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Water Pollution

# Mercury Analysis of Fish in Monroe County*

by

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## Summary

The fish in Monroe County, New York, do not contain dangerously high concentrations of mercury. Some large fish, however, have been found to contain more than 0.5 parts per million (ppm) of mercury, the guideline set by the United States Food and Drug Administration and by the New York State Department of Health as the highest allowable mercury concentration in fish. Pumpkinseed sunfish, a common 'pan' fish of the Great Lakes region, were tested for organic and inorganic mercury by the author and the results compared with data on mercury concentrations in other species of Monroe County fish collected by New York State. Several locations (in particular, the Genesee River below Rochester) had some fish with notably higher mercury concentrations than others, indicating a mosaic distribution of mercury with 'high' and 'low' spots in each body of water. Levels of total and organic mercury in fish caught at the same location were widely scattered but it could be seen that fish accumulate mercury as they age. Organic mercury constituted 52% - 86% of the total mercury in the sunfish studied; the remainder was less toxic, inorganic mercury.

## Background Information

Weathering releases the element mercury from rocks and soils into the surrounding water or air (1, 2). In water the mercury is quickly adsorbed by bottom sediments, particularly when the bottom is covered by decaying organic matter. Once on the bottom, the inorganic mercury can be converted by microorganisms to the very toxic compound methyl mercury which is very easily absorbed by animals (3). For comparison, 90-99% of the methyl mercury ingested is absorbed by various tissues while only 1% of the inorganic mercury eaten is similarly absorbed (4). In general, organisms higher in the food chain contain more mercury than those lower down; older fish may accumulate methyl mercury both by eating smaller organisms that are contaminated and by absorbing it directly across their outer membranes.

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## Dangerous mercury levels in man

Some people are more susceptible to mercury poisoning than others. Sensitive human adults with 0.2 ppm methyl mercury in their blood have shown symptoms of mercury poisoning, while others with higher levels seemed perfectly normal (4). The first evidence of methyl mercury poisoning is malfunction of the nervous system. Symptoms include blurred vision, loss of co-ordinated movement of fingers and emotional irritability. More severe mercury poisoning may result in involuntary movement, blindness, mental and emotional retardation and loss of consciousness, and can lead to permanent damage and death. Prenatal and newborn infants are believed to be particularly sensitive to low doses of mercury but this has not been confirmed.

The legal limit for total mercury content in fish set by the United States Food and Drug Administration for fish in interstate commerce is 0.5 mgm of mercury per kilogram of fish or 0.5 ppm. To arrive at this figure they started with the information that a sensitive adult will show early symptoms of methyl mercury poisoning if he eats 0.3 ppm methyl mercury a day. Then they arbitrarily decided to use a safety factor of 10 and said that the highest acceptable uptake of methyl mercury should be approximately 0.03 ppm methyl mercury each day or about 0.4 mgm for each kgm of body weight each day. This does not mean that a man may not safely eat more than 0.03 ppm methyl mercury on any given day. He can eat a great deal more at a single meal if he then does not eat any fish for a number of days, but a man who consumes large quantities of fish each day can only safely eat fish with low mercury levels. This is summarized in Fig. 3 where the assumption is made that fish is the only source of mercury to which the eater is exposed.

## Why sunfish were chosen for tests

The Pumpkinseed sunfish is a common fish species in Monroe County. A recent survey shows it to be the second most frequently found fish in shore waters of Irondequoit Bay (5). Sunfish are placed relatively 'high' in food webs, and are caught and eaten by Monroe County fishermen. Mercury levels in sunfish can indicate amounts of mercury contamination in Monroe County fish that eat the same kind of food as sunfish, such as bluegills, black crappies, yellow perch, white perch, and rock bass. They can also give us a rough measure of the amount of pollution by mercury present in Monroe County lakes and rivers.

## Methods

Sunfish were collected with a 12 foot 1/8" seine and immediately tagged and put in ice. The fish were measured (standard length) (6) and their ages determined by counting the scales growth rings (7). Mercury analysis was performed using the flameless atomic absorption method. Care was taken in preparing the reagents to avoid any outside mercury contamination. Two grams wet weight of muscle were taken from the right side of each fish. Samples were homogenized in a Waring blender for 10 to 15 minutes until no large pieces of muscle were present. The suspension from the blender was then diluted and analyzed for total and inorganic mercury by a new method (8). The difference between total and inorganic mercury is called organic mercury and is assumed to be primarily methyl mercury, since no sources of other organic mercury are known. The fish from Irondequoit Bay were pooled and only one analysis was done. Fish from other places were analyzed individually.

