

A POST-SEDIMENT REMOVAL CAGED FISH STUDY
OF THE SAGINAW RIVER WATERSHED
JUNE 18 – JULY 16, 2002

INTRODUCTION

The Saginaw River and Saginaw Bay are listed as Great Lakes Areas of Concern by the United States Environmental Protection Agency due in part to high levels of polychlorinated biphenyls (PCBs) found in sediments and fish. A remediation project was conducted in 2000/2001 during which a total of 342,433 cubic yards of contaminated sediments were removed from the Saginaw River between Middle Ground Island and the river mouth.

Caged-fish studies are used by the Michigan Department of Environmental Quality – Water Bureau (MDEQ-WB) to aid in identifying sources of bioaccumulative contaminants, to identify spatial trends in contaminant concentrations, and to evaluate the effectiveness of remedial actions. This post-remediation caged-fish study was conducted from June 18 to July 16, 2002 by the MDEQ-WB to determine whether sources of PCBs remain following sediment removal. The most recent pre-remediation study was conducted in the Saginaw River Watershed in 1998 (Day, 1999). Other caged-fish studies were conducted in 1993 (Morse, 1995), 1992 (Wood, 1993), 1988 (Morse, 1993), and in 1986 (Cornelius, 1988).

This report discusses a subset of the data collected as part of the 2002 Saginaw River watershed caged-fish study. Caged fish were placed at 19 locations in the Saginaw River Watershed to measure concentrations and determine sources of bioaccumulative pollutants. This report summarizes the results of PCB monitoring at 8 sites in the lower watershed. The results of the full caged fish study will be presented in the 2004 Annual Report of the Michigan Fish Contaminant Monitoring Program.

SUMMARY

1. Total PCB concentrations were measured in caged fish from eight Saginaw River Watershed sites in 2002. PCBs were quantified in at least three samples from each test site and in one of the four day-0 control samples.
2. The mean PCB concentration in the day-0 control samples was essentially zero and the average concentrations in the test fish are presented as net uptake.
3. Lipid-normalized PCB concentrations in samples from the mouth of the Tittabawassee River, the Saginaw River at Zilwaukee, and at the mouth of the Saginaw River, were significantly greater than concentrations in the control samples. Concentrations in samples from the other five sites were not significantly different than the control.
4. The lipid-normalized PCB concentrations in samples from the Saginaw River mouth were higher and significantly different ($p < 0.05$) than the other seven sites tested.

5. The lipid-normalized PCB concentrations in samples from the mouth of the Tittabawassee River were significantly higher ($p < 0.05$) than concentrations at the Shiawassee, Flint, and Cass River sites.
6. The lipid-normalized PCB concentrations in samples from the Zilwaukee Bridge and Shiawassee River mouth sites were significantly lower in 2002 as compared to 1998.
7. The difference between lipid-normalized total PCB concentrations at the Saginaw River mouth and the upstream sites did not change significantly between 1998 and 2002.
8. Lipid-normalized total PCB concentrations at the mouth of the Saginaw River did not change between 1998 and 2002, but concentrations have declined significantly since 1986.
9. The 2002 caged-fish study has not provided evidence of the effectiveness of the sediment removal project and further study is recommended.

METHODS

The MDEQ-WB performed all caged-fish studies in accordance with GLEAS Procedure 62 (available upon request). Caged-fish studies are a particularly useful water quality monitoring tool because the test fish are exposed to the water column under relatively controlled conditions. Some contaminants accumulate in the test fish at levels that may be orders of magnitude above the concentrations in the ambient water. The relatively high concentrations in the test fish tissue are easier and cheaper to measure than the relatively low concentrations typically found in the ambient water.

MDEQ-WB personnel placed one stainless steel cage at each of eight locations in the watershed (Figure 1). Five of the sample sites were identical to those sampled in 1998. The channel catfish used as test organisms in the experiments were purchased from a commercial fish farm, and averaged 5.5 inches in length. Control samples were obtained at the beginning of the test period by randomly selecting a subset of channel catfish and combining them into 4 composite samples of whole fish. The remaining channel catfish were divided evenly between the test sites. After 28 days the fish were removed from the cages and divided into 4 composite samples of whole fish. Each sample had a minimum total weight of 40 grams, and the number of fish per composite was determined by the size of the fish and the number surviving to the end of the 28-day test. Each composite sample was wrapped individually in aluminum foil, labeled, and frozen until analyzed.

