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Open-File Report 2009–1091

U.S. Department of the Interior
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Conversion Factors

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
micrometer (µm)	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:

$$°F=(1.8\times°C)+32$$

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 (µg/g) dry weight or µg/g wet weight.

Concentrations of Elements in Fish Fillets, Fish Muscle Plugs, and Crayfish from the 2007 Missouri Department of Conservation General Contaminant Monitoring Program

By Thomas W. May[1], Michael J. Walther[1], William G. Brumbaugh[1], and Michael J. McKee[2]

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 fish fillets, fish muscle plugs, and crayfish. Fillets of channel catfish (*Ictalurus punctatus*), bass (*Micropterus salmoides, Micropterus dolomieu, Morone chrysops*), walleye (*Sander vitreus*), common carp (*Cyprinus carpio*), lake sturgeon (*Acipenser fulvescens),* northern hog sucker (*Hypentelium nigricans*), and rainbow trout (*Oncorhynchus mykiss*) were collected from 21 sites as part of the Department's Fish Contaminant Monitoring Program. Long-pincered crayfish (*Orconectes longidigitus)* were collected from one site to assess trophic transfer of metals to fish. Fish muscle plugs were collected from smallmouth bass (*Micropterus dolomieu)* at two different locations from one site.

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 20–30 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, incorporates fish fillets, composite fillet samples, and sample replication at each site. In 2007, 22 sites (table 1, at the back of this report) were selected for sampling as part of the MDC General Contaminant Monitoring Program (GCM). Each year the GCM focuses on the selection of predator and bottom dwelling species based on the need for specific mercury (Hg) information (walleye, *Sander vitreus*; flathead catfish, *Pylodictis olivaris*); specific lead (Pb) information (*Micropterus salmoides, Micropterus punctulatus, Micropterus dolomieu, Ambloplites rupestris*); or the potentially greater risk for consumption, such as large river catfish (e.g., *Ictalurus furcatus, Ictalurus punctatus, Pylodictis olivaris*); however, actual species collected in any given year may differ based on availability. The 2007 collection consisted of common carp (*Cyprinus carpio*), lake sturgeon (*Acipenser fulvescens*), northern hog sucker (*Hypentelium nigricans*), rainbow trout (*Oncorhynchus mykiss*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), white bass (*Morone chrysops)*, channel catfish (*Ictalurus punctatus*), and walleye (*Sander vitreus*). Besides the fish fillet samples collected in 2007, tail meat was collected from long-pincered crayfish (*Orconectes longidigitus*) from one site to assess the potential risk of mercury to crayfish as well as trophic transfer of mercury and other metals via crayfish. In addition, only fish muscle plugs were collected from 31 smallmouth bass *(Micropterus dolomieu)* 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 Mike McKee at the Missouri Department of Conservation in Columbia, Missouri.

Sampling History

A shipment of 85 fish fillet composites and 31 fish muscle plugs was received by USGS personnel on November 20, 2007. The samples included skin-on (northern hog sucker) and skinless fillets (largemouth bass, smallmouth bass, white bass, walleye, lake sturgeon, common carp, and channel catfish) to reflect the form of fish tissue normally consumed by anglers because of popular tradition. Upon receipt, the shipment was assigned USGS batch number 1426 and sample identifications (IDs) 41267–41382. A second shipment of nine composite fish fillets was received on April 10, 2008, and assigned USGS

[1] U.S. Geological Survey.

[2] Missouri Department of Conservation.

batch number 1450 and sample IDs 42147–42155. 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), mercury (Hg), and lead (Pb). Because fish fillet samples were extremely variable in the way they were obtained (the fillet technique may have resulted in different amounts of tissue extracted and, thus, may have varying amounts of calcium-rich bone fragments that can be comparatively high in lead), calcium (Ca) was added to the list of requested elements as a potential means to help explain lead variability (Schmitt and Finger, 1987).

Methods

Homogenization and Lyophilization

The 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 mass samples simply were minced with a ceramic knife. All chopped and ground samples were then lyophilized, followed by either hand-kneading in a plastic (polyethylene) bag or crushing 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 muscle plugs required no homogenization and were lyophilized as received.

Chemical Preparation

To prepare fish samples for analysis of calcium, cadmium, and lead, a dried sample of approximately 0.25 grams (g) was heated with 6 mL 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 [greater than (>) 10 megOhms per centimeter (megOhm/cm)] and diluted to a final weight of 101.5 g. Final acid matrix was 6 percent nitric acid. For the determination of mercury in fish samples, there was no chemical preparation (digestion) because the dried sample was decomposed thermally during instrumental analysis (see below).

Instrumental Analysis

Calcium, cadmium, and lead 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 automatically were delivered 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}Pb+^{207}Pb+^{208}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: calcium—2,500, 5,000, and 10,000 ng/mL; lead—5, 10, 20, and 40 ng/mL; and cadmium—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 in a serial fashion 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}Pb+^{207}Pb+^{208}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 mercury in the sample was volatilized and trapped by amalgamation on a gold substrate, and was thermally desorbed and quantitated by atomic absorption spectrophotometry (U.S. Environmental Protection Agency, 1998).

