HCB	<0.05	<0.05	<0.05	0.05	0.06	0.06	0.07	0.07	0.19	0.24	0.26
	DP	PD	MDR	H	SM	HB	ES	M	WP	PVS	PVN
HCH	0.27	0.38	0.63	0.64	0.65	0.71	0.77	0.77	0.97	1.18	1.30
	DP	PD	SM	HB	M	ES	MDR	H	PVS	PVN	WP
Chlordane	2.3	3.6	5.3	6.7	6.8	9.2	9.8	10.2	17.1	18.7	19.3
	SM	PD	M	DP	MDR	ES	HB	H	PVS	PVN	WP
Selenium	250	268	270	274	320	332	394	652	722	756	1,216

[a]Site abbreviations: DP (Dana Point); ES (El Segundo); H (Hyperion); HB (Hermosa Beach); M (Malibu); MDR (Marina del Rey); PD (Point Dume); PVN (Palos Verdes North); PVS (Palos Verdes South); SM (Santa Monica); WP (White Point).

were two orders of magnitude, higher than yellow rock crab. Concentrations of DDMU, HCB, HCH, and chlordane were quite low in yellow rock crab at all locations; concentrations in white croaker were 10 to 1,000 times higher.

Selenium concentrations in white croaker tissue were more uniformly distributed among the sites than were those of the trace organic contaminants. Selenium concentrations were about two times higher in yellow rock crab than in white croaker on the Palos Verdes Shelf, and more than 10 times higher in rock crab than in croaker off Dana Point.

Figure 4.

Mean concentrations of total PCB (sum of Aroclors 1242, 1254, and 1260) in composites (five per site) of yellow rock crab (*Cancer anthonyi*) collected from White Point and Dana Point in Southern California in September 1990.

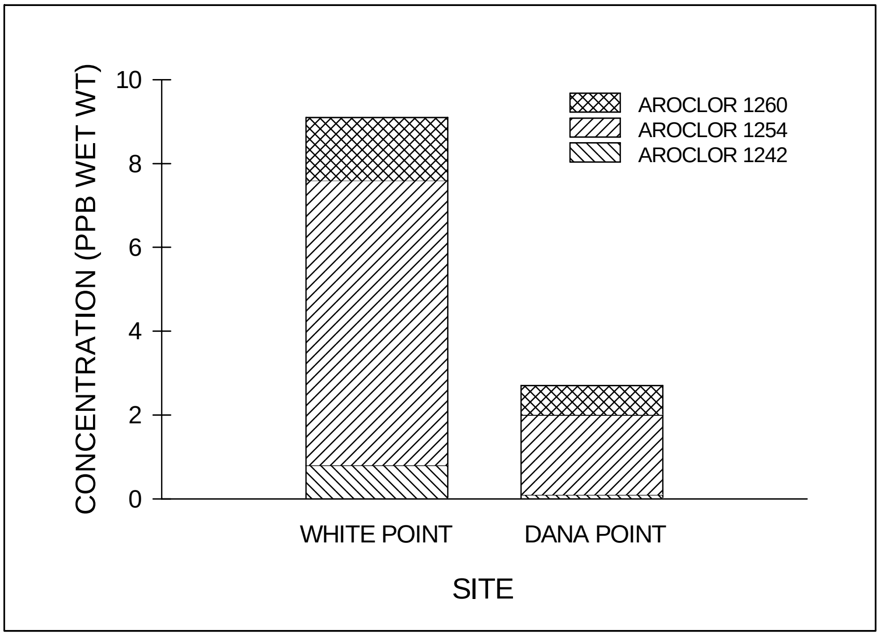
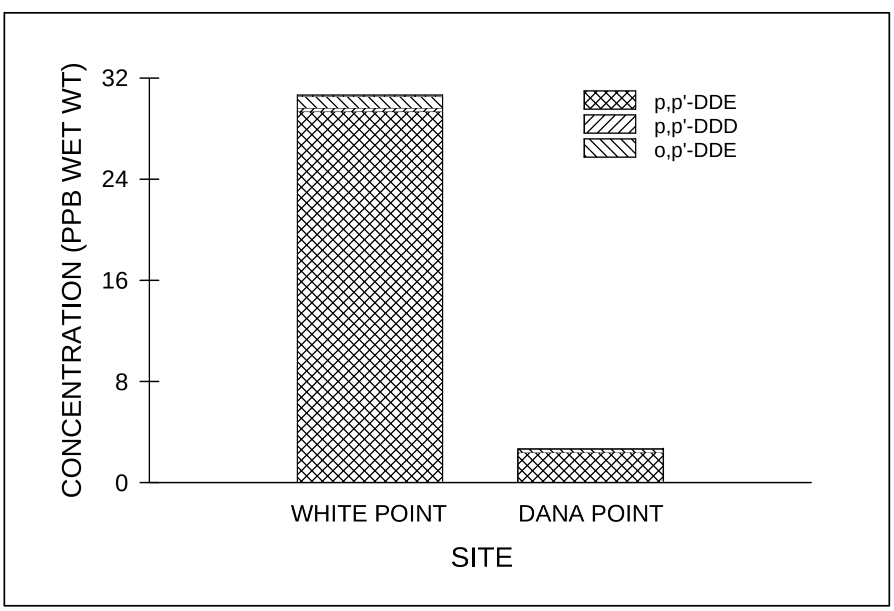