Samples were analyzed for PCBs by Research Productivity Council (RPC) using peer-reviewed methods of extraction, digestion, and quantification. The method used for the analysis of the 2002 samples had a detection level of 0.001 ppm. Results reported as below the detection level were assumed to be zero in the statistical analyses.

Total PCB concentration was estimated by summing the concentrations of PCB congeners. Individual congeners below the detection level were assigned a concentration equal to 0 for the purpose of calculating a total PCB concentration. Also, congener analyses that did not meet retention time criteria or were subject to analytical interference were assigned a concentration equal to 0 for the purpose of calculating a total PCB concentration.

PCBs are strongly lipophilic and total concentrations in fish have been shown to be highly influenced by the concentration of fats. Therefore, for statistical comparisons the concentrations of PCBs were lipid-normalized by dividing the total PCB concentration by the lipid concentration.

Net uptake of total PCB was calculated based on the relationship between the concentration in the control samples and the concentration in the test samples. Total PCB concentrations in 3 of the 4 control samples were below the detection level and these concentrations were assumed to be zero. The average concentration of lipid-normalized total PCBs in four control samples was 0.00004 parts per million (ppm). Net uptake was calculated by subtracting the average concentration in the control samples from the average concentrations in the test samples.

Statistical comparisons were considered significant at $\alpha \leq 0.05$.

RESULTS AND DISCUSSION

Mean lengths and weights of the fish included in the composite samples and the percent lipid content of the composites are presented in Table 1. PCBs were quantified in one of the four control samples and in at least three samples from each of the eight test sites. Total PCB concentrations and lipid-normalized PCB concentrations are presented in Table 2 and Figures 2 & 3.

Lipid-normalized PCB concentrations in samples from the mouth of the Tittabawassee River, in the Saginaw River at the Zilwaukee Bridge, and at the mouth of the Saginaw River, were significantly greater than concentrations in the control samples. Concentrations in the samples from the Shiawassee, Flint, and Cass Rivers, and from upstream of Middle Ground Island in the Saginaw River, were not significantly different than the control.

The highest concentrations of PCBs were found in the Saginaw River mouth samples. The average lipid-normalized PCB concentration there was nearly 17 times higher than the average at the mouth of the Tittabawassee River, the second highest site. The concentration at the mouth of the Tittabawassee was significantly higher than concentrations at the Shiawassee, Flint, and Cass River sites.

The lipid-normalized PCB concentration in the 2002 samples from the Zilwaukee Bridge and from the Shiawassee River mouth sites were significantly less than those measured in the 1998 study (Table 3 & Figure 4).

The average lipid-normalized net PCB uptake at the mouth of the Saginaw River was 34 times higher than at Middle Ground Island and 23 times higher than the at the Zilwaukee Bridge. The concentration at the Saginaw River mouth relative to the upstream sites was the same in 1998 and 2002.

Bioconcentration studies using caged fish were conducted at the mouth of the Saginaw River in 1986, 1988, 1992, 1993, 1998, and 2002. Lipid-normalized net PCB uptake has declined since 1986. PCB concentrations measured in 1998 and 2002 are statistically equivalent and are significantly lower than all previous sample years except 1992 (Figure 5).

The results of this study indicate that sources of PCB contamination may remain in the Saginaw River watershed between Middle Ground Island and the river mouth. Taft (2004) measured PCB arochlors in sediments from the Saginaw River between Middle Ground Island and the

mouth. Sediment concentrations were below the total PCB remediation target of 1 ppm, indicating that remediation targets had been met and sediments have not been re-contaminated by upstream sources.

Further study is recommended to evaluate the effectiveness of the sediment removal project. Future caged fish studies should focus on the reach of the Saginaw River between Middle Ground Island and the mouth. A caged fish study in Saginaw Bay near the river mouth should also be considered.

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- Taft, W. 2004. A sediment sampling survey of the Saginaw River, Bay County, Michigan, September 2-3, 2003. MDEQ-Water Division. Report #MI/DEQ/WD-04/001.
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Table 1. 2002 Saginaw River Watershed caged-fish mean length, weight, and percent lipids.

