SEPARATOR

35-00116

AIR

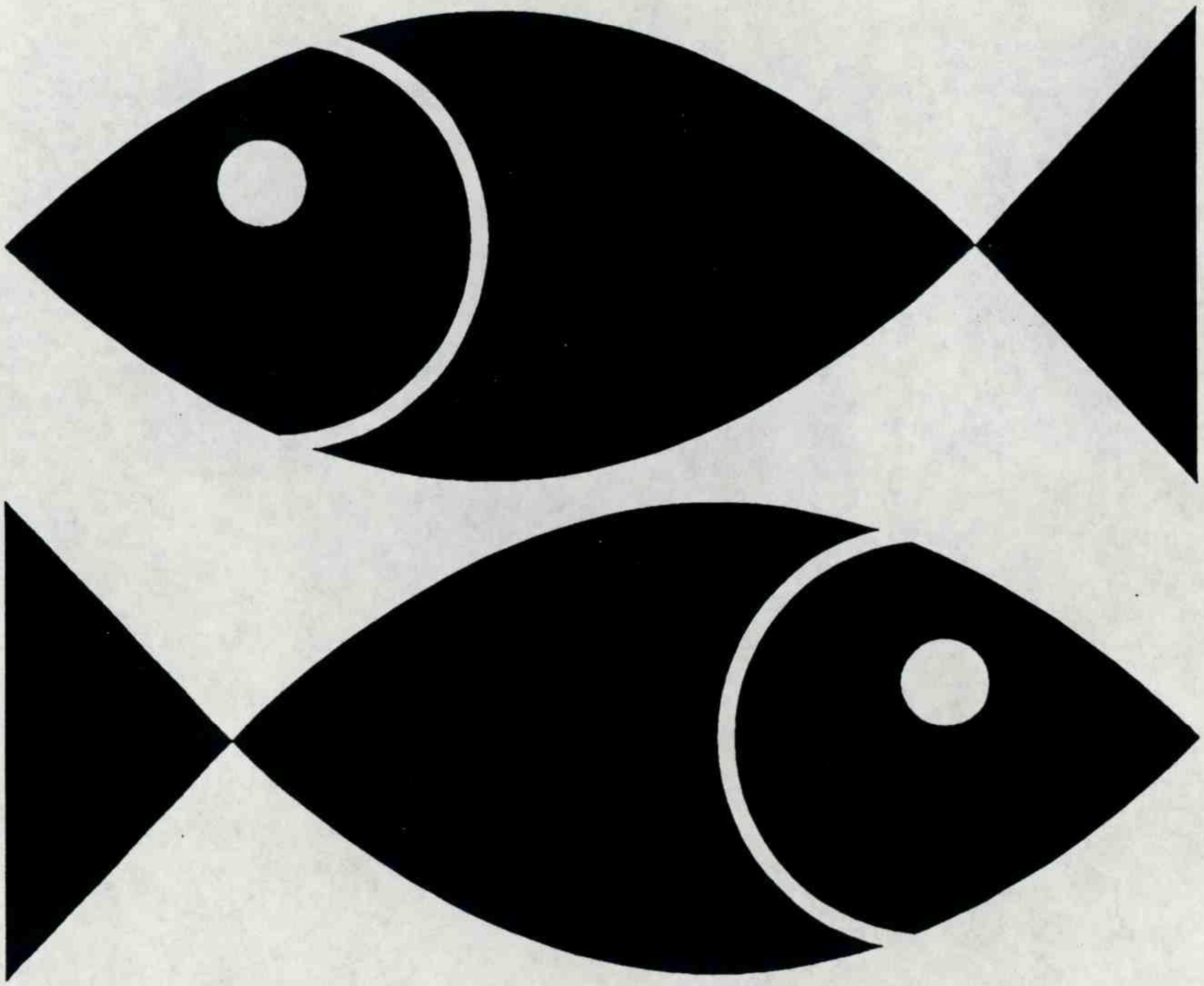
PBA

N/A

N/A

Department's Exhibit
No. ____ 43

Mercury in Arkansas: 1993 – 1994 Biennium Report



Arkansas Mercury Task Force

Mercury in Arkansas: 1993–1994 Biennium Report

Arkansas Mercury Task Force

Authors [1]

M. Armstrong [2], P. Burge[3], S. Evans[3], J. Giese[4], T. McChesney [3], J. Nix[5], A. Price[4], K. Thornton[6], and D. Turman[2]

Arkansas Mercury Task Force

Submitted to:

Office of the Governor

Capitol - Suite 238

Little Rock, AR 72201

[1]**Authors listed in alphabetical order**

[2]**Arkansas Game and Fish Commission**

[3]**Arkansas Department of Health**

[4]**Arkansas Department of Pollution Control and Ecology**

[5]**Ross Foundation**

[6]**FTN Associates, Ltd.**

June 1995

MERCURY IN ARKANSAS
1993-1994 Biennium Report and Proposed FY95Activities
EXECUTIVE SUMMARY

In the summer of 1992, Arkansas discovered a problem with mercury in fish in the Ouachita River. Over this past biennium, the Arkansas Mercury Task Force has conducted extensive sampling of lakes and streams to determine the magnitude and extent of the problem, what is causing the problem and what can be done to manage the mercury problem.

Results and findings from the first biennium studies are:

1) Over 170 lakes and streams were sampled during 1992 through 1994. Twenty-three percent (39 systems) had fish with mercury concentrations exceeding the FDA Action Level of 1 ppm. See Attached Map.

2) Arkansas is one of 36 states that have fish consumption advisories due to mercury.

3) The most extensive occurrence, and highest concentrations, of elevated mercury levels are found in largemouth bass and flathead catfish in the Gulf Coastal Plains region of south Arkansas.

4) Sources of mercury are currently unknown; natural sources might be important. A study is being done by an international expert to determine if natural sources in Arkansas can contribute to the fish mercury problems.

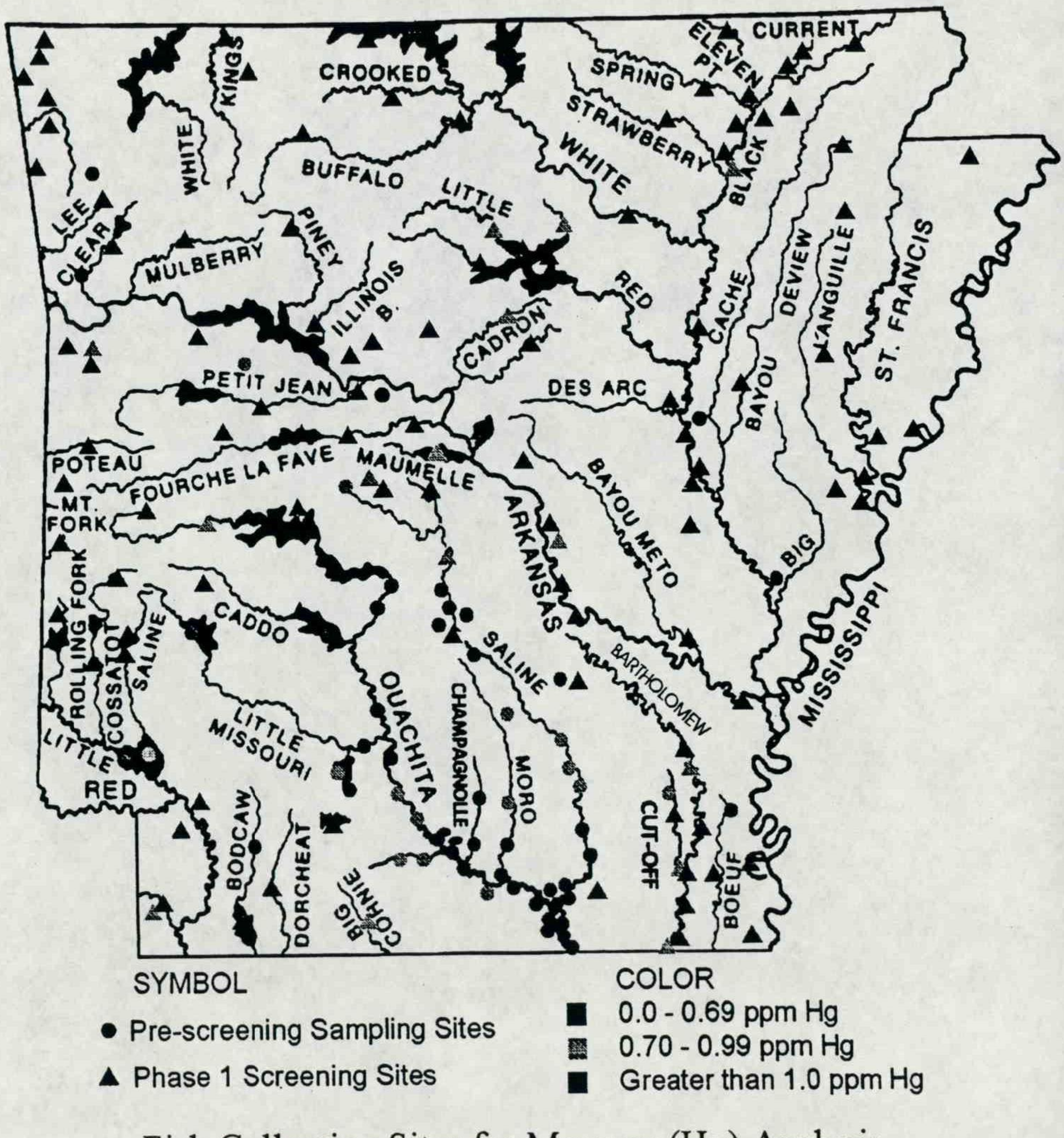
5) The problem is currently being addressed by:

   - Issuing fish consumption notices to protect human health particularly in High Risk Groups:
     * Women who are pregnant or planning to become pregnant,
     * Small children 7 years or younger, and
     * Women who are breast-feeding.
   - Providing information on the size and species of fish and fishing locations the public can eat fish without risk from mercury, and
   - Encouraging the use of catch and release and trophy bass programs in waters with consumption notices.

6) Mercury Task Force activities for 1995 and 1996 will emphasize:

   - Identifying the sources
   - Lake and stream management approaches to minimize the mercury impacts
   - Sampling buffalo and other commercial fish to try and re-open commercial fishing licenses.

Arkansas Mercury Task Force



Fish Collection Sites for Mercury (Hg) Analysis

ACKNOWLEDGEMENTS

When the mercury issue was raised in the lower Ouachita River, three state agencies - Arkansas Department of Health, Department of Pollution Control and Ecology, and Game and Fish Commission - with Ouachita Baptist University, quickly organized a coordinated, concerted effort to identify the magnitude and extent of the problem. These efforts initially were undertaken with no additional funding or personnel. The Mercury Task Force activities and efforts provide an excellent illustration of the accomplishments derived through teamwork among state agencies. The authors gratefully acknowledge the contributions of the following individuals:

Department of Health - Dr. Sandra Nichols, Director

Tom Butler, Assistant Director

Carl Long, Morris Cranmer

Department of Pollution Control & Ecology - Randall Mathis, Director

Dick Cassat, Roy James, Bill Keith, Daniel Lynch, Mike Rodgers, Joe Semberski, Terry Sligh, Richard Thompson, Pamela Tucker, Jim Wise

Game and Fish Commission - Steve Wilson, Director

Jim Alhert, Tom Bly, Les Claybrook, Jeff Farwick, Steve Filipek, Pat Fitts, Ralph Fourt, Thomas Gawf, Brett Hobbs, John Hogue, Bob Limbird, Ron Moore, Mark Oliver, Carl Perrin, Jane Rice, David Settlemeyer, Mark Shaw, Fred Shells, Ken Shirley, Jerry Smith, Stan Todd, Brian Wagner, Drew Wilson, Stuart Wooldridge

Ouachita Baptist University (Ouachita River Institute)

Technicians - Fred Buzen, Clark Kuyper, Kent Thomas

Students - Kevin Chambliss, Rex Easter, Steve Gonzales, Jim Maxwell

The authors also gratefully acknowledge the peer-review of this report and the comments and suggestions of the following individuals:

Dr. Allen Burton, Wright State University, Dayton, Ohio

Dr. Cynthia Gilmour, Academy of Natural Sciences, St. Leonard, Maryland

Dr. Dixon Landers, USEPA Environmental Research Laboratory, Corvallis, Oregon

Dr. Kenneth Steele, University of Arkansas, Fayetteville, Arkansas

Dr. Jerry Stober, USEPA, Region IV, Athens, Georgia.

LIST OF APPENDIXES

LIST OF TABLES

LIST OF FIGURES

Chapter 1: Introduction

1.1 The Problem: Mercury in Arkansas

1.1.1 The Discovery of the Mercury Problem in Arkansas

Routine sampling in the lower Ouachita River in Arkansas over several years had indicated suboptimal fish population levels. A Lower Ouachita River Work Group (LORWG) was established in 1990 to investigate the reasons for these suboptimal levels. This group collected fish during the summer of 1991 from Remmel Dam (near Malvern) to the Louisiana state line (see Figure 1.1). In the summer of 1992, the Louisiana Department of Health and Hospitals issued an advisory for the consumption of fish in the Louisiana sections of the Ouachita River because of mercury contamination, which was discovered during routine sampling.

After Louisiana issued their consumption advisory, the fish samples collected in 1991, which had been stored because of lack of funding, were subsequently analyzed for mercury. Fish in the portion of the Ouachita River below Smackover Creek to the Louisiana border were found to contain mercury concentrations that exceeded the U.S. Federal Food and Drug Administration's (FDA) recommended advisory limits of 1.0 ppm* (Figure 1.1). Fish in the upstream portions of the Ouachita River (from Remmel Dam to Smackover Creek) had concentrations below 1.0 ppm. A health advisory on the consumption of predator and nonpredator fish was issued by the Arkansas Department of Health (ADH) on 8 September 1992 for the area from Smackover Creek to the Louisiana border.

1.1.2 Confirmation of the Mercury Problem in South Arkansas

During the months of October and November 1992, the Arkansas Game and Fish Commission (AGFC) and the Arkansas Department of Pollution Control and Ecology (ADPCE) obtained additional fish samples from the lower Ouachita and some of its tributaries, including Felsenthal National Wildlife Refuge (NWR). Analysis of these samples confirmed that the concentration of mercury was in excess of 1.0 ppm in bass collected downstream from Calion, Arkansas. This expanded mercury survey found that a pattern similar to that in the Ouachita River was also present in the Saline River; mercury increased in a downstream direction. An additional advisory was issued to include the effected section of the Saline River.

Subsequent studies showed that bass with a mercury concentration above 1.0 ppm were present in (1) Lake Columbia; (2) selected oxbow lakes associated with the Ouachita River; and (3) selected farm ponds located in the lower Ouachita area, just above the floodplain of the river. ADH issued additional consumption advisories as information became available. The number of counties with fish consumption advisories continued to increase as the sampling area expanded until eight counties in South Arkansas were under advisories (Figure 1.1).

Fish and sediment sampling continued during late 1992 and early 1993. The findings from concentrations were frequently above 1.0 ppm in bass from

*NOTE: The unit convention for mercury is not standardized. Conversion factors for the units most often used in the discussions of environmental mercury status are provided in the following table.

Conversion Factors
1 ppm (part per million) = 1 mg/kg (milligram per kilogram) = 1 μg/g (microgram per gram) 1 ppb (part per billion) = 1 μg/kg (microgram per kilogram) = 1 ng/g (nanogram per gram)

the local health units in each of the counties mentioned above. Potential participants in the project were required to confirm that their recent fish consumption rate had been a minimum of two meals per month of fish taken from the lower Saline and/or Ouachita Rivers. A fish meal was defined as 8 ounces (precooked weight) of edible fish. If their consumption rate met these criteria, each individual was required to provide a 7-milliliter sample of whole blood and complete a two-page questionnaire. The questionnaire solicited information regarding fish consumption, other potential sources of mercury exposure, weight, sex, etc. A nurse was available at each local health unit to help participants complete the questionnaire. A total of 236 individuals met the criteria for fish consumption patterns. These individuals were provided with blood mercury determinations. Table 2.1 provides a breakdown by age and sex of these volunteers. Figure 2.1 graphically demonstrates the age skew of the distribution of volunteers.

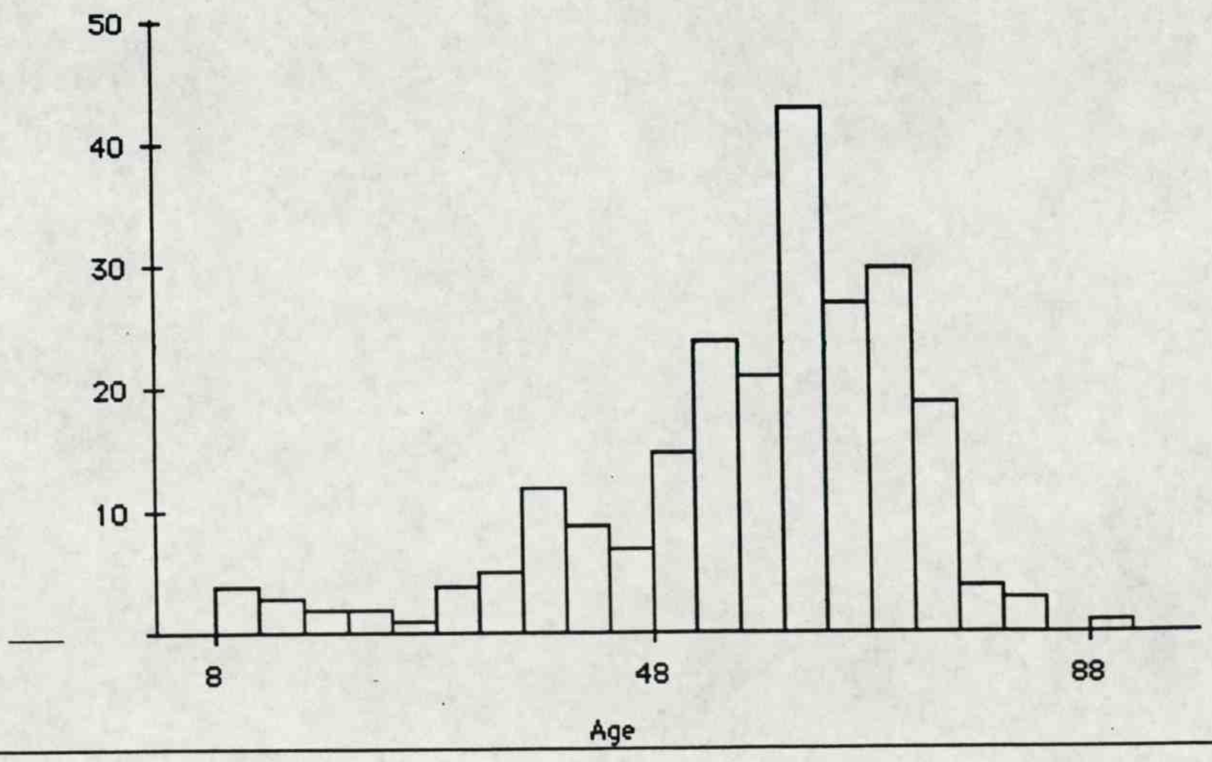
Blood samples were collected in heparinized tubes, which were certified to be free of trace metals. All samples were refrigerated at the local health units until they were collected by field representatives of the private laboratory that had contracted to perform the analyses. Whole blood is the matrix generally used to determine blood mercury levels since approximately 90% of the methyl mercury in the body is located on the red blood cells (ATSDR 1992). Blood mercury levels were determined using flow-injection atomic absorption spectrophotometry. This methodology measures total mercury in the blood. It is considered appropriate to measure total mercury as an indicator of methylmercury, because between 70% and 90% of the total mercury found in edible portions of fish is methylmercury (ATSDR 1992). For most of the population, mercury in fish is the single largest source of mercury exposure. The limit of detection for this methodology is 2 ppb (Roche 1992).

Table 2.1. Summary of Blood Screening Project, December 1992

Total Number of Participants - 236
Total Number of Males - 143
Total Number of Females - 93

Age Breakdown	Total	Males	Females
< 8 years	0	0	0
8–15 years	7	4	3
15–35 years	10	7	3
35–65 years	149	89	60
>65 years	70	43	27

Figure 2.1. Histogram of participant's age vs. number of participants per segment.



In January 1993, each participant in the project was provided with their blood mercury level. Participants were informed of the following information as well:

- For the general public, blood mercury levels below 20 ppb are not believed by the ADH to be associated with any excess risk.
- In adult males and nonpregnant, adult females, blood mercury levels above 50 ppb can be associated with reversible, nonserious changes in body chemistry.
- Blood mercury levels above 200 ppb may result in adverse symptoms to the general public.
- Since the initial advisory was issued in September 1992, the public may have altered their fish consumption patterns before the screening project. Based on the reported half-life of mercury in the blood, approximately 50 to 60 days (ATSDR 1992), it is probable that blood mercury levels might have been higher in some individuals.
- Individuals whose blood mercury levels were above 20 ppb but less than 50 ppb were advised to consider additional reductions in their fish intake; persons with blood levels above 50 ppb and up to 100 ppb were encouraged to stop eating fish for at least 60 to 70 days.
- Participants were also provided with a series of formulas which were developed to help them modulate their blood mercury levels to within safe limits through restricted intake of fish (Appendix C).

No instances of symptomatic mercury poisoning were identified during this project. Other than a few individuals who reported use of topical medications containing mercury (mercurial chloride) the only other potential exposure reported was consumption of other types of seafood which might contain mercury, primarily tuna. Based on the range, mean, and median of blood mercury levels among those eating other types of seafood, those reporting no consumption of seafood and the group as a whole, seafood consumption did not appear to influence blood mercury levels. Graphical summaries of the results are shown in Figures 2.2 and 2.3.

Other points of interest were:

- Blood mercury levels:

Range:	All data:	0–75 ppb (n=236)
	Males:	0–75 ppb (n=143)
	Females:	0–26.6 ppb (n=93)
Mean:	All data:	10.5 ppb
	Males:	12.8 ppb
	Females:	6.9 ppb
Median:	All data:	7.1 ppb
	Males:	9.0 ppb
	Females:	4.8 ppb

- 139 participants exceeded 5 ppb
- 30 participants were in the range of 20 to 75 ppb
- 25% were below the limit of detection (2 ppb)
- 15% were above 20 ppb
- 7% of the females had levels greater than 20 ppb
- 20% of the males had levels greater than 20 ppb
- 5% of the males had levels greater than 30 ppb
- No females had levels greater than 30 ppb
- The lowest levels were found in Cleveland County followed by Calhoun County
- The remaining counties were similar in percentages above 20 ppb
- No occupational sources of mercury exposure were reported on the questionnaires
- No direct relationship was observed between the self-reported amount of fish consumed and blood mercury levels
- Approximately 20% of the participants reported consumption of other types of seafood (primarily tuna) which might contain mercury.

To make valid public health recommendations, the ADH identified the need for additional monitoring of blood mercury levels in the general population. One point in particular that needed clarification was the level of protection for the high risk group afforded by the fish consumption advisories as they are now issued. For example, an examination of

Figure 2.2. Blood mercury levels by county.

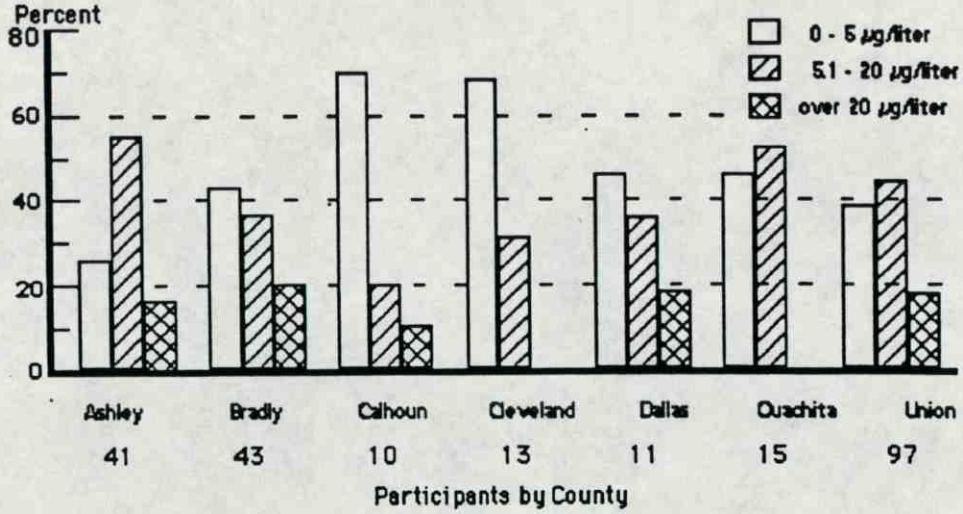
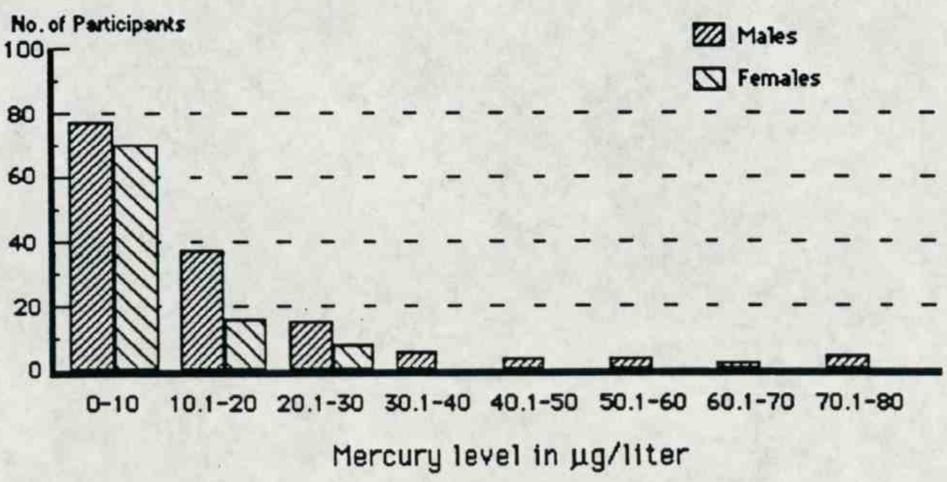


Figure 2.3. Blood mercury levels in µg/liter.



current fishing advisories for various states shows that many states begin the advisories at 0.5 ppm rather than the 1.0 ppm used in Arkansas. This results in a larger number of bodies of water under advisement. As a trade-off, these states usually allow some level of consumption of fish with mercury levels above 1.0 ppm. The blood mercury levels obtained in the screening service were not adequate to make the assumption that the Arkansas method was adequately protective for the high risk groups. A statistically valid study is needed to make defensible decisions on this and other issues.

To provide better direction for public health policy decisions, ADH began a blind study to evaluate blood mercury levels among Arkansas' "high risk" groups (i.e., children and women of childbearing age). The goal of this study is to provide an indication of the magnitude of actual blood mercury levels in the high risk population. Existing programs within the ADH (Early Periodic Screening, Diagnosis, and Testing [EPSDT]/childhood blood lead screening, sickle cell screening program) were identified as readily available points of access to the populations of interest.

It is possible that a segment of the population may consume large quantities of fish from the impacted waters due to cultural and personal preference without regard to economic status or availability of alternate food sources. Should this be the case, these individuals may be at higher than normal risk due to self-moderating consumption patterns rather than enhanced sensitivity. If the existence of this group can be confirmed, appropriate interventions should be expanded to include them.

It was determined that a two-phase design would be used. The first phase would examine blood mercury levels throughout the state in the high risk populations. The parameters for the second part of the study will be generated based on the results of statistical demographic evaluation of the first phases data. It is anticipated that as many as 5,000 blood tests might be completed in both phases of this study.

Due to the number of tests that would be required for statistical validity, funds were secured through the Mercury Task Force to purchase equipment and supplies. The ADH laboratory began analysis of samples for the blind study in July 1994.

2.2 Sampling for Mercury in Fish

Mercury levels in Arkansas fish have been measured for several years, but the majority of collections prior to 1990 focused on point source discharges or other specific pollution related programs. Much of the data generated was whole fish analysis for determination of whole-body loading or from liver tissue analysis to determine the amount of metals available in the aquatic environment. In the summer of 1992, elevated levels of mercury were found in the edible portion of fish from the Ouachita River in Louisiana. To verify Louisiana's findings, a number of collections were made from the lower Ouachita River and Saline River basins in Arkansas. Archive specimens collected by the LORWG in 1991 were retrieved and analyzed for mercury. Additional tissue samples were collected from Felsenthal NWR, the Saline River up to Benton, Lake Columbia, Lake Georgia-Pacific, and several oxbow lakes within the floodplain of both rivers (Figure 2.4). These collections were exploratory in nature and followed the sampling protocol used by the LORWG in their contaminant scan of the lower Ouachita River. The LORWG collections included both predator (spotted bass *Micropterus punctatus* or largemouth bass *Micropterus salmoides*) and bottom-feeding species (buffalo *Ictiobus sp.* and/or *Moxostoma sp.*). Sampling protocols called for the collection of livers and edible fillets from five adult fish. The Sportfish Contaminant Analysis Project (FCAP) (Shirley 1992) provided a database collected under a QA/QC plan that limited the bass size to a 300 to 375 mm (12–15 in.) range, but only the liver tissue was analyzed for mercury.

The analysis of fish tissue from the LORWG collections, FCAP database, and early exploratory collection in the fall of 1992 revealed mercury levels above the FDA Action Level (i.e., 1.0 ppm) to be widespread throughout the lower Ouachita and Saline River basins. Agency personnel speculated elevated levels of mercury might be present in other basins throughout the Gulf Coastal Plain ecosystem of south Arkansas. A screening of fish collected from major drainages throughout the state was needed to identify other areas where mercury was a problem and pro-

Arkansas Mercury Task Force

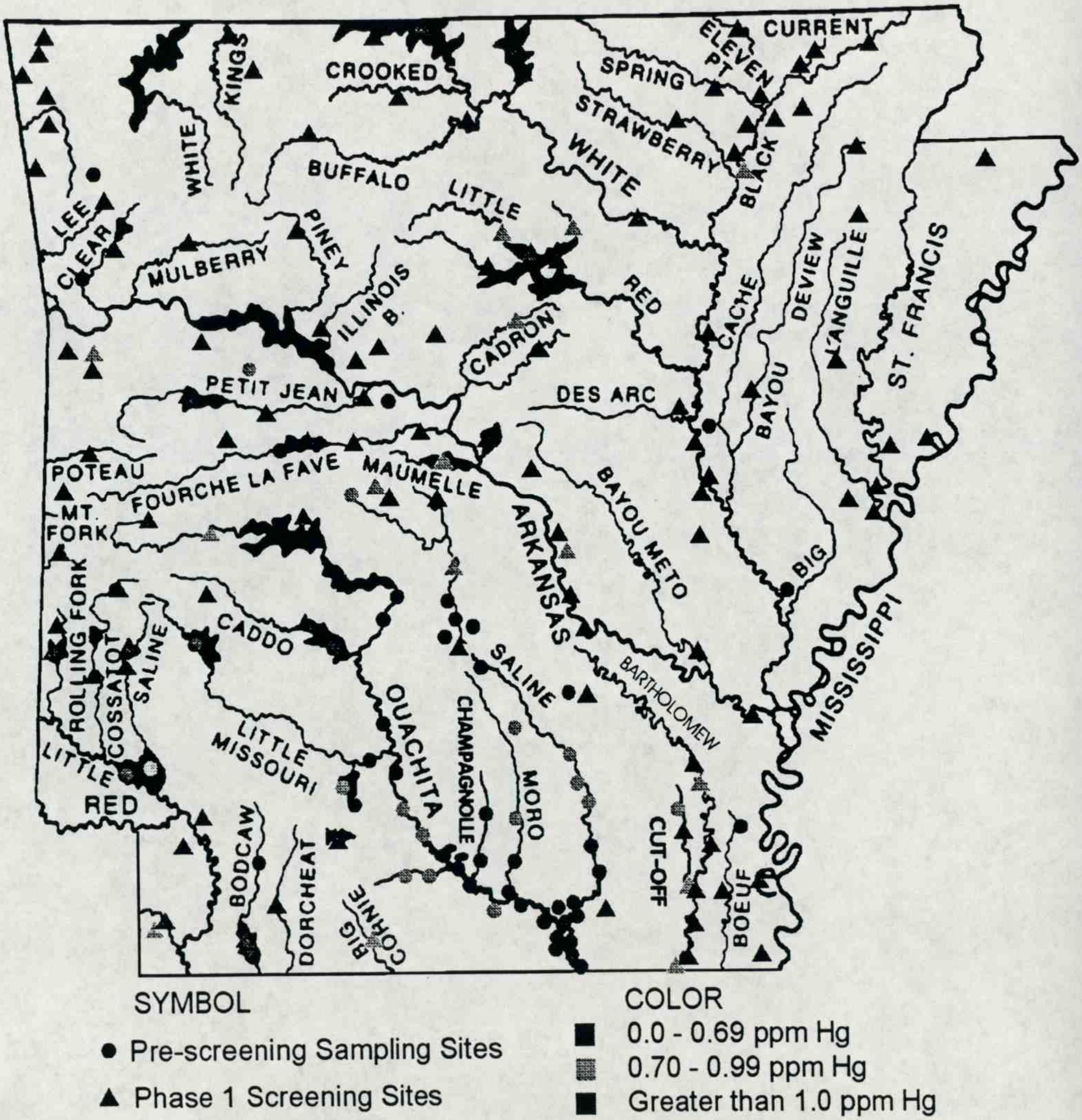


Figure 2.4. Fish collection sites for mercury (Hg) analysis, 1993–1994.

vide a baseline frame of reference for investigating the source of environmental mercury.

A statewide mercury screening study (Phase I) for fish flesh was designed and implemented to (1) provide structured base line data for evaluating levels of mercury in selected areas throughout the state; (2) identify other water bodies where mercury levels exceed tolerance limits for human health; and (3) identify hot spots and/or areas where mercury levels are very low. Personnel from the AGFC, ADPCE, ADH and the Ouachita River Institute participated in the study design, tissue collection, and laboratory analysis. Intensive sampling (Phase II) followed Phase I sampling to confirm screening results, provide geographic definition of areas considered for fish consumption advisories, determine the magnitude of contamination in other species, and examine the relationship between length and mercury concentration.

2.2.1 Selection of Sample Areas

One hundred thirty-seven sample sites (Figure 2.4) were selected for mercury screening on the basis of satisfying four criteria identified in the Mercury Task Force Strategic Plan:

1) High use recreational areas,
2) Areas suspected of having elevated mercury levels,
3) Areas lacking data, and
4) Areas needing confirmation of prescreening analysis.

High use recreational areas were selected on the recommendation of AGFC's fisheries staff.

Suspect areas were selected on the basis of their geophysical similarities (i.e., land form, geology, drainage area) to areas where elevated levels of mercury had been found previously. Most areas outside the Ouachita River and Saline River basin lacked information on mercury in edible fish tissue. Verification occurred in areas previously tested using either whole fish, livers, or single fillet samples lacking replicates or composites from several fish species.

2.2.2 Screening Protocol (Phase I)

Screening and intensive fish sampling protocols were designed to answer questions regarding the statewide distribution of mercury in fish flesh and achieve the Mercury Task Force's strategic goal of protecting human health. The study design followed the US Environmental Protection Agency's (EPA) recommended monitoring strategy in most aspects (EPA 1993b). EPA recommends a two tier study design comprised of a screening study (Phase I) and a second phase intensive sampling (Phase II) study. In the EPA protocol, single composites of a target predator and bottom feeder are screened for analyte concentrations. Intensive sampling is initiated where analyte values from the screening study suggest concentrations exceed selected threshold values. Phase II studies assess variability through the collection of replicate composites, assess size specific mercury concentration levels and the geographical extent of the contamination. The use of composites allow investigators to estimate mean contaminant levels at lower laboratory costs than analyzing individual fish and averaging results.

Our study screened only predators, but included size specific levels for two size groups in the screening phase. Our Phase II intensive sampling (discussed in the next section) combined both tasks of collecting size specific replicates and assessing geographical extent through additional site collections.

The screening target was a composite of largemouth bass (*Micropterus salmoides*) skinless edible fillets from 5($\pm$1) fish ranging from 305 to 406 mm (12 to 16 in.) total length collected from each sample location. Where possible, a larger size class composite of 3($\pm$1) largemouth bass equal to or greater than 406 mm (16 in.) total length was collected. Where the target species could not be collected, edible fillet composites of spotted bass, crappie 7 in. or greater total length or catfish (blue or flathead) equal or greater than 406 mm (16 in.) total length were substituted.

Largemouth bass was selected as the screening organism due to the species popularity as a sportfish in Arkansas (AMRA 1988), trophic position as a pis-

civorous predator (Heidinger 1975), and demonstrated tendency to bioaccumulate mercury (Eisler 1987, Ware et al. 1990). The 305 to 406 mm (12 to 16 in.) size range encompasses the most common sizes of largemouth bass caught by anglers and overlaps a fishery management target length group (12 to 15 in.) for recreational bass fishing (Anderson and Gutreuter 1983, AGFC 1991). The group is at or slightly above the minimum length most anglers begin to harvest bass, and represents the size range composing most of the angler harvest (AGFC unpublished data). The collection and analysis of the larger size class was initially designed to allow the examination of a suspected fish length (age) versus mercury concentration relationship. Subsequently, the larger composites were used to establish size specific fish consumption advisories in some areas.

Fish were collected either by electrofishing, cove-rotenone, or angling. Fillet composites were prepared in the field by removing boneless fillets from both sides of the fish, wrapping individual fillets in aluminum foil, and grouping fillet composites together in labeled zip-lock plastic bags. Instruments were washed with soap and water between composites. The majority of fish tissue analyses were performed within the 28-day holding time recommended by EPA (1993a), with a few samples stored for up to 60 days.

EPA guidelines recommended analyzing fillets of finfish with the scaled skin remaining on the fillet. However, EPA guidelines allow local dietary customs to be recognized. Our study used fillets with the skin off due to the widespread use of this preparation technique among Arkansas anglers and to remain consistent with earlier preparation procedures.

Mercury analysis was performed by either the ADPCE or Ouachita Baptist University (OBU). Analytical procedures followed EPA Method Number 245.6 Revision 2.3 with the exception that after August 1993, ADPCE used a mercury analyzer with a fluorescence detector in place of the atomic absorption spectrophotometer. OBU used a cold vapor atomic absorption spectrophotometer for all analyses. The specific methods are presented in Appendix D. Data quality was assured by inclusion of mercury standards, sample blanks, laboratory replicates and spikes during each sample run. Analyses were not performed until the instrument had met QA/QC criteria for standards and sample blanks. Laboratory replicates and spikes were used to calculate relative percent difference and percent recovery, respectively. Control charts for the mercury analyzer have been developed at OBU and ADPCE. In the early stages of using the mercury analyzer, ADPCE reanalyzed some samples due to less than satisfactory duplicate differences in the analysis. The reanalyzed data gave satisfactory results between duplicates. All data analyzed for the 1994 reporting period fell within the relative percent difference control limits for duplicate differences and showed acceptable spike recoveries.

2.2.3 Intensive Sampling (Phase II)

The objectives of Phase II sampling follow: (1) confirm the screening results, (2) aid in defining geographical boundaries for any warranted fish consumption advisory, (3) determine mercury levels in other fish species, and (4) quantify mercury concentrations in specific sizes of fish. All four objectives, however, were not addressed at each Phase II collection site.

Phase II sampling protocols varied depending on the specific objectives of the sampling. Replicate collections followed Phase I sampling protocols to confirm screening data, provide geographical definition, and determine the magnitude of contamination in other species. The relationship between size of fish and concentration of mercury was investigated using either individual fillets or size group composites. Efforts were made to collect at least three specimens for each size group for both individual fillet analysis or size group composites.

Water bodies on which Phase II sampling was performed are listed in Table 2.2.

2.2.4 Results and Discussion

Edible fillet mercury levels from fish collected prior to and during the screening study are presented in Table 2.3. (Table 2.3 is located in Appendix E because of its length. Appendix E also contains the entire ADPCE mercury database on edible fish flesh since 1990 as Table 2.4.) All data is grouped by ecoregion. In 1987, ADPCE established water

Table 2.2. Phase II sample sites and objectives.

Ecoregion	Sample Site	Sampling Objective
Ozark Highlands	Bull Shoal Lake	confirmation
Boston Mountains	Lake Shepherd Springs	confirmation mercury: fish length regression
Boston Mountains	Greers Ferry Lake	confirmation
Ouachita Mountains	Lake Winona	confirmation mercury: fish length regression
Arkansas River Valley	Lake Nimrod	confirmation
Arkansas River Valley	Blue Mountain Lake	confirmation
Gulf Coastal Plain	Felsenthal NWR	confirmation geographic distribution test other species mercury: fish length regression
Gulf Coastal Plain	Lake Columbia	confirmation test other species mercury: fish length regression
Gulf Coastal Plain	Cut-Off Creek	confirmation test other species
Gulf Coastal Plain	Cane Creek Lake	confirmation
Gulf Coastal Plain	Lake Millwood	confirmation
Gulf Coastal Plain	Ouachita River and oxbows	confirmation test other species
Gulf Coastal Plain	Saline River and oxbows	confirmation test other species

quality based ecoregions within Arkansas because of similar characteristics among lakes and streams in these ecoregions. There are six ecoregions in Arkansas (Figure 2.5).

The highest levels and most extensive distribution of mercury above 1.0 ppm is found in the Gulf Coastal Plain ecoregion, especially the lower Ouachita River in Felsenthal NWR. Predator fish (large mouth bass, spotted bass, flathead catfish) tissue with levels above 1.0 ppm were collected throughout the lower Ouachita River basin below Camden, Champagnolle Creek, Moro Creek, Saline River below Hwy 79, Dorcheat Bayou, and Lake Columbia (Figure 2.6). Nonpredator fish (bluegill, redear sunfish, drum, buffalo) also had tissue mercury concentrations exceeding 1.0 ppm in the lower Ouachita River and at one location in the Saline River (Figure 2.7). Levels above 0.70 ppm were found in the Saline River upstream into Grant County, the Sulphur River in Miller County, White Oak Lake, Smackover Creek, Tri-County Lake near Fordyce, and Calion Lake in Union County. Mercury concentrations 0.70 to 0.99 ppm in fish flesh were generally identified by agency personnel as needing further validation due to sample variance and natural variability of mercury in the fish population. Analyses are in progress to quantify sample and analytical variance.

Fish with mercury levels above 1.0 ppm were also detected within the Ouachita Mountain, Arkansas River Valley, and Boston Mountain ecoregions (Figure 2.6). Edible fillets from largemouth bass tested above 1.0 ppm in Lake Nimrod, and the Fourche La Fave River below Lake Nimrod (Figure 2.6). In the Boston Mountain Ecoregion, largemouth bass in the South Fork of the Little Red River above Greers Ferry Lake and Lake Shepherd Springs showed levels of mercury above 1.0 ppm. No samples from the Delta or Ozark Ecoregions tested above 1.0 ppm for mercury. However, mercury levels above 0.70 ppm were found in each of the ecoregions.

