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LEVELS OF TRACE ORGANIC COMPOUNDS IN SPORTFISH FROM SOUTHERN CALIFORNIA

The most important consideration in any study of contaminants in the environment is the question of whether human health is endangered. After considering ways in which Southern Californians might be exposed to significant levels of toxicants, we decided that the greatest hazard would come from eating fish containing DDT, polychlorinated biphenyls (PCB), or benzo(a)pyrene (BaP). In the research described here, we replicated the catching and cooking of fish by the subpopulation that was most likely to be exposed. Then we measured the concentrations of these and other trace organic compounds in the seafood and estimated the rate at which these contaminants could be consumed annually. We found that concentrations of DDT and PCB were elevated in sportfish residing in areas near sewage outfalls or in the Los Angeles Harbor. These levels do not exceed the World Health Organization 1971 recommended maximum safe daily intake of 5 ug/kg/day. BaP was not present in any of the samples and of all the species analyzed, white croaker had the highest levels of contaminants.

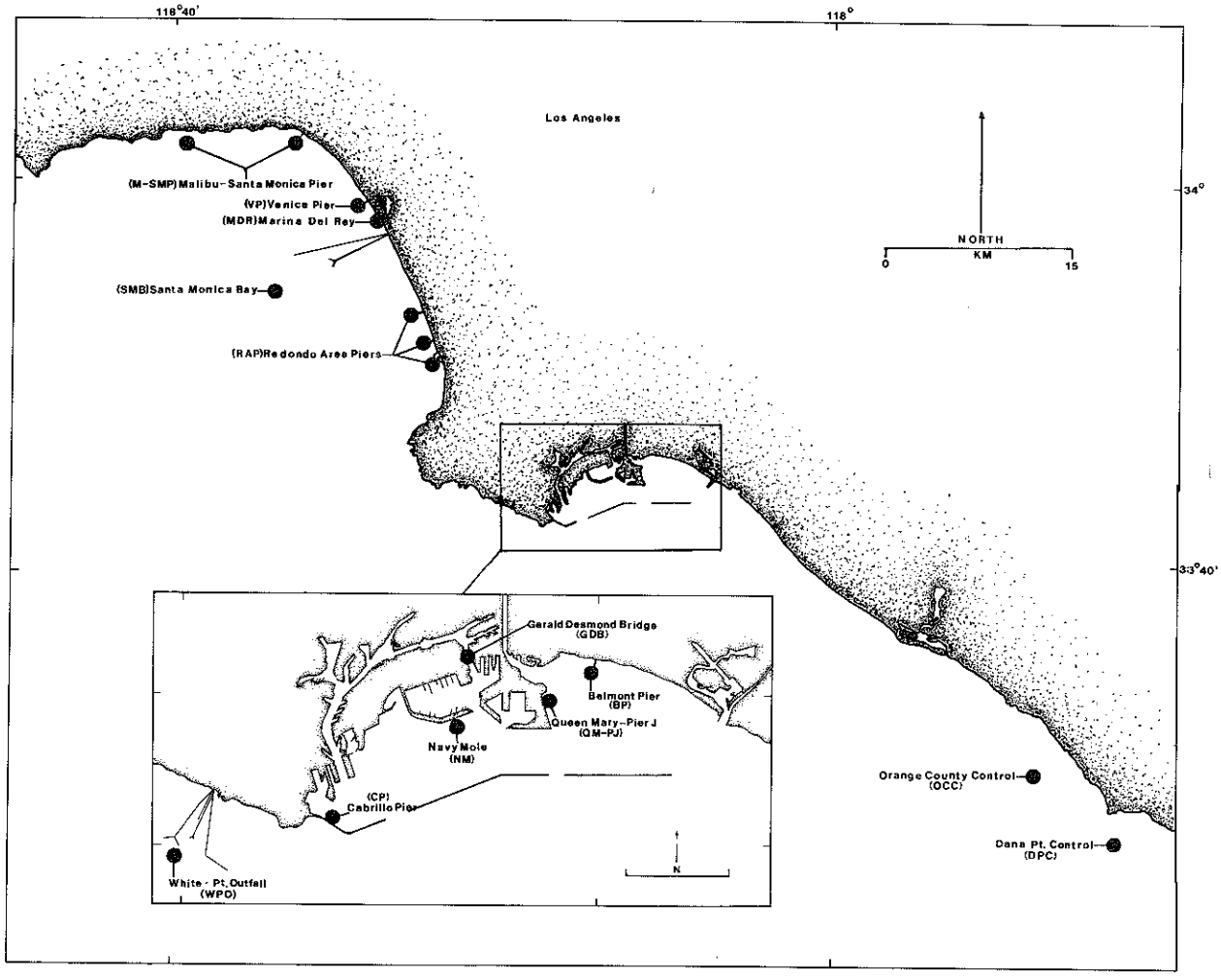
The sediments adjacent to the coast of southern California are contaminated with trace organic compounds whose main source is the submarine outfalls. Project research also has shown that certain trace organics such as DDT's and PCB's have the ability to bioaccumulate in animals commonly consumed by man. For example, white croaker sampled by trawls taken near the Los Angeles County (JWPCP) outfall in April 1975 contained mean concentrations of 39 mg/wet kg Total DDT and 2.8 mg/wet kg Total PCB (SCCWRP, unpublished data).

