

Prepared in cooperation with the Missouri Department of Conservation

Concentration of Elements in Whole-body Fish, Fish Fillets, Fish Muscle Plugs, and Fish Eggs from the 2008 Missouri Department of Conservation General Contaminant Monitoring Program

Open-File Report 2009–1278

Concentration of Elements in Whole-body Fish, Fish Fillets, Fish Muscle Plugs, and Fish Eggs from the 2008 Missouri Department of Conservation General Contaminant Monitoring Program

By Thomas W. May, Michael J. Walther, William G. Brumbaugh, and Michael J. McKee

Prepared in cooperation with the Missouri Department of Conservation

Open-File Report 2009–1278

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2009

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment, visit <http://www.usgs.gov> or call 1-888-ASK-USGS

For an overview of USGS information products, including maps, imagery, and publications, visit <http://www.usgs.gov/pubprod>

To order this and other USGS information products, visit <http://store.usgs.gov>

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Although this report is in the public domain, permission must be secured from the individual copyright owners to reproduce any copyrighted materials contained within this report.

Suggested citation:

May, T.W., Walther, M.J., Brumbaugh, W.G., McKee, M., 2009, Concentrations of elements in whole-body fish, fish fillets, fish muscle plugs, and fish eggs from the 2008 Missouri Department of Conservation general contaminant monitoring program: U.S. Geological Survey Open-File Report 2009–1278, 11 p.

Contents

Abstract.....	1
Introduction.....	1
Sampling History.....	1
Methods.....	3
Homogenization and Lyophilization	3
Chemical Preparation	3
Instrumental Analysis.....	3
Quality Control.....	3
Results	3
Quality Control Results.....	10
References Cited.....	11

Tables

1. Missouri collection sites for whole-body fish, fish fillets, fish muscle plugs, and fish eggs from the 2008 Missouri Department of Conservation General Contaminant Monitoring Program	2
2. Percent moisture and dry weight concentrations of calcium, cadmium, mercury, and lead, and [lead/calcium] molar ratios in Missouri Department of Conservation 2008 General Contaminant Monitoring Program fish tissues and egg samples	4
3. Percent moisture and wet weight concentrations of calcium, cadmium, mercury, and lead, in Missouri Department of Conservation 2008 General Contaminant Monitoring Program fish tissues and egg samples	7
4. Concentrations of total mercury in fish muscle plugs.....	10

Conversion Factors

Multiply	By	To obtain
Length		
millimeter (mm)	0.03937	inch (in.)
micrometer	0.0000393	inch (in.)
Volume		
liter (L)	33.82	ounce, fluid (fl. oz)
milliliter (mL)	.034	ounce, fluid (fl. oz)
Mass		
gram (g)	0.03527	ounce, avoirdupois (oz)
milligram (mg)	.000035	ounce (oz)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F}=(1.8\times^{\circ}\text{C})+32$$

Concentrations of chemical constituents in water are given in nanograms per milliliter (ng/mL).

Concentrations of chemical constituents in solid materials are given in either micrograms per gram ($\mu\text{g/g}$) dry weight or $\mu\text{g/g}$ wet weight.

Concentrations of Elements in Whole-body Fish, Fish Fillets, Fish Muscle Plugs, and Fish Eggs from the 2008 Missouri Department of Conservation General Contaminant Monitoring Program

By Thomas W. May¹, Michael W. Walther¹, William G. Brumbaugh¹, and Michael J. McKee²

Abstract

This report presents the results of a contaminant monitoring survey conducted annually by the Missouri Department of Conservation to examine the levels of selected elemental contaminants in whole-body fish, fish fillets, fish muscle plugs, and fish eggs. Whole-body, fillet, or egg samples of catfish (*Ictalurus punctatus*, *Ictalurus furcatus*, *Pylodictis olivaris*), largemouth bass (*Micropterus salmoides*), walleye (*Sander vitreus*), crappie (*Pomoxis annularis*, *Pomoxis nigromaculatus*), shovelnose sturgeon (*Scaphirhynchus platyrhynchus*), northern hog sucker (*Hypentelium nigricans*), and Missouri saddled darter (*Etheostoma tetrazonum*) were collected from 23 sites as part of the Missouri Department of Conservation's Fish Contaminant Monitoring Program. Fish dorsal muscle plugs also were collected from walleye (*Sander vitreus*) at one of the sites.

salmoides), walleye (*Sander vitreus*), crappie (*Pomoxis annularis*, *Pomoxis nigromaculatus*), shovelnose sturgeon (*Scaphirhynchus platyrhynchus*), northern hog sucker (*Hypentelium nigricans*), and Missouri saddled darter (*Etheostoma tetrazonum*). Besides fish fillet samples collected in 2008, fish eggs were collected from catfish (*Ictalurus furcatus*, *Pylodictis olivaris*) and shovelnose sturgeon (*Scaphirhynchus platyrhynchus*); all samples of Missouri saddled darters (*Etheostoma tetrazonum*) were whole-body. In addition, only fish dorsal muscle plugs were collected from 15 walleye (*Sander vitreus*) samples from one site. The MDC has requested the assistance of the U.S. Geological Survey (USGS) for this monitoring program because of past experience with aquatic biota monitoring projects and expertise in the preparation and analysis of fish for elemental contaminants. For more detailed information on the overall study design or specific sample information, please contact the Missouri Department of Conservation in Columbia, Missouri.

Introduction

The Missouri Department of Conservation (MDC) initiated long-term statewide fish monitoring of environmental contaminants in 1984. The objective is to select predator and bottom dwelling species annually from each of 20 to 30 lakes and streams across Missouri to characterize concentrations of targeted metal and other chemical contaminants. Actual sites monitored each year vary based on data needs, budgets, and personnel resources. Emphasis is on human health and, therefore, study components include fish fillets, composite fillet samples, and sample replication at each site. In 2008, 23 sites (table 1) were selected for sampling as part of the MDC General Contaminant Monitoring Program (GCMP). The 2008 collection consisted of catfish (*Ictalurus punctatus*, *Ictalurus furcatus*, *Pylodictis olivaris*), largemouth bass (*Micropterus*

