(29) Yu, M.; Hites, R. A. *Anal. Chem.* **1981**, *53*, 951–954.
(30) Newton, D. L.; Erickson, M. D.; Tomer, K. B.; Pellizzari, E. D.; Gentry, P.; Zweidinger, R. B. *Environ. Sci. Technol.* **1982**, *16*, 206–213.
(31) Gorse, R. A., Jr.; Riley, T. L.; Ferris, F. C.; Pero, A. M.; Skewes, L. M. *Environ. Sci. Technol.* **1983**, *17*, 198–202.
(32) Henderson, T. R.; Sun, J. D.; Royer, R. E.; Clark, C. R.; Li, A. P.; Harvey, T. M.; Hunt, D. H.; Fulford, J. E.; Lovette, A. M.; Davidson, W. R. *Environ. Sci. Technol.* **1983**, *17*, 443–449.
(33) Paputa-Peck, M. C.; Marano, R. S.; Schuetzle, D.; et al. *Anal. Chem.* **1983**, *55*, 1946–1954.
(34) Salmeen, I. T.; Pero, A. M.; Zator, R.; Schuetzle, D.; Riley, T. L. *Environ. Sci. Technol.* **1984**, *18*, 375–382.
(35) Schuetzle, D.; Jensen, T. E.; Ball, J. C. *Environ. Int.* **1985**, *11*, 169–181.
(36) Alsberg, T.; Stenberg, U.; Westerholm, R.; et al. *Environ. Sci. Technol.* **1985**, *19*, 43–50.
(37) McCann, J.; Choi, E.; Yamasaki, E.; Ames, B. N. *Proc. Natl. Acad. Sci. U.S.A.* **1975**, *72*, 5135–5139.
(38) Jensen, T. E.; Hites, R. A. *Anal. Chem.* **1983**, *55*, 594–599.
(39) Schuetzle, D.; Perez, J. M. *J. Air. Pollut. Control Assoc.* **1983**, *33*, 751–755.
(40) Ramdahl, T.; Urdal, K. *Anal. Chem.* **1982**, *54*, 2256–2260.
(41) Liberti, A.; Ciccioli, P.; Cecinato, A.; Brancaleoni, E.; DiPalo, C. *HRC CC, J. High Resolut. Chromatogr. Chromatogr. Commun.* **1984**, *7*, 389–397.
(42) Rinkus, S. J.; Legator, M. S. *Cancer Res.* **1979**, *39*, 3289–3318.
(43) Liberman, D. F.; Fink, R. C.; Shaeffer, F. L. *Appl. Environ. Microbiol.* **1982**, *43*, 1354–1359.
(44) Behymer, T. D.; Hites, R. A. *Environ. Sci. Technol.* **1984**, *18*, 203–206.
(45) Tong, H. Y.; Karasek, F. W. *Anal. Chem.* **1984**, *56*, 2129–2134.
(46) Williams, R. L.; Perez, J. M.; Griffing, M. E. *SAE Tech. Pap. Ser.* **1985**, *No. 852081*.

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Toxic Chemicals, Including Aromatic and Chlorinated Hydrocarbons and Their Derivatives, and Liver Lesions in White Croaker (*Genyonemus lineatus*) from the Vicinity of Los Angeles

Donald C. Malins,* Bruce B. McCain, Donald W. Brown, Mark S. Myers, Margaret M. Krahn, and Sin-Lam Chan

Environmental Conservation Division, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Seattle, Washington 98112

■ High concentrations of toxic chemicals in sediment and white croaker (*Genyonemus lineatus*), as well as liver diseases (e.g., carcinomas) in this species, were found in the Los Angeles area. The highest concentrations of aromatic hydrocarbons (AHs) in the sediment were in San Pedro Bay, and the highest concentrations of 1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane (DDT) derivatives were in sediment from near the White Point sewer outfall. Concentrations of AHs, polychlorobiphenyls (PCBs), and DDT derivatives were generally higher in food organisms (benthic invertebrates) from the croaker's stomach than in sediment. Moreover, croaker from San Pedro Bay and White Point were substantially contaminated with DDT derivatives and metabolites of aromatic compounds (in bile), compared to croaker from the Hyperion outfall and Dana Point (reference area). The evidence suggests that the observed pathological conditions of the liver were associated with exposure of the croaker to toxic chemicals, which occurred, at least in part, through the ingestion of contaminated food organisms.

Introduction

Bottom-feeding fish in urban coastal waters are exposed to myriad toxic chemicals (*1*, *2*), and several studies indicate that many of the chemicals accumulate in these fish (*3*, *4*) and thus create a potential for altering their health (*5–8*). For example, accumulations of metabolites of toxic chemicals in the bile (*9*, *10*), of English sole, *Parophrys vetulus*, from Puget Sound were recently shown to be associated with liver diseases, including liver cancers. In another study (*5*), similar associations were observed between toxic chemicals [e.g., aromatic hydrocarbons (AHs)] in sediments and various diseases in English sole.