Quality Control

The samples were digested and analyzed in three groups or batches for calcium, cadmium, and lead, and six batches for mercury. 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 calcium, cadmium, and lead 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 mercury 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 dry weight of calcium, cadmium, mercury, and lead, and molar ratios of [lead/calcium] (1×10^{-6}) for the GCM samples are presented in table 2, at the back of this report. To facilitate comparison with any regulatory guidelines, concentrations of

calcium, cadmium, mercury, and lead are presented in micrograms per gram wet weight in table 3, at the back of this report. Concentrations of total mercury in micrograms per gram dry and wet weight in fish muscle plugs are presented in table 4, at the back of this report. 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, generally within a factor of two to three in northern hog sucker, rainbow trout, and walleye, but increased to a factor of four to six in all other species (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 by the fish species (such as catostomids, which possess numerous tiny intermuscular bones). Fillets from some species (northern hog sucker) contained higher calcium concentrations than other species (walleye). Although calcium normally is not a target analyte, fillet calcium concentrations are useful when target analytes include those that markedly accumulate in bone (for example, lead). Thus, measurements of calcium can help explain high variation in lead concentrations for individual samples that included variable amounts of calcium-rich tissue (Schmitt and Finger, 1987). Cadmium concentrations were less than 0.050 micrograms per gram (µg/g) dry weight in most samples, with many samples having concentrations less than method quantitation and method detection limits. The two highest cadmium concentrations were from northern hog sucker samples (41324, 0.23 µg/g dry weight; 41325, 0.11 µg/g dry weight). On an individual fish basis, the highest mercury concentrations were measured in 11 largemouth bass, 1 white bass, and 3 catfish; these ranged from 1.52 to 3.42 µg/g dry weight. These samples equaled or exceeded the current (2009) U.S. Environmental Protection Agency (USEPA) fish consumption advisory for mercury of 0.30 µg/g wet weight (U.S. Environmental Protection Agency, 2001). In addition to these fillet data, concentrations of mercury in fish muscle plugs from smallmouth bass are presented in table 4 and ranged from 0.90 to 3.26 µg/g dry weight. Mercury levels exceeded the 0.30 ug/g wet weight guideline in 20 of 31 muscle plug samples. Most fish fillet samples exhibited lead concentrations less than or equal to (≤) 0.20 µg/g dry weight with the following exceptions: sample 41308, 0.22 µg/g dry weight; sample 41297, 0.25 µg/g dry weight; sample 41325, 0.30 µg/g dry weight; and sample 41277, 0.57 µg/g dry weight. Fillet samples from catfish (n=2), bass (n=1), and hog sucker species (n=3) had lead concentrations between 0.10 and 0.20 µg/g dry weight and ranging from 0.12 to 0.17 µg/g dry weight. In sample 41277, which had the highest lead concentration, the calcium concentration was lower (471 µg/g dry weight), indicating that this fillet lead concentration was less affected by inclusion of bone fragments (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 fish fillet and crayfish muscle digestates for calcium, cadmium, and lead; blanks were within plus and minus (±) 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 89 to 100 percent. Calibration verification reference tissues [National Research Council Canada (NRCC) SRM DOLT-3: Dogfish Liver; International Atomic Energy Agency (IAEA) SRM 407-Trace Elements and Methylmercury in Fish Tissue] for total mercury 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 calcium, cadmium, and lead in three tissue reference materials (NIST SRM 1566b: Oyster Tissue, n=3; NIST SRM 2976: Mussel Tissue, n=1; NRCC SRM DORM-2: Dogfish Muscle, n=1) ranged from 98 to 137 percent and averaged 103 percent. Recoveries of mercury from eight different tissue reference materials (IAEA MA-A-1: Copepod, n=1; IAEA MA-M-2: Mussel Tissue, n=1; IAEA MA-A-2: Fish Flesh Homogenate, n=1; IAEA 407: Whole-body Fish, n=6; NIST RM50: Albacore Tuna, n=5; NRCC DOLT-3: Dogfish Liver, n=6; NRCC DORM-2: Dogfish Fillet, n=6; NIST SRM 2976: Mussel Tissue, n=2) ranged from 91 to 112 percent and averaged 100 percent.

Method and Instrumental Precision.—Method precision from the triplicate digestion and analysis of fish fillets (n=6) had percent relative standard deviations (PRSDs) for calcium, cadmium, and lead that were less than (<) 34, except for lead, which had one higher PRSD of 125 because of concentrations below the method quantitation limit of 0.033 µg/g dry weight). The PRSDs for mercury (n=6) were all < 8 percent. Instrumental precision measured as relative percent difference (RPD) from the analysis of fish fillet (n=9) duplicate digestates for calcium, cadmium, and lead was < 4 percent.