Sampling History

A shipment of 27 whole-body fish, 37 fish fillets, 11 fish eggs, and 15 fish muscle plugs was received by USGS personnel on November 25, 2008. The samples included skin-on (northern hog sucker) and skinless fillets (largemouth bass, walleye, crappie, lake sturgeon, common carp, and flathead, blue and channel catfish) to reflect the form of fish tissue customarily consumed by anglers. Upon receipt, the shipment was assigned USGS batch number 1544 and sample identifications (IDs) 44797-44886. All samples had been stored frozen at -20 degrees Celsius (°C) since collection at the MDC's Resource Science Center in Columbia, Missouri, and were delivered by MDC personnel. Requested analyses included cadmium (Cd), Hg, and Pb. Calcium (Ca) also was analyzed in an effort to explain Pb variability (Schmitt and Finger, 1987). Fish fillet samples were variable in the way they were obtained, and the fillet technique may have resulted in different amounts

¹ U.S. Geological Survey

² Missouri Department of Conservation

2 Concentrations of Elements in Whole-body Fish, Fish Fillets, Fish Muscle Plugs, and Fish Eggs

Table 1. Missouri collection sites for whole-body fish, fish fillets, fish muscle plugs, and fish eggs from the 2008 Missouri Department of Conservation General Contaminant Monitoring Program.

[@, at; Hwy, Highway]

Species and common name	Sites	Matrix
<i>Ictalurus punctatus</i> Channel Catfish	Harrison County Lake	fillet
<i>Ictalurus furcatus</i> Blue Catfish	Mississippi River @ Crystal City	fillet/eggs
<i>Pylodictis olivaris</i> Flathead Catfish	Mississippi River @ Crystal City	fillet/eggs
<i>Micropterus salmoides</i> Largemouth Bass	Harrison County Lake	fillet
	Clearwater Lake	fillet
<i>Pomoxis annularis</i> White Crappie	Clearwater Lake	fillet
<i>Pomoxis nigromaculatus</i> Black Crappie	Harrison County Lake	fillet
<i>Hypentelium nigricans</i> Northern Hog Sucker	Black River below Clearwater Dam	fillet
<i>Scaphirhynchus platyrhynchus</i> Shovelnose sturgeon	Missouri River @ Napoleon	fillet
	Missouri river @ Miami	fillet
	Missouri River @ Nodaway Island	fillet
	Mississippi River @ Caruthersville	fillet
	Mississippi River @ Saverton	fillet
	Missouri River @ Mokane	fillet
	Missouri River @ Weldon Springs	fillet
	Mississippi River @ Crystal City	fillet/eggs
	Mississippi River @ Cape Girardeau	fillet/eggs
<i>Sander vitreus</i> Walleye	Stockton Lake	fillet
	Lake of the Ozarks @ Truman Tailwaters	muscle plug
<i>Etheostoma tetrazonum</i> Missouri Saddled Darter	Big River above Irondale @ Cedar Creek	whole-body
	Big River @ Irondale Access	whole-body
	Bourbeuse River @ Chateau Claim Access	whole-body
	Big River @ Desloge (Hwy 67 Bridge)	whole-body
	Big River @ Hwy K	whole-body
	Big River @ Hwy 67 North of Bonne Terre	whole-body
	Big River @ Mammoth Access	whole-body
	Big River @ Washington State Park	whole-body
Big River @ Cedar Hills	whole-body	

of tissue extracted and, thus, may have varying amounts of calcium-rich bone fragments that can be comparatively high in Pb.

Methods

Homogenization and Lyophilization

GCM fillet samples were chopped with a titanium meat cleaver on a cleaned polypropylene cutting board. Larger fillets were ground with a Hobart® meat grinder, whereas smaller fillets were ground in a modified KitchenAid® meat grinder. The smallest samples as well as fish eggs and whole body composites were minced with a titanium meat cleaver. All chopped and ground samples were lyophilized, and then hand-kneaded in a plastic (polyethylene) bag or crushed with a rolling pin in a plastic bag. All dried and ground products were stored at room temperature in a 40-milliliter (mL) glass vial in a desiccator. Fish dorsal muscle plugs required no homogenization and were lyophilized as received.

Chemical Preparation

To prepare fish samples for analysis of Ca, Cd, and Pb, a dried sample of approximately 0.25 grams (g) was heated with 6mL nitric acid in a sealed low-pressure Teflon vessel in a laboratory microwave oven. The cooled digestate liquid was transferred into a 125-mL polyethylene bottle with ultrapure water [specific resistance greater than (>) 10 megOhms per centimeter (megOhm/cm)] and diluted to a final weight of 101.5 g. Final acid matrix was 6 percent by volume concentrated nitric acid. For the determination of Hg in fish samples, there was no chemical preparation (digestion) because the dried sample was decomposed thermally during instrumental analysis (see below).

Instrumental Analysis

Calcium, Cd, and Pb analyses were conducted using a PE/SCIEX Elan 6000® inductively coupled plasma-mass spectrometer (ICP-MS), which was set up in “Standard Mode” and optimized according to the manufacturer’s specifications. Samples were delivered automatically to the ICP-MS by means of a software-controlled CETAC ASD-500 autosampler/autodiluter system. All sample digestates were analyzed with a ten-fold predilution by autodiluter.

The ICP-MS quantitative method was designed to determine the following masses: ^{44}Ca and ^{48}Ca , ^{111}Cd and ^{114}Cd , and Pb as the sum of three masses ($^{206}\text{Pb}+^{207}\text{Pb}+^{208}\text{Pb}$). The internal standards were scandium (Sc) at 10 nanograms per milliliter (ng/mL), rhodium (Rh; 10 ng/mL), and bismuth (Bi; 10 ng/mL), which were metered into the sample line via peristaltic pump. Calibration standards for analyses were as follows: Ca

– 2500, 5000, and 10,000 ng/mL; Pb – 5, 10, 20, and 40 ng/mL; and Cd - 1.5, 3.0, 6.0, and 12 ng/mL. During the actual analysis, any digestate concentration greater than the upper calibration standard for any element was automatically diluted 10-fold serially until its concentration was below this level. Where multiple masses for an element were measured, the concentration reported was based on the mass exhibiting least interferences, which were as follows: ^{44}Ca , ^{114}Cd , and Pb as the sum of three masses $^{206}\text{Pb}+^{207}\text{Pb}+^{208}\text{Pb}$).

Mercury was determined with a Milestone DMA-80 analyzer equipped with an automated sample carousel. With this method, a dried fish sample [40 to 60 milligrams (mg)] was combusted in a stream of oxygen. All Hg in the sample was volatilized and trapped by amalgamation on a gold substrate, and was thermally desorbed and quantitated by atomic absorption spectrophotometry (United States Environmental Protection Agency, 1998).