Location	Identification Number	Mean Length (cm)	Mean Weight (g)	Percent Lipids
Control	2002010-5	13.8	21.2	6
	2002010-6	13.9	20.0	5
	2002010-7	13.3	17.7	5
	2002010-8	12.8	16.7	6
Mouth, Saginaw River	2002028-5	14.3	19.4	4
	2002028-6	13.3	17.1	4
	2002028-7	13.4	16.4	4
	2002028-8	13.3	14.6	2
Upstream of Middle Ground Island	2002027-5	13.9	19.0	3
	2002027-6	14.1	19.5	3
	2002027-7	14.5	21.3	4
	2002027-8	14.9	20.2	5
Zilwaukee Bridge	2002026-5	14.2	17.9	2
	2002026-6	14.6	20.9	4
	2002026-7	14.6	21.7	2
	2002026-8	15.4	25.1	2
Shiawassee Mouth	2002025-5	14.4	23.2	4
	2002025-6	15.1	24.6	2
	2002025-7	13.8	19.3	4
	2002025-8	14.8	22.9	4
Shiawassee Fergus Rd	2002022-5	14.7	24.8	4
	2002022-6	14.4	20.7	4
	2002022-7	14.0	20.8	3
	2002022-8	14.6	22.6	3
Cass River at M-13	2002024-1	14.2	19.1	3
	2002024-2	14.7	20.1	4
	2002024-3	14.1	18.7	5
	2002024-4	14.4	19.4	4
Flint River Mouth	2002023-1	14.4	19.7	3
	2002023-2	14.8	22.9	3
	2002023-3	14.5	20.6	3
	2002023-4	14.3	20.5	3
Tittabawassee Mouth	2002021-5	14.7	21.0	4
	2002021-6	14.1	18.8	3
	2002021-7	14.3	20.6	3
	2002021-8	13.9	18.5	5

Table 2. 2002 Saginaw River Watershed caged-fish study Total PCB concentrations.

Location	Identification Number	Total PCB (ppm)	Lipid Normalized	Mean (Lipid Normalized)	Median
Control	2002010-5	0.001	0.0002	0.00004	0
	2002010-6	0.001 K	0		
	2002010-7	0.001 K	0		
	2002010-8	0.001 K	0		
Mouth, Saginaw River	2002028-5	0.24	0.06	0.065	0.056
	2002028-6	0.212	0.053		
	2002028-7	0.194	0.0485		
	2002028-8	0.201	0.100		
Upstream of Middle Ground Island	2002027-5	0.001 K	0	0.0019	0.0019
	2002027-6	0.011	0.0037		
	2002027-7	0.011	0.0028		
	2002027-8	0.005	0.001		
Zilwaukee Bridge	2002026-5	0.003	0.002	0.003	0.0024
	2002026-6	0.007	0.002		
	2002026-7	0.006	0.003		
	2002026-8	0.01	0.005		
Shiawassee Mouth	2002025-5	0.01	0.002	0.0012	0.0018
	2002025-6	0.001 K	0		
	2002025-7	0.009	0.002		
	2002025-8	0.005	0.001		
Shiawassee Fergus Rd	2002022-5	0.01	0.002	0.0008	0.0007
	2002022-6	0.001 K	0		
	2002022-7	0.003	0.001		
	2002022-8	0.001	0.0003		
Cass River at M-13	2002024-1	0.001 K	0	0.0002	0.0002
	2002024-2	0.001	0.0002		
	2002024-3	0.001	0.0002		
	2002024-4	0.001	0.0002		
Flint River Mouth	2002023-1	0.006	0.002	0.0009	0.0007
	2002023-2	0.003	0.001		
	2002023-3	0.001	0.0003		
	2002023-4	0.001	0.0003		
Tittabawassee Mouth	2002021-5	0.016	0.004	0.0039	0.0039
	2002021-6	0.012	0.004		
	2002021-7	0.011	0.0036		
	2002021-8	0.019	0.0038		

Table 3. Comparison of mean lipid-normalized PCB concentrations in Saginaw River watershed caged-fish, 1998 and 2002.

