Prepared in cooperation with the National Park Service, Whiskeytown National Recreation Area and the Burned Area Response Program

Concentrations of Mercury and other Metals in Black Bass (*Micropterus spp.*) from Whiskeytown Lake, Shasta County, California, 2005

Open File Report 2011–1297

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By Jason T. May, Roger L. Hothem, Marissa L. Bauer, and Larry R. Brown

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Open-File Report 2011–1297

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Contents

Abstract.....	1
Introduction.....	1
Purpose and Scope	5
Field Methods and Sample Preservation Techniques.....	5
Laboratory Methods of Chemical Analysis	5
Quality Assurance and Quality Control	6
Results and Discussion.....	7
Acknowledgements.....	15
References.....	15

Figures

1. Map showing fish sampling locations within Whiskeytown Lake, Shasta County, California2
2. Graph showing mercury concentration for all bass (*Micropterus spp.*) samples collected from Whiskeytown Lake, California, 2005, in relation to total length14
3. Correlation plot of mercury concentration in fillet samples in relation to whole-body samples for all bass (*Micropterus spp.*) samples collected from Whiskeytown Lake, California, 200515

Tables

1. Sites within Whiskeytown Lake, California, sampled during 20053
2. Total mercury concentrations in fillet and whole-body samples of largemouth bass (*Micropterus salmoides*) and spotted bass (*M. punctulatus*) collected from Whiskeytown Lake, California, June 7–9, 2005.....3
3. Concentrations of selected metals and sulfur in whole-body samples of largemouth bass (*Micropterus salmoides*) and spotted bass (*Micropterus punctulatus*) collected from Whiskeytown Lake, California, June 2005.....8

Conversion Factors, Horizontal Datum, Acronym and Abbreviations, and Chemical Elements

Conversion Factors

Si to Inch/Pound

Multiply	By	To obtain
Length		
millimeter (mm)	0.03937	inch (in)
Mass		
microgram (µg)	0.000000035	ounce, avoirdupois (oz)
milligram (mg)	0.000035	ounce, avoirdupois (oz)
gram (g)		ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)

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

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

Horizontal coordinate information is referenced to the “North American Datum of 1983 (NAD 83)”

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Acronyms, Abbreviations, and Chemical Notation

(additional information given in parentheses)

CRV	certified reference value
CVAAS	cold vapor atomic-absorption spectroscopy
CVAFS	cold vapor atomic-fluorescence spectrometry
dw	dry weight
ICP-MS	coupled plasma–mass spectroscopy
ICP-OES	inductively coupled plasma–optical emission spectroscopy
LOD	limit of detection
MDL	method detection limit
MOhm	megaohm
NPS	National Parks Service
NRA	National Recreation Area
NRCC	National Research Council of Canada
OEHHA	Office of Environmental Health Hazard Assessment
QA	quality assurance
QC	quality control

RPD	relative percent difference
SRM	standard reference material
SV	screening value
TERL	Trace Element Research Laboratory (College Station, Texas)
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WHIS	Whiskeytown National Recreation Area
v/v	The formula for volume percent (v/v) is: [Volume of solute (mL)/ Volume of solution (mL)] x 100
ww	wet weight
HgT	total mercury
Hg ²⁺	divalent mercury
ppm	part per million (µg/g)
spp.	species (plural)
WHIS	Whiskeytown National Recreation Area

Chemical Elements

Al	aluminum
As	arsenic
Ag	silver
B	boron
Ba	barium
Be	beryllium
Ca	calcium
Cd	cadmium
Co	cobalt
Cr	chromium
Cu	copper
Fe	iron
Hg	mercury
K	potassium
Mg	magnesium
Mn	manganese
Mo	molybdenum
Na	sodium
Ni	nickel
P	phosphorus
Pb	lead
S	sulfur
Se	selenium

Sr	strontium
Ti	titanium
V	vanadium
Zn	zinc

Chemical Compounds, Isotopes, and other Chemical Notation

CH ₃	methyl radical
CH ₄	methane
CH ₂ Cl ₂	methylene chloride
CuSO ₄	copper sulfate
Fe(II)	ferrous (divalent) iron
Fe(III)	ferric (trivalent) iron
HCl	hydrochloric acid
HF	hydrofluoric acid
HNO ₃	nitric acid
Hg ⁰	elemental mercury
Hg ⁺	mercurous ion
Hg ²⁺	mercuric ion
Hg(II)	divalent mercury
HgCl ₂	mercuric chloride
HgT	total mercury
²⁰³ Hg(II)	mercury-203 radiotracer divalent inorganic mercury
KBr	potassium bromide
MeHg	methylmercury (monomethylmercury)
N ₂	nitrogen gas
NaBEt ₄	sodium tetra-ethyl borate
O ₂	oxygen gas
SiO ₂	silicon dioxide, or silica
SnCl ₂	stannous chloride

Concentrations of Mercury and other Metals in Black Bass (*Micropterus spp.*) from Whiskeytown Lake, Shasta County, California, 2005

By Jason T. May¹, Roger L. Hothem², Marissa L. Bauer¹, and Larry R. Brown¹

Abstract

This report presents the results of a reconnaissance study conducted by the U.S. Geological Survey (USGS) to determine mercury (Hg) and other selected metal concentrations in Black bass (*Micropterus spp.*) from Whiskeytown Lake, Shasta County, California. Total mercury concentrations were determined by cold-vapor atomic absorption spectroscopy (CVAAS) in fillets and whole bodies of each sampled fish. Selected metals scans were performed on whole bodies (less the fillets) by inductively coupled plasma–mass spectroscopy (ICP-MS) and inductively coupled plasma–optical emission spectroscopy (ICP-OES). Mercury concentrations in fillet samples ranged from 0.06 to 0.52 micrograms per gram ($\mu\text{g/g}$) wet weight (ww). Total mercury (HgT) in the same fish whole-body samples ranged from 0.04 to 0.37 ($\mu\text{g/g}$, ww). Mercury concentrations in 17 percent of “legal catch size” (≥ 305 millimeters in length) were above the U.S. Environmental Protection Agency water-quality criterion for the protection of human health of 0.30 $\mu\text{g/g}$ (ww). These data will serve as a baseline for future monitoring efforts within Whiskeytown Lake.

