Body Burdens of Persistent Pollutants in Hudson River Anglers

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Abstract

Sediments, fish, and shellfish in the lower Hudson River estuary contain the residues of decades of contamination with persistent, bioaccumulative environmental pollutants. The complex mix of chemicals found in these waters includes polychlorinated biphenyls (PCBs), mercury, and residues of the organochlorine pesticides chlordane and DDT. Despite health advisories issued by the States of New York and New Jersey, many recreational and subsistence fishers still regularly consume their local catch and share it with family members and friends.

A pilot study of 46 local anglers was conducted in 1998-99 to assess human body burdens of persistent pollutants in persons who consume fish and shellfish from the lower Hudson River watershed. Questionnaire data showed that several of the species eaten most frequently – striped bass, bluefish, blackfish, and blue crabs – are among those specifically targeted by the advisories as unsafe. Frequent consumers of locally caught fish and shellfish had higher serum levels of highly chlorinated PCBs compared to infrequent consumers (e.g., PCB congener 118, mean=0.40 vs. 0.25 ng/mL); of organochlorine pesticide residues including chlordane (0.95 vs. 0.87 ng/mL) and DDT (0.66 vs. 0.54 ng/mL)); and of mercury (mean = 4.18 vs. 1.87 ng/mL in blood and 1.59 vs. 0.98 μg/g in hair).

The results of this pilot study indicate that further research is needed to characterize body burdens of biologically persistent environmental pollutants in urban anglers and family members with whom they share their catch, in order to assess the potential health risks posed by consumption of locally caught fish and shellfish.

Persistent environmental pollutants – mercury, polychlorinated biphenyls (PCBs), and other organochlorines including chlordane, DDT (dichlorodiphenyltrichlorethane), and dioxins – are widespread in many waters in North America and are highly concentrated throughout the Hudson River watershed and the New York-New Jersey harbor *(1-5)*. Past and continuing discharges from industrial and hazardous waste disposal sites are the principal sources of these pollutants.

A number of environmental pollutants, which tend to associate with lipids in organisms, accumulate in river and harbor sediments and increase in concentration as they move up the food chain *(6)*. The highest levels are found in top predator species, such as striped bass and bluefish, as well as in predatory bottom-feeders such as blue crabs, lobsters and eels (Table 1). Because of concern that these chemicals can have adverse effects on human health, state agencies in New York and New Jersey have issued advisories for two decades that include urging women of childbearing age to abstain from consumption of fish and shellfish from the lower Hudson River watershed. Nonetheless, despite these advisories, repeated questionnaire surveys indicate that anglers and their families continue to consume locally caught fish *(7,8)*. Consumption of local fish is relatively common among poor and immigrant communities whose diet traditionally is high in fish and those who rely upon local fish as an inexpensive food source *(9-13)*.

Studies undertaken previously in the Great Lakes states and in western New York have documented that persons who consume fish from waters contaminated with PCBs, mercury and other persistent pollutants, have elevated body burdens of these substances *(14,15)*. Additionally, these studies have demonstrated that the children of women who consume fish from PCB-contaminated water have decrements in central neurologic function and delays in development that appear to be related to *in utero* exposure to these toxicants *(16-18)*. No survey of body burdens of persistent pollutants has been conducted to date among anglers who fish in the Hudson River and the New York-New Jersey harbor. Therefore, it has not been possible to directly assess risks of exposure and, ultimately, of fetal neurotoxicity, among residents of this densely populated region. Need for data on human body burdens of persistent pollutants among anglers in the Hudson River watershed becomes particularly urgent as decisions loom on whether to reopen the Hudson River striped bass fishery or to dredge Hudson River sediments to remove PCBs.

This paper summarizes preliminary results of the first study conducted of body burdens of persistent environmental pollutants among anglers in the lower Hudson River and the New York-New Jersey harbor complex.

Materials and Methods.

In Autumn 1998, in collaboration with two local fishing clubs and the New Jersey Department of Environmental Protection (NJDEP), we conducted an investigation of anglers who fish and crab at sites on the lower main stem of the Hudson River and in the New York-New Jersey harbor complex. The purpose of this study was to characterize consumption patterns of fish and shellfish and to examine body burdens of persistent environmental chemicals among these anglers, and to better understand the links between fishing behavior, fish consumption and health risks.

