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PCB Intake from Sport Fishing Along the Northern Illinois Shore of Lake Michigan

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Polychlorinated biphenyls (PCBs) are chlorinated hydrocarbons with an empirical formula of $C_{12}H_{10-x}Cl_x$. The biphenyl can have from one to 10 chlorine substitutions resulting in 209 theoretical congeners. Commercial formulations of PCBs are complex mixtures of congeners; 125 congeners have been identified in commercial formulations (Alford-Stevens, 1986). PCBs have entered the aquatic environment by industrial discharge, airborne deposition, and release from sediments. The most likely route of non-occupational human exposure to PCBs is from consumption of contaminated fish.

PCBs are considered to be the most important contaminants in fish from the Great Lakes. Hence, in 1993 the Great Lakes Fish and Advisory Task Force developed a fish consumption advisory for the Great Lakes which incorporated a Health Protection Value (HPV) of 3.5 µg of PCBs/day (Anderson, 1993). Based on the HPV, five consumption groups were defined:

- PCBs < 0.050 ppm: unlimited consumption, i.e., 225 meals per year
- PCBs at 0.05 to 0.22 ppm: one meal per week
- PCBs at 0.22 to 0.94 ppm: one meal per month
- PCBs at 0.94 to 1.88 ppm: six meals per year
- PCBs > 1.88 ppm: no consumption

The Task Force assumed that the average meal of fish is composed of 227 g (l/2 pound) of uncooked fish and that the intake of PCBs are reduced by 50% due to skinning, trimming, and cooking.

Since the 1960s, brown and rainbow trout, coho and chinook salmon, and yellow perch have become the principal sport fish caught along the Illinois shore of Lake Michigan. Illinois has banned the commercial sale of Lake Michigan trout and salmon species due to their PCB content. Commercial sale of yellow perch is permitted due to its usually low PCB content. Since 1987, the Illinois Natural History Survey has performed annual surveys of the species, weights, and lengths of sport fish caught by sport fishermen along the Illinois shore of Lake Michigan (referred to as creel data) (Brofka, 1994). Also, PCB concentration data are available for sport fish caught in Lake Michigan (IDOC, 1994; IEPA, 1990).

The purpose of this study was to combine the creel species, weight, and length distribution data with the PCB monitoring data to quantitate the theoretical intake of PCBs by sport fishermen in the Chicago area. Using the same five consumption groups as the Task

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Force, theoretical PCB intake levels were calculated and compared to the HPV of 3.5 μg/day.

MATERIALS AND METHODS

Concentrations of PCBs in fish tissue are correlated with the length of fish (Voiland, 1991). PCB concentration and length data from Illinois and Wisconsin for the years 1987-1993 were combined to develop PCB concentration vs. length regression relationships for brown and rainbow trout and coho and chinook salmon above the legal minimum length of 26.5 cm. The impact of seasonality on the relationship between PCB concentration and length was not explored. A regression model for yellow perch could not be obtained. Yellow perch are rarely sampled because the results of previous analyses have generally been below detection for PCBs. Yellow perch do not bioaccumulate high levels of PCBs due to their low fat content and relatively short life span. The detection limit for PCBs is 0.1 ppm. Therefore, a theoretical maximum PCB concentration was assumed for yellow perch at 0.1 ppm.

From Illinois Natural History Survey records, a data base of species, weights, and lengths was compiled from observations at Montrose, Diversey, and Waukegan Harbors for the years 1987-1993 (Brofka, 1994). These harbors were selected because of their popularity with northeastern Illinois anglers. The data were organized by season: spring (April and May); summer (June and July); and fall (August and September). Data from 1987-1993 for the three harbors were combined, and mean lengths and weights were computed for each species and season. Substituting mean seasonal lengths into the appropriate species regression relationship yielded estimated PCB concentrations as a function of fish species and season.

Daily PCB intake is a function of species, season, time period within a season, % fish species biomass (computed from Illinois Natural History Survey records, Brofka, 1994), predicted PCB concentration (ppm), mass of uncooked fish/meal (227 g/meal; Task Force assumption), meals/year (per Task Force consumption groups), days/year (365), and reduction in PCB intake due to preparation (0.5). The daily intake of PCBs (μg/day) was calculated as follows:

$$
\begin{aligned}
PCB &= 227\ \text{g/meal} \times [(\text{meals/y})/(365\ \text{d/y})] \times \%\ \text{biomass} \times (PCB) \times 0.5 \\
&= 0.311 \times (\text{meals/y}) \times (\%\ \text{biomass}) \times (PCB)
\end{aligned}
$$

RESULTS AND DISCUSSION

The PCB (ppm) vs. length (L, in cm) regression equations, sample sizes (N), and r^2 values are as follows:

Brown trout: $PCB = 0.339\ e^{0.0391(L-26.5)}$ $(N=46,\ r^2 = 0.5)$

Rainbow trout: $PCB = 0.447\ e^{0.0108(L-26.5)}$ $(N=33,\ r^2 = 0.2)$

Coho salmon: $PCB = 0.251\ e^{0.0251(L-26.5)}$ $(N=27,\ r^2 = 0.2)$

$PCB = 0.390\ e^{0.0228(L-26.5)}$ $(N=63,\ r^2 = 0.4)$

No concentration and length data were available below 26.5 cm. Hence, these equations should only be used for lengths > 26.5 cm, which is the minimum legal length for taking trout and salmon species from Lake Michigan (IDOC, 1994). Values of r^2 are modest and indicate that additional independent variables should be added to the equations in order to improve their predictive values.

