# Fisheries Session

## Mercury Contamination in Florida Largemouth Bass

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*Abstract:* This paper provides a mercury database for largemouth bass (*Micropterus salmoides*) from 80 major lakes and streams in Florida. Elevated levels (≥0.5 mg/kg) were recorded for 51 systems requiring health advisories to be issued for > 800,000 ha of aquatic resources. Significant mercury contamination was also found in other animals.

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Accumulation of Mercury (Hg) in fish and other aquatic animals and the potential impact to human health from consumption of contaminated food products are well documented problems (Natl. Acad. Sci. 1978). The U.S. Food and Drug Administration (FDA) has established a standard of 1.0 mg/kg methyl mercury as the limit in food products for human consumption. Similarly, many state health agencies and Canada have established mercury standards for human consumption of fish. In some instances, Canadian and state criteria are more conservative than the federal standard and use 0.5 mg/kg as the unsafe level for mercury. In 1989, the Florida Department of Health and Rehabilitative Services (HRS) established the health risk assessment standard for total mercury in freshwater fish at 0.5 mg/kg to 1.5 mg/kg for limited consumption, allowing 1 0.23-kg meal per week for healthy adults and 1 meal per month for children under 15 years of age and pregnant or lactating women. HRS further recommended that fish with tissue mercury concentrations exceeding 1.5 mg/kg mercury should not be consumed.

Mercury in the environment comes from anthropogenic activities as well as natural sources. In Florida, possible sources of identified contamination are natural peat deposits, atmospheric deposition, fossil fuel generating plants, garbage incinerators, the electrical industry, medical laboratories, paint, pulp and paper productions, and agriculture. At this time there has been no principal source identified and the probable hypothesis involves both natural and man-made inputs.

In September 1982, the Florida Game and Fresh Water Fish Commission (GFC) began a contamination survey of fishes in the Chipola River in northwest Florida. This action was prompted by reported stream contamination from a now defunct battery salvaging plant releasing effluent into a tributary stream (Dry Creek). Fish were analyzed for selected pesticides and heavy metals including mercury. Data from the survey prompted investigations in a nearby uncontaminated stream for background purposes. The pristine Santa Fe River in northeast Florida was selected and samples of fishes were collected in 1983 for comparative analysis (Bigler et al. 1985).

Data from Santa Fe River fishes were surprising due to the elevated concentration of mercury in largemouth bass (*Micropterus salmoides*). Mercury concentrations in 32 bass fillets (skinned) varied between 0.02 and 0.97 mg/kg, with a mean of 0.51 mg/kg. Due to the unexpected nature of the findings, laboratories from each agency performed intercalibration tests with certified reference materials and followed mutually acceptable quality assurance protocol. Following the laboratory exercises, the Santa Fe bass survey was repeated in 1984 and yielded similar results: mean Hg was 0.50 mg/kg for 12 specimens. These results prompted a statewide survey for mercury over the next 5 years producing data presented in this paper.

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## Methods

Largemouth bass was selected as the key target species for mercury analysis due to its position in the trophic web and the well-documented biomagnification of Hg in the aquatic environment (Eisler 1987). Collections were made with electrofishing gear; fish selected were ≥400 g in size. Sample fish were measured, weighted, and labeled; placed in Ziploc plastic bags; then iced for storage in coolers. Samples were transported directly to laboratories within 36 hours. In some cases, tissue samples were extracted in the field and prepared in the same manner for shipment. Fish were removed from plastic bags, rinsed with tap water, and dissected with a surgical knife to extract a 20-g wet tissue sample from each specimen. Details of the protocol are available from the Florida Department of Environmental Regulation.

Other fishes analyzed during this investigation included redear sunfish (*Lepomis microlophus*); bluegill (*L. macrochirus*); warmouth (*L. gulosus*); black crappie (*Pomoxis nigromaculatus*); channel catfish (*Ictalurus punctatus*); white catfish (*I. catus*); brown bullhead (*I. nebulosus*); yellow bullhead (*I. natalis*); bowfin (*Amia* *calva*); Florida gar (*Lepisosteus platyrhincus*); oscar, an exotic cichlid (*Astronotus ocellatus*); and peacock bass (*Cichla ocellaris*). As part of a state-wide program on mercury contamination other wildlife species were sampled. Data on crayfish (*Procambarus alleni*), pig frog (*Rana grylio*), Florida softshell turtle (*Apalone ferox*), Everglades alligator (*Alligator mississippiensis*), mottled duck (*Anas fulvigula*), Everglades deer (*Odocoileus virginianus*) and Florida panther (*Felis concolor*) are presented. Sampling procedures and tissue preparation techniques are in the Florida Department of Environmental Regulations.