Figure 5.

Mean concentrations of total DDT (sum of DDT, DDE, and DDD) in composites (five per site) of yellow rock crab (*Cancer anthonyi*) collected from White Point and Dana Point in Southern California in September 1990.



Historical Data

Data on contaminant levels of seafood organisms collected in Santa Monica Bay were available as far back as the late 1960s and early 1970s. The most extensive studies were conducted by SCCWRP from 1973 to 1981. In the 1980s, tissue contaminant data were collected by the National Marine Fisheries Service, Los Angeles Regional Water Quality Control Board, City of Los Angeles Hyperion Treatment Plant, County Sanitation Districts of Los Angeles County, and California Department of Health Services (Risebrough 1987, Mearns *et al.* 1991, Pollock *et al.* 1991). The most extensive survey during that period was by the California Department of Health Services in 1986-1987 (Pollock *et al.* 1991).

Historical seafood contamination data were available for 22 species of fish, three species of crustaceans, and two species of mollusks (Table 3). Although some species were extensively sampled and analyzed during certain periods, the only species that was examined from the 1970s into the 1990s was white croaker. California scorpionfish (*Scorpaena guttata*), kelp bass (*Paralabrax clathratus*), Pacific sanddab (*Citharichthys sordidus*), and Dover sole (*Microstomus pacificus*) were sampled and analyzed during the 1970s and 1980s. Pacific sanddab

Table 2.

Results of t-tests comparing concentrations of contaminants in muscle tissue of the yellow rock crab (*Cancer anthonyi*) between White Point and Dana Point, California in 1990. Five samples per site. SD=one standard deviation, t=t-test statistic.

	CONCENTRATION (PPB)					
	WHITE POINT		DANA POINT			
Contaminant	Mean	SD	Mean	SD	t	p[a]
Arsenic	13,280	3,986	13,040	3,809	0.025	ns
Selenium	2,180	335	2,940	513	-3.265	*
DDT	30.8	22.0	2.9	1.9	3.837	**
Lead	22.1	5.0	9.4	3.6	0.289	ns
PCB	9.0	5.6	2.7	0.8	5.038	**
DDMU	0.35	0.39	0.37	0.43	-0.148	ns
Chlordane	0.31	0.08	0.34	0.07	-6.960	**
HCB	0.24	0.09	0.05	0.02	7.400	**
HCH	0.17	0.03	0.25	0.09	-18.559	**

[a]ns: $p>0.05$; * $p<0.05$; ** $p<0.01$.

and Dover sole are not taken by recreational or commercial fishermen in Santa Monica Bay although they are important commercial species in Central and Northern California.

Spiny dogfish taken from the Palos Verdes Shelf in 1980-1981 had the highest tissue levels [maximum values to 200 ppm DDT (mean 94 ppm) and 15 ppm PCBs (mean 6 ppm)]. Of the bony fishes, white croaker had the highest levels of DDT and PCB at every location in all surveys.