Mercury in sunfish in Monroe County

Mercury analyses of sun fish from Irondequoit Bay, Black Creek and a small pond in Durand Eastman Park are presented in Table 1. A number of conclusions can be drawn from this data:

1. No fish contained more than the allowable limit of mercury.
2. Every fish contained some mercury. The least contaminated fish was a two year old from Black Creek and it had 0.07 ppm mercury. The most contaminated fish came from the Durand Eastman pond and it was a four year old with 0.25 ppm mercury.
3. Organic (methyl) mercury was higher than inorganic mercury in every fish sampled. In one four year old 86% of the mercury was organically bound, and in every fish more than 50% was organic. Conversely 14 to 48% of the mercury was inorganic. Since 90 to 99% of the methyl mercury ingested is retained while only 1% of the inorganic mercury eaten is absorbed one possibility is that the bottoms of these 3 bodies of water still have much more inorganic than organic mercury.
4. Fish from Irondequoit Bay contained slightly more mercury (0.197 ppm) than those from Black Creek (0.157 ppm). Irondequoit Bay is heavily enriched with effluent of sewage treatment plants which were shown in other places to carry loads of mercury (9). Whether this is the source of mercury in the Bay remains to be tested.
5. Fish from Black Creek had more mercury than those from Durand Eastman pond. Although this sample is small, the difference is meaningful because the fish from Black Creek with the higher mercury content were younger and smaller than those from Durand Eastman pond.
6. At each location, older fish had more methyl mercury per unit weight than did younger ones (see Fig. 1). Inorganic mercury concentrations were scattered and followed no pattern with respect to age. Older fish are expected to have higher mercury levels than younger fish of the same area because a) they have had more time to accumulate mercury and b) the organisms they consume are from slightly higher 'links' in the food web, however, the relation between age and mercury concentration is rarely linear. Thus the average mercury content for 4-year-olds in Durand Eastman pond was 0.141 ppm, while the one 7-year-old had 0.206 ppm, but the fish with the largest amount of mercury was a 4-year-old (0.251 ppm).
7. At each location the larger fish of each age group tended to contain smaller amounts of total and organic mercury than the smallest fish. For example, the largest four-year-old sunfish at Durand Eastman pond was 13.5 cm and had a total mercury content of 0.081 ppm. The smallest 4-year-old was 12.3 cm and had a total mercury content of 0.251 ppm, a 3 fold difference. Seemingly, a fish can either convert much of the food it eats into its own weight or else burn most of it for energy and gain little weight, but in either case the mercury that was in the food remains for a while in the fish. When we compare two fish that ate similar amounts and kinds of food, the fish that grew less fast will have a higher concentration of mercury.

Distribution of mercury in the three bodies of water sampled

We found such great differences in the content of mercury that we could not account for them just by differences in ages and growth rates between the sunfish we tested. Clearly, some of the fish had been eating food with more and some with much less mercury. The actual measurements are in Fig. 2; for comparison, the measurements one might expect in sunfish exposed to a uniform amount of mercury pollution are in Fig. 4.

The scattered levels of organic and inorganic mercury indicate that mercury is unevenly distributed (perhaps in a mosiac pattern on the bottom) both in Black Creek and in Durand Eastman pond. In addition, there are indications that fish of comparable age picked up somewhat more mercury in Irondequoit Bay and Black Creek than they did in the Durand Eastman pond. One possible explanation for this is that the creek is more contaminated with mercury than the pond and that therefore the fish pick up more mercury. Other factors, however, can also explain the mercury concentration differences. 1) The tougher river habitat may stunt the sunfish living there who possibly consume as much food (together with mercury) as pond sunfish, but who use a larger portion of the energy from this food in their metabolism rather than in growth. 2) Pond and river habitats have very different chemical and physical properties. Enormous amounts of water and drifting sediments carrying contaminants pass through the creek providing a continual source of new mercury; small amounts of water flow in and out of a pond and source levels would tend to shrink as mercury becomes locked up in bottom sediments away from the food web. Sediment mercury levels and upstream sources (agriculture or industries) need to be investigated before Black Creek can be described as "more contaminated than Durand Eastman pond".