Introduction

Historic gold mining and naturally occurring mercury from geothermal sources has left many areas of California subject to mercury contamination. (California Department of Conservation, 2000; Alpers and others, 2005). The Klamath-Trinity Mountains Region, specifically Trinity Lake and the upstream watershed, have previously documented elevated levels of mercury in resident sport fish (May and others, 2005). The highest density historical mine sites within the Clear Creek Watershed occur in the upper Clear Creek area,

and are likely sources of contamination to the local environment and Whiskeytown Lake (*fig. 1*; Moore and Hughes, 2003). Run-off from abandoned mine lands has resulted in elevated levels of metals in the stream sediments (Moore and Hughes, 2003). Pristine water quality was identified by the Whiskeytown National Recreation Area (WHIS) and the National Parks Service (NPS) as WHIS’s Government Performance Results Act Goal 1a4 in their General Management Plan (National Parks Service, 1999). Whiskeytown Lake also serves as the domestic water supply for several nearby cities including Redding and Anderson. Additionally, the lake stores water for the Central Valley Project and functions as a major recreation area in Northern California, providing recreation for 700,000 visitors annually. Sport fishing is a popular recreational activity at Whiskeytown Lake and its tributaries. The lake supports recreational fishing for several species including two black bass species, largemouth bass (*Micropterus salmoides*) and spotted bass (*M. punctulatus*), which were collected as part of this reconnaissance effort. These lake fish samples are part of an ongoing effort that was begun in 2002 to characterize and monitor mercury and other metals ‘hot spots’ in the Upper Clear Creek watershed and WHIS.

During 2005, the U.S. Geological Survey (USGS) conducted a reconnaissance investigation in cooperation with the WHIS to assess mercury contamination associated with historical mining in the Clear Creek watershed. During this study, the USGS collected 63 black bass (44 largemouth bass and 19 spotted bass) from three locations within Whiskeytown Lake: Clear Creek, Brandy Creek, and Whiskey Creek arms (*fig. 1*; *tables 1* and *2*). Mercury levels were determined in boneless/skinless fillet tissue of each fish and the remaining whole-body sample of the same fish. Additional trace-metal analyses were also done on the remaining whole body.

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²U.S. Geological Survey, Western Ecological Research Center

2 Concentrations of mercury and other metals in black bass, Whiskeytown Lake, Shasta County, California, 2005

Figure 1. Fish sampling locations within Whiskeytown Lake, Shasta County, California.

Table 1. Sites within Whiskeytown Lake, California, sampled during 2005.

[USGS, U.S. Geological Survey; °, degree; ', minutes; N, north; W, west]

Official site name	Short name code	USGS site code	Range of collection areas			
			Upper latitude	Upper longitude	Lower latitude	Lower longitude
Whiskeytown Lake at Brandy Creek Arm near Whiskeytown, California	LKBB	403710122341501	40° 37.544' N	122° 35.046' W	40° 36.971' N	122° 33.469' W
Whiskeytown Lake at Clear Creek Arm near Whiskeytown, California	LKCC	403854122354801	40° 38.836' N	122° 36.232' W	40° 38.806' N	122° 35.394' W
Whiskeytown Lake at Whiskey Creek Arm near Whiskeytown, California	LKWC	403859122332301	40° 39.174' N	122° 33.393' W	40° 38.875' N	122° 33.358' W

Table 2. Total mercury concentrations in fillet and whole-body samples of largemouth bass (*Micropterus salmoides*) and spotted bass (*M. punctulatus*) collected from Whiskeytown Lake, California, June 7–9, 2005.

[LKBB, Brandy/Boulder Creek area; LKCC, Clear Creek arm; LKWC, Whiskey Creek arm; LMBA, largemouth bass; SPBA, spotted bass; HgT, total mercury; g, gram; µg, microgram; mm, millimeter; wt., weight]

Site	Species	Total length (mm)	Fillet code	Fillet sample mass (g)	Fillet HgT (µg/g, wet wt.)	Fillet moisture (percent)	Whole-body code	Whole body sample mass (g)	Whole body HgT (µg/g, wet wt.)	Whole body moisture (percent)
LKBB	LMBA	360	LKBB-060705-001F	63.7	0.119	81.8	LKBB-060705-001W	644.1	0.088	76.7
LKBB	LMBA	382	LKBB-060705-002F	76.7	0.157	82.6	LKBB-060705-002W	684.0	0.108	77.6
LKBB	LMBA	403	LKBB-060705-003F	114.5	0.343	80.4	LKBB-060705-003W	878.6	0.219	73.3
LKBB	LMBA	345	LKBB-060705-006F	47.0	0.137	81.9	LKBB-060705-006W	474.3	0.083	76.8
LKBB	LMBA	325	LKBB-060705-007F	62.3	0.214	81.4	LKBB-060705-007W	405.4	0.146	76.6
LKBB	LMBA	330	LKBB-060705-008F	53.5	0.198	81.3	LKBB-060705-008W	432.1	0.123	75.4
LKBB	LMBA	315	LKBB-060705-009F	43.7	0.169	81.7	LKBB-060705-009W	279.6	0.132	77.1
LKBB	LMBA	318	LKBB-060705-011F	34.8	0.084	81.7	LKBB-060705-011W	390.2	0.052	77.4
LKBB	LMBA	210	LKBB-060705-022F	7.8	0.096	81.3	LKBB-060705-022W	109.8	0.073	76.4
LKBB	LMBA	180	LKBB-060705-023F	10.8	0.069	81.7	LKBB-060705-023W	62.0	0.054	76.8
LKBB	LMBA	176	LKBB-060705-025F	4.8	0.135	82.9	LKBB-060705-025W	48.2	0.089	76.6
LKBB	SPBA	385	LKBB-060705-005F	76.1	0.233	79.7	LKBB-060705-005W	708.6	0.167	73.1
LKBB	SPBA	327	LKBB-060705-012F	28.5	0.209	82	LKBB-060705-012W	334.1	0.173	76.3
LKBB	SPBA	293	LKBB-060705-013F	15.7	0.091	81.1	LKBB-060705-013W	261.2	0.069	75.5
LKBB	SPBA	311	LKBB-060705-014F	28.1	0.267	80.9	LKBB-060705-014W	337.7	0.192	76.5
LKBB	SPBA	249	LKBB-060705-017F	23.7	0.104	79.5	LKBB-060705-017W	152.2	0.073	75.6
LKBB	SPBA	238	LKBB-060705-018F	18.6	0.118	79.8	LKBB-060705-018W	148.4	0.085	74.3
LKBB	SPBA	235	LKBB-060705-019F	12.7	0.148	81.6	LKBB-060705-019W	98.3	0.11	75.9
LKBB	SPBA	212	LKBB-060705-020F	13.0	0.096	79.3	LKBB-060705-020W	82.6	0.062	73.8
LKBB	SPBA	173	LKBB-060705-026F	6.1	0.092	82.4	LKBB-060705-026W	44.8	0.064	77.1
LKBB	SPBA	145	LKBB-060705-027F	3.3	0.074	81.4	LKBB-060705-027W	26.9	0.048	77.0
LKCC	LMBA	443	LKCC-060805-001F	93.3	0.469	81.3	LKCC-060805-001W	1,056.10	0.258	74.7
LKCC	LMBA	385	LKCC-060805-002F	73.3	0.252	80.5	LKCC-060805-002W	660.1	0.138	74.9
LKCC	LMBA	370	LKCC-060805-003F	77.5	0.240	81.1	LKCC-060805-003W	699.5	0.134	75.7
LKCC	LMBA	370	LKCC-060805-004F	68.4	0.21	80.7	LKCC-060805-004W	653.2	0.127	75.5

