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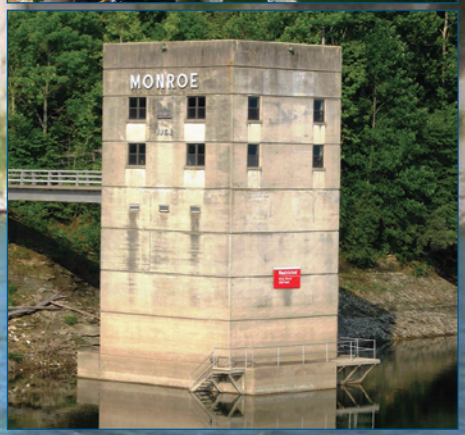
Mercury and Methylmercury in Reservoirs in Indiana



Professional Paper 1813

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Cover Photos

Background. Shoreline near Hanna Creek Marina at Brookville Lake, Indiana (photograph by Amanda L. Fredericksen, USGS).

Insets from top to bottom.

People fishing unnamed stream (from U.S. Fish and Wildlife Service Image Library, http://digitalmedia.fws.gov/).

Great blue heron in Brookville Lake headwaters near Quakertown Recreation Area, Indiana (photograph by Martin R. Risch, USGS).

Boats moored at Fairfax Marina on Monroe Lake, Indiana (photograph by Martin R. Risch, USGS).

Common carp near Newton Stewart Marina at Patoka Lake, Indiana (photograph by Martin R. Risch, USGS).

Control tower at Monroe Lake dam near Harrodsburg, Indiana (photograph by Martin R. Risch, USGS).

Tailwater at Patoka Lake dam near Cuzco, Indiana (photograph by Martin R. Risch, USGS).

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By Martin R. Risch and Amanda L. Fredericksen

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U.S. Department of the Interior
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Preface

Scientists and health officials agree that mercury is a chemical of concern because relatively small amounts of a form of mercury known as methylmercury can accumulate in the food webs of ecosystems and pose risks to humans and wildlife. Most of the United States, including Indiana, has public health advisories about eating wild-caught fish because of mercury contamination. Mercury is a worldwide contaminant, meaning that freshwater and ocean fish bought at a grocery or restaurant may contain small but significant amounts of mercury and have a health advisory. It is important to understand that the highest risks from methylmercury in fish are for the unborn and young, but adults also can be severely affected. These health risks hold true for wildlife as well as for humans—and although humans can lower their risks by selecting the type and amount of fish they eat, wildlife cannot make such choices.

The story about mercury in the environment is complex. Most of the mercury in ecosystem food webs comes from the air, arriving in precipitation and dry fallout. Much of the mercury in the air comes from human activity, such as burning coal to make electricity, cement manufacturing, and steelmaking. Local and regional sources of mercury emissions to the air have been shown to influence mercury levels in local and regional ecosystems. Regulations to reduce mercury emissions to the air in the United States are based on the belief that methylmercury levels in ecosystem food webs will diminish in response, although the timing of this response is unknown and may vary among ecosystems.

Scientists have been studying mercury in the environment in Indiana since the 1990s. Mercury science requires highly specialized tools and techniques to properly quantify the small environmental concentrations that are important in ecosystems. By analyzing thousands of samples of wild fish, precipitation, stream and lake water, wastewater, air, and forest vegetation in Indiana, we have developed a framework for describing mercury occurrence, transport, and fate.

A previous retrospective study of mercury in Indiana watersheds used the natural boundaries of water movement to group and interpret the many pieces of mercury information. A finding from the study led to the research about mercury and methylmercury in Indiana reservoirs described in this paper. Reservoirs, unlike natural lakes, are a part of river systems that are managed for flood control, which leads to unintended effects on mercury transport and methylmercury formation. Reservoir dams slow the velocity of water, allowing particles carrying mercury to settle in the reservoir pools. In the summer especially, some of the mercury in the reservoir pools can be transformed to methylmercury, the toxic form of mercury that accumulates in food webs. Water flowing out of reservoirs tends to have substantially higher ratios of methylmercury to mercury than does water in free-flowing streams. Methylmercury levels in the water of the reservoirs are related to levels of mercury in the fish. Atmospheric mercury deposition, landscape factors, and water chemistry appear to affect the levels of mercury and methylmercury in reservoirs.

Knowledge of reservoirs in Indiana can provide a reference about the potential for methylmercury in other reservoirs of the Great Lakes and Ohio River Valley region.

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Conversion Factors and Datums

International System of Units to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
liter (L)	1.057	quart (qt)
	Mass	
kilogram (kg)	2.205	pound avoirdupois (lb)

Inch/Pound to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as:
$°F = (1.8 \times °C) + 32$.

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as:
$°C = (°F - 32) / 1.8$.

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

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

Elevation, as used in this report, refers to distance above the vertical datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Turbidity is given in nephelometric turbidity ratio units (NTRU).

Concentrations of chemical constituents in water are given in either milligram per liter (mg/L) or nanogram per liter (ng/L).

Concentrations of chemical constituents in solids are given in either milligram per kilogram (mg/kg) or microgram per kilogram (µg/kg).

Atmospheric deposition is given in units of microgram per square meter ($\mu g/m^2$).

A milligram is 0.001 gram. A microgram is 0.001 milligram. A nanogram is 0.001 microgram.

Abbreviations

BAF	bioaccumulation factor
DO	dissolved oxygen
DOC	dissolved organic carbon
EPA	U.S. Environmental Protection Agency
GIS	geographic information system
GPS	global positioning system
Hg	mercury
IDEM	Indiana Department of Environmental Management
MeHg	methylmercury
NLCD	National Land Cover Database
POC	particulate organic carbon
RPD	relative percent difference

Mercury and Methylmercury in Reservoirs in Indiana

By Martin R. Risch and Amanda L. Fredericksen

Abstract

Mercury (Hg) is an element that occurs naturally, but evidence suggests that human activities have resulted in increased amounts being released to the atmosphere and land surface. When Hg is converted to methylmercury (MeHg) in aquatic ecosystems, MeHg accumulates and increases in the food web so that some fish contain levels which pose a health risk to humans and wildlife that consume these fish. Reservoirs, unlike natural lakes, are a part of river systems that are managed for flood control. Data compiled and interpreted for six flood-control reservoirs in Indiana showed a relation between Hg transport, MeHg formation in water, and MeHg in fish that was influenced by physical, chemical, and biological differences among the reservoirs. Existing information precludes a uniform comparison of Hg and MeHg in all reservoirs in the State, but factors and conditions were identified that can indicate where and when Hg and MeHg levels in reservoirs could be highest.

As part of a statewide monitoring network for Hg and MeHg in Indiana streams, 66 water samples were collected from four reservoir tailwater sites (downstream near the dams) on a quarterly schedule for 5 years. The reservoirs were Brookville Lake, Cagles Mill Lake, J. Edward Roush Lake, and Mississinewa Lake. Particulate-bound Hg concentrations were significantly lower in tailwater samples than in samples from free-flowing streams in the statewide network. (Free-flowing streams were not affected by dams and were not upstream from these reservoirs.) These data indicated the reduced flow velocity of water upstream from dams was allowing particulate-bound Hg to settle out of the water in the reservoir pools. The concentration ratios of MeHg to Hg were significantly higher in the tailwater samples than in samples from free-flowing streams, and the MeHg to Hg ratios were significantly higher in summer than in other seasons.

To evaluate the conditions related to MeHg formation, pools of three reservoirs (Brookville Lake, Monroe Lake, and Patoka Lake) were investigated during summer hydrologic conditions. Water temperature and dissolved oxygen were measured from the water surface to the lake bottom at 10 to 17 transects across each reservoir to identify three thermal strata, defined by water temperature, dissolved oxygen concentration, and depth. Depth-specific water samples were collected from these thermal strata throughout each reservoir, from the headwaters to the dam and from the tailwater. Mercury concentrations higher than 0.04 nanogram per liter (ng/L) were detected in all 53 samples, and MeHg concentrations higher than 0.04 ng/L were detected in 53 percent of the samples.