During the past two decades, the maximum tissue values of DDT and PCBs have decreased in all species with time series data (Table 4); this was generally the case for mean values as well. Both mean and maximum concentrations of DDT and PCBs decreased dramatically in Dover sole, Pacific sanddab, California scorpionfish, and kelp bass between the 1970s and 1980s. The highest values of DDT in these species always occurred in animals collected on the Palos Verdes Shelf. Although this was generally true for PCBs, in 1987 the highest concentrations for white croaker were found at Malibu and in 1981, the highest concentrations for California scorpionfish were found at the 5-mile outfall in Santa Monica Bay.

Temporal Changes by Region and Site

Although samples were generally collected from each region in different years, they were seldom collected from the same site. DDT levels in white croaker collected from the Palos Verdes Shelf and Santa Monica Bay have decreased since the early 1970s; PCB levels have decreased on the Palos Verdes Shelf but not in Santa Monica Bay. However, tissue levels of PCBs and DDT in white croaker were higher at some sites in 1990 than in 1987 (Tables 5 and 6). Since the 1970s, PCB levels in yellow rock crab decreased at Dana Point, but DDT levels did not.

Discussion

Historically deposited contaminated sediments on the Palos Verdes Shelf are the

Table 3.

Maximum reported concentrations of total DDT and PCB in muscle tissue of seafood organisms from Santa Monica Bay (including the Palos Verdes Shelf) by decade. Sources of data cited in SCCWRP *et al.* (1992).

		MAXIMUM CONCENTRATION (PPM WET WEIGHT) [a]					
		DDT			PCB		
COMMON NAME	SCIENTIFIC NAME	1970s	1980s	1990[b]	1970s	1980s	1990[b]
MOLLUSKS							
giant rock scallop	*Crassedoma giganteum*	0.225	—	—	0.020	—	—
black abalone	*Haliotis cracherodii*	0.002	—	—	0.037	—	—
CRUSTACEANS							
ridgeback rock shrimp	*Sicyonia ingentis*	—	0.450	—	—	0.089	—
California spiny lobster	*Panulirus interuptus*	1.490	—	—	0.282	—	—
yellow rock crab	*Cancer anthonyi*	—	—	0.062	—	—	0.029
FISHES							
spiny dogfish	*Squalus acanthias*	—	200.056	—	—	14.800	—
California lizardfish	*Synodus Lucioceps*	—	0.162	—	—	0.023	—
California scorpionfish	*Scorpaena guttata*	5.220	1.397	—	0.985	0.217	—
rockfishes, unid.	*Sebastes* spp.	—	0.383	—	—	0.076	—
bocaccio	*Sebastes paucispinis*	—	3.940	—	—	0.382	—
sablefish	*Anoplopoma fimbria*	0.231	—	—	0.268	—	—
kelp bass	*Paralabrax clathratus*	67.000	0.446	—	—	0.080	—
barred sand bass	*Paralabrax nebulifer*	—	0.035	—	—	0.050	—
black croaker	*Cheilotrema saturnum*	—	0.038	—	—	0.070	—
white croaker	*Genyonemus lineatus*	176.400	100.800	18.336	9.950	3.539	2.854
California corbina	*Menticirrhus undulatus*	—	0.201	—	—	0.212	—
queenfish	*Seriphus politus*	—	0.191	—	—	1.119	—
opaleye	*Girella nigricans*	—	0.000	—	—	0.003	—
surfperches, unid.	Embiotocidae, unid.	—	0.137	—	—	0.051	—
black perch	*Embiotoca jacksoni*	87.000	—	—	—	—	—
Pacific barracuda	*Sphyraena argentea*	—	0.317	—	—	0.060	—
Pacific bonito	*Sarda chiliensis*	—	0.183	—	—	0.112	—
chub mackerel	*Scomber japonicus*	—	0.115	—	—	0.057	—
Pacific sanddab	*Citharichthys sordidus*	75.278	0.024	—	3.159	0.076	—
California halibut	*Paralichthys californicus*	—	0.035	—	—	0.028	—
Dover sole	*Microstomus pacificus*	123.764	12.990	—	10.423	0.505	—
English sole	*Pleuronectes vetulus*	3.501	—	—	1.172	—	—

[a]Means, medians, and ranges were variously presented in data sources. Means and medians were not always reported but ranges were always available.