A summary of the sport fishermen catch data (creel data) and PCB concentrations predicted from the above equations are shown in Table 1.

Table 1. Weight, length, and PCB concentration by species and season over 1987-1993 for Montrose, Diversey, and Waukegan Harbors

Species	Season[a]	Weight[b] (g)	Length[b] (cm)	PCB (ppm)[c]
Yellow perch	Spring	117 (2246)	21.8 (1948)	0.10[d]
	Summer	122 (5707)	22.0 (5845)	0.10[d]
	Fall	103 (204)	21.3 (204)	0.10[d]
Brown trout	Spring	1517 (88)	47.6 (91)	0.77
	Summer	728 (5)	32.0 (5)	0.42
	Fall	2288 (4)	57.1 (4)	1.12
Rainbow trout	Spring	1890 (17)	52.4 (17)	0.59
	Summer	1074 (7)	38.1 (7)	0.51
	Fall	1975 (39)	53.6 (39)	0.60
Coho salmon	Spring	1048 (501)	49.0 (515)	0.44
	Summer	2399 (19)	60.0 (19)	0.58
	Fall	2147 (77)	57.5 (83)	0.55
Chinook salmon	Spring	1581 (7)	60.4 (7)	0.84
	Summer	5875 (18)	80.6 (18)	1.34
	Fall	4327 (339)	74.0 (356)	1.15

[a] Spring (April and May); Summer (June and July); and Fall (August and September)
[b] Weighted mean weight and length were calculated as follows: Σ(average weight or length for a year x sample size)/total number of samples for all years. Sample size is shown in parentheses.
[c] Theoretical PCB concentrations were calculated by substituting values for length into the appropriate regression equation above.
[d] The detection limit for PCBs in fish tissue is 0.1 ppm.

From the data on % fish biomass in Table 2, it can be seen that:

- coho salmon (73.6%) is the major contributor of dietary fish biomass during time period 1
- yellow perch (44.1%) and coho salmon (38%) are the major contributors of dietary fish biomass during time period 2
- yellow perch is the major contributor of dietary fish biomass during time periods 3 through 7
- chinook salmon (59.1%) and yellow perch (30.2%) are the major contributors of dietary fish biomass during time period 8
- chinook salmon (82.2%) is the major contributor of dietary fish biomass during time period 9

Table 2. Percent biomass by species and season over 1987-1993 for Montrose, Diversey, and Waukegan Harbors

Season and time period within season[a]		Yellow perch	Brown trout	Rainbow trout	Coho salmon	Chinook salmon
Spring	1	0.51	20.6	5.16	73.6	0.12
	2	44.1	12.2	2.53	38.0	3.18
	3	94.6	1.76	0.55	3.04	0
Summer	4	99.1	0	0	0.93	0
	5	99.1	0.14	0.18	0.58	0
	6	97.88	0	0.16	2.08	0.32
Fall	7	94.6	0	1.59	2.13	1.66
	8	30.2	1.04	3.13	6.49	59.1
	9	3.87	0	2.10	11.83	82.2

[a] Time period 1, April 1 - April 18; Time period 2, April 19 - May 9; Time period 3, May 10 - May 30; Time period 4, May 31 - June 20; Time period 5, June 21 - July 11; Time period 6, July 12 - August 1; Time period 7, August 2 - August 22; Time period 8, August 23 - September 12; Time period 9, September 13 - September 30

The daily PCB intake scenarios for all five species combined is presented in Table 3. From Table 3, it can be seen that:

- the unlimited dietary scenario contributes PCBs in excess of the recommended limit of 3.5 µg/day during all time periods
- the one meal per week dietary scenario contributes PCBs in excess of the recommended limit of 3.5 µg/day during time periods 1, 2, 8, and 9
- the one meal per month and six meals per year dietary scenarios do not generally contribute PCBs in excess of the recommended limit of 3.5 µg/day

The above results are a function of the available species and % biomass. If available species and/or % biomass change, the theoretical PCB intake will change. As the human toxicology of ingested PCBs becomes better understood, it will be necessary to revise the recommended limit on intake of 3.5 µg/day. Based on the data presented, the current intake limit may be exceeded under the unlimited and one meal per week dietary scenarios in the Chicago area. Hence, it appears to be important to follow the Great Lakes Fish Consumption Advisory system, especially if the angler follows an unlimited or one meal per week dietary scenario.

There are two major limitations to this study. The PCB detection limit of 0.1 ppm was assumed to be the concentration of PCBs in yellow perch. As more monitoring data become available for yellow perch, actual PCB concentrations can be used to compute more accurate daily intakes of PCBs. The equations used to predict PCB concentration as a function of length have modest predictive power, i.e. low values of r^2. Hence, a useful area for further research would involve the elucidation of additional independent variables which affect PCB concentration in fish.

Table 3. Daily intake (μg/day) of PCBs for all species by season over 1987-1993 for Montrose, Diversey, and Waukegan Harbors

Season and time period within season[a]		Unlimited (225 meals per year)	One meal per week	One meal per month	Six meals per year
Spring	1	36	8.33	1.91	0.96
	2	24.27	5.60	1.29	0.65
	3	8.74	2.02	0.46	0.24
Summer	4	7.31	1.69	0.39	0.19
	5	7.27	1.67	0.39	0.19
	6	8.02	1.86	0.43	0.21
Fall	7	9.45	2.18	0.50	0.26
	8	54.30	12.55	2.89	1.46
	9	71.85	16.60	3.83	1.91

[a]Same as Table 2.

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