The investigation found a zone of water below 8 or 9 meters, with temperatures less than 18 degrees Celsius and dissolved oxygen less than 3.5 milligrams per liter, extending through nearly half the reservoir area in Monroe Lake and Patoka Lake. This zone had abundant dissolved MeHg and concentration ratios of dissolved MeHg to Hg that ranged from 25 to 82 percent. This zone also had water with pH less than 7 and decreased dissolved sulfate, conditions indicating sulfate reduction by microorganisms that promoted a high potential for the conversion of Hg to MeHg. Reservoir outflow came from this zone at Monroe Lake and contributed to a tailwater concentration ratio for dissolved MeHg to Hg of 56 percent. Reservoir outflow at Patoka Lake was not from this zone, and dissolved MeHg was not detected in the tailwater. In contrast, samples from the summer pool at Brookville Lake had no MeHg detections even though Hg was detected, probably because the water pH higher than 7 inhibited sulfate reduction and did not promote the conversion of Hg to MeHg.

Mercury and MeHg concentrations and the concentration ratios of MeHg to Hg in water varied among the six reservoirs in Indiana, and the differences were related to a combination of factors that could apply to other reservoirs. In areas with moderate to high rates of atmospheric Hg wet and dry deposition, Hg runoff and transport to streams and reservoirs was potentially highest for reservoirs with heavily forested watersheds in steep terrains of near-surface bedrock. Methylmercury concentrations and concentration ratios of MeHg to Hg were highest for reservoirs with the longest summer pools and highest inflow-to-outflow retention times, where water-chemistry conditions favoring sulfate reduction promoted conversion of Hg to MeHg.

Methylmercury (reported as Hg) in fish-tissue samples collected for the State fish consumption advisory program was used to describe MeHg food-web accumulation and magnification in the reservoirs. The highest percentages of fish-tissue samples with Hg concentrations that exceeded the criterion of 0.30 milligram per kilogram for protection of human health were from Monroe Lake (38 percent) and Patoka Lake (33 percent). A review of the number and size of fish species caught from these two reservoirs resulted in two implications

for fish consumption by humans. First, the highest numbers of fish harvested for potential human consumption were species more likely to have MeHg concentrations lower than the human-health criterion (crappie, bluegill, and catfish). Second, although largemouth bass were likely to have MeHg concentrations higher than the human-health criterion, they were caught and released more often than they were harvested. However, the average size largemouth bass (in both reservoirs) and above-average size walleye (in Monroe Lake) that were harvested for potential human consumption were likely to have MeHg concentrations higher than the human-health criterion.

Introduction

Mercury (Hg)[1] is an environmental contaminant that can pose adverse health risks to humans and wildlife, especially in the form of methylmercury (MeHg), which accumulates and magnifies in aquatic food webs. This data compilation and interpretation of Hg and MeHg in selected reservoirs is a case study for Indiana that indicates the potential for similar occurrence in other reservoirs.

Purpose and Scope

The purpose of this report is to present two sets of U.S. Geological Survey data about Hg and MeHg in water from six flood-control reservoirs in Indiana and to interpret how the Hg and MeHg were affected by physical factors and chemical and biological conditions in the reservoirs. (Reservoirs consist of a dam with flow-control structures that include floodgates and bypass valves. Water discharged through the gates or bypass outlets enters a stream channel, where it is termed "tailwater." The water impounded behind the dam is termed "pool.") This report presents Hg and MeHg in analyses of water samples from pools and tailwaters of three reservoirs (2009) along with analyses of water samples from tailwaters of four reservoirs (2002–2006). In addition, analyses of fish-tissue samples from eight reservoirs (1996–2007) were compiled from State records and interpreted to depict food-chain accumulation and magnification of MeHg.

The scope of this report is comprehensive. The introduction uses data from Indiana and the scientific literature for an explanation of Hg and MeHg in reservoirs, along with reference benchmarks and public health advisories for Hg in fish. Methods include detailed descriptions of sampling, analysis, measurement, and quality assurance for Hg, MeHg, and other constituents in water of reservoir pools and tailwaters. Interpretations of the data from Indiana reservoirs are used to identify the factors and conditions affecting Hg and MeHg in water that could apply to reservoirs outside the study. Land cover, landscape, and atmospheric Hg deposition are examined for their effects on the transport of Hg to reservoirs. Water chemistry and reservoir characteristics are used to understand conditions that promote formation of MeHg in the reservoirs. Fish-tissue Hg data for species caught and harvested from reservoirs are discussed with their implications for human consumption and wildlife.

Mercury and Methylmercury in the Environment

Aquatic ecosystems receive Hg primarily from atmospheric deposition, originating from Hg emissions to the atmosphere from human activity (National Research Council, 2000; Lindberg and others, 2007, Driscoll and others, 2013). Wet deposition transfers atmospheric Hg that is in precipitation (rain, snow, sleet, hail, and fog) to the land surface. Dry deposition transfers gaseous, oxidized, and particulate atmospheric Hg to vegetation, soil, water, snow, and urban landscapes. Dry deposition occurs continuously and at a slower rate than wet deposition, which is episodic (Zhang and others, 2009). Dry deposition of Hg can be greater than wet deposition of Hg in many ecosystems (Lindberg and others, 2007; Zhang and others, 2012).

The Hg in atmospheric deposition is primarily inorganic Hg, which in aquatic ecosystems can be converted to organic MeHg by microorganisms as a byproduct of their metabolism. Sulfate-reducing bacteria, which process organic matter using sulfate in the environment, take up inorganic Hg and convert it to MeHg under certain conditions in riparian wetlands that are hydraulically connected to streams or lakes, as well as in some stream or lake-bottom environments (Morel and others, 1998). This MeHg can be released into the water by diffusion or resuspension of sediment. Organic carbon can affect the levels and mobility of Hg and MeHg in water, thereby enhancing the MeHg availability to the food web (Grigal, 2002; Brigham and others, 2009; Chasar and others, 2009). Methylmercury is highly absorbable and more toxic than inorganic Hg; organisms require a longer time to eliminate MeHg than Hg, and the amounts of MeHg in primary producers are preserved in successively higher levels of consumers in individual food chains within the food web (Munthe and others, 2007). Bacteria with MeHg may be consumed by the next higher level in a food chain, or the bacteria may release the MeHg to the water, where it can become part of plankton and periphyton (Bell and Scudder, 2007) that are consumed by the next level in a food chain. The concentration of MeHg magnifies in organisms at higher levels in food chains so that the highest concentrations are found in large, old, top-predator and bottom-feeding fish.

Methymercury has been linked to adverse health and reproductive effects in humans and wildlife. The health risks to humans mostly are from fish consumption (Mergler and others, 2007). People and families who catch and eat fish for subsistence have the greatest exposure to MeHg. Methylmercury

[1] In this paper, Hg is the same as what is sometimes called "total Hg." Total Hg includes MeHg by definition, but MeHg and Hg concentrations are determined separately.

is a potent neurotoxin that can slow nervous-system and cognitive development in young and unborn children. Adults can have adverse neurological and cardiovascular effects from MeHg exposure. Methylmercury has been linked to congenital birth defects, increased risk of heart attack, renal damage, and blood pressure dysfunction in humans (National Research Council, 2000). Methylmercury can interfere with reproduction in vertebrates (Klaper and others, 2006). Fish-eating mammals and birds exposed to high, environmentally relevant MeHg levels can have reproductive and developmental impairments and reduced immunity (Scheuhammer and others, 2007). Populationwide effects in terrestrial wildlife have been linked to MeHg (Evers, 2005).

According to Risch and others (2010), the median concentration of MeHg in Indiana watersheds was 0.10 nanogram per liter (ng/L), whereas the median concentration of MeHg in all fish from these watersheds was 0.13 milligram per kilogram (mg/kg). This comparison demonstrates the complexity of the Hg cycle in that MeHg accumulates and concentrates in the aquatic food chain by a factor of at least 1,300,000.[2] Studies have shown a correlation between atmospheric deposition of Hg and MeHg in fish (Cocca, 2001) and between MeHg in water and in fish (Brumbaugh and others, 2001). The strength of these relations has led to a prediction that Hg-emissions reductions will decrease MeHg concentrations in fish (Harris, Rudd, and others, 2007).