Quality Control

The samples were digested and analyzed in two groups or batches for Ca, Cd, and Pb, and five batches for Hg. The quality control incorporated in the digestion stage of the samples (for subsequent ICP-MS analysis) included digestion blanks, reference materials, replicates, and spikes. For the determination of Ca, Cd, and Pb by ICP-MS, instrumental quality control included calibration checks, laboratory control solutions, duplicate digestate analysis, analysis spikes, and interference checks (dilution percent difference and a synthetic interference solution). Quality control for Hg included blanks, independent calibration verification checks, replicates, pre-combustion spikes, and tissue reference materials. All quality-control results were tabulated to provide an overview of quality assurance and to facilitate interpretation.

Results

Percent moisture, concentrations in micrograms per gram ($\mu\text{g/g}$) dry weight of Ca, Cd, Hg, and Pb, and molar ratios (fillet samples only) of [Pb/Ca] (1×10^{-6}) for the GCM samples are presented in table 2. To facilitate comparison with any regulatory guidelines, concentrations of Ca, Cd, Hg and Pb are presented in $\mu\text{g/g}$ wet weight in table 3. Concentrations of total mercury in $\mu\text{g/g}$ dry and wet weight in fish muscle plugs are presented in table 4. For this report all sample and quality control data are discussed in terms of dry weight results only.

Calcium concentrations were variable among fillet samples; concentrations were generally within a factor of two to three among northern hog sucker, catfish, crappie, and largemouth bass, but increased to a factor of ten in sturgeon (table 2). Such variation presumably was because of variable bone content in the fillets and undoubtedly was affected by significant variations in fillet preparation techniques as well as

4 Concentrations of Elements in Whole-body Fish, Fish Fillets, Fish Muscle Plugs, and Fish Eggs

Table 2. Percent moisture and dry weight concentrations of calcium, cadmium, mercury, and lead, and [lead/calcium] molar ratios in Missouri Department of Conservation 2008 General Contaminant Monitoring Program fish tissues and egg samples.

[USGS, U.S. Geological Survey; ID, identifier; MDC, Missouri Department of Conservation; Ca, calcium; µg/g, micrograms per gram dry weight; Cd, cadmium; Hg, mercury; Pb, lead; <, less than; ---, ratio not determined for this matrix; bold and italicized values are greater than the method detection limit but less than the method quantitation limit and have higher uncertainty]

USGS ID	MDC ID	Fish common name	Matrix	Percent moisture	Ca µg/g	Cd µg/g	Hg µg/g	Pb µg/g	[Pb/Ca] Molar Ratio (1x10 ⁻⁶)
44845	2008-017-358-1	Missouri saddled darter	whole-body fish	68.1	62,000	1.18	< 0.047	48.4	---
44846	2008-017-358-2	Missouri saddled darter	whole-body fish	69.9	59,200	1.37	< 0.047	39.9	---
44847	2008-017-358-3	Missouri saddled darter	whole-body fish	69.5	74,500	1.22	< 0.047	50.0	---
44848	2008-133-358-1	Missouri saddled darter	whole-body fish	67.3	65,300	0.68	0.053	29.1	---
44849	2008-133-358-2	Missouri saddled darter	whole-body fish	67.9	62,700	0.76	< 0.047	21.2	---
44850	2008-133-358-3	Missouri saddled darter	whole-body fish	67.6	55,700	0.72	< 0.047	23.6	---
44851	2008-134-358-1	Missouri saddled darter	whole-body fish	72.2	71,100	1.02	< 0.047	51.8	---
44852	2008-134-358-2	Missouri saddled darter	whole-body fish	69.1	98,500	1.52	< 0.047	62.2	---
44853	2008-134-358-3	Missouri saddled darter	whole-body fish	72.4	71,100	1.30	< 0.047	67.8	---
44854	2008-714-358-1	Missouri saddled darter	whole-body fish	71.8	90,400	0.047	0.14	0.74	---
44855	2008-714-358-2	Missouri saddled darter	whole-body fish	66.5	73,000	0.049	0.16	0.38	---
44856	2008-714-358-3	Missouri saddled darter	whole-body fish	68.1	86,400	0.058	0.22	0.52	---
44857	2008-715-358-1	Missouri saddled darter	whole-body fish	67.6	92,900	0.18	0.29	0.64	---
44858	2008-715-358-2	Missouri saddled darter	whole-body fish	67.3	66,000	0.37	0.17	0.45	---
44859	2008-715-358-3	Missouri saddled darter	whole-body fish	66.8	69,500	0.11	0.24	0.70	---
44860	2008-716-358-1	Missouri saddled darter	whole-body fish	71.4	38,600	0.048	0.14	0.27	---
44861	2008-716-358-2	Missouri saddled darter	whole-body fish	73.5	40,600	0.16	0.095	0.53	---
44862	2008-716-358-3	Missouri saddled darter	whole-body fish	71.3	36,700	0.065	0.12	0.29	---
44863	2008-717-358-1	Missouri saddled darter	whole-body fish	80.6	74,600	2.04	< 0.047	59.1	---
44864	2008-717-358-2	Missouri saddled darter	whole-body fish	73.1	82,500	1.79	< 0.047	65.7	---
44865	2008-717-358-3	Missouri saddled darter	whole-body fish	69.5	74,900	2.00	0.053	78.9	---
44866	2008-718-358-1	Missouri saddled darter	whole-body fish	71.1	73,200	1.40	< 0.047	71.3	---

Table 2. Percent moisture and dry weight concentrations of calcium, cadmium, mercury, and lead, and [lead/calcium] molar ratios in Missouri Department of Conservation 2008 General Contaminant Monitoring Program fish tissues and egg samples.—Continued

[USGS, U.S. Geological Survey; ID, identifier; MDC, Missouri Department of Conservation; Ca, calcium; µg/g, micrograms per gram dry weight; Cd, cadmium; Hg, mercury; Pb, lead; <, less than; ---, ratio not determined for this matrix; bold and italicized values are greater than the method detection limit but less than the method quantitation limit and have higher uncertainty]