Mercury concentration in sunfish in Lake Ontario

The sunfish caught and analysed by the Department of Environmental Conservation (10, 11) in Lake Ontario averaged more mercury in their tissues than those analysed for this report (Table 2). Total mercury averaged twice as high in fish from Lake Ontario as it did in those from Durand Eastman pond, and the upper limit of mercury in the fish from the lake was over four times as high as in those from the pond. In the absence of data on age and length a verified explanation of this difference is impossible, but the collection techniques used by the DEC tend to get much larger and older fish.

Mercury concentration in other species of fish from the lower Genesee and Lake Ontario

Some of the fish from Lake Ontario were relatively heavily contaminated with mercury (Table 3) (10, 11). Every species had some members with too much mercury to be shipped in interstate commerce and other members hardly contaminated at all. Most of the fish caught in the lower Genesee could have been shipped across State lines and sold for food.

The two most likely explanations for the wide range in mercury in the fish found in the river and the lake are 1) that the older, much larger fish contain more mercury, and 2) that the waters in the county have high and low spots of mercury contamination that are reflected in the wide scattering of mercury concentration in both sunfish and other species. A positive correlation between age and mercury contamination has been demonstrated for trout (12).

Table I. Inorganic, Organic and Total Mercury in Sunfishes

| age (yrs.) | length (cm) | ←—Mercury inorganic (ppm) | organic (ppm) | (methyl) (%) | total → (ppm) |
|---|---|---|---|---|---|
| **Irondequoit Bay (combined sample)** | | | | | |
| 4 | 12.2 | | | | |
| 3 | 11.6 | | | | |
| 3 | 10.9 | 0.081 | 0.116 | (59%) | 0.197 |
| 2 | 10.1 | | | | |
| 2 | 10.0 | | | | |
| $\bar{x}$ = 2.8 | 10.96 | | | | |
| **Black Creek** | | | | | |
| 4 | 11.7 | 0.036 | 0.145 | (80%) | 0.181 |
| 3 | 11.0 | 0.076 | 0.100 | (57%) | 0.176 |
| 3 | 10.5 | 0.126 | 0.140 | (52%) | 0.266 |
| 2 | 9.0 | 0.026 | 0.060 | (70%) | 0.086 |
| 2 | 9.2 | 0.021 | 0.055 | (72%) | 0.076 |
| $\bar{x}$ = 2.8 | 10.28 | 0.057 | 0.100 | (63.7%) | 0.157 |
| **Durand Eastman Park** | | | | | |
| 7 | 17.2 | 0.076 | 0.130 | (63%) | 0.206 |
| 4 | 13.5 | 0.011 | 0.070 | (86%) | 0.081 |
| 4 | 13.4 | 0.018 | 0.093 | (83%) | 0.111 |
| 4 | 13.2 | 0.044 | 0.102 | (70%) | 0.146 |
| 4 | 12.7 | 0.029 | 0.090 | (76%) | 0.118 |
| 4 | 12.3 | 0.085 | 0.163 | (65%) | 0.251 |
| $\bar{x}$(4-yr-olds) | 13.05 | 0.037 | 0.104 | (74%) | 0.141 |
| $\bar{x}$(total) | 13.7 | 0.044 | 0.108 | (71%) | 0.152 |

Table 2. Mercury Concentrations in Pumpkinseed Sunfish from the Monroe County Area

| | total mercury average | range (ppm) | average length | average age (yrs) |
|---|---|---|---|---|
| Lake Ontario[a] | 0.31 | 0.07 - 1.20 | | |
| Black Creek[b] | 0.16 | 0.08 - 0.27 | 4.0" | 2.8 |
| Irondequoit Bay[b] | 0.20 | | 4.3" | 2.8 |
| Durand-Eastman[b] | 0.15 | 0.08 - 0.25 | 5.4" | 4.5 |

a Boulton, Patricia, and Leo J. Hetling. (1972) A Statistical Analysis of the Mercury Content of Fresh Water Fish in New York State, Technical Paper No. 19. New York State Department of Environmental Conservation, Research and Development Unit.