Reference Benchmarks for Mercury and Methylmercury

In this paper, national criteria are used that can be applied throughout Indiana and other States. Methylmercury (as Hg) in fish-tissue samples are compared with 0.30 mg/kg as the "reference benchmark for human health." The U.S. Environmental Protection Agency (EPA) freshwater water-quality criterion for MeHg is not based on a concentration in water. Rather, it is based on a concentration for MeHg in fish tissue that is protective of human health, 0.30 mg/kg wet weight (hereafter, fish-tissue concentrations refer to wet weight unless otherwise noted) (U.S. Environmental Protection Agency, 2001a).[3] Guidance for implementing the MeHg criterion (U.S. Environmental Protection Agency, 2010) states the assumption that nearly all of the Hg in fish-tissue samples is MeHg,[4] meaning that fish-tissue Hg concentrations may be compared with the 0.30-mg/kg MeHg criterion as if they were MeHg concentrations. Other reports use this same assumption (for example, U.S. Environmental Protection Agency, 1999, 2009; Harris, Krabbenhoft, and others, 2007; Scudder and others, 2009; Stahl and others, 2009), as do public health advisories for fish consumption (U.S. Environmental Protection Agency, 2010). In this report, Hg in fish-tissue samples is assumed to be nearly all MeHg for comparing with the EPA criterion but is called Hg, consistent with the data.

In this report, Hg in fish-tissue samples are also compared with the "reference benchmark for wildlife," 0.10 mg/kg. The EPA (1997) derived a 0.10-mg/kg fish-tissue MeHg criterion protective of fish-eating mammals, including mink (*Mustela vison*) and river otter (*Lutra canadensis*), and a 0.20-mg/kg fish-tissue MeHg criterion protective of fish-eating birds, including bald eagle (*Haliaeetus leucocephalus*), osprey (*Pandiaon haliatus*), and belted kingfisher (*Ceryle alcyon*). National assessments of Hg in lakes (Yeardley and others, 1998) and streams (Scudder and others, 2009) used the more conservative criterion of 0.10 mg/kg MeHg for fish-eating mammals and birds to compare with fish-tissue Hg concentrations. The 0.10-mg/kg reference benchmark for wildlife also is protective of freshwater fish. In a literature review, Sandheinrich and Wiener (2011) noted that sublethal effects of Hg on freshwater fish, including changes in reproductive health, were consistently observed in laboratory and field studies for Hg concentrations exceeding approximately 0.30 mg/kg in the whole body and 0.50 mg/kg in the fillet.

Mercury was detected in nearly all fish-tissue samples from national studies of lakes (U.S. Environmental Protection Agency, 2009) and streams (Scudder and others, 2009). The reference benchmark for human health was exceeded in these studies. Results from the statistically based national study of chemical residues in lake fish tissue (U.S. Environmental Protection Agency, 2009) estimated that 49 percent of 76,559 lakes in the lower 48 States had fish with Hg concentrations that exceeded 0.30 mg/kg. For comparison, a national compilation of fish-tissue Hg data collected by States for fish consumption advisory programs indicated that approximately 40 percent of the watershed-averaged sample concentrations exceeded 0.30 mg/kg (U.S. Environmental Protection Agency, 2010).

The reference benchmark for wildlife was exceeded 2 to 3 times more often than the reference benchmark for human health in national studies. Yeardley and others (1998) reported that Hg concentrations in fish from 26 percent of the lakes in the northeastern United States exceeded 0.30 mg/kg

[2] One milligram equals 1,000 micrograms and one microgram equals 1,000 nanograms, which means the MeHg concentration increase from 0.10 ng/L in the water to 0.13 mg/kg in the fish is 1,000 times 1,000, which equals a MeHg bioaccumulation factor of 1,300,000.

[3] The 0.30 mg/kg criterion is based on a total consumption-weighted rate of 0.175 kg of fish per day (assuming a human adult body weight default value of 70 kg and a reference dose of 0.001 mg/kg per day, accounting for different trophic levels of fish.) A reference dose is an estimate (with uncertainty) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.

[4] U.S. Environmental Protection Agency (2010) references four studies in which the mean ratios of MeHg to Hg concentrations in fish-tissue samples from studies in the northeastern United States were equal to or higher than 90 percent (Grieb and others, 1990; Bloom, 1992; Becker and Bigham, 1995; and Hammerschmidt and others, 1999). All of the fish species listed for these four studies are found in Indiana.

and 54 percent exceeded 0.10 mg/kg. For comparison, Scudder and others (2009) reported that Hg in fish from 27 percent (79 of 291) of the stream sample sites in their study exceeded 0.30 mg/kg and that nearly 75 percent (209 of 291 sites) exceeded 0.10 mg/kg, the reference benchmark for wildlife.

Previous Studies of Mercury in Reservoirs

Reservoirs, unlike natural lakes, are a part of river systems that are managed for flood control. A condition known as the reservoir effect highlights the importance of Hg and MeHg in reservoirs. Methylmercury concentrations in water from new reservoirs increase because decomposition of organic carbon from inundated forest soils and wetlands stimulate microorganisms that form MeHg from Hg, as documented by numerous investigations summarized in Bodaly and others (2004), Mailman and others (2006), and Stewart and others (2008). The result is that MeHg in the suspended particulate matter and water of reservoirs is higher than in natural lakes. Methylmercury in the water is taken up by phytoplankton and zooplankton, leading to elevated Hg in fish. Elevated MeHg may persist for many years after a reservoir is first constructed (Hall and others, 2005; Bodaly and others, 2007), and MeHg in resuspended fine particles transfers to the food chain for a long time in the protected shallow areas of reservoirs (Plourde and others, 1997).

As summarized in Canavan and others (2000), it is known that during seasonal thermal stratification of lakes and reservoirs, conditions develop in the deepest layer of water—a layer with relatively low dissolved oxygen—that promote MeHg formation. Deep reservoirs with long retention times and recurring stratification develop a biochemistry of MeHg-enriched water near the lake bottom. Unlike lakes, reservoirs are designed to release water, which can be enriched with MeHg, depending on the season and the depth of the water that is released from the reservoir.

Reservoir watershed characteristics and water-management actions can increase the potential for MeHg formation and subsequent bioaccumulation in aquatic organisms. Mast and Krabbenhoft (2010) compared Hg and MeHg in water, sediment, zooplankton, and fish from two reservoirs in Colorado. One reservoir had a Hg fish-consumption advisory and the other did not because in one reservoir, annual water-level fluctuations stimulated MeHg formation in a more organic-rich sediment of a larger area during reflooding. Negry and others (2011) combined water chemistry, lake, and land-use variables to predict Hg in fish from 17 lakes and reservoirs in California. They found the strongest statistical associations of Hg in fish were with Hg in lake sediment, percent forested area, and MeHg in water. Drenner and others (2011) studied factors affecting Hg in largemouth bass (*Micropeterus salmoides*) from 145 reservoirs in four ecoregions of Texas. They reported fish with the highest Hg were from reservoirs in the ecoregion with the highest Hg and sulfate deposition, extensive forest and wetland land cover, and little agriculture.

Description of the Study Area

Eight reservoirs (fig. 1) were constructed in Indiana between 1953 and 1979 to prevent downstream flood damage (U.S. Army Corps of Engineers, 2014)—Brookville Lake, Cagles Mill Lake, Cecil M. Harden Lake (C.M. Harden Lake hereafter; also called Raccoon Lake), Mississinewa Lake, Monroe Lake, Patoka Lake, J. Edward Roush Lake (J.E. Roush Lake hereafter; also called Huntington Lake), and Salamonie Lake. Three of these reservoirs in Indiana are sources for a public-water supply—Brookville Lake, Monroe Lake, and Patoka Lake. These riverine reservoirs differ from natural or other constructed lakes because the outflow, internal transport, and retention time are influenced by management for flood control, water supply, and water quality, as well as by inflow from precipitation runoff.

Typical operation of a flood-control reservoir involves impounding water from spring runoff and attaining a summer pool stage that is generally maintained until a drawdown in late summer or early fall. The winter pool stage is established when drawdown is completed, and the reservoir refills until summer pool stage is reestablished. The summer pool areas of the reservoirs in Indiana range from 3.7 to 43.5 square kilometers (km^2), and upstream drainage areas range from 440 to 2,093 km^2 (table 1).

Methods

Data-collection sites for reservoir tailwaters and pools are described in this section. Ultraclean protocols and low-level analyses for measuring Hg and MeHg in water are explained. Methods for water sample collection, processing, and analysis are presented, along with quality assurance of Hg and MeHg and supplementary constituents. Methods for determination of water-quality characteristics are described, including vertical profiles along reservoir-pool transects.