Study Population. The study population was comprised of anglers at least 18 years of age. Investigators from the Mount Sinai School of Medicine made presentations describing the study to local angler groups who had expressed an interest in helping with recruitment. Presentations were made at the Hudson River Anglers Association in Stony Point, New York and Hudson River Fishermen's Association chapter in Ridgefield Park, New Jersey. Additionally, anglers affiliated with a community center in Elizabeth, New Jersey were recruited. Written informed consent was obtained from each participant according to the guidelines of the Mount Sinai School of Medicine Institutional Review Board.

Exposure Assessment. To assess body burdens of organochlorines, blood samples were obtained from study participants by venipuncture and collected into 7 mL red-top Vacutainer™ tubes. Serum levels of PCBs, residues of chlordane, and DDT-derived metabolites were determined by gas chromatography. The high-resolution gas chromatography technique used for these analyses characterizes approximately 25 individual congeners of PCB *(19)*. Serum lipids were measured to allow adjustments for normal intra-individual variations in serum concentrations of toxicants that arise from fluctuations in serum lipids. Total as well as individual congeners of PCBs were examined, with particular attention to congeners known to bioaccumulate in fish. When the level of an individual PCB congener was below the limit of detection by gas chromatography, a negligible value of 0.05 ng/mL was assigned for that congener.

A structured questionnaire was administered to each angler. It was modeled on the instrument used for the "Hudson River Angler Survey" conducted by the Hudson River Sloop Clearwater, Inc. in 1991-92 *(7)*. The questionnaire, which took 15 minutes or less to complete, obtained information on duration (years) of fishing and crabbing; location and species of fish and shellfish caught; practices related to preparation, cooking, and consumption of fish and shellfish; demographic characteristics; and medical history. (Questionnaire available upon request to authors.)

Data Analysis. Self-reported data on fish and shellfish consumption from the questionnaire were used to derive several exposure indices. Information on the specific types of fish or shellfish, locations of catch, methods of preparation, and the amount, frequency and duration of consumption was analyzed.

Body burden levels of each pollutant were examined in relation to consumption frequency of any fish or shellfish, striped bass, and blue crab using age-adjusted partial correlation coefficients. The significance of differences in pollutant levels among subgroups was determined using t-tests, for both crude and age-adjusted least-squares geometric means. Exposure-response relationships between ordinal categories of consumption and mean pollutant levels were analyzed using analysis of variance (ANOVA) models. All statistical analyses were performed using SAS® statistical software programs (SAS Institute, Inc., Cary, NC).

Results.

Table 2 presents demographic and fish or shellfish consumption characteristics of the 46 study participants, who were mostly white males with a mean age of 50 years (range 28 to 77 years). Two-thirds had an annual income of at least $50,000 and 26 percent were retired. Some knowledge of the state health advisories regarding locally-caught fish and shellfish was reported by 83 percent.

Most of the participants reported eating local fish or shellfish at least once a month during the previous fishing season, with 48 percent eating at least one locally-caught fish or shellfish meal a week (Table

2). The most commonly eaten species reported by the participants were striped bass (84 percent), fluke (77 percent), bluefish (60 percent), blue crabs (60 percent), blackfish (49 percent) and flounder (49 percent).

Only 37 of the 45 collected blood samples yielded sufficient volume of serum for complete analysis. Age-adjusted geometric mean levels of low and high PCB congener levels were consistently greater in anglers recruited at the fishing club in New Jersey compared to anglers recruited at the club in New York (Table 3). Other organochlorine compounds that are prevalent at high concentrations in sediment cores from the rivers in New Jersey and the western New York-New Jersey harbor/Newark bay complex – e.g., *trans*-nonochlor, oxychlordane, DDT and DDE – were also higher in the anglers recruited in New Jersey, in particular, among those who reported eating blue crabs from local waters. Anglers recruited in New Jersey reported statistically significant more frequent consumption of local bluefish, fluke, flounder and American eel compared to anglers recruited in New York.

Total mercury was measured in 43 whole blood samples, and total and inorganic mercury was measured in 21 hair samples obtained from New Jersey anglers. The strong positive correlation (Spearman $r = 0.82$, $p<0.0001$) between mercury levels in the hair and blood of participants who gave both is consistent with other studies.*(20)* The contribution of inorganic mercury to the total mercury measurement was analyzed in the five blood and hair samples with the highest concentrations; inorganic mercury was non-detectable in all the blood samples, and comprised between 9 and 11 percent of the total in the five hair samples. Therefore, in this population, the total mercury measurement is reflective of organic mercury (methylmecury) exposure from fish consumption.