These results became of concern in 1978 when a survey of southern California sportfishermen conducted by the California Department of Fish and Game (Wine 1979) revealed that one-million angler trip hours per year were expended on fishing effort and that 30% of the fish caught were white croaker. The Department of Fish and Game did not attempt to determine the final disposition or use of fish being caught, but in 1980 the University of Southern California carried out an independent survey to assess the catch and consumption rates of sportfishermen (Puffer *et al.* 1981, 1982). The results of the USC survey indicated that there exists a subpopulation of sportfishermen along the southern California coast that catch and consume fish on a regular basis (14% go fishing 3-7 times/week). The survey also indicated that the median consumption rate for all species combined was 37 g/day/person (approximately twice the national average) and that pan-frying was the most common method of cooking.

METHODS

White croaker (*Genyonemus lineatus*) were sampled from eleven of the twelve stations used in the USC consumption survey (Figure 1), plus two coastal control stations known to have relatively lower chlorinated hydrocarbon inputs (Word and Mearns 1979). Five of these stations were chosen for more intensive sampling of four or more species of sportfish. These stations were: White Point, Cabrillo Pier, Santa Monica Bay, Belmont Pier and Orange County Control. A total of 15 additional species were collected, including scorpionfish (*Scorpaena guttata*), rockfish (*Sebastes* sp.), kelp bass (*Paralabrax clathratus*), barracuda (*Sphyraena argentea*), bonito (*Sarda chiliensis*), Pacific mackerel (*Scomber japonicus*), queenfish (*Seriphus politus*), white perch (*Phanerodon furcatus*), black perch (*Embiotoca jacksoni*), halibut (*Paralichthys californicus*), lizardfish (*Synodus lucioceps*), bocaccio (*Sebastes paucispinis*), corbina (*Menticirrhus undulatus*), barred sand bass (*Paralabrax nebulifer*) and flatfish (*Pleuronectidae* sp.).

In order to obtain results that would be representative of what a sportfisherman would catch, this study sampled fish using their methods. In most cases sampling was done by hook-and-line and in some cases, study participants sampled alongside sportfishermen on piers and sportfishing boats. Because the fish needed were not all catchable in the time frame available, some



samples were taken by trawling. The samples collected by trawl were (1) white croaker from offshore of White Point, (2) 40% of the black perch, white perch, halibut,and queenfish shown as coming from Cabrillo Pier, and (3) all samples except the white croaker from the Belmont Pier. In all cases the fish caught were handled in the same manner as a sportfisherman would treat his catch and were brought back to the laboratory and immediately frozen.

ANALYSIS

From four to forty fish (average of 20) were caught and randomly divided into five composites (when possible) for each species. Edible muscle tissue was dissected from each fish and pooled for each composite under clean laboratory conditions. All samples were kept frozen until analysis. The benzo(a)pyrene samples were kept wrapped in aluminum foil to prevent light from degrading the sample. Each sample was analyzed for the following: percent dry weight by freeze drying, percent lipid weight by chloroform/methanol extraction (Bligh and Dyer 1959), Total DDT and Total PCB by packed-column electron-capture gas chromatography, (Young *et al.*, 1976), and benzo(a)pyrene by high-pressure liquid chromatography using extraction methods of Dunn 1976). Total DDT includes the ortho plus para isomers of DDT, DDE, and DDD; total PCB includes Aroclor 1242 and Aroclor 1254.