Marine waters adjacent to Los Angeles are known to receive considerable amounts of industrial and municipal wastes (*11–13*). This environment thus affords an opportunity to expand limited knowledge available on the bioaccumulation, disposition, and food chain transfer of toxic chemicals. White croaker *Genyonemus lineatus*, were of particular interest because of their wide distribution along the California coast and because they are an important component of the skiff sports fishery. This bottom-feeding fish also forms the basis for a growing gill net fishery and is a mainstay of pier catches in Southern and Central California (*14*). Love et al. (*14*) reported that adult white croaker spawn in shallow waters (8–12 m) and younger fish tend to reside in shallow waters, migrating to deeper waters (22–36 m) as they become mature adults. Accordingly, chemical analyses were performed on sediments and on stomach contents (food organisms), liver, and bile from white croaker collected in the Los Angeles area (San Pedro Bay and near the 5-mi Hyperion and White Point sewer outfalls) and a nonurban reference area (Dana Point) (Figure 1). Observations were also made on histopathologic conditions in these fish.

Methods and Materials

Sediment samples and white croaker were collected in December 1984 from San Pedro Bay (Queensway Bay, Cerritos Channel, and near Reservation Point) and from the vicinity of the White Point and 5-mi Hyperion sewer outfalls (Figure 1). Comparable samples were obtained from Dana Point in September 1984. Surface sediments (top 2 cm) were collected with a modified

* Address correspondence to this author at his present address: Pacific Northwest Research Foundation,

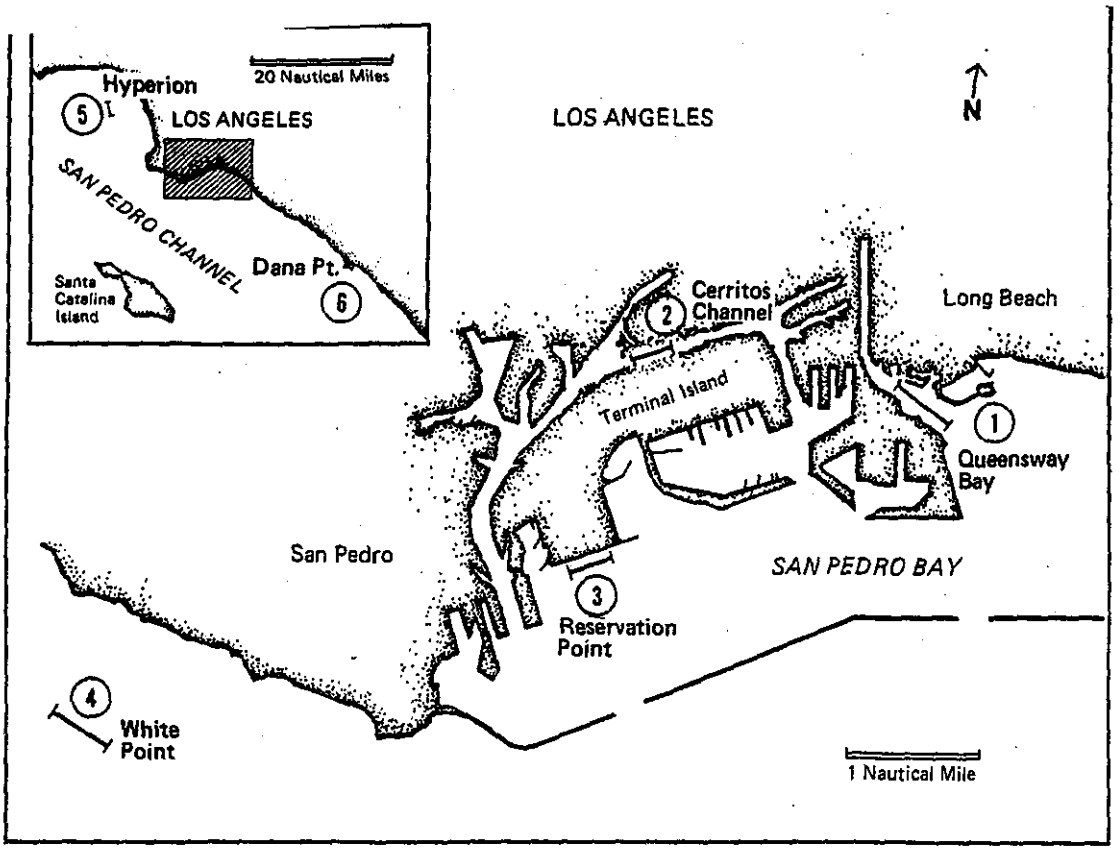

Figure 1. Map showing locations of sampling sites in the vicinity of Queensway Bay (site 1), Cerritos Channel (site 2), Reservation Point (s 3), White Point sewer outfalls (site 4), (inset) near the 5-mi Hyperion outfall (site 5) and Dana Point (site 6). The coordinates for the sampl sites were as follows: Queensway Bay, 33° 45′ 20″ N × 118° 11′ 20″ W; Cerritos Channel, 33° 43′ 49″ N × 118° 14′ 48″ W; White Po 33° 42′ 24″ N × 118° 21′ 06″ W; Hyperion, 33° 54′ 29″ N × 118° 31′ 57″ W; Dana Point, 33° 26′ 54″ N × 117° 42′ 24″ W.