Spikes.—Recoveries of calcium, cadmium, and lead spiked into fish tissue (n=12) ranged from 95 to 117 percent and averaged 102 percent. Recoveries of methylmercury hydroxide spiked into a reference material (n=4) and fish fillet tissue (n=8) ranged from 86 to 113 percent and averaged 101 percent. Post-digestion or analysis spikes for calcium, cadmium, and lead in fish fillets (n=9) had recoveries ranging from 91 to 101 percent and averaged 97 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 < 8 percent for calcium, cadmium, and lead. A synthetic solution containing high concentrations of aluminum, calcium, iron, magnesium, sodium, phosphorus, potassium, sulfur,

carbon, molybdenum, and titanium was analyzed to observe the effects of these potential interfering elements on the determination of cadmium and lead concentrations in this matrix. Recoveries were within the 80 to 120 percent tolerance.

Blank Equivalent Concentrations (BEC).—BECs (calcium, cadmium, lead) 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 calcium (21.4 BEC vs 4.3 µg/g MDL) and one instance of lead (0.018 BEC vs 0.010 µg/g MDL). All BECs for mercury were less than the corresponding mercury MDLs.

Instrument Detection, Method Detection, and Method Quantitation Limits.—Instrument detection limits (IDLs) for mercury were 0.002 and 0.003 nanograms (ng); the IDLs for other target analytes in nanograms per milliliter were as follows: calcium, 2.49; cadmium, 0.002; and lead, 0.002. The MDLs were computed in µg/g dry weight for each batch of samples as:

$$3 \times (SD_b^2 + SD_s^2)^{1/2}$$

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:

calcium, 2.20 to 4.30; cadmium, 0.010 to 0.012; mercury, 0.003 to 0.035; and lead, 0.010 to 0.024. Method quantitation limits (MQLs) were calculated in micrograms per gram dry weight as 3.3 x MDLs and were as follows: calcium, 7.3 to 14; cadmium, 0.033 to 0.040; mercury, 0.008 to 0.056; mercury, 0.011 to 0.12; and lead, 0.033 to 0.079.

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.

Tables 1–4

Table 1. Missouri collection sites for fish, fish muscle plugs, and crayfish from the 2007 Missouri Department of Conservation General Contaminant Monitoring Program.

Species and common name	Site	Sample type
Ictalurus punctatus	Blue River	Fllet
Channel catfish	LaBelle Lake	Fillet
	Watkins Mill State Park	Fillet
	Mozingo Lake	Fillet
	Locust Creek	Fillet
Micropterus salmoides	Watkins Mill State Park	Fillet
Largemouth bass	Montrose Lake	Fillet
	Lake of the Ozarks	Fillet
	Mark Twain Lake	Fillet
	Mozingo Lake	Fillet
	Stockton Lake	Fillet
	Lake St. Louis	Fillet
	Busch Memorial Conservation Area	Fillet
	Truman Lake	Fillet
Cyprinus carpio	Montrose Lake	Fillet
Common carp		
Acipenser fulvescens	Mississippi River	Fillet
Lake sturgeon		
Micropterus dolomieu	Middle Fork Black River	Fillet
Smallmouth bass	Strothers Creek	Fillet
	Black River	Fillet
	Logan Creek	Fillet
	Eleven Point	Muscle plug
Hypentelium nigricans	Middle Fork Black River	Fillet
Northern hog sucker	Strothers Creek	Fillet
	Black River	Fillet
	Logan Creek	Fillet
Morone chrysops	Clearwater Lake	Fillet
White bass	Wappapello Lake	Fillet
Sander vitreus	Stockton Lake	Fillet
Walleye		
Oncorhynchus mykiss	Mackay Park Lake	Fillet
Rainbow trout		
Orconectes longidigitus	Table Rock Lake	Tail muscle
Long-pincered crayfish		

Table 2. Percent moisture, dry weight concentrations of calcium, cadmium, mercury, lead, and [lead/calcium] molar ratios in Missouri Department of Conservation 2007 General Contaminant Monitoring fish and crayfish tissues.

[USGS, U.S. Geological Survey; ID, identification; Ca, calcium; µg/g, micrograms per gram dry weight; Cd; cadmium; Hg, mercury; Pb, lead; <, less than; bold and italicized values are greater than the method detection limit but less than the method quantitation limit and have higher uncertainty]