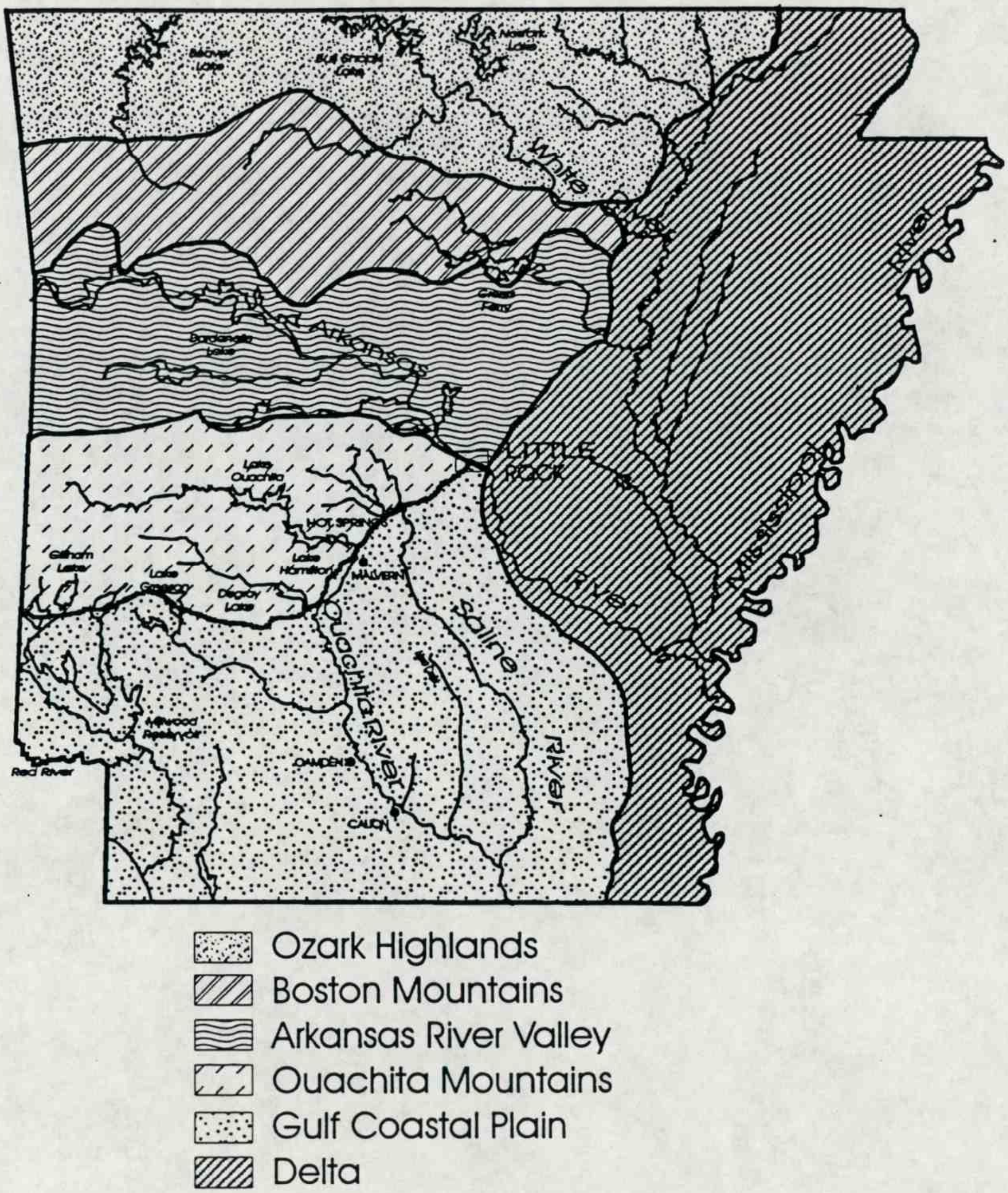
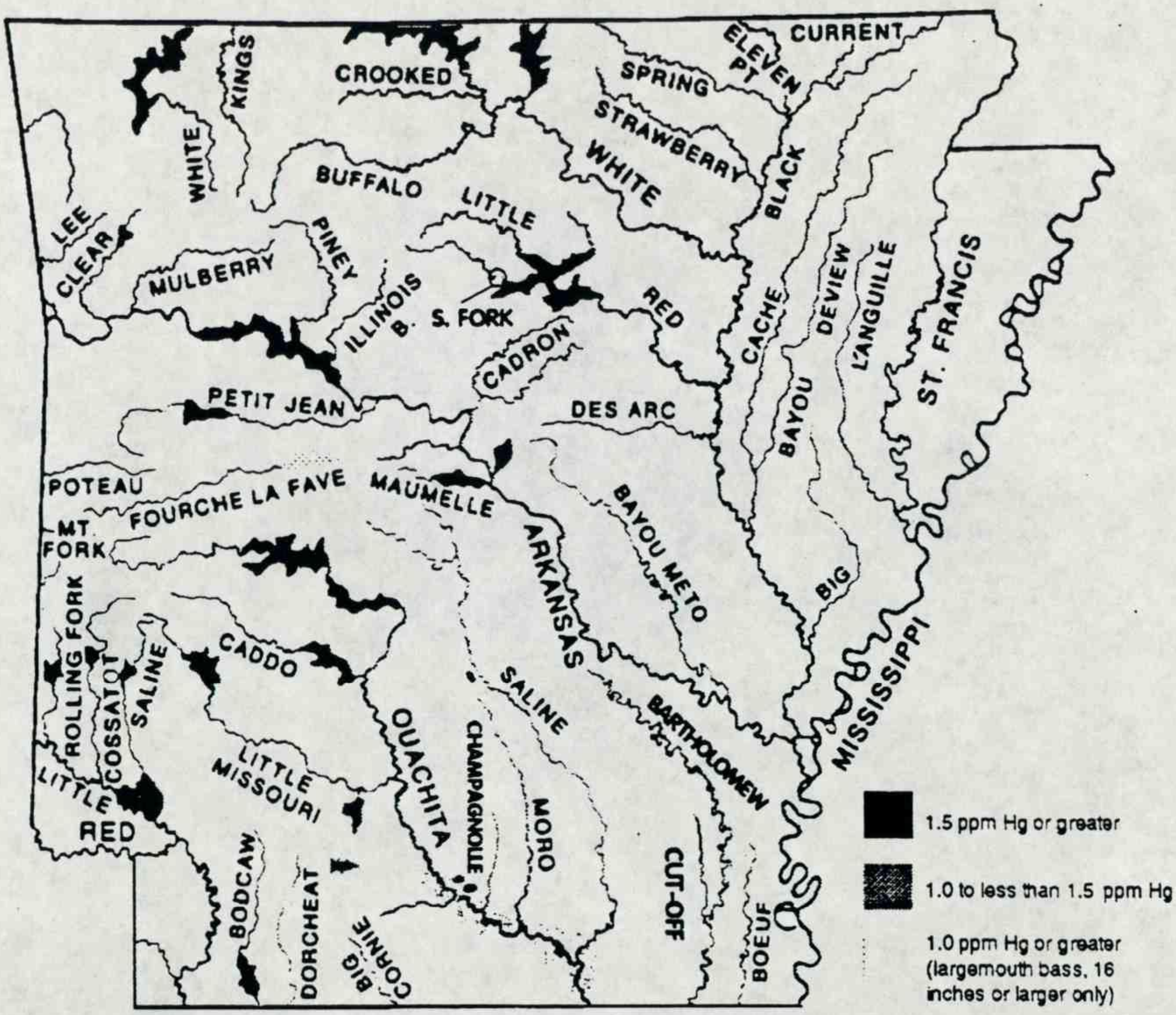


Figure 2.5. Ecoregions of Arkansas and selected lakes and streams in each ecoregion.



-Saline River from Hwy 79 (Cleveland Co.) to the Ouachita River (Bradley Co.)

-Lake Columbia (Columbia Co.)

-All ox-bow lakes, backwaters, overflow lakes, and borrow ditches formed by the Ouachita River below Camden including all waters in the Felsenthal National Wildlife Refuge* (Ouachita, Calhoun, Bradley, Ashley & Union cos.)

-Ouachita River from Smackover Creek to the Louisiana border (Ashley, Bradley, Calhoun & Union cos.)

-Champagnolle Creek to include Little Champagnolle from Hwy 4 to its confluence with the Ouachita River (Calhoun Co.)

-Moro Creek from Hwy 160 to its confluence with the Ouachita River(Bradley & Calhoun Co's.)

-Bayou Bartholomew from where it crosses Hwy 35 (Drew Co.) to its confluence with Little Bayou (Ashley Co.)

-Cut-off Creek from where it crosses Hwy 35 (Drew Co.) to its confluence with Bayou Bartholomew (Ashley Co.)

-Nimrod Lake (Yell & Perry cos.)

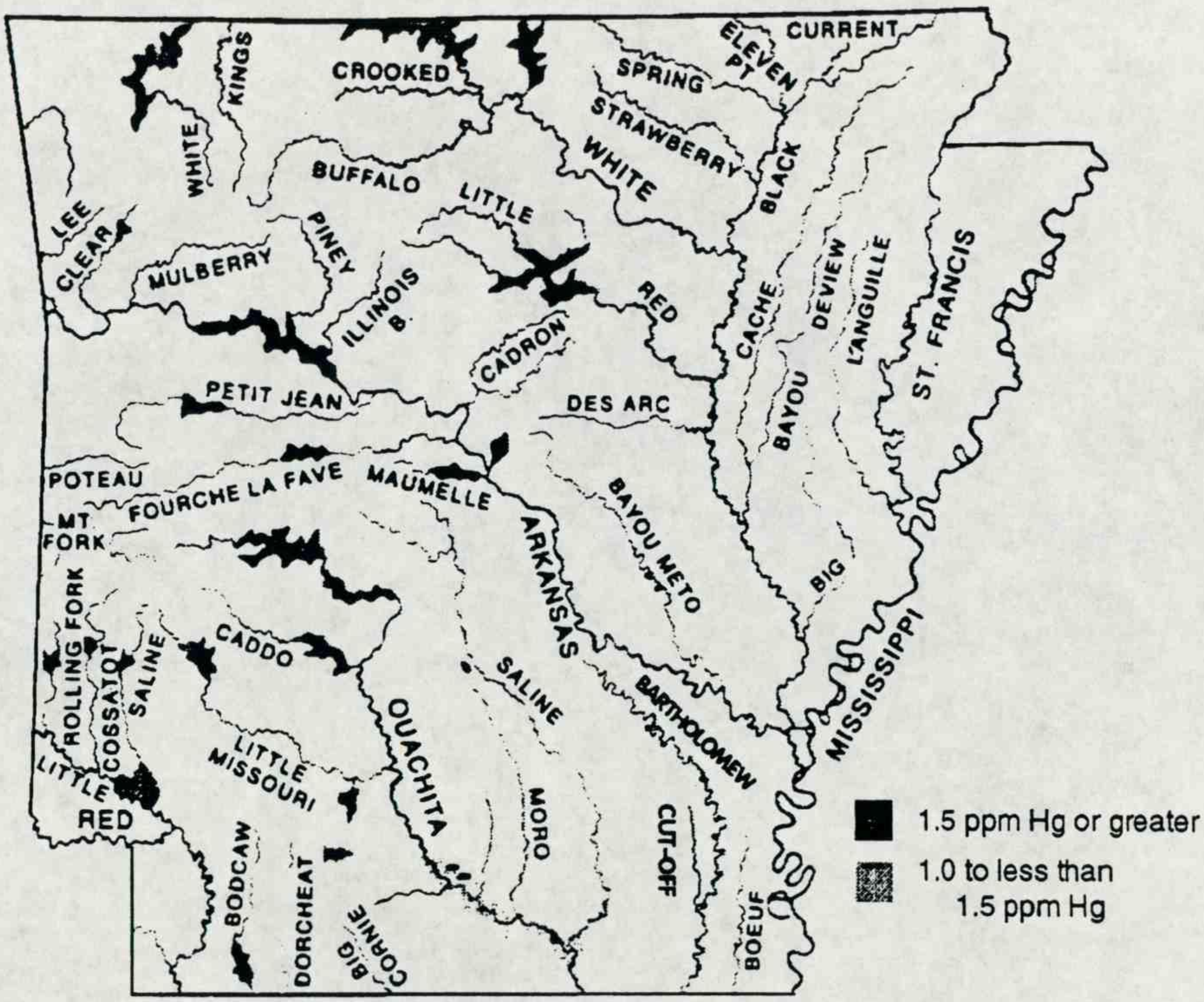
-Fourche La Fave River from Nimrod Dam to the confluence of the South Fourche (Perry Co.)

-South Fork of the Little Red River, Johnson Hole (Van Buren Co.)

-Dorcheat Bayou (Columbia Co.), largemouth bass only, 1.0 ppm Hg or greater

*No consumption limits on crappie and bluegill for the high risk groups or the general public on the Felsenthal National Wildlife Refuge.

Figure 2.6. Bodies of water currently under fish consumption advisories for mercury (Hg) in predator fish.



-Saline River from Hwy 79 (Cleveland Co.) to Hwy. 160 (Bradley Co.)

-Ouachita River from Smackover Creek to the Louisiana border (Ashley, Bradley, Calhoun & Union cos.)

-All ox-bow lakes, backwaters, overflow lakes, and borrow ditches formed by the Ouachita River below Camden to include all waters in the Felsenthal National Wildlife Refuge* (Ouachita, Calhoun, Bradley, Ashley & Union cos.)

-Cut-off Creek from where it crosses Hwy 35 (Drew Co.) to its confluence with Bayou Bartholomew (Ashley Co.)

-Dorcheat Bayou (Columbia Co.)

Figure 2.7. Bodies of water currently under fish consumption advisories for mercury (Hg) in non-predator fish.

Elevated levels of mercury in fish appear to be particularly associated with the Gulf Coastal Plain drainages and to a lesser extent with northern slopes of the Ouachita Mountain and southern drainages of the Boston Mountain ecoregions. Mercury levels in fish increase longitudinally in the Ouachita River downstream from the Camden/ Sparkman area to the Louisiana state line, while mercury levels in the sediment remained fairly uniform (Figure 2.8).

Anecdotal observations of the Ouachita River downstream from the Camden/Sparkman area indicated environmental conditions considered favorable for the methylation of mercury (i.e., anaerobic, high organic sediments, lower pH) also develop longitudinally downstream. Environmental conditions in Felsenthal National Wildlife Refuge (NWR) are conducive for mercury methylation. Felsenthal NWR is a relatively new impoundment created in 1985 by the construction of a river navigation lock and dam. The lock and dam system floods over 10,000 acres of lowlands that include channel scar and oxbow lakes formed by the river prior to development of the refuge. Some of the highest levels of mercury in fish were detected within refuge boundaries. New impoundments typically have elevated mercury concentrations in fish because environmental conditions created after flooding vegetation are conducive to mercury methylation (Abernathy and Cumbie 1977, Boday et al. 1984, Lodenius et al. 1983, Jackson 1988).

Phase II intensive sampling was conducted on thirteen different water bodies (Table 2.2). Phase II results are presented in Table 2.3 in Appendix E. The majority of Phase II sampling was conducted to confirm data generated from Phase I screening, notably in areas where screening results indicated mercury concentrations in excess of 1.0 ppm.

The geographical extent of elevated (above 1.0 ppm) mercury levels in sportfish was confirmed for the Ouachita River, Cut-Off Creek, and Fourche La Fave River. These data are presented in Table 2.3 and were used in establishing the fish consumption advisories for these waters. These data, combined with the geographical data generated through the Phase I screening, illustrate the site and ecoregion specificity of mercury levels, as discussed earlier in this section.

The magnitude of mercury contamination in other sportfish was conducted both at the screening phase and in Phase II sampling in a variety of waters throughout the state, but the greatest sampling effort was concentrated in the Ouachita River drainage of South Arkansas (Appendix E, Table 2.3). Substantial differences in mercury levels are evident among species occurring in the same body of water, with the differences attributable to degree of piscivory. For example, in the lower Ouachita River within the Felsenthal NWR, the highest levels of mercury are found among largemouth bass, flathead catfish, and blue catfish, followed in descending order in black crappie, white crappie, and bluegill. Largemouth bass, blue catfish, and flathead catfish are predators as adults and switch to piscivory at a very early age, well before the completion of their first year of life. Both black and white crappie are piscivorous as adults, but the switch to piscivory is delayed until well after their first year of life, generally when the fish reaches 5 to 6 in. in length. Bluegill feed predominantly on a variety of invertebrates throughout their life (Robison and Buchanan 1988).

Strong length:mercury concentration relationships exist for largemouth bass (L. Columbia, Felsenthal NWR, L. Winona, L. Shepherd Springs), (Figures 2.9 - 2.12, Appendix E) black and white crappie (Felsenthal NWR) (Figures 2.13 - 2.14, Appendix E), bluegill (Felsenthal NWR) (Figure 2.15, Appendix E), and channel, blue, and flathead catfish (Ouachita River) (Table 2.4, Appendix E) Considerable attention was given to the Felsenthal NWR due to the popularity of fishing in this area and fish with mercury concentrations exceeding FDA advisory levels. The refuge is within the area effected by the first consumption advisory. Early advisories covered all predator fish, defined as bass, crappie, catfish, and other native nongame species. The individual fillet analyses on largemouth bass, crappie, bluegill, channel catfish, blue catfish, and flathead catfish revealed strong relationships between fish length and mercury concentration. Statistical treatment of regression models for largemouth bass, both crappie species, and bluegill revealed all slopes were positive and significantly greater than zero ($p < 0.001$). Significant differences were detected between all y-intercepts ($p < 0.05$). Regression slopes were significantly different between largemouth bass and both species of crappie, bluegill and both species

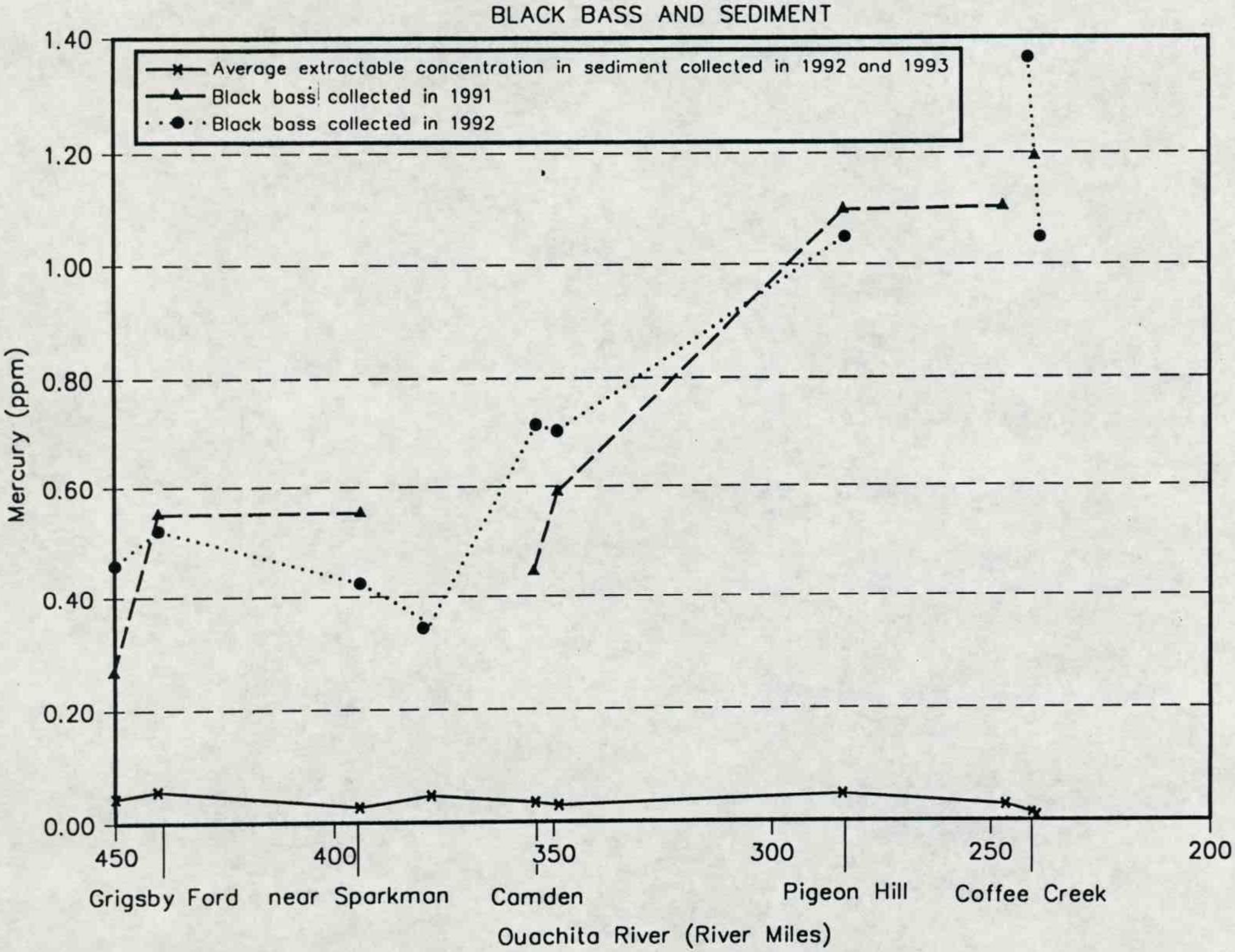


Figure 2.8. Longitudinal increase downstream in largemouth bass fish tissue mercury concentrations in the Ouachita River. Sediment total mercury concentrations, in contrast, are relatively constant throughout the lower Ouachita River.

of crappie, but not between black and white crappie or between largemouth bass and bluegill ($p < 0.05$). More precise relationships likely could be obtained by considering age versus mercury relationship in fish. However, fish length is the factor that will be used in fish consumption advisories.

Increasing mercury content with fish length and age has also been shown in walleye (*Stizostedion vitreum*), lake trout (*Salvelinus namaycush*), small mouth bass (*Micropterus dolomieu*), and northern pike (*Esox lucius*) (Lange et al. 1993). Fish size is a function of age. Increasing mercury content with size indicates mercury concentrations in Felsenthal NWR predator sportfish are strongly influenced by fish age.

The varying regression intercepts and slopes exhibited by largemouth bass, black and white crappie, and bluegill in Felsenthal NWR (Appendix E - Figures 2.9 to 2.15) suggests mercury bioaccumulation rates are species specific as well as site specific, even among predators. Differences in mercury content between black and white crappie of similar size may be the result of unequal growth rates and feeding habits. Black crappie grow slower than white crappie in Felsenthal NWR. The slower growth may result in black crappie being older than white crappie when they complete their shift to piscivory. This later shift could result in the black crappie being exposed to less mercury through its diet than the white crappie making an earlier predatory diet shift. Additional studies should be performed to improve our understanding of the biological availability and transport mechanism of mercury through aquatic community trophic levels. Understanding the transport of mercury through trophic levels may help resource managers develop management strategies to lessen the impact on the recreational fishery. The influence of fish age, diet, and local water quality and habitat characteristics on mercury content need to be examined.

2.2.5 Significance of Fish Sampling Results

Mercury in the aquatic environment is a problem of national scope. Currently 36 states have issued fish consumption advisories due to mercury. Sampling results presented in this report are indicative of the increasing attention mercury is receiving as an environmental contaminant.

The significance of our fish sampling results is best considered in light of two of the primary questions posed by the Mercury Task Force in its strategic plan (Arkansas Mercury Task Force 1993): (1) what is the magnitude and statewide distribution of mercury contamination in fish (and humans), and (2) what are the possible sources and factors contributing to mercury contamination.

Sampling results indicate that mercury in fish flesh was found throughout in Arkansas waters, occurring in all drainages sampled. However, significant patterns of association with fish species, size of fish, and ecoregion are evident. Predator species, particularly the largemouth bass and flathead catfish, tested higher than nonpredator species (bluegill, suckers, drum) when collected from the same water body in all instances except one (Cut-Off Creek). Significant and positive correlations of mercury levels with size of fish were found for each species where fish size:mercury content was specifically examined. The bioconcentration and bioaccumulation potential of mercury in wildlife has been examined and reported by other researchers (Eisler 1987) and was not unexpected in our sampling results. The nonuniformity of mercury levels in fish among ecoregions is strong evidence for the role that local watershed chemical and physical characteristics play in the bioavailability of mercury to the aquatic food chain. Effective management efforts for human consumers and resource management should focus efforts on those watersheds having characteristics suspected in facilitating methylmercury production.

The significance of the fish sampling results in answering the strategic question of sources, and contributing factors again emerge from the association between elevated mercury levels in certain predator fish species and their physiographic region. Numerous investigators have reported a link between mercury and certain water quality parameters, namely alkalinity (Lange et al. 1993), pH (Parkman 1993, Haines and Brumbaugh 1994), and total organic carbon (Field 1993). Arkansas' Gulf Coastal Plain, Ouachita Mountain, and Boston Mountain ecoregions each contain watersheds characterized by soft water with low buffering (alkalinity less than 15 mg/L), while the Ozark Highland and Delta physiographic ecoregions are more buffered with alkalinity typically exceeding 100 mg/L. While a rigorous examination of water quality and physical environmental variables with fish mercury levels is lacking for

Arkansas watersheds, the strong association of mercury levels with physiographic ecoregions and the variability of fish mercury results, even within an ecoregion suggests that mercury bioconcentration is largely determined by site-specific interrelated environmental characteristics. This relationship also may differ in relative importance from site to site (Rickman et al. 1988).

Our ability to predict where mercury bioaccumulation might or has occurred is low. Mercury levels in fish can increase progressively downstream, as in the Ouachita and Saline Rivers; be localized within specific segments of a stream, as in the Fourche La Fave River and the South Fork of the Little Red River; or differ significantly among lakes in the same geographical region as in Lake Columbia and Bois D'Arc Lake. Each of these situations indicates the strong influence of local geochemical and physical parameters on bioaccumulation rates and the need for (1) a more thorough screening in areas identified as having or potentially having mercury contamination; (2) a site specific collection of water quality and physical habitat data; (3) a rigorous analysis of data to identify those conditions necessary for methylation and bioaccumulation to occur; and (4) pathways through the food chain.

2.3 Sediment Sampling and Analysis

2.3.1 Sample Collection and Preservation

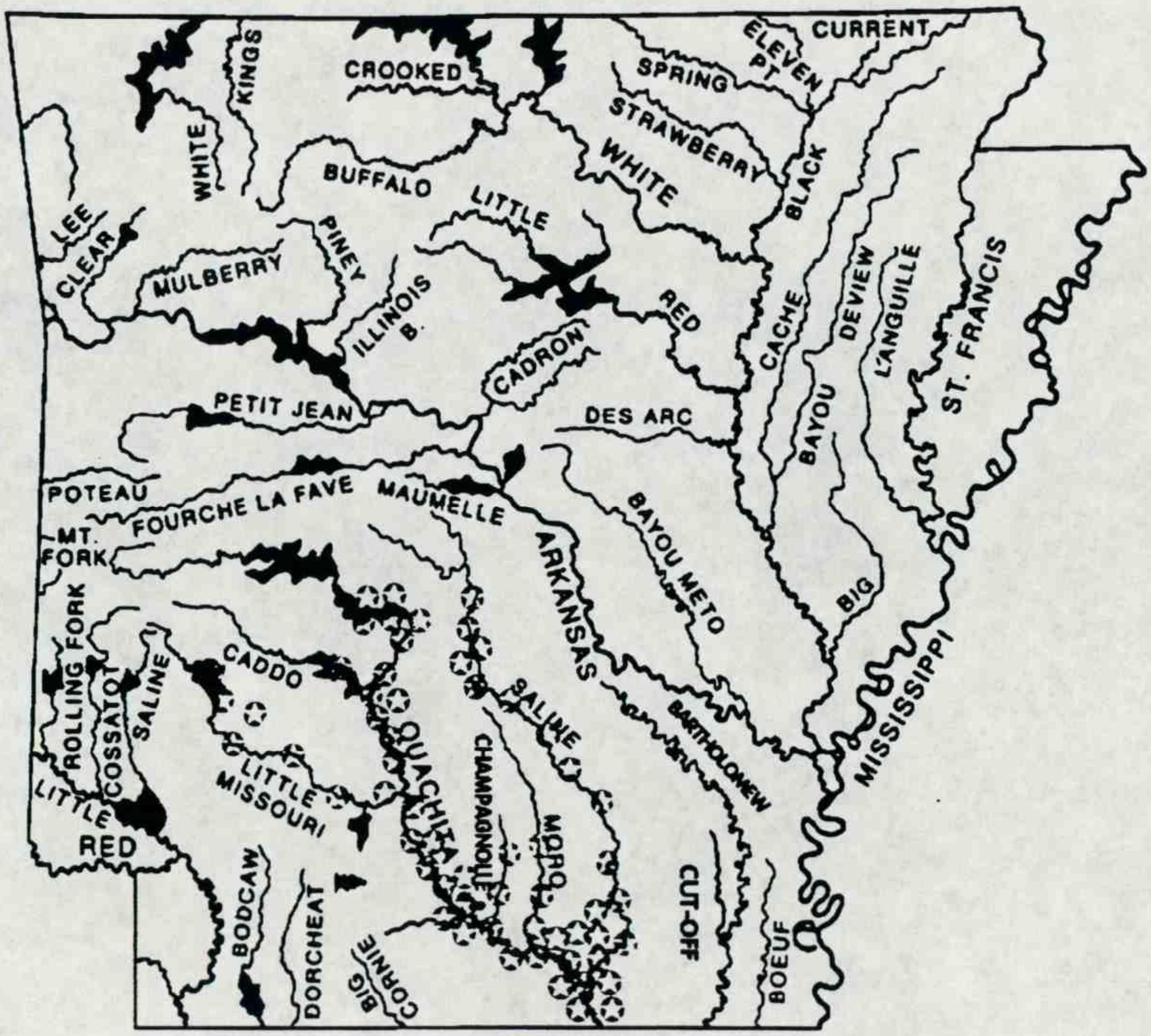
Sediment grab samples were obtained from stations throughout the lower Ouachita region, including major reservoirs, the Ouachita River, and its tributaries (see Figure 2.16). Samples were collected using a pipe dredge. A pipe dredge is a steel pipe that is closed on one end and flared on the other end. The dredge is connected to a sampling rope with a piece of heavy chain to keep the flared opening of the dredge on bottom. This dredge is then pulled (by hand) over a 5-meter to 10-meter section of bottom, and bottom material is scooped up into the sampler. Although the sampled sediment depth varied, it is reasonable to assume that it represented sediment from 1 to 5 cm in depth. In all cases, mercury analysis was done on the total sample. Gravel, etc. was not excluded from analyses. Care should be taken in comparing these data with other studies where sediment grain size partitioning occurred prior to analysis. The material recovered was assumed to be representative of the stream substrate at the location of the sample.

Samples were placed in sterile Whirl-Pak bags and placed on ice. Samples were refrigerated until time of analysis. The sampler was washed with river water, then deionized water after each sample was taken. Extreme care was taken to avoid contact of the sample with any surface other than the sampler and the container.

2.3.2 Analytical Methods

A subsample of approximately 1 g was placed in a tared aluminum dish and weighed to the nearest 0.001 g. The weighed sample was then placed in a drying oven at a temperature of 105°C for 24 hours. The sample was weighed again and the data used to calculate percent dry weight (g dry sample/g of wet sample x 100). Subsamples were not replicated because this was a screening study. The mercury concentration in the sediment was determined using the cold vapor atomic absorption method following an acid/oxidizing digestion as described in EPA Method 245.5 (EPA 1991). Prior to February 1993, a Perkin-Elmer Model 4000 Atomic Absorption Spectrometer was used for the cold vapor determination. Digestion (1 to 2 g of wet sample) was carried out in BOD bottles as described in Method 245.5. A 10 cm path length cell was placed in the beam of the spectrometer to detect the vapor generated following the addition of hydroxylamine sulfate and stannous chloride.

After 1 February 1993, an LDC automated mercury analysis system was employed. The LDC mercury analysis system is a dedicated sample processing and atomic absorption unit that automatically performs the cold vapor method on preserved water samples or digested sediment or tissue samples. Detection limits for water samples (three standard deviations of a set of blanks) is 0.02 ppb for water and 0.01 ppm for sediment and tissue. All samples (water, sediment, and tissue) were duplicated in the laboratory. No field duplicates were taken. Since the sensitivity of this system was much greater than that of the manual method, it was possible to reduce sample size to 0.25 g with a concomitant reduction in acid and permanganate. This automated system adds hydroxyl amine sulfate and stannous chloride, then degasses into a dedicated atomic absorption mercury detection unit.



✪ Sampling Sites

Figure 2.16. Sediment and water sampling locations in the Ouachita River basin.

Quality assurance consisted of (1) the use of a certified mercury standard to prepare appropriate standards for each set of samples; (2) the inclusion of at least four reagent blanks with each set of samples (24 samples); (3) the inclusion of at least two spiked samples with each set; (4) the inclusion of several standards interspersed throughout each run; (5) the replication of essentially all samples, including standards and spikes; and (6) the participation in the U.S. Geological Survey's Analytical Evaluation program (two times per year). Data from standards and replications were used to prepare appropriate control charts for accuracy and precision (EPA 1979). Data were rejected when percent recovery was not between 80% and 120%.

Detection limit (three times standard deviation for a series of blanks) was 0.05 ppm (μg/g) using the manual method and 0.01 ppm (μg/g) using the automated method.

2.3.3 Summary of results of sediment analysis

Sediment from a variety of sources in the lower Ouachita system were analyzed for mercury from September 1992 through September 1993. Table 2.5 lists the range of concentrations for some of the groups of samples.

A small number of farm ponds were sampled during early 1993 in an effort to determine if mercury was present in systems not associated with the Ouachita River or its tributaries. For this sampling effort, we also considered potential airborne mercury emissions originating in the El Dorado area. A hypothetical amount of mercury was modeled as being dispersed through a stack of an El Dorado industry. The fallout pattern predicted by the model was projected on a 1:100,000 topographic quadrangle map and 16 individual farm ponds were selected for sampling. Results of water, sediment, and fish analyses may be seen in Table 2.6. Only three of the 16 ponds were sampled for fish. In general, there was no relationship between the fallout pattern and sediment or fish mercury concentrations, both within and outside this pattern.

Sediment mercury concentrations were relatively uniform throughout the Ouachita River system, from Remmel Dam to the Louisiana Border (Figure 2.8). The mean mercury concentration for all sediment samples taken from the main channel of the Ouachita River between September 1992 and September 1993 was 0.11 ppm with 90% of the samples having a concentration under 0.05 ppm. In almost all cases, the mercury concentration of the two bank samples (i.e., quarter samples) was from two to five times greater than the sample from the center of the stream. The aluminum concentration of these samples showed a similar pattern suggesting that more clay particles were present near banks than were obtained from the center of the river. This is consistent with generally slower water velocities near the banks as opposed to the center of the stream. This distribution is being studied further.

Table 2.5. Summary of sediment analyses from South Arkansas lakes and streams.

Location	Concentration Range (μg/g; ppm)
Lower Ouachita River	0.01 to 0.12
Tributaries of Lower Ouachita River	0.01 to 0.26
Lake Greeson (near cinnabar mines)	0.16 to 0.79
Little Missouri River (below Lake Greeson)	0.01 to 0.06
Lake DeGray (upstream section)	0.10 to 0.14
Bauxite Mining area (Saline County)	0.02 to 0.31
Saline River	0.02 to 0.12
Felsenthal Pool	0.01 to 0.12
Lake Catherine	0.04 to 0.72
Oxbow Lakes (lower Ouachita system)	0.05 to 0.19
Selected ponds in lower Ouachita (outside floodplain)	0.04 to 0.52

Table 2.6. Analytical results from El Dorado area farm ponds.

Pond Number	Water				Sediment	Largemouth bass
	Temperature (°C)	Dissolved O_2 (ppm)	pH	Conductivity (μS)	Mercury (ppm)	
1	9.7	6.9	6.7	44	0.16	<0.10 - 0.41
2	8.6	8.8	6.7	253	0.44	
3	10.4	8.7	6.5	90	0.08	
4	9.2	8.4	6.7	33	0.2	
5	9.7	6.4	7	75	0.44	
6	9.4	10.4	6.8	333	–	
7	10.3	11	7.1	40	0.28	
8	10.7	11.2	7.1	38	0.52	0.68 - 1.32
9	10.4	7.4	6.7	197	0.08	
10	10.3	10.4	7	50	0.28	0.82 - 1.47
11	10.3	9.7	7	143	0.04	
12	10.1	11.4	7.1	23	0.08	
13	8.8	10.5	7.5	22	0.12	
14	16.6	8.6	7	505	0.04	
15	8	8.9	4.6	516	–	
16	11.2	7.8	6.6	59	0.2	

Total mercury concentrations in farm pond sediments averaged 0.21 ppm compared to 0.11 ppm in the main channel of the Ouachita River. In two of the three ponds sampled in the El Dorado area, largemouth bass sampled exceeded the 1.0 ppm mercury criteria in edible flesh. Additionally, black bass were sampled from other ponds outside the El Dorado area. Fish from these ponds outside the El Dorado area also exceeded the 1.0 ppm mercury level.

While this is only a cursory look at farm ponds within South Arkansas, the ponds which contained largemouth black bass exceeding the 1.0 ppm mercury level were totally separated from the river systems where mercury had previously been found. This information implies that sediment mercury does not necessarily depend on a river system for a transport mechanism and can be derived in place from rocks and soils or from other sources such as atmospheric transport.

2.3.4 Significance of Sediment Analysis

The sediment mercury concentrations found in South Arkansas are similar to those found in other lake and river systems. The concentration of mercury in sediment from southern Florida, for example, has been reported in the range of 0.03 to 0.40 ppm (Delfino et al. 1993). Gilmour and Henry (1991) summarized the mercury concentration from a variety of marine and freshwater systems with a range of 0.01 to 3.95 ppm. However, sediment mercury concentrations greater than 1.0 ppm usually indicate point source contributions. Gilmour et al. (1992) reported mercury concentrations in sediment from a variety of sites in Quabbin Reservoir, MA, ranged from 0.01 to 0.05 ppm. Harrison and Klaverkamp (1990) reported that the mean mercury concentration in the top 2 cm of sediment cores from four Saskatchewan lakes ranged from 0.03 to 0.14 ppm.

This same study also reported that the mean mercury concentration in the muscle of Northern Pike from the same four lakes was 0.46 ppm, indicating that bioaccumulation of mercury was occurring within this system. Better correlations, however, have been observed between mercury loading rates to sediments and fish tissue mercury concentrations, rather than sediment mercury concentrations (Hakanson et al. 1988, Johnson 1987).

Although some variations were observed, the range of concentration of mercury in Ouachita River sediments was not very large varying between 0.01 and 0.12 ppm. This suggests that mercury has a relatively uniform distribution throughout the river system (Figure 2.8).

When the conditions necessary for the generation of methylmercury are present, a total sediment mercury concentration in the range of 0.03 to 0.10 ppm could result in significant bioaccumulation in predator fish (Harrison and Klaverkamp 1990). If this is true, there could be an adequate source of mercury in sediment material to produce significant bioaccumulation through the food chain of a piscivorous predator at almost all of the sites sampled along the lower Ouachita River.

2.4 Geologic Sampling and Analysis

Mercury is found in small to trace quantities in most rocks. Turekian et al. (1971) and Martin and Meybeck (1979) tabulated typical concentrations of selected elements in rocks and found average mercury concentrations ranged from 0.01 ppm in basalt to 0.4 ppm in shale. Pierce, Botbol, and Learned (1970) computed statistics on selected rocks from Missouri and Kentucky and found mercury concentrations ranged from about 0.01 to 1.5 ppm. Connor and Shacklette (1975) investigated the literature for mercury concentrations in sedimentary rocks in mid-South states (Arkansas, Missouri, Kansas, Oklahoma, and Kentucky) and found concentrations ranged from <0.01 to 1.5 ppm.

The Ouachita Mountains are a mildly to severely sheared mountain range composed of Paleozoic age sedimentary rocks (Stone et al. 1995). The rock types, in decreasing order of abundance, are shale, sandstone, siltstone, chert/novaculite, limestone, conglomerate and tuff (Stone et al. 1995). Rock samples were collected from throughout the Ouachita Mountains to determine if geological erosion and weathering might represent a significant natural source of mercury to lakes and streams receiving drainage from this region.

2.4.1 Sampling and Analysis

Arkansas Geological Survey personnel collected 724 rock samples from throughout the Ouachita Mountain region (Figure 2.17). An attempt was made to sample major members of each formation. Each outcrop was first cleaned by chipping away the surface rock. Samples were collected from the exposed, fresh rock, and placed in cotton or plastic bags and labeled. Sample locations were noted on USGS 7.5' topographic maps with a brief description of the location, stratigraphic interval and lithology (Stone et al. 1995).

A subsample of about 50 g was pulverized and ground in an iron mortar. Extreme caution was used to prevent sample contamination. The ground subsample was sieved (40 mesh) and a 0.25 g aliquot taken for analysis using EPA Method 245.5 (EPA 1991). This is the same method that was used for the sediment analyses.

The QA/QC program consisted of periodic replication and spiking of samples. At least three reagent blanks and three sets of standards were processed with each set of samples.

EPA Method 245.5 was designed to evaluate mercury in sediment that is potentially available to the aquatic environment. Although it is likely that the acid leaching step of the procedure leaches most of the mercury from the ground rock, the silicate phase is not dissolved. The results, therefore, should be interpreted as a lower limit for mercury concentrations in the rock samples.

2.4.2 Rock Mercury Concentrations

The sample mercury concentrations showed a log-normal type distribution (Figure 2.18a). The geometric mean mercury concentration (and standard deviation) for these rock samples was 0.088 ppm ($\pm$2.8 ppm) (Stone et al. 1995) The mercury concentrations ranged from 0.003 ppm from a sandstone sample to 6.1 ppm from a black chert sample (Stone et al. 1995). Different principle lithologies had different average mercury concentrations with chert having the highest average concentration (0.19 ppm) and sandstone having the lowest concentration (0.05 ppm) (Table 2.7). Mercury concentrations also were higher in samples in which organic matter was indicated. Samples with a black color, or that clearly contained carbon, lignite, asphaltite or fossils had a geometric mean of 0.29 ppm ($\pm$3.8) mercury. While there were no significant differences among lithologies or among samples with and without carbon because of the large sample variances these

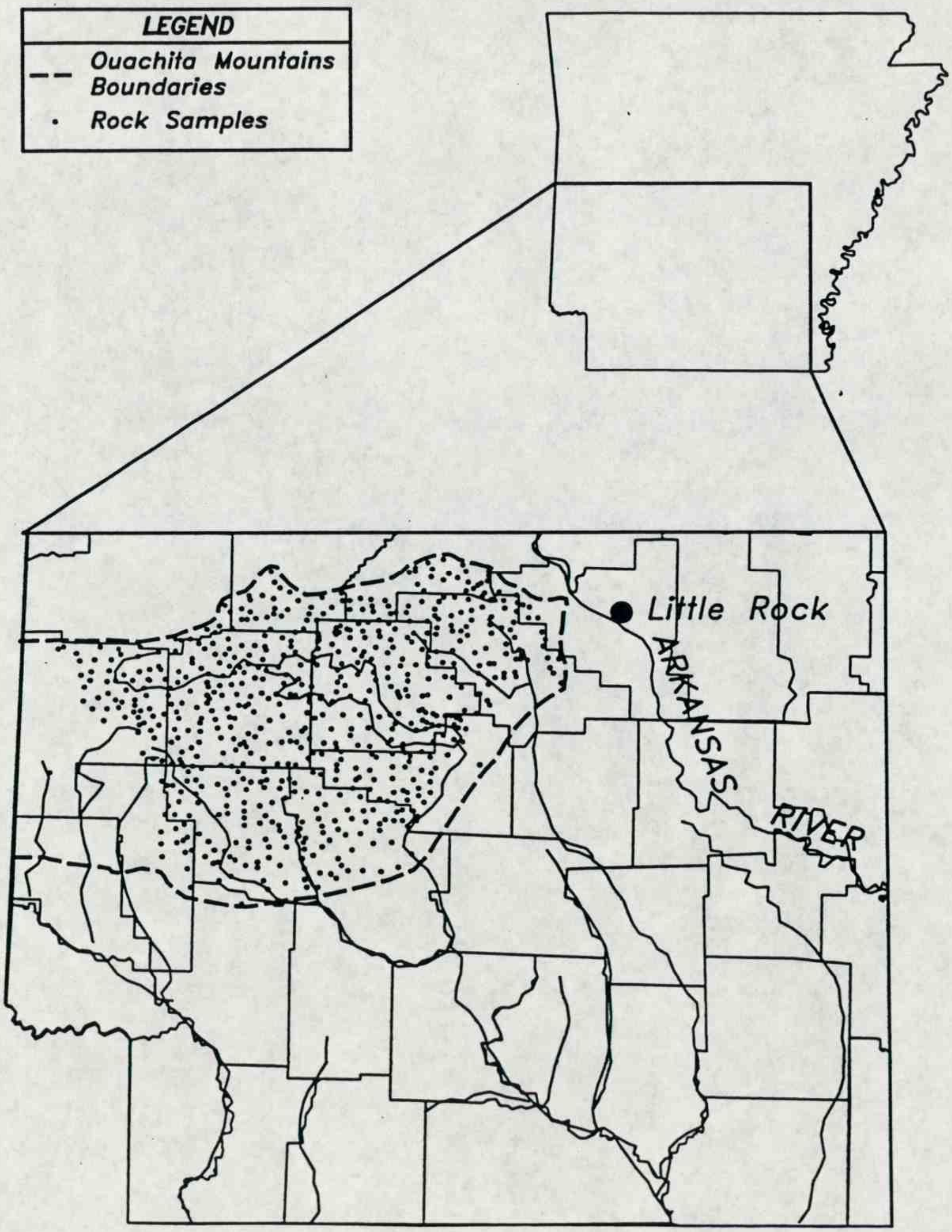


Figure 2.17. Arkansas Geological Survey rock sampling sites throughout the Ouachita Mountain region.