Data-Collection Sites

Tailwater sites at four reservoirs—Brookville Lake, Cagles Mill Lake, Mississinewa Lake, and J.E. Roush Lake (fig. 1)—were sampled as part of a statewide network for Hg in Indiana streams (Ulberg and Risch, 2008). Pools at three reservoirs—Brookville Lake, Monroe Lake, and Patoka Lake (fig. 1)—were investigated because Monroe Lake and Patoka Lake that had not been studied previously and because Brookville Lake was in a different part of Indiana from the other two. Tailwater or pool data were not available for two flood-control reservoirs in Indiana—C.M. Harden Lake and Salamonie Lake.

At the three reservoir pools, vertical profiles of water-quality characteristics were measured at the center of the 5 equal-width increments along 10 to 17 shore-to-shore transects (table 2). The transects were established downstream

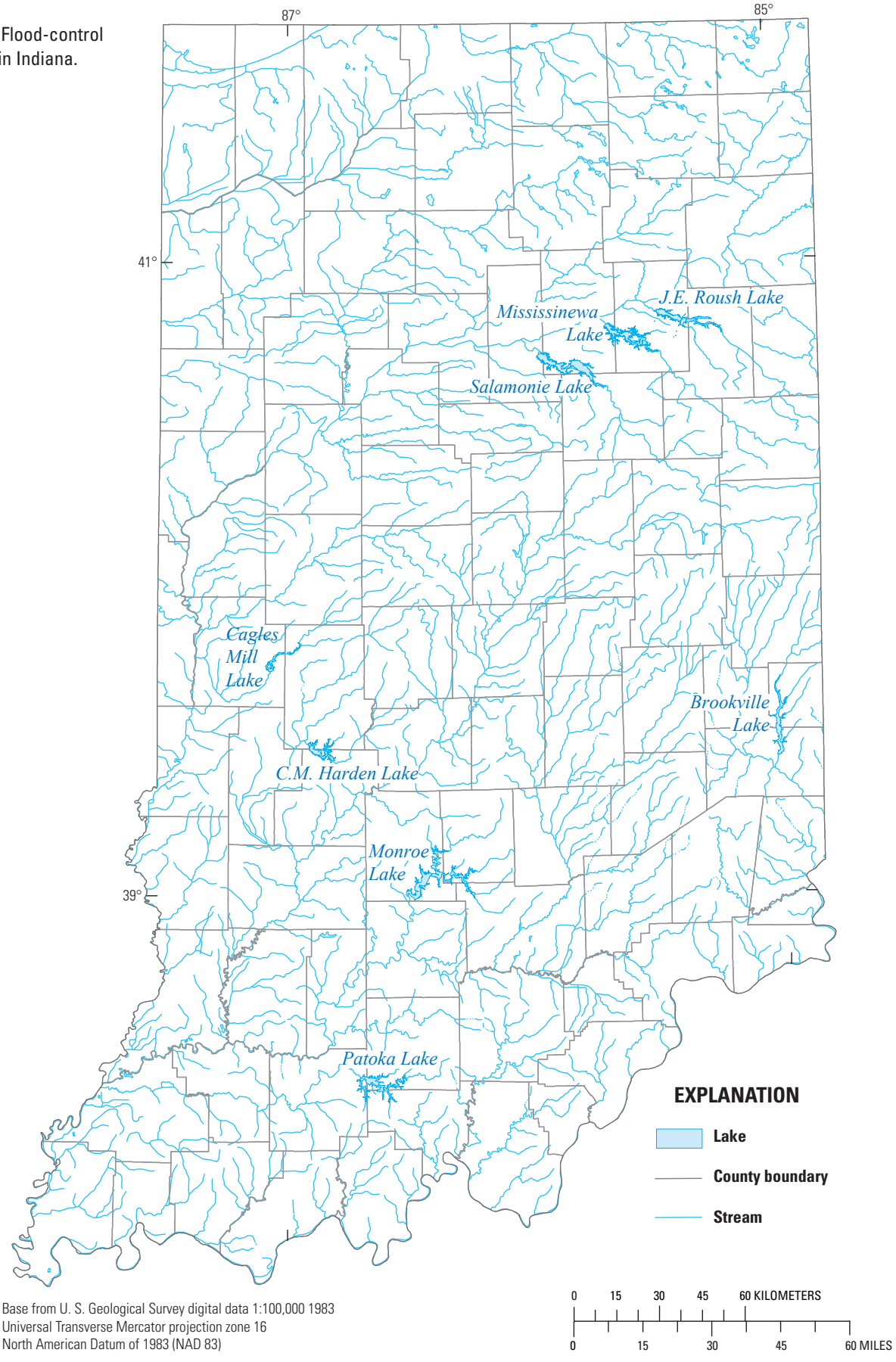

Figure 1. Flood-control reservoirs in Indiana.

Table 1. Selected information for flood-control reservoirs in Indiana.

[km², square kilometer; km, kilometer; USGS, U.S. Geological Survey; --, no data]

Reservoir project name	Summer pool area (km²)	Summer pool length (km)	Winter pool area (km²)	Winter pool length (km)	Drainage area (km²)	Average annual retention time[1] (days)	Difference of summer and winter pool (km²)	Difference as percent of summer pool	USGS gaging-station number[2]	Name of impounded stream	Year of full pool	Water supply
Brookville Lake	21.3	26.4	18.3	24.1	984	202	3.0	14	03276000	East Fork Whitewater River	1974	Yes
Cagles Mill Lake	5.9	16.1	5.7	16.1	761	44	0.3	4	03359000	Mill Creek	1953	No
C.M. Harden Lake[3]	8.5	17.4	4.5	10.8	562	128	4.1	48	03340900	Big Raccoon Creek	1961	No
Mississinewa Lake	12.9	--	5.2	--	2,093	41	7.7	60	03327000	Mississinewa River	1968	No
Monroe Lake	43.5	59.5	43.5	59.5	1,119	199	0.0	0	03372500	Salt Creek	1966	Yes
Patoka Lake	35.4	40.2	33.1	37.8	440	556	2.3	6	03374500	Patoka River	1979	Yes
J.E. Roush Lake[4]	3.7	11.3	2.3	8.0	1,867	10	1.4	37	03323500	Wabash River	1969	No
Salamonie Lake	9.2	27.4	3.5	17.7	1,443	51	5.7	62	03324500	Salamonie River	1974	No

[1] Average annual retention time, 1984–2007 (U.S. Army Corps of Engineers, written commun., 2009); all other data from U.S. Army Corps of Engineers (2014).

[2] Nearest gaging station downstream from reservoir.

[3] Also called Raccoon Lake.

[4] Also called Huntington Lake.

from the confluence of contributing streams, downstream from major bays and inlets, near dams, and in places where they would bracket water-quality sample locations. Transects were identified on maps and aerial photographs, and a geographic information system (GIS) was used to determine the coordinates of transect endpoints and the centers of five equal-width increments. A global positioning system (GPS) and digital map interface on the watercraft were used to navigate to the transects and increment center points. A total of 1,440 depth-specific measurements of water-quality characteristics were measured at 1.52-meter (m) (5-foot [ft]) intervals from the water surface to the lake bottom along each transect (fig. 2), creating a vertical profile.

The sampling design for the three reservoirs included sites in headwaters, inlets, main body, area near the dam, and tailwater. A depth-sounding fathometer connected to the GPS and digital map interface on the watercraft were used to record bathymetric data of the lake-bottom topography along each transect (fig 2). The fathometer was used to identify the thalweg of the original stream channel as the deepest water with all three thermal strata present. At sampling sites between transects in the main body of the lake, a vertical profile of water-quality characteristics was measured to selected depths for two or three point samples. Sites in the headwaters and inlets or bays typically involved water depths less than 2 m and included a point sample at a single depth.

Table 2. Reservoir-pool water-quality transect information.

Reservoir	Number of transects	Mean transect length (meters)	Range of transect lengths (meters)	Maximum water depth (meters)	Number of measurements[1]
Brookville Lake	10	235	83–408	32.3	523
Monroe Lake	14	272	131–525	13.7	333
Patoka Lake	17	166	73–413	12.8	584

[1] At each measurement, a total of five water-quality characteristics were determined. Measurements were made at 1.52-meter (5-foot) intervals from the water surface to lake bottom.