RESULTS

White Croaker Survey

Results of the analysis of white croaker for Total DDT, Total PCB, and other physical measurements are listed in Table 1. Mean values at hook and line sportfishing locations ranged from 0.053 mg/wet kg Total DDT and 0.015 mg/wet kg Total PCB in the Malibu/Santa Monica Pier samples to 2.8 mg/wet kg Total DDT and 0.42 mg/wet kg Total PCB in the Gerald Desmond Bridge samples. Higher DDT levels were found in the white croaker trawled from the White Point station. These fish were collected from near the waste outfall to document what is probably the worst possible case; they are not normally caught by sportfishermen.

Table 1. Results of the analysis (n=5) of the edible muscle tissue of white croaker (*Genyonemus lineatus*) collected from the metropolitan Los Angeles area.

Group[a]	Station	Number Caught	Whole Body Wt. (gm)	Standard Length (mm)	Muscle Tissue % Dry/Wet Weight	Muscle Tissue % Lipid/Wet Weight	Total DDT mg/wet kg mean	Total DDT mg/wet kg ± 1 SD	Total PCB mg/wet kg mean	Total PCB mg/wet kg ± 1 SD
A	White Point[b]	25	118	177	22.2	1.68	7.6	3.5	0.38	0.11
B	Gerald Desmond Bridge	24	114	176	20.8	0.92	2.8	2.5	0.42	0.21
B	Cabrillo Pier	20	130	180	20.8	1.69	1.7	0.7	0.18	0.06
C	Santa Monica Bay	40	145	192	23.5	1.24	0.57	0.44	0.20	0.10
C	Venice Pier	15	158	193	20.1	1.30	0.69	0.95	0.099	0.076
C	Belmont Pier	24	99	167	21.0	1.32	0.45	0.31	0.10	0.05
D or E	Redondo Area Piers	25	178	204	20.3	0.55	0.22	0.17	0.055	0.046
D or E	Navy Mole	23	156	188	23.6	1.71	0.28	0.10	0.10	0.06
E	Queen Mary/ Pier J	28	142	182	21.7	0.99	0.17	0.10	0.085	0.052
C or D	Marina del Rey	25	164	198	20.7	0.71	0.77	0.16	0.12	0.16
E	Orange County-Control	25	182	212	21.3	0.89	0.14	0.08	0.018	0.007
E	Dana Pt.-Control	23	135	182	19.8	0.63	0.14	0.12	0.024	0.013
F	Malibu/Santa Monica Pier	15	213	210	20.6	0.36	0.053	0.017	0.015	0.004

[a]Grouping demonstrates the similarity in concentration of Total DDT based on results of Multiple Comparison Test (Zar, 1974).

[b]Sample was trawled and is unlikely to be regularly fished by sportfishermen.

There were several methods for analyzing the results statistically. First, we compared the Total DDT to the Total PCB median values for all the stations and found that the rankings were significantly similar ($r_s = 0.937$; $p < .001$) indicating a common source for both the Total DDT and Total PCB in white croaker at all stations. Next, we compared the stations and found there were statistically different concentrations of Total DDT and Total PCB between the stations. This indicated that some stations had significantly higher levels of these contaminants than others ($H_{DDT} = 46.54$, $H_{PCB} = 50.40$, DF = 12, $p < .001$). Finally, we compared the results from each station to all the others to determine which stations had similar concentrations. For example, the stations with the highest concentrations that were significantly different from the other stations formed one group. Then the stations with the next highest concentrations formed the next and so on.

The Total DDT values for the thirteen stations were ranked into 6 groups and are presented in Table 1. The trend was similar for Total PCB. White Point and the Gerald Desmond Bridge fell in the group that had the highest levels of Total PCB. Cabrillo Pier, Santa Monica Bay, Venice Pier, Belmont Pier, Marina Del Rey, Navy Mole,and Queen Mary/Pier J stations were all in an intermediate group. The two control sites, Orange County and Dana Point were in the group with the Malibu/Santa Monica Pier that had the lowest concentration. The Redondo Area Piers results were between the intermediate group and the group with the lowest concentration.

Intensive Survey

Four stations with elevated concentrations of DDT and PCB measured in the white croaker samples, plus one control station, were resampled for an additional four or more species of sportfish. The stations chosen were White Point, Cabrillo Pier, Santa Monica Bay, Belmont Pier, and Orange County Control. The samples from Cabrillo Pier and Belmont Pier stations were collected at the same location as the white croaker,but the White Point, Santa Monica Bay and Orange County Control stations were sampled from sportfishing boats and varied up to approximately 3 km from the original white croaker sampling stations.