Mercury Distribution Ouachita Mountains

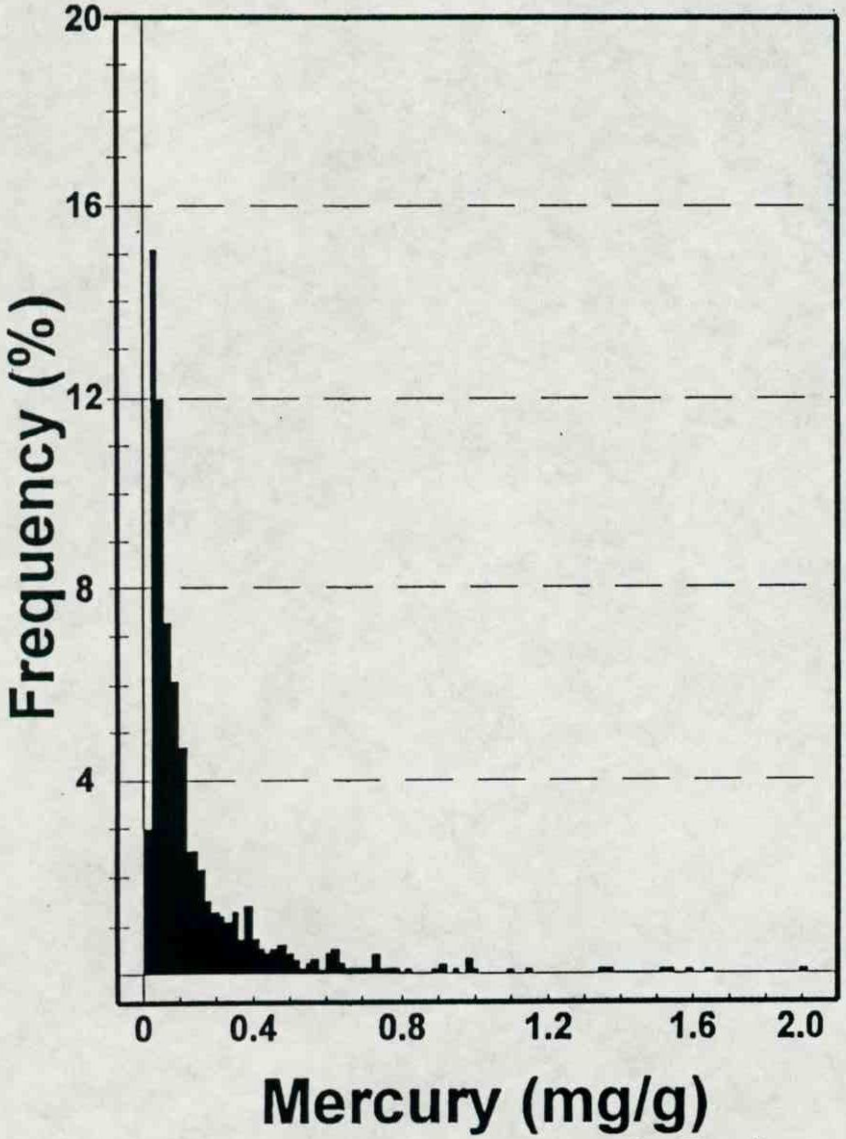


Figure 2.18a. Mercury in Rock

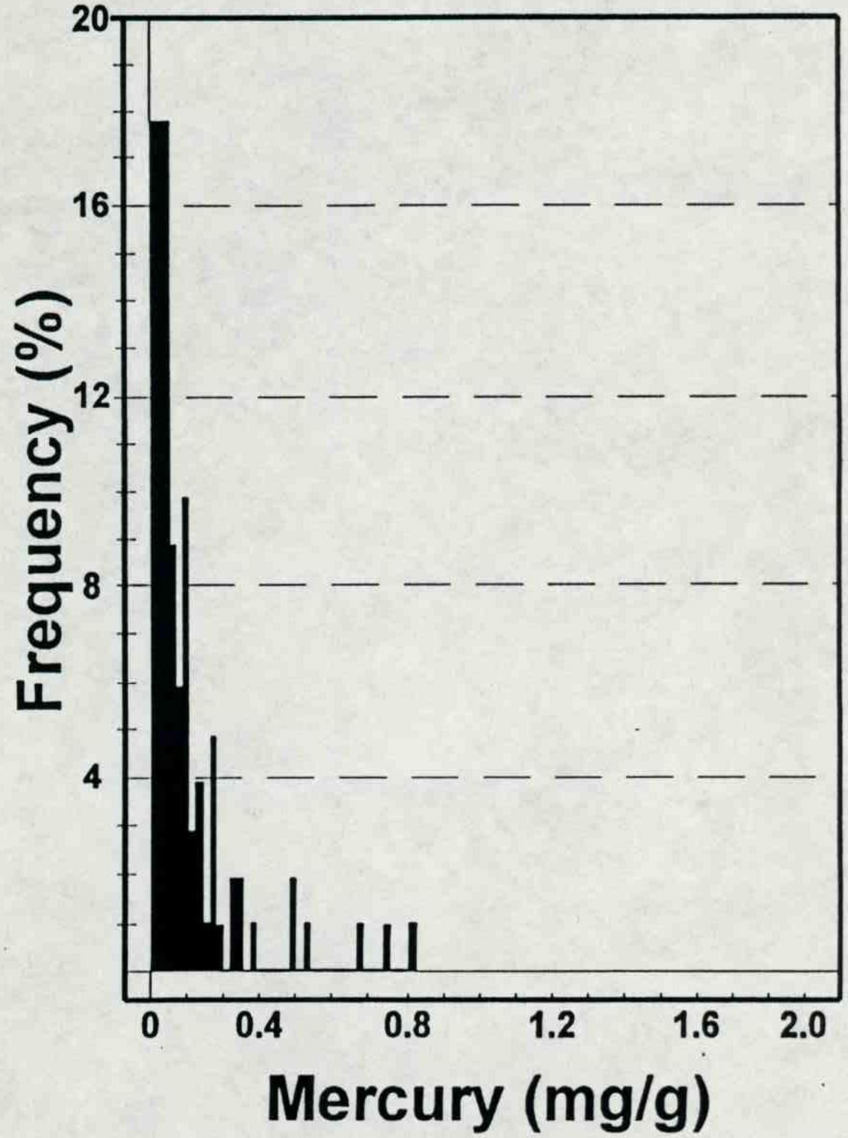


Figure 2.18b. Mercury in Sediment

Table 2.7. Average mercury concentrations in various rock types (lithology) in the Ouachita Mountains.

Principle Lithology	N	Geometric Mean (ppm)	Geometric Std. Dev. (ppm)
Chert	66	0.19	2.72
Limestone	24	0.11	3.16
Siltstone	17	0.11	2.7
Shale	514	0.09	2.7
Igneous	21	0.06	3.01
Sandstone	37	0.05	2.66

qualitative differences do provide insight on geologic attributes that might contribute to mercury concentrations observed in southern Arkansas.

2.4.3 Significance of Geologic Analyses

Contributions of mercury to remote aquatic systems have been assumed by some researchers to be contributed from atmospheric deposition of natural and anthropogenic mercury sources (Fitzgerald 1993, Jensen and Jensen 1991, Lindqvist et al. 1991, Swain et al. 1992). Dating sedimentation rates in sediment cores has been used to partition natural from anthropogenic contributions. Because mercury is such a volatile element, however, distinguishing atmospheric from geologic contributions to aquatic systems will be exceedingly difficult. While there is recognition that mercury from air provides, in most cases, the main source of mercury to water bodies and fish (EPA 1994), there are some indications that geologic sources might be important natural contributors of mercury to both the atmosphere and to aquatic systems (Rasmussen 1994). For example, there is high degree of similarity ($p < 0.05$) between the distribution of mercury in Ouachita region sediments versus mercury in Ouachita region rocks (Figure 2.18b). While this does not confirm geologic origin as the source of the mercury, it does indicate there might be other mercury sources besides anthropogenically-derived atmospheric deposition.

2.5 Round Robin Fish Tissue Analysis

During Summer 1994, fish were collected from Lake Winona, analyzed by the ADPCE laboratory, and the larger largemouth bass were found to have mercury concentrations exceeding the FDA Action Level of 1 ppm. A fish consumption advisory was issued for Lake Winona. Subsequently, additional fish were collected by another agency during Fall 1994, prepared and forwarded to a commercial laboratory for analysis. The results of these analyses indicated fish concentrations were lower than previously reported and below the FDA Action Level. Additional fish were collected by ADPCE,and ADPCE and the commercial laboratories repeated their analyses, again with significantly different results. To resolve these different analytical results, six laboratories were solicited to participate in a round-robin study to analyze fish tissue mercury concentration during December 1994.

The purpose of this round-robin study was to determine if there was potential bias (i.e., consistently higher mercury concentrations than actually occur) in the fish tissue mercury analyses used for issuing fish consumption advisories. Round-robin analyses are a standard approach used to evaluate and assess potential laboratory bias. The study was conducted specifically to identify areas for improving analytical procedures, not to castigate any particular laboratory. Confimation of results is a normal and critical part of any scientific study.

ADPCE personnel collected samples of three different sized largemouth bass from Arkansas lakes previously found to have fish with tissue mercury concentrations covering a range from less than 0.5 ppm to more than 2 ppm. Three sets of fish composite samples were prepared: low fish tissue comcentrations (Sample 1), moderate fish tissue concentrations (Sample 2), and high fish tissue concentrations (Sample 3). Aliquots from each of these homogenized samples were frozen and forwarded to the following laboratories for analysis:

States with Mercury Fish Consumption Advisories

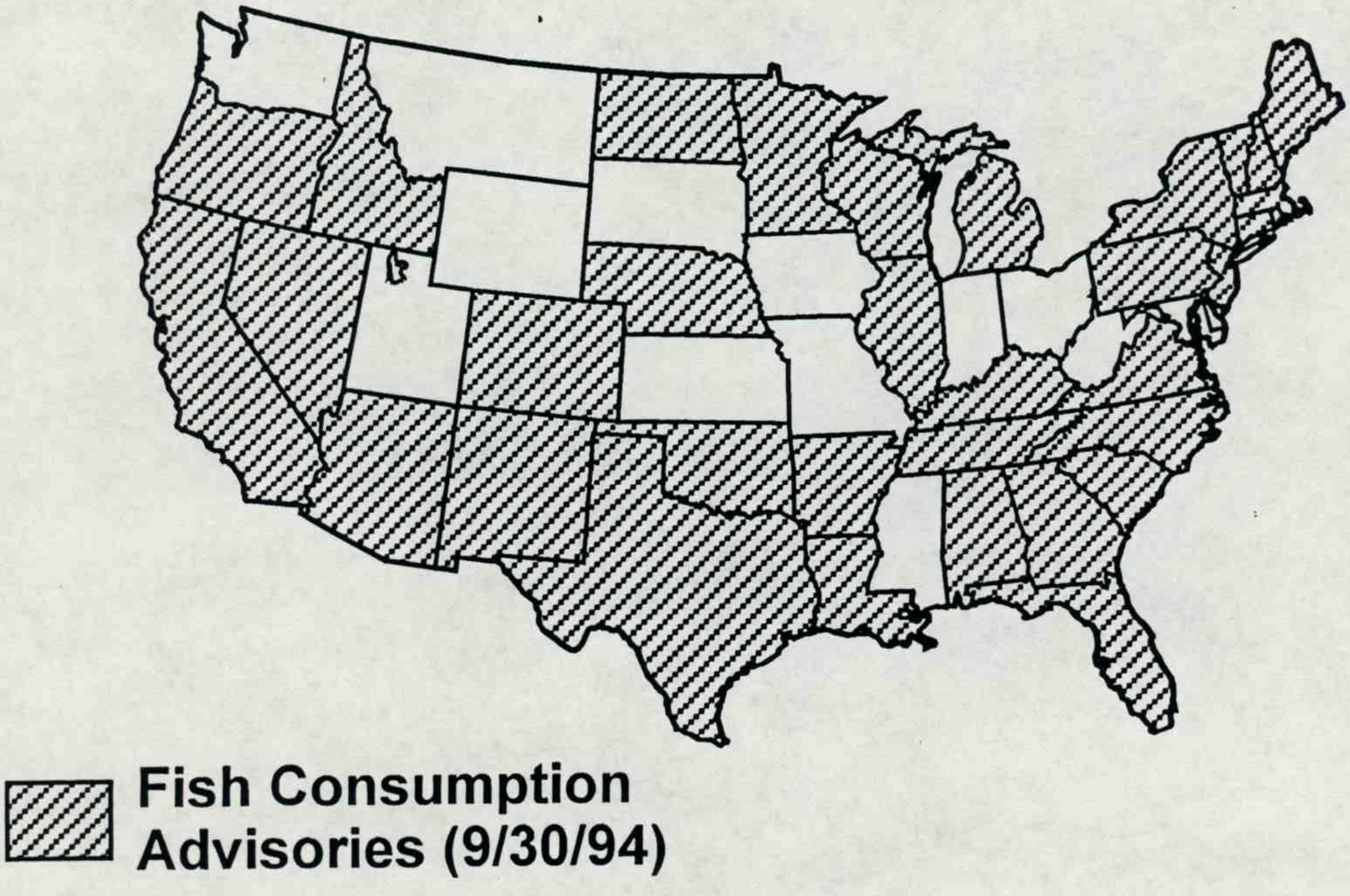


Figure 3.1. States (dark hatching) that currently have mercury advisories for fish consumption.

Chapter 4: What are possible sources, relative contributions, and factors contributing to mercury contamination?

Three factors must exist for mercury concentrations in fish tissue to exceed FDA Action levels: (1) there must be a source; (2) the right combination of environmental conditions must exist for methylation; and (3) the food chain must have top predator or piscivorous fish. This chapter will discuss each of these factors in Arkansas.

4.1 Possible Sources

Mercury is a natural element that can be found in trace amounts in many geologic formations, fossil fuels, raw industrial materials, and industrial products. There are three generic source categories for mercury based on their emission properties: natural, area, and point sources (EPA 1994). Natural sources are defined as nonanthropogenic sources unrelated to human activities. Area sources of mercury emissions are anthropogenic sources that are typically small but numerous and that usually cannot be readily located geographically (EPA 1994). Point sources are those anthropogenic sources associated with a fixed geographic location (EPA 1994). There are multiple possible sources of mercury emissions to the atmosphere in each of these generic source categories (Table 4.1) as well as watershed point and nonpoint source loadings to aquatic systems.

4.1.1 Natural Sources

Global Atmospheric Sources

The principal natural sources of atmospheric emissions include, in descending order of probable importance, volatilization from marine and aquatic environments; volatilization from vegetation; degassing of geologic materials; particulate matter and vapor emissions during volcanic and geothermal activity; wind-blown dust and particulate matter; and vapor emissions during forest and brush fires, or agricultural burning (EPA 1994). The magnitude of emissions from natural sources is unknown but probably significant. Air-water exchanges of mer-cury in aquatic systems and biologically-mediated volatilization of mercury are both important processes influencing mercury emissions (Nriagu 1989). These two processes result in a relatively constant flux of mercury emissions to the atmosphere and might compose 30% to 50% of total natural mercury emissions (Nriagu 1989). Published estimates of total global mercury emissions from 100 to 30,000 Mg/yr (110 to 33,000 tons/yr) (EPA 1994). An expert panel on mercury atmospheric processes, indicated natural sources could range from 25% to 50% of the total annual global input (EPRI 1994). However, recent estimates cluster in the 2,000 to 3,000 Mg/yr (2,200 to 3,300 tons/yr) range or about 40% of total global emissions from all sources (EPA 1994, Lindqvist et al. 1991, Nriagu 1989, Rasmussen 1994).

These natural emission estimates also consider re-emission of deposited mercury from other s-ources. Current levels of mercury emission appear to be elevated relative to preindustrial levels by a factor from 2 to 5 (Benoit et al. 1994, EPRI 1994, Norton et al. 1990, Swain et al. 1992). More than ⅔ of world mercury production has occurred since 1900, and mercury emissions have been widely dispersed and recycled. Present day natural emission estimates, therefore, incorporate historical or previously deposited anthropogenic emissions. Natural emission estimates are unknown for Arkansas, but may be assumed to be at least equal to global estimates of about 40% of the total mercury emissions from all sources.

Table 4.1. Sources of mercury emissions (after EPA 1993c).

Natural	Anthropogenic			
	Area	Point		
		Combustion	Manufacturing	Miscellaneous
Oceans[a]	Electric lamp breakage	Utility boilers	Chlor-alkali production	Oil shale retorting[a]
Aquatic Systems[a]	Paints use[a]	Commercial/industrial boilers	Lime manufacturing	Mercury catalysts[a]
Rocks[a]	Laboratory use	Residential boilers	Primary mercury production[a]	Pigment production[a]
Soils[a,b]	Dental preparations	Municipal waste combustion	Mercury compounds production[a]	Explosives manufacturing[a]
Volcanoes[a]	Crematories	Medical waste incinerators	Battery production	Geothermal power plants
Dust[a]	Mobile sources[a]	Sewage sludge incinerators	Electrical apparatus manufacturing	Turf products[a]
Wildfires[a]	Agricultural burning[a]	Hazardous waste incinerators[a] Wood combustion[a]	Carbon black production	
Vegetation[a]	Landfills[a]		Byproduct coke production[a]	
	Sludge application[a]		Primary copper smelting	
			Cement manufacturing	
			Primary lead smelting	
			Petroleum refining	
			Instrument manufacture	
			Zinc mining	

[a] Mercury sources for which there is insufficient information to estimate emissions.

[b] Emissions from soils might include the re-emission of previously deposited anthropogenic emissions as well as naturally occurring mercury compounds.

Arkansas Natural Watershed Sources

Arkansas has naturally occurring deposits of cinnabar (HgS or mercury sulfide) that were commercially mined in Howard, Pike, and Clark counties in Southwest Arkansas (Figure 4.1; Clardy and Bush 1976). This mercury district lies in a belt about 10 km (6 mi) wide and about 50 km (30 mi) long, extending from eastern Howard County through Pike County and into western Clark County. Many of the shales found throughout the Ouachita Mountain Ecoregion and other areas of Arkansas contain trace or greater amounts of mercury, but not in economical quantities. Cinnabar mining in the mercury district occurred for about 15 years and reached its peak during World War II. No mines are currently active. Mercury complexes occurring as sulfides in distilled water have low solubilities, but low levels of sulfides, polysulfides, or organic sulfur compounds can greatly enhance its solubility (Gilmour personal communication). Under the right conditions, this mercury can be dissociated and volatilized or methylated.

Arkansas also has black shales that contain trace amounts of mercury (Figure 4.1). Rock samples are usually low in mercury, averaging between 0.001 and 0.01 ppm for various types of igneous and sedimentary rocks (Drever 1982, Hem 1979). Rocks from the Ouachita Mountains typically had higher geometric average mercury concentrations, ranging from 0.05 to 0.19 ppm (Table 2.7). Bituminous or black shales, however, can have higher concentrations, varying between 0.03 and 0.35 ppm (Henriques 1972, Ferm and Larsson 1973). Lithologies with black color or carbon in the Ouachita Mountains averaged 0.29 ppm, with black shales averaging 0.98 ppm ($n=40$). Sandstone samples from this same region have an order of magnitude lower mercury concentrations (Nix, unpublished data). The erosion rates, from highest to lowest order by lithology, are likely to be shale > siltstone > limestone + sandstone > igneous + chert. Therefore, the black shales, containing higher mercury concentrations, might be expected to contribute a relatively greater proportion of these erosion products. These contributions might help explain the similarity in distributions between mercury concentrations found in the Ouachita River sediments and rock samples (Figure 2.15).

Although these data suggest that sediment originating from these rocks have sufficient mercury to provide a source for possible mercury methylation, there is a question as to the biochemical reactivity, and bioavailability, of mercury contained in these rocks. If the mercury is present as the sulfide (cinnabar), it might not be biologically available for methylation. Mercury derived from atmospheric deposition may be much easier to methylate than that eroded as sulfides or incorporated in a silicate matrix (Mason et al. 1993, Zillioux et al. 1993). Recent studies, however, indicate that mercury polysulfides might be more soluble and susceptible to methylation than previously thought (Paquette and Helz 1994, Zemach et al. 1994). Until this matter is resolved, it will be difficult to identify the source of mercury which ultimately accumulates in predator fish.

Bioavailable Mercury

The Mercury Task Force, therefore, issued a request for proposal to determine the biological availability of mercury-sulfur complexes for microbial methylation. After peer-review, a contract was issued with Dr. Cynthia Gilmour, Academy of Natural Sciences (Academy), to (1) begin to examine the dissolved mercury species that are available to microorganisms for methylation; (2) examine the control of mercury solubility and speciation in sediments, in general, using existing data and mathematical approaches; and (3) apply this to aquatic sediments in Arkansas, measuring the bulk and dissolved concentration of mercury in sediments and calculating its availability for methylation.

To examine the control of mercury solubility in sediments, an existing mathematical model of mercury speciation, including newly measured complex ation coefficients for a mercury-polysulfide, will be applied to the Academy's existing database of total and dissolved mercury concentrations and pore water chemistry for a variety of sediments. Comparing calculated concentrations of dissolved mercury to measured concentrations will help determine what form(s) of mercury control its solubility. Of particular interest are two forms of mercury sulfide (cinnabar and metacinnabar) and mercury bound to complex organics.

movement of mercury through the food chain in these areas.

The Gulf Coastal Plain ecoregion streams typically change from relatively steep gradients with bedrock and gravel substrates in the upper part of the basin to low gradient streams with mud and silt substrates near the Louisiana border. Forested watersheds are common throughout the Gulf Coastal Plain. Least disturbed streams in this ecoregion typically have low dissolved oxygen (DO) during the summer period, with some least disturbed streams having DO concentrations less than 2 mg/L. These streams also have slightly acidic pH values and low alkalinities (e.g., 20 mg/L) (Figure 2.5).

The Delta streams have very low gradients, typically with mud and silt substrates, and are associated with agricultural watersheds. They have relatively high BOD values during the summer, with relatively high sulfate values but also relatively high alkalinity values. Their pH values are circumneutral. There are lakes in the Delta, however, that have low DO, low pH and low alkalinity (Figure 2.5). DO concentrations in least disturbed streams in the Delta also are low.

The Arkansas River Valley streams have mixed forest and agricultural watersheds. The streams range from relatively high gradient in their headwaters to floodplain conditions near their confluence with the Arkansas River. The associated substrates range from bedrock in the headwaters to mud and silt in the floodplain. These streams typically have low DO and sulfate concentrations, slightly acidic pH values, and moderate alkalinity (Figure 2.5).

Streams in the Ouachita Mountain, Boston Mountain, and Ozark Highlands are typically high gradient streams located in predominantly forested watersheds (Figure 4.4). The stream substrate is typically bedrock to sand and gravel. These least disturbed streams have high DO values, circumneutral to alkaline pH values, and low to high alkalinity (the Ozark Highlands are located in karst topography).

Streams in the Gulf Coastal Plain and Delta typically have low gradients, mud and organic muck bottoms, low DO, (circumneutral in the Delta), low alkalinity, high organic carbon and moderate sulfate concentrations (Figure 4.4). The navigation pools, oxbows, and tributary reservoirs in the Gulf Coastal Plain represent a sedimenting environment for many of the fine clay (shale) particles transported from the Ouachita Mountains. Environmental conditions are suited for mercury methylation. The Delta streams, oxbows, and navigation pools have very similar environmental conditions to the Gulf Coastal Plain systems, but do not receive drainage from the Ouachita Mountains (i.e., low source contributions).

Several of these factors also relate with fish mercury concentrations. In 1994, water quality and habitat variables also were collected in conjunction with the fish sampling. All the lakes with known physical attributes, measured hypolimnetic water quality constituents and fish available were used to investigate relationships among fish tissue mercury concentrations and physicochemical characteristics. Simple linear regression analyses were performed on two data subsets. The first subset related water quality constituent concentrations directly with fish mercury concentrations. In the second subset, fish were aggregated by observed mercury concentration into 6 to 8 levels in increments of 0.25 ppm (e.g., 0.25 to 0.5 ppm = Level 1, 0.5 to 0.75 ppm = Level 2, ... 1.5 to 1.75 ppm = Level 6, ...). Positive relationships were observed between fish mercury concentration and hypolimnetic sulfate, total organic carbon, and manganese (Figure 4.5) concentrations and negative relationships between fish mercury concentrations and pH (Figure 4.6) in both subsets (Table 4.3). Similar negative relationships were observed between fish mercury concentrations and pH by Lange et al. (1993) in Florida lakes and Greib et al. (1990) in Michigan lakes. The positive relationship between sulfate concentrations and fish mercury concentrations might be expected if sulfate reducing bacteria are sulfate limited at lower sulfate concentrations. The positive relationship between fish mercury concentrations and manganese in the hypolimnion might be because manganese is a surrogate for redox potential. The redox potential at which sulfate reduction occurs is similar to that at which manganese becomes reduced (Gunnison et al. 1981, Postgate 1984). These analyses have just been initiated and will continue into the next biennium, including comparisons of standardized fish mercury concentrations and environment constituents.

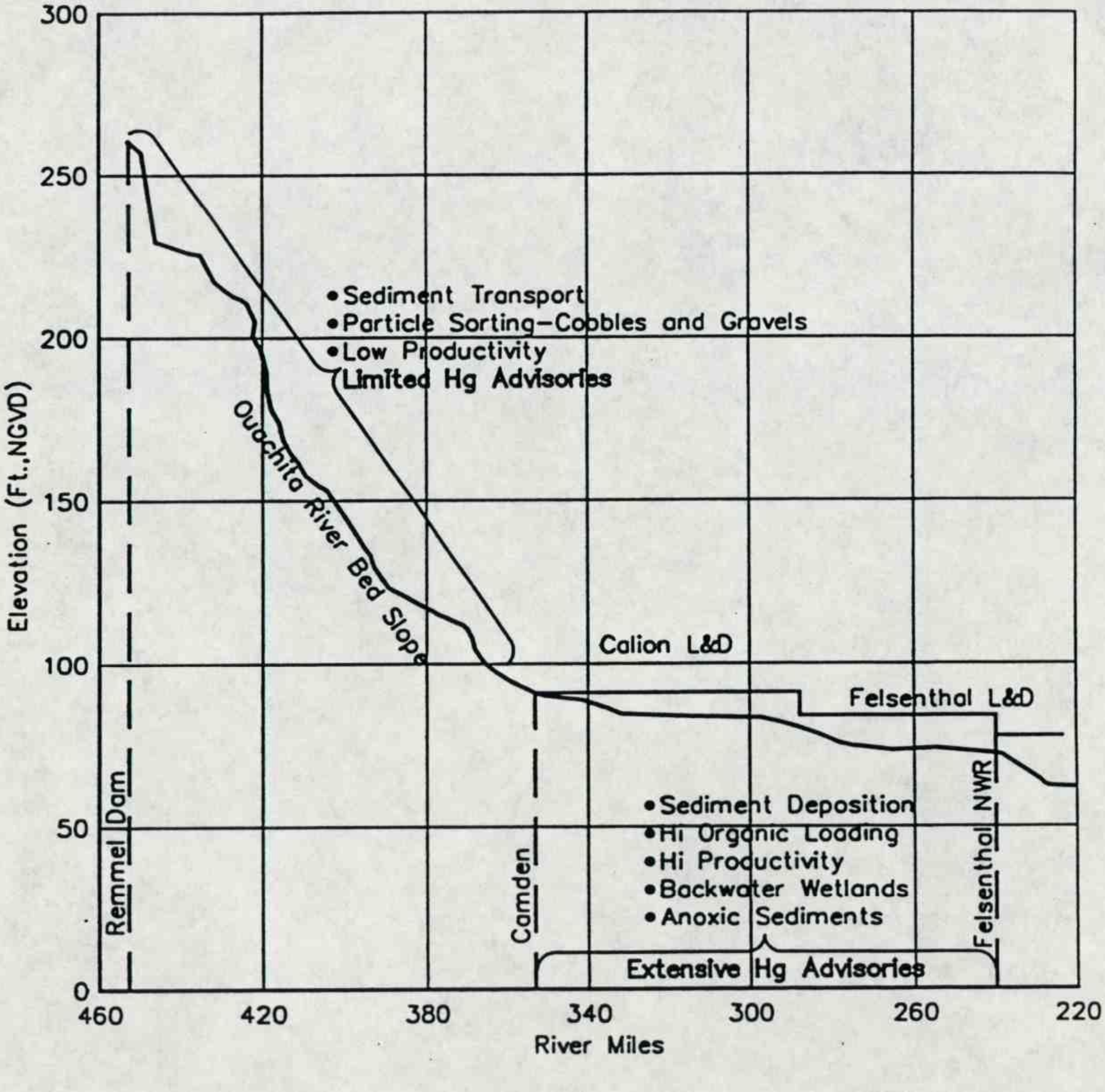


Figure 4.4. Differences in stream characteristics above and below Camden, which is the general vicinity where consumption advisories begin in the southern half of the state.

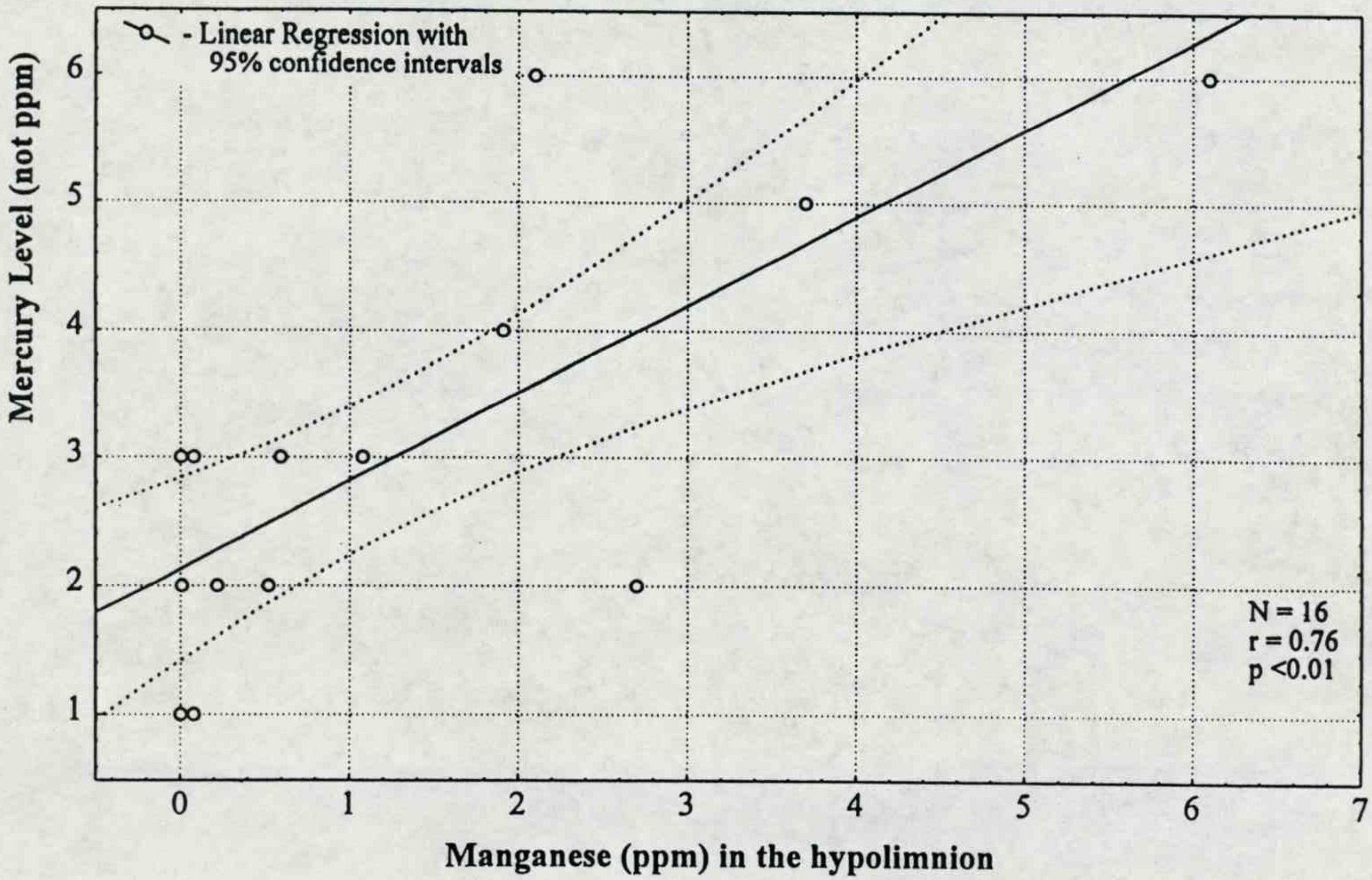


Figure 4.5. Relationship between mercury level in fish and manganese in the hypolimnion. Manganese is a surrogate for redox potential.

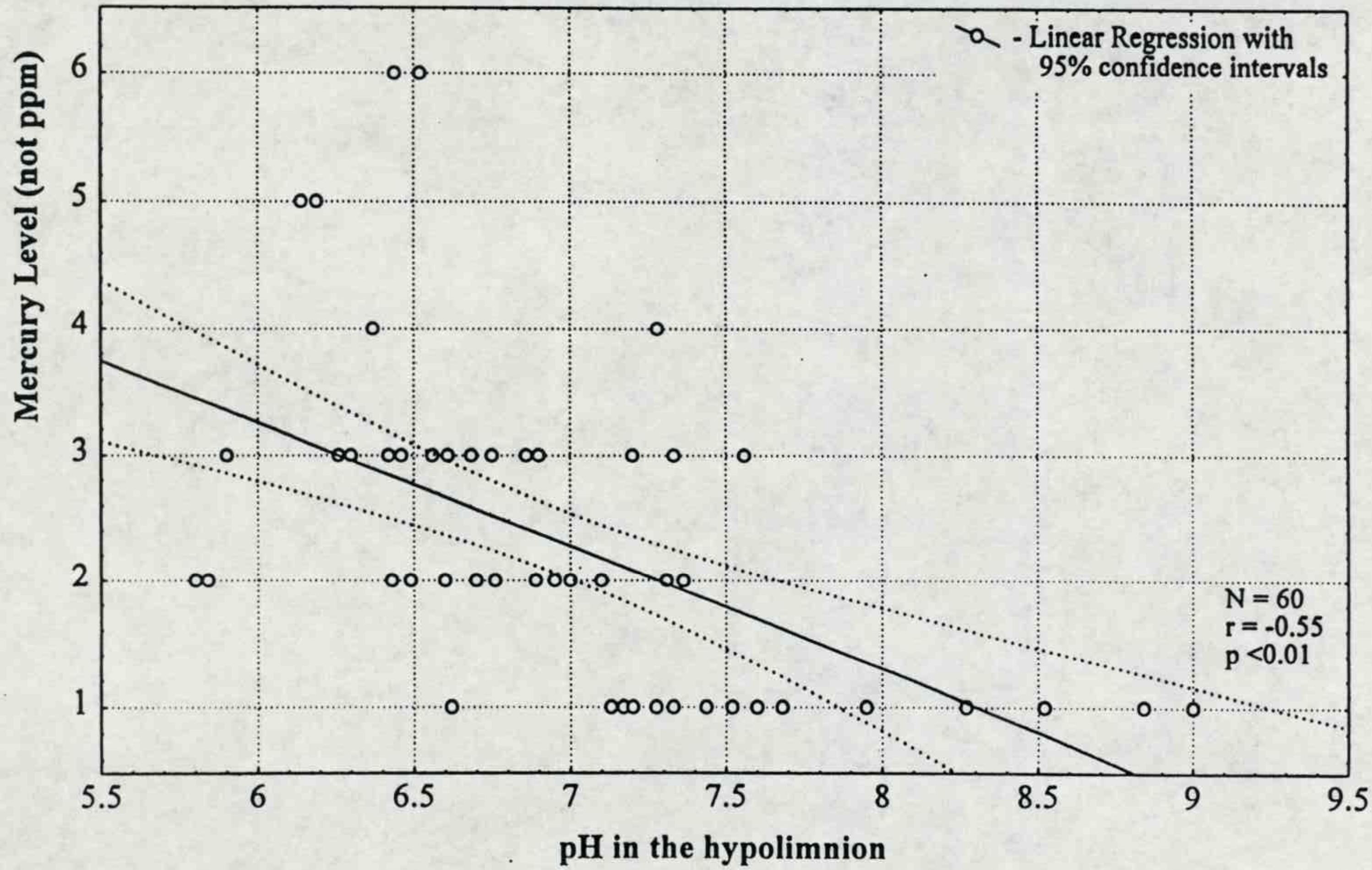


Figure 4.6. Relationship between mercury level in fish and pH in the hypolimnion.

Table 4.3. Associations between lake hypolimnetic water quality constituents and fish mercury concentration.

Parameter	Correlated with Fish	N	r	r^2	P
Sulfates	Real Hg Content	80	0.17	0.03	0.12
	Hg assigned value	80	0.27	0.07	0.01
Total Organic Carbon	Real Hg Content	67	0.19	0.04	0.11
	Hg assigned value	67	0.41	0.17	<0.01
pH	Real Hg Content	76	-0.42	0.18	0.00
	Hg assigned value	76	-0.51	0.26	0.00
Manganese	Real Hg Content	25	0.68	0.46	0.00
	Hg assigned value	25	0.74	0.55	0.00

Because mercury is a naturally occurring element, it is also naturally found in soils, vegetation, and biota. One of the characteristics of many new impoundments is an increase in mercury concentrations throughout the food chain (Abernathy and Cumbie 1977, Jackson 1988, Verdon et al. 1991). Inundating terrestrial vegetation during impoundment typically results in (1) rapid decomposition of organic matter releasing nutrients, carbon, sulfate and mercury species into the water column; (2) development of an anaerobic, reducing environment conducive to sulfate reducing bacteria and methylation of mercury; and (3) increased productivity in the reservoir for several years (i.e., 7 to 10 years) following impoundment. Fish mercury concentrations, do eventually decline as the reservoir ages and the initial phase of organic matter decomposition decreases. This decrease in fish mercury concentrations, however, might not occur for 15 to 30 years following impoundment. This increase in mercury following impoundment was one of the concerns associated with the LaGrande hydroelectric complex in Quebec (Verdon et al. 1991). Subsistence fish consumption is an important part of the local native population's diet in this remote area of Canada.

In 1985, Felsenthal NWR was expanded with inundation of bottom land areas. Lake Columbia was impounded in 1986. Both of these lakes have fish consumption advisories and have environmental conditions that are conducive to methylation of mercury, similar to those listed above. The effects of impoundment on the mercury concentrations in these lakes needs to be confirmed, because recent inundation could be one of the factors contributing to the elevated fish mercury concentrations.

Chapter 5: What can we do to remediate or manage this problem?

5.1 Public Education

Once mercury contamination occurs in an ecological system, it tends to persist for an extended period of time. Although the mercury issue in Arkansas was only identified in 1992, similar situations have been known for other states (Florida, Michigan, Minnesota, Wisconsin, etc.) for several years. These states have found that one of the strongest management tools available to protect the public health from the adverse affects of mercury is education. A challenge to the use of this tool is the constant flux in the population. For example, Minnesota has been dealing with mercury in its native fish population for more than twenty years. Educational tools that had proven effective in the management of public health had to be revised when an influx of individuals who did not speak or understand English moved into the state. The Arkansas approach to management of the mercury problem is both taking advantage of the experiences of our sister states as well as developing interventions which are tailored to the unique set of circumstances in our state.

5.1.1 Multimedia Approaches

Early on, the agencies involved in management of the mercury issue in Arkansas realized that public education and outreach was critical. Also, it was identified that there were a variety of groups that should receive this education either because of heightened sensitivities to the detrimental effects of mercury (pregnant women and children) or because of probable levels of consumption (recreational anglers, subsistence fishermen, etc.). Therefore, it was decided that a multimedia approach would have the widest audience impact. This approach has been directed at the public media (newspapers, television and radio stations), civic and recreational organizations (Rotary Clubs, bass clubs, etc.), public events such as county fairs, professional organizations, local service providers (local Health Units and local Department of Human Services offices) as well as grass roots efforts through organizations such as the Ministerial Alliance, schools and community advisory panels. Appendix H contains a memo prepared by the ADH Bureau of Health Resources that summarizes both ongoing and planned activities in this effort.

Counties where fish consumption advisories are in place have been the primary targets of the education and outreach activities. Recognizing the possibility that many anglers travel considerable distances from their home counties to fish, the need for expansion of these programs to other counties is being reviewed.

The multimedia approach used to communicate the status of the mercury issue has included numerous public presentations by the staffs of the ADPCE, AGFC and ADH, a series of video tapes (one of which is in wide circulation), the fish consumption advisory pamphlets, and a series of Public Service Announcements. Because it is very important that local issues and concerns be addressed in the public outreach effort, the Mercury Task Force Advisory Committee conducted a brainstorming session which provided feedback to the Task Force regarding effective mechanisms of communication with the target populations. This brainstorming session addressed five questions:

1) What groups need to hear the mercury message?
2) What message should be told?
   - For those at risk?
   - For secondary providers of information?
3) What are the ways to reach target audiences?
4) What are the obstacles to communicating with target audiences?

5) What followup strategies should be implemented?

The results from this brainstorming session are included as Appendix H.

5.1.2 Risk Clarification

The principal of risk clarification is important because a high level of unnecessary avoidance behavior may result when anglers are uncertain about what bodies of water and species and sizes of fish are contaminated (Cable and Udd 1990). People respond to the hazards they perceive. Such avoidance can result in unnecessary economic impacts on the local community and inefficient use of the resource. The 8-county area encompassing the Lower Ouachita and Saline Rivers in south Arkansas experienced over a 20% drop in the annual sales of sport fishing licenses following the issuance of the first fish consumption advisory in the fall of 1992 (R. Sebren, AGFC, pers. comm.). Sims and Baumann (1983) suggest that for an advisory to be effective in eliciting an appropriate behavioral response, the advisory message (1) must be clear, (2) must convey the appropriate response, (3) must be perceived as coming from a credible source, (4) must be reinforced socially at the local level, (5) should be issued through more than one medium, and (6) must consider and assess the type of appeal (i.e., threats or fear are often much less effective than a more positive approach).

The opposite of avoidance behavior is disbelief among anglers that an actual health risk exists. Cable and Udd (1990) found that large percentages of anglers relied on their sensory information to make judgements about the presences of toxics in waters they fished. Lacking clear dose-response evidence among the public, anglers exposed to an invisible hazard like mercury could place themselves at unnecessary risk, especially among the high risk groups (infants, pregnant women, and subsistence anglers).

5.1.3 High Risk Group Efforts

As noted elsewhere in this document, two potential target groups for the adverse effects of mercury in Arkansas fish have been identified: (1) the "high risk" group composed of fetuses (through their mother) and young children and (2) consumers of large amounts of native fish. Individual videos addressing pertinent issues for each group have been developed. *Mercury in Arkansas - A Problem We Can Live With* and *Fishin' in Arkansas: the Mercury Alert* are geared toward sports fishermen as well as the general public. The first video has been widely shown throughout the state; schools, civic organizations, bass clubs, etc. The second video, which has just recently been produced, is intended for the same audience. *Because Everything I Do Now, I Do For Two*, a third video, is geared toward the expectant mother, nursing mother, or parents of young children. It will be shown in the local health units and made available to other agencies and organizations who may have access to this group. Distribution of this video is currently underway.

Another mechanism that has been employed is the provision of background and technical information to health care providers who are likely to service members of the high risk group. An article on the presence of mercury in Arkansas and its toxicology was published by ADH personnel in the April 1994, *Journal of the Arkansas Medical Society*. In March 1994, a presentation was made by ADH staff to the Pre- and Perinatal Health Care Providers, a professional nursing association. An agreement has also been reached between the ADH and the Agency for Toxic Substances and Disease Registry to provide education to physicians in the impacted counties during 1995.

5.2 Compatible Fisheries Management

Another part of public education is to ensure people understand that only the consumption of contaminated fish is hazardous. An array of angling opportunities should be employed to motivate anglers while acknowledging the presence of a contaminant. These include (1) alternative fishing locations; (2) alternative target species; (3) intensively managing for certain size groups; and (4) altering frequency of consumption.

5.2.1 Alternative Fishing Locations

Anglers, whose prime motivation to fish is consuming their catch, need to be informed of alternative fishing locations where mercury advisories do not exist. For example, anglers in the Crossett, AR area have shown a willingness to travel to nearby Lake Georgia-Pacific and Lake Chicot as alternative fishing areas to harvest fish low in mercury (Charles Kinnard, pers. comm.). Results from previous and future screening of lakes and rivers for mercury need to be widely disseminated to the public as they become available. The AGFC's Arkansas Outdoors news service has begun publishing results from the screening study in a series of news articles targeted to media outlets serving local areas where the screening was performed.

5.2.2 Alternative Target Species

Mercury does not bioaccumulate similarly in all species of sportfish, even among functional predators (see Section 2.2.4 this report). Identification of species specific levels of mercury and issuing fish consumption advisories reflecting that only certain species of fish are hazardous to consume has been performed on some waters (e.g., Felsenthal NWR). Species specific analyses are an objective of Phase II sampling (see Section 2.2.3) and needs to be completed in all areas covered by a fish consumption advisory.

Determining mercury levels among different sportfish species and clarification of the advisories will allow management to focus on tailoring specific harvest regulations to achieve an optimum sustained yield from the fishery. The screening study has indicated largemouth bass might be the only species requiring a consumption advisory. Other popular sportfish species, (crappie, bluegill, catfish) can and should be managed for consumptive harvest when not covered under a consumption advisory. Catch-and-release management may be appropriate and should be considered in areas where "no consumption" has been advised, such as Felsenthal NWR. Orciari and Leonard (1990) described the success of maintaining the popularity of a Connecticut trout stream contaminated with PCBs using catch-and-release management. Largemouth bass managed under catch-and-release regulations have gained in popularity across the southeastern United States. Anglers have demonstrated a willingness to forgo the benefits of bass harvest in return for increased bass catch (and release) rates.

5.2.3 Managing for Sizes of Fish

Mercury concentrations in edible fish fillets show a positive correlation with size in largemouth bass, crappie, and bluegill (see Section 2.2.5 this report) in Felsenthal NWR and Lake Columbia (largemouth bass only). An earlier fish consumption advisory on all predator fish species in Lake Columbia was revised to reflect only largemouth bass over 405 mm (16 in.) in length posed a consumption hazard. Completing size specific analysis on other areas covered under a fish consumption advisory will allow the crafting of harvest regulations that reinforce the advisory and allow the efficient utilization of the size groups not under the advisory.

The Trophy Bass Management program (AGFC 1991) may be particularly appropriate management strategy for these situations as in Lake Columbia. In the trophy bass management strategy, largemouth bass between 406 and 530 mm (16 and 21 in.) must be released immediately back into the water if caught. The daily creel is reduced from 10 to 4 fish per day of which only one can be over 530 mm (21 in.). The purpose of the regulations is to protect large bass over 465 mm (16 in.) in the population from harvest, while allowing sufficient harvest of smaller bass (under 406 mm or 16 in.) to satisfy anglers wanting to harvest bass for consumption while preventing the stockpiling and resulting slow growth of smaller bass.

Managing for large, or trophy, bass has proven to be an effective management strategy in Florida and Texas (Phil Durocher, Texas Department of Parks and Wildlife, personal communication), even in the absence of contaminant problems. Anglers are becoming increasingly specialized in their motivations to fish with certain subgroups of anglers preferring trophy bass and catch-and-release harvest restrictions (Chipman and Helfrich 1988). Fishery management programs that focus on the recreational benefits other than the consumption of fish (i.e., high catch rates of bass or increased probability of catching a trophy-sized bass) may prove effective alternative means of motivating anglers to fish waters having a fish consumption advisory.

5.2.4 Species Specific Management

Species specific sampling has been conducted on bluegill, largemouth bass, black crappie, and white crappie from Felsenthal NWR. Results indicate a significant and positive correlation exists between length and mercury content for all four species. Although a statistical treatment of these regressions has yet to be performed, results suggest that bioconcentration differs significantly between species. These differences may reflect life histories resulting in different exposures to mercury. For example, largemouth bass convert to piscivory at an earlier age, generally within their first year upon reaching 75 to 100 mm (3 to 4 in.), whereas black and white crappie continue to feed on macroinvertebrates until late in their second year (Age 1+) or early third year of life (Age 2+) when they reach 150 to 175 mm (6 to 7 in.) total length. In Felsenthal NWR, a variety of prey fish species are available for largemouth bass and crappie, including threadfin shad (*Dorosoma petenense*) which along with bluegill are presumed to comprise the majority of the bass and crappie diet. Threadfin shad and bluegill may contain higher levels of mercury in their tissue than macroinvertebrates, resulting in a higher exposure to the bass feeding on them. Similarly, the apparent differences in the regression lines exhibited by black and white crappie may be the influence of differing growth rates, diets, or other life history aspects that reduce the species exposure to mercury. Understanding the biological transport of mercury through the aquatic community in Felsenthal NWR would benefit the development of management strategies.

