NOTES

SURVEY OF POLYCHLORINATED BIPHENYLS IN SELECTED FINFISH SPECIES FROM UNITED STATES COASTAL WATERS

Polychlorinated biphenyls (PCB's) were manufactured commercially under the trade name Aroclor[1] by Monsanto Chemical Company, the sole U.S. producer. They were first marketed in 1929 and thereafter found extensive industrial applications until domestic production ceased in 1977. The PCB's, as a class of organic chemicals containing typically 20-70% chlorine, have certain chemical and physical properties that make them particularly useful (Broadhurst 1972; American National Standards Institute, Inc. 1974). They are extremely stable and chemically inert compounds, resistant to decomposition by heat, have a high dielectric constant, and are nonflammable. They have been used as insulating fluids in electrical transformers and capacitors, heat exchange fluids, hydraulic fluids, paints, plasticizers, printing inks, retardants, and carbonless copy paper. Because they are carcinogenic to animals, the use of PCB's has been restricted except in closed-system applications thereby minimizing but not eliminating their loss into the environment. As a result of their widespread industrial production and inherent resistance to degradation, PCB's have become ubiquitous and persistent environmental contaminants and have been found in the fatty tissues of a wide range of aquatic and land animals (Anas and Wilson 1970; Bagley et al. 1970; Addison et al. 1972; Claeys et al. 1975; Spagnoli and Skinner 1977; Smith et al. 1977).

The deleterious biological effects of PCB's have been extensively documented during the last decade with particular emphasis on embryo toxicity and a variety of sublethal effects in the consuming animal (Kinter et al. 1972; Aulerich et al. 1973; Hansen et al. 1974; Healton 1974[2]; Barsotti and Allen 1975[3]). Concern over accumulation of PCB's in foods (fish, dairy products, eggs, poultry, and animal feed ingredients) and the possible exposure of the U.S. population to their toxic effects led to the proposed Food and Drug Administration's (FDA) regulatory action of 1973, establishing limits for the amounts of PCB's that may be present in food as a result of contamination (Gardner 1973).

The tolerance set for fish at that time was 5.0 parts per million (ppm) on a wet weight basis. Recent toxicological data on PCB's, however, have caused the FDA to consider the need to lower these limits. In particular, a reduction in the tolerance level from 5.0 to 2.0 ppm is under active consideration by the FDA (Schmidt 1974).

Unlike freshwater fish (for which considerably higher PCB levels have been reported), marine fish have been considered to be largely uncontaminated, at least relative to the 5.0 ppm guideline. Limited "market basket" surveys by FDA have indicated PCB levels in common commercial saltwater species to average <0.2 ppm (Jelinek and Corneliussen 1975). Surveys of this type tend to be misleading, however, because of the emphasis on popular commercial seafoods that are low in fat content.

Fish samples screened for PCB contamination under the National Pesticide Monitoring Program indicate that estuarine pollution levels are declining (Butler and Schutzmann 1978). However, the experimental design and intent of this program emphasizes juvenile rather than adult, market-size fish. Although the results of an EPA-NOAA estuarine monitoring program conducted during 1976-77 indicate few high PCB levels according to the 5.0 ppm guideline for the fishes examined (Butler[4]), several species and/or geographic locations clearly stand out as candidates for more detailed investigation. The estuarine and near coastal waters of the United States are receiving the heaviest load of PCB's (Harvey et al. 1974), many of which find their way into the sediments through absorption by particulates, thus providing a potentially enormous sink of contamination for eventual though gradual release into the marine ecosystem. The food chain magnification of PCB's (and many other organic contaminants) is complex, reflecting the diversity of interspecies relationships and physiological characteristics of in-

[1]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

[2]Healton, D. C. 1974. Review of PCB's in the Great Lakes area, U.S. Food and Drug Administration. Presented at the Governor's Great Lakes Regional Interdisciplinary Pesticide Council, Chicago, Ill., 30 p. Available Northeast Fisheries Center Gloucester Laboratory, National Marine Fisheries Service, NOAA, Emerson Avenue, Gloucester, MA 01930.

[3]Barsotti, D. A., and J. R. Allen. 1975. Effects of polychlorinated biphenyls on reproduction in the primate. Presented at the Meeting of the Federation of American Societies for Experimental Biology, Atlantic City, N.J.

[4]Butler, P.A. 1977. EPA-NOAA Cooperative Estuarine Monitoring Program. Final Report, October, 8 p.

dividual organisms. It is clear, however, that PCB's do accumulate principally in the fats of fishes and that the longer fishes are exposed to contaminated waters and food the greater will be their accumulation of PCB's.

The fish to be monitored were selected on the basis of several criteria: Importance to man (commercial and recreational), ecological importance, and their biochemical, physiological, and behavioral diversity. The sampling sites were chosen to be representative of major coastal and estuarine habitats which differ from one another in ecosystem and function (Fig. 1).

When sampled, the organisms recommended gave a cross section of trophic levels at which the different degrees of accumulation may occur. Examples of these are:

1) Plankton-feeding fishes of wide range, high in lipid content, and commercially important.
2) Benthic-feeding fishes of wide range and of commercial importance.
3) Migratory-feeding fishes, anadromous, top carnivores that migrate into and out of areas that are highly polluted and are of recreational importance.
4) Commercially important species of the mackerel family, pelagic.
5) Upper dwellers, weakly migratory, and commercially important species.
6) Species indigenous to the area being sampled which are of commercial recreational importance.

The sites from which the fish samples were collected represented known or suspected highly contaminated areas, pristine locations, and recreational and commercial areas. The Atlantic, Gulf, and Pacific coasts and one inland site were sampled.