The overall average mercury level in blood (reflecting current exposure) was relatively low – median value 3 ng/mL, arithmetic mean 5.56 ng/mL, geometric mean 2.82 ng/mL (Table 3). However, 19 percent of samples had concentrations greater than 10 ng/mL, the current recommended threshold value in the U. S. for environmentally exposed individuals.( ) The mean blood mercury level was greater in anglers recruited in New Jersey compared to anglers recruited in New York.

The data showed positive correlations between self-reported frequency of consuming locally caught fish and biomarkers of exposure for several environmental contaminants known to have serious health effects. As shown in Table 4, anglers who ate at least one meal a week of any local fish or shellfish had higher serum concentrations of highly chlorinated PCBs compared to infrequent consumers (e.g., PCB congener 118, mean = 0.40 vs. 0.25 ng/mL); of organochlorine pesticide residues (e.g., chlordane, mean = 0.95 vs. 0.87 ng/mL and DDT, mean = 0.66 vs. 0.54 ng/mL); and of mercury (mean = 4.18 vs. 1.87 ng/mL in blood and 1.59 vs. 0.98 μg/g in hair). After statistical adjustment for age, striped bass consumption was not consistently associated with elevated serum levels of contaminants. Anglers who frequently consumed blue crabs had the highest levels of highly chlorinated PCB congeners and pesticide residues. Figures 1 through 3 show the exposure-response gradients between self-reported frequency of eating locally caught fish or crabs and body burden of persistent pollutants. There was a linear relationship between frequency of eating any locally caught fish or crabs and mercury in blood and hair (Figure 3), although no specific type of fish or shellfish showed a particularly strong association with mercury levels.

Discussion.

The major finding of this pilot study is that body burdens of persistent environmental pollutants generally are greater in Hudson River anglers who frequently consume locally caught fish and crabs than among similar individuals who rarely consume these foods. The second principal finding is that there exist positive exposure-response relationships between frequency of local fish and crab consumption and body burdens of persistent pollutants. The PCB concentrations were corrected for total lipids, and all comparisons were age-adjusted; however, body mass index, a significant determinant of some contaminant concentrations in other studies, was not measured in this population. Information on height and weight will be collected in future studies.

As members of organized fishing clubs, the study participants were presumably better informed than the general population about New York or New Jersey state fishing advisories, with 83 percent reporting some knowledge of the advisories' contents. The data suggest that despite this knowledge, a significant proportion of recreational anglers are eating contaminated species of fish and shellfish from waters in the Hudson River watershed. Those with the highest consumption of fish and crabs have increased body burdens of environmental toxins. Since the anglers reported often sharing their catch with others, clearly some of their friends and family members also share the health risks along with the food. Indeed, in two previous surveys of Hudson River anglers, two-thirds of the anglers who reported eating some of the fish they catch (about half of those surveyed) also said they share their catch with young women of childbearing age and children *(7,8)*. Greater subsistence fishing was reported among low-income, African-American and Latino groups in those surveys, particularly in the lower Hudson River watershed region that includes New York City *(7)*. Fewer than half of all anglers were aware of fishing bans and health advisories, and the level of awareness was lowest among women and members of ethnic minority and low-income groups in the lower Hudson region. In both surveys, the fish and shellfish that were kept and consumed were among the most contaminated in the River. Despite notably higher levels of awareness about the health risks in this pilot study population, several of the species eaten most frequently – striped bass, bluefish, blackfish, and blue crabs – are among those specifically targeted by the advisories as unsafe *(21,22)*. An extensive chemical analysis was conducted in 1993 by the New York State Department of Environmental Conservation (NYSDEC) on edible species found in the estuarine region of the lower Hudson River *(6)*. As summarized in Table 1, average PCB concentrations for American eel, white perch, larger striped bass and bluefish, and the hepatopancreas of blue crab and American lobster exceeded the 2 ppm regulatory tolerance for the protection of human health. Similar elevations in the concentrations of DDT and chlordane residues were found in these species.