USGS ID	MDC ID	Fish common name	Matrix	Percent moisture	Ca µg/g	Cd µg/g	Hg µg/g	Pb µg/g	[Pb/Ca] Molar Ratio (1x10 ⁻⁶)
44867	2008-718-358-2	Missouri saddled darter	whole-body fish	69.9	64,200	1.34	< 0.047	65.6	---
44868	2008-718-358-3	Missouri saddled darter	whole-body fish	69.7	63,600	1.08	< 0.047	60.4	---
44869	2008-719-358-1	Missouri saddled darter	whole-body fish	67.5	67,300	1.29	< 0.047	40.7	---
44870	2008-719-358-2	Missouri saddled darter	whole-body fish	66.5	71,200	1.03	< 0.047	53.4	---
44871	2008-719-358-3	Missouri saddled darter	whole-body fish	67.0	58,200	1.48	< 0.047	47.7	---
44797	2008-005-232-1-E	blue catfish	fish eggs	58.2	1,400	0.014	< 0.044	0.15	---
44798	2008-005-232-2-E	blue catfish	fish eggs	58.9	1,420	0.007	< 0.044	0.042	---
44799	2008-005-232-3-E	blue catfish	fish eggs	59.4	1,530	0.052	0.22	0.029	---
44800	2008-005-245-1-E	flathead catfish	fish eggs	61.4	2,160	0.011	0.070	0.033	---
44801	2008-005-245-2-E	flathead catfish	fish eggs	58.2	2,150	0.009	< 0.044	0.019	---
44802	2008-005-245-3-E	flathead catfish	fish eggs	57.3	2,420	0.026	< 0.044	0.034	---
44803	2008-005-011-1-E	shovelnose sturgeon	fish eggs	12.4	37.8	0.035	< 0.044	0.023	---
44804	2008-005-011-3-E	shovelnose sturgeon	fish eggs	41.9	770	0.036	< 0.044	0.096	---
44805	2008-005-011-4-E	shovelnose sturgeon	fish eggs	40.6	58.2	0.009	< 0.044	0.016	---
44806	2008-005-011-5-E	shovelnose sturgeon	fish eggs	56.3	306	0.024	< 0.044	0.052	---
44807	2008-297-011-2-E	shovelnose sturgeon	fish eggs	49.9	236	0.010	< 0.044	0.055	---
44830	2008-713-406-1	largemouth bass	fish fillet	79.0	389	< 0.007	2.29	0.12	59.7
44831	2008-713-406-2	largemouth bass	fish fillet	79.0	333	< 0.007	2.46	0.057	33.1
44832	2008-713-406-3	largemouth bass	fish fillet	79.1	565	< 0.007	2.02	0.030	10.3
44833	2008-713-430-1	black crappie	fish fillet	80.3	1,570	< 0.007	1.18	0.029	3.6
44834	2008-713-430-2	black crappie	fish fillet	79.2	1,660	< 0.007	0.63	0.058	6.8
44835	2008-713-430-3	black crappie	fish fillet	79.9	2,390	< 0.007	0.77	0.036	2.9
44836	2008-165-431-1	white crappie	fish fillet	80.2	560	< 0.007	1.38	0.042	14.5
44837	2008-165-431-2	white crappie	fish fillet	80.8	1,740	< 0.007	1.48	0.026	2.9
44838	2008-165-431-3	white crappie	fish fillet	80.7	787	< 0.007	1.33	0.014	3.4
44839	2008-165-406-1	largemouth bass	fish fillet	78.2	736	0.039	2.02	0.014	3.7
44840	2008-165-406-2	largemouth bass	fish fillet	79.1	494	< 0.007	2.42	0.015	5.9
44841	2008-165-406-3	largemouth bass	fish fillet	78.3	318	< 0.007	2.35	0.023	14.0
44842	2008-710-053-1	northern hog sucker	fish fillet	78.5	1,800	0.016	1.89	0.021	2.3
44843	2008-710-053-2	northern hog sucker	fish fillet	78.8	1,210	0.019	2.16	0.016	2.6

6 Concentrations of Elements in Whole-body Fish, Fish Fillets, Fish Muscle Plugs, and Fish Eggs

Table 2. Percent moisture and dry weight concentrations of calcium, cadmium, mercury, and lead, and [lead/calcium] molar ratios in Missouri Department of Conservation 2008 General Contaminant Monitoring Program fish tissues and egg samples.—Continued

[USGS, U.S. Geological Survey; ID, identifier; MDC, Missouri Department of Conservation; Ca, calcium; µg/g, micrograms per gram dry weight; Cd, cadmium; Hg, mercury; Pb, lead; <, less than; ---, ratio not determined for this matrix; bold and italicized values are greater than the method detection limit but less than the method quantitation limit and have higher uncertainty]

USGS ID	MDC ID	Fish common name	Matrix	Percent moisture	Ca µg/g	Cd µg/g	Hg µg/g	Pb µg/g	[Pb/Ca] Molar Ratio (1x10 ⁶)
44844	2008-710-053-3	northern hog sucker	fish fillet	78.6	1,390	0.012	2.00	0.080	11.1
44808	2008-005-232-1-F	blue catfish	fish fillet	76.0	251	0.020	0.74	0.046	35.5
44809	2008-005-232-2-F	blue catfish	fish fillet	78.9	254	< 0.003	0.60	0.040	30.5
44810	2008-005-232-3-F	blue catfish	fish fillet	79.6	209	0.049	3.50	0.020	18.5
44811	2008-713-230-1	channel catfish	fish fillet	78.5	320	0.007	0.46	0.069	41.7
44812	2008-713-230-2	channel catfish	fish fillet	79.5	381	0.008	0.43	0.071	36.0
44813	2008-713-230-3	channel catfish	fish fillet	77.3	337	0.004	0.41	0.064	36.7
44814	2008-005-245-1-F	flathead catfish	fish fillet	72.2	259	0.006	1.78	0.017	12.7
44815	2008-005-245-2-F	flathead catfish	fish fillet	76.7	256	< 0.003	1.44	0.17	128.
44816	2008-005-245-3-F	flathead catfish	fish fillet	79.0	345	0.003	2.44	0.091	51.0
44817	2008-004-011	shovelnose sturgeon	fish fillet	76.9	264	0.026	0.46	0.047	34.4
44818	2008-005-011-F-1	shovelnose sturgeon	fish fillet	74.1	1,800	0.034	0.47	0.052	5.6
44819	2008-005-011-F-3	shovelnose sturgeon	fish fillet	76.6	230	0.022	0.57	0.055	46.3
44820	2008-005-011-F-4	shovelnose sturgeon	fish fillet	75.1	247	0.018	0.43	0.040	31.3
44821	2008-005-011-F-5	shovelnose sturgeon	fish fillet	78.8	290	0.076	0.70	0.052	34.7
44822	2008-297-011	shovelnose sturgeon	fish fillet	75.0	247	0.005	0.38	0.034	26.6
44823	2008-297-011-F-2	shovelnose sturgeon	fish fillet	67.1	188.	0.019	0.42	0.045	46.3
44824	2008-337-011	shovelnose sturgeon	fish fillet	81.6	356.	0.026	0.54	0.026	14.1
44825	2008-477-011	shovelnose sturgeon	fish fillet	76.9	270.	0.005	0.28	0.027	19.3
44826	2008-491-011	shovelnose sturgeon	fish fillet	81.1	2,030.	0.036	0.62	0.063	6.0
44827	2008-507-011	shovelnose sturgeon	fish fillet	78.2	282.	0.018	0.44	0.025	17.1
44828	2008-675-011	shovelnose sturgeon	fish fillet	79.8	565	0.024	0.56	0.040	13.7
44829	2008-676-011	shovelnose sturgeon	fish fillet	81.3	1,310	0.038	0.58	0.059	8.7