The results of the analysis of the edible muscle tissue for Total DDT (DDE+DDD+DDT) and Total PCB (Aroclor 1242+Aroclor 1254) are listed in Table 2. The mean Total DDT concentrations for all stations combined ranged from 0.036 mg/wet kg in rockfish from the Orange County Control station to 0.76 mg/wet kg in scorpionfish from the White Point station. The mean Total PCB concentrations for all stations combined ranged from 0.011 mg/wet kg in rockfish from the Orange County Control station to 0.16 mg/wet kg in black perch from the Belmont Pier station.

An analysis of variance detected significant differences among stations for the concentrations of both Total DDT and Total PCB ($H_{DDT} = 20.38$, $H_{PCB} = 27.03$; $p < .001$) when all samples were used, including the white croaker results. This indicates that there is a significant increase in the concentration of these contaminants at one or more of the stations over background levels, but it does not indicate what the individual station differences are. Because several species were sampled at more than one station, this allowed us to consider the station differences using those species.

Bonito and Pacific mackerel, both migratory fish, spend a smaller amount of time in any specific area and do not have higher levels of contaminants in samples from contaminated areas than in uncontaminated areas. For fish that may be residents and spend a longer period of time at their respective stations our analyses did detect significant differences among the stations. For the rockfish which were collected from the White Point, Santa Monica Bay,and Orange County Control stations there were significant differences in contaminant concentrations ($H_{DDT} = 10.82$, $H_{PCB} = 12.50$, $p < .005$). Scorpionfish from the White Point station and

Table 2. Results of the analysis of the edible muscle tissue of sportfish collected from the metropolitan Los Angeles area.

Station	Species	n[a]	Whole Body Wt. (g)	Standard Length (mm)	% Dry/Wet Weight	% Lipid/Wet Weight	Total DDT mg/wet kg mean	± 1 S.D.	Total PCB mg/wet kg mean	± 1 S.D.
White Point	Scorpionfish	8(5)	240	182	23.5	0.77	0.76	0.58	0.066	0.028
	Rockfish	18(5)	182	180	22.4	0.75	0.44	0.23	0.057	0.015
	Kelp Bass	24(5)	206	204	23.7	0.96	0.28	0.15	0.042	0.010
	Barracuda	25(5)	866	505	27.0	1.85	0.19	0.10	0.047	0.011
	Bonito	15(5)	1048	417	28.9	0.95	0.12	0.06	0.022	0.013
	P. Mackerel	25(5)	388	300	26.2	0.78	0.051	0.021	0.014	0.008
Cabrillo Pier	Queenfish	25(5)	99	179	21.7	0.94	0.24	0.09	0.058	0.029
	White Perch	23(5)	75	143	22.6	1.09	0.20	0.06	0.034	0.011
	Black Perch	17(5)	127	142	21.9	1.23	0.16	0.11	0.029	0.013
	Halibut	25(5)	202	216	22.5	0.81	0.16	0.04	0.052	0.004
Santa Monica Bay	Scorpionfish	12(5)	540	233	22.8	0.86	0.54	0.52	0.13	0.07
	Rockfish	13(5)	332	209	25.2	0.90	0.22	0.11	0.12	0.03
	Lizardfish	9(5)	403	388	24.5	0.79	0.097	0.044	0.017	0.006
	Bocaccio	25(5)	400	286	23.9	0.86	0.058	0.010	0.020	0.004
	P. Mackerel	26(5)	345	278	25.8	0.84	0.057	0.037	0.015	0.007
Belmont Pier	Corbina	6(4)	531	275	18.6	0.65	0.33	0.52	0.15	0.23
	Black Perch	24(5)	228	182	24.4	1.87	0.29	0.24	0.16	0.09
	White Perch	25(5)	132	170	23.6	2.09	0.18	0.04	0.11	0.02
	Halibut	4(4)	1380	418	23.8	0.66	0.13	0.06	0.062	0.034
	Barred Sand Bass	6(3)	200	184	23.6	1.15	0.077	0.022	0.052	0.018
	Flatfish	18(5)	164	174	23.1	0.83	0.041	0.012	0.021	0.011
Orange County Control	P. Mackerel	25(5)	436	315	26.4	0.78	0.13	0.09	0.034	0.022
	Kelp Bass	25(5)	281	219	22.5	0.96	0.061	0.032	0.021	0.006
	Bonito	15(5)	1288	421	27.5	0.80	0.062	0.036	0.019	0.008
	Rockfish	19(5)	113	161	21.1	0.74	0.036	0.011	0.011	0.005

[a]numbers in parenthesis are the number of composites used in the analysis for % Dry/wet, % Lipid/wet, Total DDT, Total PCB and BaP.