[b]Data from present study.

primary source of DDT and PCBs off Los Angeles (Mearns *et al.* 1991, MBC 1993), and probably the primary source of the significantly higher DDT, PCB, and HCB concentrations in white croaker and yellow rock crab collected off Palos Verdes in this study. Although white croaker had significantly higher levels of DDMU, HCH, and chlordane on the Palos Verdes Shelf, yellow rock crab (a less mobile species) had significantly higher levels of these contaminants at Dana Point. White croaker collected off Palos Verdes may have accumulated some of their body burdens elsewhere, such as Los Angeles-Long Beach Harbors (Mearns *et al.* 1991) or sediments near the Hyperion 5-mile or 7-mile outfalls. Relatively high levels of PCBs were found in California scorpionfish near the Hyperion 5-mile outfall in 1981 (Gossett *et al.* 1983).

Table 4.
Total DDT and PCB in muscle tissue of seafood organisms from Santa Monica Bay and the Palos Verdes Shelf by decade from the 1970s to the 1990s.

	CONCENTRATION (PPM WET WEIGHT)					
	DDT			PCB		
SPECIES[a]	1970s	1980s	1990[b]	1970s	1980s	1990[b]
kelp bass						
mean	—[c]	0.1	—	—	0.0	—
maximum	67.0	0.4	—	—	0.0	—
minimum	0.2	0.0	—	—	0.1	—
n	126	40	—	—	40	—
site with maximum	PV[d]	PV	—	—	PV	—
white croaker						
mean	39.0	3.8	2.4	2.8	0.3	0.6
maximum	176.4	100.8	18.3	10.0	3.5	2.9
minimum	5.2	0.0	0.0	0.3	0.0	0.0
n	10	99	50	10	99	50
site with maximum	PV	PV	PV	PV	Mal	PV
Dover sole						
mean	14.7	7.2	—	1.1	0.3	—
maximum	123.8	13.0	—	10.4	0.5	—
minimum	0.2	3.6	—	0.1	0.2	—
n	31	5	—	31	5	—
site with maximum	PV	PV	—	PV	PV	—
Pacific sanddab						
mean	17.3	0.0	—	0.5	0.0	—
maximum	75.3	0.0	—	3.2	0.1	—
minimum	0.0	0.0	—	0.0	0.0	—
n	44	5	—	44	5	—
site with maximum	PV	PV	—	PV	PV	—
California scorpionfish						
mean	3.6	0.2	—	0.6	0.0	—
maximum	5.2	1.4	—	1.0	0.2	—
minimum	2.0	0.0	—	0.4	0.0	—
n	4	58	—	4	58	—
site with maximum	PV	PV	—	PV	SMB	—

[a]Scientific names: kelp bass (*Paralabrax clathratus*); white croaker (*Genyonemus lineatus*); Dover sole (*Microstomus pacificus*); Pacific sanddab (*Citharichthys sordidus*); California scorpionfish (*Scorpaena guttata*).
[b]Data from present study.
[c]Data from Smokler *et al*. (1979). Medians were given for season and area.
[d]Mal = Malibu; PV = Palos Verdes Shelf; SMB = Santa Monica Bay (5-mile outfall).

The significant increase in PCBs and DDT in white croaker at Palos Verdes North and White Point, and the increase in DDT at Palos Verdes South, between 1987 and 1990 may be due to differences in analytical methods, increased release of contaminants from the sediments, inclusion of fish that have spent more time feeding in contaminated areas, or other reasons.

Although tissue contamination in seafood organisms collected on the Palos Verdes Shelf generally decreased during the past decade, DDT and PCB concentrations were still higher there in 1990 than in Santa Monica Bay or at Dana Point. Levels of total PCB and total DDT in surface sediments on the Palos Verdes Shelf have declined since the mid1970s as contaminated sediments were progressively buried by cleaner particles. Nevertheless, the concentration of DDT and PCBs in surface sediments are higher on the Palos Verdes Shelf than elsewhere in Santa Monica Bay (MBC 1993).