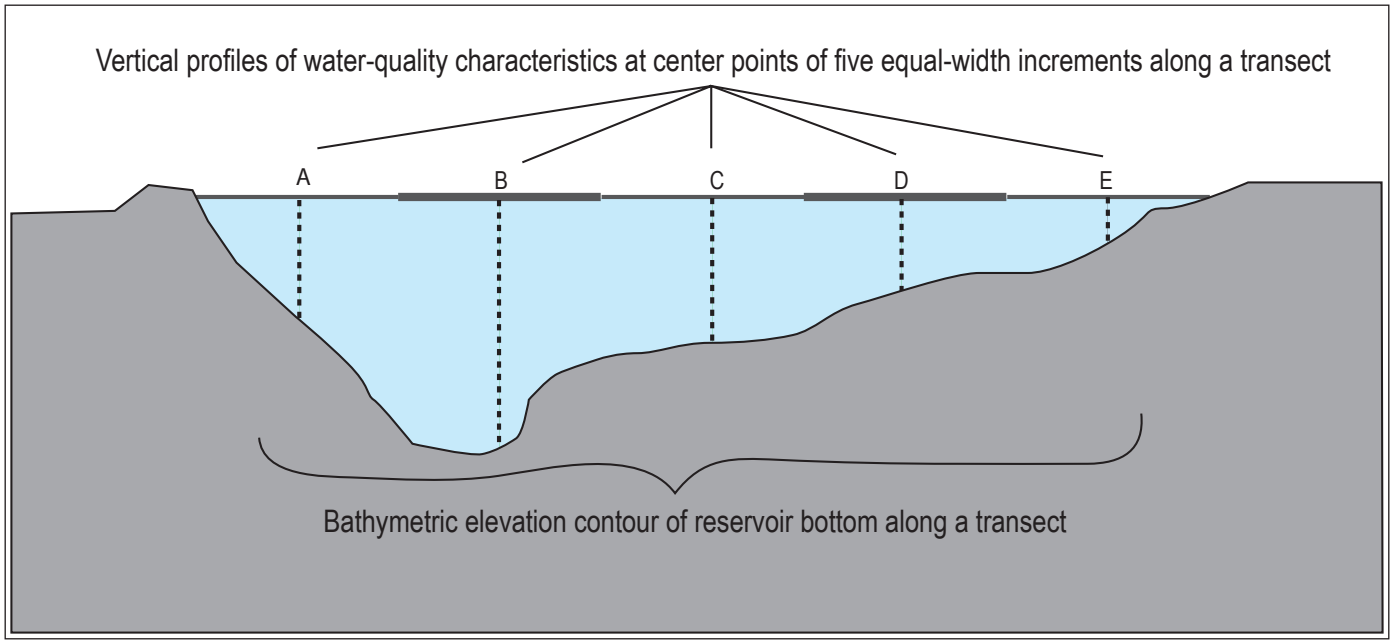

Figure 2. Generalized diagram of reservoir-pool-monitoring transect, water-quality verticals, and lake-bottom topography.

Water-Quality Characteristics

Five water-quality characteristics were measured at the tailwater and reservoir-pool sites and in the vertical profiles along the 10 to 17 transects in each reservoir pool. A multiparameter instrument was used to measure pH, specific conductance, dissolved oxygen, and water temperature (table 3). The meter was calibrated each day prior to its use, following procedures outlined in U.S. Geological Survey (variously dated). A portable optical turbidimeter was used to measure turbidity in three aliquots of each water sample, and the median was reported. The turbidimeter was checked with secondary standards each day prior to its use. The water sample for turbidity at the tailwater sites came from a composite sample mixed in a churn-style sample splitter. The water sample for turbidity at the reservoir sites was a depth-specific grab sample collected with a Kemmerer sampler. Water-quality characteristics were determined at the time of water-sample collection at the tailwater sites as described in Ulberg and Risch (2008). For the 2002–2006 and 2009 tailwater sites, the values of the water-quality characteristics were a composite integrated through the stream width and depth. For the 2009 reservoir-pool sites, depth-specific point measurements of water-quality characteristics were made at the depth the water samples were collected.

Water-Sample Collection, Processing, and Analysis

Ultraclean protocols were used for collecting water samples to be analyzed for Hg and MeHg, described in U.S. Geological Survey (variously dated). These protocols are designed to avoid the unintentional introduction of Hg or other contaminants into a sample and are comparable to trace-metals methods in EPA Method 1669 (U.S. Environmental Protection Agency, 1996) and the USGS Inorganic Protocol (Horowitz and others, 1994). Supplies that contacted water samples (sample bottles, pump tubing, and filter holders) were made of fluorocarbon resin (Teflon), specially cleaned in the laboratory with hot acid and Hg-free water rinses, dried, and double bagged. Supplies were used for one sample and returned to the laboratory for cleaning. Equipment that contacted water samples (intake weight, sampler cap and nozzle, and churn) also were made of fluorocarbon resin. These equipment items were cleaned with a series of detergent, Hg-free water, and acid rinses between samples. Personnel wore powder-free disposable nitrile gloves that were changed frequently to protect sample integrity. A minimum of two USGS personnel collected samples; one person handled sample bottles and inner bags of double-bagged supplies, and the other person handled sampling equipment and the outer bag of double-bagged supplies.

Water samples at three reservoir pools were collected from a motorized watercraft with the motor off and the watercraft anchored fore and aft. Depth-specific point samples were collected with a peristaltic-pump apparatus (fig. 3) suspended from a handline. A Teflon weight with intake ports was lowered with a Kevlar handline to the desired sampling depths. The weight was connected to an optimal length of small-diameter Teflon tubing inserted in a short piece of flex tubing at the pump head. Water was pumped into sample bottles handled inside an isolation chamber on the watercraft.

Water samples were collected at tailwater sites by using stream-width- and streamflow-integrating techniques described in Ulberg and Risch (2008) and Risch and others (2010). Water samples were collected from a bridge, while wading, or from an inflatable, rubberized boat with a wooden floor (at Cagles Mill Lake). Samples were collected from a bridge by use of an isokinetic sampler suspended from a cable reel on a portable bridge crane. Samples were collected while wading or from a boat by use of an isokinetic sampler on a rod. Representative samples were collected according to USGS procedures that are intended to composite water collected across the full width and depth of the stream, thus accounting for differences in velocity and water chemistry.

Water samples collected for Hg and MeHg analysis were transported or shipped overnight to the USGS Indianapolis office, where they were processed within 24 hours of collection. Water samples for Hg and MeHg analysis were filtered and preserved in a Class 100, laminar-flow, high-efficiency particulate-air-filter workstation. Filtered water and particulate samples were prepared by vacuum filtration, using equipment and procedures described in U.S. Geological Survey (variously dated). Water samples for Hg and MeHg analysis were preserved with concentrated high-purity hydrochloric acid. Particulate sample filters were frozen until analysis for Hg and MeHg.

Table 3. Methods and reporting limits for determinations of water-quality characteristics.

[µS/cm, microsiemens per centimeter; mg/L, milligram per liter; °C, degree Celsius; NTRU, nephelometric turbidity ratio unit]

Constituent or property	Method	Reporting limit, precision, and unit
pH	In situ measurement with multiparameter instrument	0.1 ± 0.01 standard unit
Specific conductance	In situ measurement with multiparameter instrument	1 ± 1 µS/cm
Dissolved oxygen	In situ measurement with multiparameter instrument	0.01 ± 0.01 mg/L
Water temperature	In situ measurement with multiparameter instrument	0.01 ± 0.01 °C
Turbidity	Field measurement of composite sample with portable turbidimeter	0.1 ± 0.1 NTRU