5.2.5 Frequency of Consumption

ADH fish consumption advisories for mercury allow for limited consumption (two meals per month, assumes an 8-ounce portion per meal) when the mercury level in edible meat is between 1.0 and 1.5 ppm. In addition to risk clarification discussed above (Section 5.1.2), fish management strategies compatible with limited consumption may reinforce the concept with anglers. Allowing anglers to harvest 10 largemouth bass per day from where a consumption advisory has been issued may send conflicting signals about what level of harvest and consumption is safe. An appropriate management response may be to reduce the daily creel of bass, which will reduce the quantity of fish fillets available for consumption. Hess (1991) showed that significant reductions in the harvest of bass are not realized until the daily limit is reduced below six.

5.2.6 Angler Education

Each of the approaches and strategies discussed above carries an implicit need for angler acceptance and compliance. Similar to the fish consumption advisory message, efforts to more anglers away from traditional consumptive resource use patterns through more restrictive regulations may be resisted (Chipman and Hefrich 1988). The concepts and rationale for the alternative management strategy need to be clearly presented through a variety of mediums. Along with education programs for the angler, those individuals and businesses having an economic stake in the potential positive or negative impact of any regulation change should be involved throughout the management decision-making process. These interests can play a key supportive role in the success of a new program by facilitating information transfer to the public and help recognize potential programs on the local level.

5.3 Process Control

As stated previously, there are three factors that are critical for mercury accumulation in fish: (1) mercury sources; (2) conditions suitable for methylation; and (3) receptor food chain. If one of these three factors is not present, the bioaccumulation of mercury in fish can be decreased or eliminated. (A number of processes creating the right conditions for mercury methylation were discussed in Section 4.3.) Modifying some of these processes, therefore, might reduce or eliminate bioaccumulation of mercury in fish. Some of the approaches that might be used to modify the process are shown in Table 5.1.

Knowledge about process control technology varies widely from techniques that have been widely used to those that are speculative. Most mercury species have concentrations 2 to 3 times higher at pH 5 than at pH 7 (Lindqvist 1991). If pH values are less than 6.5, it might be possible to lime the watershed, wetland, lake or stream to increase the pH and reduce mercury transport from the watershed or drainage area (Lindqvist 1991). Lake liming not only increases pH but also increases calcium carbonate concentrations that might complex with mercury (Lindqvist 1991). Lake liming has resulted in up to a 40% reduction in fish mercury concentrations in pike and perch in Swedish lakes and is one of the few techniques listed above that has been effective in most of the lakes to which it has been applied (Linqvist 1991). The other techniques discussed below have not been universally effective or can result in other environmental problems if not applied appropriately. Fertilization or nutrient addition has been proposed in some Scandinavian systems to increase biological production and dilute the concentration of methylmercury in individual organisms and, therefore, reduce mercury concentrations in

Table 5.1. Approaches for reducing biogeochemical conditions for mercury methylation and uptake (after Lindqvist 1991).

Approach	Rationale
Watershed/ Wetland Liming	Increase soil pH to reduce mercury transport to the receiving aquatic system (Lindqvist 1991)
Lake Liming	Increase pH to reduce concentrations of biologically available mercury (Lindqvist 1991)
Nutrient Addition/ Fertilization	Alter the food webs and "dilute" biologically available mercury in individual organisms (Lindqvist 1991)
Selenium Treatment	Reduce biological available mercury through chemical complexation (Lindqvist 1991)
Sediment Covering	Addition of fine clay with low mercury concentrations to cover organic matter/high Hg sediments (Parks et al. 1987)
Sediment Nitrate Addition	Oxidize the sediment to eliminate reducing conditions conducive for sulfate reduction and methylation ($CaNO_3$ - Ripl 1978, 1983)
Aeration	Eliminate reducing environment conducive for sulfate reduction and methylation

the food chain. Increasing production, however, also might increase the decomposition of additional organic matter and promote anaerobic processes favoring sulfate reduction and methylation. The intensity of reducing conditions and methylmercury formation, however, is unclear. Selenium can inhibit the uptake of methylmercury. Potential deleterious effects of selenium, however, have been clearly identified in other aquatic systems (Cutter 1993). The remedial use of selenium to reduce mercury contamination in fish requires significant additional testing and is not recommended. Sediment nitrate addition is a procedure developed to reduce the anoxic conditions in lake sediments by providing an oxygen source to satisfy biochemical oxygen demand. The approach has been used to reduce or eliminate the internal loading of phosphorus (Ripl 1978, 1983; Verner 1983). Creating oxic sediments also might reduce the potential for mercury methylation by significantly decreasing the potential for sulfate reduction. Aeration of the overlying water column also might reduce or eliminate anaerobic conditions in the water and surficial sediment layer. Aeration, therefore, might eliminate sulfate reduction by eliminating the anoxic conditions. Additional treatment alternatiaves will be investigated and feasibility studies conducted on those alternatives that appear to be applicable for Arkansas lakes and streams. These feasability studies will be evaluated during FY95.

5.4 Source Control/Reduction

Atmospheric point sources can be controlled through the use of electrostatic precipitators, scrubbers, and baghouses, but this is controlling the emissions not the source. Pollution prevention and source reduction is the desired approach because it is ultimately more effective than command and control approaches. Possible source controls are listed in Table 5.2. Not all of these approaches are feasible, and they might not be necessary if the source is a minor contributor. However, recycling, proper disposal of mercury containing products, and alternative raw materials are potentially useful activities and considerations regardless of their impact on mercury input to the environment. The feasibility of various source reductions will be evaluated following more accurate source identification and emission estimates. Ultimately, source reduction is the only viable long-term solution.

Table 5.2. Source control/reduction approaches.

Approach	Rationale
Fuel Switching	Burning natural gas or other low mercury content fuel to reduce coal combustion and associated mercury emissions.
Recycling	Reuse and recycle mercury containing products.
Separation	Reduce exposure to mercury containing products, such as batteries, mercury vapor lamps, switches, etc., by separation from other waste and proper disposal.
Process Alteration	Identify alternative processes for product manufacturing to reduce mercury requirements or volatilization.

5.5 Regional Approach

The geographical distribution of fish containing mercury at or above 1.0 ppm included several bodies of water - boundary waters or streams crossing state lines - shared by Arkansas and our neighboring states. As a natural consequence, lines of communication were established between the various departments of the states which traditionally address public health, environmental and wildlife management. This informal network of professionals grew to encompass most of the states in EPA Regions IV and VI: Arkansas, Louisiana, Texas, Oklahoma, Mississippi, Georgia, North and South Carolina, Florida, and Alabama as the presence of mercury at levels of concern was documented in more and more areas.

Although different approaches to management of mercury were utilized in the respective states, many commonalities became evident. It was recognized that, while much of the federal research had addressed mercury in the northern states and their biogeological characteristics, little had been done to expand this body of information to include conditions and behaviors unique to the southern tier of states. In order to provide a unified voice to articulate these concerns a group was formed, the "Southern States Mercury Working Group" (SSMWG). This group functions without any formal support or funding. However, it is composed of dedicated individuals with common concerns. The following points were identified as initial targets for the group:

- Uniform guidelines for fish consumption to maintain blood mercury at or below safe levels;
- Uniform fish sampling and analysis protocols;
- "Round robin" split sampling to facilitate validation of state laboratory's fish sampling results .

The efforts of the SSMWG have been recognized on a federal level. At the 1994 National Forum on Mercury In Fish, representatives from the SSMWG were the only state-level group invited to present their concerns and needs from the podium. Also, the SSMWG was contacted by the EPA and asked to provide input into needs by the state for federal assistance (Appendix I).

Chapter 6: Have we always had this problem or did it develop recently?

6.1 Historical Mercury Data

Following the discovery of the mercury problem in south Arkansas, an attempt was made to review existing data on mercury in fish from other locations in Arkansas. Although some data existed through various programs at ADPCE and AGFC, comparison with recent data was not feasible. In many cases the earlier analyses were conducted on whole fish or livers making direct comparison with fish fillets impossible. The frequency and consistency of sampling also presented problems in data interpretation. It is also important to understand that analytical methods for the determination of low levels of mercury have been greatly improved in recent years and that most earlier investigations did not have appropriate quality assurance programs in place. No meaningful trends or relationships could be developed from data obtained prior to 1990.

6.1.1 Sediment Analyses and Dating

Studies of lake sediment cores in north temperate lake systems have shown recent increases in mercury accumulation rates (Meger 1986, Wiener et al. 1990, Linqvist et al. 1991, Swain et al. 1992). This increase in mercury accumulation rates has been attributed to increased atmospheric deposition (Meger 1986, Swain et al. 1992). Recently, Delfino et al. (1993) used lead-210 dating to analyze deposition rates in wetland peat cores in Florida. Delfino et al. (1993) also found increased mercury accumulation rates similar to the rates found in north temperate systems. Delfino et al. (1993) found mercury has been accumulating about 6.5 times more rapidly over the past 90 years than in preindustrial times. However, Delfino et al. (1993) were not able to identify any direct causal relationship between changes in mercury accumulation rates and regional human activities.

Sediment core samples approximately 20 cm in length were obtained from the upper end of Lake DeGray (Caddo River, tributary of Ouachita) and from the Felsenthal NWR to determine if there were greater mercury concentrations in the upper portion of the core compared to the deeper portions of the cores. These cores were cut into 2 cm sections and each section analyzed for mercury. There was no statistical difference in the mercury concentration throughout these two cores. However, there is no data to support the basic integrity (lack of mixing) of these cores nor is there data on sedimentation rates. It is not known whether there has been any increase in mercury accumulation rates in the recent past based on these core samples. Additional studies will use lead-210 and Cesium-137 to date cores selected from locations that will permit a longer period to be analyzed.

6.1.2 Retrospective Fish and Wildlife Estimates

Mercury accumulates in avian feathers and mammal hair in addition to accumulation in muscle and nervous tissue (Berg et al. 1966, Cumbie 1975, Furness et al. 1986, Johnels et al. 1979, Lindberg and Odsjo 1983). Relationships between mercury concentrations in the muscle, liver or blood versus hair and feathers have been developed for different bird and mammal species such as goshawks and ospreys (Johnels et al. 1979), raccoon, and bobcats (Cumbie 1975). A protocol has been developed for evaluating the historical contamination of mercury in the hair and feathers of museum specimens to determine if the mercury problem is recent or existed historically (KBN 1993).

One potential problem with museum specimens might be the use of mercury compounds as preservatives, particularly on pelts and skins. A review of tanning and preservation practices in museums, however, indicated the use of mercurial compounds is not a common practice in the preparation of bird skins (KBN 1993). In addition, the preparation of mammalian skins with hair typically used a chrome tanning practice rather than any mercurial compounds (KBN 1993).

Historical analyses of birds from 1840 to 1966 indicated there has always been some background exposure and uptake of mercury, but there also have been patterns related to the anthropogenic use of mercury as agricultural seed disinfectants and fungicides (Berg et al. 1966, Johnels et al. 1979). Analyses of hair or feathers from museum specimens of river otter or fish-eating birds collected in the Ouachita River Basin might provide an indication of historical and recent levels of mercury contamination. As mentioned in Section 4.2, hair taken from three river otter trapped in Felsenthal NWR in 1992 contained 35 ppm mercury. Historical analyses might illuminate past patterns of mercury contamination in birds and wildlife, but results must be interpreted carefully.

6.2 Current and Recent Trends

Throughout the investigation of the mercury problem in South Arkansas, an attempt was made to review current literature regarding mercury pollution. It was quickly determined that the contamination of predator fish with mercury had been found in at least 28 states and now has been found in 36 states (Figure 4.2). As stated previously, the mercury problem is not local, it is at least a regional, and perhaps, a global problem. Currently, there is limited information to determine trends because the analytical capability to measure small increases in mercury concentration have only been developed in the past 5 years. Historical measures are suspect, particularly low concentration measurements.

There has been concern as to whether the current mercury contamination is historical or has developed recently. This is a question that we have not been able to answer. Until the recent sampling for mercury, available data were sparse. A statewide mercury sampling effort was conducted during the late 70s. One of a handful of positive results was from the Lower Ouachita River before Felsenthal NWR was constructed. The positive result was a composite fish sample of gar and bowfin collected in 1977, which resulted in a whole fish concentration of 2.03 ppm mercury. Subsequent sampling conducted in 1978, 1979, 1980, and 1982 did not detect mercury at that level.

Due to the lack of samples and the nonstandardized collection methods used in the past, it is impossible to document historical trends. The trend question, however, is relevant, and a monitoring program is being designed to detect future trends and assess whether fish mercury concentrations are increasing or decreasing.

Chapter 7: Next Steps and Recommendations

7.1 1993–1994 Biennium Activities

During the 1993–1994 Biennium, the Mercury Task Force focused on the following: strategic planning; sampling and analysis, particularly fish screening sampling throughout the state; reporting these findings to the public; and coordinating and communicating with the Arkansas Mercury Advisory Committee and the public on mercury in Arkansas. Some of the activities conducted in each of these categories follow:

Strategic Planning

1) Developed and implemented a strategic plan for addressing mercury in Arkansas in 1993.
2) Prepared and implemented a revised work plan for 1994.
3) Submitted a work plan to EPA Region VI for lake treatment/management experiments.

Sampling and Analysis

1) Conducted free blood-mercury screening analyses for the eight-county area in South Arkansas to identify individuals with elevated mercury concentrations and alleviate concerns of many citizens.
2) Sampled and analyzed fish from over 180 lakes, streams, and farm ponds throughout the state, and used this information to issue fish consumption advisories.
3) Sampled and analyzed individual fish to develop length versus mercury relationships, and used this information to revise fish consumption advisories.
4) Sampled and analyzed water and sediment mercury throughout the Ouachita River Basin to determine possible sources.
5) Sampled water quality and habitat parameters associated with 1994 fish sampling to understand why the mercury problem might be occurring.
6) Analyzed over 700 rock samples throughout the Ouachita Mountain Ecoregion to investigate possible natural sources.
7) Ongoing analysis of about 5,000 blood samples to determine the mercury concentration in the high-risk population from throughout the state.
8) Initiated mercury biological availability study with The Academy of Natural Sciences to determine if natural sources are as available for methylation as atmospheric sources.

Reporting

1) Published fish consumption advisories on a periodic basis from September 1992 to the present.
2) Prepared and distributed a video, *Mercury in Fish: A Problem We Can Live With.*
3) Prepared and distributed a video, *Because Everything I Do Now, I Do for Two.*
4) Prepared and distributed a video, *Fishing Arkansas...The Mercury Alert.*
5) Published peer-reviewed report, *Mercury in Arkansas: 1993 Status Report and Proposed 1994 Activities* in 1994.
6) Will publish peer-reviewed report, *Mercury in Arkansas: 1993–1994 Biennium Report* in May 1995.
7) Provided Governor of Arkansas Executive Summary of 1993 Status Report.
8) Provided Governor of Arkansas Executive Summary of 1993–1994 Biennium Report.
9) Published paper on *Communicating Risks of Mercury in Arkansas* in EPA National Forum on Mercury in Fish Proceedings.
10) Presentations at the 12th International Neurotoxicology Conference on Neurotoxicity of Mercury: Indicators and Effects of Low-level Exposure.

11) Published paper on *Mercury Contamination in Arkansas Gamefish, A Public Health Perspective* in the Journal of the Arkansas Medical Society for physicians and other health care providers.

Coordination and Communication

1) Established Arkansas Mercury Advisory Committee and held six meetings with this group of over 30 representatives of federal, state, and local agencies and civic and private organizations.
2) Held public meetings in El Dorado, Warren, and Crossett to explain the mercury problem to the public.
3) Had information distribution booths at county fairs and other community events.
4) Made presentations at churches, bass clubs, Rotary, Kiwannis and other civic organizations.
5) Co-founded the Southern States Mercury Coordinating Committee to coordinate and communicate information on mercury among 13 southern states.
6) Hosted the second meeting of the Southern States Mercury Coordinating Committee in Little Rock.
7) Held brain-storming sessions on information dissemination and used suggestions to form two subcommittees of the Advisory Committee: providing information on mercury to health care professionals, and providing information on mercury to secondary information providers.

7.2 Remaining Uncertainties

Screening information has been collected on the general distribution of mercury in fish throughout the state. Areas where fish consumption advisories are warranted have been identified as well as the groups that are at higher risk for consuming fish with mercury contamination. General information on blood mercury levels in fish consumers in South Arkansas is also available. Finally, general information on water, sediment, and rock total mercury concentrations in South Arkansas has been collected, but, for each of these data sets, considerable uncertainties about the mercury issue remain.

Additional information is needed on the blood-mercury levels in the high risk groups, particularly subsistence fish consumers and minority members of the population. Furthermore, background levels of mercury in blood for the general population throughout the state are needed for comparison with the high risk subpopulation and the general population in South Arkansas.

The ADH is still in the process of collecting and evaluating data on the blood-mercury levels of Arkansans. The interventions and management techniques and approaches that have been proposed in this report may be modified as the results of these tests warrant. This could include modification of all segments of the intervention and management programs, including public education, fish consumption advisories, etc,

Statistical evaluation of the blind blood-mercury study that is now underway is expected to be completed by midyear. This will provide the first set of data that can reliably be used to make public health decisions concerning the extent of mercury exposure to the high risk groups. It is premature to make assumptions on this data until the evaluation has been completed. However, it is appropriate to discuss some pieces of information that will be of interest. For example, geographical distribution, demographics, and seasonal variations are some attributes that will be examined closely. The information obtained from the high risk groups study will also be used to refine and target our management programs.

There is now relatively good fish sampling coverage over the entire state, but there are some fish species that have not been adequately sampled, such as buffalo, crappie, bluegill, and catfish. In addition, species-specific differences in mercury concentrations versus length relationships are needed for other water bodies, particularly for those systems with current fish advisories. Because of the species-specific relationships developed for Felsenthal, it was possible to relax the fish consumption advisory for Felsenthal NWR and exclude crappie and bluegill from the advisories. It is likely similar relationships exist for other water bodies, but this information has not been collected. It also might be possible to consider re-opening commercial fishing for selected species, if this information were available.

Public uncertainty about mercury continues to be a critical issue. Additional efforts are needed to inform the public about the mercury issue: what is factual, what is conjecture, and what is wrong. One of the real challenges is how to reach the low income, poverty level subpopulation that is likely to subsist on fish from these systems.

Potential sources of mercury have been tentatively identified but the relative contribution of these various sources is unknown. Source apportionment is an important activity but is considered secondary to public health issues and public education. Determining the relative contribution of mercury from various sources will take longer. During the interim, management approaches need to be identified and evaluated.

7.3 Recommended Activities

Based on these uncertainties, several activities have been recommended by the Mercury Task Force for the remainder of FY94 (4 April to 30 June) and the beginning of FY95 (1 July through 31 December).

The Mercury Task Force approved the following recommendations for the remainder of calendar year 1995:

1) Conduct confirmation sampling for buffalo, crappie, bluegill and catfish in the Ouachita and Saline Rivers and oxbows.
2) Develop species-specific length versus mercury relationships for other species such as buffalo, crappie, bluegill, and catfish for other areas besides Felsenthal NWR.
3) Conduct statistically valid blood analysis studies, including additional sampling for specific subpopulations that might be underrepresented in South Arkansas
4) Develop educational information and communication approaches for interfacing with the high risk group and secondary information providers
5) Continue to issue fish consumption advisories, where needed, but include fish species that can be eaten as well as those that cannot be eaten.
6) Develop better understanding of the sources and bioavailability of mercury in the affected areas.
7) Evaluate lake and pond treatment techniques that might be appropriate for Arkansas lakes and ponds, and solicit external funds to begin testing some of these techniques.
8) Evaluate and implement additional fisheries management procedures to reduce the concentration of mercury in fish and relax fish consumption advisories.
9) Reevaluate commercial fishing in the Ouachita River and consider reopening commercial fishing licenses.
10) Establish trend monitoring sites throughout the state to assess changes in mercury contamination of fish.
11) Continue to coordinate with the Southern States Coordinating Committee and federal agencies on the mercury problem.
12) Complete the investigations on biologically available mercury from geological formations.

7.4 Priorities and Schedule

Figure 7.1 shows a timeline for the high priority studies and their associated phasing. This list of studies and activities will be reviewed following the completion of this summer's sampling effort, and appropriate reprioritization will occur based on the results of these field efforts and additional data analyses.

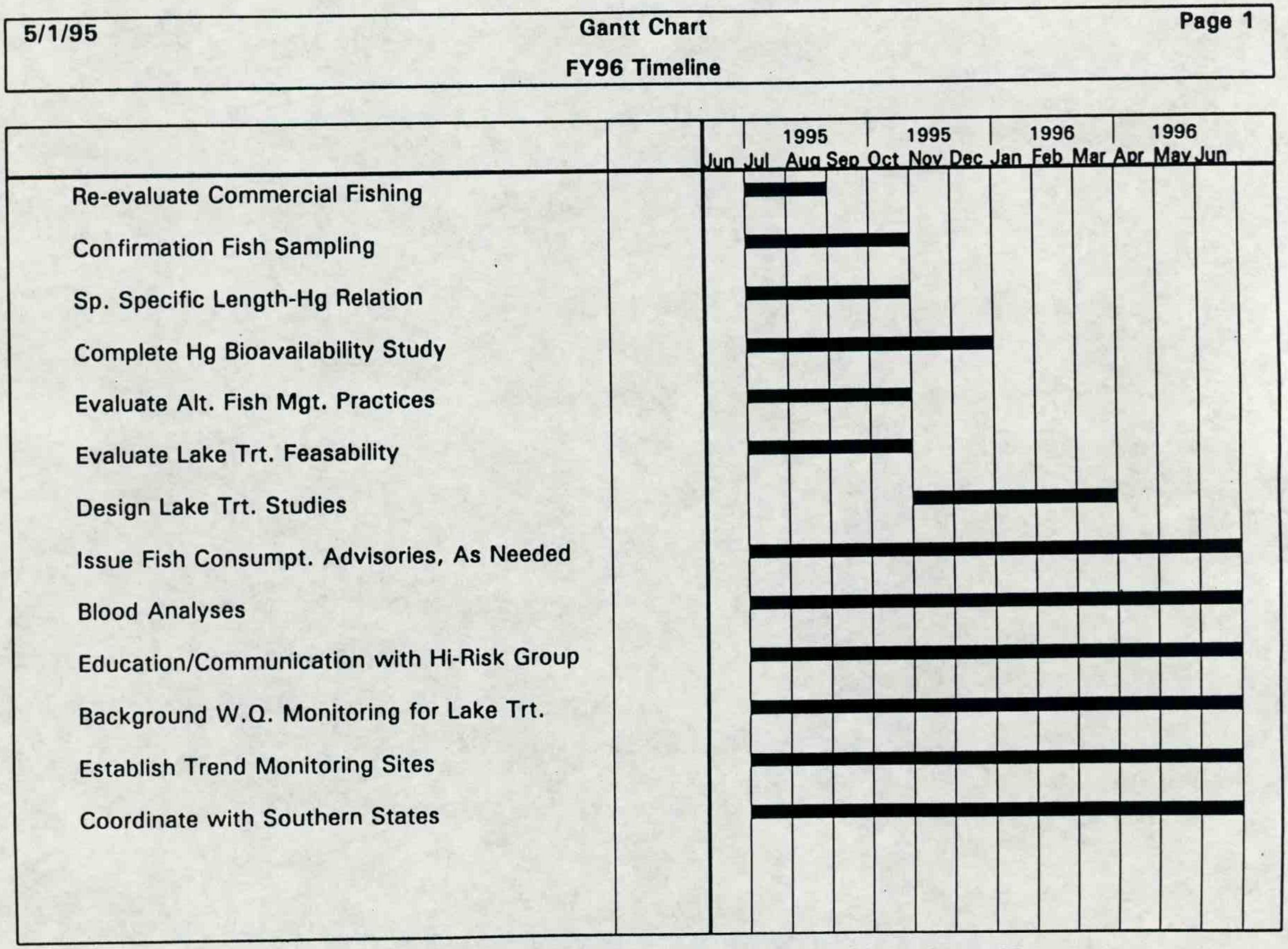


Figure 7.1. Timeline for proposed Mercury Task Force activities during FY95.

Chapter 8: References

Abernathy, A.K. and P.M. Cumbia. 1977. Mercury accumulation in largemouth bass (Micropterus salmoides) in recently impounded reservoirs. Bull. Env. Contam. Toxicol. 17:595-602.

Agency for Toxic Substances and Disease Registry (ATSDR). 1992. Case Studies in Environmental Medicine. Mercury Toxicity. No. 17, 1-19.

Agency for Toxic Substances and Disease Registry (ATSDR). 1993. "Toxicological Profile for Mercury - Draft," February 19, 1993.

Anderson, R.O. and S.J. Gutreuter. 1983. Length, weight, and associated structural indices. Pages 283-300 in Larry A. Nielsen and David L. Johnson, editors. Fisheries Techniques. American Fisheries Society. Bethesda, MD.

Area Marketing Research Associates. 1988. Fisherman attitude study. Arkansas Game and Fish Commission. Little Rock, AR.

Arkansas Department of Pollution Control and Ecology. 1987. Physical, chemical and biological characteristics of least-disturbed reference streams in Arkansas' ecoregions. Vol. I - Data Compilation. Vol. II - Data Analyses. Arkansas Department of Pollution Control and Ecology. Little Rock, AR. June 1987.

Arkansas Game and Fish Commission. 1991. Arkansas largemouth bass management plan. Arkansas Game and Fish Commission. Little Rock, AR.

Arkansas Mercury Task Force. 1993. Strategic Plan for Assessing Mercury in Arkansas: Report to the Governor. Submitted to Office of the Governor, State of Arkansas. Little Rock, AR.

Arkansas Mercury Task Force. 1994. Mercury in Arkansas: 1993 Status Report and Proposed 1994 Activities. Submitted to Office of the Governor. State of Arkansas. Little Rock, AR.

Beijer, K. and A. Jernelov. 1979. Methylation of mercury in aquatic environments. in Nriagu, J. [ed]. The biogeochemistry of mercury in the environment. Elsevier/North-Holland Biomedical Press.

Beniot, J.M., W. F. Fitzgerald and A.W.H. Damman. in press. Historical atmospheric mercury deposition in mid-continental U.S. as recorded in an ombrotrophic peat bog. in: Mercury Pollution: Integration and Synthesis (eds. C. Watras and J. Huckabee). Lewis Publishers. Boca Raton, FL.

Berg, W., A.G. Johnels, B. Sjostrand, and T. Westermark. 1966. Mercury Content in Feathers of Swedish Birds from the Past 100 Years. Oikos 17: 71-83.

Bloom, N.S., 1993. On the chemical form of mercury in edible fish and marine invertebrate tissue. Canadian Journal of Fish and Aquatic Science 49:1010-1017.

Bodaly, R.A., R.E. Hecky, and R.J.P. Fudge. 1984. Increases in fish mercury levels in lakes flooded by the Churchill River diversion, northern Manitoba. Can. Jour. Fish. Aquat. Sci. 41:682-691.

Burge, P. and S. Evans. 1994. Mercury contamination in Arkansas gamefish. A public health perspective. J. AR Medical Soc. 90:542-544.

Cable, T. T. and E. Udd. 1990. Effective communication of toxic chemical warnings to anglers. North American Journal of Fisheries Management 10:382-387.

Cumbia, M. 1975. Mercury in hair of bobcats and raccoons. J. Wildlife Mgm. 39:419-425.

Chipman, B.D. and L.A. Helfrich. 1988. Recreational specialization and motivations of Virginia River anglers. North American Journal of Fisheries Management 8:390-398.

Choi, C.M., Lapham, L.W., Amin-Zaki, L, et al. 1978. Abnormal neuronal migration, deranged cerebral cortical organization and diffuse white matter astrocytosis of human fetal brain: A major effect of methylmercury poisoning in utero. J Neuropathol Exp Neurol 37:719-732.

Clardy, B.F. and W.V. Bush. 1976. Mercury district of southwest Arkansas. Info. Circular 23. Arkansas Geological Commission. Little Rock, AR.

Clarkson, T.W. 1990. Human health risks from methylmercury in fish. Environ. Toxicol. Chem. 9:957-961.

Connor, J.J. and H. T. Shacklette. 1975. Background geochemistry of some rocks, soils, plants and vegetables in the conterminous United States, U.S. Geological Survey Professional Paper 574-F.

Delfino, J.J., T.L. Crisman, J.F. Gottgens, B.E. Rood, and C.D.A. Earle. 1993. Spatial and temporal distribution of mercury in Everglades and Okefenokee wetland sediments. Project Report. University of Florida, Gainesville, FL.

D'Itri, F.M. 1990. The biomethylation and cycling of selected metals and metalloids in aquatic sediments. in R. Baudo, J.P. Giesy, and H. Muntau. Sediments: Chemistry and Toxicity of In-Place Pollutants. Lewis Publishers, Inc. Boca Raton, FL.

Drever, J.I. 1982. The Geochemistry of Natural Waters. Prentice-Hall, Inc. Englewood Cliffs, N.J.

Eisenreich, S.J. and W.M.J. Strachan, eds. 1992. Estimating atmospheric deposition of toxic substances to the Great Lakes: An Update. Proceed. Workshop at Canada Centre for Inland Waters. Burlington, Ont. Great Lakes Protection Fund and Environment. Canada. February 1992.

Eisler, Robert. 1987. Mercury hazards to fish, wildlife, and invertebrates: a synoptic review. U. S. Fish and Wildlife Service Biological Report 85. 90 pp.

EPA. 1979. Handbook for analytical quality control in water and wastewater laboratories. Environmental Protection Agency. Cincinnati, OH.

EPA. 1991. EPA method number 245.6, Determination of mercury in tissues by cold vapor atomic absorption spectrometry. In Methods for the Determination of Metals in Environmental Samples. Environmental Protection Agency. Cincinnati, OH.

EPA. 1993a. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories. Volume 1: Fish Sampling and Analysis. EPA 823-R-93-002.

EPA. 1993b. Monitoring strategy. In Guidance for assessing Chemical Contaminant Data for use in Fish Advisories Volume 1: Fish Sampling and Analysis. Environmental Protection Agency. Washington D.C.

EPA. 1993c. National emissions inventory of mercury and mercury compounds: Interim Final Report. EPA-453/R-93-048. Environmental Protection Agency. Office of Air and Radiation, Research Triangle Park, NC.

EPA. 1994. Mercury Study Report to Congress. Workshop Review Draft. U.S. Environmental Protection Agency. Office of Research and Development. EPA/600/P-94/002Aa. Washington, D.C.

EPRI. 1994. Mercury Atmospheric Processes: A Synthesis Reports EPRI/TR-104214. Electric Power Research Institute. Palo Alto, CA.

Ferm, R. and Larsson, J.E. 1973. Mercury usage, control and environmental effects. Report No. 421. Swedish Env. Prot. Agency. S-171, 85 Solna, Sweden.

Fitzgerald, W.F., R.P. Mason, and G.M. Vandal. 1991. Atmospheric cycling and air-water exchange of mercury over mid-continental lacustrine regions. Wat. Air Soil Pollut. 56:745-768.

Fitzgerald, W.F. In press. Is mercury increasing in the atmosphere? The need for an atmospheric mercury network (AMNETL) in C. Watras and J. Huckabee (eds). Mercury as a Global Pollutant. Lewis Publishers, Boca Raton, FL.

Furness, R.W., S.J. Murihead, and M. Woodburn. 1986. Using bird feathers to measure mercury in the environment: relationships between mercury content and moult. Marine Pollution Bulletin 17:27-30.

Gilmour, C.C. and E.A. Henry. 1991. Mercury methylation in aquatic systems affected by acid deposition. Env. Pollut. 71:131-169.

Gilmour, C.C., E.A. Henry, and R. Mitchell. 1992. Sulfate stimulation of mercury methylation in freshwater sediments. Env. Sci. Technol. 26:2281-2287.

Gilmour, C.C. In press. Comparison of sediment Hg methylation rates and the contribution of sediment MeHg production to the MeHg mass balance among ecosystems. in C. Watras and J. Huckabee (eds). Mercury as a Global Pollutant. Lewis Publishers, Boca Raton, FL.

Glass, G.E., J.A. Sovenson, K.W. Schmidt, G.R. Rapp, Jr., D. Yap, and D. Fraser. 1991. Mercury deposition and sources for the upper Great Lakes region. Wat. Air Soil Pollut. 56:235-250.

Grieb, T.M., C.T. Driscoll, S.P. Gloss, C.L. Schofield, G.L. Bowie, and D.B. Porcella. 1990. Factors affecting mercury accumulation in fish in the upper Michigan peninsula. Environ. Toxicol. Chem. 9:919-930.

Gunnism, D. and J. M. Brannon. 1981. Characterization of anaerobic chemical processes in reservoirs: Problem description and conceptual model formulation. Tech Rept. E-81-6. USAE Waterways Experiment Station. Vicksburg, MS.

Håkanson, L., Å.Nilsson, and T. Andersson. 1988. Mercury in fish in Swedish lakes. Environ. Pollut. 49:145-162.

Harrison, S.E. and J.F. Klaverkamp. 1990. Metal contamination in liver and muscle of Northern Pike (*Esox lucius*) and White Sucker (*Catostomus commersoni*) and in sediment from lakes near the smelter at Flin Flon, Manitoba, Envir. Toxicol. and Chem. 9:941-956.

Hem, J.D. 1985. Study and interpretation of the chemical characteristics of natural water. USGS Water Supply Paper 2254. US Geological Survey Alexandria, VA. 3rd Ed.

Henriques, A. 1972. Mercury distribution in bedrock and ores in Sweden. SNV Report. Swedish Env. Protection Agency. S-171, 85 Solna, Sweden.

Hess, T. B. 1991. The impact of daily creel limits on sportfish harvest in Georgia. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 45:282-287.

Hudson, R.J.M., S. A. Gherini, C.J. Watras, and D.B. Porcella. in press. A mechanistic model of the biogeochemical cycle of mercury in lakes. in C.J. Watras and J.W. Huckabee, eds. Mercury as a Global Pollutant. Lewis Publishers. Chelsea MI (in press).

Inskip, M.J. and J.K. Piotrowski. 1985. Review of the health effects of methylmercury. Journal of Applied Toxicology, Vol. 5, No. 3, pp 113-127.

Jackson, T.A. 1988. The mercury problem in recently formed reservoirs of northern Manitoba, Canada: effects of impoundment and other factors on the production of methylmercury by microorganisms in sediments. Can. Jour. Fish. Aquat. Sci. 45:97-121.

Jensen, A.A., Slorach, S.A. 1991. Chemical Contaminants in Human Milk. CRC Press. pp 280-281.

Johnels, A., G. Tyler, and T. Westermark. 1979. A history of mercury levels in Swedish fauna. Ambio 8:160-169.

Appendix A

First Fish Consumption Advisory Brochure

Where Does Mercury Come From?

lercury has many sources. It is a natural compo-ent of the earth's crust and is found in low levels in ediment throughout Arkansas. Mercury ore (cin-abar) was formerly mined in Arkansas. Another ource of mercury in the environment is due to coal urning and municipal waste incineration. Acid rain icreases acidity in lakes and rivers, causing the iercury to be more soluble and more easily ab-orbed by fish and other organisms.

How Does Mercury Get Into Fish?

he presence of mercury in water or sediment oesn't cause a problem. Other conditions are eeded. These include the presence of high or-anic material like dead leaves, waste discharges om cities and industries, slightly acid water, and ie presence of anaerobic (lack of oxygen) bacte-a which convert metallic mercury into soluble me-iyl mercury. This is the form that can be absorbed y fish.

/hen methyl mercury is released into the water, nall organisms accumulate it. These organisms e eaten by small fish, and the mercury is concen-ated in them. Methyl mercury is concentrated at ach step in the food chain up to the predator spe-es of fish like **bass, crappie, catfish, gar** and **owfin.** Non-predator fish like **bream** are one step own this food chain. Bottom feeders like **suckers** id **buffalo** are yet another step down the chain.

How Long Will These Fish Advisories Last?

ealth advisories are in effect indefinitely. Fish iminate mercury very slowly. The government is eking the source of this mercury contamination.

Can We Make Fish Safe to Eat?

No special cleaning or cooking methods will decrease mercury in fish. Mercury is stored in the fish fillet or muscle portion, not the fat. Removing fat or skin from fish will not lower mercury levels.

Health risks from eating fish with mercury in it can be reduced in the following ways:

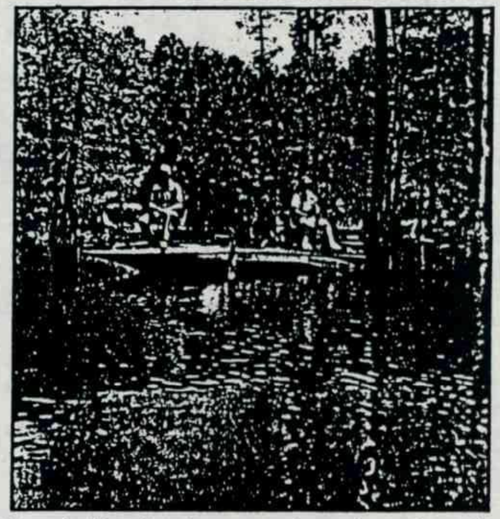
- Always eat the smaller fish within the species since younger, smaller fish contain less mercury.
- Choose non-predator fish over predator fish whenever possible since non-predator fish usually have less mercury in them.

Where Can I Get More Information on Mercury?

For more information on the mercury advisories or on how to reduce health risks in eating fish in the affected areas, contact the Arkansas Department of Health at 661-2986.

Produced by:
Arkansas Department of Health
Arkansas Game and Fish Commission
Arkansas Department of Pollution Control and Ecology
(Issued May, 1993)

A FISHING ADVISORY FOR SOUTH ARKANSAS



Elevated levels of mercury have been found in fish flesh in South Arkansas. Advisories limiting consumption of fish caught in contaminated areas have been issued by the Arkansas Department of Health.

Pregnant women, women who plan to get pregnant, women who are breastfeeding, and children age 7 years or younger are considered at high risk for health effects due to mercury exposure and should not eat the fish from affected areas.

Persons who eat fish from affected areas occasionally are not at risk for health effects from mercury. This includes people who vacation around and fish in affected areas.

Affected areas are the lower Ouachita and Saline rivers and nearby oxbow lakes, Felsenthal National Wildlife Refuge, parts of Moro, Champagnolle and Cut-Off creeks and Lake Columbia.

A FISHING ADVISORY FOR SOUTH ARKANSAS

Fish Consumption Advisories

No fish should be eaten from Cut-Off Creek where it crosses the Highway 35 bridge in Drew County to its confluence with Bayou Bartholomew in Ashley County including Cut-Off Creek Wildlife Management Area.

TABLE 1

Persons **should not eat PREDATOR FISH** such as **bass, crappie, catfish, gar and bowfin** from:

- **Saline River** from Highway 160 bridge to the Ouachita River
- Main channel of the **Ouachita River** from Smackover Creek to the Louisiana border, including Felsenthal Reservoir.
- **Moro Creek** from Highway 160 to the Ouachita River
- All oxbow lakes, backwaters, overflow lakes and bar ditches formed by the Ouachita River below Camden, including all Felsenthal refuge water.

No more than **two meals a month of NON-PREDATOR FISH (bream, buffalo and suckers)** may be eaten per month.

A meal consists of 8 ounces of fish.

TABLE 2

No more than **two meals a month of PREDATOR FISH** should be eaten from:

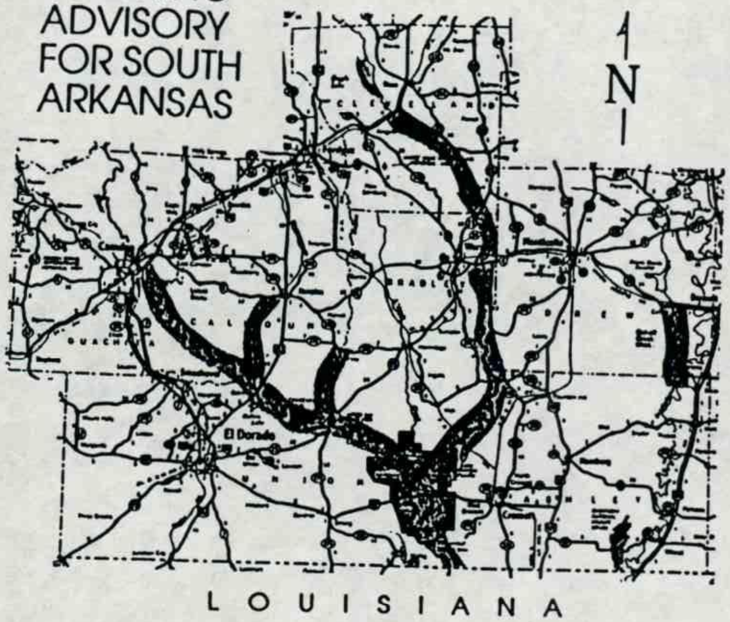
- **Saline River** from Highway 79 in Cleveland County to Highway 160 in Bradley and Ashley counties
- **Champagnolle Creek,** including Little Champagnolle from Highway 4 to the Ouachita River
- **Gray's Lake** in Cleveland County

A meal consists of 8 ounces of fish.

There is no restriction on eating **NON-PREDATOR FISH** from these waters.

All areas affected by these advisories have been closed to commercial fishing.

Fish continue to be tested in other areas of the state and additional advisories will be issued if needed.



Areas with Fish Advisories*

PLEASE NOTE:
TABLE 1: Oxbow lakes under advisory that are not shown on the map: Snow Lake and Big Johnson Lake in Calhoun County, Lake Benjamine in Union County and Lake Piroque in Bradley County.
TABLE 2: Lake under advisory that is not shown on the map is Lake Columbia in Columbia County.

* It is important to note that the areas indicated above represent the South Arkansas Fish Consumption Advisories issued effective May, 1993 and that testing is continuing for additional affected areas in South Arkansas

What is Mercury?

Mercury is a chemical that occurs naturally in s[oil,] water and air. It can exist in several forms such [as] elemental mercury used in thermometers, inorgan[ic] mercury (used in manufacturing), and organic me[r]cury (which builds up in the food chain). All thr[ee] forms are toxic and are a threat to human health [in] large doses.

What is the Risk of Eating Fish with Mercury?

The federal Food and Drug Administration (FDA) has established a 1.0 part per million (PPM) actio[n] level for mercury in fish for human consumption.

The amounts of mercury found in Arkansas fis[h] doesn't cause immediate sickness. Mercury ca[n] collect in the body over time and could have effect[s] on human health.

Pregnant women, women who plan to get preg[nant], women who are breastfeeding, and childre[n] age 7 years or younger are considered at hig[h] risk for health effects due to mercury exposur[e] and should not eat the fish from affected areas.

Mercury affects the human nervous system and ability to feel, see, taste and move. Unborn children and pregnant women are more sensitive to mercury than other adults. Children are more susceptible because their nervous systems are still developing. A woman may pass contaminants to her unborn child through the placenta or to a nursing child through breast milk.

Long-term exposure to mercury can permanently damage the brain, and kidneys of an unborn child. Nerve and brain damage symptoms caused by mercury include hand tremors, speech impediments, and lack of coordination. Other disturbances include tunnel vision, blindness and deafness.

Health effects generally can be corrected among the general population if exposure to mercury is stopped. The human body can eliminate half of its mercury burden in 50 to 60 days.

Since mercury contamination is a long-term problem with no solution in the near future, residents who fish in the affected areas need to reduce their health risks from mercury exposure.

Appendix B

Strategic Plans

Strategic Plan for Assessing Mercury in Arkansas: Report to the Governor

I. PURPOSE:

This Strategic Plan for Assessing Mercury in Arkansas satisfies the charge given to the Arkansas Department of Pollution Control and Ecology by Governor Jim Guy Tucker on 11 January 1993 to:

Governor's Charge - Develop a Plan

- Develop a plan for determining the extent, impact, and potential sources of mercury contamination in Arkansas;
- Request information and assistance from the U.S. Environmental Protection Agency and other states currently experiencing mercury contamination within their boundaries;
- Recommend management strategies for controlling or eliminating mercury contamination in Arkansas; and
- Submit a plan and initial report summarizing the mercury contamination problem to the Governor and members of the Legislature by 1 March 1993.

This Strategic Plan:

Strategic Plan Contents

1) Presents recommendations for resolving the mercury issue in Arkansas, which includes requested budget and labor distribution by state agency to implement this program;
2) Provides a brief history of the mercury problem and advisories in Arkansas and its potential health, ecological, and economic impacts;
3) Provides a brief description of how mercury contamination occurs in fish;
4) Identifies 5 questions that must be answered to address and resolve the mercury issue;
5) Presents the goals and objectives of a program to resolve the mercury contamination issue in Arkansas;
6) Provides potential administrative constraints to program implementation; and
7) Presents a schedule for accomplishing the tasks.

Economic Impact Estimated at over $11 million

There are significant existing, and potential, economic impacts from mercury contamination in fish. For example, there are over a quarter million visitor trips to Felsenthal National Wildlife Refuge annually. Fishing is the predominant activity of these trips. The economic value of fishing in Ashley, Bradley, Calhoun, Columbia, Ouachita, and Union counties is estimated at over $11 million dollars annually. Impacts on associated local businesses such as grocery stores, bait and tackle shops, lodging, gasoline and boat sales, and rentals are currently unknown but assumed to be severe.