4 Concentrations of mercury and other metals in black bass, Whiskeytown Lake, Shasta County, California, 2005

Table 2. Total mercury concentrations in fillet and whole-body samples of largemouth bass (*Micropterus salmoides*) and spotted bass (*M. punctulatus*) collected from Whiskeytown Lake, California, June 7–9, 2005. —Continued

[LKBB, Brandy/Boulder Creek area; LKCC, Clear Creek arm; LKWC, Whiskey Creek arm; LMBA, largemouth bass; SPBA, spotted bass; HgT, total mercury; g, gram; µg, microgram; mm, millimeter; wt., weight]

Site	Species	Total length (mm)	Fillet code	Fillet sample mass (g)	Fillet HgT (µg/g, wet wt.)	Fillet moisture (percent)	Whole-body code	Whole body sample mass (g)	Whole body HgT (µg/g, wet wt.)	Whole body moisture (percent)
LKCC	LMBA	345	LKCC-060805-006F	30.5	0.201	82.2	LKCC-060805-006W	487.8	0.15	76.0
LKCC	LMBA	273	LKCC-060805-011F	19.6	0.115	80.4	LKCC-060805-011W	267.1	0.088	78.3
LKCC	LMBA	223	LKCC-060805-012F	15.0	0.064	80.6	LKCC-060805-012W	125.8	0.045	75.2
LKCC	LMBA	248	LKCC-060805-013F	15.2	0.107	80.2	LKCC-060805-013W	174.9	0.08	75.9
LKCC	LMBA	260	LKCC-060805-014F	11.8	0.095	80.2	LKCC-060805-014W	213.3	0.072	79.1
LKCC	LMBA	200	LKCC-060805-015F	11.7	0.074	80.9	LKCC-060805-015W	96.1	0.054	76.9
LKCC	LMBA	195	LKCC-060805-016F	10.0	0.077	81.2	LKCC-060805-016W	68.7	0.055	76.4
LKCC	LMBA	335	LKCC-060905-005F	53.9	0.186	81.4	LKCC-060805-005W	500.6	0.108	76.3
LKCC	LMBA	283	LKCC-060905-008F	22.6	0.129	81.7	LKCC-060805-008W	273.5	0.106	77.1
LKCC	LMBA	350	LKCC-060905-021F	48.5	0.149	81.4	LKCC-060905-021W	521.6	0.088	76.1
LKCC	LMBA	300	LKCC-060905-022F	40.4	0.094	81.9	LKCC-060905-022W	329.5	0.074	77.6
LKCC	LMBA	275	LKCC-060905-023F	31.9	0.115	80.2	LKCC-060905-023W	292.7	0.071	74.5
LKCC	LMBA	202	LKCC-060905-025F	14.3	0.066	80.5	LKCC-060905-025W	84.3	0.049	74.3
LKCC	SPBA	174	LKCC-060805-017F	6.8	0.089	81.6	LKCC-060805-017W	41.9	0.074	76.8
LKCC	SPBA	288	LKCC-060905-010F	14.1	0.117	79.4	LKCC-060805-010W	247.3	0.076	76.5
LKCC	SPBA	275	LKCC-060905-026F	29.6	0.11	79.0	LKCC-060905-026W	230.3	0.078	72.7
LKCC	SPBA	290	LKCC-060905-027F	30.6	0.106	80.2	LKCC-060905-027W	250.8	0.082	73.9
LKWC	LMBA	450	LKWC-060905-001F	93.6	0.39	81.7	LKWC-060905-001W	1,269.7	0.224	75.2
LKWC	LMBA	415	LKWC-060905-002F	79.1	0.33	80.9	LKWC-060905-002W	861.3	0.182	75.2
LKWC	LMBA	342	LKWC-060905-003F	36.2	0.166	81.8	LKWC-060905-003W	511.5	0.107	77.8
LKWC	LMBA	330	LKWC-060905-004F	31.7	0.241	80.7	LKWC-060905-004W	445.2	0.155	75.9
LKWC	LMBA	286	LKWC-060905-005F	37.0	0.218	80.5	LKWC-060905-005W	289.9	0.125	79.5
LKWC	LMBA	304	LKWC-060905-006F	41.0	0.178	81.4	LKWC-060905-006W	322.4	0.121	78.8
LKWC	LMBA	195	LKWC-060905-007F	10.2	0.197	80.5	LKWC-060905-007W	73.4	0.123	75.3
LKWC	LMBA	165	LKWC-060905-008F	6.2	0.154	80.5	LKWC-060905-008W	45.8	0.106	75.7
LKWC	LMBA	470	LKWC-060905-012F	64.9	0.518	82.8	LKWC-060905-012W	1,369.30	0.371	74.6
LKWC	LMBA	358	LKWC-060905-013F	59.8	0.139	80.7	LKWC-060905-013W	634.5	0.09	74.5
LKWC	LMBA	320	LKWC-060905-014F	26.2	0.193	81.6	LKWC-060905-014W	439.4	0.152	75.2
LKWC	LMBA	337	LKWC-060905-015F	27.5	0.127	82.4	LKWC-060905-015W	483.8	0.103	79.3
LKWC	LMBA	336	LKWC-060905-017F	30.0	0.2	80.8	LKWC-060905-017W	490.2	0.128	74.8
LKWC	LMBA	306	LKWC-060905-019F	19.6	0.115	81.3	LKWC-060905-019W	346.2	0.086	77.8
LKWC	LMBA	282	LKWC-060905-020F	14.3	0.175	83.2	LKWC-060905-020W	254.6	0.129	79.3
LKWC	LMBA	188	LKWC-060905-021F	4.0	0.124	80.7	LKWC-060905-021W	67.2	0.077	75.6
LKWC	SPBA	363	LKWC-060905-009F	30.9	0.329	77.9	LKWC-060905-009W	609	0.187	70.6
LKWC	SPBA	214	LKWC-060905-010F	11.1	0.171	79.8	LKWC-060905-010W	90.4	0.134	73.6
LKWC	SPBA	388	LKWC-060905-022F	34.8	0.228	80.0	LKWC-060905-022W	627.9	0.144	72.6
LKWC	SPBA	275	LKWC-060905-023F	13.8	0.094	79.5	LKWC-060905-023W	210.9	0.07	74.7
LKWC	SPBA	243	LKWC-060905-024F	12.2	0.11	79.9	LKWC-060905-024W	138.1	0.075	74.5