Table 3. Percent moisture and wet weight concentrations of calcium, cadmium, mercury, and lead, in Missouri Department of Conservation 2008 General Contaminant Monitoring Program fish tissues and egg samples.

[USGS, U.S. Geological Survey; ID, identifier; MDC, Missouri Department of Conservation; Ca, calcium; µg/g, micrograms per gram wet weight; Cd, cadmium; Hg, mercury; Pb, lead; @, at; <, less than; Hwy, Highway; Crk, creek; bold and italicized values are greater than the method detection limit but less than the method quantitation limit and have higher uncertainty]

USGS ID	MDC ID	Collection site	Matrix	Percent moisture	Ca µg/g	Cd µg/g	Hg µg/g	Pb µg/g
44845	2008-017-358-1	Big River @ Mammoth Access	whole-body saddled darter	68.1	19,800	0.38	<0.015	15.5
44846	2008-017-358-2	Big River @ Mammoth Access	whole-body saddled darter	69.9	17,800	0.41	<0.015	12.0
44847	2008-017-358-3	Big River @ Mammoth Access	whole-body saddled darter	69.5	22,700	0.37	<0.015	15.2
44848	2008-133-358-1	Big River @ Cedar Hills	whole-body saddled darter	67.3	21,300	0.22	0.017	9.51
44849	2008-133-358-2	Big River @ Cedar Hills	whole-body saddled darter	67.9	20,100	0.24	<0.015	6.81
44850	2008-133-358-3	Big River @ Cedar Hills	whole-body saddled darter	67.6	18,000	0.23	<0.015	7.64
44851	2008-134-358-1	Big River @ Hwy 67 North of Bon Terre	whole-body saddled darter	72.2	19,800	0.28	<0.015	14.4
44852	2008-134-358-2	Big River @ Hwy 67 North of Bon Terre	whole-body saddled darter	69.1	30,400	0.47	<0.015	19.2
44853	2008-134-358-3	Big River @ Hwy 67 North of Bon Terre	whole-body saddled darter	72.4	19,600	0.36	<0.015	18.7
44854	2008-714-358-1	Big River above Irondale @ Cedar Crk	whole-body saddled darter	71.8	25,500	0.013	0.038	0.21
44855	2008-714-358-2	Big River above Irondale @ Cedar Crk	whole-body saddled darter	66.5	24,500	0.016	0.055	0.13
44856	2008-714-358-3	Big River above Irondale @ Cedar Crk	whole-body saddled darter	68.1	27,600	0.019	0.069	0.17
44857	2008-715-358-1	Big River @ Irondale Access	whole-body saddled darter	67.6	30,100	0.058	0.095	0.21
44858	2008-715-358-2	Big River @ Irondale Access	whole-body saddled darter	67.3	21,600	0.12	0.056	0.15
44859	2008-715-358-3	Big River @ Irondale Access	whole-body saddled darter	66.8	23,000	0.036	0.079	0.23
44860	2008-716-358-1	Boubeuse River @ Chateau Claim Access	whole-body saddled darter	71.4	11,000	0.014	0.039	0.08
44861	2008-716-358-2	Boubeuse River @ Chateau Claim Access	whole-body saddled darter	73.5	10,800	0.042	0.025	0.14
44862	2008-716-358-3	Boubeuse River @ Chateau Claim Access	whole-body saddled darter	71.3	10,500	0.019	0.035	0.083
44863	2008-717-358-1	Big River @ Desloge (Hwy 67 Bridge)	whole-body saddled darter	80.6	14,500	0.40	<0.015	11.5
44864	2008-717-358-2	Big River @ Desloge (Hwy 67 Bridge)	whole-body saddled darter	73.1	22,200	0.48	<0.015	17.7
44865	2008-717-358-3	Big River @ Desloge (Hwy 67 Bridge)	whole-body saddled darter	69.5	22,800	0.61	0.016	24.0
44866	2008-718-358-1	Big River @ Hwy K	whole-body saddled darter	71.1	21,200	0.40	<0.015	20.6
44867	2008-718-358-2	Big River @ Hwy K	whole-body saddled darter	69.9	19,300	0.40	<0.015	19.8
44868	2008-718-358-3	Big River @ Hwy K	whole-body saddled darter	69.7	19,300	0.33	<0.015	18.3
44869	2008-719-358-1	Big River @ Washington State Park	whole-body saddled darter	67.5	21,800	0.42	<0.015	13.2
44870	2008-719-358-2	Big River @ Washington State Park	whole-body saddled darter	66.5	23,800	0.34	<0.015	17.9
44871	2008-719-358-3	Big River @ Washington State Park	whole-body saddled darter	67.0	19,200	0.49	<0.015	15.7
44797	2008-005-232-1-E	Mississippi River @ Crystal City, Mo.	blue catfish fish eggs	58.2	586.	0.006	<0.020	0.063
44798	2008-005-232-2-E	Mississippi River @ Crystal City, Mo.	blue catfish fish eggs	58.9	584.	0.003	<0.020	0.017
44799	2008-005-232-3-E	Mississippi River @ Crystal City, MO	blue catfish fish eggs	59.4	621.	0.021	0.088	0.012

Table 3. Percent moisture and wet weight concentrations of calcium, cadmium, mercury, and lead, in Missouri Department of Conservation 2008 General Contaminant Monitoring Program fish tissues and egg samples.—Continued