Fish tissue samples were prepared for analysis by homogenizing a skinned fillet from 1 side of the fish in a stainless steel chopper. One gram of homogenized tissue was placed in a 250-ml digestion tube with 10 ml of concentrated nitric acid. Samples were kept at room temperature for 3 to 12 hours and then gradually heated for 2 hours in a block digester to 96 C, and kept at 96 C for 8 to 12 hours. Tubes were cooled and 2 ml of 30% hydrogen peroxide added to each tube. Samples were then heated to 96 C for another 2 hours, filtered, and brought up to a volume of 50 ml with distilled water.

A Varian 475 atomic absorption spectrophotometer equipped with a VGA-76 vapor generator was used for mercury analysis. Sodium tetrahydridoborate and hydrochloric acid were used in the vapor generation process.

Atomic absorption standards for analyses were prepared from 1,000-mg/kg certified standards solutions (Fisher Sci. Co.). U.S. National Bureau of Standards (NBS) and Environmental Protection Agency (EPA) reference and research materials and spiked samples were digested and analyzed with each batch of samples to evaluate procedures and analyses.

Lakes and streams chosen for mercury analysis were selected on a systematic basis with public recreational sportfisheries given highest priority. A minimum of 12 specimens by fish species were taken at each location if public health considerations were involved. During preliminary surveys, 3 individuals per species were analyzed.

## Results and Discussion

Mercury analyses on largemouth bass in 80 Florida lakes and rivers revealed in 51 of the systems elevated levels approaching the Florida health standard of 0.5 mg/kg (Table 1). High mercury values were found throughout the state. Highest concentrations were discovered in the Florida Everglades, where mean values exceeding 2.0 mg/kg were found in the samples taken from Conservation Area III (center of Everglades). An advisory was issued against consumption of any bass from the Everglades area in south Florida (Fig. 1). This was the first public health advisory concerning mercury in Florida and also served as the catalyst for an organized statewide interagency probe into the problem. Limited consumption health advisories were issued for an additional 20 locations across the state where mean mercury concentrations ranged between 0.5 and 1.5 mg/kg. These areas were the