The objective of this work was to develop extensive quantitative data on the concentration of PCB's in the edible tissues of targeted finfishes taken from the chosen areas of U.S. waters.

Materials and Methods

Collections were made between the fall of 1979 and winter of 1981. The collection sites and common names of fishes monitored are shown in Figure 1. Target species from pristine and contaminated sampling areas, supporting substantial recreational and commercial areas, were collected seasonally.

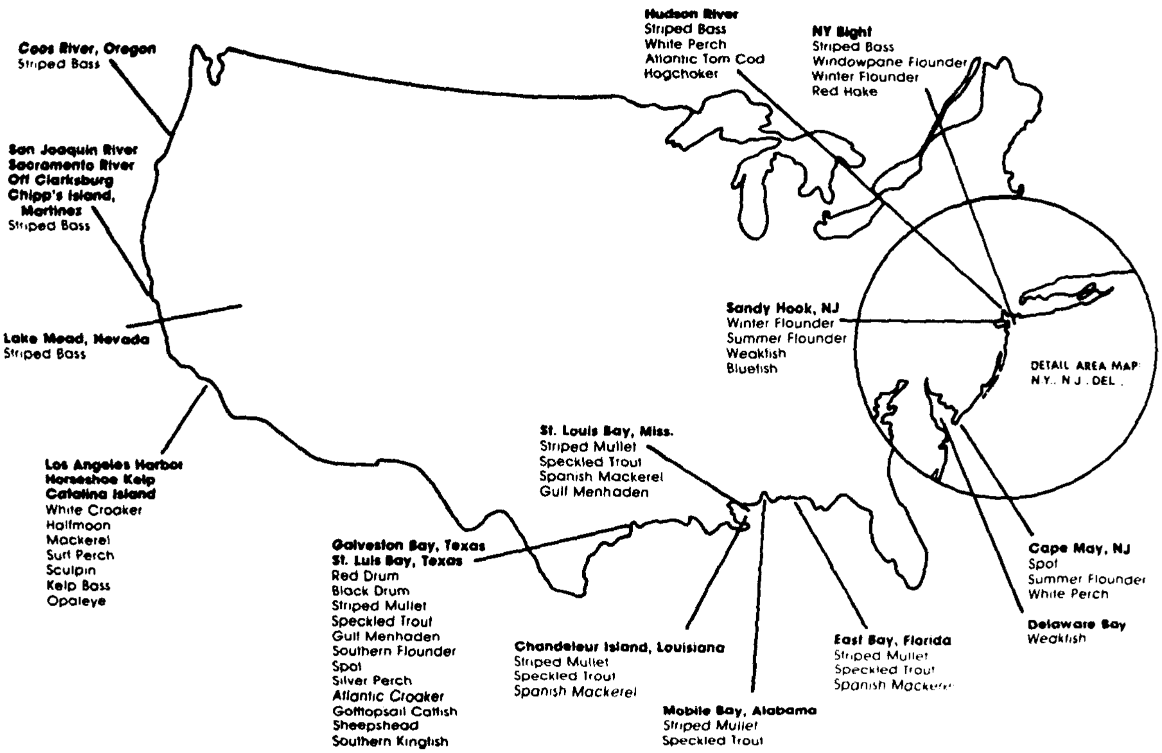

FIGURE 1.—National PCB survey sampling sites and targeted species.

Collections were made by crews operating out of Montclair State College and the New Jersey Marine Sciences Consortium Seaville Field Station; Gulf Coast Research Laboratory, Ocean Springs, Miss.; Texas A&M University of Galveston Marine Laboratory at Galveston, Tex.; University of Southern California Institute for Marine and Coastal Studies, Los Angeles, Calif.; and the Southwest Fisheries Center Tiburon Laboratory of the National Marine Fisheries Service (NMFS), Tiburon, Calif. Sampling of target species was accomplished by using appropriate gear, including beach seines, gill nets, otter trawls, and hook and line. Following capture, specimens were cooled and stored in ice. Subsequently, all specimens were measured, weighed, sexed, and aged. Fish were then filleted, the right side serving for analysis samples and the left for NMFS archives. Gonad and liver tissues also were archived for future reference. All samples were frozen in prerinsed aluminum foil prior to shipment to Gloucester. All samples were composited at the Gloucester Laboratory and consisted of equal weights of 10 deboned, skinless fillets from the right side of 10 individual fish. Target species included are shown on Table 1 and are arranged in phyletic sequence, according to families to which they belong.

Analytical procedure was in accordance with the AOAC multiresidue procedure for pesticides (Horwitz 1980). Briefly, homogenates were extracted with petroleum ether. The extract was concentrated, the solvent completely removed, and the weight of fat determined. Three grams or less of fat were taken for acetonitrile partitioning between petroleum ether. The extract was concentrated to ca. 10 ml and transferred to a florisil column. PCB's were eluted with 6% diethyl ether in petroleum ether, concentrated to 5 ml, and analyzed by gas-liquid chromatography. The florisil extract was further concentrated or diluted for eventual cleanup by silicic acid chromatography (Armour and Burke 1970). A suitable aliquot was charged onto the column. PCB's were eluted with petroleum ether, concentrated, and made up to a definite volume. An aliquot of the silicic acid extract was injected on a Perkin-Elmer Sigma 1 gas chromatograph, equipped with a Ni^{63} electron capture detector. A 6-ft by 2 mm i.d. glass coiled column consisting of 1.5% SP-2250 + 1.95 SP-2401 on 100/120 mesh Supelcoport was used as the analytical column. The carrier gas was argon/methane 95/5 at a flow rate of 20 ml/min. A makeup flow of 40 ml/min was added for a total detector flow of 60 ml/min. Injector temperature was set at 225°C, detector 300°C, and oven 200°C. The electrometer range was set at 1.0 nA. Efficiency of the column for p, p'-DDT was determined to be 931 theoretical plates per foot.