Mercury Problem is Nationwide

There are currently 28 other states besides Arkansas that have issued mercury advisories. Continued sampling in Arkansas and discussions with other states and federal agencies lead to the following conclusions:

Extent of Statewide Mercury Contamination is Unknown

1. The problem exists in both the rivers and associated oxbow lakes in the Lower Ouachita and Saline River areas.
2. Data are very spotty outside these areas but the data does suggest there may be other areas in the State that have a similar problem.
3. There are large areas of the State where there is no information because no samples have been collected.
4. There is a need to expand the studies because of the potential impact on the health of Arkansas citizens and tourists.

IV. HOW FISH GET CONTAMINATED BY MERCURY

Simple Presence of Mercury Not Enough

Special Conditions Must Occur to Get Methyl Mercury

During the 1970's, mercury contamination was found in fish and resulted in deaths in Japan, Sweden, and several other countries. Although research in this area is on-going, these early studies provided a basis for how mercury gets into fish. The simple presence of mercury in water or sediment is not sufficient to cause a problem. There are special conditions that have to occur before mercury can be converted to a form that can be taken up by fish or by the organisms that fish eat. These conditions include sediment or water that contains substantial organic matter (e.g., dead leaves, organic waste discharges from municipalities or industries), is devoid of oxygen (called anaerobic), and that contains a bacteria that lives in anaerobic environments (these bacteria are naturally occurring and are found everywhere). Under these special conditions, mercury can be

converted into methyl mercury, which is the form that can be taken up by fish or the food they eat.

Biomagnification is the Key to Mercury Contamination

When methyl mercury is released into the water, small organisms living in the water accumulate this methyl mercury. As these small organisms are eaten by small fish, the methyl mercury is concentrated in these smaller fish. Concentrations of methyl mercury can be several hundred times higher in the small fish than in the organisms they eat. This is called biomagnification. When the small fish are eaten by bigger fish, methyl mercury is concentrated again by several hundred times. Methyl mercury is concentrated at each step in this food chain from the small organisms in the water to the small fish to be bigger fish to the largemouth bass or top predator fish. The mercury concentration in fish can be over 10,000-100,000 times the mercury concentration found in the water. Because of this magnification up the food chain, the highest mercury concentrations are found in different bass species. Other species such as bluegill or channel catfish are one step down in the food chain, have one step less biomagnification, and, therefore, have lower mercury concentrations. Bottom feeders such as suckers and buffalo are yet another step down the food chain and have even lower mercury concentrations in their edible flesh.

Predator Fish Have Highest Mercury Concentrations

No Problems with Drinking Water, or Swimming

Biomagnification of mercury is why the mercury concentration in Arkansas' waters does not pose a problem for direct human exposure through drinking water. The main source of human exposure to mercury is through the consumption of predator fish such as the different species of bass.

There are three factors that must be present for mercury contamination in fish to exceed advisable limits:

Three Key Conditions Must Exist

1. There must be a source of mercury,
2. Conditions for converting mercury to methyl mercury must occur, and
3. There must be a viable food chain from the small organisms up through the predator fish such as bass.

V. STRATEGIC QUESTIONS, GOALS, AND OBJECTIVES

To resolve the mercury issue in Arkansas, answers are needed to five questions:

Five Strategic Questions Must Be Answered

1. What is the magnitude and statewide distribution of mercury contamination in fish? Are there hot spots where contamination is worse? Are there areas that don't have mercury contaminated fish?
2. What are the risks to the health of Arkansas people and tourists from eating mercury contaminated fish? Are there areas of the State where the risk is significantly higher than others?
3. What are the relative sources and factors contributing to mercury contamination?
4. Have we always had this problem or did it develop recently?
5. What can we do to remediate or manage the problem?

Goals and Objectives of the Strategic Plan

This Strategic Plan was developed to address these five questions. Briefly, the two highest priorities are to protect public health and establish a Mercury Task Force to prepare and implement a work plan to address the mercury issue. Developing communication channels and networks to keep the public informed about the extent of the mercury problem and updates on what is being done to correct this problem is the next highest priority. The final priority items for the Mercury Task Force are identifying the sources of mercury and developing and implementing management and remediation programs. The specific goals and objectives of the Strategic Plan are:

GOAL 1 **Protect human health from detrimental effects of elevated mercury levels in fish.**

Objective 1.1 *Determine statewide distribution of mercury in sport and commercial fish species from high use recreational areas, suspect areas, areas with no data, and areas needing verification of previous testing.*

Objective 1.2 *Determine if any significant correlation exists between the size of fish and the concentration of mercury in edible tissue from high use areas (e.g. Felsenthal National Wildlife Refuge, Columbia County Lake).*

Objective 1.3 *Determine consensus among human health agencies (Arkansas Department of Health, U.S. Food and Drug Administration, U.S. Environmental Protection Agency, medical profession) on appropriate consumption tolerance levels for mercury in Arkansas.*

Objective 1.4 *Perform screening of mercury levels in human blood.*

Objective 1.5 *Develop and implement long term monitoring plan for determining trends of mercury in fish and sediments.*

Objective 1.6 *Determine sediment mercury concentrations and composition in high use recreation areas, suspect areas, areas with no data, and areas needing verification of previous testings. (Second biennium, if needed).*

GOAL 2 Develop a formal framework and secure funding for a statewide Mercury Task Force and salaried coordinator to oversee and facilitate strategic objectives and work plans.

Objective 2.1 *Create and empower a Mercury Task Force comprised of independent salaried coordinator and representatives.from Arkansas Game and Fish Commission, Arkansas Department of Pollution Control & Ecology, Arkansas Department of Health, Ouachita River Institute, and Arkansas Water Resources Center to oversee implementation of goals and objectives of the Mercury Assessment Strategic Plan.*

Objective 2.2 *Hire a salaried coordinator with associated support services to facilitate Mercury Task Force activities.*

Objective 2.3 *Seek and secure funding from state, federal, and private sources to implement Mercury Task Force goals and objectives.*

Objective 2.4 *Create a Mercury Task Force Advisory Group comprised of federal representatives, state representatives, and private entities to act as a resource group for the Mercury Task Force. (Appendix A)*

Objective 2.5 *Initiate a regional mercury workgroup among Arkansas, Louisiana, Texas, and Oklahoma to review and coordinate mercury issues regionally.*

Objective 2.6 *Develop a detailed work plan to address Strategic Plan's goals and objectives including assessment of current state of knowledge and peer review by national experts.*

Objective 2.7 *Develop a detailed work plan for second biennium including the needs for statewide blood screening, sediment sampling and analysis, remedial action assessment, and ecological assessment.*

GOAL 3 Develop public information and education programs to disseminate information and educate the public regarding mercury issues.

Objective 3.1 *Develop information and education vehicles (e.g. newsletters, brochures, videos) for timely communication of Mercury Task Force information.*

Objective 3.2 *Develop public education material (e.g. brochures, video) on health aspects of mercury and consumption advisories.*

Objective 3.3 *Develop a communication network with key civic leaders and interested citizens willing to support and enhance recreational fishing opportunities in waters under a consumption advisory.*

Objective 3.4 *Disseminate information to civic and sportsman's organizations, businesses, schools, fairs, and the general public.*

Objective 3.5 *Participate in national mercury workgroups, seminars, and communication networks to remain current with mercury issues.*

GOAL 4 Investigate, develop, and promote management programs for Arkansas' Natural Resources compatible with existing and anticipated mercury advisories.

Objective 4.1 *Develop and coordinate fisheries management plans (e.g. trophy bass regulations) compatible with consumption advisories.*

Objective 4.2 *Develop and coordinate commercial fishing regulations compatible with consumption advisories.*

Objective 4.3 *Assess remedial technologies to determine viable actions (review, first biennium; detailed assessment, second biennium).*

Objective 4.4 *Implement feasible remedial actions (ongoing review with initiation in first biennium if funds available).*

Objective 4.5 *Perform ecological assessment of mercury on fish/wildlife (second biennium, if needed).*

GOAL 5 Identify potential and probable sources of mercury statewide and regionally.

Objective 5.1 *Identify factors associated with mercury contamination in fish (methylation process)*

Objective 5.2 *Identify and rank relative contributions from atmospheric, geologic and other sources of mercury in Arkansas and regionally (review only, first biennium).*

Objective 5.3 *Investigate historical mercury concentrations to determine how long the problem has existed.*

VI. POTENTIAL IMPACTS ON CURRENT AGENCY ACTIVITIES

Some Agency Priorities Will Change

To accomplish these goals and objectives, some existing or planned activities will be postponed or eliminated. For example, the Arkansas Game and Fish Commission currently does not have the staff to provide

2 person-years of labor to achieve all the goals and objectives of the Mercury Task Force without postponing or eliminating other fisheries management activities. In addition, Amendment 35 of the Arkansas Constitution prohibits the Commission from directly receiving state general revenue. Game and Fish estimate their annual costs to be about $96,500 per year. Different funding mechanisms might be required for the Commission to fully participate in Mercury Task Force activities. The Arkansas Department of Pollution Control and Ecology and Arkansas Department of Health will require additional staff to conduct analyses or will have to contract the additional sample load to support the Mercury Task Force.

VII. SCHEDULE

Biennial Schedule

The schedule for accomplishing these goals and objectives over the next four years is shown in Figure 2. The high priority tasks are scheduled to occur during the first two years. Some of the activities are sequential but many of the activities must be initiated on or before 1 July 1993 for the Mercury Task Force to achieve its goals and objectives by 30 June 1995. Some of the activities will occur continuously over the next four years while other activities will be phased based on the extent of mercury contamination in fish and the results of on-going studies. The need for any additional activities during the second biennium will be determined at the end of the first biennium, based on the findings of the tasks completed during the first biennium.

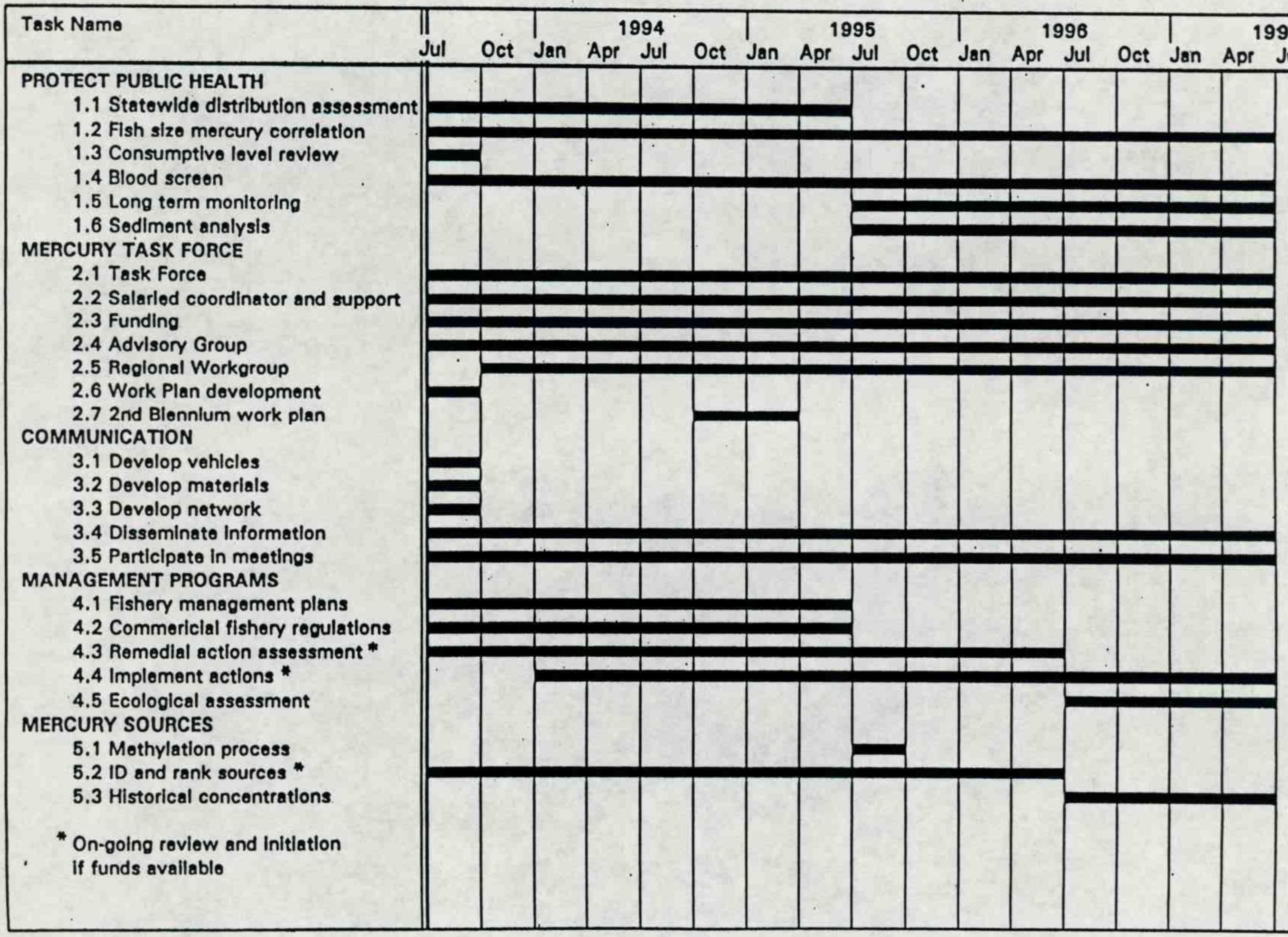


Figure 2. Timeline for Proposed Activities

Appendix A
Mercury Task Force Advisory Group
Possible Membership

Purpose: **Serve as a resource to the Mercury Task Force and aid in communication of Task Force findings to the general public.**

Chair

Governor's Office

Federal Representatives

Department of Agriculture
- Agricultural Stabilization and Conservation Service
- Soil Conservation Service

Corps of Engineers

Department of Health and Human Services
- Public Health Service
  - Food and Drug Administration
  - National Center for Toxicological Research
  - American Toxicological Substance Disease Registry

Department of Interior
- Geological Survey
- Fish & Wildlife Service

State Representatives

Health Service Agency
Industrial Development Commission
Science and Technology Authority
Waterways Commission
Department of Education
Game and Fish Commission
Geological Commission
Department of Health
House of Representatives
Senate
Department of Human Services
Department of Parks and Tourism
Department of Pollution Control & Ecology
Soil & Water Conservation Commission

Private Representatives

Arkansas Environmental Federation
Arkansas Wildlife Federation
Arkansas Nature Conservancy
Sierra Club
Arkansas Water Research Center
Ouachita Research Institute
Arkansas Medical Society

3013-340\app-a.wp

Appendix C

Blood Mercury Formulas

APPENDIX C

Formulas Supplied to Facilitate

Self-Maintenance/Monitoring of Blood Mercury Levels

I. Where Baseline Blood Mercury Levels Are Known:

Short Term Consumption

$$\frac{(20 - \text{ppm in blood}) \times (\text{body weight in lbs})}{400 \times (\text{ppm mercury in fish})} = \text{lbs/vacation}$$

Where 400 is a constant

Long Term Consumption

$$\frac{(20 - \text{ppm in blood}) \times (\text{body weight in lbs})}{2000 \times (\text{ppm in fish})} \text{ lbs/month}$$

Where 2000 is a constant

II. Where Baseline blood Mercury Levels Are Not Known:

Short Term Consumption

$$\frac{\text{Body weight in lbs}}{(\text{ppm mercury in fish}) \times 25} = \text{lbs fish/vacation}$$

Where 25 is a constant

Long Term Consumption

$$\frac{\text{Body weight in lbs}}{(\text{ppm mercury in fish}) \times 150} = \text{lbs fish/month}$$

Where 150 is a constant

III. Formals Based on Amount of Fish Consumed:

Short Consumption (i.e., Vacationers) Pattern

[((400 lbs fish/vacation) x (ppm Hg in fish)/body weight] + 5 ppm

Where 400 is a constant

Extended Consumption Pattern

[((2000 x lbs fish/month)x(ppm Hg in fish)/body weight] + 5 ppm

Where 2000 is a constant

References

Agency for Toxic Substances and Disease Registry (ATSDR). 1992. Case Studies in Environmental Medicine. Mercury Toxicity. No. 17, 1-19

Bloom, N. S., On the Chemical Form of Mercury in Edible Fish and Marine Invertebrate Tissue, Canadian Journal of Fish and Aquatic Science, 49:1010-1017

Choi, C.M., lapham, L.W., Amin-Zaki, L, et al. 1978. Abnormal neuronal migration, deranged cerebral cortical organization and diffuse white matter astrocytosis of human fetal brain: A major effect of methylmercury poisoning in utero. J Neuropathol Exp Neurol 37:719-732

Environmental Protection Agency (EPA), Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1: Fish Sampling and Analysis, EPA 823-R93-002, August, 1993.

Insldp, M.J. and J.K. Piotrowsld. Review of the Health Effects of Methylmercury. Journal of Applied Toxicology, Vol. 5, No. 3, pp 113-127 (1985)

Kershaw, T.G., Clarkson, T.W., Dhahir, P.H., The relationship between blood levels and dose of methylmercury in man. Arch. Environ Health, 1980; 35;(l): 28-36

Jensen, A.A. , Slorach, S.A., Chemical Contaminants in Human Milk, CRC Press, 1991, pp 280-281

Roche Biomedical Laboratories, Biological Monitoring Information Sheet NO. 085324, Mercury Blood, 1992.

Roche Biomedical Laboratories. Mercury: Technical Review. Roche Biomedical Laboratories, Inc. 1992.

World Health Organization (WHO), 1990, Environmental Health Criteria 101: Methylmercury. Geneva, Switzerland.

Appendix D

Mercury Analysis Methodology

METHOD 245.6

DETERMINATION OF MERCURY IN TISSUES BY COLD VAPOR ATOMIC ABSORPTION SPECTROMETRY

Edited by Larry B. Lobring and Billy B. Potter
Inorganic Chemistry Branch
Chemistry Research Division

Revision 2.3
April 1991

ENVIRONMENTAL MONITORING SYSTEMS LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

METHOD 245.6

DETERMINATION OF MERCURY IN TISSUES BY COLD VAPOR ATOMIC ABSORPTION SPECTROMETRY

1. SCOPE AND APPLICATION

1.1 This procedure measures total mercury (organic + inorganic) in biological tissue samples.

1.2 The range of the method is 0.2 to 5 μg/g. The range may be extended above or below the normal range by increasing or decreasing sample size or by optimizing instrument sensitivity.

2. SUMMARY OF METHOD

2.1 A weighed portion of the tissue sample is digested with sulfuric and nitric acid at 58°C followed by overnight oxidation with potassium permanganate and potassium persulfate at room temperature. Mercury in the digested sample is reduced with stannous chloride to elemental mercury and measured by the conventional cold vapor atomic absorption technique.

3. DEFINITIONS

3.1 BIOCHEMICAL OXYGEN DEMAND (BOD) BOTTLE - BOD bottle, 300 ± 2 mL with a ground glass stopper or an equivalent flask, fitted with a ground glass stopper.

3.2 CALIBRATION BLANK - A volume of ASTM type II reagent water prepared in the same manner (acidified) as the calibration standard.

3.3 CALIBRATION STANDARD (CAL) - A solution prepared from the mercury stock standard solution used to calibrate the instrument response with respect to analyte concentration.

3.4 INSTRUMENT DETECTION LIMIT (IDL) - The mercury concentration that produces a signal equal to three times the standard deviation of the blank signal.

3.5 LABORATORY FORTIFIED BLANK (LFB) - An aliquot of ASTM type II reagent water to which known quantities of inorganic and/or organic mercury are added in the laboratory. The LFB is analyzed exactly like a sample, and its purpose is to determine whether method performance is within accepted control limits.

3.6 LABORATORY FORTIFIED SAMPLE MATRIX (LFM) - A portion of a tissue sample to which known quantities of calibration standard are added in the laboratory. The LFM is analyzed exactly like a sample, and its purpose is to determine whether the sample matrix contributes

bias to the analytical results. The background concentrations of the analytes in the sample matrix must be determined in a separate aliquot and the measured values in the LFM corrected for the concentrations found.

3.7 LABORATORY REAGENT BLANK (LRB) - An aliquot of ASTM type II reagent water that is treated exactly as a sample including exposure to all glassware, equipment, and reagents used in analyses. The LRB is used to determine if method analyte or other interferences are present in the laboratory environment, the reagents or apparatus.

3.8 LINEAR DYNAMIC RANGE (LDR) - The concentration range over which the analytical working curve remains linear.

3.9 METHOD DETECTION LIMIT (MDL) - The minimum concentration of mercury that can be identified, measured and reported with 99% confidence that the analyte concentration is greater than zero and determined from analysis of laboratory fortified tissue sample matrix (LFM).

3.10 QUALITY CONTROL SAMPLE (QCS) - A tissue sample containing known concentration of mercury derived from externally prepared test materials. The QCS is obtained from a source external to the laboratory and is used to check laboratory performance.

3.11 TISSUE SAMPLE - A biological sample matrix exposed to a marine, brackish or fresh water environment. It is limited by this method to the edible tissue portion.

3.12 STOCK STANDARD SOLUTION - A concentrated solution containing mercury prepared in the laboratory using assayed mercuric chloride or stock standard solution purchased from a reputable commercial source.

4. INTERFERENCES

4.1 Interferences have been reported for waters containing sulfide, chloride, copper and tellurium. Organic compounds which have broad band UV absorbance (around 253.7 nm) are confirmed interferences. The concentration levels for interferants are difficult to define. This suggests that quality control procedures (Sect. 10) must be strictly followed.

4.2 Volatile materials which absorb at 253.7 nm will cause a positive interference. In order to remove any interfering volatile materials, the dead air space in the BOD bottle should be purged before the addition of stannous chloride solution.

4.3 Interferences associated with the tissue matrix are corrected for in calibration procedure (Sect. 9).

5. SAFETY

5.1 The toxicity and carcinogenicity of each reagent used in this method has not been fully established. Each chemical should be regarded as a potential health hazard and exposure to these compounds should be minimized by good laboratory practices[1]. Normal accepted laboratory safety practices should be followed during reagent preparation and instrument operation. Always wear safety glasses or full-face shield for eye protection when working with these reagents. Each laboratory is responsible for maintaining a current safety plan, a current awareness file of OSHA regulations regarding the safe handling of the chemicals specified in this method [2, 3].

5.2 Mercury compounds are highly toxic if swallowed, inhaled, or absorbed through the skin. Analyses should be conducted in a laboratory exhaust hood. The analyst should use chemical resistant gloves when handling concentrated mercury standards.

5.3 All personnel handling tissue samples should beware of biological hazards associated with tissue samples. Bivalve mollusk may concentrate toxins and pathogenic organisms. Tissue dissection should be conducted in a bio-hazard hood and personnel should wear surgical mask and gloves.

6. APPARATUS AND EQUIPMENT

6.1 ABSORPTION CELL - Standard spectrophotometer cells 10-cm long, having quartz windows may be used. Suitable cells may be constructed from plexiglass tubing, 1-in. O.D. by 4-1/2-in. long. The ends are ground perpendicular to the longitudinal axis and quartz windows (1-in. diameter by 1/16-in. thickness) are cemented in place. Gas inlet and outlet ports (also of plexiglass but 1/4-in. O.D.) are attached approximately 1/2-in. from each end. The cell is strapped to a burner for support and aligned in the light beam to give the maximum transmittance.

6.2 AERATION TUBING - Inert mercury-free tubing is used for passage of mercury vapor from the sample bottle to the absorption cell. In some systems, mercury vapor is recycled. Straight glass tubing terminating in a coarse porous glass aspirator is used for purging mercury released from the tissue sample in the BOD bottle.

6.3 AIR PUMP - Any pump (pressure or vacuum system) capable of passing air at 1 L/min is used. Regulated compressed air can be used in an open one-pass system.

6.4 ATOMIC ABSORPTION SPECTROPHOTOMETER - Any atomic absorption unit having an open sample presentation area in which to mount the absorption cell is suitable. Instrument settings recommended by the particular manufacturer should be followed. Instruments designed specifically for mercury measurement using the cold vapor technique

7.1.8 Sodium Chloride (NaCl), (CASRN 7647-14-5); assayed mercury level is not to exceed 0.05 ppm.

7.1.9 Stannous Chloride ($SnCl_2 \cdot 2H_2O$), (CASRN 10025-69-1); assayed mercury level is not to exceed 0.05 ppm.

7.1.10 Stannous Sulfate ($SnSO_4$), (CASRN 7488-55-3); assayed mercury level is not to exceed 0.05 ppm.

7.1.11 Sulfuric Acid (H_2SO_4), concentrated (sp.gr. 1.84), (CASRN 7664-93-9); assayed mercury level is not to exceed 1 ppb.

7.2 MERCURY CALIBRATION STANDARD - To each volumetric flask used for serial dilutions, acidify with (0.1 to 0.2% by volume) HNO_3 (Sect. 7.1.4). Using mercury stock standard (Sect. 7.3), make serial dilutions to obtain a concentration of 0.1 µg Hg/mL. This standard should be prepared just before analyses.

7.3 MERCURY STOCK STANDARD - Dissolve in a 100-mL volumetric flask 0.1354 g $HgCl_2$ (Sect. 7.1.3) with 75 mL of reagent water (Sect. 7.1.7). Add 10 mL of conc. HNO_3 (Sect. 7.1.4) and dilute to mark. Concentration is 1.0 mg Hg/mL.

7.4 POTASSIUM PERMANGANATE SOLUTION - Dissolve 5 g of $KMnO_4$ (Sect. 7.1.5) in 100 mL of reagent water (Sect. 7.1.7).

7.5 POTASSIUM PERSULFATE SOLUTION - Dissolve 5 g of $K_2S_2O_8$ (Sect. 7.1.6) in 100 mL of reagent water (Sect. 7.1.7).

7.6 SODIUM CHLORIDE-HYDROXYLAMINE SULFATE SOLUTION - Dissolve 12 g of NaCl (Sect. 7.1.8) and 12 g of $(NH_2OH)_2 \cdot H_2SO_4$ (Sect. 7.1.2) or 12 g of $NH_2OH \cdot HCl$ (Sect. 7.1.1) dilute with reagent water (Sect. 7.1.7) to 100 mL.

7.7 STANNOUS CHLORIDE SOLUTION - Add 25 g $SnCl_2 \cdot 2H_2O$ (Sect. 7.1.9) or 25 g of $SnSO_4$ to 250 mL of 0.5 N H_2SO_4 (Sect. 7.8). This mixture is a suspension and should be stirred continuously during use.

7.8 SULFURIC ACID, 0.5 N - Slowly add 14.0 mL of conc. H_2SO_4 (Sect. 7.1.10) dilute to 1 L with reagent water (Sect. 7.1.7).

8. SAMPLE COLLECTION, PRESERVATION AND STORAGE

8.1 Because of the extreme sensitivity of the analytical procedure and the presence of mercury in a laboratory environment, care must be taken to avoid extraneous contamination. Sampling devices, sample containers and plastic items should be determined to be free of mercury; the sample should not be exposed to any condition in the laboratory that may result in contact or airborne mercury contamination.

8.2 The tissue sample should be preserved and dissected in accordance with Method 200.3, "Sample Preparation Procedure for Spectrochemical Determination of Total Recoverable Elements in Biological Tissues", only Sect. 8. Tissue Dissection, is used in this method.

8.3 Weigh 0.2- to 0.3-g portions of each sample and place in the bottom of a dry BOD bottle. Care must be taken that none of the sample adheres to the side of the bottle. Immediately cap and cover the top of the BOD bottle with aluminum foil.

9. CALIBRATION AND STANDARDIZATION

9.1 The calibration curve is prepared from values determined for portions of fortified tissue treated in the manner used for the tissue samples being analyzed. For preparation of the calibration standards, blend a portion of tissue in a Waring blender.

9.2 Transfer accurately weighed portions to each of five dry BOD bottles. Each sample should weigh about 0.2 g. Add 4 mL of conc. H_2SO_4 and 1 mL of conc. HNO_3 to each bottle and place in a water bath maintained at 58°C until the tissue is completely dissolved (30 to 60 minutes).

9.3 Cool and transfer 0.5, 2.0, 5.0 and 10.0 mL aliquots of the CAL (Sect. 7.2) solution containing 0.5 to 1.0 μg of Hg to the BOD bottles containing tissue. Cool to 4°C in an ice bath and cautiously add 15 mL of potassium permanganate solution (Sect. 7.4) and 8 mL of potassium persulfate (Sect. 7.5). Allow to stand overnight at room temperature under oxidizing conditions.

9.4 Construct a standard curve by plotting peak height or maximum response of the standard (obtained in Sect. 11.7) versus micrograms of mercury contained in the bottles. The standard curve should comply with Sect. 10.2.3. Calibration using computer or calculator based regression curve fitting techniques on concentration/response data is acceptable.

10. QUALITY CONTROL

10.1 Each laboratory using this method is required to operate a formal quality control (QC) program. The minimum requirements of this program consist of an initial demonstration of laboratory capability by analyses of laboratory reagent blanks, fortified blanks and samples used for continuing check on method performance. Standard Reference Materials (SRMs)[5, 6] are available and should be used to validate laboratory performance. Commercially available tissue reference materials are acceptable for routine laboratory use. The laboratory is required to maintain performance records that define the quality of data generated.

10.2 INITIAL DEMONSTRATION OF PERFORMANCE

10.2.1 The initial demonstration of performance is used to characterize instrument performance (MDLs and linear calibration ranges) for analyses conducted by this method.

10.2.2 A mercury MDL should be established using LFM at a concentration of two to five times the estimated detection limit[7]. To determine MDL values, take seven replicate aliquots of the LFM and process through the entire analytical method. Perform all calculations defined in the method and report the concentration values in the appropriate units. Calculate the MDL as follows:

$$MDL = (t) \times (S)$$

where, t = Student's t value for a 99% confidence level and a standard deviation estimate with n-1 degrees of freedom [t = 3.14 for seven replicates].

S = standard deviation of the replicate analyses.

A MDL should be determined every six months or whenever a significant change in background or instrument response is expected (e.g., detector change).

10.2.3 Linear calibration ranges - The upper limit of the linear calibration range should be established for mercury by determining the signal responses from a minimum of three different concentration standards, one of which is close to the upper limit of the linear range. Linear calibration ranges should be determined every six months or whenever a significant change in instrument response is observed.

10.3 ASSESSING LABORATORY PERFORMANCE - REAGENT AND FORTIFIED BLANKS

10.3.1 The laboratory must analyze at least one LRB (Sect. 3.7) with each set of samples. LRB data are used to assess contamination from the laboratory environment and to characterize spectral background from the reagents used in sample processing. If an mercury value in a LRB exceeds its determined MDL, then laboratory or reagent contamination is suspect. Any determined source of contamination should be corrected and the samples reanalyzed.

10.3.2 The laboratory must analyze at least one LFB (Sect. 3.5) with each batch of samples. Calculate accuracy as percent recovery (Sect. 10.4.2). If the recovery of mercury falls outside control limits (Sect. 10.3.3), the method is judged out of control. The source of the problem should be identified and resolved before continuing analyses.

10.3.3 Until sufficient data (usually a minimum of 20 to 30 analyses) become available, each laboratory should assess its performance against recovery limits of 85-115%. When sufficient internal performance data become available, develop control limits from the percent mean recovery (x) and the standard deviation (S) of the mean recovery. These data are used to establish upper and lower control limits as follows:

UPPER CONTROL LIMIT = x + 3S
LOWER CONTROL LIMIT = x - 3S

After each five to ten new recovery measurements, new control limits should be calculated using only the most recent 20 to 30 data points.

10.4 ASSESSING ANALYTE RECOVERY - LABORATORY FORTIFIED SAMPLE MATRIX

10.4.1 The laboratory must add a known amount of mercury to a minimum of 10% of samples or one sample per sample set, whichever is greater. Select a tissue sample that is representative of the type of tissue being analyzed and has a low mercury background. It is recommended that this sample be analyzed prior to fortification. The fortification should be 20% to 50% higher than the analyzed value. Over time, samples from all routine sample sources should be fortified.

10.4.2 Calculate the percent recovery, corrected for background concentrations measured in the unfortified sample, and compare these values to the control limits established in Sect. 10.3.3 for the analyses of LFBs. A recovery calculation is not required if the concentration of the analyte added is less than 10% of the sample background concentration. Percent recovery may be calculated in units appropriate to the matrix, using the following equation:

$$R = \frac{C_s - C}{s} \times 100$$

where, R = percent recovery
C_s = fortified sample concentration
C = sample background concentration
s = concentration equivalent of fortifier added to tissue sample.

10.4.3 If mercury recovery falls outside the designated range, and the laboratory performance is shown to be in control (Sect. 10.3), the recovery problem encountered with the fortified tissue sample is judged to be matrix related, not system related. The result for mercury in the unfortified sample must be labelled to inform the data user that the results are suspect due to matrix effects.

11. PROCEDURE

11.1 Add 4 mL of conc. H_2SO_4 (Sect. 7.1.10) and 1 mL of conc. HNO_3 (Sect. 7.1.4) to each bottle and place in a water bath maintained at 58°C until the tissue is completely dissolved (30 to 60 min).

11.2 Cool to 4°C in an ice bath and cautiously add 5 mL of potassium permanganate solution (Sect. 7.4) in 1 mL increments. Add an additional 10 mL or more of permanganate, as necessary to maintain oxidizing conditions. Add 8 mL of potassium persulfate solution (Sect. 7.5). Allow to stand overnight at room temperature.

As an alternative to the overnight digestion, tissue solubilization may be carried out in a water bath at 80°C for 30 min. The sample is cooled and 15 mL of potassium permanganate solution (Sect. 7.4) added cautiously followed by 8 mL of potassium persulfate solution (Sect. 7.5). At this point, the sample is returned to the water bath and digested for an additional 90 min at 30°C. Calibration standards are treated in the same manner.

11.3 Turn on the spectrophotometer and circulating pump. Adjust the pump rate to 1 L/min. Allow the spectrophotometer and pump to stabilize.

11.4 Cool the BOD bottles to room temperature and dilute in the following manner:

11.4.1 To each BOD bottle containing the CAL, LFB and LRB, add 50 mL of reagent water (Sect. 7.1.7).

11.4.2 To each BOD bottle containing a tissue sample, QCS or LFM, add 55 mL of reagent water (Sect. 7.1.7).

11.5 To each BOD bottle, add 6 mL of sodium chloride-hydroxylamine sulfate solution (Sect. 7.6) to reduce the excess permanganate.

11.6 Treating each bottle individually:

11.6.1 Placing the aspirator inside the BOD bottle and above the liquid, purge the head space (20 to 30 sec) to remove possible gaseous interferents.

11.6.2 Add 5 mL of stannous chloride solution (Sect. 7.7) and immediately attach the bottle to the aeration apparatus.

11.6.3 The absorbance, as exhibited either on the spectrophotometer or the recorder, will increase and reach maximum within 30 sec. As soon as the recorder pen levels off, approximately 1 min, open the bypass value (or optionally remove aspirator from the BOD bottle if it is vented under the hood) and continue the aeration until the absorbance returns to its minimum value.

11.7 Close the bypass value, remove the aspirator from the BOD bottle and continue the aeration. Repeat step (Sect. 11.6) until all BOD bottles have been aerated and recorded.

12. CALCULATIONS

12.1 Measure the peak height of the unknown from the chart and read the mercury value from the standard curve.

12.2 Calculate the mercury concentration in the sample by the formula:

$$\mu g\ Hg/g = \frac{\mu g\ Hg \text{ in the aliquot}}{\text{wt. of the aliquot in grams}}$$

12.3 Report mercury concentrations as follows: Below 0.1 µg/g, < 0.1 µg/g; between 0.1 and 1 µg/g, to the nearest 0.01 µg; between 1 and 10 µg/g, to nearest 0.1 µg; above 10 µg/g, to nearest µg.

13. PRECISION AND ACCURACY

13.1 The standard deviation for mercury in fish tissue samples are reported as 0.19 ± 0.02 µg Hg/g , 0.74 ± 0.05 µg Hg/g and 0.74 ± 0.05 µg Hg/g with recoveries for LFM being 112%, 93%, and 86%, respectively. These tissue samples were fortified with methyl mercuric chloride.

14. REFERENCES

1. "Safety in Academic Chemistry Laboratories", American Chemical Society Publication, Committee on Chemical Safety, 3rd Edition, 1979.

2. "OSHA Safety and Health Standards, General Industry", (29CFR 1910), Occupational Safety and Health Administration, OSHA 2206, revised January, 1976.

3. "Proposed OSHA Safety and Health Standards, Laboratories", Occupational Safety and Health Administration, Federal Register, July 24, 1986.

4. "Specification for Reagent Water," Annual Book of ASTM Standards, D1193, Vol. 11.01, 1990.

5. National Institute of Standards and Technology, Office of Standards Reference Materials, Gaithersburg, MD 20899: Aquatic Plant - Lagarosiphon major (CRM 8030), Aquatic Plant - Platihypnidium riparioides (CRM 8031), Oyster Tissue (SRM 1566a), Albacore Tuna (RM 50).

6. National Research Council of Canada, Marine Analytical Chemistry Standards Program, Division of Chemistry, Montreal Road, Ottawa, Ontario K1A OR9, Canada: Dogfish Liver (DOLT-1), Dogfish Muscle (DORM-1), Non Defatted Lobster Hepatopancreas (LUTS-1), Lobster Hepatopancreas (TORT-1).

7. Code of Federal Regulations 40, Ch. 1, Pt. 136 Appendix B.

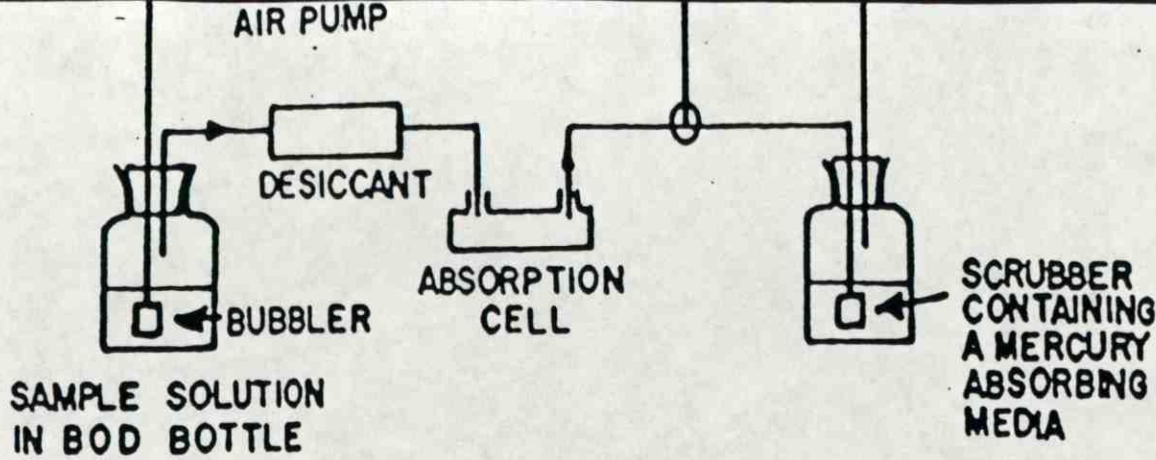


Figure 1. Apparatus for Flameless Mercury Determination

Because of the toxic nature of mercury vapor, inhalation must be avoided. Therefore, a bypass has been included in the system to either vent the mercury vapor into a exhaust hood or pass the vapor through some absorbing media, such as:
a) equal volumes of 0.1 N $KMnO_4$ and 10% H_2SO_4
b) 0.25% iodine in a 3% KI solution.

A specially treated charcoal that will absorb mercury vapor is also available from Barnebey and Cheney, P.O. Box 2526, Columbus, OH 43216, Catalog No. 580-13 or 580-22.

*U.S. Government Printing Office: 1991 — 548-187/40551

Table 2.3. Fish tissue mercury concentrations for sampled lakes and streams. The data are sorted by ecoregions.

Arkansas River Valley
(Lakes)

Waterbody Collected	Area Collected	Date Collected	Species Collected	Length Range (mm)	Quantity in sample	Mercury Content (ppm)
Atkins		07/06/93	Largemouth bass	302 - 360	5	0.28
				415 - 458	4	0.42
Bailey		06/16/92	Channel catfish	508 - 673	3	0.87
		07/23/93	Largemouth bass	300 - 305	5	0.56
Blue Mountain	Crow Creek	07/18/91	Channel catfish	406 - 432	3	0.3
			Largemouth bass	219 - 368	3	1.07
		07/20/93	Largemouth bass	290 - 344	5	0.6
	Hise Hill Access	02/16/93	Largemouth bass	293 - 415	5	0.6
			White crappie	226 - 263	5	0.19
Brewer		07/22/92	Largemouth bass	267 - 343	3	0.22
		07/23/93	Largemouth bass	300 - 303	5	0.18
				400 - 405	3	0.33
Conway		08/24/93	Largemouth bass	338 - 399	5	<0.10
				420 - 540	3	0.55
Cove		07/22/92	Largemouth bass	305 - 337	3	0.73
Greenwood		06/08/94	Largemouth bass	295 - 405	5	0.35
Harris Brake		07/23/93	Largemouth bass	295 - 360	6	<0.10
				400 - 524	2	0.31
Maumelle	Jim's Island and above	11/09/93	Largemouth bass	360 - 396	5	0.56
				406 - 480	3	0.74
Nimrod	Upper	08/05/91	Channel catfish	540 - 546	2	0.65
			Largemouth bass	305 - 387	3	1.26
	Sunlight Bay Access Area	02/16/93	Largemouth bass	290 - 463	5	0.6
			White crappie	233 - 260	5	0.25
		10/11/93	Largemouth bass	293 - 395	6	0.47
				493 - 531	2	1.23
Overcup		07/23/93	Largemouth bass	325 - 357	5	0.16
				401 - 461	3	0.23
Paris City		10/11/93	Largemouth bass	295 - 358	6	0.31
				392 - 402	4	0.39

Table 2.3. Continued.

Delta
(Lakes)

Waterbody Collected	Area Collected	Date Collected	Species Collected	Length Range (mm)	Quantity in sample	Mercury Content (ppm)
Grampus		04/26/93	Largemouth bass	320 - 417	5	0.34
Grand		04/28/93	Largemouth bass	319 - 508	5	0.22
Horseshoe		04/28/93	Largemouth bass	310 - 378	5	<0.10
				421 - 466	2	0.16
Old River	Steel Bend	11/24/93	Largemouth bass	345 - 369	5	<0.10
				460 - 488	3	0.15
Peckerwood		08/27/93	Black crappie White crappie	222 - 308 258 - 279	2 3	0.2
			Largemouth bass	466 - 471	2	0.68
Portia Bay		08/05/93	Crappie	261 - 340	5	0.14
			Largemouth bass	399 - 478	3	0.62
Shirey Bay		08/05/93	White crappie	225 - 322	5	0.27
Storm Creek		04/26/93	Largemouth bass	310 - 359	5	0.2
				403 - 434	3	0.4
Wallace		04/21/93	Largemouth bass	285 - 540	5	0.61
Wilson		04/26/93	Largemouth bass	310 - 510	5	0.55
White River oxbow lakes						
DeValls Bluff Basin Oxbow		08/24/93	Largemouth bass	313 - 385	5	0.6
				413	1	0.76
Horseshoe	near DeValls Bluff	08/24/93	White crappie	230 - 267	5	0.26
Moon	Monroe County	08/26/93	White crappie	227 - 239	5	0.27
Taylor Bay		08/25/93	Largemouth bass	321 - 363	5	0.4
Upshaw		08/24/93	Crappie	177 - 230	5	0.25

Table 2.3. Continued.

Delta (Rivers and Bayous)

Waterbody Collected	Area Collected	Date Collected	Species Collected	Length Range (mm)	Quantity in sample	Mercury Content (ppm)
Arkansas River	Pendleton bridge area	07/10/94	Largemouth bass	2	340 - 400	<0.10
				2	408 - 515	0.30
Bayou Bartholomew	near Baxter	06/29/93	Channel catfish	330 - 375	2	0.37
			Largemouth bass	235 - 325	4	1.29
				465	1	0.72
	near Little Bayou	06/25/93	Largemouth bass	230 - 325	4	0.97
	near state line	10/13/93	Blue catfish	360 - 395	3	0.80
				411 - 471	2	0.75
Bayou DeView	near Weiner	10/11/93	Largemouth bass	317 - 335	2	0.36
				410	1	0.36
	around Hwy. 17 bridge	05/31/94	Largemouth bass	306-308	4	0.52
			White crappie	271 - 370	4	0.62
Bayou Meto	near mouth	06/15/94	Largemouth bass	309 - 360	3	0.28
				426 - 494	4	0.5
Black River	above Hwy. 62 east of Corning	09/27/94	White crappie	229 - 252	3	0.39
			Smallmouth buffalo	550 - 670	3	0.44
			Drum	366 - 510	3	0.79
	near Lynn	07/21/93	Flathead catfish	305 - 325	3	0.22
			Spotted bass	381 - 410	3	0.93
Boeuf River	north of Hwy. 52	05/05/94	White crappie	241 - 317	4	<0.10
Cache River	above Hwy. 70 bridge	05/31/94	White crappie	254 - 291	5	0.24
Canal No. 43	near McArthur and Hwy. 1	10/10/93	Largemouth bass	325 - 400	5	<0.10
				430 - 440	2	<0.10
Current River	above Johnston's Eddy	09/27/94	Black bass	289 - 314	4	0.46
			Black crappie	221 - 281	5	0.35
			Smallmouth buffalo	490 - 590	3	0.59
St. Francis River	near Tulot	08/04/93	White crappie	190 - 245	5	0.10
	Huxtable Pump Station	11/30/92	Largemouth bass	282 - 362	3	0.27

Table 2.3. Continued.