**Table 1.** Mercury data summary for Largemouth Bass in Florida.

| Lake | *N* | Min | Max | Mean | SE |
|---|---|---|---|---|---|
| Conservation Area III | 20 | 1.10 | 3.64 | 2.73 | 0.16 |
| C-123 Canal (Conservation Area III) | 2 | 2.30 | 3.10 | 2.70 | 0.40 |
| L-67A Canal (Conservation Area III) | 19 | 1.70 | 4.40 | 2.62 | 0.19 |
| Tamiami Canal (L-29) | 8 | 1.50 | 2.65 | 2.20 | 0.16 |
| Everglades National Park | 15 | 0.69 | 3.50 | 1.85[a] | |
| Miami Canal | 3 | 1.20 | 2.40 | 1.80 | 0.35 |
| Conservation Area II | 17 | 0.95 | 2.92 | 1.73 | 0.13 |
| Savannas State Park | 11 | 0.91 | 2.40 | 1.63[a] | |
| Brick Lake | 6 | 1.31 | 1.50 | 1.38 | 0.03 |
| L-28 Seminole Indian Reservation | 6 | 0.70 | 2.01 | 1.37 | 0.21 |
| Lake Annie | 7 | 0.92 | 1.90 | 1.33 | 0.14 |
| East Lake Tohopekaliga | 29 | 0.90 | 2.03 | 1.33 | 0.05 |
| Equaloxic Creek | 2 | 1.24 | 1.30 | 1.27 | 0.03 |
| L-7 Canal (Conservation Area I) | 2 | 0.99 | 1.40 | 1.20 | 0.20 |
| Steinhatchee River | 3 | 0.95 | 1.50 | 1.18 | 0.16 |
| L-5 Canal | 5 | 0.25 | 1.97 | 1.16 | 0.30 |
| Econlockhatchee River | 6 | 0.66 | 1.60 | 1.12 | 0.14 |
| Puzzle Lake | 10 | 0.79 | 1.41 | 1.10 | 0.07 |
| Crooked River | 3 | 1.00 | 1.20 | 1.10 | 0.06 |
| L-40 Canal (Conservation Area I) | 2 | 0.86 | 1.30 | 1.08 | 0.22 |
| Waccasassa River | 3 | 1.00 | 1.10 | 1.03 | 0.03 |
| Big Gully Creek | 1 | 1.03 | 1.03 | 1.03 | 0.00 |
| Ocheesee Pond | 6 | 0.70 | 1.40 | 1.00 | 0.10 |
| St. Mary's River | 15 | 0.66 | 1.40 | 0.98 | 0.06 |
| Santa Fe River | 10 | 0.65 | 1.27 | 0.96 | 0.05 |
| Yellow River | 21 | 0.41 | 1.65 | 0.95 | 0.07 |
| L-18 Canal | 8 | 0.22 | 2.50 | 0.92 | 0.34 |
| L-3 Canal | 5 | 0.79 | 1.05 | 0.89 | 0.05 |
| Suwannee River | 69 | 0.08 | 1.80 | 0.88 | 0.04 |
| Hillsborough River | 100 | 0.14 | 1.90 | 0.88 | 0.04 |
| Ocean Pond | 12 | 0.31 | 1.90 | 0.87 | 0.14 |
| Fisheating Creek | 3 | 0.59 | 1.30 | 0.87 | 0.22 |
| Blackwater River | 12 | 0.35 | 1.65 | 0.86 | 0.10 |
| Deerpoint Lake/Econfina Creek | 27 | 0.26 | 1.60 | 0.86 | 0.06 |
| Lake Talquin | 15 | 0.36 | 1.40 | 0.84 | 0.08 |
| Lake Placid | 3 | 0.65 | 0.98 | 0.80 | 0.10 |
| Lake Harney | 12 | 0.32 | 1.50 | 0.74 | 0.11 |
| L-23 Canal | 8 | 0.47 | 1.22 | 0.73 | 0.09 |
| Lake Sawgrass | 10 | 0.48 | 1.05 | 0.72 | 0.05 |
| Escambia River | 15 | 0.31 | 1.20 | 0.69 | 0.07 |
| Lake Tohopekaliga | 37 | 0.42 | 1.10 | 0.67 | 0.03 |
| Perdido River | 15 | 0.27 | 1.30 | 0.66 | 0.06 |
| L-12 Canal | 3 | 0.49 | 0.81 | 0.65 | 0.09 |
| Lake Kissimmee | 27 | 0.33 | 1.12 | 0.63 | 0.03 |
| Lake Iamonia | 12 | 0.33 | 0.93 | 0.63 | 0.06 |
| Lake Miccosukee | 11 | 0.31 | 0.84 | 0.50 | 0.05 |
| Apalachicola River | 6 | 0.22 | 0.72 | 0.49 | 0.07 |
| Caloosahatchee River | 3 | 0.28 | 0.70 | 0.48 | 0.12 |
| Lake Trafford | 17 | 0.24 | 0.95 | 0.46 | 0.04 |
| Choctawhatchee River | 3 | 0.41 | 0.51 | 0.46 | 0.03 |
| Aucilla River | 12 | 0.20 | 0.70 | 0.45 | 0.04 |
| Blue Cypress | 12 | 0.13 | 0.84 | 0.44 | 0.07 |
| Tamiami Canal | 3 | 0.34 | 0.49 | 0.43 | 0.04 |
| Lake Jackson | 12 | 0.25 | 0.61 | 0.41 | 0.03 |

*(continued)*

**Table 1.** *(continued)*

| Lake | $N$ | Min | Max | Mean | SE |
|---|---|---|---|---|---|
| Kissimmee River | 6 | 0.29 | 0.65 | 0.40 | 0.05 |
| L-20 Canal | 12 | 0.22 | 0.59 | 0.39 | 0.04 |
| Peace River | 3 | 0.24 | 0.61 | 0.38 | 0.11 |
| L-10 Canal | 3 | 0.29 | 0.50 | 0.38 | 0.06 |
| Wacissa River | 3 | 0.26 | 0.47 | 0.37 | 0.06 |
| Green Cove Springs | 10 | 0.16 | 0.72 | 0.36 | 0.06 |
| Anclote River | 3 | 0.29 | 0.41 | 0.34 | 0.04 |
| Withlacoochee River | 3 | 0.23 | 0.46 | 0.33 | 0.07 |
| Sopchoppy River | 5 | 0.20 | 0.47 | 0.32 | 0.05 |
| Lake Monroe | 10 | 0.16 | 0.59 | 0.28 | 0.04 |
| Faka Union Canal | 4 | 0.24 | 0.33 | 0.28 | 0.02 |
| St. Johns River | 6 | 0.21 | 0.27 | 0.24 | 0.01 |
| Lake Okeechobee | 15 | 0.07 | 0.85 | 0.23 | 0.05 |
| Orange Lake | 6 | 0.15 | 0.29 | 0.21 | 0.03 |
| Lake Griffin | 46 | 0.07 | 0.48 | 0.20 | 0.01 |
| Golden Gate Canal | 5 | 0.15 | 0.21 | 0.18 | 0.01 |
| Lake George | 10 | 0.05 | 0.18 | 0.14 | 0.01 |
| Lake Apopka | 3 | 0.05 | 0.09 | 0.07 | 0.01 |
| St. John's-Farm 13 Reservoir | 7 | 0.03 | 0.11 | 0.06 | 0.01 |
| Lake Parker | 3 | 0.04 | 0.06 | 0.05 | 0.01 |