USGS ID	Field/Lab ID	Fish common name	Percent moisture	Ca (µg/g)	Cd (µg/g)	Hg (µg/g)	Pb (µg/g)	[Pb/Ca] molar ratio ($1x10^{-6}$)
41274	2007-006-230-1	Channel catfish	81.7	414	0.048	1.23	0.078	36.4
41270	2007-012-230-1	Channel catfish	75.6	394	<0.010	0.23	0.050	24.5
41271	2007-012-230-2	Channel catfish	76.2	598	<0.010	0.32	0.10	32.3
41272	2007-012-230-3	Channel catfish	76.7	434	<0.010	0.32	0.066	29.4
41290	2007-081-230-1	Channel catfish	77.3	364	0.049	0.35	0.050	26.6
41291	2007-081-230-2	Channel catfish	77.6	1,250	<0.010	0.31	0.058	8.98
41292	2007-081-230-3	Channel catfish	77.8	380	***0.012***	0.31	0.062	31.6
41267	2007-544-230-1	Channel catfish	81.7	421	<0.010	0.70	0.12	55.1
41268	2007-544-230-2	Channel catfish	80.5	418	<0.010	0.68	0.095	44.0
41269	2007-544-230-3	Channel catfish	79.5	433	<0.010	0.55	***0.030***	13.4
41280	2007-222-230-1	Channel catfish	83.1	1,740	<0.010	2.66	0.086	9.56
41281	2007-222-230-2	Channel catfish	78.3	680	***0.012***	1.79	0.067	19.1
41282	2007-222-230-3	Channel catfish	77.1	356	<0.010	0.70	0.071	38.6
41283	2007-222-230-4	Channel catfish	82.4	388	<0.010	0.80	0.059	29.4
41284	2007-222-230-5	Channel catfish	76.8	392	<0.010	0.24	0.12	59.2
41285	2007-651-230-1	Channel catfish	78.8	412	<0.010	1.40	0.052	24.4
41286	2007-651-230-2	Channel catfish	80.1	684	<0.010	0.88	0.043	12.2
41287	2007-651-230-3	Channel catfish	78.1	318	<0.010	2.49	***0.019***	11.6
41288	2007-651-230-4	Channel catfish	71.8	247	<0.010	0.28	***0.024***	18.8
41289	2007-651-230-5	Channel catfish	74.3	289	<0.010	0.28	***0.015***	10.0
41276	2007-040-070-1	Carp	79.9	2,170	<0.010	0.25	0.067	5.97
41277	2007-315-010-1	Lake sturgeon	76.7	471	<0.010	0.35	0.57	234.
41278	2007-315-010-2	Lake sturgeon	75.1	316	<0.010	0.31	0.063	38.6
41279	2007-315-010-3	Lake sturgeon	77.0	1,220	***0.011***	0.52	0.049	7.77
41273	2007-006-406-1	Largemouth bass	80.1	492	<0.010	1.62	0.077	30.3
41293	2007-025-406-1	Largemouth bass	79.3	423	<0.010	0.36	0.077	35.2
41294	2007-025-406-2	Largemouth bass	78.8	526	***0.014***	0.38	0.074	27.2
41295	2007-025-406-3	Largemouth bass	79.0	411	<0.010	0.46	***0.021***	9.88
41275	2007-040-406-1	Largemouth bass	78.6	488	<0.010	0.18	0.038	15.1
41296	2007-074-406-1	Largemouth bass	79.0	468	<0.010	0.79	***0.016***	6.61
41297	2007-074-406-2	Largemouth bass	78.5	655	0.18	1.18	0.25	73.8
41329	2007-118-406-1	Largemouth bass	81.0	574	***0.019***	0.65	0.050	16.9
41330	2007-118-406-2	Largemouth bass	80.8	729	***0.021***	0.50	0.046	12.2
41331	2007-118-406-3	Largemouth bass	80.5	433	***0.013***	0.56	***0.047***	21.0
41338	2007-151-406-1	Largemouth bass	80.2	1,070	< 0.010	1.52	0.10	18.1
41339	2007-151-406-2	Largemouth bass	80.2	3,310	< 0.010	1.55	***0.027***	1.58
41340	2007-151-406-3	Largemouth bass	79.7	1,200	< 0.010	1.62	***0.053***	8.54
41341	2007-152-406-1	Largemouth bass	79.9	571	< 0.010	2.64	***0.032***	10.8
41342	2007-152-406-2	Largemouth bass	80.0	470	< 0.010	3.42	***0.025***	10.3
41335	2007-241-406-1	Largemouth bass	79.8	416	< 0.010	1.64	***0.047***	21.9
41336	2007-241-406-2	Largemouth bass	80.1	402	< 0.010	1.58	***0.060***	28.9
41337	2007-241-406-3	Largemouth bass	80.0	754	< 0.010	1.59	< 0.024	6.16
41343	2007-540-406-1	Largemouth bass	77.5	2,200	***0.020***	0.68	0.092	8.09
41344	2007-540-406-2	Largemouth bass	77.0	377	< 0.010	0.63	***0.050***	25.7
41345	2007-540-406-3	Largemouth bass	77.5	387	< 0.010	0.74	***0.036***	18.0
41298	2007-651-406-1	Largemouth bass	78.8	895	***0.011***	1.77	***0.031***	6.70
41299	2007-651-406-2	Largemouth bass	80.5	677	< 0.010	1.57	***0.026***	7.43

Table 2. Percent moisture, dry weight concentrations of calcium, cadmium, mercury, lead, and [lead/calcium] molar ratios in Missouri Department of Conservation 2007 General Contaminant Monitoring fish and crayfish tissues.—Continued

[USGS, U.S. Geological Survey; ID, identification; Ca, calcium; µg/g, micrograms per gram dry weight; Cd; cadmium; Hg, mercury; Pb, lead; <, less than; bold and italicized values are greater than the method detection limit but less than the method quantitation limit and have higher uncertainty]