at each site by otter trawl, were measured (mm), weighed (g), and necropsied. At each site, the following samples were collected for chemical analyses: bile, from 10 individual fish; stomach contents (food organisms), a composite from 10 fish; liver, a composite from 5 fish. The mean lengths (mm) of fish from each site used for chemical analyses were as follows: Queensway Bay, 221 ± 41; Cerritos Channel, 153 ± 13; Reservation Point, 200 ± 36; White Point, 201 ± 7; Hyperion, 255 ± 7; Dana Point, 191 ± 21. All samples were kept at −20 °C until analyzed. Sediments and stomach contents were analyzed for a broad spectrum of AHs and chlorinated hydrocarbons (CHs) by using capillary column gas chromatography with mass spectrometry, flame ionization, and electron capture detectors (*15*). A high-pressure liquid chromatographic/fluorescence detection technique (*9, 10*) was employed to measure metabolites of aromatic compounds in bile. This technique was used because analyses of AHs (e.g., components of fossil fuels and their combustion products) in tissues are of limited value due to the extensive metabolism of these compounds, especially in the liver (*16–18*). Samples of liver tissues were analyzed (*15*) for the more metabolically resistant CHs (*2*). Stomach contents from a composite of five fish were also collected at each site and preserved in 10% neutral, buffered formalin for taxonomic characterization. Also, as part of the fish necropsy procedure, liver tissue was routinely collected for histopathological examination and preserved and processed by previously reported methods (*5*). Lesion classification followed previously described diagnostic criteria (*19–23*).

Results

Chemicals in Sediments and Stomach Contents. Sediment-associated AHs, including benzo[*a*]pyrene (BaP), were found at the San Pedro Bay sites at summed co centrations of 890–2800 ng/g dry weight. ("Summ concentrations" refers to total concentrations of cor pounds in Table I; all concentrations for sediments, ston ach contents, and liver are on a dry-weight basis.) Co centrations of AHs in sediment from Dana Point wer generally close to, or below, the limits of detection (Tab I). The highest concentrations of 1,1,1-trichloro-2,2-bi (*p*-chlorophenyl)ethane- (DDT-) related compounds an PCBs were found in sediments from the vicinity of th White Point sewer outfalls (summed concentrations, 130 and 520 ng/g, respectively). The concentrations of DD and related compounds were 15 and 100 times lower tha those previously reported for sediments collected in th vicinity of this site by Brown et al. (*24*) in 1982 and b Young et al. (*25*) in 1976, respectively. These difference do not necessarily imply reductions in sediment concen trations over time; they could be due to an uneven dis tribution of chemical contaminants in surface sediment at the White Point site.

Stomach contents (food organisms) of white croake captured inside San Pedro Bay contained substantially higher summed concentrations of AHs than did samples from the Hyperion and White Point sites (Table I). For example, the stomach contents from Cerritos Channel had 20 times the summed concentrations of AHs (30 000 ng/g) than did the sample from the Hyperion site. Concentrations of AHs in the stomach organisms from Dana Point were all close to or below the limits of analytical detection (Table I).

Highest concentrations of CHs in the stomach contents were found in fish from near White Point; the summed concentrations of DDT-related compounds and PCBs were 13 000 and 1000 ng/g, respectively (Table I). DDT and

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Table I. Aromatic and Chlorinated Compounds (ng/g, Dry Weight) in Sediment (S), Stomach Contents (SC), and Livers (L) of White Croaker from the Los Angeles Area and a Reference Area (Dana Point)[a]