Gulf Coastal Plain
(Lakes)

Waterbody Collected	Area Collected	Date Collected	Species Collected	Length Range (mm)	Quantity in sample	Mercury Content (ppm)
Benjamin		12/02/92	Bluegill	177 - 196	5	0.52
			Largemouth bass	373 - 432	5	1.56
Big Johnson		12/07/92	Black crappie	222 - 280	5	0.31
			Largemouth bass	337 - 506	5	1.71
Bois d'Arc		04/13/93	Largemouth bass	325 - 455	5	<0.10
Bradley County Park		04/16/93	Channel catfish	372 - 385	4	0.93
			Largemouth bass	440 - 510	5	0.70
Calion		09/17/91	Largemouth bass	337 - 508	5	1.02
		02/16/93	Largemouth bass	311 - 483	5	0.41
		03/24/93	Largemouth bass	415 - 438	4	0.87
Cane Creek		05/11/93	Largemouth bass	270 - 500	3	1.01
		07/27/93	Largemouth bass	265 - 376	7	0.24
				272 - 350	6	0.26
				415	1	0.66
Columbia	see inch class study, also	10/07/92	Largemouth bass	412 - 554	3	1.36
Cox Creek		06/23/92	Largemouth bass	292 - 343	5	0.63
		10/27/93	Largemouth bass	340 - 345	2	0.35
				410 - 505	3	0.58
Crane		09/27/93	Largemouth bass	305 - 340	3	0.99
Eagle		12/07/92	Channel catfish	553 - 670	2	1.54
			Largemouth bass	312 - 462	3	2.45
Erling		01/01/92	Largemouth bass	368 - 508	3	1.14
		03/05/93	Channel catfish	483	1	0.21
			Largemouth bass	362 - 432	3	0.55
		04/12/93	Largemouth bass	380 - 475	5	0.60
Felsenthal Reservoir	Shallow Lake	09/17/92	Bluegill	170 - 200	5	0.60
			Largemouth bass	328 - 428	4	0.59

Table 2.3. Continued.

Gulf Coastal Plain
(Lakes)

Waterbody Collected	Area Collected	Date Collected	Species Collected	Length Range (mm)	Quantity in sample	Mercury Content (ppm)
Felsenthal Reservoir (continued)	Lapile Cr.	09/10/92	Black crappie		5	1.19
	Wildcat	09/21/92	Black crappie	211 - 304	5	1.50
			Bluegill	175 - 199	5	0.93
			Largemouth bass	321 - 489	5	1.91
First Old River		05/03/93	Largemouth bass	320 - 370	5	0.16
				403 - 435	3	0.26
Georgia-Pacific		04/29/94	Largemouth bass	300 - 382	4	0.32
				413 - 515	2	0.79
Grays		02/08/93	Largemouth bass	337 - 520	5	1.08
			Crappie	225 - 300	5	0.43
Greens		12/07/92	Bluegill	141 - 190	5	0.83
			Largemouth bass	360 - 500	5	2.06
			White crappie	324 - 397	5	1.42
Jones		12/07/92	Bluegill	178 - 213	5	0.76
			Largemouth bass	398 - 518	5	3.17
		12/01/94	Largemouth bass	346 - 374	4	1.60
				427 - 455	2	3.03
June		02/09/93	Largemouth bass	381 - 520	3	0.09
Millwood	4-State bass tournament	04/24/93	Largemouth bass	430 - 550	5	0.77
	Okay Landing Area	04/26/93	Channel catfish	450 - 565	4	0.16
			Black crappie White crappie	260 305 - 320	3	0.18
			Largemouth bass	340 - 410	5	0.37
	State Park Area	05/06/93	Largemouth bass	305 - 355	5	0.39
				420 - 490	3	1.01
		08/25/93	Largemouth bass	445 - 521	5	0.57
		09/11/93	Largemouth bass	426 - 478	4	0.27
Pine Bluff		11/05/93	Largemouth bass	312 - 337	3	<0.10

Table 2.3. Continued.

Gulf Coastal Plains
(Rivers, Bayous, Streams and Creeks)

Waterbody Collected	Area Collected	Date Collected	Species Collected	Length Range (mm)	Quantity in sample	Mercury Content (ppm)
Saline River Continued	Fitzhugh access	10/27/92	Black crappie	200 - 276	4	0.56
			Largemouth bass Spotted bass	365 - 436 285 - 390	3 2	0.86
	Jenkins Ferry	10/23/92	Black crappie	197 - 252	5	0.61
			Bluegill	135 - 150	4	0.25
			Spotted bass	302 - 411	5	0.78
	Lees Ferry	10/23/92	Black crappie	195 - 221	4	0.68
	Lees Ferry (continued)	10/23/92	Bluegill	175 - 190	5	0.36
			Channel catfish	254 - 579	5	0.81
			Spotted bass	280 - 405	5	0.64
	Mt. Elba	10/22/92	Black crappie	206 - 225	5	0.78
			Bluegill	169 - 198	5	0.60
			Channel catfish	455 - 600	2	1.13
			Largemouth bass Spotted bass	341 - 391 366 - 386	2 2	0.93
	at Hwy. 4	10/22/92	Black crappie	223 - 315	5	1.15
	Hwy. 4 continued	10/22/92	Bluegill	165 - 192	5	0.60
			Channel catfish	352 - 389	3	0.69
			Largemouth bass	352 - 483	5	1.32
	Ashley and Bradley Counties	10/02/92	Flathead catfish	485 - 552	5	1.00
			Largemouth bass	254 - 298	2	1.13
			Spotted bass	406	1	1.70
	below L'Aigle Creek	09/21/92	Bluegill	178 - 209	5	0.49
			Black crappie White crappie	165 - 270 322	3 1	1.50
			Largemouth bass	393 - 472	5	1.78
Smackover Creek	near mouth	10/06/92	Bluegill	180 - 193	5	0.65
			Black crappie White crappie	203 272	1 1	0.65

Table 2.3. Continued.

Gulf Coastal Plains
(Rivers, Bayous, Streams and Creeks)

Waterbody Collected	Area Collected	Date Collected	Species Collected	Length Range (mm)	Quantity in sample	Mercury Content (ppm)
Smackover Creek	near mouth continued	10/06/92	Largemouth bass	283 - 335	2	0.97
Sulphur River	Miller County	06/30/93	Channel catfish	432 - 457	4	0.34
			Largemouth bass	290 - 390	5	0.54
		08/06/93	Black bass	325 - 360	3	0.32
			Channel catfish	350 - 410	4	0.14
			White crappie	240 - 280	5	0.49

Ouachita Mountain
(Rivers and Streams)

Waterbody Collected	Area Collected	Date Collected	Species Collected	Length Range (mm)	Quantity in sample	Mercury Content (ppm)
Ouachita River	McGuire access	05/19/94	Largemouth bass	312 - 335	2	0.60
			Spotted bass	305 - 350	5	0.41
	Cherry Hill access	05/20/94	Largemouth bass	408 - 494	3	0.89
			Spotted bass	314 - 326	4	0.65
	Oden access	05/02/94	Largemouth bass	340 - 396	2	0.98
			Spotted bass	326 - 394	3	
		05/19/94	Largemouth bass	283 - 341	3	0.24
			Spotted bass	307 - 373	3	0.79
Rolling Fork River	west of Gillham	10/20/94	Green sunfish	170 - 200	5	0.26
			Flathead catfish	370	1	0.35
			Yellow bullhead	130	1	
			Golden redhorse (whole fish)	220 - 330	3	0.10
South Fork Caddo River	near Hopper	10/21/94	Smallmouth bass	238	1	0.41
			Spotted bass	185 - 294	3	

Table 2.3. Continued.

Ouachita Mountain
(Lakes)

Waterbody Collected	Area Collected	Date Collected	Species Collected	Length Range (mm)	Quantity in sample	Mercury Content (ppm)
Huston (USDA-USFS)	Perry County	04/20/94	Largemouth bass	332 - 354	4	0.39
				416	1	0.83
Degray	Point Cedar Use Area	09/17/91	Channel catfish	502 - 622	3	0.25
			Flathead catfish	635 - 868	2	0.52
		04/18/94	Largemouth bass	302 - 358	5	0.27
				406 - 552	3	0.88
DeQueen	Oak Grove Use Area	10/20/94	Largemouth bass	325 - 400	4	0.27
Dierks	near dam	10/21/94	Largemouth bass	305 - 320	2	0.56
			Spotted bass	335 - 400	3	0.31
Dry Fork (USDA-USFS)		04/11/94	Largemouth bass	302 - 374	3	0.64
			White crappie	213 - 342	4	0.63
Gillham		04/21/93	Largemouth bass	324 - 445	5	0.68
Greeson	Bear Creek Arm	08/14/91	Channel catfish	400 - 464	3	0.29
			Largemouth bass	343 - 406	4	0.37
Hamilton		05/21/93	Largemouth bass	290 - 378	5	0.41
Irons Fork		10/12/93	Largemouth bass	331 - 374	5	0.48
Norrell		11/02/93	Largemouth bass	340 - 385	5	0.47
				420 - 480	3	0.65
Ouachita	nr Mountain Harbor	05/04/94	Largemouth bass	328 - 385	5	0.41
				445 - 500	3	0.82
Shady		04/26/93	Largemouth bass	309 - 360	5	0.38
Wilhelmina		10/25/94	Largemouth bass	314 - 396	4	0.64
				442	1	0.64
Winona		06/04/92	Largemouth bass	318 - 349	5	0.86
		11/05/93	Largemouth bass	381 - 393	5	0.54
				428 - 485	3	0.96

Table 2.3. Continued.

Ozark Highlands
(Lakes)

Waterbody Collected	Area Collected	Date Collected	Species Collected	Length Range (mm)	Quantity in sample	Mercury Content (ppm)
Avalon		06/09/93	Largemouth bass	302 - 337	5	0.25
				427 - 450	3	0.22
Beaver	Joe Creek nr. Horseshoe Bend Rec. Area	08/23/94	Largemouth bass	351 - 374	3	0.18
			Spotted bass	354 - 397	3	0.24
Bull Shoals	West Sugar Loaf	05/04/93	Largemouth bass	329 - 360	5	0.21
				413 - 448	3	0.56
	Mountain Creek	05/02/93	Largemouth bass	337 - 380	5	0.56
	Howard Creek	05/01/93	Largemouth bass	Unavailable		0.93
	Trimble Creek arm	05/01/94	Largemouth bass	331 - 360	5	<0.10
				405 - 408	3	0.38
Crystal		05/20/93	Largemouth bass	310 - 333	6	0.33
				478 - 502	3	0.49
Norfork	Pigeon Creek	05/20/93	Largemouth bass	341 - 372	5	0.35
				409 - 421	3	0.43
	Float Creek	05/05/93	Largemouth bass	312 - 365	5	0.39
				409 - 472	3	0.7
	Shoal Creek	05/03/93	Largemouth bass	341 - 371	6	0.45
				408 - 420	3	0.47
	1st cove south of Hwy. 62 bridge	04/27/94	Largemouth bass	307 - 355	5	<0.10
SWEPCO		04/06/93	Largemouth bass	302 - 389	5	<0.10

Table 2.3. Continued.

Ozark Highlands
(Rivers, Streams and Creeks)

Waterbody Collected	Area Collected	Date Collected	Species Collected	Length Range (mm)	Quantity in sample	Mercury Content (ppm)
Buffalo River	Buffalo Point	10/29/93	Smallmouth bass	257 - 298	5	0.15
	0.25 miles above White River confluence	08/08/93	Largemouth bass	339 - 396	5	<0.10
Crooked Creek	Lower	07/26/93	Smallmouth bass	293 - 350	5	<0.10
	Upper	08/26/93	Smallmouth bass	255 - 293	2	<0.10
Current River	Johnson's Eddy - upstream from Reyno	09/09/93	Largemouth bass	300 - 335	2	0.49
			Spotted bass	300 - 395	4	0.5
				416 - 425	2	0.52
Eleven Point River	near confluence with Black River	09/07/93	Largemouth bass	318 - 357	2	0.56
			Spotted bass	300 - 375	3	
	nr. Warm Springs	09/26/94	Smallmouth bass	280 - 467	4	0.60
			Golden redhorse	337 - 391	5	0.20
Illinois River	Washington County off Robinson Road	10/07/93	Largemouth bass Spotted bass	316 368 - 380	1 4	0.2
Kings River	near Grandview	08/16/93	Largemouth bass	356 - 406	2	0.33
			Smallmouth bass	279 - 419	3	0.46
			Spotted bass	254 - 406	2	0.75
Osage Creek	below Berryville	08/17/93	Largemouth bass	260 451	4	0.4
			Spotted bass	254 - 343	4	0.42
Spavinaw Creek	north of Cherokee City	07/19/93	Bluegill	165 - 180	2	0.31
			Rock bass	200, 200	2	
			Spotted bass	250	1	
Spring River	Imboden and Ravenden	09/02/93	Spotted bass	300 - 320	5	0.38
Strawberry River	near Franklin	10/04/93	Largemouth bass	580	1	0.41
			Spotted bass	300 - 363	2	0.33

Table 2.3. Continued.

Ozark Highlands
(Rivers, Streams and Creeks)

Waterbody Collected	Area Collected	Date Collected	Species Collected	Length Range (mm)	Quantity in sample	Mercury Content (ppm)
Strawberry River continued	at Hwy. 167	10/13/93	Spotted bass	287 - 375	5	0.4
	at Poughkeepsie	10/08/93	Smallmouth bass	275 - 290	3	0.31
White River	above dam at Batesville	08/05/93	Largemouth bass Spotted bass	315 - 319 300 - 322	2 3	0.3

Table 2.4. Species specific fish tissue mercury concentrations for fish collected from Felsenthal National Wildlife Refuge. All fish were collected 27 April 1993.

Black bass (Largemouth and Spotted)				
Length Class mm (inches)	Actual Length (mm)	Weight (grams)	Mercury (ppm)	Mean Mercury Content for Length Class (ppm)
508 - 533 (20 - 21)	533	2086	2.46	2.14
	522	2300	1.84	
	510	2200	2.11	
483 - 508 (19 - 20)	501	2500	2.62	2.48
	490	1740	2.33	
457 - 483 (18 - 19)	481	1940	1.83	2.11
	480	1650	2.25	
	472	1430	1.91	
	472	1130	2.83	
	465	1360	1.97	
	462	1550	1.91	
	460	1140	2.62	
	459	1450	1.52	
432 - 457 (17 - 18)	452	1360	2.14	1.78
	449	1400	1.57	
	442	1320	2.18	
	441	1200	1.68	
	437	1260	1.66	
	434	1140	1.47	
406 - 432 (16 - 17)	430	1040	1.13	1.67
	427	1160	1.92	
	424	1080	1.77	
	420	1060	2.29	
	415	870	1.43	
	409	980	1.22	
	409	1010	1.92	
381 - 406 (15 - 16)	406	875	1.29	1.54
	406	850	1.39	
	404	705	2.21	
	403	945	1.10	
	403	850	2.03	
	397	885	1.40	
	396	880	1.81	
	395	760	1.34	
	389	760	1.21	
	383	725	1.24	
	382	780	1.87	

Table 2.4. Continued.

Black bass (Largemouth and Spotted)				
Length Class mm (inches)	**Actual Length (mm)**	**Weight (grams)**	**Mercury (ppm)**	**Mean Mercury Content for Inch Class (ppm)**
356 - 381 (14 - 15)	378	670	1.52	1.44
	378	660	1.90	
	377	580	2.30	
	374	870	1.34	
	373	680	1.57	
	372	720	1.21	
	367	615	1.03	
	366	770	1.17	
	363	620	1.50	
	360	600	1.30	
	360	620	1.69	
	359	550	0.57	
	357	435	1.63	
330 - 356 (13 - 14)	355	640	1.34	1.13
	355	560	1.01	
	354	530	1.15	
	354	575	1.28	
	353	635	1.03	
	351	550	1.17	
	347	680	0.98	
	345	515	1.14	
	343	535	1.14	
	342	575	1.10	
	339	520	1.05	
	339	500	1.27	
	335	560	0.98	
	335	510	0.97	
	334	495	0.86	
	331	390	1.47	
	331	480	1.32	

Table 2.4. Continued.

Black bass (Largemouth and Spotted)				
Length Class mm (inches)	Actual Length (mm)	Weight (grams)	Mercury (ppm)	Mean Mercury Content for Inch Class (ppm)
305 - 330 (12 - 13)	330	460	1.89	1.09
	328	505	1.13	
	328	545	0.87	
	328	500	1.05	
	323	405	0.89	
	322	450	1.49	
	322	385	1.24	
	316	420	0.53	
	315	555	0.74	
	315	440	1.19	
	311	390	1.08	
	311	420	1.14	
	310	380	0.92	
	306	325	1.00	
	305	380	1.13	

White Crappie			
Length Class mm (inches)	Actual Length (mm)	Mercury (ppm)	Mean Mercury Content for Length Class (ppm)
381 - 406 (15 - 16)	405	0.73	0.73
357 - 380 (14 - 15)	378	0.97	0.78
	375	0.69	
	374	0.70	
	370	0.64	
	369	0.85	
	368	0.82	
331 - 356 (13 - 14)	353	0.71	0.65
	345	0.58	
	342	0.73	
	341	0.58	
305 - 330 (12 - 13)	323	0.72	0.72
254 - 305 (10 - 12)	294	0.31	0.36
	293	0.36	
	292	0.26	
	262	0.32	
	260	0.57	

Table 2.4. Continued.

White Crappie			
Length Class mm (inches)	**Actual Length (mm)**	**Mercury (ppm)**	**Mean Mercury Content for Length Class (ppm)**
127 - 254 (5 - 10)	253 245 228 203 152 138	0.37 0.25 0.21 0.32 0.21 0.27	0.27

Black Crappie			
Length Class mm (inches)	**Actual Length (mm)**	**Mercury (ppm)**	**Mean Mercury Content for Length Class (ppm)**
305 - 406 (12 - 16)	405 334 333 307	0.73 1.46 0.88 1.00	1.02
254 - 406 (10 - 11)	265 259 258 255	1.00 0.84 0.71 0.88	0.81
229 - 254 (9 - 10)	253 252 248 242 233 231 231	0.90 0.66 0.65 0.75 0.76 0.70 0.93	0.76
204 - 229 (8 - 9)	227 222 212 208 206 204	0.53 0.73 0.71 0.75 0.78 0.49	0.66

Table 2.4. Continued.

Black Crappie			
Length Class mm (inches)	**Actual Length (mm)**	**Mercury (ppm)**	**Mean Mercury Content for Length Class (ppm)**
178 - 204 (7 - 8)	203 202 201 199 197 193 187 187 187 184 183 180	0.67 0.54 0.66 0.87 0.67 0.54 0.60 0.83 0.64 0.90 0.38 0.81	0.67
153 - 178 (6 - 7)	175 170 169 168 165 165 162 160	0.60 0.47 0.55 0.50 0.51 0.47 0.46 0.50	0.51
102 - 152 (4 - 6)	152 125	0.21 0.37	0.29

Table 2.4. Continued.

Bluegill			
Length Class mm (inches)	**Actual Length (mm)**	**Mercury (ppm)**	**Mean Mercury Content for Inch Class (ppm)**
204 - 229 (8 - 9)	215	0.61	0.59
	213	0.51	
	210	0.44	
	210	0.82	
	209	0.62	
	209	0.53	
	209	0.49	
	208	0.67	
	207	0.68	
	207	0.53	
178 - 203 (7 - 8)	203	0.81	0.53
	203	0.69	
	203	0.68	
	202	0.50	
	202	0.68	
	202	0.53	
	202	0.51	
	198	0.63	
	198	0.43	
	195	0.46	
	193	0.67	
	193	0.38	
	193	0.39	
	192	0.41	
	191	0.29	
	190	0.57	
	185	0.53	
	185	0.40	
	185	0.64	
	182	0.43	
	179	0.47	
	178	0.55	
	178	0.45	

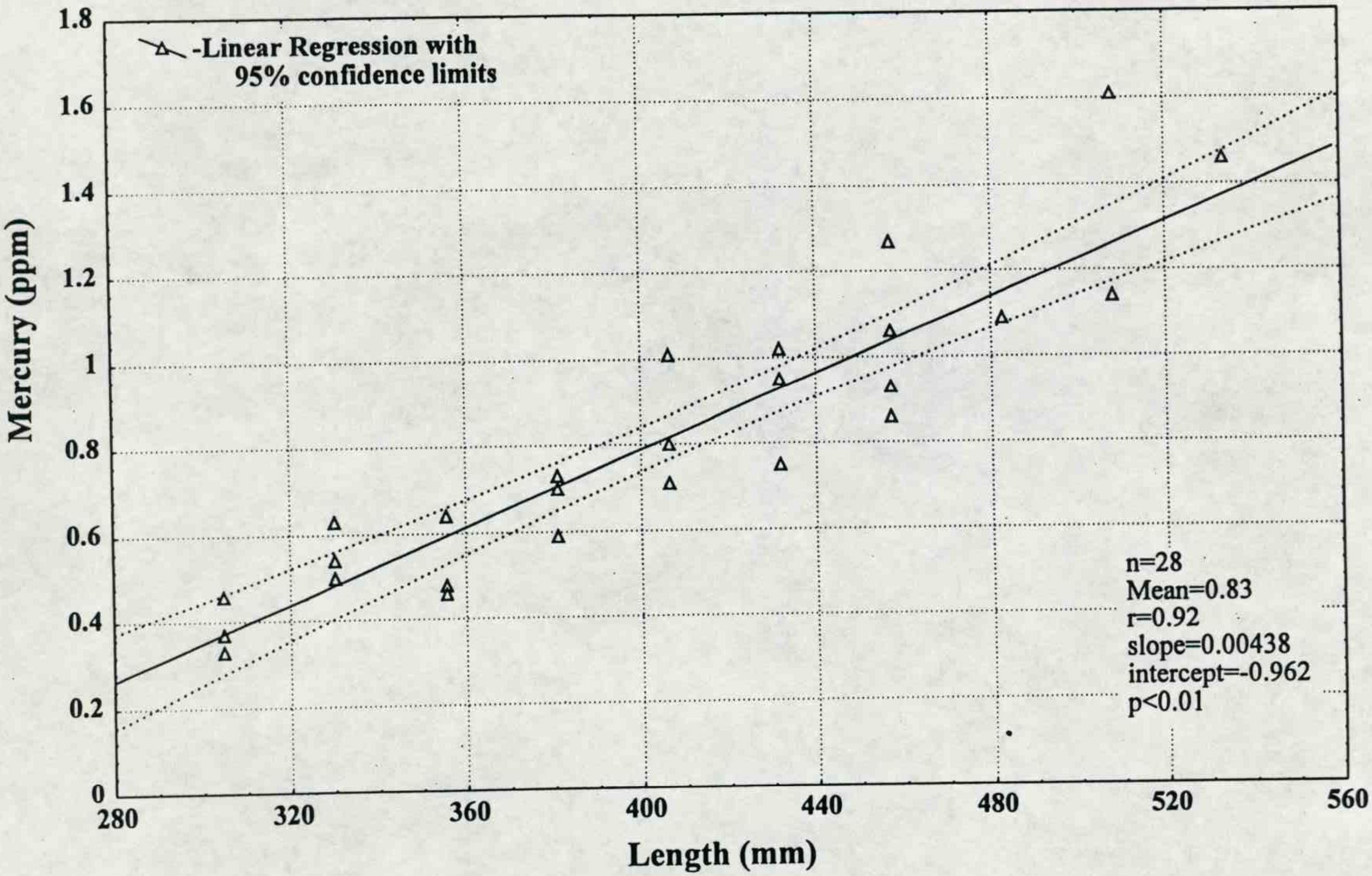


Figure 2.9. Length-fish tissue mercury concentration relationship for Lake Columbia largemouth bass.

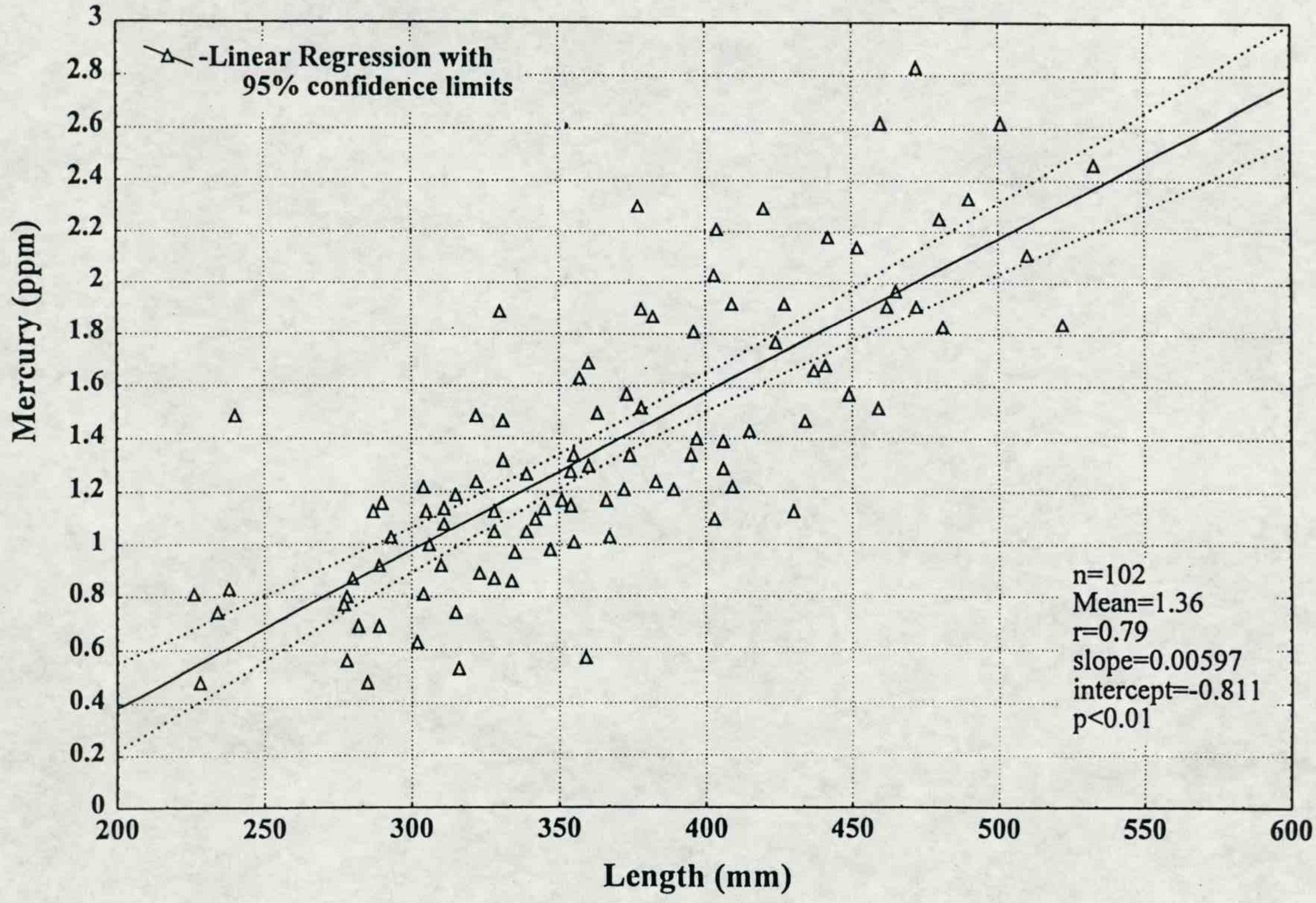


Figure 2.10. Length-fish tissue mercury concnetration relationship for Felsenthal NWR largemouth bass.

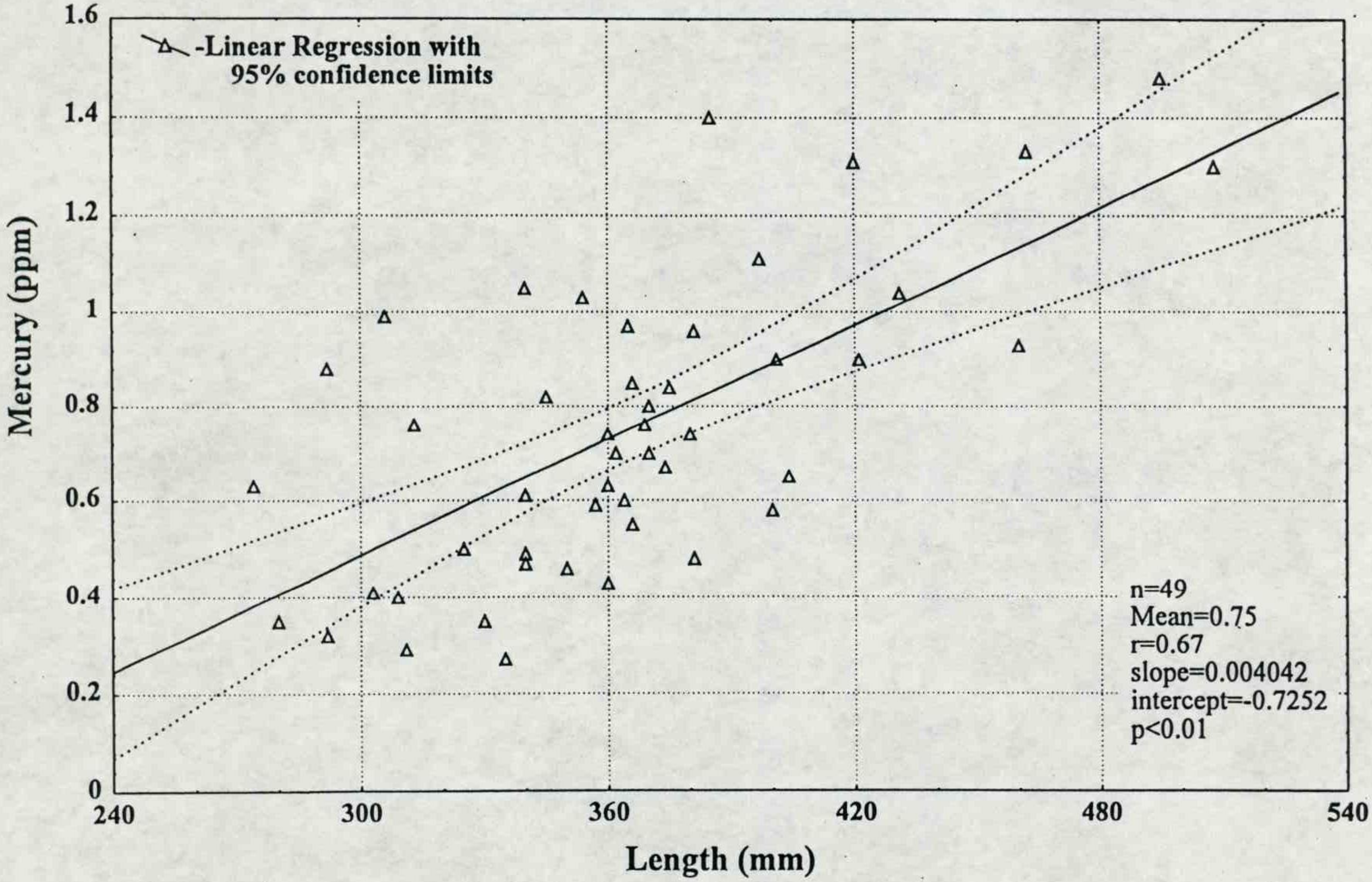


Figure 2.11. Length-fish tissue mercury concentration relationship for Lake Winona largemouth bass.

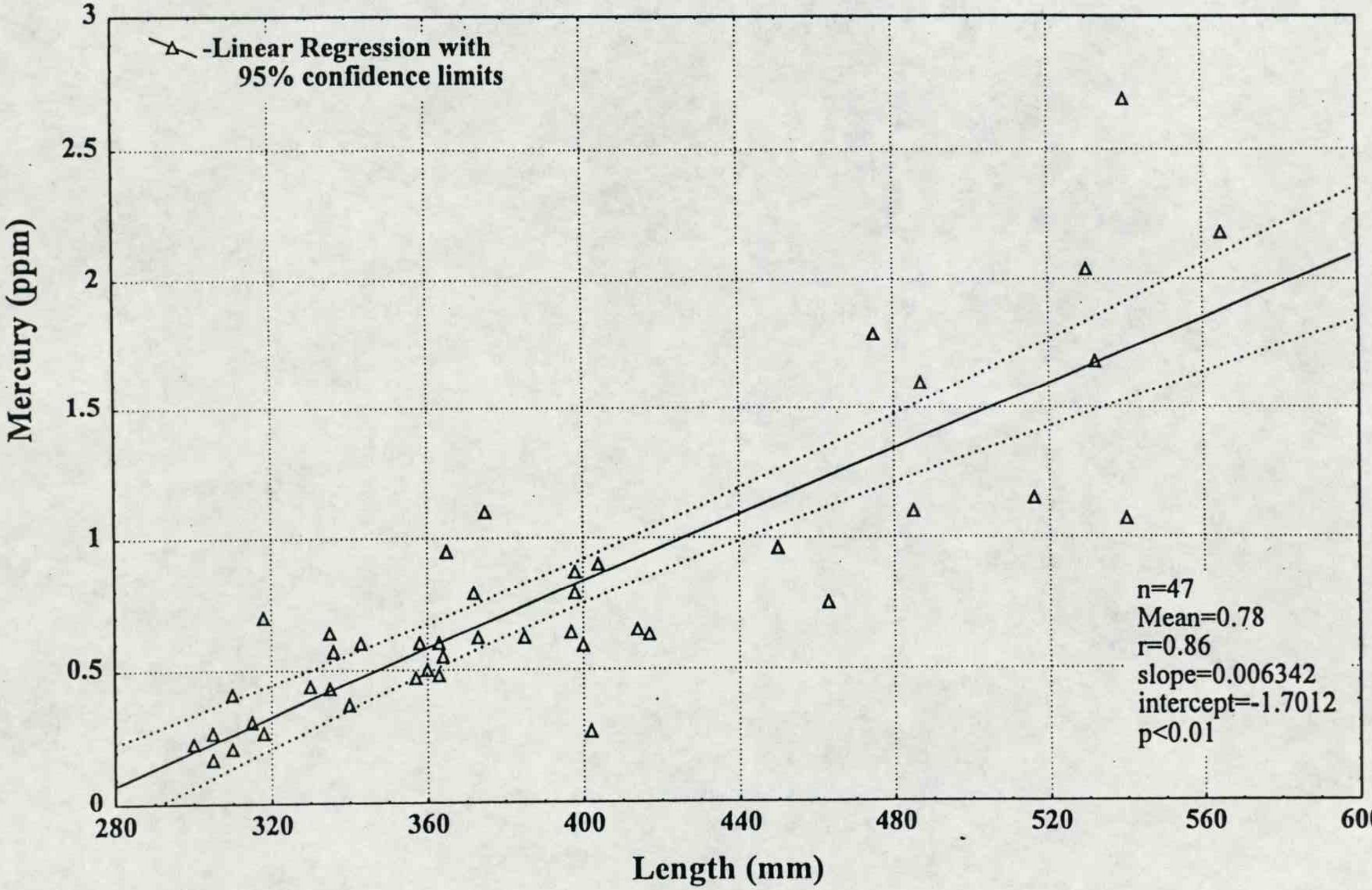


Figure 2.12. Length-fish tissue mercury concentration relationship for Lake Shepherd Springs largemouth bass.

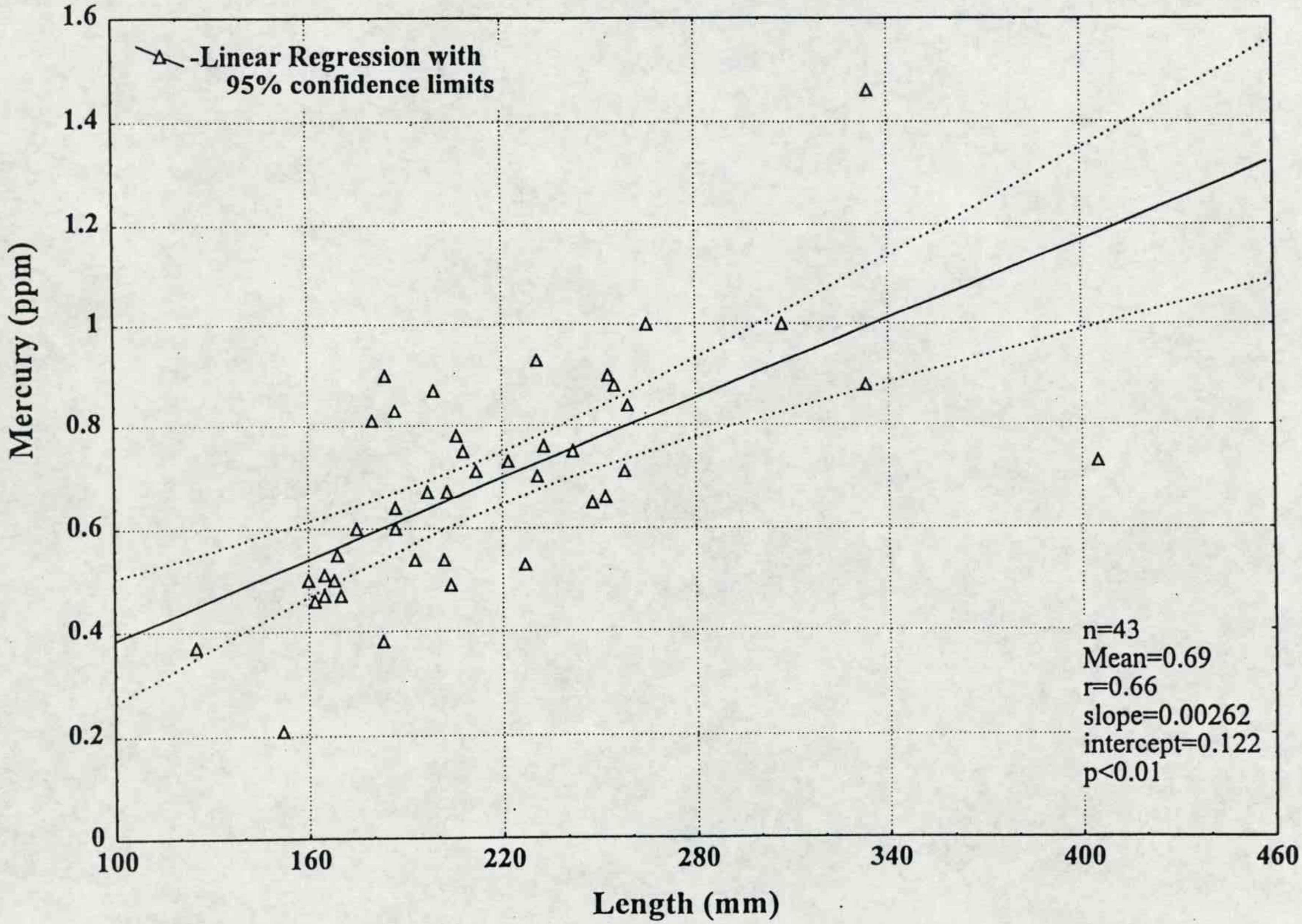


Figure 2.13. Length-fish tissue mercury concentration relationship for Felsenthal NWR black crappie.

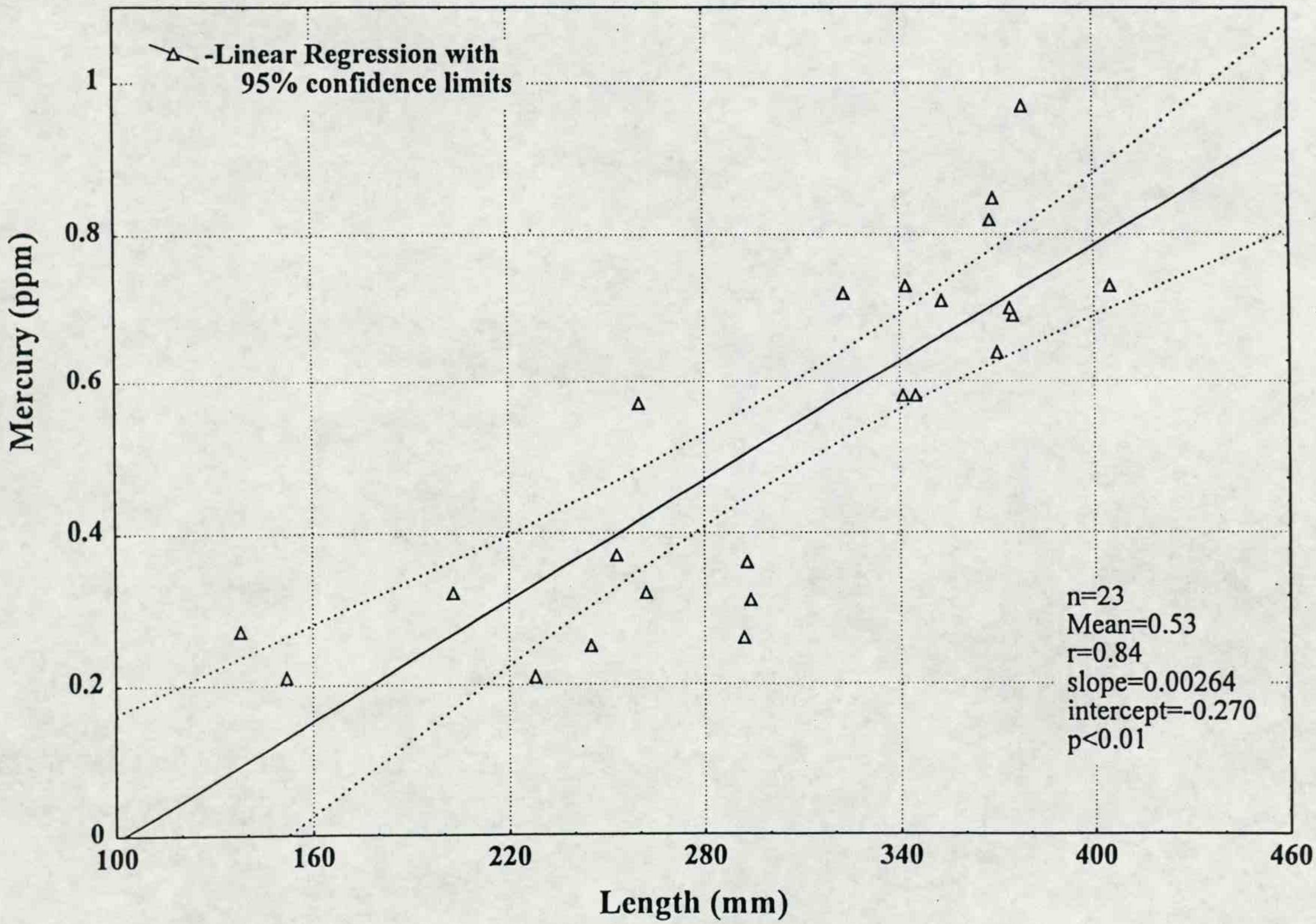


Figure 2.14. Length-fish tissue mercury concentration relationship for Felsenthal NWR white crappie.

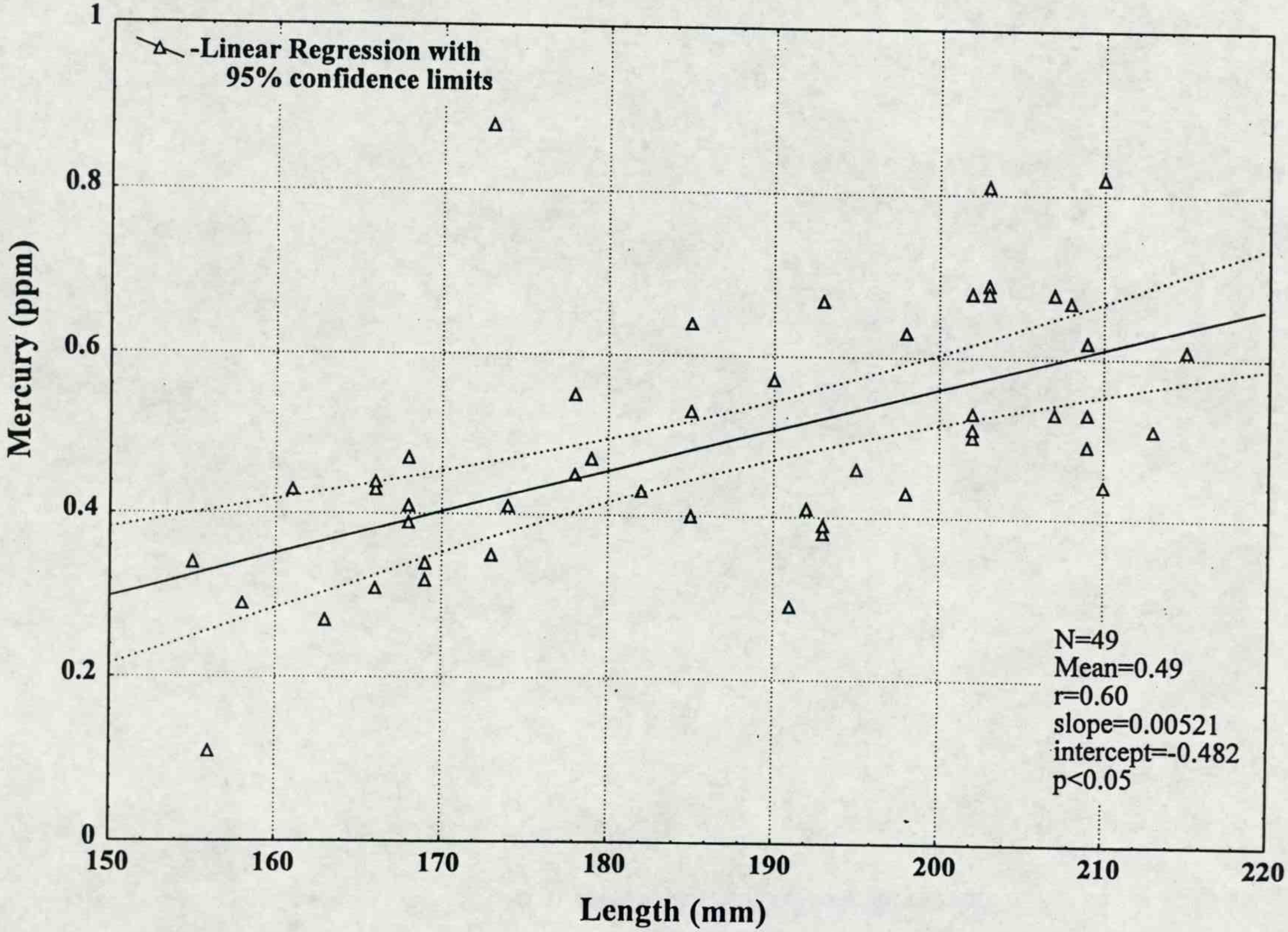


Figure 2.15. Length-fish tissue mercury concentration relationship for Felsenthal NWR bluegill.