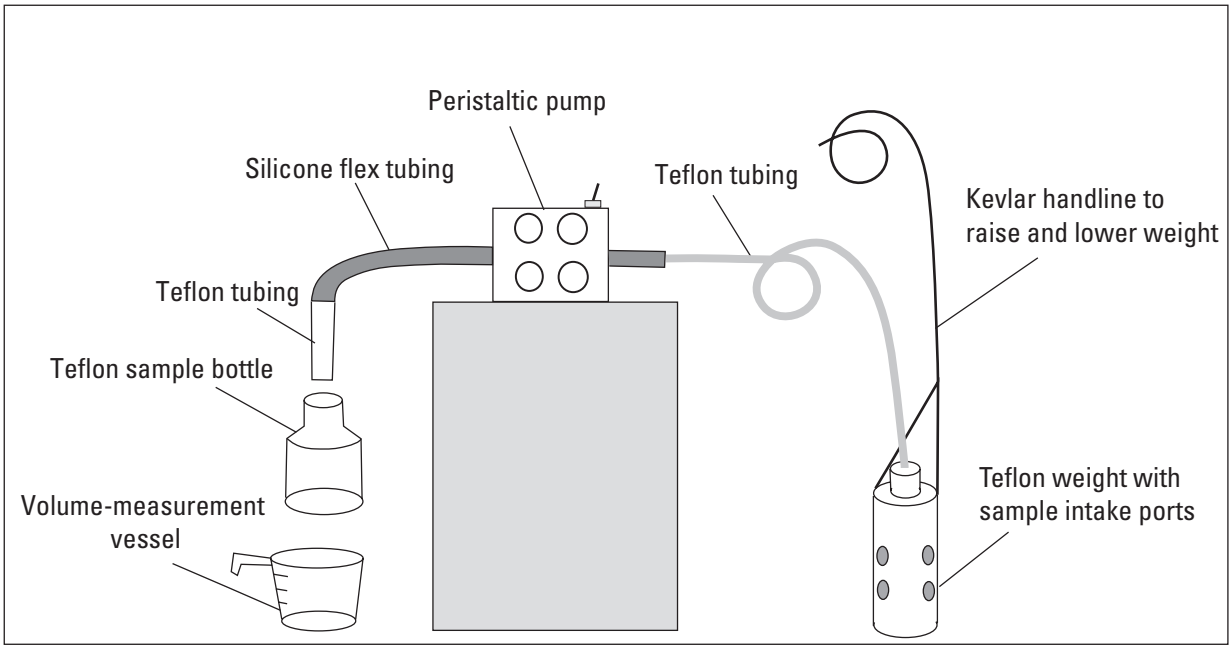

Figure 3. Apparatus for collection of water samples for mercury analysis.

Water and particulate samples collected by USGS were analyzed for low-level Hg[5] and MeHg (table 4) at the USGS Mercury Research Laboratory. Mercury concentration was determined by oxidation, purge and trap, and cold vapor atomic fluorescence spectrometry (Olson and DeWild, 1997), equivalent to EPA Method 1631 (U.S. Environmental Protection Agency, 2002). Methylmercury samples were prepared by distillation and analyzed by aqueous phase ethylation and gas chromatography separation with cold vapor atomic fluorescence detection (DeWild and others, 2002), equivalent to EPA Method 1630 (U.S. Environmental Protection Agency, 2001c).

Analytical data for the tailwater samples included determinations of Hg and MeHg in unfiltered and filtered forms, in which case "particulate" Hg and MeHg concentrations were computed as the difference of unfiltered and filtered forms. Analytical data for the reservoir pool and tailwater samples included determinations of Hg and MeHg in particulate forms measured on filters and dissolved forms in filtered water. In this case, "whole-water" Hg and MeHg concentrations were computed as the sum of dissolved and particulate forms.[6] If a dissolved or particulate concentration was less than the reporting limit for a sample, it was assumed to be zero for computing a whole-water concentration, consistent with the approach used by other investigators (for example, Brigham and others, 2009). The "ratio of the MeHg to Hg concentration" in this report can refer to the ratios of unfiltered MeHg to unfiltered Hg, whole-water MeHg to whole-water Hg, or dissolved MeHg to dissolved Hg, depending on context.

Reservoir-pool water samples for analysis of dissolved sulfate, organic carbon, particulate carbon and nitrogen, and chlorophyll were filtered and processed in a mobile laboratory van within a few hours of sample collection, following procedures in U.S Geological Survey (variously dated) and references in table 4.

Quality Assurance

Quality assurance included analysis of field and laboratory quality-control samples, and the USGS laboratory followed a written quality-assurance plan (U.S. Geological Survey, 2007). Field quality-control data for tailwater samples were explained and evaluated by Ulberg and Risch (2008). These quality-control data indicated that the Hg and MeHg data from tailwater samples were representative and unbiased.

For the reservoir-pool water samples, field blank samples (source water/bottle blanks and equipment blanks) were prepared to evaluate cleaning of the sampling equipment. Field blank data were evaluated by using procedures for EPA Method 1631 (U.S. Environmental Protection Agency, 2001b). Field duplicate samples were collected by sequentially filling a second set of sample bottles from the same tubing. Field duplicate samples were a measure of the natural variability of Hg concentrations in the water and the variability associated with sample collection and processing, rather than a measure of analytical precision. Analytical precision in the determination

[5] In this report, the analytical determination of Hg means total Hg.

[6] In water samples with levels of suspended particulates consistent with turbidity values higher than 20 nephelometric ratio turbidity units (NTRU), the MeHg concentration in an unfiltered sample is generally equivalent to the sum of dissolved and particulate MeHg concentrations, if reporting limits are the same. Unfiltered water samples with less than 20 NTRU and low levels of suspended particulates generally will have lower MeHg concentrations than those determined as the sum of dissolved and particulate MeHg concentrations. This difference is attributable to the more sensitive particulate MeHg determination.

Table 4. Methods for analysis of mercury, particulate, and supplementary constituents in water.

[ng/L, nanogram per liter; µm, micrometer (pore size of filters); HCl, hydrochloric; mg/L, milligram per liter; °C, degree Celsius]

Constituent	Reporting limit and units	Method	Preparation	Reference[1]
Dissolved total mercury	0.04 ng/L	Oxidation, purge and trap, and cold-vapor atomic fluorescence spectrometry	Water passed through quartz fiber filter with 0.7-µm pore size, before preservation with high-purity HCl	1
Particulate total mercury	0.04 ng/L	Oxidation, purge and trap, and cold-vapor atomic fluorescence spectrometry	Particle isolation on pre-baked quartz fiber filter	2
Dissolved methylmercury	0.04 ng/L	Gas chromatographic separation with cold vapor atomic fluorescence detection	Water passed through quartz fiber filter with 0.7-µm pore size, before preservation with high-purity HCl; distillation and aqueous phase ethylation	3
Particulate methylmercury	0.04 ng/L	Gas chromatographic separation with cold vapor atomic fluorescence detection	Particle isolation on pre-baked quartz fiber filter; distillation and aqueous phase ethylation	4
Total suspended particulates	15 mg/L	Gravimetric from filtration and evaporation	Filtered in the lab	5
Total particulate carbon	0.1 mg/L	Elemental analysis	Particle isolation on filter	6
Particulate organic carbon	0.12 mg/L	Elemental analysis	Particle isolation on filter	6
Particulate inorganic carbon	0.06 mg/L	Elemental analysis	Particle isolation on filter	6
Total particulate nitrogen	0.034 mg/L	Elemental analysis	Particle isolation on filter	6
Dissolved organic carbon	0.1 mg/L	Shimadzu Total Organic Carbon Analyzer; catalytically aided platinum, 680 °C combustion	Particle isolation on filter	7
Chlorophyll	0.0001 mg/L	Chromatography-fluorometry	Particle isolation on filter	8
Dissolved sulfate	0.18 mg/L	Ion chromatography	Water passed through filter with 0.45-µm pore size	9

[1] References:

1. Olson and DeWild, 1997.
2. Olson and DeWild, 1997; Olund and others, 2004.
3. DeWild and others, 2002.
4. DeWild and others, 2002; DeWild and others, 2004.
5. Guy, 1969.
6. Patton and others, 2000.
7. Based on Bird and others, 2003.
8. Arar and Collins, 1997.
9. Fishman and Friedman, 1989.

of Hg concentrations was quality assured by the laboratory through analysis of duplicate or triplicate aliquots of water from the same sample bottle until a control limit for relative percent difference of less than 10 percent was attained.

Field quality-control data indicated the analytical results for water samples from the three reservoirs were representative and comparable. Field blank samples for the pool and tailwater samples indicated no bias caused by Hg or MeHg artifacts from sampling (appendix table 1–1). Precision of Hg and MeHg, affected by natural variability and variability from sampling and processing, was measured by relative percent difference[7] (RPD) in pairs of field duplicate samples. Particulate Hg and dissolved Hg were reported in all duplicates, and the mean RPD was less than 20 percent (appendix table 1–2). Particulate and dissolved MeHg were reported in six duplicates, and the mean RPD was less than 25 percent.