The geometric mean body burdens of highly chlorinated PCBs (4.70 ppb) and DDE (4.82 ppb) measured in the anglers in this study are similar to exposure levels found for male fish eaters in other recent reports from the Great Lakes region (range of 3.7 to 7.2 ppb for PCBs, and 3.5 to 6.9 ppb for DDE) *(25)* and northern New York State (2.8 ppb for PCBs) *(26)*. The finding that recreational anglers who consume local fish and shellfish have elevated body burdens of PCBs and organochlorine pesticide residues is consistent with findings of other epidemiological investigations. Studies undertaken in western and northern New York State and in the Great Lakes states have also shown positive associations between consumption of locally caught fish and body burdens of persistent pollutants, including correlation between body burdens of PCBs and total years of fish consumption *(14,15,23-27)*. Similarly, cohorts of fisheaters from the Great Lakes that are contaminated with mercury have shown correlations between total fish consumption and body burdens of mercury *(28,29)*.

This study's results have implications for regional public health policy and environmental decision-making. Major policy decisions affecting the Hudson River watershed include whether to reopen the Hudson River commercial striped bass fishery, an important resource that has been closed since 1976 because of concern for the health consequences of high PCB levels in those fish, and whether to dredge portions of the upper Hudson River to remove sediments most highly contaminated with PCBs.

After age adjustment, one meal a week of striped bass, the species most closely monitored in the Hudson River for PCB levels, was not consistently associated with elevated serum levels of the contaminants measured in this study. Recent data from the NYSDEC fish contaminant database, for samples of fish collected in the lower Hudson River watershed in 1997-98, show that average PCB levels in striped bass fillets are hovering around the USFDA tolerance limit of 2 ppm *(30)*. However, the data also indicate wide ranges of concentrations, as well as significant gender, size, and spatial variability among the striped bass sampled. In other resident species, PCB concentrations remain high and temporal declines have not been discerned. It is clear that local fish and crabs contain significant levels of PCBs and other contaminants and that they still represent an important potential route of human exposure. Human body burdens of certain organochlorine contaminants, including DDT and DDE, appear to be steadily declining with time in North American populations *(31-33)*. However, PCB levels have not shown the same trend, perhaps reflecting the longer biological half-life of PCBs *(34,35)*. In light of recent epidemiologic studies showing that *in utero* exposures to PCBs at relatively low levels (≅ 3 ppb in maternal blood) are associated with persisting cognitive impairment in children *(36)*, any expansion of the commercial Hudson River fisheries should proceed with extreme caution.

The debate about whether to dredge portions of the upper Hudson River will also be informed by the data from the study. The findings suggest that PCBs in river sediments represent an important reservoir of aquatic, and thus ultimately, of human exposure. The potential for these compounds to cause fetal neurotoxicity underscores the question of whether these toxic chemicals should remain in the river sediments where they will be biologically available for decades to come.

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Table 1. PCB Residue Levels in Edible Fish, Bivalves, and Crustaceans from New York-New Jersey Harbor, Fall, 1993

Species		No. of samples	Total PCB Concentration (ppm) Arithmetic Mean	Range
Finfish				
American Eel		24	3.79	0.02 - 18.25
Atlantic Herring		8	0.29	0.12 - 0.53
Atlantic Tommy Cod		9	0.34	0.17 - 0.49
Bluefish:	<559mm	34	0.99	0.16 - 3.06
	>559mm	24	2.27	0.20 - 8.80
Striped Bass:	<610mm	48	1.21	0.22 - 3.97
	>610mm	38	2.06	0.25 - 13.40
White Perch		22	2.83	0.21 - 10.92
Bivalves				
Blue Mussel		11	0.32	< 0.03 - 1.06
Eastern Oyster		11	0.30	0.22 - 0.46
Crustaceans				
Lobster:	Muscle	11	0.07	< 0.03 - 0.18
	Hepatopancreas	11	13.16	0.40 - 78.00
Blue Crab:	Muscle	25	0.03	< 0.03 - 0.07
	Hepatopancreas	25	6.55	0.26 - 23.80

SOURCE: New York State Department of Environmental Conservation, Division of Fish, Wildlife and Marine Resources, 1996 (6)

Table 2. Demographic Characteristics and Frequency of Fish and Shellfish Consumption in the Anglers Health Study Population