Purpose and Scope

The purpose of this report is to present information regarding the concentration of metals in sport fish from the Whiskeytown Lake. Data were collected by USGS personnel. In addition, this data report adds to the limited number of studies for metal concentration in sport fish for this lake. The data from this report will be of use to scientists, managers, and other persons concerned with the metals concentrations in sport fish from Whiskeytown Lake and regional sport fisheries.

Field Methods and Sample Preservation Techniques

Field and laboratory preparatory methods were similar to those used by May and others (2000, 2005). All fish were collected by using electrofishing equipment and dip nets. Fish were held in clean containers with ambient water until they were weighed, to the nearest gram, and measured for standard and total length, in millimeters. After recording the length and mass, spines or scales were removed from each fish for future age determination. Each fish was then wrapped in clean, heavy-duty aluminum foil, labeled, placed in a plastic bag on wet ice and held for less than 8 hours. The fish were then taken to the USGS Dixon Field Station laboratory, where they were stored frozen until they were processed and sent to the contract laboratory for chemical analyses.

The processing of fish followed standard procedures (U.S. Environmental Protection Agency, 1995). Fish were handled with powder-free latex gloves, and dissections were performed on a new sheet of heavy-duty aluminum foil for each fish. High-quality stainless steel instruments and disposable scalpel blades were used in the processing of the fish samples. Scalpel blades were changed and instruments were cleaned thoroughly between samples. Cleaning the instruments involved washing with deionized water and laboratory detergent, acid washing, and finally rinsing with deionized water before and after dissection of each fish specimen.

Larger fish were thawed and scaled before dissection. Boneless and skinless fillet portions were taken from the left upper medial-axial region of the fish in an approximately rectangular shape. Excised tissues were placed directly into labeled, chemically cleaned borosilicate-glass jars on a pre-tared balance. The sample mass was recorded, and a Teflon-lined lid was screwed atop each jar and sealed with Parafilm.

Fish tissue samples were stored frozen in sealed sample jars until they were packed in coolers with dry ice and shipped to the contract analytical laboratory at Texas A&M University in College Station, Texas. The remaining whole-body of each fish was packaged into jars with Teflon-lined lids and analyzed for total metals.

Laboratory Methods of Chemical Analysis

Analysis of mercury (Hg) in fish samples was done at the Trace Element Research Laboratory (TERL) at Texas A&M University in College Station, Texas, under the direction of Dr. Robert Taylor. Samples were received frozen and were assigned unique identification numbers upon arrival at the laboratory. Tissue samples were transferred to labeled, tared polyethylene zip-lock bags, weighed, and lyophilized in a Labconco Freezone 12L freeze dryer. Moisture content was determined by weight loss following freeze drying for both fillet and whole-body samples.

Procedures that require tissue samples to be freeze-dried to determine mercury concentrations result in removal of the original moisture in the sample. Additionally, tissue moisture is a relative measure of the quality of the tissue sample. Moisture content was determined by weight loss upon freeze drying and is expressed as weight percentage of the original wet sample. Depending on sample size, either the whole sample or a representative aliquot was frozen and then dried under vacuum until a constant weight was attained. Samples were prepared and dried using plastic materials to minimize potential contamination artifacts.

Both fillet and whole-body tissue samples were prepared for analysis by powdering freeze dried tissue in a Spex 6800 cryomill. Samples were transferred to polycarbonate containers, chilled to liquid nitrogen temperatures, and ground to a fine powder with a stainless steel impactor in the cryomill. Homogenized samples were stored in zip-lock bags until analyzed. Aliquots of dry, powdered tissue samples were weighed to the nearest 0.0001 g and transferred to polypropylene digestion vessels. Samples were digested at a temperature of 95°C with nitric and hydrochloric acids and hydrogen peroxide (3, 1, and 2 mL milliliters, respectively) in a CPI graphite block digester. Digest solutions were made to volume with Milli-Q 18 MOhm (megaohm) deionized water and were stored in polyethylene bottles until analyzed.

Three methods were used to determine metal concentrations in fish tissue: cold-vapor atomic absorption spectroscopy (CVAAS) for HgT in filets and whole body; inductively coupled plasma–mass spectroscopy (ICPMS); and, inductively coupled plasma–optical emission spectroscopy (ICP-OES) for other trace metals in the whole body.

Before samples were analyzed for Hg by CVAAS, the Hg was converted to the divalent mercury (Hg^{2+}) form. Mercury was digested using a modified version of U.S. Environmental Protection Agency (USEPA) methods 245.5 and 245.6 (U.S. Environmental Protection Agency, 1991, 1995, 2001, 2003). Tissue samples were homogenized in the original sample containers by using a Tekmar Tissumizer, and then subsampled. Tissue subsamples were digested with nitric acid, sulfuric acid, potassium permanganate, and potassium persulfate in polypropylene tubes in a water bath at 90 to 95 degrees Celsius ($^{\circ}\text{C}$). Before analysis, hydroxylamine hydrochloride was added to reduce excess permanganate, and the samples were brought to volume using distilled-deionized water.