[7] Relative percent difference is the nonnegative difference of the paired duplicate sample concentrations divided by the average of the concentrations, expressed as a percentage.

Mercury and Methylmercury in Reservoirs in Indiana

The available data for Hg and MeHg in reservoir tailwaters and reservoir pools in Indiana are presented here. Principal topics discussed are (1) factors related to the transport of Hg to reservoirs, (2) factors related to the conversion of Hg to MeHg in reservoirs, and (3) fish-tissue Hg data, which are presented and used to depict the food-web accumulation and magnification of MeHg.

Reservoir Tailwaters

Mercury and MeHg data from analysis of 66 water samples collected at 4 reservoir tailwater sites in Indiana—Brookville Lake, Cagles Mill Lake, J.E. Roush Lake, and Mississinewa Lake—are summarized in table 5 and listed in appendix table 1–3. Unfiltered Hg concentrations in the tailwater samples ranged up to 15.0 ng/L, and the mean was 2.6 ng/L (figs. 4*A*–4*D*) . The ratio of particulate Hg to Hg was a maximum of 100 percent, and the mean was 58.4 percent. The ratio of unfiltered MeHg to Hg was a maximum of 64.8 percent (fig. 4*E*), and the mean was 9.1 percent. By comparison, in samples from sites on free-flowing streams, the mean ratio of particulate Hg to Hg was higher (67 percent) and the mean ratio of unfiltered MeHg to Hg was lower (3.6 percent) (Risch and others, 2010).

Statistical analysis[8] indicated significant seasonal differences in Hg and MeHg concentrations (Kruskal-Wallis, $p = 0.035$, $p = 0.017$) and in the ratio of unfiltered MeHg to Hg ($p = 0.008$). Unfiltered Hg concentrations in winter samples (median, 2.7 ng/L) were higher than those in autumn samples (median, 1.2 ng/L). Unfiltered MeHg concentrations in summer samples (median, 0.13 ng/L) were significantly higher than those in autumn samples (median, <0.04 ng/L). The ratios of unfiltered MeHg to Hg from summer samples (median, 10.9 percent) were significantly higher than those in winter samples (median, 1.7 percent). The ratios of unfiltered MeHg to Hg for Cagles Mill Lake, J.E. Roush Lake, and Mississinewa Lake were nearly always highest in summer (appendix table 1–3, fig. 4).

[8] Nonparametric statistical methods were used to compare data from different sites and seasons and to evaluate the strength and significance of relations among variables. According to Helsel and Hirsch (1995), nonparametric tests minimize the effect of outliers and apply to sample sizes of 15 to 19. A significance level of $\alpha = 0.05$ was used for the statistical tests, and a p-value less than 0.05 indicated a significant difference. The Kruskal-Wallis rank-sum test (called Kruskal-Wallis hereafter) was used to evaluate whether the distributions of data from more than two groups were different. The Tukey multiple comparison of medians of 95-percent confidence intervals (called Tukey hereafter) was used to determine which groups were significantly different, regardless of the group size. Strengths and significance of statistical correlations were evaluated with the Spearman rank correlation coefficient (*rho*), where near zero is weak and near 1 is strong correlation. Hereafter, *rho* means Spearman's rho.

Table 5. Mercury data summary for tailwaters at four reservoirs in Indiana.

[Hg, unfiltered mercury; ng/L, nanogram per liter; PHg, particulate mercury; MeHg, unfiltered methylmercury]

Reservoir	Summary description	Hg (ng/L)	Ratio of PHg to Hg (percent)[1]	Ratio of MeHg to Hg (percent)[2]
All four reservoirs (66 samples)	Maximum	15	100	64.8
	Mean	2.6	58.4	9.1
	Detections[3]	65	64	34
Brookville Lake (17 samples)	Maximum	1.8	100	15.4
	Mean	0.6	47.3	15.4
	Detections[3]	17	16	1
Cagles Mill Lake (18 samples)	Maximum	3.3	100	64.8
	Mean	1.8	60.1	20.6
	Detections[3]	18	18	8
J.E. Roush Lake (16 samples)	Maximum	15.0	87	15
	Mean	5.0	65.5	5.2
	Detections[3]	16	15	14
Mississinewa Lake (15 samples)	Maximum	6.6	100	16
	Mean	2.9	61.3	5.1
	Detections[3]	15	15	11

[1] Ratio of particulate Hg to unfiltered Hg, multiplied by 100.

[2] Ratio of unfiltered MeHg to unfiltered Hg, multiplied by 100.

[3] Reporting limits for Hg and MeHg were 0.3 ng/L in 2002–2003 and 0.04 ng/L in 2004–2006.

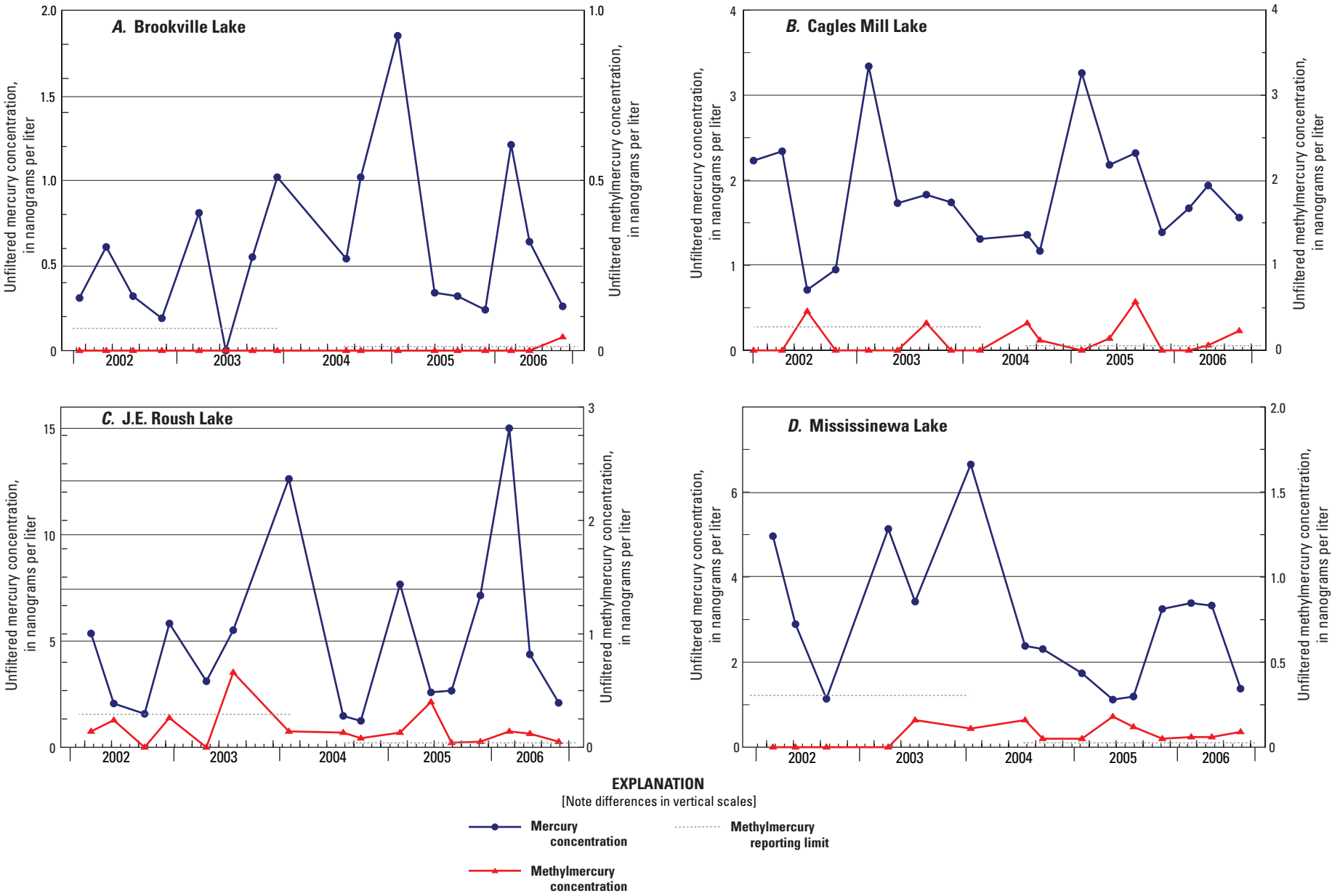

Figure 4. Mercury and methylmercury concentrations in water samples from tailwater sites at four reservoirs.