	Queensway Bay (1)			Cerritos Channel (2)			Reservation Point (3)			White Point (4)			Hyperion (5)			Dana Point (6)		
compounds[b]	S	SC	D[c]	S	SC	L	S	SC	L	S	SC	L	S	SC	L	S	SC	L
aromatic hydrocarbons																		
methylnaphthalenes	80	410		14	91		<4[d]	94		17	<27		120	180		<4	<17	
phenanthrene	220	1100		65	2100		10	330		<2	310		19	150		10	<12	
1-methylphenanthrene	14	1100		4	300		<3	<7		<2	<20		<10	<4		<3	<11	
anthracene	20	520		6	1100		11	<7		<2	<20		<1	<4		<3	<11	
fluoranthene	430	1200		180	7100		29	370		67	310		26	280		22	<13	
pyrene	560	1100		180	4900		670	1200		290	1100		47	500		13	<12	
benz[*a*]anthracene	240	98		53	3100		51	160		4	52		51	58		<2	<15	
chrysene	530	1000		160	4200		160	560		9	160		52	76		<3	<15	
benzo[*e*]pyrene	250	570		93	2700		160	350		26	<22		21	64		9	<14	
benzo[*a*]pyrene	210	330		73	2900		180	310		19	<26		16	27		<2	<17	
perylene	140	380		39	680		400	590		110	680		21	190		<2	<24	
dibenz[*a*,*h*]anthracene	63	230		26	480		14	64		22	<33		<2	<6		<3	<41	
aromatic hydrocarbons	2800	8000		890	30000		1700	4000		560	2600		370	1500		54	NA[e]	
chlorinated hydrocarbons																		
α-chlordane	22	160	1000	7	<1	460	<	5	63	7	10	140	2	20	86	1	75	19
trans-nonachlor	18	130	1300	6	<1	620	1	5	99	4	10	170	1	18	110	<1	4	42
o,p'-DDE	<1	110	3200	<1	110	1400	7	39	1900	190	1100	6000	9	35	220	<1	<4	37
p,p'-DDE	51	370	33000	15	920	14000	39	420	18000	890	11000	89000	100	1100	6000	1	<2	1400
p,p'-DDD	43	170	4300	12	730	8700	5	36	2200	200	1200	7100	7	72	320	1	<5	79
p,p'-DDT	9	16	67	4	71	380	<1	3	18	<4	18	63	<1	10	18	<1	<3	26
DDT and related compds	100	670	41000	31	1800	24000	51	500	22000	1300	13000	100000	120	1200	6600	2	NA	1500
trichlorobiphenyls	40	81	330	15	81	160	2	31	51	35	83	330	21	32	71	<1	36	48
tetrachlorobiphenyls	140	290	3700	53	540	3700	24	110	840	160	260	2000	80	250	750	<1	56	150
pentachlorobiphenyls	150	340	4300	54	380	8800	64	160	2100	220	380	2800	110	350	1600	3	290	240
hexachlorobiphenyls	82	200	2400	30	230	7900	47	110	1700	71	210	1600	74	210	1200	3	77	290
heptachlorobiphenyls	38	77	1600	15	120	2300	10	27	420	21	59	540	27	54	310	<1	14	120
octachlorobiphenyls	8	29	220	5	24	440	1	6	110	9	20	150	7	22	100	<1	3	34
nonachlorobiphenyls	3	11	77	3	9	130	1	1	36	4	4	60	2	5	29	<1	<4	15
polychlorobiphenyls	460	1000	13000	170	1400	23000	150	450	5300	520	1000	7500	320	920	4100	6	480	900

[a] Only major components in each category of compounds are presented. [b] concentrations were calculated with internal standards (*16*). [c] Aromatic hydrocarbons were not measured in liver. [d] The less than symbol (<) indicates that the chemical was not detected; the value given is the detection limit. [e] Not applicable.

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Compounds, Measured at Benzo[*a*]pyrene (BaP) and Naphthalene (NPH) Wavelengths, in Bile of White Croaker

site	equivalents, mean ± SD, ng/g (wet weight)	
	BaP (*n*)	NPH (*n*)
Queensway Bay (1)	330 ± 160 (11)[a]	140 000 ± 52 000 (11)[a]
Cerritos Channel (2)	5500 ± 1200 (8)	330 000 ± 100 000 (6)
Reservation Point (3)[b]	3700 ± 3100 (7)	410 000 ± 230 000 (7)
White Point (4)	960 ± 1600 (12)	170 000 ± 61 000 (12)
Hyperion (5)	78 ± 25 (5)	64 000 ± 47 000 (5)
Dana Point (6)	79 ± 75 (8)	39 000 ± 13 000 (8)

[a] It was not possible to obtain sufficient bile from fish sampled at this site in December 1984; accordingly, values obtained from a subsequent sampling (August 1985) are given. [b] Individual compounds in the bile were determined in our laboratories by gas chromatographic/mass spectroscopic analysis. The results (wet weight) from the analysis of bile from one white croaker from Reservation Point, for example, were as follows: BaP, 160 ng/g; dibenzofuranol, 1500 ng/g (two isomers); 9-fluorenol, 520 ng/g; fluoranthanol, 6400 ng/g (two isomers); pyrenol, 21 000 ng/g (three isomers); 3-hydroxybenzo[*a*]pyrene, 44 ng/g.

related compounds were not detected in the stomach contents from the Dana Point fish; however, 480 ng/g PCBs were found. Relatively high concentrations of both DDT and related compounds and PCBs were found in the stomach contents of fish from the Cerritos Channel, Queensway Bay, and Hyperion sites.