TABLE 1.—Common and scientific names of fish species listed in phylogenetic order.

Gulf menhaden	*Brevoortia patronus*
Gafftopsail catfish	*Bagre marinus*
Red hake	*Urophycis chuss*
Atlantic tomcod	*Microgadus tomcod*
Whiting (silver hake)	*Merluccius bilinearis*
Striped bass	*Morone saxatilis*
White perch	*Morone americana*
Kelp bass	*Paralabrax clathratus*
Bluefish	*Pomatomus saltatrix*
Sheepshead	*Archosargus probatocephalus*
Weakfish	*Cynoscion regalis*
Speckled trout	*Cynoscion nebulosus*
Spot	*Leiostomus xanthurus*
Black drum	*Pogonias cromis*
Red drum	*Sciaenops ocellatus*
Silver perch	*Bairdiella chrysoura*
Atlantic croaker	*Micropogonias undulatus*
Southern kingfish	*Menticirrhus americanus*
White croaker	*Genyonemus lineatus*
Opaleye	*Girella nigricans*
Halfmoon	*Medialuna californiensis*
White seaperch	*Phanerodon furcatus*
Striped mullet	*Mugil cephalus*
Chub mackerel	*Scomber japonicus*
Spanish mackerel	*Scomberomorus maculatus*
California scorpionfish	*Scorpaena guttata*
Winter flounder	*Pseudopleuronectes americanus*
Summer flounder	*Paralichthys dentatus*
Windowpane flounder	*Scophthalmus aquosus*
Hogchoker	*Trinectes maculatus*
Pacific sanddab	*Citharichthys sordidus*
Southern flounder	*Paralichthys lethostigma*

PCB's were measured by comparing total area of residue peaks with total area of peaks from appropriate Aroclor reference material. Only those peaks from samples that could be attributed to chlorobiphenyls and which were present in the chromatogram of reference material were used. PCB residues, with chromatographic patterns which were altered extensively from Aroclor references, were measured by individual peak area comparisons, using Aroclor reference material weight factors. Each PCB peak was calculated against an appropriate individual reference peak with exactly the same absolute retention time. Total PCB's were obtained by summing individual peak values.

Quality Assurance Program

Before processing any samples, a method blank (minus flesh) was run to insure that all glassware, reagents, and solvents were interference free. Each time there was a new set of samples, or occasionally to check reagents, a method blank would be processed as a safeguard against chronic contamination. Standard quality assurance practices were used with this method. For checking the accuracy of PCB determinations, check standards were prepared.

Analyses were replicated to validate the precision of the analysis. Agreement among triplicate samples extracted on the same day was ±5% of the mean. A sample was fortified with 1.0 ppm Aroclor 1254 each week to check percent recovery. The spiking solution was pipetted directly onto the homogenized flesh contained in the blender jar and worked up by AOAC multiresidue procedure. Check of final recovery precision was ±11% of the mean. Degradations of specified Aroclors 1242, 1254, and 1260 were monitored by running standard mixtures of the compounds through the entire procedure in the absence of any sample material. This was done whenever new materials or reagents were used.

Validation studies were accomplished at the 1.0, 0.5, and 0.1 ppm levels. Recovery efficiency for seven samples spiked at the 1.0 ppm level was 83.88%. At the 0.5 ppm level recovery was 85.66%, and at 0.1 ppm, 79%. Coefficient of variation ranged from 6.9 to 11.5 for the three levels. In addition, a blind sample of homogenized carp was introduced into the sampling system periodically. This sample was provided and thoroughly analyzed by J. D. Petty of the Fish and Wildlife Service, Columbia National Fisheries Research Laboratory, Columbia, Mo.

Finally, the Gloucester Laboratory participated in the ICES[5] fourth organochlorine intercalibration exercise for unspiked and spiked fish oils. The accuracy and precision of the Gloucester Laboratory exceeded the performance level accepted by ICES.

Confirmation of PCB's by GC-MS

A 12 m by 0.21 mm i.d. fused silica column (OVID-101) was coupled to a Hewlett-Packard 5992 B GC-MS (gas chromatography-mass spectrometry) and operated in the selected ion monitoring mode. Four extracts of striped bass and four extracts of white perch were analyzed by GC-MS to confirm the presence of chlorosubstituted biphenyls. Ion masses of 235, 246, 263, 292, 326, and 360 were selected. In this manner, tetrachloro, pentachloro, hexachloro, heptachlorobiphenyls, aldrin, analogues of DDT, and p,p'-DDE could be detected. The presence of chlorosubstituted biphenyls (4, 5, 6, and 7) was indicated. Also, mass spectra of some of the individual peaks were obtained and stored during production of a total ion chromatogram. Subsequently, the individual peaks were identified by comparing their spectra with those in the system's library using a library search program.

Results

Table 2 gives the mean PCB concentrations (ppm, wet weight), lipid content, length, weight, age, number of samples, and location for each of the species. A total of 270 samples were analyzed by the AOAC procedure with additional cleanup by silicic acid chromatography. PCB's were detected for all of the samples analyzed. Total PCB values of marine finfish averaged 0.33 ppm, well below the FDA limit of 5 ppm and 3/20 of the proposed 2 ppm standard.

The highest concentration measured in any species was 22.0 ppm in a white perch sampled from the Hudson River. White perch sampled from Cape May Peninsula had an average total PCB content of 0.06 ppm. The Hudson River is known to be heavily laden with PCB's. White perch fished in the Hudson River appear to be strong candidates for regulatory action. Total PCB content for white perch young-of-a-year (YOY) sampled from the Hudson River was 1.9 ppm.