[USGS, U.S. Geological Survey; ID, identifier; MDC, Missouri Department of Conservation; Ca, calcium; µg/g, micrograms per gram wet weight; Cd, cadmium; Hg, mercury; Pb, lead; @, at; <, less than; Hwy, Highway; Crk, creek; bold and italicized values are greater than the method detection limit but less than the method quantitation limit and have higher uncertainty]

USGS ID	MDC ID	Collection site	Matrix	Percent moisture	Ca µg/g	Cd µg/g	Hg µg/g	Pb µg/g
44800	2008-005-245-1-E	Mississippi River @ Crystal City, MO	flathead catfish fish eggs	61.4	834	0.004	0.027	0.013
44801	2008-005-245-2-E	Mississippi River @ Crystal City, MO	flathead catfish fish eggs	58.2	900	0.004	< 0.020	0.008
44802	2008-005-245-3-E	Mississippi River @ Crystal City, MO	flathead catfish fish eggs	57.3	1,034	0.011	< 0.020	0.015
44803	2008-005-011-1-E	Mississippi River @ Crystal City, MO	shovelnose sturgeon fish eggs	12.4	33.1	0.031	< 0.040	0.020
44804	2008-005-011-3-E	Mississippi River @ Crystal City, MO	shovelnose sturgeon fish eggs	41.9	448	0.021	< 0.030	0.056
44805	2008-005-011-4-E	Mississippi River @ Crystal City, MO	shovelnose sturgeon fish eggs	40.6	34.6	0.005	< 0.030	0.010
44806	2008-005-011-5-E	Mississippi River @ Crystal City, MO	shovelnose sturgeon fish eggs	56.3	134	0.010	< 0.020	0.023
44807	2008-297-011-2-E	Mississippi River @ Cape Girardeau, MO	shovelnose sturgeon fish eggs	49.9	118	0.005	< 0.022	0.028
44830	2008-713-406-1	Harrison County Lake	largemouth bass fish fillet	79.0	81.8	< 0.002	0.48	0.025
44831	2008-713-406-2	Harrison County Lake	largemouth bass fish fillet	79.0	70.1	< 0.002	0.52	0.012
44832	2008-713-406-3	Harrison County Lake	largemouth bass fish fillet	79.1	118	< 0.002	0.42	0.006
44833	2008-713-430-1	Harrison County Lake	black crappie fish fillet	80.3	310	< 0.002	0.23	0.006
44834	2008-713-430-2	Harrison County Lake	black crappie fish fillet	79.2	345	< 0.002	0.13	0.012
44835	2008-713-430-3	Harrison County Lake	black crappie fish fillet	79.9	480	< 0.002	0.15	0.007
44836	2008-165-431-1	Clearwater Lake	white crappie fish fillet	80.2	111	< 0.002	0.27	0.008
44837	2008-165-431-2	Clearwater Lake	white crappie fish fillet	80.8	334	< 0.002	0.28	0.005
44838	2008-165-431-3	Clearwater Lake	white crappie fish fillet	80.7	152	< 0.002	0.26	0.003
44839	2008-165-406-1	Clearwater Lake	largemouth bass fish fillet	78.2	161	0.009	0.44	0.003
44840	2008-165-406-2	Clearwater Lake	largemouth bass fish fillet	79.1	103	< 0.002	0.50	0.003
44841	2008-165-406-3	Clearwater Lake	largemouth bass fish fillet	78.3	68.9	< 0.002	0.51	0.005
44842	2008-710-053-1	Below Clearwater Dam	northern hog sucker fish fillet	78.5	387	0.003	0.41	0.005
44843	2008-710-053-2	Below Clearwater Dam	northern hog sucker fish fillet	78.8	256	0.004	0.46	0.003
44844	2008-710-053-3	Below Clearwater Dam	northern hog sucker fish fillet	78.6	297	0.003	0.43	0.017
44808	2008-005-232-1-F	Mississippi River @ Crystal City, MO	blue catfish fillet	76.0	60.3	0.005	0.18	0.011

Table 3. Percent moisture and wet weight concentrations of calcium, cadmium, mercury, and lead, in Missouri Department of Conservation 2008 General Contaminant Monitoring Program fish tissues and egg samples.—Continued

[USGS, U.S. Geological Survey; ID, identifier; MDC, Missouri Department of Conservation; Ca, calcium; µg/g, micrograms per gram wet weight; Cd, cadmium; Hg, mercury; Pb, lead; @, at; <, less than; Hwy, Highway; Crk, creek; bold and italicized values are greater than the method detection limit but less than the method quantitation limit and have higher uncertainty]

USGS ID	MDC ID	Collection site	Matrix	Percent moisture	Ca µg/g	Cd µg/g	Hg µg/g	Pb µg/g
44809	2008-005-232-2-F	Mississippi River @ Crystal City, MO	blue catfish fillet	78.9	53.5	<0.001	0.13	0.008
44810	2008-005-232-3-F	Mississippi River @ Crystal City, MO	blue catfish fillet	79.6	42.6	0.010	0.71	0.004
44811	2008-713-230-1	Harrison County Lake	channel catfish fillet	78.5	68.7	0.002	0.10	0.015
44812	2008-713-230-2	Harrison County Lake	channel catfish fillet	79.5	78.1	0.002	0.09	0.015
44813	2008-713-230-3	Harrison County Lake	channel catfish fillet	77.3	76.3	0.001	0.09	0.014
44814	2008-005-245-1-F	Mississippi River @ Crystal City, MO	flathead catfish fillet	72.2	72.1	0.002	0.50	0.005
44815	2008-005-245-2-F	Mississippi River @ Crystal City, MO	flathead catfish fillet	76.7	59.6	<0.001	0.34	0.040
44816	2008-005-245-3-F	Mississippi River @ Crystal City, MO	flathead catfish fillet	79.0	72.5	0.001	0.51	0.019
44817	2008-004-011	Mississippi River @ Caruthersville, MO	shovelnose sturgeon fillet	76.9	61.0	0.006	0.11	0.011
44818	2008-005-011-F-1	Mississippi River @ Crystal City, MO	shovelnose sturgeon fillet	74.1	466	0.009	0.12	0.013
44819	2008-005-011-F-3	Mississippi River @ Crystal City, MO	shovelnose sturgeon fillet	76.6	53.9	0.005	0.13	0.013
44820	2008-005-011-F-4	Mississippi River @ Crystal City, MO	shovelnose sturgeon fillet	75.1	61.5	0.004	0.11	0.010
44821	2008-005-011-F-5	Mississippi River @ Crystal City, MO	shovelnose sturgeon fillet	78.8	61.5	0.016	0.15	0.011
44822	2008-297-011	Mississippi River @ Cape Girardeau, MO	shovelnose sturgeon fillet	75.0	61.8	0.001	0.094	0.009
44823	2008-297-011-F-2	Mississippi River @ Cape Girardeau, MO	shovelnose sturgeon fillet	67.1	61.8	0.006	0.14	0.015
44824	2008-337-011	Missouri River @ Miami, MO	shovelnose sturgeon fillet	81.6	65.6	0.005	0.099	0.005
44825	2008-477-011	Mississippi River @ Saverton, MO	shovelnose sturgeon fillet	76.9	62.4	0.001	0.065	0.006
44826	2008-491-011	Missouri River @ Nodoway Island	shovelnose sturgeon fillet	81.1	383	0.007	0.12	0.012
44827	2008-507-011	Missouri River @ Weldon Springs	shovelnose sturgeon fillet	78.2	61.6	0.004	0.096	0.005
44828	2008-675-011	Missouri River @ Mokane, MO	shovelnose sturgeon fillet	79.8	114	0.005	0.11	0.008
44829	2008-676-011	Missouri River @ Napoleon, MO	shovelnose sturgeon fillet	81.3	246	0.007	0.11	0.011