USGS ID	Field/Lab ID	Fish common name	Percent moisture	Ca (µg/g)	Cd (µg/g)	Hg (µg/g)	Pb (µg/g)	[Pb/Ca] molar ratio ($1x10^{-6}$)
41304	2007-098-402-1	Smallmouth bass	78.9	3,050	< 0.012	0.59	0.034	2.16
41305	2007-098-402-2	Smallmouth bass	79.0	1,840	< 0.012	0.44	***0.029***	3.05
41306	2007-098-402-3	Smallmouth bass	79.7	988	< 0.012	0.44	0.036	7.05
41316	2007-099-402-1	Smallmouth bass	77.5	316	< 0.010	0.80	***0.027***	16.5
41317	2007-099-402-2	Smallmouth bass	78.5	990	< 0.012	0.84	***0.014***	2.74
41318	2007-099-402-3	Smallmouth bass	78.5	470	< 0.010	1.21	***0.021***	8.64
41322	2007-130-402-1	Smallmouth bass	78.6	2,130	< 0.012	0.29	0.081	7.36
41323	2007-130-402-2	Smallmouth bass	78.8	405	< 0.012	0.26	0.043	20.5
41310	2007-532-402-1	Smallmouth bass	77.7	630	< 0.010	0.68	***0.027***	8.29
41311	2007-532-402-2	Smallmouth bass	77.2	841	< 0.012	0.67	< 0.010	2.30
41312	2007-532-402-3	Smallmouth bass	77.3	469	< 0.012	0.58	0.040	16.5
41300	2007-594-402-1	Smallmouth bass	78.6	963	<0.012	0.64	0.042	8.44
41301	2007-594-402-2	Smallmouth bass	79.1	2,380	<0.010	0.63	***0.021***	1.71
41326	2007-165-310-1	White bass	78.8	566	<0.012	2.82	0.079	27.0
41327	2007-165-310-2	White bass	79.3	421	<0.012	1.34	***0.022***	10.1
41328	2007-165-310-3	White bass	79.1	946	<0.012	0.73	0.054	11.0
41346	2007-684-310-1	White bass	80.4	1,570	<0.010	0.67	***0.029***	3.57
41347	2007-684-310-2	White bass	80.7	908	0.044	0.88	0.14	29.8
41348	2007-684-310-3	White bass	80.9	1,500	<0.010	0.70	***0.029***	3.74
41349	2007-031-608-1	Long-pincered crayfish	81.2	707	<0.010	0.19	< 0.024	6.57
41351	2007-041-608-1	Long-pincered crayfish	77.7	647	***0.013***	0.32	0.13	38.87
41350	2007-428-608-1	Long-pincered crayfish	81.0	611	<0.010	0.19	< 0.024	7.60
41307	2007-098-053-1	Northern hog sucker	82.3	2,330	<0.012	0.14	0.13	10.8
41308	2007-098-053-2	Northern hog sucker	81.6	2,880	<0.012	0.13	0.22	14.8
41309	2007-098-053-3	Northern hog sucker	83.0	1,750	<0.012	0.087	0.17	18.8
41319	2007-099-053-1	Northern hog sucker	79.9	2,150	***0.027***	0.63	0.039	3.51
41320	2007-099-053-2	Northern hog sucker	80.2	2,450	<0.012	0.43	0.073	5.76
41321	2007-099-053-3	Northern hog sucker	80.2	2,020	<0.012	0.31	0.053	5.08
41324	2007-130-053-1	Northern hog sucker	82.4	1,080	0.23	0.18	0.14	25.1
41325	2007-130-053-2	Northern hog sucker	82.6	2,520	0.11	0.20	0.30	23.0
41313	2007-532-053-1	Northern hog sucker	81.2	2,530	***0.014***	0.40	0.073	5.58
41314	2007-532-053-2	Northern hog sucker	81.5	1,480	***0.033***	0.32	0.054	7.06
41315	2007-532-053-3	Northern hog sucker	81.4	2,670	***0.013***	0.27	0.066	4.78
41302	2007-594-053-1	Northern hog sucker	81.2	2,080	***0.013***	0.23	0.050	4.65
41303	2007-594-053-2	Northern hog sucker	81.0	2,430	***0.020***	0.22	0.046	3.66
42147	2007-695-030-1-1	Rainbow trout	74.4	1,170	<0.010	<0.035	***0.041***	6.78
42148	2007-695-030-1-2	Rainbow trout	74.3	1,590	<0.010	<0.035	< 0.024	2.92
42149	2007-695-030-1-3	Rainbow trout	75.7	1,650	<0.010	***0.036***	< 0.024	1.17
42150	2007-695-030-2-1	Rainbow trout	77.7	939	0.082	***0.039***	***0.055***	11.3
42151	2007-695-030-2-2	Rainbow trout	77.1	1,120	***0.020***	***0.042***	< 0.024	4.15
42152	2007-695-030-2-3	Rainbow trout	78.2	1,240	***0.011***	***0.043***	< 0.024	3.74
42153	2007-695-030-3-1	Rainbow trout	79.6	1,910	***0.021***	***0.053***	***0.039***	3.95
42154	2007-695-030-3-2	Rainbow trout	80.0	1,110	***0.011***	***0.047***	< 0.024	4.18
42155	2007-695-030-3-3	Rainbow trout	78.4	1,150	***0.026***	***0.045***	***0.034***	5.72
41332	2007-117-318-1	Walleye	79.0	970	<0.010	0.66	0.030	5.98
41333	2007-117-318-2	Walleye	79.1	629	<0.010	0.50	< 0.024	7.38
41334	2007-117-318-3	Walleye	79.3	800	<0.010	0.45	< 0.024	5.80

Table 3. Percent moisture and wet weight concentrations of calcium, cadmium, mercury, and lead in Missouri Department of Conservation 2007 General Contaminant Monitoring fish fillets.