Striped bass sampled from estuaries of the Hudson River averaged 1.5 ppm. Range of PCB results from five samples indicate that this species is another candidate in need of more intensive monitoring. A sample of the YOY had a total PCB content of 1.1 ppm. One sample from the New York Bight Apex had a PCB value of 3.6 ppm. The lowest PCB values for striped bass were found in Lake Mead, Nev. Striped bass fished from Coos River, Oreg., averaged 0.27 ppm. Coos River was considered one of the pristine areas for sampling striped bass. Striped bass fished from the San Francisco Delta region averaged 0.39 ppm. There is intensive agriculture in the Central Valley of this region with drainage by the Sacramento and San Joaquin Rivers into the Delta and San Francisco Bay. Sites considered to be contaminated from agricultural runoff were sampled. One sample from the Sacramento River had a PCB content of 4.00 ppm. Seventy-nine striped bass samples were analyzed from the western coastal U.S. waters. The total PCB content averaged 0.32 ppm.

Table 3 summarizes PCB values according to family grouping. The average PCB values in ppm for the following families were:

bluefish	1.2	porgies	0.07
cods	0.08	sea basses	0.04
drums	0.19	sea chubs	0.02
herrings	0.34	scorpionfishes	0.07
mackerels	0.14	surfperches	0.13
mullets	0.13	temperate basses	2.84

[5]ICES (International Council for the Exploration of the Sea). An intercalibration exercise on PCB's in biological materials carried out by 24 participants using unspiked and spiked samples of cod liver oil to determine agreement among analysts.

TABLE 2.—Total PCB content of the edible portions of targeted samples in respect to length, weight, age, and lipid content. Mean ranges are in parentheses.