Characteristic		N (%)
Age (years)	≤ 40	11 (24%)
	41 – 50	13 (28%)
	51 – 60	15 (33%)
	≥ 61	7 (15%)
Gender	Male	43 (93%)
	Female	3 (7%)
Race	White	42 (91%)
	Black	4 (9%)
Frequency of Any Local Fish or Shellfish Consumption	Never	2 (4%)
	< 1 meal/month	5 (11%)
	1-4 meals/month	17 (37%)
	2-6 meals/week	21 (46%)
	> 6 meals/week	1 (2%)
Frequency of Local Striped Bass Consumption	Never	9 (20%)
	< 1 meal/month	10 (22%)
	1-2 meals/month	16 (35%)
	3-4 meals/month	8 (17%)
	≥ 2-3 meals/week	3 (6%)
Frequency of Local Blue Crab Consumption	Never	20 (43%)
	< 1 meal/month	6 (13%)
	1-2 meals/month	10 (22%)
	3-4 meals/month	4 (9%)
	≥ 2-3 meals/week	6 (13%)

Table 3. Exposure Levels of Persistent Pollutants in the Anglers Health Study Population

Pollutant	All Anglers (n=37)			New Jersey Anglers (n=19)	New York Anglers (n=15)
	Geometric Mean	Geometric Std. Dev.	Range	Geometric Mean	Geometric Mean
Total Low PCB congeners (ng/mL) [a,b]	1.11	1.67	(0.48 – 6.63)	1.40*	0.85
Total High PCB congeners (ng/mL) [a,c]	4.70	1.79	(1.83 – 16.88)	5.17	4.74
Chlordane residues [d] (ng/mL)	0.91	1.93	(0.33 – 4.72)	0.99	0.90
trans-nonachlor (ng/mL)	0.57	1.85	(0.20 – 2.35)	0.62	0.54
Oxychlordane (ng/mL)	0.32	2.24	(0.07 – 2.37)	0.35	0.33
pp'- DDT (ng/mL)	0.60	1.37	(0.37 – 2.54)	0.66	0.54
pp'- DDE (ng/mL)	4.82	2.82	(0.83 – 57.80)	5.77	4.59
Total Mercury in blood (ng/mL)	2.82	4.79	(0 – 22)	4.17	2.53
Total Mercury [e] in hair (μg/g)	1.52	1.25	(0.17 – 6.18)	---	---

*p-value < 0.05 for Student's t-test comparing age-adjusted least-squares geometric means for New Jersey club anglers versus New York club anglers. Three anglers from a community center in New Jersey were not included in this comparison.

[a]**PCB concentrations, statistically adjusted for total serum lipids measured in the sample. Nondetectable values for individual PCB congeners were set to 0.05.**

[b]**Total Low PCB congeners** = (IUPAC # 56+66+74+99+101)

[c]**Total High PCB congeners**
= (IUPAC # 105+118+138+146+153+156+167+170+172+174+177+178+180+183+187+199+203)

[d]**Chlordane residues** = (*trans*-nonachlor + oxychlordane)

[e]**Hair samples for mercury analysis were collected only from 21 anglers in New Jersey.**

Table 4. Comparison of Mean Exposure Levels of Persistent Pollutants, by Frequency of Fish or Crab Consumption in the Anglers Health Study Population

Consumption Characteristic	N	Total Low PCBs[a,b] (ng/mL)	Total High PCBs[a,c] (ng/mL)	PCB Congener 118[a] (ng/mL)	PCB Congener 153[a] (ng/mL)	Chlordane Residues[d] (ng/mL)	*pp'*- DDT (ng/mL)	*pp'*- DDE (ng/mL)	Total Mercury in Blood (ng/mL)	Total Mercury in Hair (µg/g)
Any fish or shellfish:										
< 1 meal/week	18	1.03	4.22	0.25	1.05	0.87	0.54	4.78	1.87	0.98
≥ 1 meal/week	19	1.20	5.23	0.40*	1.51	0.95	0.66*	4.85	4.17	1.59
Striped Bass:										
< 1 meal/week	27	1.10	4.75	0.32	1.23	0.88	0.58	5.10	2.55	1.19
≥ 1 meal/week	10	1.15	4.56	0.29	1.39	0.98	0.64	4.13	3.93	1.35
Blue Crab:										
< 1 meal/week	29	1.15	4.42	0.29	1.20	0.90	0.60	4.46	2.94	1.07
≥ 1 meal/week	8	1.00	5.98	0.42	1.55	0.96	0.57	6.41	2.46	2.91

***p-value < 0.05 for Student's t-test comparing age-adjusted least-squares geometric means according to consumption frequency.**

[a]PCB concentrations statistically adjusted for total serum lipids measured in the sample. Nondetectable values for individual PCB congeners set to 0.05.