In the CVAAS procedure for determination of Hg, divalent mercury (Hg^{2+}) in aqueous samples (digests of tissue samples) is reduced to the elemental state (Hg^0) by a strong reducing agent (stannous chloride). Gaseous Hg^0 enters the sweep gas and is introduced into an atomic absorption cell, where light produced by a mercury-vapor lamp is absorbed by the free Hg^0 atoms. Mercury concentration in the sample is determined by comparing light absorption of the sample with that of external calibration standards. The range limit of detection (LOD) for these analyses was 0.01 to 0.06 $\mu\text{g/g}$, dry weight (dw).

Inductively coupled plasma–mass spectroscopy was used during the metals scan to determine arsenic (As), cadmium (Cd), lead (Pb), and selenium (Se). Tissue digests were diluted with Milli-Q 18 MOhm deionized water as necessary to reduce their nitric acid concentrations to no greater than 2 percent v/v (volume by volume) and were then analyzed in pulse mode on a Perkin Elmer/Sciex DRC 2 ICP-MS instrument equipped with a dynamic reaction cell to eliminate molecular ion interferences on several elements (For example: As, Se, Cr, and V). Elemental concentrations were determined using

internal standards to compensate for slight matrix effects and instrumental performance changes.

Inductively coupled plasma–optical emission spectroscopy was used to determine aluminum (Al), barium (Ba), calcium (Ca), chromium (Cr), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), phosphorus (P), sulfur (S), strontium (Sr), titanium (Ti), and zinc (Zn) in fish samples. Digest solutions were analyzed undiluted on an axial Spectro CirOs instrument, using internal standards to compensate for matrix effects and instrument drift. Final calculations utilized off-peak background correction and inter-element correction equations.

Quality Assurance and Quality Control

As part of normal quality-assurance (QA) and quality-control (QC) procedures, a standard number of procedural blanks, laboratory duplicate samples, spiked samples, and standard reference materials were analyzed at the TERL during 2005–2006 for each set of fish samples from Whiskeytown Lake.

Procedural blanks were analyzed to quantify the amount of total mercury and other metals that may have been added inadvertently during sample processing. A total of 4 procedural blanks were analyzed. All QA/QC results were within acceptable limits for TERL standards for all the samples.

Laboratory replicate samples were analyzed to provide a measure of the precision of the methods used for analysis. Fifteen of the 63 samples were used as laboratory replicates. After the sample was homogenized, two separate subsamples were taken and analyzed. Replicates had to meet certain criteria to fall within the 95 percent confidence interval. If the sample concentration was within 2 to 10 times the limit of detection (LOD), the replicate had to be within 20 percent of the original value. If the sample concentration was greater than 10 times the LOD, the replicate sample had to be within 10 percent of the original value.

Relative percentage difference (RPD) is another measure of precision for replicate samples. It is computed as 100 times the absolute value of the difference between two replicate analyses divided by their mean. Values of RPD ranged from 0.24 to 9.17 percent, well within acceptable limits are set by TERL.

Spiked samples were analyzed to provide a measure of the accuracy of the methods used for analysis. Subsamples from 18 of the 63 fish were used as spiked samples and were evaluated for spike recovery. After the sample was homogenized, two separate subsamples were taken, one was processed as a sample, and the other spiked with a known quantity of analyte. Spike recovery was calculated as the measured concentration from the spiked sample minus the measured concentration from the unspiked sample, divided by the expected concentration in the spiked sample, and multiplied by 100 percent. Spike recoveries were determined to be between 93.5 to 107 percent. Spike recoveries were considered acceptable if the average recovery was 85 to 115 percent (Robert Taylor, Trace Element Research Laboratory, College Station, Texas, written commun., 2011).

Standard reference material (SRM) was analyzed to provide an estimate of range in accuracy of the laboratory instrument used for the determination of total mercury concentration and to ensure that this method produced results that were comparable to those obtained by an independent organization. The SRM used by the TERL was dogfish (*Squalus* sp.) muscle (DORM-2), certified by the National Research Council Canada (NRCC) as having a certified reference value (CRV) of 4.64 µg/g mercury (dry). The percentage recovery for the 18 analyses of DORM-2 in the three sample sets ranged from 82.7 to 107 percent, which is within acceptable limits (Robert Taylor, Trace Element Research Laboratory, College Station, Texas, written commun., 2011).

Results and Discussion

A total of 63 black bass (largemouth and spotted bass) were collected and processed for total mercury in fillet and whole-body samples (*table 2*). Whole-body samples were also analyzed for total metals (*table 3*). Total mercury in fillet samples ranged from 0.06 to 0.52 µg/g ww (wet weight) and 0.04 to 0.37 µg/g ww in whole-body samples. Mercury concentrations in 5 of the 30 black bass fillet samples that were of legal catch size (≥ 305 millimeters in length) exceeded the USEPA water-quality criterion for the protection of human health (0.3 µg/g ww), (U.S. Environmental Protection Agency, 2001). Black bass collected from Whiskeytown Lake show a general trend of increasing mercury concentration with increasing size (*figure 2*) and similar concentrations of total mercury in fillet and whole-body samples ($r^2 = 0.937$) (*figure 3*).

Each whole-body sample was processed for total metals scan. The following metals of ecological importance are reported alphabetically in µg/g dry weight with mean µg/g, range µg/g, and percent of non-detects (percent nd) in parentheses: arsenic (1.1 µg/g, 1.82–0.746 µg/g), cadmium (1.11 µg/g, 1.35–0.024 µg/g, 2 percent nd), copper (2.18 µg/g, 9.54–0.89 µg/g), mercury (0.466 µg/g, 1.46–0.18 µg/g), nickel (5.83 µg/g, 172.0–0.46 µg/g, 24 percent nd), lead (0.088 µg/g, 0.205–0.047 µg/g, 90 percent nd), selenium (2.4 µg/g, 3.83–1.8 µg/g), and zinc (75.39 µg/g, 121.0–48.4 µg/g). Visual comparisons of the ranges of data from metal scans indicated that there is no substantial difference between collection area or species for any metal.

Table 3. Concentrations of selected metals and sulfur in whole-body samples of largemouth bass (*Micropterus salmoides*) and spotted bass (*Micropterus punctulatus*) collected from Whiskeytown Lake, California, June 2005.