The taxonomic analyses of stomach contents revealed that the white croaker had fed primarily on benthic invertebrates. Analyses were performed on stomach contents of fish from the Queensway Bay, Cerritos Channel, Reservation Point, and Hyperion sites. (Sufficient sample was not available from the White Point fish for taxonomic analysis.) The mean percentages, by weight, of the identifiable food organisms for the four sites were as follows: 53 ± 13% polychaetes, 27 ± 10% crustaceans, 4 ± 2% bivalves, 7 ± 2% small fish, and 7 ± 4% nemertean worms. (Only trace amounts of nonbiological material, mostly fine sand particles, were found in the stomach contents.) The composition of food organisms in fish from Dana Point was quite similar to that of fish from the other sampling sites (41% polychaetes, 12% crustaceans, 9% bivalves, 5% small fish, and 6% nemertean worms), except that brachipods (27%) were also found.

Chemicals in Liver and Bile of White Croaker. CHs were present in the livers of white croaker from all six sites; however, substantial differences in concentrations were found between samples from Dana Point and those from the Los Angeles area. For example, summed concentrations of DDT and related compounds in the livers of the White Point fish (100 000 ng/g; Table I) were about 70 times higher than those in the livers of the Dana Point fish. Relatively high concentrations of these compounds were also found in the livers of fish from the Queensway Bay, Cerritos Channel, and Reservation Point sites. In San Pedro Bay, the summed concentrations of PCBs in livers were 6 and 25 times higher for Reservation Point and Cerritos Channel fish, respectively, compared to livers from the Dana Point fish (Table I).

In addition, the analyses of bile (Table II) revealed large differences in concentrations of metabolites of aromatic compounds in fish from the Los Angeles area (except those from the Hyperion site) compared to fish from Dana Point, regardless of whether the values were obtained at BaP or naphthalene (NPH) wavelengths. The values obtained at BaP and NPH wavelengths primarily represent metabolites of polynuclear AHs, characteristic of fossil fuel com-

carbons present in the kerosene/gasoline fraction c
troleum, respectively. White croaker from Cer
Channel had concentrations of bile metabolites fluore
at BaP wavelengths that were approximately 75 t
higher than those obtained from the Dana Point and
Hyperion outfall fish. The pattern of values obtaine
NPH wavelengths was similar to that for BaP; the hig
concentrations measured at NPH wavelengths were for
of white croaker from certain sites in San Pedro Bay (
Cerritos Channel and Reservation Point), whereas
lowest values were from the Dana Point and Hyperion
The bile metabolite values obtained at BaP wavelen
from the Dana Point and Hyperion fish were compar
to those obtained with English sole from nonurban
erence areas in Puget Sound (*6*, *7*, *9*, *10*); however,
NPH values in white croaker were 5–7 times higher.

Liver Lesions in White Croaker. The white croa
subjected to chemical analysis were also examined
histopathological conditions. Of the liver lesions detect
only the most apparently serious conditions are report
here. A more detailed description of the histopathologi
characterstics of these lesions will be presented elsewhe
(*26*). The liver lesions included neoplasms, putative
preneoplastic lesions (i.e., basophilic foci of hepatocellul
alteration), megalocytic hepatosis, and hepatocellular n
clear pleomorphism (*5–7*, *19*, *21–23*, *27*, *28*). The types
fish liver neoplasms and the sites from which they we
captured are as follows: a cholangiocellular carcinoma i
one fish (25 fish examined) from Queensway Bay; a h
patocellular carcinoma in one fish (25 fish examined) fro
near Reservation Point; a cholangioma in one fish (25 fis
examined) from near the Hyperion outfall (Figure 2).
basophilic focus was detected in the liver of another fis
from Queensway Bay. Megalocytic hepatosis was detecte
only in white croaker from Cerritos Channel, at a preva
lence of 13% (3 of 23 fish). It is noteworthy that none o
the above-mentioned liver lesions were detected in fis
from Dana Point (27 fish examined). The prevalence of
nuclear pleomorphism in white croaker from Cerritos
Channel (26.1%) was significantly higher ($P \leq 0.05$) than
that in fish from Dana Point (3.7%) and near Reservation
Point (4.0%) as determined by the G test for heterogeneity (*29*).

In other fish (*20*, *30*) and mammalian species (*31*), the probability of developing detectable liver neoplasms, as well as certain other liver lesions, increases with age. Because the presence of white croaker with liver neoplasms at the Los Angeles sites could partially be due to the capture and sampling of older fish rather than the results of exposure to environmental carcinogens, it is important that the age composition of white croakers from reference areas be comparable to that of croaker from urban areas. The approximate mean age of white croaker with liver neoplasms and preneoplasms, estimated from a published growth curve (*14*), was between 5 and 7 years (mean length = 255 ± 30 mm). Only two white croaker with lengths corresponding to this 5–7-year age group were captured at Dana Point (the reference site); however, 32 white croaker in this age group (mean length = 249 ± 18 mm), collected during the same time period in 1984 along the central coast of California (Bodega Bay and San Francisco Bay) as part of NOAA's National Status and Trends Program, did not have detectable liver neoplasms or preneoplastic lesions (*32*).