Table 2.5. Mercury Concentrations of Blue, Channel and Flathead Catfish from Felsenthal and Calion Lock and Dam.

Lock and Dam	Length (mm)	Weight (g)	Hg Concentration (ppm)
Blue catfish			
Calion	337	350	0.26
Calion	340	370	0.58
Calion	362	405	0.33
Calion	363	450	0.31
Calion	370	400	0.39
Calion	378	515	0.5
Calion	402	610	0.61
Calion	402	610	0.63
Calion	407	535	0.85
Calion	408	565	0.45
Calion	415	650	0.43
Calion	418	570	0.74
Calion	484	990	0.63
Calion	494	1110	0.72
Felsenthal	321	290	0.9
Felsenthal	362	370	1.4
Felsenthal	381	440	1.11
Felsenthal	386	490	0.77
Felsenthal	433	820	1.19
Felsenthal	482	870	1.46
Channel catfish			
Calion	312	285	0.01
Calion	320	320	0.05
Calion	358	420	0.05
Calion	393	555	0.29

Table 2.5. Continued.

Lock and Dam	Length (mm)	Weight (g)	Hg Concentration (ppm)
Calion	395	490	0.14
Calion	405	575	0.24
Calion	407	570	0.35
Calion	431	710	0.19
Calion	448	780	0.24
Calion	462	910	0.48
Calion	465	950	0.4
Felsenthal	339	295	0.96
Felsenthal	377	470	0.25
Felsenthal	397	570	0.89
Felsenthal	465	570	0.85
Felsenthal	475	920	0.61
Felsenthal	501	1070	1.19
Flathead catfish			
Calion	391	660	1.3
Calion	482	1330	1.38
Calion	502	1440	1.19
Calion	578	2200	1.27
Felsenthal	305	270	1.03
Felsenthal	307	200	1.61
Felsenthal	309	320	1.53
Felsenthal	323	350	1.3
Felsenthal	328	355	1.31
Felsenthal	335	460	1.65
Felsenthal	338	390	0.89
Felsenthal	345	410	1.61
Felsenthal	348	410	1.53

Table 2.5. Continued.

Lock and Dam	Length (mm)	Weight (g)	Hg Concentration (ppm)
Felsenthal	370	570	1.46
Felsenthal	380	610	1.71
Felsenthal	383	545	1.9
Felsenthal	384	450	1.24
Felsenthal	387	630	1.72
Felsenthal	393	610	1.48
Felsenthal	393	590	1.75
Felsenthal	396	595	2
Felsenthal	410	630	1.34
Felsenthal	429	805	1.29
Felsenthal	432	710	1.67
Felsenthal	434	810	1.87
Felsenthal	438	835	2.65
Felsenthal	442	930	1.94
Felsenthal	450	920	1.73
Felsenthal	465	1060	2.16
Felsenthal	598	2720	2.9

Table 2.6. Mercury Concentrations in Black Bass from Lake Winona.

Largemouth bass			
Length (mm)	Weight (g)	Mercury (ppm)	Nearest Inch Class
280	230	0.35	11
292	302	0.32	11
303	345	0.41	12
309	369	0.4	12
311	370	0.29	12
313	366	0.76	12
325	435	0.5	13
330	434	0.35	13
335	462	0.27	13
340	443	1.05	13
340	530	0.61	13
340	512	0.49	13
340	419	0.47	13
350	568	0.46	14
357	546	0.59	14
360	700	0.43	14
360	673	0.63	14
362	551	0.7	14
364	571	0.6	14
365	535	0.97	14
366	599	0.55	14
366	610	0.85	14
369	589	0.76	15
369	600	0.76	15
370	670	0.8	15
370	670	0.7	15
374	661	0.67	15
375	687	0.84	15
380	756	0.74	15
381	861	0.96	15
381	702	0.48	15
385	667	1.4	15
400	831	0.58	16
404	1083	0.65	16
420	1006	1.31	17
421	958	0.9	17
431	1026	1.04	17

Largemouth bass continued			
Length (mm)	Weight (g)	Mercury (ppm)	Nearest Inch Class
460	1173	0.93	18
462	1583	1.33	18
495	2165	1.48	19
508	1766	1.3	20

Spotted bass			
Length (mm)	Weight (g)	Mercury (ppm)	Nearest Inch Class
274	310	0.63	11
292	335	0.88	11
306	403	0.99	12
345	654	0.82	14
354	654	1.03	14
360	729	0.74	14
397	1134	1.11	16
401	1078	0.9	16

Table 2.7. Mercury Concentrations in Fish from Shepherd Springs Lake.

Largemouth bass			
Length (mm)	Weight (g)	Mercury (ppm)	Nearest Inch Class
310	363	0.21	12
318	364	0.27	13
402	900	0.27	16
315	408	0.31	12
340	499	0.37	13
310	363	0.41	12
335	499	0.43	13
330	544	0.45	13
357	590	0.47	14
363	600	0.48	14
360	515	0.50	14
360	705	0.51	14
364	590	0.54	14
364	655	0.55	14
336	648	0.57	13
400	905	0.59	16
363	672	0.60	14
358	782	0.60	14
343	518	0.60	14
385	760	0.62	15
373	745	0.62	15
417	1,000	0.63	16
335	590	0.64	13
397	875	0.64	16
414	1,000	0.65	16
318	448	0.70	13
463	1,500	0.75	18
372	665	0.79	15
398	800	0.79	16
404	1,000	0.90	16
365	630	0.95	14
450	1,150	0.96	18
540	2,720	1.07	21
485	810	1.10	19
375	790	1.10	15
516	1,850	1.15	20
487	1,300	1.60	19
532	2,150	1.68	21

Largemouth bass continued			
Length (mm)	Weight (g)	Mercury (ppm)	Nearest Inch Class
475	1,450	1.79	19
530	2,200	2.04	21
565	2,810	2.18	22
540	2,300	2.69	21

Spotted bass			
Length (mm)	Weight (g)	Mercury (ppm)	Nearest Inch Class
305	408	0.17	12
300	318	0.23	12
305	363	0.27	12
330	499	0.44	13
398	900	0.87	16

Table 2.8. Mercury Concentrations in Fish from Arkansas Lakes and Reservoirs (Sorted from highest to lowest concentration).

COLLECTION SITE	SPECIES COLLECTED	DATE	MERCURY (PPM)
JONES LAKE	5 LARGEMOUTH BASS	12/07/92	3.17
JONES LAKE	3 LARGEMOUTH BASS >16"	12/01/94	3.03
SNOW LAKE	1 BOWFIN	12/07/92	2.88
EAGLE LAKE	3 LARGEMOUTH BASS	12/07/92	2.45
GREENS LAKE	2 CHAIN PICKEREL	12/07/92	2.25
EAGLE LAKE	2 BOWFIN	12/07/92	2.19
JONES LAKE	2 CHAIN PICKEREL	12/07/92	2.15
GREENS LAKE	5 LARGEMOUTH BASS	12/07/92	2.06
WILDCAT FELSENTHAL	LARGEMOUTH BASS	09/21/92	1.91
GREENS LAKE	2 BOWFIN	12/07/92	1.90
LAKE PIROQUE	4 LARGEMOUTH BASS	12/02/92	1.75
SHALLOW LAKE LAPILLE CREEK	SPOTTED GAR	09/10/92	1.73
BIG JOHNSON LAKE	5 LARGEMOUTH BASS	12/07/92	1.71
LAKE PIROQUE	2 BOWFIN	12/02/92	1.65
JONES LAKE	2 BOWFIN	12/07/92	1.64
EAGLE LAKE	3 CHAIN PICKEREL	12/07/92	1.62
JONES LAKE	4 LARGEMOUTH BASS	12/01/94	1.60
LAKE BENJAMIN	5 LARGEMOUTHBASS	12/02/92	1.56
EAGLE LAKE	2 CHANNEL CATFISH	12/07/92	1.54
WILDCAT FELSENTHAL	BLACK CRAPPIE	09/21/92	1.50
LAKE BENJAMIN	2 CHAIN PICKERAL	12/02/92	1.48
LAKE BENJAMIN	2 SPOTTED GAR	12/02/92	1.46
SNOW LAKE	5 LARGEMOUTH BASS	12/07/92	1.42
GREENS LAKE	5 WHITE CRAPPIE	12/07/92	1.42
LAKE PIROQUE	2 CHAIN PICKERAL	12/02/92	1.38
LAKE COLUMBIA	LARGEMOUTH BASS	10/07/92	1.36
SHALLOW LAKE FELSENTHAL	SPOTTED GAR	09/17/92	1.36
GREENS LAKE	1 CHANNEL CATFISH	12/07/92	1.35
LAKE PIROQUE	2 FRESHWATER DRUM	12/02/92	1.27
DRY FORK LAKE (USFS) - PERRY CO.	1 LARGEMOUTH BASS 495 MM	04/11/94	1.27
LAKE NIMROD	LARGEMOUTH BASS	08/05/91	1.26
COVE CREEK WATERSHED LAKE PERRY CO	1 LARGEMOUTH BASS >16 "	04/20/94	1.25
NIMROD LAKE	2 LARGEMOUTH BASS >16 INCHES	10/11/93	1.23
SHALLOW LAKE/LAPILLE CREEK	BLACK CRAPPIE	09/10/92	1.19
BIG JOHNSON LAKE	1 CHAIN PICKEREL	12/07/92	1.17
LAKE ERLING	LARGEMOUTH BASS	01/01/92	1.14
LAKE BENJAMIN	3 BIG MOUTH BUFFALO	12/02/92	1.12
SHEPHERD SPRINGS LAKE	3 LARGEMOUTH BASS >16"	05/17/94	1.12
JONES LAKE	3 BIGMOUTH BUFFALO	12/07/92	1.09
GRAYS LAKE CLEVELAND CO.	5 LARGEMOUTH BASS	02/08/93	1.08
BLUE MOUNTAIN LAKE	LARGEMOUTH BASS	07/18/91	1.07
SHEPHERD SPRINGS LAKE	LARGEMOUTH BASS 540 MM 2.72 KG	06/09/24	1.07
SPRING LAKE	3 LARGEMOUTH BASS	07/23/92	1.05
CALION LAKE	LARGEMOUTH BASS	09/17/91	1.02
CANE CREEK LAKE	3 LARGEMOUTH BASS	05/11/93	1.01
GREENS LAKE	3 BIGMOUTH BUFFALO	12/07/92	1.01
MILLWOOD LAKE LOWER (STATE PARK) AREA	3 LARGEMOUTH BASS >16"	05/06/93	1.01
COVE CREEK WATERSHED LAKE PERRY CO.	1 LARGEMOUTH BASS < 16"	04/20/94	1.00
CRANES LAKE - CLEVELAND COUNTY	3 LARGEMOUTH BASS <16"	09/27/93	0.99
LAKE WINONA	3 LARGEMOUTH BASS >16"	11/05/93	0.96

Table 2.8. Continued.

COLLECTION SITE	SPECIES COLLECTED	DATE	MERCURY (PPM)
TRI COUNTY LAKE	LARGEMOUTH BASS	09/17/91	0.94
EAGLE LAKE	1 BLUEGILL	12/07/92	0.93
WILDCAT FELSENTHAL	BLUEGILL	09/21/92	0.93
BRADLEY COUNTY PARK	CHANNEL CATFISH	04/16/93	0.93
BULL SHOALS LAKE (HOWARD CREEK) LOWER REGION	LARGEMOUTH BASS	05/01/93	0.93
LAKE PIROQUE	4 BLACK CRAPPIE 1 WHITE CRAPPIE	12/02/92	0.89
DEGRAY LAKE - PT. CEDAR AREA	3 LARGEMOUTH BASS >16"	04/18/94	0.88
LAKE BAILEY CONWAY CO.	3 CHANNEL CATFISH	06/16/92	0.87
CALION LAKE	4 LARGEMOUTH BASS	03/24/93	0.87
LAKE WINONA	5 LARGEMOUTH BASS	06/04/92	0.86
LAKE WRIGHT	4 LARGEMOUTH BASS >16"	05/18/94	0.85
LAKE WRIGHT	LARGEMOUTH BASS	04/28/93	0.84
TRI COUNTY LAKE	LARGEMOUTH BASS	03/23/93	0.84
HUSTON WATERSHED LAKE PERRY CO.	1 LARGEMOUTH BASS >16"	04/22/94	0.83
GREENS LAKE	5 BLUEGILL	12/07/92	0.83
GREERS FERRY LAKE	2 WALLEYE	03/25/93	0.82
LAKE OUACHITA MARINA COVE AT MOUTAIN HARBOR	LARGEMOUTH BASS >16"	05/04/94	0.82
LAKE GEORGIA PACIFIC	2 LARGEMOUTH BASS > 16"	04/29/94	0.79
BULL SHOALS LAKE (MOUNTAIN CREEK) MIDDLE REGION	5 LARGEMOUTH BASS	05/02/93	0.78
MILLWOOD LAKE 4 STATE BASS TOURNAMENT	5 LARGEMOUTH BASS >16"	04/24/93	0.77
LAKE FORT SMITH	1 LARGEMOUTH BASS COMPOSITE	08/03/94	0.77
JONES LAKE	5 BLUEGILL	12/07/92	0.76
SEVEN DEVILS SWAMP	4 LARGEMOUTH BASS <16"	06/24/93	0.76
DEVALLS BLUFF BASIN OXBOW (WHITE R.)	1 LARGEMOUTH BASS >16"	08/24/93	0.76
SNOW LAKE	2 REDEAR	12/07/92	0.76
LOWER WHITE OAK LAKE	5 LARGEMOUTH BASS	04/12/93	0.75
EAGLE LAKE	3 SPOTTED SUCKERS	12/07/92	0.74
LAKE MAUMELLE	3 LARGEMOUTH BASS >16"	11/09/93	0.74
GRAYS LAKE CLEVELAND CO.	3 BOWFIN	02/08/93	0.74
COVE LAKE	3 LARGEMOUTH BASS	07/22/92	0.73
LAKE ENTERPRISE	LARGEMOUTH BASS	04/28/93	0.72
BRADLEY COUNTY PARK	LARGEMOUTH BASS	04/16/93	0.70
NORFORK LAKE (FLOAT CR) MID REGION	3 LARGEMOUTH BASS >16"	05/05/93	0.70
CLEAR LAKE NR ENGLAND	5 LARGEMOUTH BASS >16"	10/26/93	0.70
GILLHAM LAKE	LARGEMOUTH BASS	04/21/93	0.68
PECKERWOOD LAKE	2 LARGEMOUTH BASS >16"	08/27/93	0.68
EAGLE LAKE	1 REDEAR	12/07/92	0.66
LAKE PIROQUE	5 BLUEGILL	12/02/92	0.66
CANE CREEK LAKE	1 LARGEMOUTH BASS > 16 INCHES	07/27/93	0.66
LOWER WHITE OAK LAKE	LARGEMOUTH BASS	09/18/91	0.66
LAKE NORREL	3 LARGEMOUTH BASS >16"	11/02/93	0.65
LAKE NIMROD	CHANNEL CATFISH	08/05/91	0.65
DRY FORK LAKE (USFS) - PERRY CO.	3 LARGEMOUTH BASS <16"	04/11/94	0.64
LAKE WILHELMINA	1 LARGEMOUTH BASS - 442 MM	10/25/94	0.64
LAKE WILHELMINA	4 LARGEMOUTH BASS 314 - 396 MM	10/25/94	0.64
JONES LAKE	5 SPOTTED SUCKERS	12/07/92	0.63
SNOW LAKE	4 BLACK + 1 WHITE CRAPPIE	12/07/92	0.63
COX CREEK LAKE	5 LARGEMOUTH BASS	06/23/92	0.63
DRY FORK LAKE (USFS) - PERRY CO.	4 WHITE CRAPPIE	04/11/94	0.63
PORTIA BAY LAWRENCE COUNTY	3 LARGEMOUTH BASS ~16" OR >	08/05/93	0.62
LAKE WILHELMINA	PREDATOR COMPOSITE	10/02/91	0.62

Table 2.8. Continued.

COLLECTION SITE	SPECIES COLLECTED	DATE	MERCURY (PPM)
BIG JOHNSON LAKE	1 BIGMOUTH BUFFALO	12/07/92	0.61
BIG JOHNSON LAKE	2 BLUEGILL	12/07/92	0.61
LAKE WALLACE	LARGEMOUTH BASS	04/21/93	0.61
BLUE MT LAKE	COMPOSITE LARGEMOUTH BASS	02/16/93	0.60
BLUE MOUNTAIN LAKE CROW CREEK AREA	5 LARGEMOUTH BASS <16"	07/20/93	0.60
SHALLOW LAKE FELSENTHAL	BLUEGILL	09/17/92	0.60
LAKE ERLING	LARGEMOUTH BASS	04/12/93	0.60
DEVALLS BLUFF BASIN OXBOW (WHITE R.)	5 LARGEMOUTH BASS <16"	08/24/93	0.60
NIMROD LAKE SUNLIGHT BAY	LARGEMOUTH BASS COMPOSITE	02/16/93	0.60
SHALLOW LAKE FELSENTHAL	LARGEMOUTHBASS	09/17/92	0.59
GREENS LAKE	5 SPOTTED SUCKERS	12/07/92	0.59
COX CREEK LAKE	3 LARGEMOUTH BASS >16"	10/27/93	0.58
LAKE PIROQUE	2 BIG MOUTH BUFFALO	12/02/92	0.58
SHEPHERD SPRINGS LAKE	2 WHITE CRAPPIE	06/09/24	0.58
MILLWOOD LAKE	6 LARGEMOUTH BASS >16"	08/25/93	0.57
DIERKS LAKE LOWER END	2 LARGEMOUTH BASS 305 - 320 MM	10/21/94	0.56
LAKE MAUMELLE	5 LARGEMOUTH BASS <16"	11/09/93	0.56
BULL SHOALS LAKE (W. SUGAR LOAF) UPPER	3 LARGEMOUTH BASS >16"	05/04/93	0.56
LAKE BAILEY	LARGEMOUTH BASS<16"	07/23/93	0.56
LAKE WILSON	LARGEMOUTH BASS	04/26/93	0.55
LAKE CONWAY	3 LARGEMOUTH BASS >16"	08/24/93	0.55
LAKE ERLING	LARGEMOUTH BASS COMPOSITE	03/05/93	0.55
SNOW LAKE	2 BIGMOUTH BUFFALO	12/07/92	0.54
LAKE WINONA	5 LARGEMOUTH BASS <16"	11/05/93	0.54
BULL SHOALS LOWER	4 LARGEMOUTH BASS	08/17/92	0.53
UPPER LAKE DEGRAY	FLATHEAD CATFISH	09/17/91	0.52
LAKE BENJAMIN	5 BLUEGILL	12/02/92	0.52
BIG JOHNSON LAKE	4 GOLDEN REDHORSE+1 SPOTTED SUCKER	12/07/92	0.52
GREERS FERRY LAKE - FIVE FINGERS AREA	2 LARGEMOUTH BASS >16"	04/14/94	0.52
LAKE PICKTHORNE	5 FLORIDA BASS <16"	04/19/94	0.52
GREERS FERRY LAKE - LITTLE PETER CREEK AREA	3 LARGEMOUTH BASS >16"	04/13/94	0.51
GRAYS LAKE CLEVELAND CO.	5 SPOTTED SUCKERS	02/08/93	0.51
SNOW LAKE	5 SPOTTED SUCKERS	12/07/92	0.50
LAKE JUNE	20.5 LARGEMOUTH BASS	02/09/93	0.50
LAKE FRIERSON	5 LARGEMOUTH BASS <16"	08/04/93	0.49
CRYSTAL LAKE	3 LARGEMOUTH BASS >16"	05/20/93	0.49
LAKE PIROQUE	5 SPOTTED SUCKERS	12/02/92	0.48
IRONS FORK LAKE	5 LARGEMOUTH BASS <16"	10/12/93	0.48
NIMROD LAKE	6 LARGEMOUTH BASS <16 INCHES	10/11/93	0.47
NORFORK LAKE (SHOAL CR) LOWER LAKE	3 LARGEMOUTH BASS >16"	05/03/93	0.47
LAKE NORRELL	5 LARGEMOUTH BASS <16"	11/02/93	0.47
NORFORK LAKE (SHOAL CR) LOWER LAKE	6 LARGEMOUTH BASS <16"	05/03/93	0.45
SHEPERD SPRINGS LAKE	4 LARGEMOUTH BASS <16"	05/17/94	0.45
BULL SHOALS LOWER	3 CHANNEL CATFISH	08/17/92	0.44
LAKE DUNN	LARGEMOUTH BASS	04/20/93	0.44
BIG JOHNSON LAKE	2 REDEAR	12/07/92	0.43
NORFORK LAKE (PIGEON CR) UPPER	3 LARGEMOUTH BASS >16"	05/20/93	0.43
GRAYS LAKE CLEVELAND CO.	5 CRAPPIE	02/08/93	0.43
BURNT CANE LAKE	2 LARGEMOUTH BASS >16"	04/28/93	0.42
LAKE ATKINS	4 LARGEMOUTH BASS >16"	07/06/93	0.42
LAKE PICKTHORNE	2 FLORIDA BASS ~16" OR >	04/19/94	0.42

Table 2.8. Continued.

COLLECTION SITE	SPECIES COLLECTED	DATE	MERCURY (PPM)
LAKE HAMILTON	5 LARGEMOUTH BASS	05/21/93	0.41
CALION LAKE	LARGEMOUTH BASS COMPOSITE	02/16/93	0.41
LAKE OUACHITA - MARINA COVE AT MOUNTAIN HARBOR	LARGEMOUTH BASS <16"	05/04/94	0.41
TAYLOR BAY (WHITE R. OXBOW)	5 LARGEMOUTH BASS	08/24/93	0.40
STORM CREEK LAKE	3 LARGEMOUTH BASS >16"	04/26/93	0.40
PARIS CITY LAKE	4 LARGEMOUTH BASS >16 INCHES	10/11/93	0.39
NORFORK LAKE (FLOAT CREEK) MID REGION	5 LARGEMOUTH BASS <16"	05/05/93	0.39
HUSTON WATERSHED LAKE PERRY CO.	4 LARGEMOUTH BASS <16"	04/22/94	0.39
MILLWOOD LAKE LOWER (STATE PARK) AREA	5 LARGEMOUTH BASS <16"	05/06/93	0.39
SHADY LAKE POLK COUNTY	LARGEMOUTH BASS	04/26/93	0.38
UPPER WHITE OAK LAKE	LARGEMOUTH BASS	03/25/93	0.38
BULL SHOALS LAKE MARION CO.	3 LARGEMOUTH BASS > 16"	05/01/94	0.38
MILLWOOD LAKE OKAY LANDING AREA	5 LARGEMOUTH BASS <16"	04/26/93	0.37
LAKE GREESON	LARGEMOUTH BASS	08/14/91	0.37
BEAR CREEK LAKE	LARGEMOUTH BASS	04/22/93	0.36
GREENWOOD CITY LAKE	5 LARGEMOUTH BASS < 16 IN	06/08/94	0.35
COX CREEK LAKE	2 LARGEMOUTH BASS <16"	10/27/93	0.35
NORFORK LAKE (PIGEON CR) UPPER	5 LARGEMOUTH BASS <16"	05/28/93	0.35
BULL SHOALS UPPER	4 LARGEMOUTH BASS	08/17/92	0.34
LAKE GRAMPUS	LARGEMOUTH BASS	04/26/93	0.34
BREWER LAKE	LARGEMOUTH BASS >16"	07/29/93	0.33
CRYSTAL LAKE	6 LARGEMOUTH BASS <16"	05/20/93	0.33
LAKE FORT SMITH	2 SPOTTED BASS COMPOSITE	08/03/94	0.33
LAKE GEORGIA PACIFIC	4 LARGEMOUTH BASS < 16"	4/29/94	0.32
LAKE WRIGHT	5 LARGEMOUTH BASS <16"	05/18/94	0.32
PARIS CITY LAKE	6 LARGEMOUTH BASS <16 INCHES	10/11/93	0.31
BIG JOHNSON LAKE	5 BLACK CRAPPIE	12/07/92	0.31
HARRIS BRAKE LAKE	LARGEMOUTH BASS >16"	07/23/93	0.31
DIERKS LAKE - LOWER END	3 SPOTTED BASS 335 - 400 MM	10/21/94	0.31
GREERS FERRY LAKE - FIVE FINGERS AREA	5 LARGEMOUTH BASS <16"	04/14/94	0.30
BLUE MOUNTAIN LAKE	CHANNEL CATFISH	07/18/91	0.30
LAKE GREESON	CHANNEL CATFISH	08/14/91	0.29
TRI COUNTY LAKE	3 BLACK CRAPPIE	03/23/93	0.29
LAKE ATKINS	5 LARGEMOUTH BASS <16"	07/06/93	0.28
MOON LAKE (WHITE R. OXBOW IN MONROE CO.)	5 WHITE CRAPPIE	08/26/93	0.27
MILLWOOD LAKE	4 LARGEMOUTH BASS >16"	09/11/93	0.27
DEGRAY LAKE - PT. CEDAR AREA	5 LARGEMOUTH BASS <16"	04/18/94	0.27
SHIREY BAY LAWRENCE COUNTY	5 WHITE CRAPPIE	08/05/93	0.27
DEQUEEN LAKE	4 LARGEMOUTH BASS 425 - 400 MM	10/20/94	0.27
BIG LAKE WILDLIFE REFUGE	5 LARGEMOUTH BASS <16"	09/03/93	0.26
GREERS FERRY LAKE - LITTLE PETER CREEK AREA	5 LARGEMOUTH BASS <16"	04/13/94	0.26
CANE CREEK LAKE	6 LARGEMOUTH BASS < 16 INCHES	07/27/93	0.26
HORSESHOE LAKE (WHITE R. OXBOW NR DEVALLS BLUFF	5 WHITE CRAPPIE	08/24/93	0.26
FIRST OLD RIVER LAKE	3 LARGEMOUTH BASS >16"	05/03/93	0.26
AVALON LAKE	5 LARGEMOUTH BASS <16"	06/09/93	0.25
UPSHAW LAKE (WHITE R. OXBOW)	5 CRAPPIE	08/24/93	0.25
NIMROD LAKE SUNLIGHT BAY ACCESS	WHITE CRAPPIE COMPOSITE	02/16/93	0.25
UPPER LAKE DEGRAY	CHANNEL CATFISH	09/17/91	0.25
CANE CREEK LAKE	7 LARGEMOUTH BASS < 16 INCHES	07/27/93	0.24
BEAVER LAKE	JOE CREEK AREA 3 SPOTTED BASS 351 - 374 MM	08/23/94	0.24
LAKE OVERCUP	LARGEMOUTH BASS >16"	07/23/93	0.23

Table 2.8. Continued.

COLLECTION SITE	SPECIES COLLECTED	DATE	MERCURY (PPM)
LAKE BENJAMIN	5 SPOTTED SUCKERS	12/02/92	0.23
CALION LAKE	WHITE CRAPPIE	02/16/93	0.22
AVALON LAKE	3 LARGEMOUTH BASS >16"	06/09/93	0.22
GRAND LAKE	LARGEMOUTH BASS	04/28/93	0.22
BREWER LAKE	3 LARGEMOUTH BASS	07/22/92	0.22
BULL SHOALS LAKE (W. SUGAR LOAF) UPPER	5 LARGEMOUTH BASS <16"	05/04/93	0.21
LAKE ERLING	CHANNEL CATFISH 19.0 IN 2.375 LBS.	03/05/93	0.21
PECKERWOOD LAKE	5 CRAPPIE	08/27/93	0.20
STORM CREEK LAKE	5 LARGEMOUTH BASS <16"	04/26/93	0.20
BLUE MT LAKE	WHITE CRAPPIE COMPOSITE	02/16/93	0.19
BREWER LAKE	LARGEMOUTH BASS <16"	07/29/93	0.18
MILLWOOD LAKE OKAY LANDING AREA	4 CRAPPIE	04/26/93	0.18
BEAVER LAKE - JOE CREEK AREA	3 LARGEMOUTH BASS 354 - 397 MM	08/23/94	0.18
FIRST OLD RIVER LAKE	5 LARGEMOUTH BASS <16"	05/03/93	0.16
MILLWOOD LAKE OKAY LANDING AREA	4 CHANNEL CATFISH	04/26/93	0.16
HORSESHOE LAKE	2 LARGEMOUTH BASS >16"	04/28/93	0.16
LAKE CHICOT	5 LARGEMOUTH BASS	05/09/93	0.16
LAKE OVERCUP	LARGEMOUTH BASS < 16"	07/23/93	0.16
LAKE JUNE	17.0 IN. LARGEMOUTH BASS	02/09/93	0.14
PORTIA BAY LAWRENCE COUNTY	5 CRAPPIE	08/05/93	0.14
LAKE FORT SMITH	SMALL LARGEMOUTH BASS COMPOSITE	08/03/94	0.13
LAKE DES ARC	LARGEMOUTH BASS	04/22/93	0.13
SWEPCO LAKE	LARGEMOUTH BASS	04/06/93	<0.10
HORSESHOE LAKE	5 LARGEMOUTH BASS <16"	04/28/93	<0.10
OLD RIVER LAKE - STEEL BEND	3 LARGEMOUTH BASS >16"	11/24/90	<0.10
BOIS D'ARC LAKE	LARGEMOUTH BASS	04/13/93	<0.10
BURNT CANE LAKE	5 WHITE CRAPPIE	04/28/93	<0.10
HARRIS BRAKE LAKE	LARGEMOUTH BASS <16"	07/23/93	<0.10
NORFORK LAKE BAXTER CO.	5 LARGEMOUTH BASS < 16"	04/27/94	<0.10
LAKE JUNE	LARGEMOUTH BASS COMPOSITE	02/09/93	<0.10
LAKE CONWAY	5 LARGEMOUTH BASS <16"	08/24/93	<0.10
LAKE PINE BLUFF	3 LARGEMOUTH BASS >16"	11/05/93	<0.10
BULL SHOALS RESERVOIR MARION CO.	5 LARGEMOUTH BASS < 16"	05/01/94	<0.10
LAKE JUNE	13.5 LARGEMOUTH BASS	02/09/93	<0.10
LAKE CHARLES	5 LARGEMOUTH BASS <16"	08/02/93	<0.10
OLD RIVER LAKE - STEEL BEND	5 LARGEMOUTH BASS <16"	11/24/90	<0.10
LAKE PINE BLUFF	3 LARGEMOUTH BASS <16"	11/05/93	<0.10
BRODIE BEND OFF ARKANSAS RIVER	3 LARGEMOUTH BASS >16"	11/10/93	<0.10
BRODIE BEND OFF ARKANSAS RIVER	4 LARGEMOUTH BASS + 1 SPOTTED BASS <16"	11/10/93	<0.10

Table 2.9. Mercury Concentrations in Fish from Arkansas Rivers and Streams (Sorted from highest to lowest concentration).

COLLECTION SITE	SPECIES COLLECTED	DATE	MERCURY (PPM)
SOUTH FORK LITTLE RED RIVER (JOHNSON HOLE)	2 LARGEMOUTH BASS >16"	08/23/93	2.12
DORCHEAT BAYOU	5 LARGEMOUTH BASS >16"	08/27/93	2.06
CUT OFF CREEK IN WMA DREW CO.	4 DRUM	02/10/93	1.91
OUACHITA RIVER BELOW FELSENTHAL	FLATHEAD CATFISH	09/19/92	1.86
SALINE RIVER BELOW L'AIGLE CREEK	LARGEMOUTH BASS	09/21/92	1.78
OUACHITA RIVER FROM 82 BRIDGE TO LOCK & DAM	FLATHEAD CATFISH	09/17/92	1.73
SALINE RIVER ASHLEY AND BRADLEY COUNTIES	SPOTTED BASS	10/02/92	1.70
MORO CREEK AT HWY 160	2 CHANNEL CATFISH	11/23/92	1.58
MORO CREEK AT HWY 160	5 LARGEMOUTH BASS	11/23/92	1.56
CHAMPAGNOLLE CREEK ABV LITTLE CHAMPAGNOLLE	5 BOWFIN	11/24/92	1.52
SALINE RIVER BELOW RIVER BELOW L'AIGLE CREEK	CRAPPIE	09/21/92	1.50
OUACHITA RIVER PIGION HILL	BLACK CRAPPIE	10/01/92	1.46
OUACHITA RIVER ABOVE LAPILE CREEK	BLACK CRAPPIE	09/19/92	1.43
MORO CREEK ABOVE STATE PARK	3 LARGEMOUTHBASS	11/30/92	1.42
MORO CREEK ABOVE STATE PARK	2 SPOTTED GAR	11/30/92	1.41
OUACHITA RIVER PIGEON HILL	LARGEMOUTH BASS	10/01/92	1.40
CHAMPAGNOLLE CREEK ABV LITTLE CHAMPAGNOLLE	1 BLACK CRAPPIE	11/24/92	1.39
OUACHITA RIVER BELOW FELSENTHAL	BASS	09/19/92	1.36
CHAMPAGNOLLE CREEK ABV LITTLE CHAMPAGNOLLE	4 LARGEMOUTHBASS	11/24/92	1.34
SALINE RIVER AT HIGHWAY 4	LARGEMOUTH BASS	10/22/92	1.32
CUT OFF CREEK IN WMA DREW CO.	4 BOWFIN	02/10/93	1.30
BAYOU BARTHOLOMEW (BAXTER)	4 LARGEMOUTH BASS <16"	06/29/93	1.29
MORO CREEK ABOVE STATE PARK	2 CHAIN PICKERAL	11/30/92	1.29
FOURCHE LA FAVE RIVER	2 LARGEMOUTH BASS >16 IN	09/19/93	1.24
OUACHITA RIVER BELOW FESENTHAL	BLACK CRAPPIE	09/19/92	1.18
MORO CREEK AT HWY 275	5 BOWFIN	11/23/92	1.18
SALINE RIVER AT HIGHWAY 4	BLACK CRAPPIE	10/22/92	1.15
CUT OFF CREEK IN WMA DREW CO.	7 LARGEMOUTH BASS	02/10/93	1.14
SALINE RIVER AT MT. ELBA	CHANNEL CATFISH	10/22/92	1.13
OUACHITA RIVER BELOW SMACKOVER CREEK	LARGEMOUTH BASS FILLET	07/13/92	1.13
SALINE RIVER ASHLEY AND BRADLEY COUNTIES	LARGEMOUTH BASS	10/02/92	1.13
CHAMPAGNOLLE CREEK AT HWY 4	2 CHAIN PICKERAL	11/23/92	1.12
OUACHITA RIVER AT PIGEON HILL ACCESS	BLACK BASS	08/25/92	1.05
OUACHITA RIVER BELOW COFFEE CREEK	BLACK BASS	08/25/92	1.05
SALINE RIVER AT MT. ELBA	RIVER REDHORSE	10/22/92	1.04
MORO CREEK AT HWY 160	5 BLACK CRAPPIE	11/23/92	1.04
CUT OFF CREEK	4 LARGEMOUTH BASS	05/25/93	1.03
CUT OFF CREEK IN WMA DREW CO.	6 CRAPPIE	02/10/93	1.00
SALINE RIVER ASHLEY AND BRADLEY COUNTIES	FLATHEAD CATFISH	10/02/92	1.00
SOUTH FORK LITTLE RED RIVER (JOHNSON HOLE)	6 LARGEMOUTH BASS <16"	08/17/93	0.99
SALINE RIVER AT MT. ELBA	DRUM	10/22/92	0.98
MORO CREEK AT HWY 160	5 BOWFIN	11/23/92	0.98
OUACHITA RIVER MONTGOMERY CO.	5BASS <16"	05/02/94	0.98
CUT OFF CREEK IN WMA DREW CO.	3 BUFFALO	02/10/93	0.98
LITTLE BAYOU BAYOU BARTHOLOMEW	4 LARGEMOUTH BASS <16"	06/25/93	0.97
SMACKOVER CREEK	LARGEMOUTH BASS	10/06/92	0.97
CUT OFF CREEK IN WMA DREW CO.	5 CHANNEL CATFISH	02/10/93	0.94
CHAMPAGNOLLE CREEK ABV LITTLE CHAMPAGNOLLE	4 BIGMOUTH BUFFALOE	11/24/92	0.94
SALINE RIVER AT MT. ELBA	BLACK BASS	10/22/92	0.93
BLACK RIVER NEAR LYNN.	3 SPOTTED BASS	07/21/93	0.93
MORO CREEK ABOVE STATE PARK	5 SPOTTED SUCKERS	11/30/92	0.93

Table 2.9. Continued.

COLLECTION SITE	SPECIES COLLECTED	DATE	MERCURY (PPM)
CORNIE BAYOU UNION CO.	4 LARGEMOUTH BASS < 16"	05/04/94	0.90
SOUTH FORK LITTLE RED RIVER LEWIS ACRES BELOW JOHNSON HOLE	1LARGEMOUTH BASS >16	09/28/93	0.90
MORO CREEK AT HWY 275	5 LARGEMOUTHBASS	11/23/92	0.90
CADRON CREEK WEST OF WOOSTER	4 LARGEMOUTH BASS >16"	04/25/94	0.90
OUACHITA RIVER AT CHERRY HILL ACCESS	3 LARGEMOUTH BASS >16"	05/20/94	0.89
DEVILS FORK LITTLE RED RIVER	3 LARGEMOUTH BASS >16"	11/04/93	0.86
SALINE RIVER FITZHUGH ACCESS	BLACK BASS	10/27/92	0.86
MORO CREEK AT HWY 160	1 GOLDEN REDHORSE	11/23/92	0.84
OUACHITA RIVER PIGEON HILL	BLUEGILL	10/01/92	0.81
SALINE RIVER AT LEES FERRY	CHANNEL CATFISH	10/23/92	0.81
SALINE RIVER AT I-30 BRIDGE	3 SPOTTED BASS 383 - 400 MM	10/05/94	0.80
MORO CREEK AT HWY 160	5 SPOTTED SUCKERS	11/23/92	0.80
SALINE RIVER AT MT. ELBA	FLATHEAD CATFISH	10/22/92	0.80
MERCER BAYOU MILLER COUNTY	2 LARGEMOUTH BASS >16"	05/11/93	0.80
BAYOU BARTHOLOMEW - STATE LINE	3 BLUE CATFISH <16"	10/13/93	0.80
OUACHITA RIVER NR ODEN	3 SPOTTED BASS <16"	05/19/94	0.79
(WHI0003) BLACK RIVER	3 DRUM 366 - 510 MM	09/27/94	0.79
SOUTH FORK LITTLE RED RIVER OLD WATERWORKS	2 CHANNEL CATFISH	10/03/93	0.79
SALINE RIVER AT MT. ELBA	BOWFIN	10/22/92	0.78
SALINE RIVER AT MT. ELBA	BLACK CRAPPIE	10/22/92	0.78
SALINE RIVER AT JENKINS FERRY	SPOTTED BASS	10/23/92	0.78
BAYOU BARTHOLOMEW LINCOLN CO.	5 LARGEMOUTH BASS	02/09/93	0.78
OUACHITA RIVER BELOW SMACKOVER CREEK	SPOTTED BASS FILLET	07/13/92	0.76
MORO CREEK AT HWY 275	5 SPOTTED SUCKERS	11/23/92	0.76
BAYOU BARTHOLOMEW - STATE LINE	2 BLUE CATFISH >16"	10/13/93	0.75
OUACHITA RIVER AT GRIGSBY FORD	REDHORSE	08/24/92	0.75
KINGS RIVER	SPOTTED BASS	08/16/93	0.75
CUT OFF CREEK	5 BLUEGILL	05/25/93	0.74
MORO CREEK AT HWY 275	3 BLACK CRAPPIE	11/23/92	0.73
SALINE RIVER AT JENKINS FERRY	RIVER REDHORSE	10/23/92	0.72
EAST FORK CADRON CREEK ABOVE HWY 25	2 LARGEMOUTH BASS >16"	04/25/94	0.72
BAYOU BARTHOLOMEW (BAXTER)	1 LARGEMOUTH BASS >16"	06/29/93	0.72
CUT OFF CREEK	10 CRAPPIE	03/19/93	0.71
SMACKOVER CREEK	BOWFIN	10/06/92	0.71
SALINE RIVER AT LEES FERRY	RIVER REDHORSE	10/23/92	0.71
OUACHITA RIVER ABOVE CAMDEN	BLACK BASS	07/13/92	0.71
OUACHITA RIVER BELOW WEST TWO BAYOU	BLACK BASS	07/13/92	0.70
SALINE RIVER AT HIGHWAY 4	CHANNEL CATFISH	10/22/92	0.69
CUT OFF CREEK IN WMA DREW CO.	8 BLUEGILL	02/10/93	0.69
CUT OFF CREEK	1 CHANNEL CATFISH	05/25/93	0.69
CHAMPAGNOLLE CREEK AT HWY 4	5 LARGEMOUTH BASS	11/23/92	0.68
SALINE RIVER AT LEES FERRY	BLACK CRAPPIE	10/23/92	0.68
SALINE RIVER AT HIGHWAY 4	RIVER REDHORSE	10/22/92	0.67
SALINE RIVER AT LEES FERRY	BOWFIN	10/23/92	0.66
LITTLE MISSOURI RIVER	BASS	10/02/92	0.66
SMACKOVER CREEK	BLUEGILL	10/06/92	0.65
OUACHITA RIVER ABOVE CAMDEN	REDHORSE	07/13/92	0.65
OUACHITA RIVER SMACKOVERIVERCREEK	CRAPPIE	10/06/92	0.65
OUACHITA RIVER AT CHERRY HILL ACCESS	4 SPOTTED BASS <16"	05/20/94	0.65
WHITE RIVER AT ST. CHARLES	5 SPOTTED BASS <16"	08/26/93	0.65
SALINE RIVER AT LEES FERRY	SPOTTED BASS	10/23/92	0.64

Table 2.9. Continued.

COLLECTION SITE	SPECIES COLLECTED	DATE	MERCURY (PPM)
SALINE RIVER AT LEES FERRY	DRUM	10/23/92	0.63
CHAMPAGNOLLE CREEK ABV LITTLE CHAMPAGNOLLE	5 BLUEGILL	11/24/92	0.62
BAYOU DEVEIW HWY 17	4 WHITE CRAPPIE	05/31/94	0.62
MORO CREEK ABOVE STATE PARK	2 BLUEGILL	11/30/92	0.62
SALINE RIVER AT JENKINS FERRY	BLACK CRAPPIE	10/23/92	0.61
MORO CREEK AT HWY 160	5 BLUEGILL	11/23/92	0.61
OUACHITA RIVER ABOVE LAPILE CREEK	BLUEGILL	09/19/92	0.61
SALINE RIVER AT MT. ELBA	BLUEGILL	10/22/92	0.60
ELEVEN POINT RIVER NR WARM SPRINGS	4 SMALLMOUTH BASS 280 - 467 MM	09/26/94	0.60
OUACHITA RIVER AT MCGUIRE ACCESS	5 SPOTTED BASS <16"	05/19/94	0.60
SALINE RIVER AT HIGHWAY 4	BLUEGILL	10/22/92	0.60
CURRENT RIVER AT JOHNSTON'S EDDY	3 BUFFALO 490 - 590 MM	09/27/94	0.59
OUACHITA RIVER BELOW COFFEE CREEK	BUFFALO	08/25/92	0.57
MORO CREEK AT HWY 275	5 BLUEGILL	11/23/92	0.57
SMACKOVER CREEK	CATFISH	10/06/92	0.56
SALINE RIVER FITZHUGH ACCESS	BLACK CRAPPIE	10/27/92	0.56
ELEVEN POINT RIVER	5 BASS <16"	09/07/93	0.56
SULPHUR RIVER MILLER COUNTY	5 LARGEMOUTH BASS <16"	06/30/93	0.54
FOURCHE LA FAVE RIVER	3 LARGEMOUTH BASS <16IN	09/19/93	0.54
SULPHUR RIVER MILLER COUNTY	1 BLACK CRAPPIE	06/30/93	0.53
BAYOU DEVEIW - HWY 17	4 LARGEMOUTH BASS < 16 IN	05/31/94	0.52
SOUTH FORK LITTLE RED RIVER OLD WATERWORKS	5 BLACK BASS <16IN	10/03/93	0.52
CURRENT RIVER	4 SPOTTED BASS <16"	09/09/93	0.52
OUACHITA RIVER BELOW SMACKOVER CREEK	CARP	07/13/92	0.52
OUACHITA RIVER AT GRIGSBY FORD	BASS	08/24/92	0.52
CHAMPAGNOLLE CREEK AT HWY 4	2 BLACK CRAPPIE	11/23/92	0.51
BAYOU METO - AT MOUTH	4 LARGEMOUTH BASS >16 IN	06/15/94	0.50
CURRENT RIVER	2 SPOTTED BASS >16"	09/09/93	0.50
OUACHITA RIVER BELOW FELSENTHAL	BLUEGILL	09/19/92	0.49
SALINE RIVER BELOW L'AGILE CREEK	BLUEGILL	09/21/92	0.49
ILLINOIS BAYOU BELOW HIWAY 7 BRIDGE N OF DOVER	5 SPOTTED BASS	09/27/94	0.49
SULPHUR RIVER	5 WHITE CRAPPIE	08/06/93	0.49
CURRENT RIVER	2 LARGEMOUTH BASS <16"	09/09/93	0.49
MIDDLE FORK LITTLE RED RIVER	3 LARGEMOUTH BASS >16"	11/04/93	0.48
BAYOU BARTHOLOMEW LINCOLN CO.	5 CRAPPIE	02/09/93	0.48
OUACHITA RIVER BELOW WEST TWO BAYOU	LARGEMOUTH BUFFALO	07/13/92	0.47
MULBERRY RIVER AT BYRD'S CANOE RENTAL		04/25/94	0.47
MERCER BAYOU MILLER COUNTY	6 LARGEMOUTH BASS <16"	05/11/93	0.47
OUACHITA RIVER BELOW COVE CREEK (REMMEL DAM)	BLACK BASS	07/13/92	0.46
KINGS RIVER	3 SMALLMOUTH BASS	08/16/93	0.46
CURRENT RIVER AT JOHNSTON'S EDDY	4 BLACK BASS 289 - 314 MM	09/27/94	0.46
SULPHUR RIVER	3 BUFFALO	08/06/93	0.46
BIG PINEY CREEK AT HWY 123 DOUGLAS FORD	1 LARGEMOUTH BASS >16 INCHES	10/05/93	0.45
(WHI0003) BLACK RIVER	3 BUFFALO 550 - 670 MM	09/27/94	0.44
CHAMPAGNOLLE CREEK ABV LITTLE CHAMPAGNOLLE	1 CHANNEL CATFISH	11/24/92	0.44
CHAMPAGNOLLE CREEK AT HWY 4	5 BLUEGILL	11/23/92	0.44
CHAMPAGNOLLE CREEK AT HWY 4	5 SPOTTED SUCKERS	11/23/92	0.43
POTEAU RIVER - NR CAUTHRON	4 LARGEMOUTH BASS <16IN	06/08/94	0.43
OSAGE CREEK	SPOTTED BASS	08/17/93	0.42
OUACHITA RIVER AT DALLAS CO. ACCESS	BASS	08/26/92	0.42
BIG PINEY CREEK AT HWY 123 DOUGLAS FORD	5 BLACK BASS < 16 INCHES	10/05/93	0.42

Table 2.9. Continued.