SITE	Mean \pm 95% C.I.	
	1998	2002
Mouth, Saginaw River	0.075 \pm 0.033	0.065 \pm 0.038
Upstream of Middle Ground Island	0.013 \pm 0.015	0.002 \pm 0.003
Zilwaukee Bridge	0.020 \pm 0.005	0.003 \pm 0.002
Shiawassee Mouth	0.011 \pm 0.002	0.0012 \pm 0.002
Shiawassee Fergus Rd	---	0.001 \pm 0.0006
Cass River at M-13	---	0.0002 \pm 0.0002
Flint River Mouth	---	0.0009 \pm 0.001
Tittabawassee Mouth	0.009 \pm 0.009	0.004 \pm 0.003

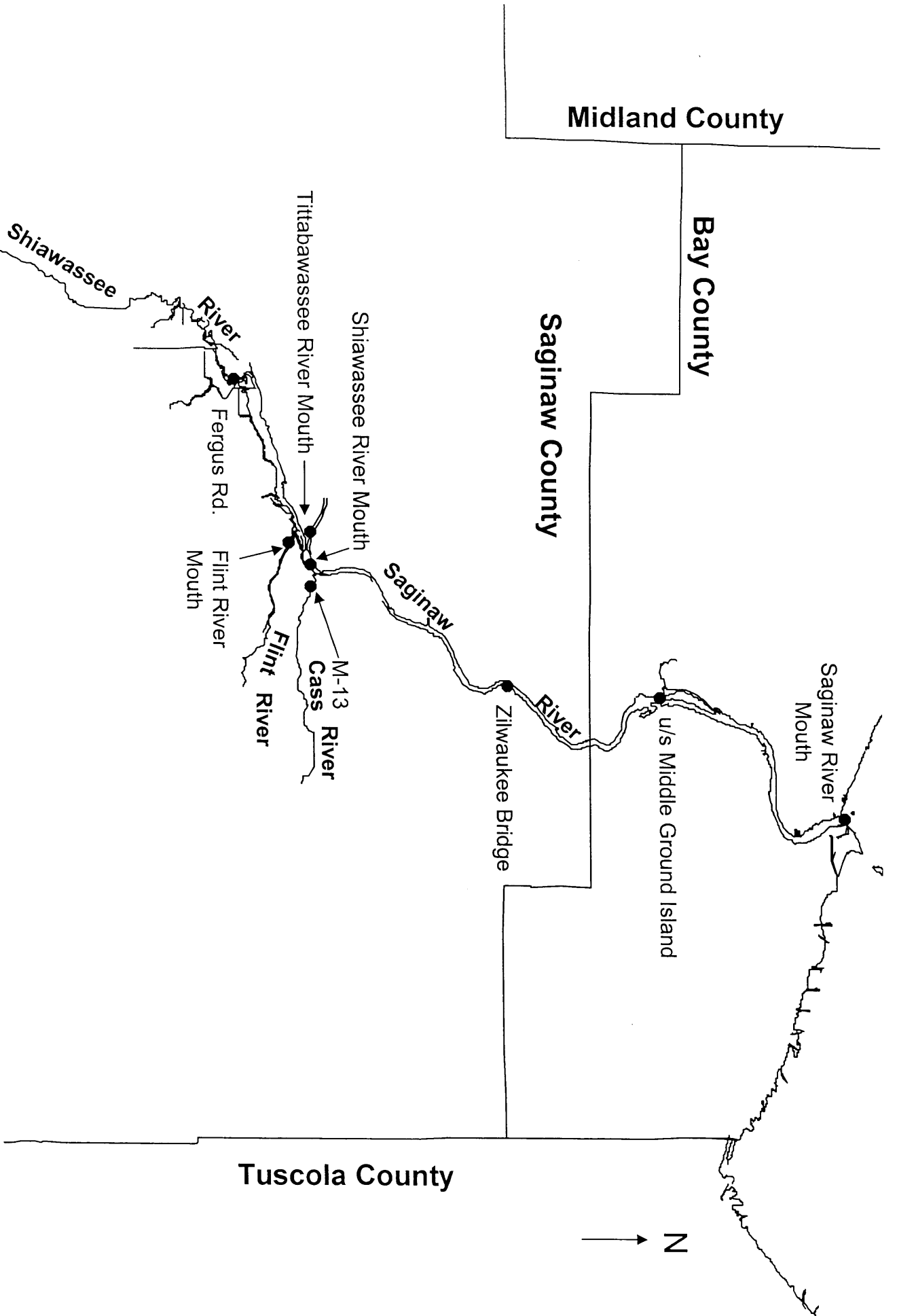


Figure 1. Saginaw River Watershed caged-fish monitoring location in 2002.