Species and location	No. of samples	Length (cm)	Weight (kg)	Age (yr)	Lipid content (%)	Total PCB's (ppm)
Gulf menhaden						
Bay St. Louis, Miss.	2	18(15-33)	0.14(0.09-0.30)	3(2-3)	8.4(5.5-11.4)	0.19(0.10-0.29)
Galveston Bay, Tex.	4	25(19-28)	0.21)0.14-0.34)	1(1-2)	12.6(9.8-14.5)	0.49(0.43-0.54)
San Luis Pass, Tex.	3	24(16-29)	0.20(0.08-0.31)	1(1-3)	8.6(5.3-11.1)	0.34(0.31-0.41)
Gafftopsail catfish						
Galveston Bay, Tex.	2	51(44-55)	1.23(0.78-1.5)	2(1-3)	2.3(2.1-2.5)	0.10(0.04-0.17)
San Luis Pass, Tex.	2	44(27-40	1.04(0.17-2.10)	2(0+-3)	2.4(1.5-3.2)	0.10(0.04-0.17)
Red hake						
New York Bight	8				1.7(1.6-1.8)	0.10(0.03-0.34)
Atlantic tomcod						
Hudson River	1	18(17-19)	0.06(0.05-0.10)	2(2-3)	1.6(1.6-1.6)	0.10(0.10-0.10)
Silver hake						
San Luis Pass, Tex.	1	26(18-30)	0.16(0.06-0.38)	1(1-2)	1.2(1.2-1.2)	0.03(0.03-0.03)
Striped bass						
Hudson River	5	20(4-32)	0.14(0.00-0.39)	4(YOY[1]-7)	2.6(2.0-3.9)	1.5(1.1-2.1)
New York Bight Apex	4	26(18-70)	0.59(0.05-4.25)	Large fishes-13 others undetermined	3.3(1.2-8.2)	1.1(0.2-3.60)
San Joaquin River, Calif. (off Antioch)	7	64(57-72)	3.54(1.86-6.52)	5(4-7)	2.1(1.3-3.0)	0.35(0.29-0.5)
Sacramento River, Calif. (off Clarksberg)	11	66(51-91)	3.83(1.53-8.88)	6(4-9)	2.5(1.4-3.7)	0.75(0.2-4.00)
Chipp's Island, Calif.	17	40(25-74)	1.04(0.18-4.53)	3(2-4)	2.4(0.8-6.0)	0.22(0.11-0.78)
Martinez Shore, Calif.	9	66(32-121)	4.22(0.34-16.20)	5(2-14)	1.7(1.0-2.8)	0.24(0.07-0.57)
Coos River, Oreg.	28	77(49-101)	7.08(1.80-15.44)	7(4-19)	2.5(1.3-5.3)	0.27(0.04-1.86)
Lake Mead, Nev.	7	47(37-59)	0.95(0.55-1.37)	3(2-3)	1.3(0.6-2.4)	0.10(0.03-0.34)
White perch						
Hudson River	5	15(5-23)	0.07(0.00-0.19)	4(YOY-6)	6.1(2.6-10.7)	10.2(1.9-22.0)
Cape May Peninsula	3	22(19-28)	0.16(0.05-0.30)	—	1.5(1.1-1.8)	0.06(0.04-0.08)
Kelp bass						
Backside Catalina	2	22(19-36)	0.28(0.10-1.02)	4(2-7)	1.6(1.4-1.7)	0.03(0.02-0.04)
Frontside Catalina	2	26(16-36)	0.40(0.18-1.74)	5(3-9)	1.3(1.2-1.4)	0.05(0.04-0.06)
Bluefish						
Sandy Hook Bay	1	46(45-47)	1.13(0.99-1.27)	9(8-9)	9.0(9.0-9.0)	1.2(1.2-1.2)
Sheepshead						
Galveston Bay, Tex.	1	37(31-42)	0.87(0.73-1.26)	2(2-2)	2.1(2.1-2.1)	0.06(0.06-0.06)
San Luis Pass, Tex.	2	36(26-44)	0.94(0.42-1.56)	2(1-3)	1.6(1.0-2.2)	0.08(0.02-0.14)
Weakfish						
Sandy Hook Bay	6	36(9-77)	0.84(0.01-3.72)	4(YOY-10)	1.7(1.2-2.5)	0.23(0.12-0.02)
Cape May Peninsula	1	38(32-48)	0.58(0.43-1.07)	5(3-6)	3.8(3.8-3.8)	0.35(0.35-0.35)
Speckled trout						
East Bay, Fla.	5	31(25-41)	0.41(0.21-0.99)	3(3-5)	2.2(1.0-3.2)	0.18(0.03-0.61)
Mobile, Ala.	4	32(25-0.38)	0.45(0.22-0.76)	4(3-4)	5.9(2.3-10.7)	0.24(0.07-0.43)
Bay St. Louis, Miss.	4	36(24-46)	0.73(0.21-1.31)	4(3-6)	4.3(2.8-6.4)	0.10(0.05-0.25)
Chandeleur Sound, La.	1	25(18-41)	0.27(0.10-0.92)	3(2-5)	0.9(0.9-0.9)	0.02(0.02-0.02)
Galveston Bay, Tex.	1	31(21-49)	0.41(0.11-1.14)	2(1-2)	4.0(4.0-4.0)	0.14(0.14-0.14)
San Luis Pass, Tex.	2	46(26-67)	1.27(0.20-3.17)	3(1-5)	3.1(0.17-4.6)	0.12(0.11-0.14)
Spot						
Sandy Hook Bay	1	30(30-31)	0.40(0.37-0.43)	—	1.8(1.8-1.8)	0.24(0.24-0.29)
Cape May Peninsula	1	15(13-16)	0.04(0.03-0.07)	4(2-4)	1.5(1.5-1.5)	0.03(0.03-0.03)
Galveston Bay, Tex.	1	16(15-19)	0.06(0.1 -0.08)	1(1-1)	2.5(2.5-2.5)	0.20(0.20-0.20)
San Luis Pass, Tex.	1	21(18-22)	0.14(0.08-0.18)	1(1-1)	1.0(1.0-1.0)	0.13(0.13-0.13)
Black drum						
Galveston Bay, Tex.	4	33(21-44)	0.60(0.14-1.34)	1(1-2)	1.5(0.6-2.3)	0.05(0.02-0.10)
San Luis Pass, Tex.	2	27(21-37)	0.41(0.15-0.70)	1(1-2)	1.5(1.3-1.6)	0.06(0.02-0.10)
Red drum						
Galveston Bay, Tex.	4	44(30-62)	1.03(0.34-2.67)	1+(0+-1+)	1.3(1.1-1.5)	0.03(0.02-0.04)
San Luis Pass, Tex.	1	51(47-54)	1.47(1.22-1.73)	1(1-2)	1.6(1.6-1.6)	0.02(0.02-0.02)
Silver perch						
Galveston Bay, Tex.	1	20(19-20)	0.12(0.11-0.12)	2(2-2)	5.2(5.2-5.12)	0.23(0.23-0.23)
San Luis Pass, Tex.	3	18(17-21)	0.08(0.04-0.15)	1(1-2)	2.6(1.6-4.3)	0.11(0.08-0.14)
Atlantic croaker						
Galveston Bay, Tex.	2	21(15-32)	0.14(0.03-0.44)	1(0+-1)	9.2(6.2-12.1)	0.22(0.13-0.31)
San Luis Pass, Tex.	1	31(28-32)	0.41(0.28-0.57)	1(1-1)	3.9(3.9-3.9)	0.09(0.09-0.09)
Southern kingfish						
San Luis Pass, Tex.	1	24(29-38)	0.47(0.31-0.68)	2(2-2)	2.2(2.2-2.2)	0.04(0.04-0.04)
White croaker						
Inside LA Harbor	2	23(20-25)	0.21(0.11-0.27)	6(5-7)	2.1(1.1-3.2)	0.75(0.74-0.76)
Outside LA Harbor	2	21(16-26)	0.16(0.08-0.28)	5(3-7)	2.1(1.0-3.2)	0.72(0.50-0.95)
Opaleye						
Frontside Catalina	1	23(18-29)	0.36(0.22-0.71)	3(2-4)	1.2(1.2-1.2)	0.01(0.01-0.01)
Backside Catalina	1	20(15-25)	0.30(0.14-0.47)	2(2-3)	0.7(0.7-0.7)	0.01(0.01-0.01)
Halfmoon						
Inside LA Harbor	2	22(17-26)	0.35(0.14-0.71)	3(2-5)	2.3(1.0-3.6)	0.04(0.01-0.07)
Outside LA Harbor	1	23(20-26)	0.23(0.13-0.35)	3(3-5)	1.1(1.1-1.1)	0.04(0.04-0.04)
Frontside Catalina	2	21(17-24)	0.27(0.14-0.35)	3(2-3)	1.1(0.7-1.6)	0.02(0.01-0.03)
Backside Catalina	2	21(17-25)	0.25(0.06-0.35)	3(2-3)	1.5(1.2-1.8)	0.03(0.01-0.06)
White seaperch						
Inside LA Harbor	1	17(15-18)	0.11(0.10-0.13)	3(2-3)	1.1(1.1-1.1)	0.13(0.13-0.13)