[Concentrations are in micrograms per gram (µg/g), dry weight except where otherwise noted. Geometric means are reported for element concentrations; arithmetic means are reported for length, moisture, and mass. **Abbreviations:** g, gram; LKBB, Brandy/Boulder Creek area; LKCC, Clear Creek area; LKWC, Whiskey Creek area; mm, millimeter; NC, mean was not calculated if the element was detected in fewer than <50 percent of the samples; —, not applicable; ^, differences in laboratory detection limit are established by laboratory calibration curves for each batch of chemical analyses, therefore, they are not the same for every run; <, below the limit of detection; %, percent]

Species	Whole body code (site-date-sample)	Total length (mm)	Moisture (%)	Sample mass (g)	Aluminum^	Arsenic	Barium	Cadmium	Calcium	Chromium	Copper	Iron	Mercury	Magnesium
Largemouth Bass (LMB)	LKBB-060705-001W	360	76.7	644.1	140	0.93	10.9	1.35	60,700	11.3	2.9	280	0.377	1,650
	LKBB-060705-002W	382	77.6	684	66.6	1.16	9.25	0.07	75,900	21.9	2.41	254	0.481	1,950
	LKBB-060705-003W	403	73.3	878.6	<4.64	1.27	5.09	0.11	63,000	365	4.74	1,900	0.821	1,650
	LKBB-060705-006W	345	76.8	474.3	9.94	1.01	10.9	0.05	68,300	35	2.52	288	0.359	1,700
	LKBB-060705-007W	325	76.6	405.4	9.66	1.04	5.53	0.05	58,500	8.92	1.32	146	0.626	1,650
	LKBB-060705-008W	330	75.4	432.1	8.61	0.99	5.64	0.05	55,400	5.62	3.51	111	0.5	1,590
	LKBB-060705-009W	315	77.1	279.6	<4.66	0.89	4.27	0.05	46,800	4.36	1.6	108	0.578	1,560
	LKBB-060705-011W	318	77.4	390.2	5.46	0.9	7.07	0.02	46,600	3.55	1.45	98.9	0.232	1,530
	LKBB-060705-022W	210	76.4	109.8	6.7	1.2	7.52	0.06	69,700	<0.47	1.41	52.7	0.311	1,860
	LKBB-060705-023W	180	76.8	62	6.6	1.29	7.86	0.05	62,100	3.14	2.52	71.7	0.232	1,840
Mean for all LMB collected														
Spotted bass (SPBA)	LKBB-060705-005W	385	73.1	708.6	6.4	0.85	4.93	0.05	58,800	79.6	1.97	710	0.619	1,570
	LKBB-060705-012W	327	76.3	334.1	11.3	1.07	4.46	<0.02	56,800	2.77	1.22	72.3	0.729	1,630
	LKBB-060705-013W	293	75.5	261.2	15.1	0.98	6.04	0.04	55,700	2.72	0.89	81.4	0.283	1,750
	LKBB-060705-014W	311	76.5	337.7	8.08	0.9	4.91	0.03	48,000	0.55	1.29	66.3	0.819	1,570
	LKBB-060705-017W	249	75.6	152.2	14.2	0.75	3.23	0.06	40,000	2.5	1.49	96.5	0.301	1,410
	LKBB-060705-018W	238	74.3	148.4	6.01	1.27	6.06	0.05	54,800	1.06	1.4	49	0.331	1,660
	LKBB-060705-019W	235	75.9	98.3	13.9	1.13	6.64	0.06	66,700	1.04	1.34	61.1	0.457	1,850
	LKBB-060705-020W	212	73.8	82.6	<4.74	1.44	5.87	0.02	58,000	1.68	1.01	40.7	0.235	1,650
	LKBB-060705-026W	173	77.1	44.8	<6.82	1.37	5.2	0.05	67,500	2.05	1.83	65.4	0.278	1,750
	LKBB-060705-027W	145	77	26.9	13.6	1.17	7.02	0.09	68,700	1.71	1.97	79.3	0.208	1,820
Mean for all SPBA collected														
Mean for all fish (both species) from LKBB														
Percentage of fish from LKBB with concentrations above detection limits														
		257	75.5	219	8	1.07	5.32	0.04	56,800	2,358	1,396	83.71	0.3812	1,661
		—	—	—	9.127	1.092	6.132	0.05	59,700	4,367	1,773	119	0.3981	1,692
		—	—	—	85.7	100	100	95.2	100	95.2	100	100	100	100

Table 3. Concentrations of selected metals and sulfur in whole-body samples of largemouth bass (*Micropterus salmoides*) and spotted bass (*Micropterus punctulatus*) collected from Whiskeytown Lake, California, June 2005.—Continued

[Concentrations are in micrograms per gram ($\mu\text{g/g}$), dry weight except where otherwise noted. Geometric means are reported for element concentrations; arithmetic means are reported for length, moisture, and mass. **Abbreviations:** g, gram; LKBB, Brandy/Boulder Creek area; LKCC, Clear Creek area; LKWC, Whiskey Creek area; mm, millimeter; NC, mean was not calculated if the element was detected in fewer than <50 percent of the samples; —, not applicable; ^, differences in laboratory detection limit are established by laboratory calibration curves for each batch of chemical analyses, therefore, they are not the same for every run; <, below the limit of detection; %, percent]

[illegible]

Table 3. Concentrations of selected metals and sulfur in whole-body samples of largemouth bass (*Micropterus salmoides*) and spotted bass (*Micropterus punctulatus*) collected from Whiskeytown Lake, California, June 2005.—Continued

[Concentrations are in micrograms per gram (µg/g), dry weight except where otherwise noted. Geometric means are reported for element concentrations; arithmetic means are reported for length, moisture, and mass. **Abbreviations:** g, gram; LKBB, Brandy/Boulder Creek area; LKCC, Clear Creek area; LKWC, Whiskey Creek area; mm, millimeter; NC, mean was not calculated if the element was detected in fewer than <50 percent of the samples; —, not applicable; ^, differences in laboratory detection limit are established by laboratory calibration curves for each batch of chemical analyses, therefore, they are not the same for every run; <, below the limit of detection; %, percent]