[a]Individual data points not available.

Hillsborough River, Suwannee River, Santa Fe River, Perdido River, Escambia River, Blackwater River, Yellow River, St. Mary's River, Deer Point Lake, Lake Talquin, Lake Iamonia, Ocean Pond, upper St. Johns River (Lakes Harney, Puzzle, Washington, Hellen Blazes, Poinsett), East Lake Tohopekaliga, Lake Tohopekaliga, Lake Kissimmee, and Lake Istokpoga. More than 800,000 ha of Florida aquatic resources were affected by mercury health advisories.

Generally, lower trophic level fish species (e.g., bluegill) exhibited mercury values <0.5 mg/kg. Predator fishes, e.g. bowfin and gar, contained levels similar to bass values, including the highest recorded value in Florida fishes of 7 mg/kg for a bowfin in Conservation Area III. Some other exceptions were yellow bullhead ($\bar{x}$ = 0.89 mg/kg) in the Everglades National Park, oscars ($\bar{x}$ = 0.58 mg/kg) and warmouth ($\bar{x}$ = 0.94 mg/kg) in Conservation Areas II and III, and bluegill showing a mean value of 1.01 mg/kg from Brick Lake, a small headwater lake in the upper Kissimmee valley.

Analyses of tissues from several species of wildlife in Florida have also revealed elevated levels of mercury (Fig. 2). Of particular interest are tissue samples from Florida panthers (endangered species), which showed high levels of mercury in 7 of 11 animals analyzed. One specimen found dead from unknown causes in Everglades National Park contained a liver concentration of 94 mg/kg. The Florida Panther Technical Subcommittee concluded "that mercury toxicosis was involved in the death of this animal."