Santa Monica Bay stations were not significantly different ($U = 15$, $p < .2$), but kelp bass from the White Point station and Orange County Control stations were ($U_{DDT} = 24$, $p < .02$; $U_{PCB} = 25$, $p < .01$). These results indicate that the resident fish from contaminated areas have higher levels of these compounds than fish from uncontaminated areas, while migrant fish from the same location do not show increased levels.

Priority Pollutants in White Croaker

Subsamples were taken from white croaker composites and sent to California Analytical Laboratories in Sacramento for analysis by Gas Chromatography Mass Spectrometry (GC/MS) for all the nonpurgeable EPA priority pollutants (U.S. Environmental Protection Agency 1977). Phenol was the only compound present above the GC/MS detection limit, which for most of the compounds is 25 ug/kg. The concentrations of phenol measured were 42 ug/wet kg in the White Point sample, 96 ug/wet kg in the Santa Monica Bay sample, 100 ug/wet kg in the Belmont Pier sample, 116 ug/wet kg in the Cabrillo Pier sample, and 231 ug/wet kg in the Orange County control. Dioxin was not detected in any samples.

Benzo(a)Pyrene Results

All samples were analyzed by Robert Arthur of USC for benzo(a)pyrene (BaP) and in all cases concentrations were below detectable limits of 1 ug/wet kg. This was surprising, especially for the Cabrillo Pier station, since levels of 1.7 + 1.0 ug/wet kg were detected in white croaker muscle tissue from this location in 1979, only two years earlier (Mearns and Young 1979-1980). To insure that the technique was working properly we re-analyzed archived tissue from the 1979 samples and obtained results similar to the 1979 results. As a secondary check we also sampled

surface water, sediments, and mussels (*Mytilus edulis*) from 9 of the 13 white croaker stations (Table 3). BaP concentrations in the surface water ranged from below detectable limits of 0.001 ug/ℓ at four of the stations to 0.118 ug/ℓ at the Navy Mole station. The sediments ranged from below detectable limits at the Redondo Area Piers station to 18000 ug/dry kg at the Navy Mole, and the mussels ranged from 3 ug/wet kg in the Queen Mary/Pier J sample to 280 ug/wet kg in the Cabrillo Pier sample.

These results indicate that benzo(a)pyrene is present in the environment, especially at the Navy Mole station, at surprisingly high levels. The findings that BaP was not detectable in the edible muscle tissue of fish caught at these stations might be explained by the ability of these fish to metabolize this compound (Stegeman 1981, von Hofe *et al.* 1979).

Cooking

Results of the USC survey indicated that pan frying was the most popular method of cooking by sportfishermen. To determine the effect of pan frying on the contaminant concentrations, white croaker muscle tissue from the Santa Monica Bay and Orange County Control stations were pan fried and then analyzed for DDT, PCB, and BaP levels. Fillets were taken from the opposite side of the fish analyzed for fresh tissue concentrations and fried in 30 mls of Wesson oil at 88°C (190°F) for 4 minutes per side in a Westbend Teflon coated electric skillet (Krone and Iwaoka 1981). The fillets were weighed before and after frying to determine water loss due to the frying. The fillets were then composited in the same manner as the uncooked samples and analyzed for % lipid, DDT, PCB and BaP.

The fried muscle tissue exhibited lower concentrations of chlorinated hydrocarbons than fresh muscle samples. For the Orange County Control samples the average mass of DDT declined 39% to 1.2 ug, and the average mass of PCB declined 29% to 0.18 ug. For the Santa Monica Bay samples the average mass of DDT declined 74% to 2.3 ug and the average mass of PCB declined 65% to 1.1 ug. We were unable to analyze the used cooking oil to determine if the loss in chlorinated hydrocarbons was due to leaching into the cooking oil, but that is a possibility,

Table 3. Concentrations of benzo(a)pyrene (n = 1) determined by Robert Arthur of USC in water (0 - 10 cm below the sea surface), sediment (0 - 2 cm) and whole soft body mussels (*Mytilus edulis*) from the metropolitan Los Angeles area. Benzo(a)pyrene was below detectable limits of 1 ug/wet kg in all sportfish samples.