Net Total PCB Concentration (ppm)

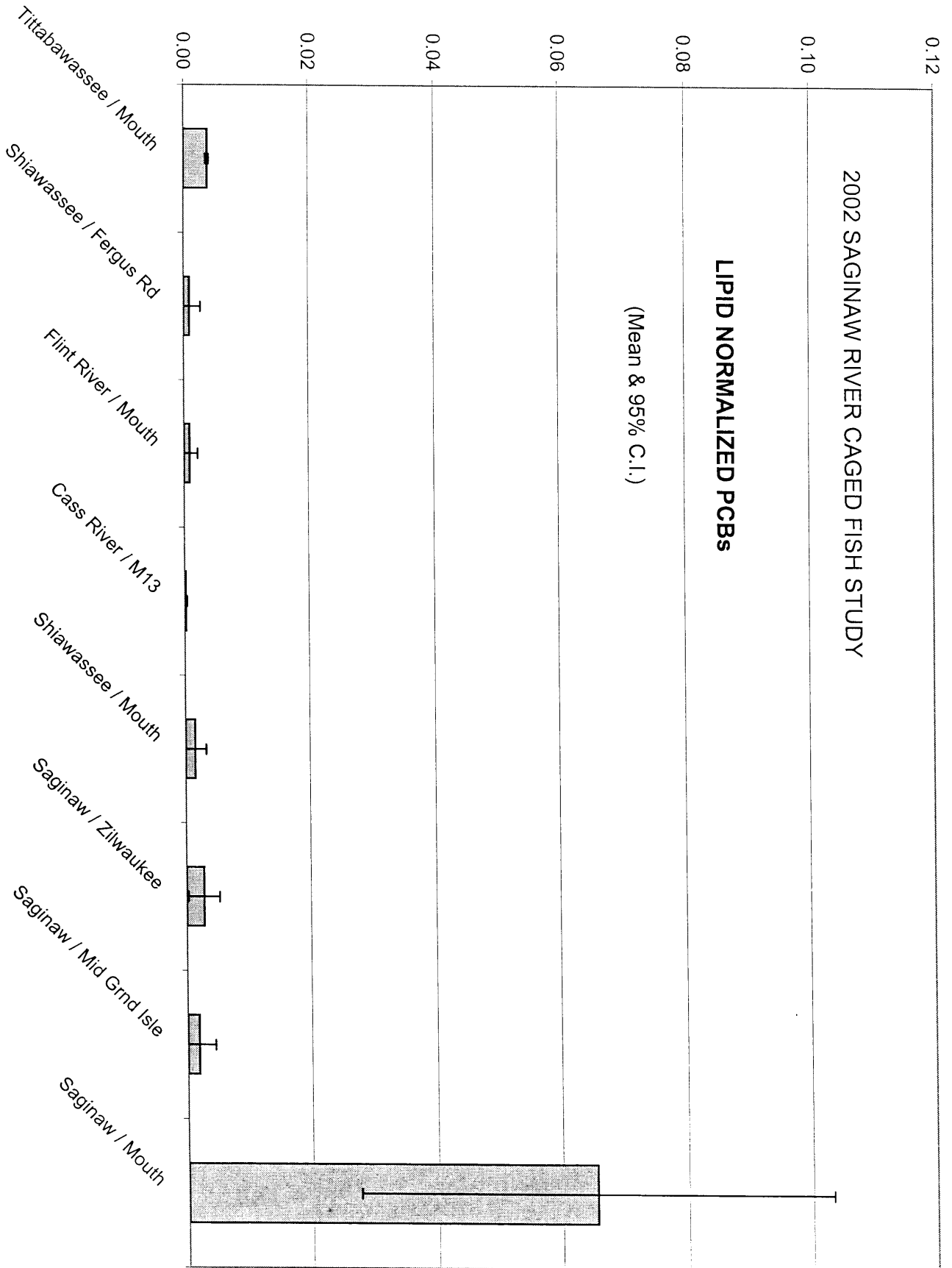


Figure 2. Lipid-normalized net uptake of PCBs in caged fish placed at eight sites in the Saginaw River watershed in 2002.