[USGS, U.S. Geological Survey; ID, identification; Ca, calcium; µg/g, micrograms per gram wet weight; Cd; cadmium; Hg, mercury; Pb, lead; <, less than; bold and italicized values are greater than the method detection limit but less than the method quantitation limit and have higher uncertainty]

USGS ID	Field/Lab ID	Fish common name	Percent moisture	Ca (µg/g)	Cd (µg/g)	Hg (µg/g)	Pb (µg/g)
41274	2007-006-230-1	Channel catfish	81.7	75.7	0.009	0.22	0.014
41270	2007-012-230-1	Channel catfish	75.6	96.1	<0.002	0.056	0.012
41271	2007-012-230-2	Channel catfish	76.2	142	<0.002	0.076	0.024
41272	2007-012-230-3	Channel catfish	76.7	101	<0.002	0.075	0.015
41290	2007-081-230-1	Channel catfish	77.3	82.5	0.011	0.079	0.011
41291	2007-081-230-2	Channel catfish	77.6	280	<0.002	0.069	0.013
41292	2007-081-230-3	Channel catfish	77.8	84.5	***0.003***	0.069	0.014
41267	2007-544-230-1	Channel catfish	81.7	77.2	<0.002	0.13	0.022
41268	2007-544-230-2	Channel catfish	80.5	81.4	<0.002	0.13	0.019
41269	2007-544-230-3	Channel catfish	79.5	88.9	<0.002	0.11	***0.006***
41280	2007-222-230-1	Channel catfish	83.1	295	<0.002	0.45	0.015
41281	2007-222-230-2	Channel catfish	78.3	148	***0.003***	0.39	0.015
41282	2007-222-230-3	Channel catfish	77.1	81.4	<0.002	0.16	0.016
41283	2007-222-230-4	Channel catfish	82.4	68.4	<0.002	0.14	0.010
41284	2007-222-230-5	Channel catfish	76.8	91.1	<0.002	0.056	0.028
41285	2007-651-230-1	Channel catfish	78.8	87.3	<0.002	0.30	0.011
41286	2007-651-230-2	Channel catfish	80.1	136	<0.002	0.17	0.009
41287	2007-651-230-3	Channel catfish	78.1	69.6	<0.002	0.55	***0.004***
41288	2007-651-230-4	Channel catfish	71.8	69.7	<0.002	0.079	***0.007***
41289	2007-651-230-5	Channel catfish	74.3	74.2	<0.002	0.072	***0.004***
41276	2007-040-070-1	Carp	79.9	435	<0.002	0.050	0.013
41277	2007-315-010-1	Lake sturgeon	76.7	110	<0.002	0.082	0.13
41278	2007-315-010-2	Lake sturgeon	75.1	78.7	<0.002	0.077	0.016
41279	2007-315-010-3	Lake sturgeon	77.0	280	***0.003***	0.12	0.011
41273	2007-006-406-1	Largemouth bass	80.1	97.8	<0.002	0.32	0.015
41293	2007-025-406-1	Largemouth bass	79.3	87.7	<0.002	0.07	0.016
41294	2007-025-406-2	Largemouth bass	78.8	112	***0.003***	0.08	0.016
41295	2007-025-406-3	Largemouth bass	79.0	86.4	<0.002	0.10	<0.005
41275	2007-040-406-1	Largemouth bass	78.6	104	<0.002	0.04	0.008
41296	2007-074-406-1	Largemouth bass	79.0	98.1	<0.002	0.17	<0.005
41297	2007-074-406-2	Largemouth bass	78.5	141	0.04	0.25	0.054
41329	2007-118-406-1	Largemouth bass	81.0	109	***0.004***	0.12	0.009
41330	2007-118-406-2	Largemouth bass	80.8	140	***0.004***	0.10	0.009
41331	2007-118-406-3	Largemouth bass	80.5	84.3	***0.003***	0.11	***0.009***
41338	2007-151-406-1	Largemouth bass	80.2	212	<0.002	0.30	0.02
41339	2007-151-406-2	Largemouth bass	80.2	657	<0.002	0.31	***0.005***
41340	2007-151-406-3	Largemouth bass	79.7	244	<0.002	0.33	***0.011***
41341	2007-152-406-1	Largemouth bass	79.9	115	<0.002	0.53	***0.006***
41342	2007-152-406-2	Largemouth bass	80.0	94.2	<0.002	0.69	***0.005***
41335	2007-241-406-1	Largemouth bass	79.8	83.8	<0.002	0.33	***0.009***
41336	2007-241-406-2	Largemouth bass	80.1	80.0	<0.002	0.31	***0.012***
41337	2007-241-406-3	Largemouth bass	80.0	151	<0.002	0.32	<0.005
41343	2007-540-406-1	Largemouth bass	77.5	495	***0.004***	0.15	0.021
41344	2007-540-406-2	Largemouth bass	77.0	86.8	< 0.002	0.15	***0.012***
41345	2007-540-406-3	Largemouth bass	77.5	86.9	< 0.002	0.17	***0.008***
41298	2007-651-406-1	Largemouth bass	78.8	189	***0.002***	0.37	***0.007***
41299	2007-651-406-2	Largemouth bass	80.5	132	< 0.002	0.31	***0.005***