TABLE 2.—*Continued.*

Species and location	No. of samples	Length (cm)	Weight (kg)	Age (yr)	Lipid content (%)	Total PCB's (ppm)
Striped mullet						
Mobile Bay, Ala.	5	29(25-32)	0.42(0.28-0.67)	2(2-3)	4.4(1.7-9.5)	0.34(0.04-0.85)
East Bay, Fla.	5	29(23-33)	0.47(0.21-0.69)	2(2-3)	4.6(1.4-12.1)	0.17(0.04-0.34)
Bay St. Louis, Miss.	4	29(25-28)	0.47(0.26-0.99)	2(2-3)	3.3(1.2-5.9)	0.11(0.01-0.21)
Chandeleur Sound, La.	4	27(21-38)	0.39(0.15-0.96)	2(2-3)	3.4(2.4-4.6)	0.05(0.02-0.10)
Galveston Bay, Tex.	4	30(21-37)	0.31(0.10-0.57)	1(1-2)	2.0(1.2-3.0)	0.09(0.04-0.12)
San Luis Pass, Tex.	4	32(23-50)	0.45(0.14-1.65)	1(1-2)	3.1(1.5-7.6)	0.03(0.02-0.04)
Chub mackerel						
Inside LA Harbor	2	30(26-40)	0.39(0.23-0.79)	3(2-5)	5.2(5.0-5.5)	0.19(0.11-0.27)
Outside LA Harbor	2	231(26-39)	0.46(0.25-0.94)	3(2-4)	5.5(5.0-6.5)	0.18(0.06-0.31)
Frontside Catalina	1	31(26-37)	0.41(0.26-0.82)	3(2-4)	6.3(6.3-6.3)	[illegible](0.06-0.06)
Spanish mackerel						
East Bay, Fla.	2	30(26-35)	0.28(0.18-0.38)	1(1-1)	3.2(1.8-4.6)	0.90(0.89-0.92)
Bay St. Louis, Miss.	2	33(27-44)	0.41(0.17-1.08)	2(2-2)	8.0(1.4-14.6)	0.05(0.02-0.09)
Chandeleur Sound, La.	2	39(32-43)	0.42(0.25-0.82)	1(1-1)	4.7(1.8-7.7)	0.09(0.09-0.09)
California scorpionfish						
Inside LA Harbor	1	22(17-30)	0.26(0.14-0.48)	4(3-5)	1.9(1.9-1.9)	0.03(0.03-0.03)
Outside LA Harbor	2	21(16-34)	0.29(0.14-0.52)	3(2-5)	1.3(1.2-1.5)	0.11(0.11-0.12)
Backside Catalina	1	22(18-38)	0.42(0.23-0.88)	3(2-5)	1.4(1.4-1.4)	0.07(0.07-0.07)
Winter flounder						
Sandy Hook Bay	4	19(15-31)	0.09(0.03-0.40)	2(2-3)	1.5(1.3-1.6)	0.07(0.05-0.13)
New York Bight	13				2.2(1.7-3.1)	0.23(0.06-0.56)
Summer Flounder						
Sandy Hook Bay	2	33(28-37)	0.40(0.20-0.63)	6(5-7)	1.3(1.1-1.6)	0.04(0.04-0.04)
Cape May Peninsula	2	34(29-30)	0.40(0.24-0.57)	8(7-9)	0.8(0.7-1.0)	0.02(0.02-0.02)
Windowpane flounder						
New York Bight	10				2.0(1.4-2.9)	0.21(0.04-0.63)
Hogchoker						
Hudson River	2	12(10-14)	0.03(0.01-0.05)	3(2-3)	2.1(1.7-2.5)	0.11(0.10-0.12)
Pacific sanddab						
Frontside Catalina	2	20(13-27)	0.14(0.04-0.28)	3(2-6)	1.2(1.1-1.2)	0.02(0.02-0.02)
Backside Catalina	2	20(16-26)	0.14(0.01-0.25)	3(2-6)	1.4(1.3-1.5)	0.04(0.03-0.06)
Southern flounder						
Galveston Bay, Tex.	2	34(21-42)	0.54(0.31-1.02)	1(1-3)	1.31(1.2-1.5)	0.02(0.02-0.02)
San Luis Pass, Tex.	2	29(20-42)	0.29(0.08-0.46)	1(0+-3)	1.3(1.3-1.3)	0.02(0.02-0.02)

[1]YOY = young of a year.

TABLE 3.—National PCB survey of targeted finfishes.

Family	Species	No. of samples	PCB levels (ppm) Mean	PCB levels (ppm) Range
Bluefish	Bluefish	1	1.2	1.2 -1.2
Cod	Atlantic tomcod	1	0.10	0.10-0.10
	Red hake	8	0.10	0.03-0.34
	Whiting	1	0.03	0.03-0.03
Drum	Atlantic croaker	3	0.18	0.09-0.31
	Black drum	6	0.05	0.02-0.10
	Red drum	5	0.03	0.02-0.04
	Silver perch	4	0.14	0.08-0.23
	Southern kingfish	2	0.09	0.04-0.14
	Speckled trout	17	0.16	0.02-0.43
	Spot	4	0.16	0.03-0.35
	Weakfish	9	0.20	0.11-0.35
	White croaker	4	0.73	0.50-0.95
Flatfish	Hogchoker	2	0.11	0.10-0.16
	Pacific sanddab	5	0.03	0.02-0.06
	Southern flounder	4	0.02	0.02-0.02
	Summer flounder	4	0.03	0.02-0.04
	Windowpane flounder	10	0.21	0.04-0.63
	Winter flounder	17	0.15	0.05-0.56
Herring	Gulf menhaden	9	0.34	0.10-0.54
Mackerel	Pacific mackerel	5	0.16	.06-0.31
	Spanish mackerel	6	0.11	0.02-0.92
Mullet	Spriped mullet	26	0.13	0.01-0.85
Porgy	Sheepshead	3	0.07	0.02-0.14
Scorpion-fish	California scorpionfish	4	0.07	0.03-0.12
Sea bass	Kelp bass	4	0.04	0.02-0.06
Sea cat-fish	Gafftopsail catfish	4	0.10	0.04-0.17
Sea chub	Halfmoon	7	0.03	0.01-0.07
	Opaleye	3	0.01	0.01-0.01
Surfperch	Surfperch	1	0.13	0.13-0.13
Temperate bass	Striped bass	88	0.56	0.01-4.00
	White perch	8	5.13	0.04-22.00

Species indigenous to the Galveston Bay and Los Angeles Harbor areas had slightly higher PCB values than those species sampled from their pristine counterparts—namely, San Luis Pass and Catalina Island.