Discussion

The chemical analyses revealed that sediments from the Los Angeles area contained substantially higher concen-

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Figure 2. Photomicrographs of livers of white croaker showing representative histopathological conditions. (A) Liver with normal architecture, including hepatocytes arranged in regular cords of a thickness of 1 to 2 cells, with the cords separated by sinusoids. Arrows indicate melanomacrophage centers: 133×, hematoxylin and eosin (H and E). (B) Cholangiocellular carcinoma in the liver of a male white croaker from San Pedro Bay. The biliary cells composing the neoplasm were anaplastic and had a disorganized architecture. The borders of the nodule were irregular, and neoplastic components had clearly invaded the surrounding normal parenchyma: 80×, H and E. (C) Cholangioma in the liver of a female white croaker from the site near the Hyperion 5-mi outfall. The ductular structures in the nodule were composed of moderately well-differentiated biliary epithelium, and the noninvasive margin (arrows) of the nodule was surrounded by normal parenchyma: 80×, H and E.

trations of AHs and CHs compared to sediments from Dana Point. Most striking, however, were the differences in concentrations of AHs and CHs in the biological samples with respect to the Los Angeles area and Dana Point. Differences, for example, in the concentrations of bile metabolites measured at BaP wavelengths for fish from Cerritos Channel and Reservation Point were, as indicated, many times greater than those for Dana Point. These findings provide clear evidence of the high degree to which the white croaker form the Los Angeles area had been exposed to toxic chemicals. Interestingly, the concentrations of aromatic compounds in the bile of fish from Cerritos Channel and Reservation Point were higher than those obtained with English sole from Eagle Harbor in Puget Sound where the sediments were heavily impregnated with creosote AHs (*7*). In Eagle Harbor, the English sole had bile values, determined at BaP wavelengths, of 21 ± 1500 ng/g (*7*).

The observed high degree of uptake of aromatic compounds, such as fossil fuel hydrocarbons, by white croaker from the Los Angeles area and the contamination of food organisms with AHs and CHs have not been reported

the application of the relatively new technique for bile analysis (*9, 10*) made it possible to firmly establish the uptake and metabolism of aromatic compounds by white croaker.

Chlorinated hydrocarbons have previously been identified in white croaker from the Los Angeles area. Brown et al. (*4*) reported concentrations of DDT and related compounds similar to our values for livers of white croaker from White Point and Dana Point (178000 and 2800 ng/g, respectively, converted to dry weight by using a multiplier of 5; n = 10 per site). Gossett et al. (*12*) reported the concentrations of DDT and related compounds in muscle of white croaker from White Point and Dana Point to be 38000 and 700 ng/g, respectively. Although studies reported by Young et al. (*33*) and Bascum (*34*) demonstrated that body burdens of DDTs and PCBs increased with trophic level, no prior evidence relating to the important question of contamination of food organisms consumed by white croaker, or the route(s) of uptake of chemicals by this species, was provided.

The liver neoplasms, preneoplasms, and other liver lesions (e.g., megalocytic hepatosis) in white croaker, demonstrated here for the first time, resemble those found in bottom-feeding fish from other polluted coastal areas (*5–7, 19, 20, 27*). Furthermore, the megalocytic hepatosis, as well as the neoplastic and preneoplastic liver lesions in the white croaker, compares morphologically to those identified in laboratory animals exposed to toxic and/or carcinogenic chemicals (*21, 28*). Overall, the chemical and biological findings suggest a possible relationship between toxic environmental chemicals and the observed liver lesions; however, on the basis of previous data from Puget Sound (*2, 5–7, 10*), it was surprising to find relatively low prevalences of neoplastic and preneoplastic liver lesions in the white croaker from the Los Angeles area. Clearly, more work is needed to determine if these differences are species-related and/or are attributable to other factors. In this regard, we do not feel that seasonal variability was a significant factor in the differences observed. For example, there is no reason to believe on the basis of present evidence that tissue concentrations of xenobiotics would vary significantly over a 3-month period. Moreover, for the five sites sampled in a single month (December), substantial differences were found in concentrations of chemical contaminants in sediments and fish, as well as in prevalences of fish diseases.

The benthic invertebrates eaten by the Los Angeles fish had apparently bioconcentrated AHs and CHs present in polluted sediments. That is, the concentrations of chemicals in the food organisms were generally higher than those in the sediment. For example, food organisms of the fish from Cerritos Channel had concentrations of summed AHs, PCB, and DDT-related compounds that were 34, 8 and 58 times those in the sediment, respectively.