Table 4. Concentrations of total mercury in fish muscle plugs.

[USGS, U.S. Geological Survey; ID, identifier; MDC, Missouri Department of Conservation; Hg, mercury; ug/g, micrograms per gram; wet weight concentrations estimated assuming 78 percent moisture]

USGS ID	MDC ID	Collection location	Fish common name and matrix	Hg $\mu\text{g/g}$ dry weight	Hg $\mu\text{g/g}$ wet weight
44872	2008-025-406-1	Lake of the Ozarks @ Truman Tailwaters	walleye muscle plug	0.75	0.16
44873	2008-025-406-2	Lake of the Ozarks @ Truman Tailwaters	walleye muscle plug	0.53	0.12
44874	2008-025-406-3	Lake of the Ozarks @ Truman Tailwaters	walleye muscle plug	0.54	0.12
44875	2008-025-406-4	Lake of the Ozarks @ Truman Tailwaters	walleye muscle plug	0.35	0.077
44876	2008-025-406-5	Lake of the Ozarks @ Truman Tailwaters	walleye muscle plug	1.16	0.26
44877	2008-025-406-6	Lake of the Ozarks @ Truman Tailwaters	walleye muscle plug	0.32	0.070
44878	2008-025-406-7	Lake of the Ozarks @ Truman Tailwaters	walleye muscle plug	0.95	0.21
44879	2008-025-406-8	Lake of the Ozarks @ Truman Tailwaters	walleye muscle plug	0.86	0.19
44880	2008-025-406-9	Lake of the Ozarks @ Truman Tailwaters	walleye muscle plug	0.42	0.093
44881	2008-025-406-10	Lake of the Ozarks @ Truman Tailwaters	walleye muscle plug	0.27	0.059
44882	2008-025-406-11	Lake of the Ozarks @ Truman Tailwaters	walleye muscle plug	1.10	0.24
44883	2008-025-406-12	Lake of the Ozarks @ Truman Tailwaters	walleye muscle plug	0.44	0.10
44884	2008-025-406-13	Lake of the Ozarks @ Truman Tailwaters	walleye muscle plug	0.73	0.16
44885	2008-025-406-14	Lake of the Ozarks @ Truman Tailwaters	walleye muscle plug	0.33	0.072
44886	2008-025-406-15	Lake of the Ozarks @ Truman Tailwaters	walleye muscle plug	0.97	0.21

by the fish species. For example, catostomids possess numerous tiny intermuscular bones. Accordingly, fillets from some species (northern hog sucker and black crappie) contained higher Ca concentrations than other species (catfish). Although Ca normally is not a target analyte, fillet Ca concentrations are useful when target analytes include those that markedly accumulate in bone (for example, Pb). Thus, measurements of Ca can help explain high variation in Pb concentrations for individual samples that included variable amounts of Ca-rich tissue (Schmitt and Finger, 1987). Cadmium concentrations were less than 0.080 $\mu\text{g/g}$ dry weight in all fish egg and fillet samples, with a number of samples having concentrations less than method quantitation and method detection limits. Cadmium concentrations were considerably higher in whole-body Missouri saddled darters, ranging from 0.047 to 2.04 $\mu\text{g/g}$ dry weight. Two-thirds of the darter samples ($n=18$) had Cd concentrations greater than 0.5 $\mu\text{g/g}$ dry weight. On an individual fish basis, the highest Hg concentrations were measured in fillets of 6 largemouth bass, 3 northern hog suckers, and 3 catfish; these ranged from 1.78 to 3.50 $\mu\text{g/g}$ dry weight. These samples equaled or exceeded the current (2009) United States Environmental Protection Agency (USEPA) fish consumption advisory for Hg of 0.30 $\mu\text{g/g}$ wet weight, or about 1.5 $\mu\text{g/g}$ dry weight based on an 80 percent moisture content (United States Environmental Protection Agency, 2001). Apart from the fillet data, fish eggs and whole-body darters had Hg concentrations that were all less than 0.30 $\mu\text{g/g}$ dry weight. Concentrations of Hg in fish muscle plugs from walleye are presented in table 4 and ranged from 0.27 to 1.16 $\mu\text{g/g}$ dry weight; all plug values were less than the 0.30 $\mu\text{g/g}$ wet weight consumption

advisory guideline. All fish fillet and egg samples exhibited Pb concentrations less than 0.20 $\mu\text{g/g}$ dry weight and all but two fillet samples and one egg sample were less than 0.10 $\mu\text{g/g}$ dry weight. Whole-body saddled darter samples from the Bourbeuse River and Big River (above Irondale at Cedar Creek and Irondale Access sites) had the lowest Pb concentrations, ranging between 0.27 and 0.74 $\mu\text{g/g}$ dry weight. Lead concentrations in whole-body darters from all other Big River sites were much higher, ranging from 21.2 to 78.9 $\mu\text{g/g}$ dry weight (table 2).