COLLECTION SITE	SPECIES COLLECTED	DATE	MERCURY (PPM)
SOUTH FORK CADDO RIVER NR HOPPER	4 BLACK BASS 185 - 294 MM	08/04/94	0.41
OUACHITA RIVER AT MCGUIRE ACCESS	2 LARGEMOUTH BASS <16"	05/19/94	0.41
SOUTH FORK LITTLE RED RIVER LEWIS ACRES BELOW JOHNSON HOLE	<16INLARGEMOUTH BASS	09/28/93	0.41
WHITE RIVER AT AUGUSTA	5 SPOTTED BASS <16"	08/25/93	0.41
STRAWBERRY RIVER FRANKLIN	1LARGEMOUTH BASS >16 IN	10/04/93	0.41
OUACHITA RIVER BELOW COVE CREEK (REMMEL DAM)	GOLDEN REDHORSE	07/13/92	0.40
DEVILS FORK LITTLE RED RIVER	5 LARGEMOUTH BASS <16"	11/04/93	0.40
STRAWBERRY RIVER AT HWY 167 BRIDGE	5 SPOTTED BASS <16 IN	10/13/93	0.40
OSAGE CREEK	4 LARGEMOUTH BASS	08/17/93	0.40
FOURCHE LA FAVE RIVER	1 HYBRID STRIPED BASS (610 MM)	09/19/93	0.39
(WHI0003) BLACK RIVER WHITE CRAPPIE	229 - 252 MM	09/27/94	0.39
SPRING RIVER	5 SPOTTED BASS <16"	09/02/93	0.38
ILLINOIS BAYOU BELOW HIWAY 7 BR N OF DOVER	3 LARGEMOUTH BASS	09/27/94	0.38
EAST FORK CADRON CREEK ABOVE HWY 25	4 LARGEMOUTH BASS <16"	04/25/94	0.37
SALINE RIVER FITZHUGH ACCESS	REDHORSE	10/27/92	0.37
OUACHITA RIVER BELOW TATES BLUFF	REDHORSE	08/24/92	0.37
BAYOU BARTHOLOMEW (BAXTER)	2 CATFISH	06/29/93	0.37
BAYOU DEVIEW NEAR WEINER	1 LARGEMOUTH BASS >16IN	10/11/93	0.36
PETIT JEAN RIVER 1.5 MI ABOVE PONTOON RAMP	2 LARGEMOUTH BASS >16 INCHES	10/05/93	0.36
BAYOU DE VEIW WMA NEAR WEINER	2 LARGEMOUTH BASS <16IN	10/11/93	0.36
SALINE RIVER AT LEES FERRY	BLUEGILL	10/23/92	0.36
OUACHITA RIVER BELOW TATES BLUFF	BASS	08/24/92	0.35
CURRENT RIVER AT JOHNSTON'S EDDY	5 BLACK CRAPPIE 221 - 281 MM	09/27/94	0.35
ROLLING FORK CREEK W OF GILLHAM	1 FH 1 BH CATFISH 230 - 340 MM	10/20/94	0.35
COSSATOT RIVER BELOW LAKE GILLHAM	7 LARGEMOUTH BASS	10/31/94	0.35
SULPHUR RIVER MILLER COUNTY	4 CHANNEL CATFISH	06/30/93	0.34
SALINE RIVER AT JENKINS FERRY	DRUM	10/23/92	0.33
STRAWBERRY RIVER FRANKLIN	2 BLACK BASS <16 IN	10/04/93	0.33
KINGS RIVER	LARGEMOUTH BASS	08/16/93	0.33
MIDDLE FORK LITTLE RED RIVER	5 LARGEMOUTH BASS <16"	11/04/90	0.33
SULPHUR RIVER	3 MIXED SPECIES OF BLACK BASS <16"	08/06/93	0.32
STRAWBERRY RIVER AT POUGHKEEPSIE	3 SMBAS <16 IN	10/08/93	0.31
SPAVINAW CREEK N OF CHEROKEE CITY AND UPSTREAM	MULTISPECIES COMP.	07/19/93	0.31
WHITE RIVER AT BATESVILLE ABOVE DAM	3 SPOTTED/2 LARGEMOUTH BASS <16"	08/05/93	0.30
PETIT JEAN RIVER 1.5 MI ABOVE PONTOON RAMP	5 LARGEMOUTH BASS <16 INCHES	10/05/93	0.30
LITTLE MISSOURI RIVER	CRAPPIE	10/02/92	0.30
LEE CREEK AT LEE CREEK COMMUNITY	3 SPOTTED BASS <16"	07/20/93	0.29
FROG BAYOU ON HWY 282	1 LARGEMOUTH BASS	07/21/93	0.29
BAYOU METO - AT MOUTH	3 LARGEMOUTH BASS < 16 IN	06/15/94	0.28
ST. FRANCIS RIVER AB AND BL HUXTABLE PUMP STATION	3 LARGEMOUTH BASS <16"	11/30/93	0.27
BAYOU BARTHOLOMEW LINCOLN CO.	4 CHANNEL CATFISH	02/09/93	0.27
ROLLING FORK CREEK W OF GILLHAM	5 GREEN SUNFISH	10/20/94	0.26
WHITE RIVER AT DEVALLS BLUFF	5 WHITE CRAPPIE	08/24/93	0.26
LITTLE MISSOURI RIVER	CHANNEL CATFISH	10/02/92	0.26
STRAWBERRY RIVER AT HWY 167 BRIDGE	1 FLATHEAD CATFISH	10/13/93	0.26
LITTLE MISSOURI RIVER	BLUEGILL	10/02/92	0.26
SALINE RIVER FITZHUGH ACCESS	CHANNEL CATFISH	10/27/92	0.25
SALINE RIVER AT JENKINS FERRY	BLUEGILL	10/23/92	0.25
OUACHITA RIVER AT DALLAS COUNTY ACCESS	SUCKER AND BUFFALO	08/26/92	0.25
BAYOU BARTHOLOMEW LINCOLN CO.	3 BUFFALO	02/09/93	0.24
OUACHITA RIVER NR ODEN	3 LARGEMOUTH BASS >16"	05/19/94	0.24

Table 2.9. Continued.

COLLECTION SITE	SPECIES COLLECTED	DATE	MERCURY (PPM)
CACHE RIVER	5 WHITE CRAPPIE	05/31/94	0.24
BLACK RIVER NEAR LYNN	3 FLATHEAD CATFISH	07/21/93	0.22
OUACHITA RIVER ABOVE LAPILE CREEK	LARGEMOUTHBASS	09/19/92	0.21
ELEVEN POINT RIVER NR WARM SPRINGS	5 GOLDEN REDHORSE 337 - 391 MM	09/26/94	0.20
ILLINOIS RIVER WASHINGTON CO. OFF ROBINSON ROAD	5 BLACK BASS	10/07/93	0.20
BARREN FORK @ DUTCH MILLS (ARK0007)	5 SMALLMOUTH BASS <16"	07/20/93	0.19
CADRON CREEK WEST OF WOOSTER	4 CRAPPIE	04/25/94	0.18
CHAMPAGNOLLE CREEK ABV LITTLE CHAMPAGNOLLE	4 SPOTTED SUCKERS	11/24/92	0.18
OUACHITA RIVER AT PIGEON HILL ACCESS	SUCKERS	08/25/92	0.16
BUFFALO RIVER AT BUFFALO POINT	5 SMALLMOUTH BASS <16"	08/08/93	0.15
SALINE RIVER AT JENKINS FERRY	CHANNEL CATFISH	10/23/92	0.14
SULPHUR RIVER	4 CHANNEL CATFISH	08/06/93	0.14
ROLLING FORK RIVER W OF GILLHAM	3 GOLDEN REDHORSE 220 - 230 MM	10/20/94	0.10
ST. FRANCIS RIVER	5 WHITE CRAPPIE	08/04/93	0.10
LOWER CROOKED CREEK	5 SMALLMOUTH BASS <16"	07/26/93	<0.10
CANAL 43 - DESHA COUNTY	3 LARGEMOUTH BASS >16"	10/10/93	<0.10
UPPER CROOKED CREEK	2 SMALLMOUTH BASS <16"	08/26/93	<0.10
CANAL 43 - DESHA COUNTY	5 LARGEMOUTH BASS <16"	10/10/93	<0.10
BUFFALO RIVER 1/4 MI AB CONF WHITE RIVER	5 LARGEMOUTH BASS	10/29/93	<0.10
BOEUF RIVER CHICOT CO.	5 WHITE CRAPPIE	05/05/94	<0.10

Appendix F

ATSDR Endorsement of 1 ppm Action Level Used By ADH for Fish Consumption Advisories

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Agency for Toxic Substances
and Disease Registry
Atlanta GA 30333

March 16, 1993

Morris Cranmer, Ph.D. CIH, A.T.S.
Arkansas Department of Health
Mail Slot 32
4815 West Markham Street
Little Rock, Arkansas 72205

Dear Dr. Cranmer:

The enclosed Health Consultation was prepared by the Emergency Response and Consultation Branch in response to your request of March 1, 1993. If you have any questions concerning this Health Consultation or need further assistance, please contact Dr. Steven Kinsler at (404) 639-6360.

Sincerely yours,

Robert C. Williams, P.E., DEE
Director
Division of Health Assessment
and Consultation

Enclosure

Arkansas Department of Health
Little Rock, Arkansas
(6#AR)

March 15, 1993

Emergency Response and Consultation Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

Concurrence:

Director, DHAC, ATSDR (E32) ____
Chief, ERCB, DHAC, ATSDR (E57) ____
Acting Chief, TSS, ERCB, DHAC, ATSDR (E57) ____

MERCURY CONTAMINATION IN FISH

BACKGROUND AND STATEMENT OF ISSUES

The Agency for Toxic Substances and Disease Registry (ATSDR) was requested by the Arkansas Department of Health (ADH) to evaluate potential public health threats posed by consumption of mercury-contaminated fish in the State of Arkansas [1].

Mercury has been detected in fish taken from several lakes, rivers, and streams in south central Arkansas including Felsenthal Reservoir and the Saline and Ouachita Rivers. Methyl mercury levels measured in fish have ranged from 1 to 3 parts-per-million (ppm) in the fillet [2]. The ADH has issued an advisory concerning consumption of mercury-contaminated fish.

DISCUSSION

Mercury is a naturally occurring element in the environment. In elemental form, mercury is a shiny, silver-white liquid. Mercury in the environment is usually found in combination with other elements, such as chlorine, carbon, or oxygen, forming mercury compounds. While all forms of mercury are considered poisonous, methyl mercury, the most common organic form of mercury, is of particular concern due to its tendency to build up or accumulate in certain fish; when larger fish eat smaller fish that contain methyl mercury, the larger fish will store most of the methyl mercury [3]. This can result in high mercury levels in the larger fish.

Available analytical data indicate the presence of methyl mercury at levels ranging from 1 to 3 ppm in fish fillet [2]. Fish were collected from several lakes, rivers, and streams in south central Arkansas including Felsenthal Reservoir and the Saline and Ouachita Rivers.

Methyl mercury is readily absorbed in humans following oral exposure. Following oral exposure, methyl mercury is distributed throughout the body, with the greatest accumulation in the kidneys. The predominant excretory route for methyl mercury is the feces; less than one-third is excreted via the urine.

Mercury has a wide range of toxic effects in the body [3]. The most sensitive affected system from oral exposure to organic mercury is the developing nervous system (fetuses and young children); severe toxicity can also occur in the central nervous system of adults exposed to low levels. Because all forms of mercury preferentially deposit in the kidney, all mercury compounds can exhibit kidney toxicity to some degree. Other organ systems affected by mercury include respiratory, cardiovascular, hematologic, immune, and reproductive.

For the general population, a major route of exposure is ingestion of mercury-contaminated fish [3]. Most of the mercury in fish is in the form of methyl mercury [3]. Regular and frequent consumption of mercury-contaminated fish can result in exposure to high levels of mercury.

The Food and Drug Administration (FDA) has set an action level of 1 ppm methyl mercury in fish [4]. This action level is health-based and assumes an ingestion rate of 30 grams of fish per day. In survey data from ADH, some fishermen reported consuming more than 30 grams of fish per day.

CONCLUSIONS

1. Consumption of fish that contain methyl mercury at levels equal to or greater than 1 ppm may pose a public health threat.

RECOMMENDATIONS

1. ATSDR considers it prudent public health policy for individuals to avoid regular and frequent consumption of fish that contain methyl mercury at levels equal to or greater than 1 ppm.

2. Disseminate information to educate the public about the health threat of consuming mercury-contaminated fish.

Steven Kinsler, Ph.D.

REFERENCES

1. Steven Kinsler, ATSDR, ATSDR Record of Activity, Dr. Morris Cranmer, Arkansas Department of Health, March 1, 1993.

2. Jennifer Lyke, ATSDR, ATSDR Record of Activity, Doc McChesney, Arkansas Department of Health, February 12, 1993.

3. ATSDR Draft Toxicological Profile for Mercury, US Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, October, 1992.

4. Hazardous Substances Data Base, 1993.

Appendix G

Recent Fish Consumption Advisory Brochure and Information Pamphlet

Fish Consumption Notices in Arkansas: Mercury in Fish

Produced by: Arkansas Department of Health • Arkansas Game and Fish Commission • Arkansas Department of Pollution Control and Ecology

WHAT IS MERCURY?

Mercury is a chemical that occurs naturally in soil, water and air. It can exist in several forms such as elemental mercury used in thermometers, inorganic mercury used in manufacturing and organic mercury which builds up in the food chain. All three forms are a threat to human health at certain doses.

WHERE DOES MERCURY COME FROM?

Mercury has many sources. It is a natural component of the earth's crust and is found in low levels in sediment throughout Arkansas. Mercury ore, also known as cinnabar, was mined in Arkansas in the past. Another source of mercury in the environment is due to coal burning and municipal waste incineration. Acid rain increases acidity in lakes and rivers, causing the mercury to be more soluble and more easily available to fish and other organisms.

WHAT IS THE RISK OF EATING FISH WITH MERCURY?

The federal Food and Drug Administration (FDA) has established a 1.0 part per million (PPM) action level for mercury in fish for human consumption.

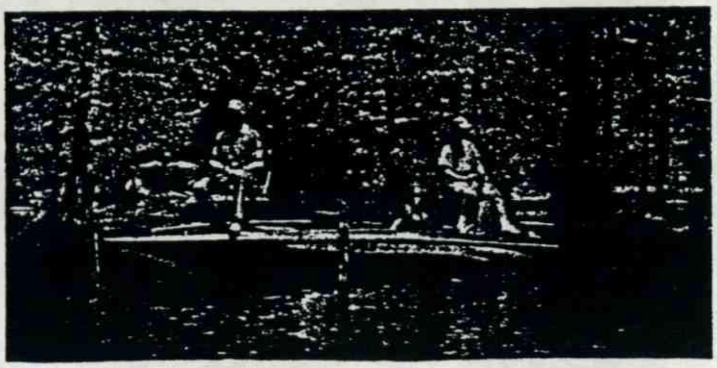
The amounts of mercury found in Arkansas fish don't cause immediate sickness. Mercury can collect in the body over time and could have effects on human health. Mercury can cause damage to the nervous system and/ or the kidneys.

Children, including unborn children, are more sensitive to mercury than healthy adults. This means that amounts of mercury that would not cause symptoms in an adult may harm children. Children are more sensitive because their nervous systems are still developing. The effects of mercury in children may be permanent. A mother may pass mercury to her unborn child through the placenta or to a nursing child through breast milk.

Because of the sensitivity of children to mercury, pregnant women, women who plan to get pregnant, women who are breastfeeding and children under the age of 7 years are considered high risk groups for health effects due to mercury exposure. As a general rule, they should not eat fish from the consumption notice areas.

In the general population, the health effects of mercury can usually be reversed if exposure to mercury is stopped.

Vacationers and persons who occasionally eat fish from the fish consumption notice areas (once every 2 - 3 months or less) are not at risk from the health effects due to mercury exposure.



HOW DOES MERCURY GET INTO FISH?

The presence of mercury in water or sediment doesn't cause a problem. Other conditions are needed. These include the presence of high organic material like dead leaves, waste discharges from cities and industries, slightly acid water, and the presence of anaerobic (lack of oxygen) bacteria which convert elemental and inorganic mercury into soluble methylmercury. Methylmercury is then taken up by small organisms in the water. These organisms are eaten by small fish, who are in turn eaten by larger fish and on up the food chain. This is how methylmercury is concentrated at each step in the food chain up to the predator species like bass, crappie, catfish, gar and bowfin. Non-predator fish like bream are one step down this food chain. Bottom feeders like suckers and buffalo are yet another step down the chain.

HOW LONG DO FISH CONSUMPTION NOTICES LAST?

Fish consumption notices are in effect indefinitely. Fish eliminate mercury very slowly. The source of mercury contamination in Arkansas waters is probably from atmospheric depositions and natural geological formations. Investigations are underway to determine the exact sources.

CAN WE MAKE FISH SAFE TO EAT?

No special cleaning or cooking methods will decrease mercury in fish. Mercury is stored in the fish fillet or muscle portion, not the fat. Removing fat or skin from fish will not lower mercury levels.

Health risks from eating fish contaminated with mercury can be reduced in the following ways:

- Always eat the smaller fish within the species since younger, smaller fish contain less mercury.
- Choose non-predator fish over predator fish when ever possible since non-predator fish usually have less mercury in them.
- Eat fish from a variety of sources (including fish markets and grocery stores) to break up routine fish consumption patterns

WHERE CAN I GET INFORMATION?

For more information on the fish consumption notices for Mercury, contact the Division of Epidemiology, Arkansas Department of Health at 1-800-482-5400, extension 2986 or 2761.

Effective July, 1994

Fish Consumption Notices

Effective July, 1994

Location (see map on back) Key: ◈ South ◈ North ◈ Central	High Risk Groups*		General Public	
	Predators	Non-Predators	Predators	Non-Predators
Lake Columbia (Columbia County) ◈	Do not consume	Do not consume	No more than 2 meals a month. No restrictions on large mouth bass less than 16 inches in length.	No restrictions
Cut-off Creek (from where the creek crosses Highway 35 in Drew County to its confluence with Bayou Bartholomew) ◈	Do not consume	Do not consume	No more than 2 meals per month	Do not consume
Bayou Bartholomew (from where it crosses Highway 35 in Drew County to its confluence with Little Bayou in Ashley County) ◈	Do not consume	Do not consume	No more than 2 meals per month	Do not consume
Big Johnson Lake (Calhoun County) ◈	Do not consume	Do not consume	No more than 2 meals per month	No restrictions
Snow Lake (Calhoun County) ◈	Do not consume	Do not consume	Do not consume	No restrictions
Grays Lake (Cleveland County) ◈	Do not consume	Do not consume	No more than 2 meals per month	No restrictions
Moro Bay Creek (from Highway 160 to its confluence with the Ouachita River) (Bradley County) ◈	Do not consume	Do not consume	Do not consume	No more than 2 meals per month
Champagnolle Creek (to include Little Champagnolle from Highway 4 to its confluence with the Ouachita River) (Calhoun County) ◈	Do not consume	Do not consume	No more than 2 meals per month	No restrictions
Ouachita River (from Smackover Creek to the Louisiana border not including the Felsenthal Wildlife Refuge) does not include Ouachita River above Smackover Creek (Union County) ◈	Do not consume	Do not consume	Do not consume	No more than 2 meals per month
Felsenthal Wildlife Refuge (Union, Bradley, Ashley Counties) ◈	Crappie - no restrictions Do not consume all other predators.	Bluegill - no restrictions Do not consume all other non-predators.	Crappie - no restrictions Do not consume all other predators.	Bluegill - no restrictions Do not consume more than 2 meals a month of all other non-predators.

* Pregnant women, women who plan to get pregnant, women who are breastfeeding, and children under the age of 7 years are considered high risk groups for health effects due to mercury exposure and as a general rule should not eat fish from the consumption notice areas.

Predator species include bass, pickerel, catfish, crappie, gar and bowfin. Non-predator species include bream, drum, buffalo, red horse and suckers.

A meal consists of 8 ounces of fish.

Vacationers and persons who occasionally eat fish from fish consumption notice areas (once every 2 - 3 months or less) are not at risk for health effects due to mercury exposure.

All areas affected by these notices have been closed to commercial fishing. Fish continue to be tested in other areas of the state and additonal fish consumption notices will be issued if needed.

Fish Consumption Notices

Effective July, 1994

Location (see map on back) Key: ⓢ South ⓝ North- ⓒ Central	High Risk Groups*		General Public	
	Predators	Non-Predators	Predators	Non-Predators
All ox-bow lakes, backwaters, overflow lakes, and barrow ditches formed by the Ouachita River below Camden to Louisiana border ⓢ	Do not consume	Do not consume	Do not consume	No more than 2 meals per month
Saline River (from Highway 79 in Cleveland County to Highway 160 bridge) ⓢ	Do not consume	Do not consume	No more than 2 meals per month	No more than 2 meals per month
Saline River (below Highway 160 to the Ouachita River) ⓢ	Do not consume	Do not consume	Do not consume	No restrictions
Dorcheat Bayou ⓢ	Do not consume	Do not consume	No consumption of large mouth bass, 16 inches or longer. No more than 2 meals per month of all other predators.	No restrictions
Fouche La Fave River (from Nimrod Dam to the confluence of the South Fouche, Perry County) ⓒ	No consumption of large mouth bass, 16 inches or longer. No restrictions for all other predators.	No restrictions	No more than 2 meals per month of large mouth bass, 16 inches or longer. No restictions on all other predators.	No restrictions
Johnson Hole (South Fork of the Little Red River, Van Buren County) ⓝ	No consumption of large mouth bass, 16 inches or longer. No restrictions for all other predators.	No restrictions	No consumption of large mouth bass, 16 inches or longer. No restrictions for all other predators.	No restrictions
Nimrod Lake (Yell and Perry Counties) ⓒ	No consumption of large mouth bass, 16 inches or longer. No restrictions for all other predators.	No restrictions	No more than 2 meals per month of large mouth bass, 16 inches or longer. No restrictions on all other predators.	No restrictions
Lake Winona (Saline County) ⓒ	No consumption of black bass 16 inches or longer. No restrictions for all other predators.	No restrictions	No more than 2 meals per month of black bass 16 inches or longer. No restrictions for all other predators.	No restrictions

* Pregnant women, women who plan to get pregnant, women who are breastfeeding, and children under the age of 7 years are considered **high risk** groups for health effects due to mercury exposure and as a general rule should not eat fish from the consumption notice areas.

Predator species include bass, pickerel, catfish, crappie, gar and bowfin. Non-predator species include bream, drum, buffalo, red horse and suckers.

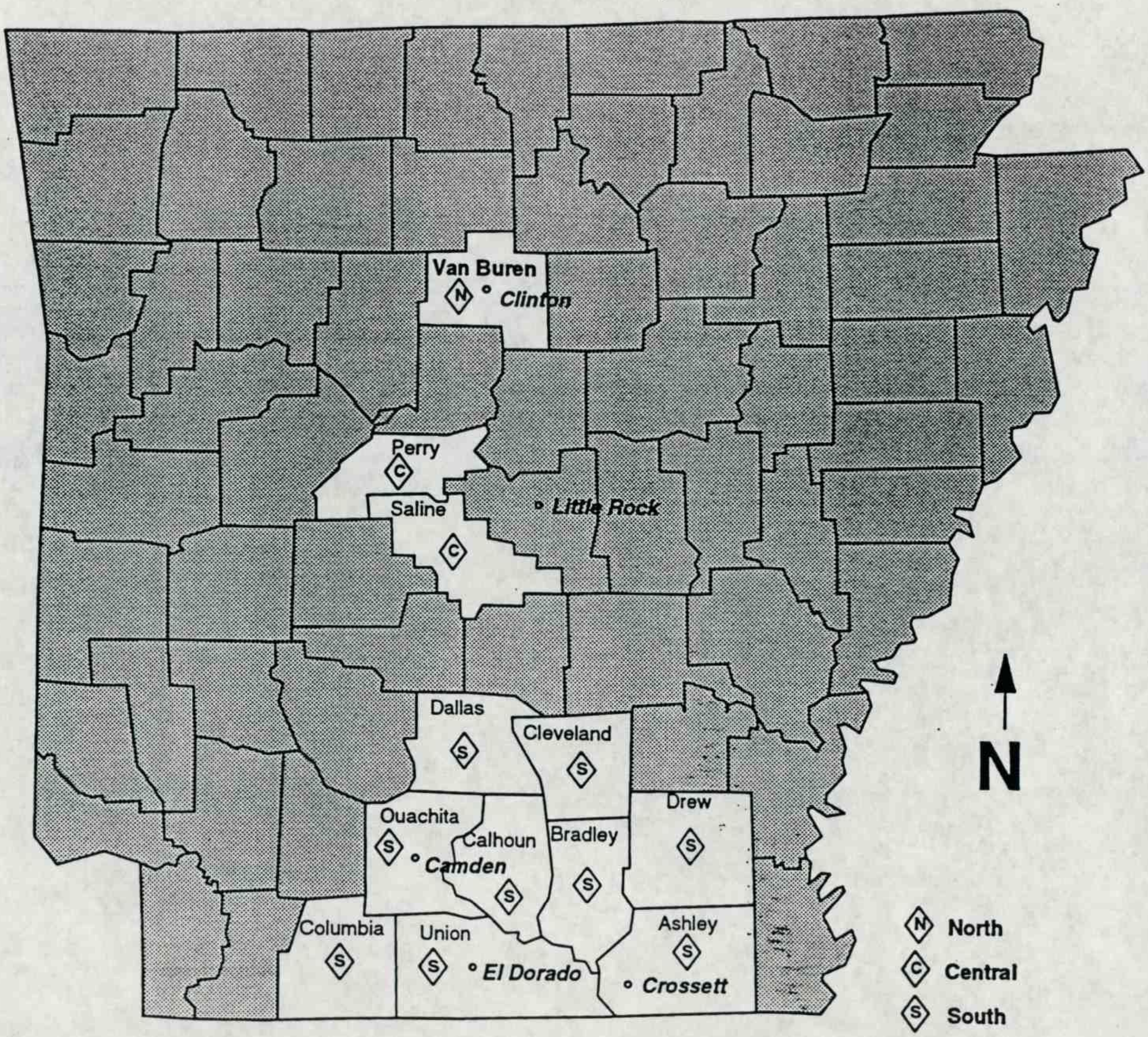
A meal consists of 8 ounces of fish.

Vacationers and persons who occasionally eat fish from fish consumption notice areas (once every 2 - 3 months or less) are not at risk for health effects due to mercury exposure.

All areas affected by these notices have been closed to commercial fishing. Fish continue to be tested in other areas of the state and additonal fish consumption notices will be issued if needed.

Arkansas Counties with Fish Consumption Notices Due to Mercury

(Counties noted in white)



For bodies of water under fish consumption notice, see inside.

Effective July 1994

Arkansas Department of Health

Keeping Your Hometown Healthy

4815 West Markham Street • Little Rock, Arkansas 72205 - 3867 • (501) 661-2000

Sandra B. Nichols, M.D.
Director

Jim Guy Tucker
Governor

Press Release

FOR IMMEDIATE RELEASE
February 22, 1995

FOR MORE INFORMATION CONTACT:
Arkansas Department of Health
Dr. Thomas McChesney
Phone: 501-661-2597

(Little Rock) --Dr. Sandra Nichols, Director of the Arkansas Department of Health, has issued a fish consumption notice for mercury on Shepherd Springs Lake in Crawford County. This fish consumption notice applies only to persons who routinely eat more than 2 meals of black bass (large mouth and spotted bass) 16 inches or longer per month from Shepherd Springs Lake and all persons in high risk groups. High risk groups include women who plan to become pregnant, pregnant women, breastfeeding women and children under the age of 7. Vacationers and those who eat fish occasionally from these waters are not considered to be at risk. A meal is considered to be 8 ounces of fish. (See attached fact sheets for more information on current fish consumption notices for mercury.)

This notice has been issued as a result of fish samples collected during 1994. The following is a summary of the data and recommendations of fish consumption:

The Food and Drug Administration action level of mercury is 1.0 ppm in the edible fish fillets. Therefore, the Arkansas Department of Health issues fish consumption notices when there is enough fish data to indicate that this level has been reached. Samples of black bass sixteen (16) inches in length but less than twenty (20) inches in length contained between 1.0 and 1.5 ppm of mercury. Black bass twenty (20) inches and longer contained greater than 1.5 ppm of mercury.

RECOMMENDATIONS:

High Risk Groups

-No black bass sixteen (16) inches in length or longer should be consumed;

-There is no restriction on consumption of black bass less than sixteen (16) inches in length, other predator species or non-predator species.

ARKANSAS FACT SHEET

MERCURY IN FISH

The Food and Drug Administration recommends that the public be informed when mercury levels in fish are found to be 1 part per million (PPM) or higher. Fish in certain bodies of water in Arkansas have been found to contain 1 ppm or more of mercury. Fish Consumption Notices are intended for persons who routinely eat more than 2 meals of fish per month from affected waters and high risk groups.

The Arkansas Department of Health recommends the following consumption guidelines for these fish:

	Consumption Guidelines	
Mercury Levels in Fish	General Public	High Risk Groups
Less than 1 ppm	No restrictions	No restrictions
1-1.5 ppm	2 meals/month	0 meals/month
More than 1.5 ppm	0 meals/month	0 meals/month

*A meals consists of 8 ounces of fish.

*Vacationers and those who eat fish occasionally are not considered to be at risk.

*Persons in High Risk Groups are women who plan to become pregnant, pregnant women, breastfeeding women and children under the age of 7 years.

The public should always use the following guidelines when selecting fish to eat:

*Choose non-predator species (including bream, drum, buffalo, red-horse, and suckers) over predator species (including bass, pickerel, catfish, crappie, bowfin).

*When possible, consume the smaller fish of any species.

Current Fish Consumption Notices
April 20, 1994

Predator species include bass, pickerel, catfish, crappie, gar, bowfin, etc.

Non-predator species include bream, drum, buffalo, red-horse, suckers, etc.

A meal consists of 8 ounces of fish.

Pregnant women, women who plan to get pregnant, women who are breastfeeding, and children under the age of 7 are considered high risk groups for health effects due to mercury exposure and as a general rule should not eat fish from the consumption notice areas.

Vacationers and person who occasionally eat fish from advisory areas (once every 2-3 months or less) are not at risk from mercury.

All areas affected by these advisories have been closed to commercial fishing. Fish continue to be tested in other areas of the state and additional advisories will be issued if needed.

Lake Columbia (Columbia Co.)

High Risk Group:
Predators: Do not consume
Non-Predators: Do not consume

General Public:
Predators: No more than 2 meals per months. No restrictions on largemouth bass less than 16 inches in length
Non-Predators: No restrictions

Cut-off Creek (from where the creek crosses Hwy. 35 in Drew Co. to its confluence with Bayou Bartholomew)

High Risk Group:
Predators: Do not consume
Non-Predators: Do not consume

General Public:
Predators: No more than 2 meals per month
Non-Predators: Do not consume

Bayou Bartholomew (from where it crosses Hwy. 35 in Drew Co. to its confluence with Little Bayou in Ashley Co.)

High Risk Group:
Predators: Do not consume
Non-Predators: Do not consume

General Public:
Predators: No more than 2 meals per month
Non-Predators: Do not consume

Big Johnson Lake (Calhoun Co.)

High Risk Group:
Predators: Do not consume
Non-Predators: Do not consume

General Public:
Predators: No more than 2 meals per month
Non-Predators: No restrictions

Snow Lake (Calhoun Co.)

High Risk Group:
Predators: Do not consume
Non-Predators: Do not consume

General Public:
Predators: Do not consume
Non-Predators: No restrictions

Grays Lake (Cleveland Co.)

High Risk Group:
Predators: Do not consume
Non-Predators: Do not consume

General Public:
Predators: No more than 2 meals per month
Non-Predators: No restrictions

Moro Bay Creek (from Hwy. 160 to its confluence with the Ouachita River)

High Risk Group:
Predators: Do not consume
Non-Predators: Do not consume

General Public:
Predators: Do not consume
Non-Predators: No more than 2 meals per month

Champagnolle Creek (to include Little champagnolle from Hwy. 4 to its confluence with the Ouachita River)

High Risk Group:
Predators: Do not consume
Non-Predators: Do not consume

General Public:
Predators: No more than 2 meals per month
Non-Predators: No restrictions

Ouachita River (from Smackover Creek to the Louisiana border) except Felsenthal Wildlife Refuge

High Risk Group:
Predators: Do not consume
Non-Predators: Do not consume

General Public:
Predators: Do not consume
Non-Predators: No more than 2 meals per month

Felsenthal Wildlife Refuge

High Risk Group:
Predators: Crappie(no restriction); do not consume all other predators
Non-Predators: Bluegill(no restriction); do not consume all other predators

General Public:
Predators: Crappie (no restriction); do not consume all other predators
Non-Predators: Bluegill (no restriction); do not consume more than 2 meals per month for all other non-predators

All ox-bow lakes, backwaters, overflow lakes, and barrow ditches formed by the Ouachita River below Camden except Felsenthal Wildlife Refuge

High Risk Group:
Predators: Do not consume
Non-Predators: Do not consume

General Public:
Predators: Do not consume
Non-Predators: No more than 2 meals per month

Saline River (from Hwy. 70 in Cleveland Co. to the Hwy. 160 bridge)

High Risk Group:
Predators: Do not consume
Non-Predators: Do not consume

General Public:
Predators: No more than 2 meals per month
Non-Predators: No more than 2 meals per month

Saline River (below Hwy. 160 to the Ouachita River)

High Risk Group:
Predators: Do not consume
Non-Predators: Do not consume

Genreal Public:
Predators: Do not consume
Non-Predators: No restrictions

Dorcheat Bayou

High Risk Group:
Predators: Do not consume
Non-Predators: Do not consume

General Public:
Predators: No consumption of largemouth bass 16 inches or longer. No more than 2 meals per month of all other predators including largemouth bass less than 16 inches
Non-Predators: No restrictions

Johnson Hole (South Fork of the Little Red River)

High Risk Group:
Predators: No consumption of largemouth bass 16 inches or longer. No restrictions of all other predators including largemouth bass less than 16 inches
Non-Predators: No restrictions

General Public:
Predators: No consumption of largemouth bass 16 inches or longer. No restrictions of all other predators including largemouth bass less than 16 inches.
Non-Predators: No restrictions

Fouche La Fave River from Nimrod Dam to the confluence of the South Fouche

High Risk Group:
Predators: No consumption of largemouth bass 16 inches or longer. No restrictions of all other predators including largemouth bass less than 16 inches.
Non-Predators: No restrictions

General Public:
Predators: No more than 2 meals per month of largemouth bass 16 inches or longer. No restrictions of all other predators including largemouth bass less than 16 inches.
Non-Predators: No restrictions

Nimrod Lake

High Risk Group:
Predators: No consumption of largemouth bass 16 inches or longer. No restrictions of all othe predators including largemouth bass less than 16 inches
Non-Predators: No restrictions

General Public:
Predators: No more than 2 meals per month of largemouth bass 16 inches or longer. No restriction of all other predators including largemouth bass less than 16 inches.
Non-Predators: No restrictions

Lake Winona

High Risk Group:

Predators: No consumption of black bass 16 inches or longer. No restrictions of all other predators including black bass less than 16 inches

Non-Predators: No restrictions

General Public:

Predators: No more than 2 meals per month of black bass 16 inches or longer. No restrictions of all other predators including black bass less than 16 inches

Non-Predators: No restrictions

Shepherd Springs Lake

High Risk Group:

-No black bass 16 inches in length or longer should be consumed

-There is no restriction on consumption of black bass less than 16 inches in length, other predator species or non-predator species

General Public:

-No black bass 20 inches in length or longer should be consumed

-No more than 2 meals per month of black bass 16 inches in length to less than 20 inches in length should be consumed

-There is no restriction on consumption of black bass less than 16 inches in length, other predator species or non-predator species.

Appendix H

Brainstorming Notes from Mercury Advisory Committee Meeting

Results from the Mercury Task Force Education Brainstorming Session, January 1995

I. What Groups Need to Hear the Mercury Message?

GOAL: To develop a list of all individuals and groups that should be made aware of the presence of mercury in fish, what steps are being taken to manage the situation, and how harm can be avoided.

1. Women of reproductive age
2. Pregnant women
3. Young children
4. Parents of young children
5. Anglers - consumers of large amounts of fish
6. Members of bass clubs
7. Members of anglers' families
8. Health care providers (especially Obs, pediatricians, nurses practitioners, nutritionists, AHEC staff, community health center staffs)
9. Teachers
10. Minority groups who consume large amounts of native fish
11. Leaders of minority communities
12. Local media
13. Commercial fishermen
14. Local political leaders
15. Fishing supply stores
16. Tourists
17. Sources of tourist information
18. State legislators/Governor
19. Civic clubs (Lions, Rotary, Boy and Girl Scouts, 4H, etc.)
20. Impacted government agencies (federal and state level)
21. County Extension service
22. Community Health Centers

II. What Message Should Be Told

GOAL: To list the topics that should be communicated to the target audiences identified in Section I. (After going through the previous exercise, we noticed that there were two broad groups that should be educated about mercury; the first group is made up of individuals who are at risk ; the second group ("secondary information providers") is composed of individuals who the at-risk group might turn to for additional information, interpretation of information, or confirmation of information. Both groups should be given hard facts as much as possible.)

II.A. Messages for Those At Risk

1. How and why harm can occur
2. Actual affects to:
   a. Fetuses and children
   b. Adults
3. How to manage their exposure
4. Some message on how the occurrence of mercury in fish is being managed
5. How they can find out what their mercury level is
6. Make sure they know they are at risk and why
7. Give alternatives to fish consumption
8. Results of blood testing that is being done

II. Secondary Providers of Information

(The group noted that on-going, reliable and consistent communication is needed for this group)

1. Background on the mercury problem; should be in-depth information so they can speak with authority
2. For medical providers, adequate toxicity information to facilitate diagnosis, appropriate testing, etc.
3. Get them to believe the data - share facts
4. Same basic information as the "At Risk" group
5. How and where to refer individuals for more information or to get more information themselves
6. Emphasize why they (local contacts) need to help identify and refer
7. Background on the fish monitoring program and the fish consumption advisories
8. This will be an on-going management process
9. Give them knowledgeable contacts for referrals or questions
10. Keep the contacts going; should be an on-going process with advance notice of information made publicly available (new consumption advisories, news releases, monitoring results, etc.)
11. Need budget to provide materials to Secondary Providers
12. Need to keep the situation in perspective

III. Ways to Reach Target Audiences

GOAL: To develop a list of ways to get the messages identified in Section II to the target audiences in Section I.

(We started by taking each of the targets identified in Section I. and thinking of ways they could be reached. It became evident that such an approach would be redundant. For that reason, all the "Way to Reach" ideas have been grouped together; obviously some are appropriate for some audiences and formats and not for others).

1. Literacy may be a problem; some verbal-only techniques will need to be utilized
2. Local businesses (posters, flyers, etc. in banks, grocery stores, etc.)
3. Healthy Baby Coupon Book
4. Traditional PR campaign
5. Cooperative Extension Service programs
6. Videos at local health units, doctors' offices, AHECs, Community Health Centers
7. TV and radio spots
8. School programs
9. Local health unit prenatal classes
10. Message should dispel the misconception that mercury is in the water, making it unsafe for drinking, swimming, etc.
11. Churches and other community groups
12. County fairs
13. Food Stamp distribution and any similar commodity/assistance programs
14. WIC/EPSDT
15. DHS programs
16. Game and Fish Commission activities
17. Encourage the media to attend meetings where mercury information will be presented
18. Develop an information package for local community and political leaders
19. Make sure the information flow to the "Secondary Information Providers" is ongoing
20. Put together a speakers bureau on mercury
21. Send videos to ministers
22. Ask to present at church consortium meetings (might also be a way to contact ministers in the target areas)
23. Routine updates in the Arkansas Medical Society Journal
24. Make sure individuals likely to be contacted about mercury at UAMS, poison control or ACH are aware of our activities
25. Make sure fish consumption advisories get to AHECs and CHCs.
26. Continue the medical education program
27. Pursue the use of the interactive video program at UAMS to provide information to health care providers

28. Articles in the ADH's physician bulletins
29. Local health units make staff available to present local programs
30. Present at annual conferences of various health care providers (Obs, pediatricians, Arkansas Perinatal Association, Dr. Quark's conference)
31. Prepared press releases; should make sure that there is "news" in the news release
32. Information of the length/mercury concentration relationship
33. Provide information on how Arkansas is handling the mercury situation as opposed to other states
34. Try to get AETN to air spots or produce a program on the management plan
35. Use personal contacts within each community to make sure the media knows what we know
36. Provide information to the fishing industry that will help it (i.e., trophy bass programs, safe sizes/species, etc.)
37. Work with the fishing industry to develop positive management approaches
38. Help the fishing industry answer the question (positively) "Can I eat the fish I catch here?"

IV. Obstacles to Communicating with Target Audiences

GOAL: To identify situations which may prevent getting the Section II messages to the Section I audience.

1. Misconception about the nature of the problem (i.e., mercury is in the water)
2. Physicians may have told their patients that mercury isn't a problem
3. Education/information overload
4. Mercury may be much less of a problem than other things individuals are faced with
5. Difficult to demonstrate any adverse affects in Arkansas
6. Certain target groups will be very difficult to reach
7. Literacy
8. Mis-information
9. The database we have is not complete and is therefore not conclusive
10. Negative impact on tourism and fishing industries
11. The message may be different for different groups (i.e., children & women vs. older population)
12. Will probably need to work one-on-one with fishing industry proprietors and use a pilot program to work out the kinks.

V. Follow-up on Information Strategies

GOAL: To define what type of follow-up (format, frequency, target audience, content, etc.) is needed.

1. Need to share information about the status of mercury in the environment
2. Conduct polling (observance of fish consumption advisories, catch-and-release, etc.) at selected access points
3. Keep the media, health care providers and other Secondary Information Providers current on all developments
4. Ask that all outdated materials be destroyed (fish consumption advisories, etc.)
5. Survey target county residents to check their general attitude toward the mercury management plan, compliance (market survey); use this information to modify as needed the outreach activities
6. Be aware of the "scare factor"; perhaps lump with other "no-no's" (smoking)
7. Make sure Secondary Information Providers receive consistent messages from all primary sources
8. Survey the medical community to determine their awareness of the mercury managed plan

Appendix I

SSMWG Report to EPA on Federal Assistance Needs

DRAFT

Southern States Mercury Working Group

Report to the EPA:

Federal Assistance Needs

1. Federal coordinator or point of contact for coordination of state and regional studies.

2. Bulletin Board or similar depository for exchange of information.

3. Studies on fish sampling/sub-sampling to reduce amount of tissue for analysis; also holding time studies.

4. Deposition estimates and deposition monitoring network; revive NAAP for mercury guidance.

5. Tissue standards for methylmercury; water standards for methylmercury; current tissues standards from NRCC.

6. Round robin programs for sediment, tissue and water samples; QA checks with state participation.

7. Financial support for regional mercury task force efforts by the states.

8. Financial support for outreach activities to access impacted segments of the public.

9. Source studies applicable to the southern U.S., including the role of southern bottom- land hardwood wetlands.

10. Continued dialogue between the FDA and EPA on a consensus of option on risk for all groups.

11. Alternative fish management programs for impacted fisheries.

12. Human biomarker studies in areas where impacted fisheries are found. These should be long-term studies involving high risk groups (pregnant women, young children and subsistence fishermen) whose blood mercury levels are between 20

ppb and 200 ppb.

13. National database on blood and hair levels for mercury where the consumption of fish is the source of mercury exposure.

14. A comparison of the health benefits vs. the detrimental effects of eating fish contaminated with mercury at various levels (i.e., 0.5 mg/kg, 1.0 mg/kg, 1.5 mg/kg) for both the general public and high risk groups.

15. Standard approaches for fish consumption advisories; leadership at the federal level