Species	Whole body code (site-date-sample)	Total length (mm)	Moisture (%)	Sample mass (g)	Aluminum^	Arsenic	Barium	Cadmium	Calcium	Chromium	Copper	Iron	Mercury	Magnesium
Largemouth Bass (LMBA)	LKWC-060905-001W	450	75.2	1,269.7	<4.38	0.94	7.06	0.17	58,000	1.07	2.77	78.1	0.902	1,500
	LKWC-060905-002W	415	75.2	861.3	4.75	1.12	9.84	0.12	59,400	1.64	2.25	101	0.735	1,570
	LKWC-060905-003W	342	77.8	511.5	106	1.27	9.53	0.11	67,400	2.96	1.86	195	0.484	1,840
	LKWC-060905-004W	330	75.9	445.2	11.4	0.95	7.59	0.12	41,100	3.72	2.67	177	0.643	1,380
	LKWC-060905-005W	286	79.5	289.9	14	1.25	15.3	1.04	57,000	0.806	4.46	123	0.61	1,700
	LKWC-060905-006W	304	78.8	322.4	13.5	0.93	7.33	0.28	45,500	2.82	4.97	135	0.573	1,600
	LKWC-060905-007W	195	75.3	73.4	10.2	1.39	4.35	0.062	58,100	1.25	2.01	69.4	0.497	1,790
	LKWC-060905-008W	165	75.7	45.8	17.7	1.52	4.93	0.112	59,200	2.11	2.21	80.7	0.438	1,730
	LKWC-060905-012W	470	74.6	1,369.3	<4.54	1.08	4.32	0.17	52,200	3.82	1.02	83.7	1.46	1,490
	LKWC-060905-013W	358	74.5	634.5	4.55	0.99	6.86	0.07	45,600	1.84	1.33	92	0.354	1,420
	LKWC-060905-014W	320	75.2	439.4	<4.38	0.96	2.31	0.08	34,400	2.51	1.31	64.8	0.611	1,280
	LKWC-060905-015W	337	79.3	483.8	26.8	0.92	7.62	0.05	39,800	1.47	1.63	84.1	0.499	1,430
	LKWC-060905-017W	336	74.8	490.2	<4.38	1.24	4.95	0.05	50,900	4.36	1.59	81.6	0.509	1,450
	LKWC-060905-019W	306	77.8	346.2	8.57	1.04	7.01	0.07	46,100	1.47	2.56	90.9	0.386	1,600
Spotted bass (SPBA)	LKWC-060905-020W	282	79.3	254.6	<4.74	0.89	5.26	0.09	45,700	1.52	1.57	79.5	0.625	1,500
	LKWC-060905-021W	188	75.6	67.2	9.33	1.1	4.64	0.14	59,100	1.31	2.87	51.1	0.314	1,650
	Mean for all LMBA collected	317.8	76.53	494.03	7.533	1.085	6.244	0.115	50,450	1.934	2.116	93.13	0.5607	1,551
	LKWC-060905-009W	363	70.6	609	<4.70	0.86	1.94	0.07	30,400	1.97	1.27	67.5	0.636	1,150
	LKWC-060905-010W	214	73.6	90.4	<4.72	1.07	6.54	0.64	50,300	1.01	1.25	40.6	0.508	1,690
	LKWC-060905-022W	388	72.6	627.9	<4.66	1.1	5.99	0.03	54,800	1.84	1.02	59.1	0.524	1,590
	LKWC-060905-023W	275	74.7	210.9	7.79	1.68	4.71	0.06	54,200	0.602	1.84	43.5	0.277	1,700
	LKWC-060905-024W	243	74.5	138.1	4.54	1.51	3.83	0.06	50,200	0.648	1.51	45.7	0.295	1,640
	Mean for all SPBA collected	296.6	73.2	335.27	NC	1.207	4.24		46,950	1.074	1.351	50.3	0.4248	1,538
	Mean for all fish (both species) collected for LKWC	—	—	—	6.235	1.113	5.69	0.11	49,590	1.681	1.902	80.42	0.5248	1,548
	Percentage of fish from LKWC with concentrations above detection limits	—	—	—	61.9	100	100	100	100	100	100	100	100	100
	Mean for all fish (both species) collected from sites	—	—	—	9.05	1.09	5.69	0.07	53,770	2.329	1.886	97.07	0.4232	1,603

Table 3. Concentrations of selected metals and sulfur in whole-body samples of largemouth bass (*Micropterus salmoides*) and spotted bass (*Micropterus punctulatus*) collected from Whiskeytown Lake, California, June 2005.—Continued

[Concentrations are in micrograms per gram (µg/g), dry weight except where otherwise noted. Geometric means are reported for element concentrations; arithmetic means are reported for length, moisture, and mass. **Abbreviations:** g, gram; LKBB, Brandy/Boulder Creek area; LKWC, Clear Creek area; LKCC, Clear Creek area; LKWC, Whiskey Creek area; mm, millimeter; NC, mean was not calculated if the element was detected in fewer than <50 percent of the samples; —, not applicable; ^, differences in laboratory detection limit are established by laboratory calibration curves for each batch of chemical analyses, therefore, they are not the same for every run; <, below the limit of detection; %, percent]