[b]**Total Low PCB congeners** = (IUPAC # 56+66+74+99+101)

[c]**Total High PCB congeners** = (IUPAC # 105+118+138+146+153+156+167+170+172+174+177+178+180+183+187+199+203)

[d]**Chlordane residues** = (*trans*-nonachlor + oxychlordane)

Figure 1. **Exposure-response gradient for PCB congener IUPAC #118 level associated with increasing fish or shellfish consumption in the Anglers Health Study Population.**

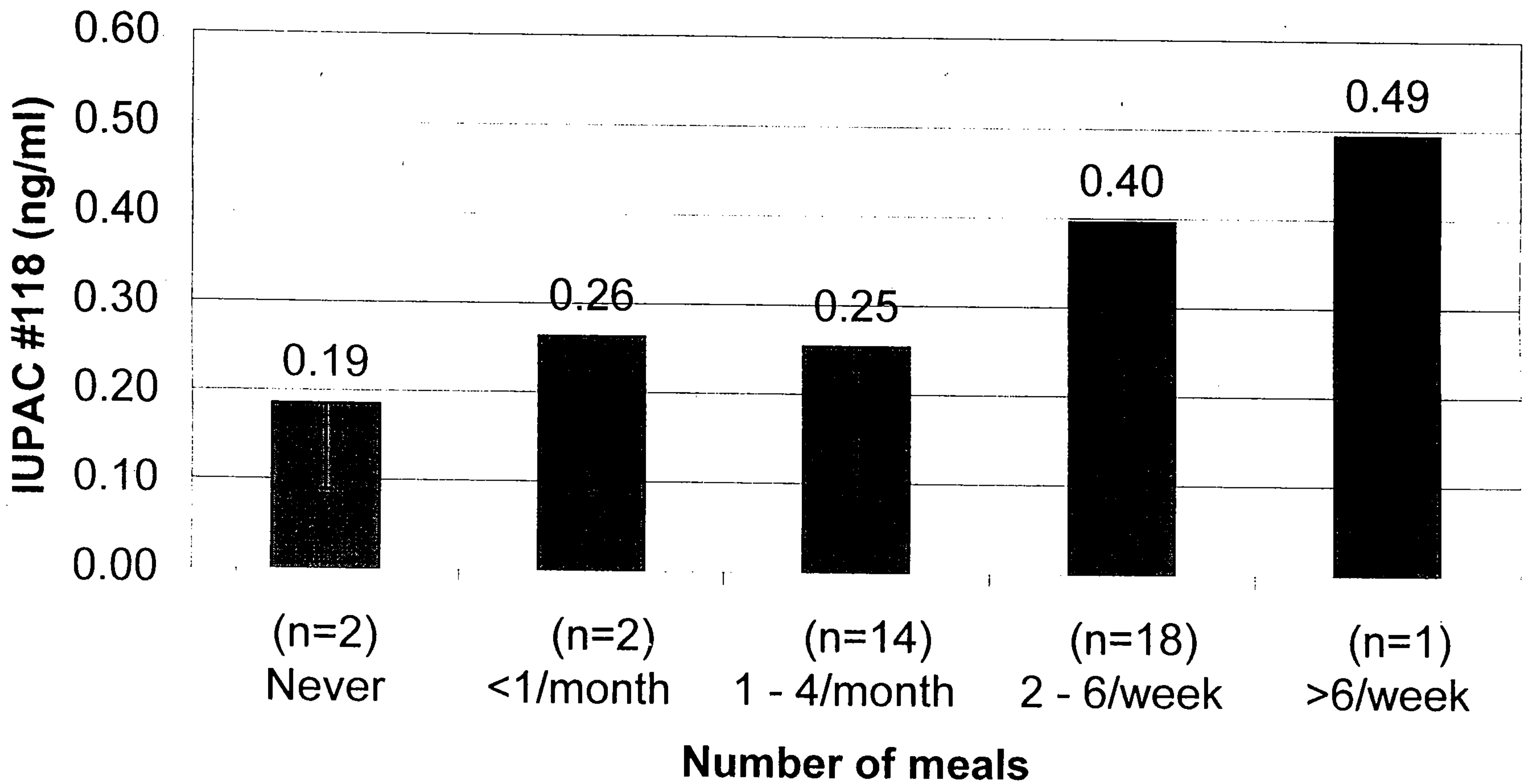

***Figure 2*. Exposure-response gradient for *pp'* - DDE level associated with increasing blue crab consumption in the Anglers Health Study Population.**