Elevated mercury levels were also discovered from Everglades alligators and

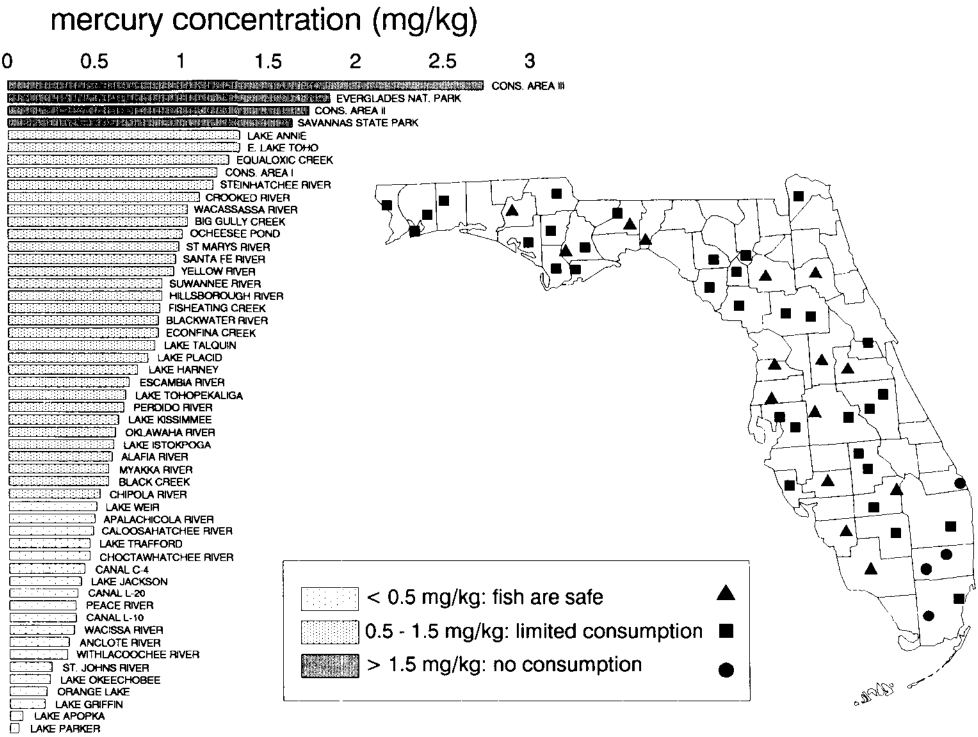


**Figure 1.** Distribution of mercury contamination in Florida largemouth bass.

Florida softshell turtles (Fig. 2). Lower in the trophic web, crayfish and pig frogs showed low mercury levels, but sufficient concentrations to biomagnify substantially up the food chain. Everglades deer and mottled ducks contained low mercury levels as would be expected in herbivorous animals. Additional work is underway with raccoons *(Procyon lotor)*, bobcats *(Felis rufus)*, river otters *(Lutra canadensis)*, and other aquatic animals.

Within 1 year of the March 1989 advisory, 24 separate water bodies were placed on mercury restrictions. These were located in the Alabama and Georgia border streams and throughout the state to the Florida Keys. Significantly, lakes and streams were equally affected; concentrations appeared to be linked to soil drainage type and watershed activity. There was a demonstrated positive relationship between elevated mercury in bass tissue and low pH waters from swamp or peat drainage. This observation is consistent with research in northern lakes where systems with low acid neutralizing capacity (ANC) contain fishes with elevated mercury (Richman et al. 1988). Also, a negative association between mercury concentration and lake trophic status was evident in Florida lakes. In these situations, apparently the organic nature and high pH of the system binds mercury to the bottom sediments, making

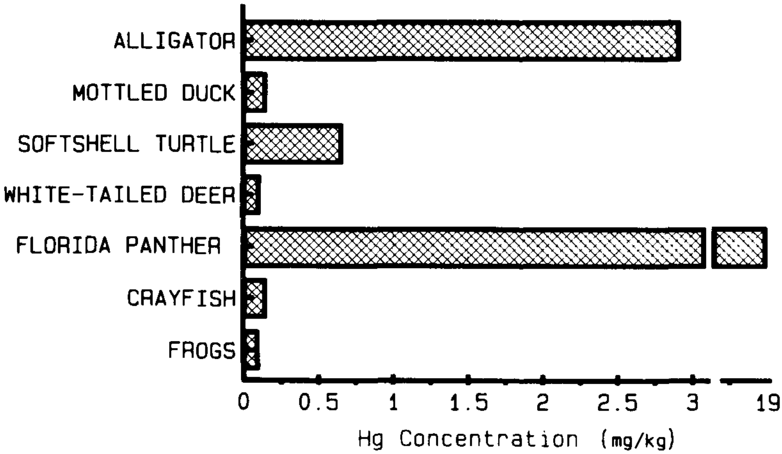


**Figure 2.** Mercury (Hg) contamination in Florida wildlife. Mercury contamination for 1 specimen of Florida panther was 94 mg/kg.

it unavailable for uptake by the aquatic food chain. None of Florida's hypereutrophic natural lakes showed evidence of elevated mercury in fishes (Fig. 1).

Mechanisms for movement of mercury through the aquatic environment in Florida are unknown. The most popular hypothesis identifies peat which may act either as a mercury sponge for atmospheric deposition or contain a natural geologic burden. Contact with acidic water allows for the mobilization of mercury into aquatic systems. Microbes biosynthesize the inorganic form into the methylated form (toxic organic), where it can move up the food chain through biomagnification, producing elevated levels in top predators such as largemouth bass, bowfin, and Florida gar.

If the peat hypothesis proves valid, this would explain the extremely high values found in Conservation Area III which receives substantial run-off from agricultural peat farms immediately upstream. Farming practices of tilling and burning peat soils may facilitate mercury mobilization through direct contact with acid rain or vaporization, producing elevated downstream levels found in top predators of the Conservation Areas.

The Florida scenario with mercury illustrates a heretofore unknown environmental problem that may have been overlooked for many years. In the early phase of this investigation, 1982–1987, there was little recognition of the public health ramifications of mercury contamination. Although data from the Hillsborough River indicated mercury levels in bass tissue near the FDA action level of 1 mg/kg, state health officials had not established state standards to deal with the problem. However, discovery of potentially dangerous levels at 2 to 3 mg/kg in Everglades largemouth bass attracted large scale news media attention and immediate action by public health officials.

Fishery workers in other states can learn from the Florida experience with heavy metals and may wish to plan investigations into ecosystems suspected of metals contamination. Low pH waters should receive first consideration for mercury, especially if they drain through peat or swamp soils. Top predators should be targeted and fillet samples, rather than whole fish, should be analyzed.

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