Species	Whole body code (site-date-sample)	Total length (mm)	Moisture (%)	Sample mass (g)	Manganese	Nickel [^]	Phosphorus	Potassium	Sodium	Sulfur	Selenium	Strontium	Titanium	Zinc
Largemouth Bass (LMB)	LKWC-060905-001W	450	75.2	1,269.7	10.3	0.62	30,600	10,100	4,060	7,720	2.09	99.4	1.16	59.3
	LKWC-060905-002W	415	75.2	861.3	8.99	1.01	30,500	10,500	4,240	7,310	2.46	101	1.64	70.6
	LKWC-060905-003W	342	77.8	511.5	17.7	1.05	36,300	12,700	4,860	9,360	2.92	112	9.4	72.3
	LKWC-060905-004W	330	75.9	445.2	5.95	1.65	24,600	10,700	3,710	7,710	2.92	60.4	3.33	70.2
	LKWC-060905-005W	286	79.5	289.9	37.2	0.71	31,200	11,900	4,780	8,620	3.73	84.8	1.21	71.8
	LKWC-060905-006W	304	78.8	322.4	11	0.59	27,800	13,800	5,090	9,770	2.99	66.8	7.81	74.5
	LKWC-060905-007W	195	75.3	73.4	5.56	<0.470	32,800	11,400	4,050	8,940	2.58	81.6	1.28	94.1
	LKWC-060905-008W	165	75.7	45.8	11.7	1.02	32,800	11,300	3,720	8,560	2.16	84.8	1.52	98.3
	LKWC-060905-012W	470	74.6	1,369.3	4.56	1.47	28,900	10,900	4,080	6,960	2.65	73.6	0.84	55
	LKWC-060905-013W	358	74.5	634.5	14.8	1.54	26,300	10,400	3,770	7,550	2.78	87.2	0.8	104
	LKWC-060905-014W	320	75.2	439.4	4.07	0.68	22,300	11,600	3,310	9,280	2.78	46.5	3.37	62.1
	LKWC-060905-015W	337	79.3	483.8	16.2	0.87	24,700	13,200	4,190	8,900	3.72	63.2	1.21	62.5
	LKWC-060905-017W	336	74.8	490.2	4.32	1.68	28,500	10,300	4,120	8,480	2.49	84.8	0.78	64.2
	LKWC-060905-019W	306	77.8	346.2	4.08	<0.450	27,600	12,900	4,170	9,310	2.8	89.9	0.98	67.8
	LKWC-060905-020W	282	79.3	254.6	9.65	0.66	27,400	12,500	4,560	9,090	3.83	71.6	0.77	69
	LKWC-060905-021W	188	75.6	67.2	6.24	0.46	32,600	11,100	4,060	9,150	2.24	89.6	1.05	94.7
Mean for all LMB collected		317.8	76.53	494.03	8.771	0.7762	28,840	11,530	4,149	8,504	2.776	79.32	1.598	73.09
Spotted bass (SPBA)	LKWC-060905-009W	363	70.6	609	1.8	0.65	20,100	9,640	2,730	7,030	2.18	49.7	0.85	48.4
	LKWC-060905-010W	214	73.6	90.4	5.9	<0.470	29,500	10,500	3,550	7,790	3.62	68.2	0.78	100
	LKWC-060905-022W	388	72.6	627.9	2.42	1.01	29,700	10,300	3,740	7,810	1.98	108	0.81	71.2
	LKWC-060905-023W	275	74.7	210.9	3.01	<0.440	30,800	11,500	3,350	7,930	2.31	103	0.9	80
Mean for all SPBA collected		296.6	73.2	335.27	2.908	NC	27,610	10,700	3,334	7,653	2.503	80.81	0.8475	76.17
Mean for all fish (both species) collected for LKWC		—	—	—	6.744	0.6537	28,540	11,330	3,939	8,293	2.708	79.67	1.374	73.81
Percentage of fish from LKWC with concentrations above detection limits		—	—	—	100	76.2	100	100	100	100	100	100	100	100
Mean for all fish (both species) collected for from sites		—	—	—	6.9	0.8993	30,490	11,460	3,980	8,373	2.36	90.44	1.515	73.78

Figure 2. Mercury concentration for all bass (*Micropterus spp.*) samples collected from Whiskeytown Lake, California, 2005 in relation to total length.

The data presented in this report represent a baseline for future monitoring efforts. Black bass in Whiskeytown Lake have elevated concentrations of total mercury and show a bioaccumulation effect of increasing mercury with increasing size. While mercury values from fish collected

from Whiskeytown Lake are not as elevated as values from fish in the adjacent Trinity Lake and watershed (May and others 2005), it is evident that more samples are needed to thoroughly evaluate the potential risk these fish may pose to human and wildlife consumers.

Figure 3. Correlation plot of mercury concentration in fillet samples in relation to whole-body samples for all bass (*Micropterus* spp.) samples collected from Whiskeytown Lake, California, 2005.

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References

- Alpers, C.N., Hunerlach, M.P., May, J.T., and Hothem, R.L., 2005, Mercury contamination from historic gold mining in California: U.S. Geological Survey Fact Sheet 2005–3014, 2nd ed., 6 p. Available at http://pubs.usgs.gov/fs/2005/3014/fs2005_3014_v1.1.pdf
- California Department of Conservation, 2000, California's Abandoned mine lands: Chapter 3.3 Clear Creek Watershed, p. 41–47, Volume II: A report on the magnitude and Scope of the issue in the State: California Department of Conservation, Abandoned Mines Unit, Sacramento, California, 137 p.
- May, J.T., Hothem, R.L., Alpers, C.N., and Law, M.A., 2000, Mercury bioaccumulation in fish in a region affected by historic gold mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999: U.S. Geological Survey, Open-File Report 00-367, 35 p. Available at <http://pubs.usgs.gov/of/2000/0367/report.pdf>
- May, J.T., Hothem, R.L., and Alpers, C.N., 2005, Mercury Concentrations in fishes from select water bodies in Trinity County, California, 2000–2002: U.S. Geological Survey Open-File Report 2005–1321, 14 p. Available at http://pubs.usgs.gov/of/2005/1321/USGS_2005-1321.pdf
- Moore, J.N., and Hughes, D., 2003, Trace metals in sediments of a mine impacted river basin: Clear Creek, California Project, Final Report: Department of Geology, University of Montana, Missoula, masters thesis, December 30, 2003, 136 p.

National Park Service, 1999, General Management Plan and Environmental Impact Statement Whiskeytown Unit Shasta County, California, 117 p., accessed June, 2008 at <http://www.nps.gov/whis/parkmgmt/upload/GMPfinal.pdf>

U.S. Environmental Protection Agency, 1991, Methods for the determination of metals in environmental samples: U.S. Environmental Protection Agency, Office of Research and Development, Environmental Monitoring Systems Laboratory, EPA- PA/600 4-91-010, 293 p.

U.S. Environmental Protection Agency, 1995, Guidance for assessing chemical contaminant data for use in fish advisories, Volume 1, Fish sampling and analysis (2nd ed.): U.S. Environmental Protection Agency, Office of Water, EPA823-R-95-007, variously paged.

U.S. Environmental Protection Agency, 2001, Water quality criterion for protection of human health—Methylmercury: U.S. Environmental Protection Agency, Office of Water, EPA-823-R-01-001, 269 p.

U.S. Environmental Protection Agency, 2003, Draft update IVA of SW-846, 7000 series, Method 7473, Mercury in solids and solutions by thermal decomposition, amalgamation, and atomic absorption spectrophotometry: U.S. Environmental Protection Agency, Office of Water, accessed July, 2005 at http://www.epa.gov/epaoswer/hazwaste/test/up4a.htm#7_series