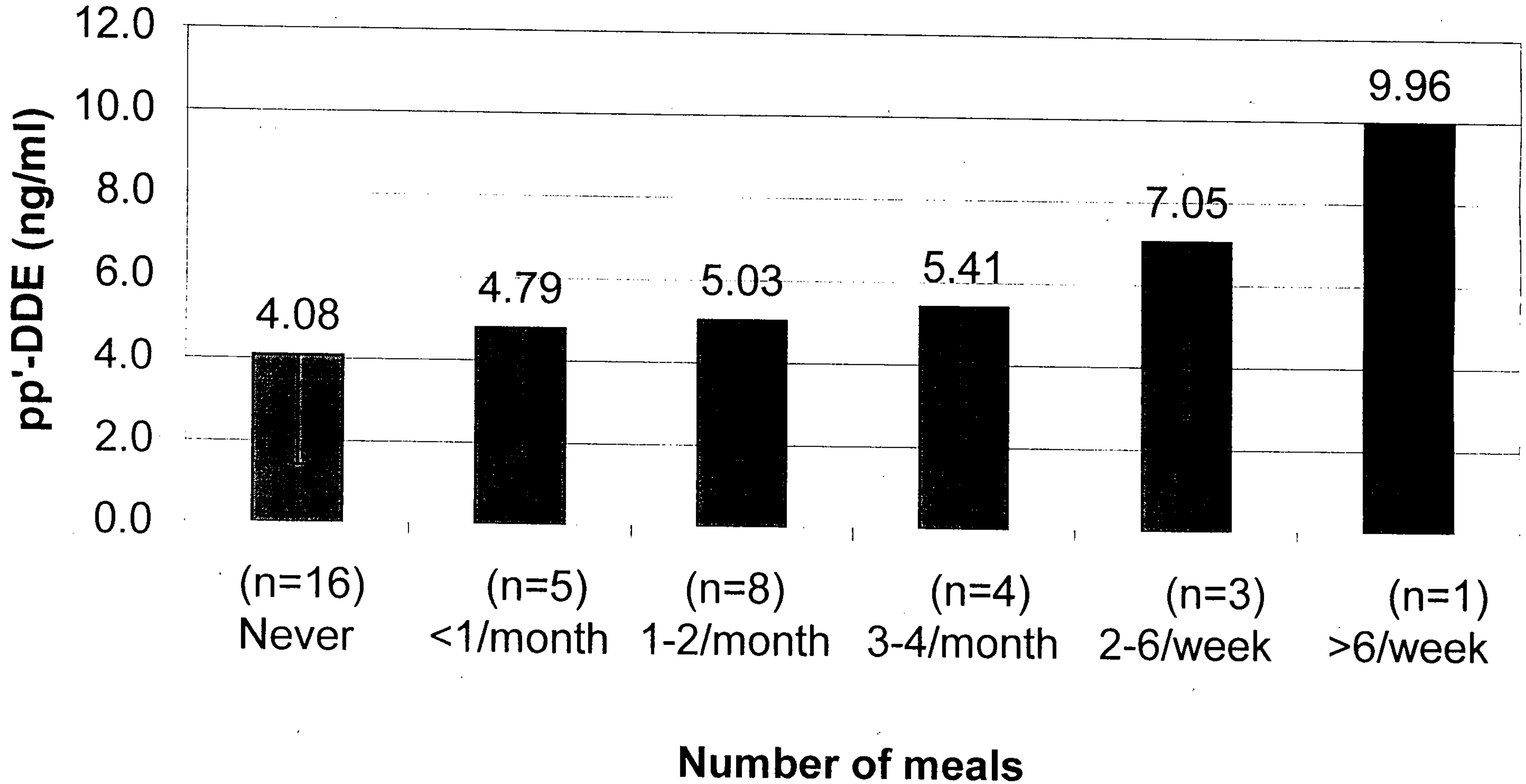

Figure 3. **Exposure-response gradient for mercury levels in whole blood and hair samples with increasing fish or shellfish consumption**