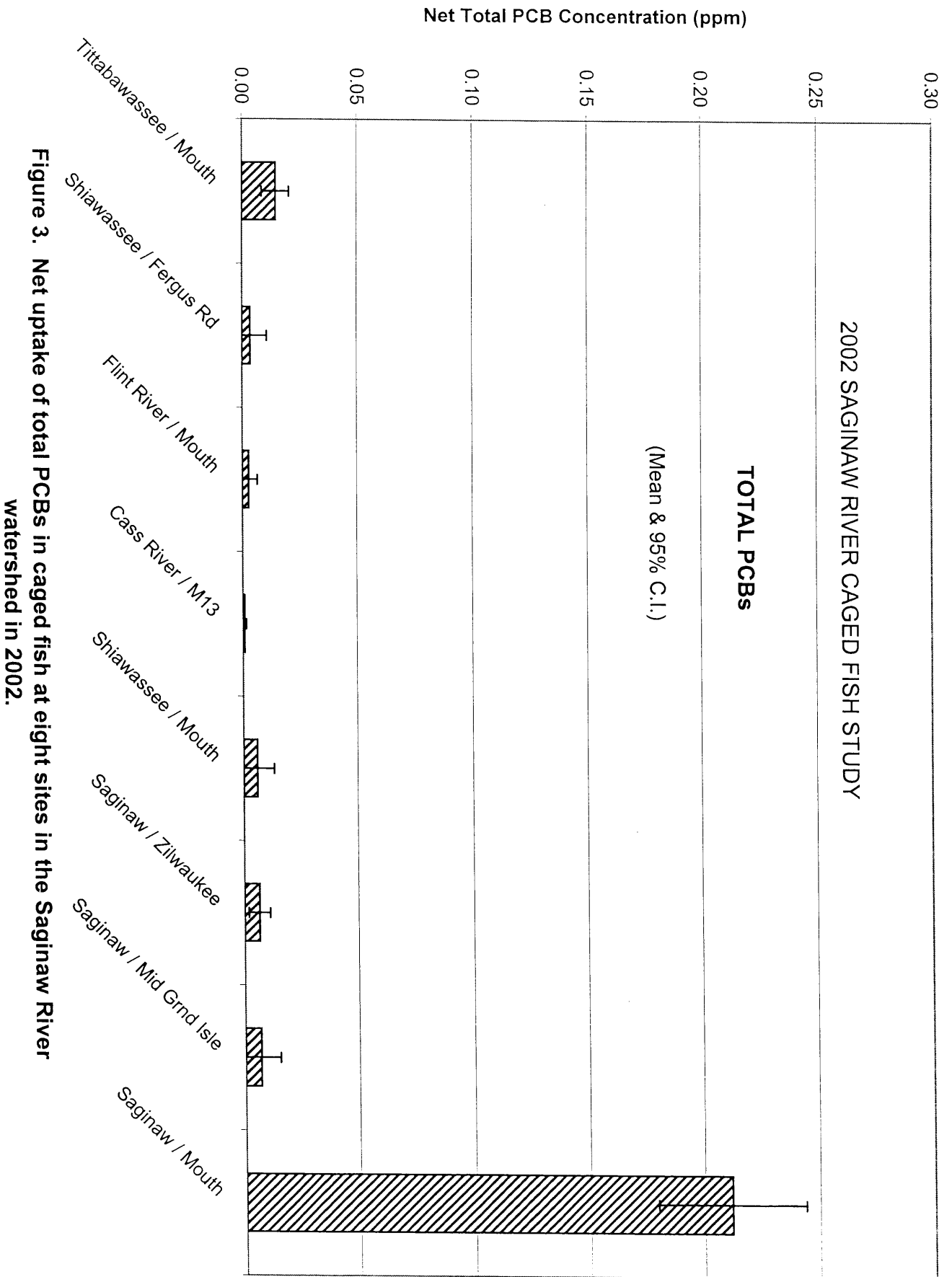


Figure 3. Net uptake of total PCBs in caged fish at eight sites in the Saginaw River watershed in 2002.