b author

**Table 3. Mercury Concentrations in Several Species of Fish from the Monroe County Area**

| Species | lower Genesee River[b] total mercury range (ppm) | lower Genesee River[b] average length | Lake Ontario[a] total mercury average | Lake Ontario[a] total mercury range (ppm) | average length |
|---|---|---|---|---|---|
| white perch | 0.1 - 0.3 | | 0.88 | 0.1 - 2.0 | 9.6" |
| rock bass | 0.1 - 0.6 | 8" | 0.86 | 0.1 - 2.7 | 8.4" |
| perch | 0.8 | | | | |
| northern pike | | | 0.76 | 0.2 - 1.8 | 25.1" |
| goldfish | | | 0.69 | 0.3 - 1.4 | |
| small mouth bass | 0.4 - 0.6 | 10½" | 0.66 | 0.05- 1.5 | 12.1" |
| pike-perch (walleye) | 0.1 - 1.7 | 15 - 28½" | | | |
| white bass | 0.05- 0.48 | | 0.53 | 0.05- 1.7 | |
| brown trout[c] | 0.3, 0.7 | | | | |
| yellow perch | | | 0.47 | 0.2 - 1.2 | |
| bullhead | 0.2 | 10" | 0.37 | 0.05- 1.4 | |
| channel catfish | | | 0.29 | 0.05- 1.3 | |
| black crappie | 0.1 | 10" | 0.23 | 0.05- 0.7 | |
| carp | | | 0.25 | 0.05- 1.1 | |

a Boulton, Patricia, and Leo J. Hetling. (1972). A Statistical Analysis of the Mercury Content of Fresh Water Fish in New York State, Technical Paper No. 19. New York State Department of Environmental Conservation, Research and Development Unit.

b Holmes, Ned. (personal communication). May 17, 1972. Department of Environmental Conservation, Avon, N.Y.