During the past two decades, the mass emissions of PCBs and DDTs from the Joint Water Pollution Control Plant's White Point outfall and Hyperion's 5-mile and 7-mile outfalls in Santa Monica Bay have significantly decreased. Mass emissions of DDT from the White Point outfall declined from 1.44 mt in 1974

Table 5.

Results of t-tests comparing arithmetic mean concentrations of total PCBs (Aroclors 1254+1260)[a] in edible muscle tissue of white croaker (*Genyonemus lineatus*) from Southern California in 1987 and 1990. Five samples per site. SD=one standard deviation; t=t-test statistic; p=probability.

	PCB CONCENTRATION (PPB)					
	1987		1990			
SITE	Mean	SD	Mean	SD	t	p[b]
Point Dume	309	196	89	23	2.574	ns
Malibu	552	169	130	41	7.074	**
SM/Venice Piers (1987)	81	78				
Santa Monica (1990)			76	69	0.113	ns
Marina del Rey	51	31	138	95	1.963	ns
Palos Verdes NW (1987)	94	52				
Palos Verdes N (1990)			721	202	3.675	*
Point Vicente (1987)	526	88				
Palos Verdes S (1990)			839	478	0.512	ns
White Point	288	167	683	142	4.024	**
Dana Point	1	2	22	10	7.759	**

[a] Aroclor 1242 was not measured in 1987 data (Pollock *et al.* 1991); hence only sum of Aroclors 1254 and 1260 were compared

[b] ns: $p>0.05$; * $p<0.05$; ** $p<0.01$.

Table 6.

Results of t-test comparing arithmetic mean concentrations of total DDTs (DDT+DDE+DDD) in edible muscle tissue of white croaker (*Genyonemus lineatus*) from Southern California in 1987 and 1990.

	DDT CONCENTRATION (PPB)					
	1987		1990			
SITE	Mean	SD	Mean	SD	t	p[a]
Point Dume	287	224	159	35	0.092	ns
Malibu	532	206	246	145	2.538	*
SM/Venice Piers (1987)	87	74				
Santa Monica (1990)			137	110	0.845	ns
Marina del Rey	66	38	243	139	2.232	*
Palos Verdes NW (1987)	355	186				
Palos Verdes N (1990)			11,904	3,775	7.033	**
Point Vicente (1987)	2,673	472				
Palos Verdes S (1990)			10,196	6,237	4.535	*
White Point	2,625	1,791	12,574	2,961	6.428	**
Dana Point	6	4	88	64	6.043	**

[a] ns: $p>0.05$; * $p<0.05$; ** $p<0.01$.

to zero in 1991; mass emissions of PCBs declined from 5.16 mt in 1974 to zero in 1991 (Mitchell and McDermott 1975, SCCWRP 1992). Mass emissions of DDT from the Hyperion outfalls decreased from 0.82 mt in 1975 to zero in 1991; mass emissions of PCBs decreased from 1.99 mt in 1975 to zero in 1991 (Shafer 1976, SCCWRP 1992). The reductions of contaminant levels in municipal wastewater effluents discharged into Santa Monica Bay during the past two decades is due to source control and improved wastewater treatment practices (Shafer 1989). The declines in PCB and DDT levels in seafood organisms during this period confirm the importance of these measures in reducing contaminant levels in seafood organisms in Santa Monica Bay.

Benthic seafood organisms generally had higher muscle tissue concentrations of chlorinated hydrocarbons than pelagic organisms. Benthic species are more likely to live near a source of contamination while pelagic species are more likely to move through a contaminated area. Hence, benthic species are more likely to accumulate contaminants from that source.

Spiny dogfish, a demersal shark, had the highest levels of chlorinated hydrocarbons in the historical data base (1980-1981; Shafer *et al.* 1982, Gossett *et al.* 1983).

This is probably due to a high liver lipid content and a high trophic position. Benthic fishes generally had higher levels of chlorinated hydrocarbons than benthic invertebrates because they usually occupy higher trophic levels. The high concentrations of contaminants in white croaker may be due to the high lipid content of its muscle tissue and/or its tendency to feed in contaminated sediments near outfalls.