Station	Water	Sediments		Mussels	
	ug/ℓ	% Dry Weight	ug/dry kg	% Dry Weight	ug/wet kg
Gerald Desmond Bridge	0.024	75	30	c	c
Cabrillo Pier	<0.001	72	42	13	280
Venice Pier	<0.001	78	4	14	8
Belmont Pier	0.110	73	2	21	59
Redondo Area Piers	0.079	81	<1	15	12
Navy Mole	0.118	36	18000	18	170
Queen Mary/Pier J	<0.001	a	a	13	3
Marina del Rey	0.116	71	65	13	10
Santa Monica Pier	<0.001	78[b]	6	14	71

[a]Sample not collected due to rocks.

[b]Insufficient sample volume collected to determine dry weight, therefore we estimated the percent dry weight using the Venice Pier station result, which should be similar.

[c]There were no mussels present at this station.

since the cooking temperature is too low to break down these compounds. BaP was not detected in any of the fried tissue samples, therefore frying fish does not increase the levels of this contaminant either.

DISCUSSION

Edible muscle tissue of sportfish from the metropolitan Los Angeles area contain concentrations of Total DDT and Total PCB that are above background levels. To assess the possible health hazard from eating these fish we determined the daily intake rates of these contaminants based on the white croaker results and the median consumption rates for all species combined for each station (Puffer *et al.* 1981). These results are listed in Table 4 and may be higher than actual intake rates due to the fact that white croaker are not the major portion of fish consumed at every station. The White Point station has been omitted because the consumption rate for that station was computed from surveying people fishing from the shore and our white croaker were taken near the outfall, which is not normally fished. Results of the USC Survey indicated that 10% of the sportfishermen consume as much as 85.2 g/day/person of white croaker. If these fish had been taken at the Gerald Desmond Bridge their daily intake could be as much as 239 ug DDT and 36 ug PCB. There is a group of local sportfishermen who fish for rockfish from the same boat 3-4 times per week in Santa Monica Bay. Everyone on board usually catches their limit of 15 fish which is mainly one species, bocaccio. Assuming they consume approximately 150 g per day, their daily intake rates would be 8.7 ug DDT and 3.0 ug PCB based on our analysis of the bocaccio caught by us from the same boat (Table 2).

The World Health Organization (WHO) recommends that daily intake be no more than 5 ug/kg/day for DDT (U.S. Environmental Protection Agency 1978). If the average man weighs 70 kg, the recommended maximum, safe daily intake would be 350 ug. This level is not reached by any of the stations we surveyed, even in the White Point sample, when you assume an average consumption rate of 36.9 g/day/person, the level only reaches 280 ug. The FDA has a limit of 5 mg/wet kg DDT for the interstate transport of fish. This limit was exceeded by white croaker only from the White Point station. Please note that these guidelines are based on technical grade

Table 4. Estimated daily intake of Total DDT and Total PCB from the consumption of white croaker taken from the metropolitan Los Angeles area.

Station	Median[a] Consumption Rate (g fish/day/person)	Estimated Daily Intake (ug) Total DDT	Total PCB
Gerald Desmond Bridge	26.3	73.6	11.0
Cabrillo Pier	36.3	61.7	11.1
Santa Monica Bay	96.8	55.2	19.4
Venice Pier	47.7	32.9	4.7
Belmont Pier	32.3	14.5	3.2
Redondo Area Piers	62.5	13.8	3.4
Navy Mole	52.4	14.7	5.2
Queen Mary/Pier J	18.5	3.1	1.6
Marina del Rey	13.1	10.1	1.6
Orange County Control	36.9[b]	5.2	0.7
Dana Pt. Control	36.9[b]	5.2	0.9
Malibu/Santa Monica Pier	49.5	2.6	0.7

[a]Median Consumption Rate for all species combined. Taken from Puffer *et al.*, 1981, Table 7.

[b]The Median Consumption Rate for all stations combined was used for these stations.

DDT which is 92% DDT, 4.1% DDE,and 0.4% DDD. Our analysis of fish tissue showed the actual percentages of these compounds to be approximately 90% DDE and 10% DDT. DDE is approximately one-eighth as toxic as DDT (National Institute for Occupational Safety and Health, 1979). Therefore, based on the actual quantity of Total DDT found in these fish, none of the samples exceeded the FDA limit.

The concentrations of these trace organic compounds are not sufficiently high to cause acute toxicity. It would take 237 years for a 70 kg fisherman eating 85.2 g/day of white croaker from the White Point station to consume enough DDE to reach the rat LD 50 level (800 mg/kg). However, there is the possibility of sub-acute effects and these results would suggest the need for further research into the uptake rate and metabolism of these contaminants by man. It might be possible to look at the medical histories of the sportfishermen who consume these fish on a regular basis to determine if a specific illness could be attributed to this consumption.

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