c Caught in upper Genesee River in Allegheny County

**Figure 1. Organic Mercury in Sunfish**

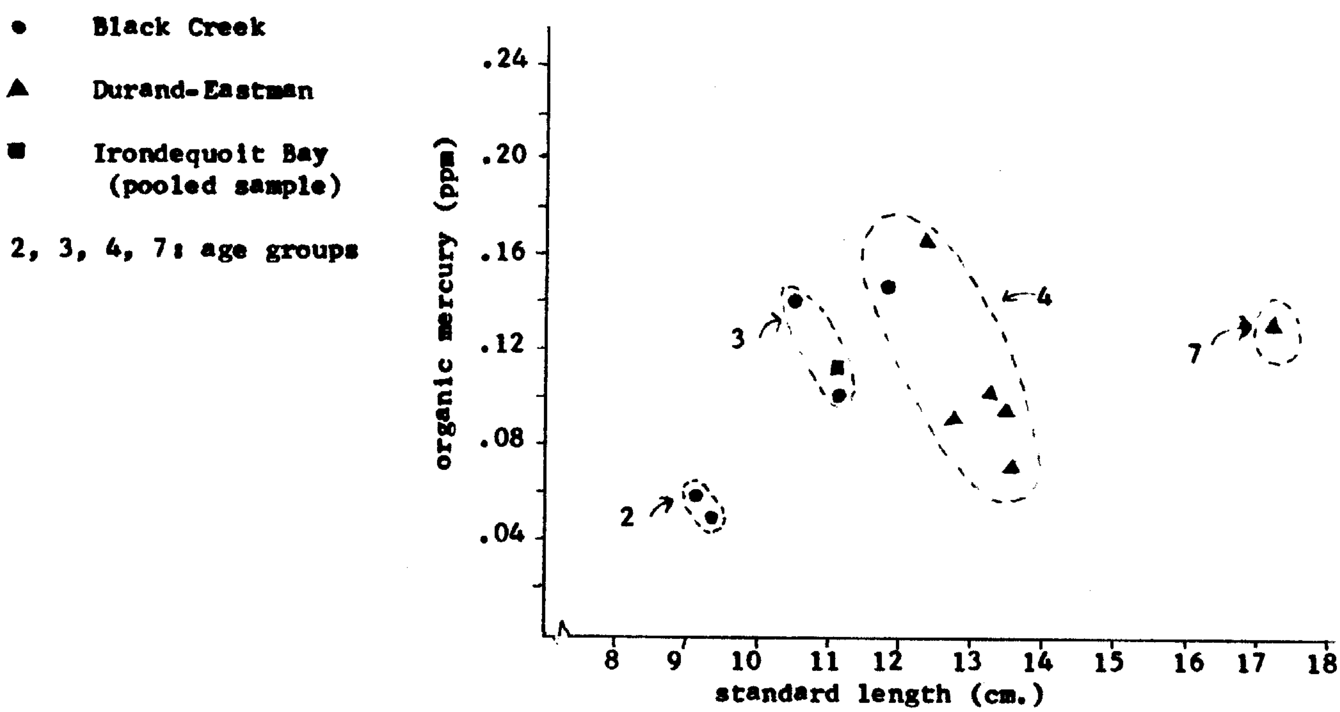


Figure 2. Inorganic and Total Mercury in Sunfish

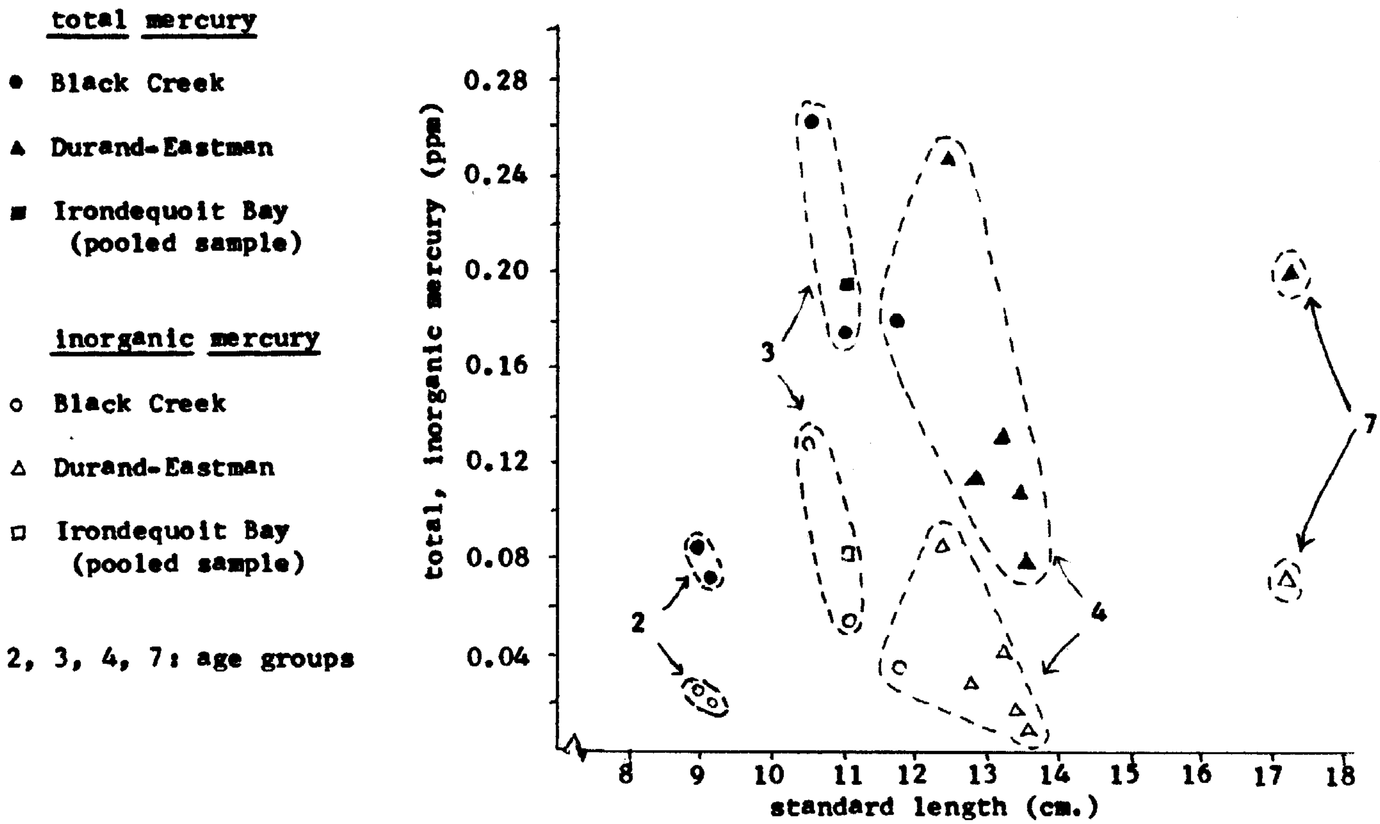


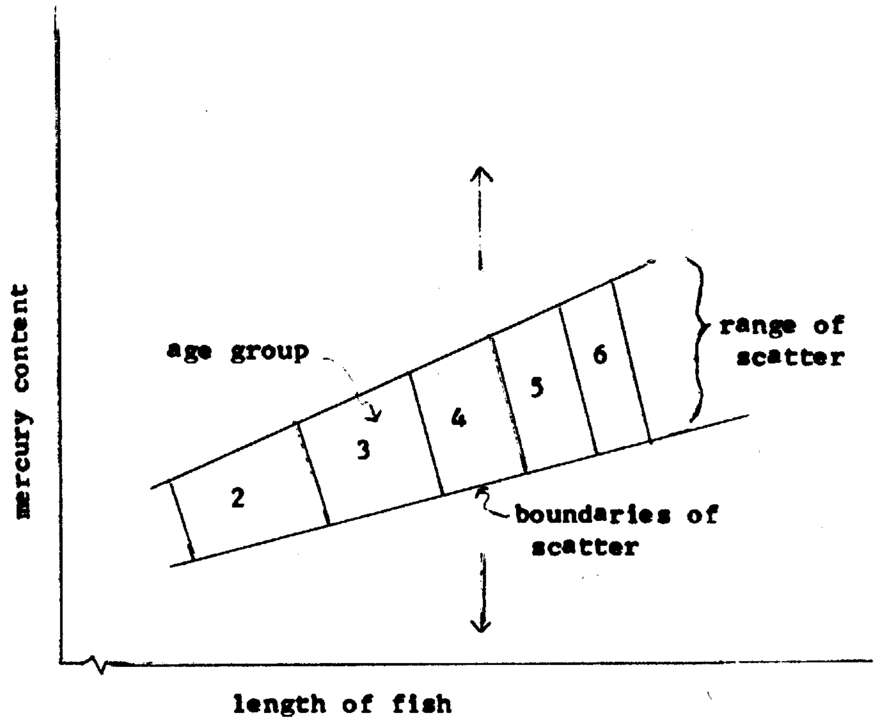

Figure 3. Mercury Intake from Eating Fish (Modified from Reference 4)

| | fish consumption | mercury conc. in fish that will result in ingestion of 0.03 mg/day by man |
|---|---|---|
| very high consumption | 1.1 lb/day | 0.06 ppm |
| above average consumption* | 0.22 lb/day | 0.3 ppm |
| average consumption | 0.063 lb/day | 1.0 ppm |

* 10% of adult men in Sweden eat an average of 2/10 of a pound of fish or more each day

Figure 4. Theoretical Diagram of the Relation of Age and Size to Mercury Content in Fish from Small Areas with a Uniform Mercury Distribution

(boundaries may move vertically depending on background mercury levels)




References

(1) Selikoff, I. J., editor-in-chief. 1971. Hazards of Mercury. Environmental Research 4(1), Special Report to the Secretary's Pesticide Advisory Committee, Dept. Health, Education and Welfare.

(2) United States Geological Survey. 1970. Mercury in the Environment, Professional Paper #713. U.S. Government Printing Office, Washington.