The observed contamination of the fish through the consumption of benthic food organisms revealed an important route of exposure to toxic chemicals; however, other routes are possible—both AHs and CHs are known to be bioconcentrated by fish from the sediment (*35, 36*) and water column (*16, 37, 38*). Undoubtedly, the relative impact on the croaker of the various routes of exposure will have to await further studies in the field and laboratory.

Clearly, the complementary use of chemical analytical data on stomach contents, bile, and liver of the white croaker, in conjunction with histopathologic examination

... sediment analyses alone. Moreover, in the broad sense, the findings reported here heighten interest in the extent of contamination of food chain organisms in urban coastal environments and the consequences to higher forms of marine life and to humans.

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Registry No. DDT, 50-29-3; o,p'-DDE, 3424-82-6; p,p'-DDE, 72-55-9; p,p'-DDD, 72-54-8; methylnaphthalene, 1321-94-4; phenanthrene, 85-01-8; 1-methylphenanthrene, 832-69-9; anthracene, 120-12-7; fluoranthrene, 206-44-0; pyrene, 129-00-0; benz[a]anthracene, 56-55-3; chrysene, 218-01-9; benzo[e]pyrene, 192-97-2; benzo[a]pyrene, 50-32-8; perylene, 198-55-0; dibenz[a,h]anthracene, 53-70-3; α-chlordane, 5103-71-9; *trans*-nonachlor, 39765-80-5; trichlorobiphenyl, 25323-68-6; tetrachlorobiphenyl, 26914-33-0; pentachlorobiphenyl, 25429-29-2; hexachlorobiphenyl, 26601-64-9; heptachlorobiphenyl, 28655-71-2; octachlorobiphenyl, 55722-26-4; nonachlorobiphenyl, 53742-07-7.