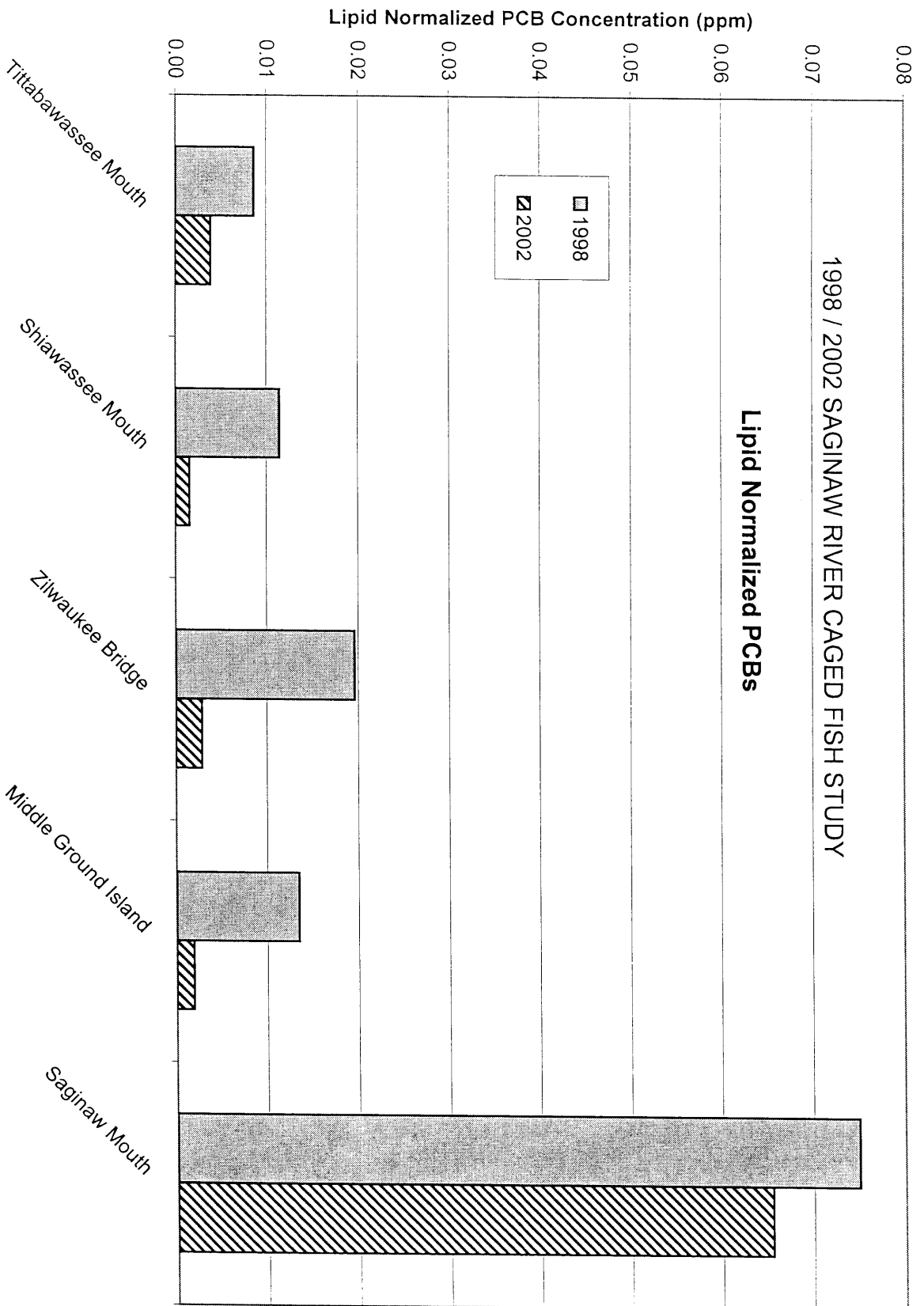


Figure 4. Comparison of lipid-normalized net uptake of PCBs in caged fish at five sites in the Saginaw River watershed, 1998 & 2002.