Apparent trends from the limited number of samples per species collected were: Flounders from the New York Bight Apex had higher PCB values than those flounders sampled from Cape May Peninsula and Sandy Hook Bay; striped mullets collected from Chandeleur Sound, La., and San Luis Pass, Tex., had lower PCB values than striped mullets sampled from other sites of the Gulf; seatrouts had slightly higher PCB values in the northeast than in the eastern part of the Gulf of Mexico; and species with high fat content sampled from contaminated sites had higher PCB values, e.g., Spanish mackerel, Gulf menhaden, than those species sampled from pristine sites.

Discussion

The lack of a consistent pattern of higher body burdens in selected contaminated areas may be related to the mobility of the species sampled. It is possible, though conjectural, that a large proportion of the measured PCB body burdens is acquired in estuarine or other contaminated areas but that the migratory nature of most megafauna (and/or of their prey) yields the observed pattern of low body burdens across large areas of the continental shelf. Several authors have reported PCB results of a broader scale and have similarly noted low-level contamination throughout a region but no strikingly high PCB values in contaminated areas or elsewhere (Sims et al. 1977; McDermott-Ehrlich et al. 1978; Stout 1980; Stout and Beezhold 1981; Stout et al. 1981).

A condition factor could also be obscuring any tendency of fish from contaminated areas to show higher PCB body burdens. PCB's have an affinity for fats, so composites with a greater fat content might be expected to accumulate more PCB's. The average lipid content of white perch in the flesh sampled from the Hudson River was 6.1% versus 1.5% from Cape May. Striped bass from the Hudson River had an average lipid content of 1.5%. This may account for the higher PCB levels found in the flesh of white perch from the estuaries of the Hudson River. If fat content of the species examined is somehow inversely related to environmental stress, this will tend to confuse any direct relationship between environmental contamination and PCB body burdens and could contribute to the observed absence of dramatically elevated muscle burdens in targeted species.

Conclusions

The current proposed FDA tolerance or "action level" for PCB's in foodfish is 2 ppm. The FDA tolerance now being considered is 1 ppm. PCB's in edible fishes remain far below existing or proposed maximum permissible levels for the majority of species investigated. Also, estuarine and coastal regions of the world are increasingly subjected to a wide range of environmental alterations. Degradation ensues through the action of man's activities, energy needs, and increasing population. Such degradation may be gradual, but eventually results in rivers, estuaries, and coasts with greatly depleted natural resources. For example, the pollution of the Hudson and Delaware Rivers in the eastern United States is extremely high. Degradation of rivers on the east coast with the loss of striped bass and other species has already occurred. Striped bass is recognized as being one of the most important anadromous and coastal commercial and recreational fishes in the United States.

The New York Bight is the ultimate repository for wastes from over 20 million people as well as a host of major industries. Mutagens in bight waters may be associated with higher than normal incidences of developmental problems and mortalities in fish eggs and larvae. The New York Bight Apex is also a spawning and nursing area for some commercial species. The Hudson River valley is a conduit for New York Bight Apex contaminants. Presently, there is insufficient information on the long-term effects of pollution. The first step is to recognize the present or potential sources of pollutants. This should be followed by intensive efforts to determine the fate and effects of the pollutants over both short- and long-exposure periods. Unless curtailed, pollution could ultimately deplete marine resources, including fisheries.

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Literature Cited

ADDISON, R. F., M. E. ZINCK, AND R. G. ACKMAN.
1972. Residues of organochlorine pesticides and polychlorinated biphenyls in some commercially produced Canadian marine oils. J. Fish. Res. Board Can. 29:349-355.

AMERICAN NATIONAL STANDARDS INSTITUTE, INC.
1974. American National Standard guidelines for handling and disposal of capacitor- and transformer- grade askarels containing polychlorinated biphenyls. U.S. Gov. Print. Off., Wash., D.C.

ANAS, R. E., AND A. J. WILSON, JR.
1970. Organochlorine pesticides in nursing fur seal pups. Pestic. Monit. J. 4:114-116.

ARMOUR, J. A., AND J. A. BURKE.
1970. Method for separating polychlorinated biphenyls from DDT and its analogs. J. Assoc. Off. Anal. Chem. 53:761-768.

AULERICH, R. J., R. K. RINGER, AND S. IWAMOTA.
1973. Reproductive failure and mortality in mink fed on Great Lakes fish. J. Reprod. Fertil. Suppl. 19:365-376.

BAGLEY, G. E., W. L. REICHEL, AND E. CROMARTIE.
1970. Identification of polychlorinated biphenyls in two bald eagles by combined gas-liquid chromatography-mass spectrometry. J. Assoc. Off. Anal. Chem. 53:251-261.

BROADHURST, M. G.
1972. Use and replaceability of polychlorinated biphenyls. Environ. Health Perspect. 2:81-102.