(3) Wood, John M. 1972. A Progress Report on Mercury. Environment 14(1):33-39.

(4) Berglund, Frederick, et al. 1971. Methyl Mercury in Fish. Nordisk Hygienisk Tidskrift Supplementum 4, Stockholm.

(5) Gittelman, S. and Claire Buchanan. 1971. A Survey of the Fish of Irondequoit Bay. Rochester Committee for Scientific Information, Rochester, N.Y. Bulletin #130

(6) Hubbs, C. and Lagler, K. 1964. Fishes of the Great Lakes Region. University of Michigan Press, Ann Arbor.

(7) Lagler, Karl and John Bardach, Robert Miller. 1962. Ichthyology. John Wiley & Sons, NY.

(8) Magos, L. 1971. Selective Atomic Adsorption Determination of Inorganic Mercury and Methyl Mercury in Undigested Biological Samples. Analyst 96:847-853.

(9) Royal Society of Canada. 1971. Mercury in Man's Environment. Proceedings of the Symposium, Ottawa, Canada.

(10) New York State Department of Environmental Conservation (Patricia Boulton and Leo J. Hetling). 1972. A Statistical Analysis of the Mercury Content of Fresh Water Fish in New York State. Technical Paper #19. Environmental Quality Research and Development Unit.

(11) Ned Holmes, personal communication. May 17, 1972. Department of Environmental Conservation, Avon, N.Y.

(12) Bache, C. A., Gutenmann, W. H., and Lisk, D. J. Science, 172, 951 (1971)