Quality Control Results

Calibration Verification: A calibration blank and an independent calibration verification standard (ICVS) were analyzed every 10 samples to confirm the calibration status of the ICP-MS during instrumental analyses of the whole-body fish, fish fillet, and fish egg digestates for Ca, Cd, and Pb; blanks were within plus or minus (\pm) three times the instrument detection limits for each element, and ICVS recoveries were within the target of 90 to 110 percent of the ICVS standard concentration for each element. Two reference solutions [National Institute of Standards and Technology (NIST) Standard Reference Material (SRM) 1643e: Trace Elements in Water; and High Purity Standards Certified Reference Solution Trace Metals in Fish: HP CRM-TF] used as laboratory-control samples exhibited elemental recoveries ranging from 97 to 102 percent. Calibration verification reference tissues for total Hg [National Research Council Canada (NRCC) DOLT-3:

Dogfish Liver; International Atomic Energy Agency (IAEA) 407-Trace Elements and Methylmercury in Fish Tissue] were analyzed at the beginning and end of the instrumental runs to confirm the calibration status of the DMA-80 system; percent errors were within the target of ± 10 percent.

Reference Materials: Recoveries of Ca, Cd and Pb in three tissue reference materials [National Institute of Standards and Technology (NIST) 1566b: Oyster Tissue, n=2; NIST SRM 2976: Mussel Tissue, n=2; NIST 1577: Bovine Liver, n=1] ranged from 76 to 102 percent and averaged 96 percent. Recoveries of Hg from seven different tissue reference materials (IAEA MA-A-1: Copepod, n=3; IAEA MA-A-2: Fish Flesh Homogenate, n=5; IAEA 407: Whole-body Fish, n=4; NIST RM50: Albacore Tuna, n=1; NRCC DOLT-3: Dogfish Liver, n=4; NRCC DORM-2: Dogfish Fillet, n=4; NIST 2976: Mussel Tissue, n=1) ranged from 89 to 108 percent and averaged 99 percent.

Method and Instrumental Precision: Method precision as estimated from measurement variation for triplicate digestion and analysis of whole-body fish (n=2), had percent relative standard deviations (PRSDs) for Ca, Cd, and Pb that were < 12. PRSDs for fish eggs were 0.5 for Ca, but 47 and 46 for Cd and Pb; however, the higher variation for Cd was not unusual because the concentrations were below the method quantitation limit of 0.010 $\mu\text{g/g}$ dry weight). PRSDs for fish fillets were 69 and 77 for Ca and ranged from 18 to 39 for Cd and Pb. All PRSDs for Hg (n=5) were < 9 percent. Instrumental precision measured as relative percent difference (RPD) from the analysis of fish fillet (n= 5) and fish egg (n=1) duplicate digestates for Ca, Cd, and Pb was < 3 percent except for a 17 RPD for Ca in one fish fillet duplicate digestate.

Spikes: Recoveries of Ca, Cd, and Pb spiked into fish tissue (n=10) ranged from 71 to 106 percent and averaged 98 percent. Recoveries of methylmercury hydroxide spiked into whole-body fish (n=2), fish eggs (n=2), fish muscle plugs (n=2), and fish fillet tissue (n=4) ranged from 78 to 108 percent and averaged 97 percent. Post-digestion or analysis spikes for Ca, Cd, and Pb in fish fillets (n=9) had recoveries ranging from 95 to 105 percent and averaged 100 percent.

Interference Checks: As a check for potential interferences, dilution percent differences (DPDs) based on fivefold dilutions of fish fillet digestates (n=9) were determined. DPDs were ≤ 16 percent for Ca, Cd, and Pb. A synthetic solution containing high concentrations of aluminum, Ca, iron, magnesium, sodium, phosphorus, potassium, sulfur, carbon, molybdenum, and titanium was analyzed (n=4) to observe the effects of these potential interfering elements on the determination of Cd and Pb concentrations in this matrix. Recoveries were within the 80 to 120 percent tolerance.

Blank Equivalent Concentrations (BEC): BECs (Ca, Cd, Pb) for digestion blanks prepared with each batch were determined; all BECs were less than the corresponding method detection limits (MDLs) except for one instance of Cd (0.006 BEC compared to 0.003 $\mu\text{g/g}$ MDL) and two instances of Pb (0.033 BEC compared to 0.002 $\mu\text{g/g}$ MDL; 0.006 BEC compared to 0.005 $\mu\text{g/g}$ MDL). The BEC exceptions each represent very low concentrations that were not considered unusual. All BECs for Hg were less than the corresponding Hg MDLs.

Instrument Detection, Method Detection, and Method Quantitation Limits: The instrument detection limit (IDL) for Hg was 0.002 nanograms (ng); the IDLs for other target analytes in nanograms per milliliter were as follows: Ca, 2.49; Cd, 0.002; and Pb, 0.002. MDLs were computed in $\mu\text{g/g}$ dry weight for each batch of samples as:

$$3 \times (\text{SD}_b^2 + \text{SD}_s^2)^{1/2}$$

where

SD_b = standard deviation of a blank (n=3); and
 SD_s = standard deviation of a low level sample or spiked sample (n=3) and were as follows:

Ca, 1.2 to 4.0; Cd, 0.003 to 0.007; Hg, 0.015 to 0.072; and Pb, 0.002 to 0.010. Method quantitation limits (MQLs) were calculated in $\mu\text{g/g}$ dry weight as 3.3 x MDLs and were as follows: Ca, 4.0 to 13; Cd, 0.010 to 0.023; Hg, 0.008 to 0.056; Hg, 0.048 to 0.24; and Pb, 0.007 to 0.033. All quality-control results for the study were within acceptable limits as specified by USGS.

References Cited

- Schmitt, C.J., and Finger, S.E., 1987, The effects of sample preparation on measured concentrations of eight elements in edible tissues of fish from streams contaminated by lead mining: Archives of Environmental Contamination and Toxicology, v.16, p.185–207.
- U.S. Environmental Protection Agency, 1998, Mercury in solids and solutions by thermal decomposition, amalgamation, and atomic absorption spectrophotometry: accessed August 28, 2007, at http://www.epa.gov/epaoswer/hazwaste/test/up4a.htm#7_series.
- U.S. Environmental Protection Agency, 2001, Water quality criterion for protection of human health: methylmercury: U.S. Environmental Protection Agency, EPA-823-R-01-001, January 2001, Office of Water, Washington, D.C., 16 p.

Publishing support provided by:
Rolla Publishing Service Center

For more information concerning this publication, contact:
Director, USGS Columbia Environmental Research Center
4200 New Haven Road
Columbia, MO 65201
(573) 875-5399

Or visit the Columbia Environmental Research Center Web site at:
<http://www.cerc.usgs.gov/>