The Dana Point site sampled in this and other studies is an appropriate reference site for most tissue contamination studies in the Southern California Bight. Contaminant levels have been consistently low there for the past 15 years. However, yellow rock crab from Dana Point had significantly higher concentrations of selenium, DDMU, chlordane, and HCH than rock crab from the Palos Verdes Shelf suggesting that Dana Point may not be a good reference site for these contaminants.

Conclusions

Although tissue levels of contaminants in seafood organisms have generally decreased during the past decade, concentrations of DDT and PCBs are still relatively high in organisms collected from the Palos Verdes Shelf and low in organisms collected off Dana Point. Sediments on the Palos Verdes Shelf are probably still the primary source of DDT and PCBs, however there may be additional sources of PCBs and other pesticides in the area. Chemical analytical methods have improved during the past two decades and past data may not be directly comparable to present data. Archived samples should be analyzed with current methods to determine the comparability of past and present data.

The Santa Monica Bay Restoration Project is studying the seafood consumption patterns of recreational anglers that fish in Santa Monica Bay. Information from the consumption study and the contamination study will be used to assess the risk of consuming seafood organisms caught in Santa Monica Bay.

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Appendix

Definitions of chemicals analyzed in tissue samples of white croaker and yellow rock crab in 1990.

Aroclor
trade name of commercial PCB mixture manufactured by Monsanto Corporation from 1930 to 1977. Product name has four numbers (e.g. 1242, 1254, 1260). First two digits indicate that biphenyl molecule contains 12 carbons, last two indicates percent by weight of chlorine.

Arsenic
toxic heavy metal; trioxide is used in insecticides and herbicides.

Chlordane
insecticidal chlorohydrocarbon used as a contact poison and fumigant; mixture *cis*- and *trans*-chlordane, chlordene, heptachlor, nonachlor, and other compounds.

DDD
dichlorodiphenyldichloroethane. Nondegradable insecticidal chlorohydocarbon derivative of DDT with two isomers: *o,p'*-DDD and *p,p'*-DDD. Used as subsurface control of termites and for dipping tops and roots of food plants.

DDE dichlorodiphenyldichoroethene. Main metabolic degradation product of DDT, but not an insecticide. Two isomers: *o,p'*-DDE and *p,p'*-DDE.

DDMU
dichlorodiphenylmonochloroethene. Metabolite of DDT.

DDT
dichlorodiphenyltrichloroethane. Polychlorinated nondegradable pesticide with two isomers: *o,p'*-DDT and *p,p'*-DDT. Toxic and potential human carcinogen.

HCB
hexachlorobenzene (also perchlorobenzene). Selective fungicide and used in organic syntheses.

HCH
hexachlorocyclohexane. Organochlorine insecticide with four isomers that differ in position of chlorine atoms: α-HCH, β-HCH, Γ-HCH (lindane), and σ-HCH (not quantified in this study). Lindane is an insecticide (contact, stomach, and respiratory poison) that is more toxic than DDT. Potential human carcinogen.

Lead
toxic heavy metal that exists in nature as lead sulfate and lead carbonate. Used extensively in alloys, storage batteries, electrical cable coverings, water and noise proofing, antiknock agents, paints, and high quality glass.

PCB
polychlorinated biphenyl. Derivatives of biphenyls in which 1 to 10 hydrogen atoms have been replaced by chlorine atoms; theoretically 209 isomers. Potential carcinogens. Industrial uses in capacitors, transformers, hydraulic fluid, plasticizers, adhesives, and fire retardants.

PCDD
polychorinated dibenzodioxins. Derivatives of dibenzodioxin where chlorine has replaced some hydrogen atoms; 75 isomers. Occur as trace impurities in aromatic compounds (e.g., chlorophenols), herbicides, and PCBs.

PCDF
polychlorinated dibenzofurans. Derivatives of dibenzofuran where chlorine has replaced some hydrogen atoms; 135 isomers. PCDDs occur as trace impurities in aromatic compounds (e.g., chlorophenols), herbicides, and PCBs.

Selenium
toxic metal present in soil as elemental selenium or as basic ferric selenate or calcium selenate. Trace quantities are a metabolic requirement. Present in plating, plastic, metal-working, chemical effluents, and fossil fuels.