BUTLER, P. A., AND R. L. SCHUTZMANN.
1978. Residues of pesticides and PCBs in estuarine fish, 1972-1976—National Pesticide Monitoring Program. Pestic. Monit. J. 12:51-59.

CLAEYS, R. R., R. S. CALDWELL, N. H. GUTSHALL, AND R. HOLTON.
1975. Chlorinated pesticides and polychorinated biphenyls in marine species, Oregon/Washington coast, 1972. Pestic. Monit. J. 9:2-10.

GARDNER, S.
1973. Contamination of animal feeds, foods, and food-packaging materials. Fed. Reg. 38:18096-18103.

HANSEN, D. J., P. R. PARRISH, AND J. FORESTER.
1974. Aroclor 1016: Toxicity to and uptake by estuarine animals. Environ. Res. 7:363-373.

HARVEY, G. R., H. P. MIKLAS, V. T. BOWEN, AND W. G. STEINHAUER.
1974. Observations on the distribution of chlorinated hydrocarbons in Atlantic Ocean organisms. J. Mar. Res. 32:103-118.

HORWITZ, W. (editor).
1980. Official methods of analysis of the AOAC. Assoc. Off. Anal. Chem. 13:466-475.

JELINEK, C. F., AND P. E. CORNELIUSSEN.
1975. Levels of PCB's in the U.S. food supply. U.S. Food Drug Admin., Bur. Foods, 8 p.

KINTER, W. B., L. S. MERKENS, R. H. JANICKI, AND A. M. GUARINO.
1972. Studies on the mechanism of toxicity of DDT and polychlorinated biphenyls (PCBs): Disruption of osmoregulation in marine fish. Environ. Health Perspect. 1:169-173.

MCDERMOTT-EHRLICH, D., D. R. YOUNG, AND T. C. HEESEN.
1978. DDT and PCB in flatfish around southern California municipal outfalls. Chemosphere 7:453-461.

SCHMIDT, A. M.
1974. Poisonous or deleterious substances in food. Fed. Reg. 39:42743-42748.

SIMS, G. G., J. R. CAMPBELL, F. ZEMLYAK, AND J. M. GRAHAM.
1977. Organochlorine residues in fish and fishery products from the northwest Atlantic. Bull. Environ. Contam. Toxicol. 18:697-705.

SMITH, F. A., R. P. SHARMA, R. I. LYNN, AND J. B. LOW.
1974. Mercury and selected pesticide levels in fish and wildlife of Utah: II. Levels of mercury, DDT, DDE, dieldrin and PCB in chukars, pheasants and waterfowl. Bull. Environ. Contam. Toxicol. 12:153-157.

SPAGNOLI, J. J., AND L. C. SKINNER.
1977. PCB's in fish from selected waters of New York State. Pestic. Monit. J. 11:69-87.

STOUT, V. F.
1980. Organochlorine residues in fishes from the northwest Atlantic Ocean and Gulf of Mexico. Fish. Bull., U.S. 78:51-58.

STOUT, V. F., AND F. L. BEEZHOLD.
1981. Chlorinated hydrocarbon levels in fishes and shellfishes of the northeastern Pacific Ocean, including the Hawaiian Islands. Mar. Fish. Rev. 43(1):1-12.

STOUT, V. F., C. R. HOULE, AND F. L. BEEZHOLD.
1981. A survey of chlorinated hydrocarbon residues in menhaden fishery products. Mar. Fish. Rev. 43(3):1-13.

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FOODS OF COASTAL FISHES DURING BROWN SHRIMP, *PENAEUS AZTECUS*, MIGRATION FROM TEXAS ESTUARIES (JUNE-JULY 1981)

During May, June, and July, brown shrimp, *Penaeus aztecus*, migrate from Texas bays and estuaries to offshore waters. These shrimp are, for the most part, smaller than the 114 mm total length (TL) legal fishing limit. To prevent overfishing of these juvenile and subadult (60-130 mm TL) shrimps and to allow them to move farther offshore during this period, the Gulf of Mexico Fishery Management Council and the State of Texas simultaneously prohibited nocturnal shrimping from the shoreline out to 370 km. The closure remained in effect over the period 22 May through 15 July 1981. The rationale for the closure was an expected increase in yield from additional growth of the protected brown shrimp and from elimination of waste due to discarding of undersized brown shrimp (Gulf of Mexico Fishery Management Council 1980; Caillouet and Koi 1981).

NOAA's RV *Oregon II* conducted a trawl survey of shrimp size distribution and abundance by depth in the closure area from 4 June through 3 July 1981. The survey provided us the opportunity to describe the foods of Texas coastal fishes while evaluating the natural mortality of brown shrimp due to predation. This paper examines the foods of 81 species of fishes collected during the shrimp survey. We present size- and depth-related changes in diet for the more abundant fishes, and further examine predation on penaeid shrimps.

Materials and Methods

Fish samples were taken from trawl catches by the RV *Oregon II* on 100 stations in 9-64 m waters off the Texas coast (Fig. 1). The survey was conducted from 4 June through 3 July 1981. All trawls were made at night (brown shrimp are nocturnally active) with a 12.2 m semiballoon trawl rigged with a tickler chain and 2.4 m × 1.0 m wooden doors towed at 3 kn. Four stations south of Galveston Bay were repeated at 2-wk intervals; thus, a total of 108 trawl tows were made over the entire coastline. Details of the sampling strategy are given by Matthews (1982). Species composition, abundance, and biomass data for fishes and invertebrates were recorded and standardized to catch per 30-min tow for 89 of the 108 trawl catches. Only penaeid shrimp data were recorded for the other 19 catches. All fishes from each catch (up to a 45 kg maximum) were labelled and frozen for stomach contents analysis.