Table 3. Percent moisture and wet weight concentrations of calcium, cadmium, mercury, and lead in Missouri Department of Conservation 2007 General Contaminant Monitoring fish fillets.—Continued

[USGS, U.S. Geological Survey; ID, identification; Ca, calcium; µg/g, micrograms per gram wet weight; Cd; cadmium; Hg, mercury; Pb, lead; <, less than; bold and italicized values are greater than the method detection limit but less than the method quantitation limit and have higher uncertainty]

USGS ID	Field/Lab ID	Fish common name	Percent moisture	Ca (µg/g)	Cd (µg/g)	Hg (µg/g)	Pb (µg/g)
41304	2007-098-402-1	Smallmouth bass	78.9	645	< 0.002	0.12	0.007
41305	2007-098-402-2	Smallmouth bass	79.0	386	< 0.002	0.092	***0.006***
41306	2007-098-402-3	Smallmouth bass	79.7	201	< 0.002	0.090	0.007
41316	2007-099-402-1	Smallmouth bass	77.5	71.1	< 0.002	0.18	***0.006***
41317	2007-099-402-2	Smallmouth bass	78.5	213	< 0.002	0.18	***0.003***
41318	2007-099-402-3	Smallmouth bass	78.5	101	< 0.002	0.26	***0.005***
41322	2007-130-402-1	Smallmouth bass	78.6	455	< 0.002	0.062	0.017
41323	2007-130-402-2	Smallmouth bass	78.8	86.0	< 0.002	0.055	0.009
41310	2007-532-402-1	Smallmouth bass	77.7	141	< 0.002	0.15	***0.006***
41311	2007-532-402-2	Smallmouth bass	77.2	192	< 0.002	0.15	<0.002
41312	2007-532-402-3	Smallmouth bass	77.3	107	< 0.002	0.13	0.009
41300	2007-594-402-1	Smallmouth bass	78.6	206	< 0.002	0.14	0.009
41301	2007-594-402-2	Smallmouth bass	79.1	497	< 0.002	0.13	***0.004***
41326	2007-165-310-1	White bass	78.8	120	< 0.002	0.60	0.017
41327	2007-165-310-2	White bass	79.3	87.3	< 0.002	0.28	***0.005***
41328	2007-165-310-3	White bass	79.1	198	< 0.002	0.15	0.011
41346	2007-684-310-1	White bass	80.4	307	< 0.002	0.13	***0.006***
41347	2007-684-310-2	White bass	80.7	175	0.008	0.17	0.027
41348	2007-684-310-3	White bass	80.9	287	< 0.002	0.13	***0.006***
41349	2007-031-608-1	Long-pincered crayfish	81.2	133	< 0.002	0.036	<0.004
41351	2007-041-608-1	Long-pincered crayfish	77.7	144	***0.003***	0.071	0.029
41350	2007-428-608-1	Long-pincered crayfish	81.0	116	< 0.002	0.036	<0.004
41307	2007-098-053-1	Northern hog sucker	82.3	413	< 0.002	0.025	0.023
41308	2007-098-053-2	Northern hog sucker	81.6	530	< 0.002	0.024	0.041
41309	2007-098-053-3	Northern hog sucker	83.0	298	< 0.002	0.015	0.029
41319	2007-099-053-1	Northern hog sucker	79.9	432	***0.005***	0.13	0.008
41320	2007-099-053-2	Northern hog sucker	80.2	484	< 0.002	0.085	0.014
41321	2007-099-053-3	Northern hog sucker	80.2	400	< 0.002	0.061	0.011
41324	2007-130-053-1	Northern hog sucker	82.4	190	0.041	0.032	0.025
41325	2007-130-053-2	Northern hog sucker	82.6	438	0.019	0.035	0.052
41313	2007-532-053-1	Northern hog sucker	81.2	475	***0.003***	0.075	0.014
41314	2007-532-053-2	Northern hog sucker	81.5	274	***0.006***	0.059	0.010
41315	2007-532-053-3	Northern hog sucker	81.4	497	***0.002***	0.050	0.012
41302	2007-594-053-1	Northern hog sucker	81.2	391	***0.002***	0.043	0.009
41303	2007-594-053-2	Northern hog sucker	81.0	461	***0.004***	0.042	0.009
42147	2007-695-030-1-1	Rainbow trout	74.4	299	<0.002	0.009	***0.010***
42148	2007-695-030-1-2	Rainbow trout	74.3	408	<0.002	0.009	<0.006
42149	2007-695-030-1-3	Rainbow trout	75.7	401	<0.002	***0.009***	<0.006
42150	2007-695-030-2-1	Rainbow trout	77.7	209	0.018	***0.009***	***0.012***
42151	2007-695-030-2-2	Rainbow trout	77.1	256	***0.005***	***0.010***	<0.006
42152	2007-695-030-2-3	Rainbow trout	78.2	270	***0.002***	***0.009***	<0.006
42153	2007-695-030-3-1	Rainbow trout	79.6	390	***0.004***	***0.011***	***0.008***
42154	2007-695-030-3-2	Rainbow trout	80.0	222	***0.002***	***0.009***	<0.006
42155	2007-695-030-3-3	Rainbow trout	78.4	248	***0.006***	***0.010***	***0.007***
41332	2007-117-318-1	Walleye	79.0	204	<0.002	0.14	<0.006
41333	2007-117-318-2	Walleye	79.1	132	<0.002	0.10	<0.006
41334	2007-117-318-3	Walleye	79.3	166	<0.002	0.093	<0.006