SAGINAW RIVER MOUTH
CAGED FISH STUDY

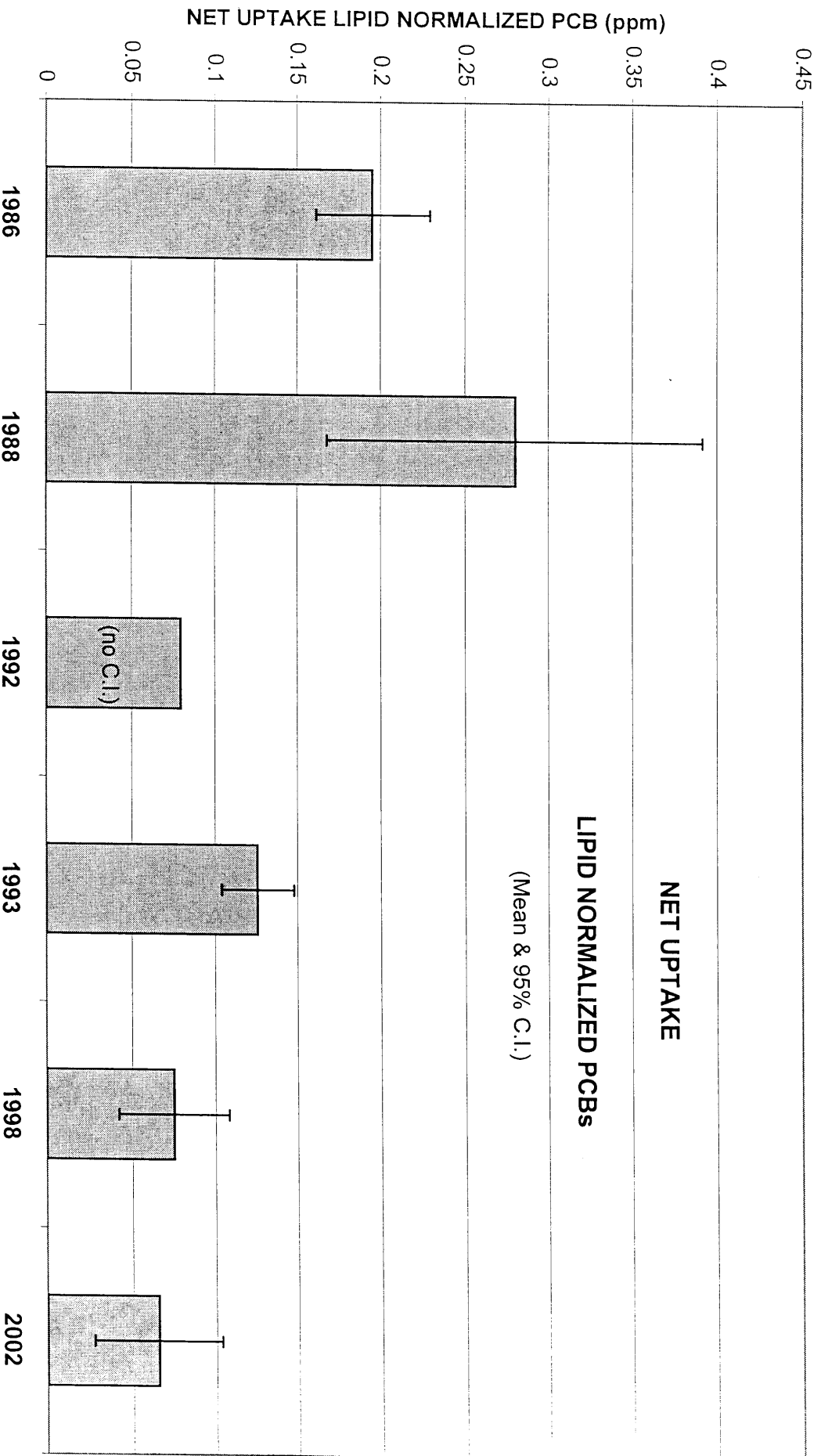


Figure 5. Comparison of lipid-normalized net uptake of PCBs in caged fish from the mouth of the Saginaw River from 1986 to 2002.