Literature Cited

(1) Kraybill, H. F. *Ann. N.Y. Acad. Sci.* **1977**, *298*, 80–89.
(2) Malins, D. C. *Environ. Sci. Technol.* **1980**, *14*, 32–37.
(3) O'Connor, J. M.; Klotz, J. B.; Kneip, T. J. In *Ecological Stress and the New York Bight: Science and Management*; Mayer, G. F., Ed.; Estuarine Research Foundation: Columbia, SC, 1982; pp 631–653.
(4) Brown, D. A.; Gossett, R. W.; Jenkins, K. D. In *Physiological* Mechanisms *of Marine Pollution Toxicity*; Vernberg, W. B.; Calabrese, A.; Thurberg, F. P.; Vernberg, F. J. Eds.; Academic: New York, 1982; pp 197–213.
(5) Malins, D. C.; McCain, B. B.; Brown, D. W.; Chan, S.-L.; Myers, M. S.; Landahl, J. T.; Prohaska, P. G.; Friedman, A. J.; Rhodes, L. D.; Burrows, D. G.; Gronlund, W. D.; Hodgins, H. O. *Environ. Sci. Technol.* **1984**, *18*, 705–713.
(6) Malins, D. C.; Krahn, M. M.; Brown, D. W.; Rhodes, L. D.; Myers, M. S.; McCain, B. B.; Chan, S.-L. *JNCI, J. Natl., Cancer Inst.* **1985**, *74*, 487–494.
(7) Malins, D. C.; Krahn, M. M.; Rhodes, L. D.; Brown, D. W.; Krone, C. A.; McCain, B. B.; Chan, S.-L. *Carcinogenesis (London)* **1985**, *6*, 1463–1469.
(8) Sherwood, M. J. In *Ecological Stress and the New York Bight: Science and Management*; Mayer, G. F., Ed.; Estuarine Research Federation: Columbia, SC, 1982; pp 359–377.
(9) Krahn, M. M.; Myers, M.S.; Burrows, D. G.; Malins, D. C. *Xenobiotica* **1984**, *14*, 633–646.
(10) Krahn, M. M.; Rhodes, L. D.; Myers, M. S.; Moore, L. K.; MacLeod, W. D., Jr.; Malins, D. C. *Arch. Environ. Contam. Toxicol.* **1986**, *15*, 61–67.
(11) Schafer, H. In *Biennial Report for 1983–1984*; Bascom, W., Ed.; Southern California Coastal Water Research Project: Long Beach, CA, 1984; pp 11–19.
(12) Gosset, R. W.; Puffer, H. W.; Arthur, R. H.; Alfafar, J. F.; Young, D. R. *Mar. Pollut. Bull.* **1983**, *14*, 60–65.
(13) Eganhouse, R.; Kaplan, I. *Environ. Sci. Technol.* **1982**, *16*, 180–186.
(14) Love, M. S.; McGowen, G. E.; Westphal, W.; Laven R. J.; Martin, L. *Fish. Bull.* **1984**, *82*, 179–198.
(15) MacLeod, W. D., Jr.; Brown, D. W.; Friedman, A Burrows, D. G.; Maynes, O.; Pearce, R.; Wigren, C Bogar, R. G. NOAA Technical Memo; U.S. Departme Commerce: Washington, DC, 1985; NMFS F/NWC
(16) Roubal, W. T.; Collier, T. K.; Malins, D. C. *Arch. Envi Contam. Toxicol.* **1977**, *5*, 513–529.
(17) Varanasi, U.; Gmur, D. J. *Aquatic Toxicol.* **1981**, *1*, 49
(18) Gmur, D. J.; Varanasi, U. *Carcinogenesis (London)* 1 *3*, 1397–1403.
(19) Myers, M. S.; Rhodes, L. D.; McCain, B. B. *JNCI, J. N Cancer Inst.* **1987**, *78*, 333–351.
(20) Malins, D. C.; McCain, B. B.; Brown, D. W.; Sparks, A. Hodgins, H. O.; Chan, S.-L. NOAA Technical Memo; U Department of Commerce: Washington, DC, 19 OMPA-19.
(21) Jones, G.; Butler, W. In *Mouse Hepatic Neoplasia*; Butl W. H.; Newberne, P. M., Eds.; Elsevier: Amsterdam, 19 pp 21–60.
(22) Stewart, H. L.; Williams, G.; Keysser, C. H.; Lombard, S.; Montoli, R. J. *JNCI, J. Natl. Cancer Inst.* **1980**, 179–206.
(23) Frith, C. H.; Ward, J. M. *J. Environ. Pathol. Toxicol.* 19 *3*, 329–351.
(24) Brown, D. A.; Gossett, R. W.; Hershelman, G. P.; War C. F.; Westcott, A. M.; Cross, J. N. *Mar. Environ. Res.* 198 *18*, 291–310.
(25) Young, D. R.; McDermott-Ehrlich, D. J.; Heesen, T. *J.—Water Pollut. Control Fed.* **1976**, *48*, 1919–1928.
(26) Myers, M. S.; Johnson, L. L.; Rhodes, L. D.; Olson, O. P McCain, B. B., unpublished data.
(27) Murchelano, R. A.; Wolke, R. E. *Science (Washington, D.C.* **1985**, *228*, 587–589.
(28) Hendricks, J. D.; Meyers, T. R.; Shelton, D. W.; Casteel J. L.; Bailey, G. S. *JNCI, J. Natl. Cancer Inst.* **1985**, *74* 839–851.
(29) Zar, J. H. *Biostatistical Analysis*; Prentice-Hall: Englewood Cliffs, NJ, 1974; p 620.
(30) Rhodes, L. D.; Myers, M. S.; Gronlund, W. D.; McCain, B. B. *J. Fish. Biol.*, in press.
(31) Robbins, S. L.; Cotran, R. S.; Kumor, V. *Pathologic Basis of Disease*, 3rd ed.; W. B. Saunders: Philadelphia, PA, 1984; p 1467.
(32) Malins, D. C.; Chan, S.-L.; MacLeod, W. D., Jr.; McCain, B. B.; Clark, R. C., Jr. *Oceans* '86, conference record; The Institute of Electrical and Electronics Engineers: Piscataway, NJ, 1986; pp 566–571.
(33) Young, D. R.; Mearns, A. J.; Jan, T.-K.; Hessen, T. C.; Moore, M. D.; Eganhouse, R. P.; Hershelman, G. P.; Gossett, R. W. *Calif. Coop. Oceanic Fish. Invest.* **1980**, *21*, 197–206.
(34) Bascom, W. *Environ. Sci. Technol.* **1982**, *16*, 226A–236A.
(35) Stein, J. E.; Hom, T.; Varanasi, U. *Mar. Environ. Res.* **1984**, *13*, 97–117.
(36) Varanasi, U.; Reichert, W. L.; Stein, J. E.; Brown, D. W.; Sanborn, H. R. *Environ. Sci. Technol.* **1985**, *19*, 836–841.
(37) Jarvinen, A. W.; Hoffman, M. J.; Thorslund, T. W. *J. Fish. Res. Board Can.* **1977**, *34*, 2089–2103.
(38) Malins, D. C.; McCain, B. B.; Krahn, M. M.; Myers, M. S.; Stein, J. E.; Roubal, W. T.; Brown, D. W.; Varanasi, U.; Hodgins, H. O.; Chan, S.-L. In *Water Chlorination: Chemistry, Environmental Impact and Health Effects*; Jolley, R. L.; Bull, R.; Davis, W.; Katz, S.; Roberts, M., Jr.; Jacobs, V., Eds.; Louis: Chelsea, MI, 1985; pp 399–414.

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