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

[USGS, U.S. Geological Survey; ID, identification; Hg, mercury; µg/g, micrograms per gram; wet weight concentrations estimated assuming 78 percent moisture]

USGS ID	Field ID	Site	Location	Sample type	Hg (µg/g) dry weight	Hg (µg/g) wet weight
41352	2007-015-402-2	Eleven Point	Cane Bluff	Dorsal muscle plug	2.11	0.46
41353	2007-015-402-9	Eleven Point	Cane Bluff	Dorsal muscle plug	1.36	0.30
41354	2007-015-402-7	Eleven Point	Cane Bluff	Dorsal muscle plug	1.27	0.28
41355	2007-015-402-8	Eleven Point	Cane Bluff	Dorsal muscle plug	1.96	0.43
41356	2007-015-402-1	Eleven Point	Cane Bluff	Dorsal muscle plug	1.50	0.33
41357	2007-015-402-4	Eleven Point	Cane Bluff	Dorsal muscle plug	2.12	0.47
41358	2007-015-402-5	Eleven Point	Cane Bluff	Dorsal muscle plug	2.04	0.45
41359	2007-015-402-3	Eleven Point	Cane Bluff	Dorsal muscle plug	2.89	0.64
41360	2007-015-402-6	Eleven Point	Cane Bluff	Dorsal muscle plug	1.90	0.42
41361	2007-015-402-10	Eleven Point	Cane Bluff	Dorsal muscle plug	3.26	0.72
41362	2007-621-402-15	Eleven Point	Hwy 160	Dorsal muscle plug	1.22	0.27
41363	2007-621-402-23	Eleven Point	Hwy 160	Dorsal muscle plug	1.33	0.29
41364	2007-621-402-26	Eleven Point	Hwy 160	Dorsal muscle plug	0.98	0.22
41365	2007-621-402-29	Eleven Point	Hwy 160	Dorsal muscle plug	1.15	0.25
41366	2007-621-402-19	Eleven Point	Hwy 160	Dorsal muscle plug	1.47	0.32
41367	2007-621-402-20	Eleven Point	Hwy 160	Dorsal muscle plug	1.50	0.33
41368	2007-621-402-21	Eleven Point	Hwy 160	Dorsal muscle plug	1.30	0.29
41369	2007-621-402-27	Eleven Point	Hwy 160	Dorsal muscle plug	1.22	0.27
41370	2007-621-402-11	Eleven Point	Hwy 160	Dorsal muscle plug	1.13	0.25
41371	2007-621-402-14	Eleven Point	Hwy 160	Dorsal muscle plug	1.30	0.29
41372	2007-621-402-22	Eleven Point	Hwy 160	Dorsal muscle plug	1.47	0.32
41373	2007-621-402-30	Eleven Point	Hwy 160	Dorsal muscle plug	1.30	0.29
41374	2007-621-402-12	Eleven Point	Hwy 160	Dorsal muscle plug	1.61	0.35
41375	2007-621-402-24	Eleven Point	Hwy 160	Dorsal muscle plug	1.89	0.42
41376	2007-621-402-25	Eleven Point	Hwy 160	Dorsal muscle plug	1.85	0.41
41377	2007-621-402-28	Eleven Point	Hwy 160	Dorsal muscle plug	2.41	0.53
41378	2007-621-402-31	Eleven Point	Hwy 160	Dorsal muscle plug	1.58	0.35
41379	2007-621-402-13	Eleven Point	Hwy 160	Dorsal muscle plug	0.90	0.20
41380	2007-621-402-16	Eleven Point	Hwy 160	Dorsal muscle plug	2.30	0.51
41381	2007-621-402-17	Eleven Point	Hwy 160	Dorsal muscle plug	1.69	0.37
41382	2007-621-402-18	Eleven Point	Hwy 160	Dorsal muscle plug	1.41	0.31

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