E. **Ratio of unfiltered methylmercury to unfiltered mercury in four reservoirs**

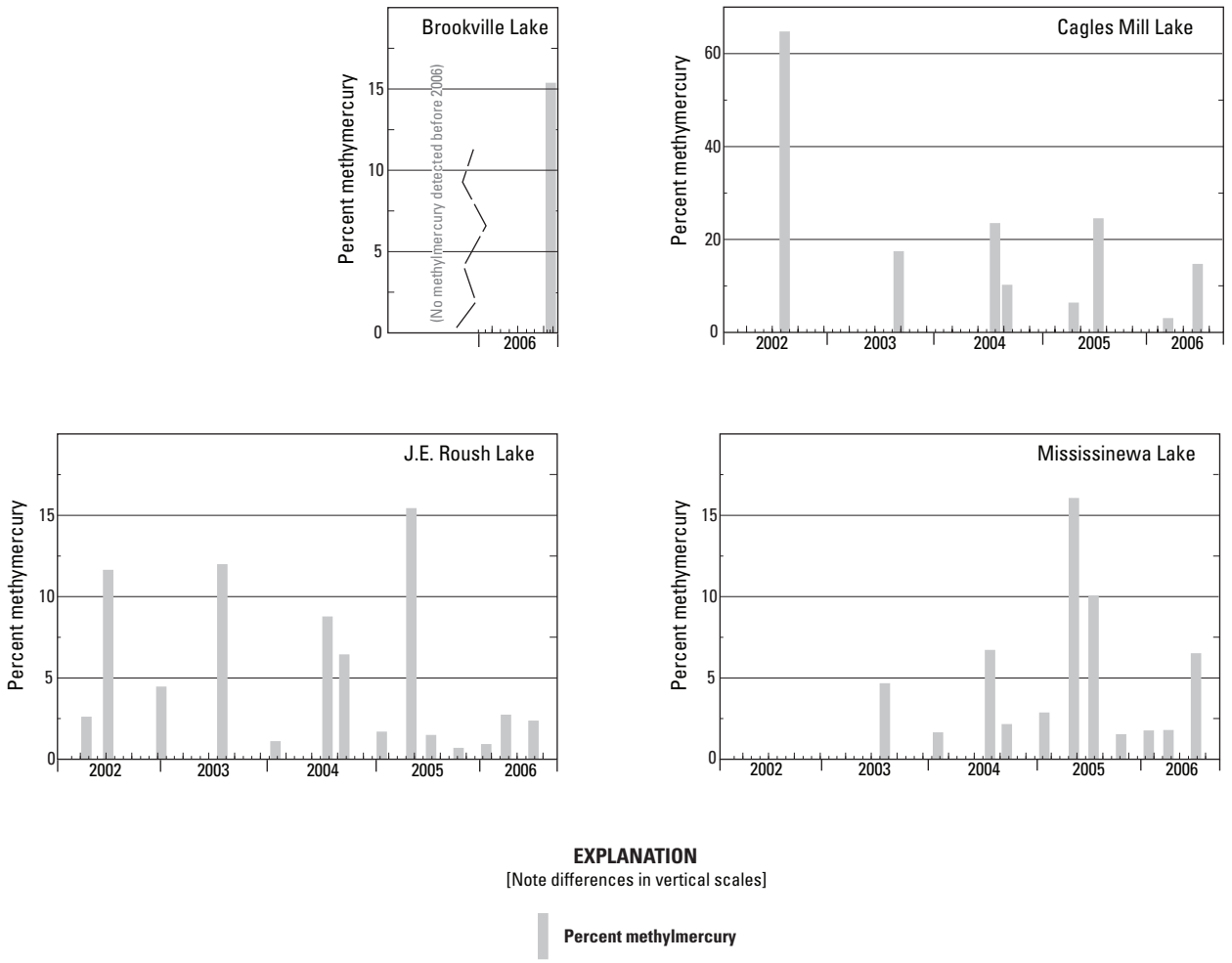

Figure 4. Mercury and methylmercury concentrations in water samples from tailwater sites at four reservoirs.—Continued

Concentrations of unfiltered Hg and MeHg from Brookville Lake tailwater samples (appendix tables 1–3) were determined to be significantly lower than concentrations in tailwater samples from the other three reservoirs (Kruskal-Wallis, $p < 0.001$; Tukey). The median whole-water Hg concentration from Brookville Lake tailwater samples was 0.54 ng/L (table 5), compared with medians in the tailwater samples from Cagles Mill Lake (1.7 ng/L), J.E. Roush Lake (3.7 ng/L), and Mississinewa Lake (2.9 ng/L). Whole-water MeHg was detected in only 1 of 17 tailwater samples from Brookville Lake (0.04 ng/L).

The summer pool area of Mississinewa Lake was 60 percent larger than the winter pool area, and the summer pool area of J.E. Roush Lake was 37 percent larger than the winter pool (table 1). For these two reservoirs, MeHg was reported in most of the tailwater samples—73 percent for Mississinewa Lake and 93 percent for J.E. Roush Lake. Other studies have shown that reservoirs with fluctuating water levels create periodic reduction and oxidation conditions, which in turn create and release MeHg into the water (Kelly and others, 1997; St. Louis and others, 2004; Mast and Krabbenhoft, 2010).

Reservoir Pools

One round of 53 water samples was collected at the reservoir pools—16 samples from 8 sites at Brookville Lake, 17 samples from 9 sites at Monroe Lake, and 20 samples from 12 sites at Patoka Lake. Maps showing locations of the sampling sites are in figures 5, 6, and 7, and information about the sampling sites is in table 6. Precipitation runoff was minimal during a 5-day time period when sampling took place at each reservoir, making the sets of data from each reservoir internally representative of similar hydrologic conditions (appendix table 1–4).

Whole-water Hg (the sum of particulate and dissolved Hg fractions) was detected in all 53 water samples from the pools and tailwaters of the three reservoirs (appendix table 1–5). Median and maximum whole-water Hg concentrations in samples from the pools of Monroe Lake and Patoka Lake were considerably higher than those from Brookville Lake (table 7). The whole-water Hg concentration in the tailwater sample from Monroe Lake was higher than the median concentration from the Monroe Lake pool samples, unlike Brookville Lake and Patoka Lake, where the tailwater concentration was lower. At Brookville Lake, whole-water Hg concentrations were less than 2 ng/L in all samples (fig. 8). At Monroe Lake, whole-water Hg concentrations were higher than 2 ng/L in samples collected below 8-m depths in the main body of the lake and at headwater sites (fig. 9). At Patoka Lake, the highest whole-water Hg concentrations were in samples collected below 9-m depths in the main body of the lake and at headwater sites (fig. 10). Whole-water Hg concentrations in the pool of Brookville Lake did not have a pattern with depth like those from Monroe Lake and Patoka Lake. Reservoir-pool data (table 7) also indicated lower median Hg in Brookville Lake (0.56 ng/L), compared with medians in the pool samples from Monroe Lake (1.36 ng/L) and Patoka Lake (1.24 ng/L). Methylmercury was detected in 1 of 16 samples from Brookville Lake (0.13 ng/L), compared with 14 of 17 in Monroe Lake and 13 of 20 in Patoka Lake (appendix table 1–5).

Particulate Hg in water from the Monroe Lake and Patoka Lake reservoirs pools, as a ratio to whole-water Hg (62 and 68 percent), was higher than in Brookville Lake (44 percent, table 7). Because whole-water Hg in samples from the Monroe Lake and Patoka Lake pools was predominantly particulate bound, the pattern with depth observed for whole-water Hg was repeated, and the highest ratios of particulate Hg were in samples collected below 8- and 9-m depths (appendix table 1–5). Brookville Lake particulate Hg did not have a pattern with depth. Ratios of particulate Hg to whole-water Hg in tailwaters of Monroe Lake and Patoka Lake (55 and 63 percent) were similar to the 58.4-percent mean for the tailwater samples from four reservoirs (table 5).

Whole-water MeHg was reported in 53 percent (28 of 53) of the samples from the pools and tailwaters of the three reservoirs. At Monroe Lake and Patoka Lake, whole-water MeHg was detected in 14 of 17 samples and 13 of 20 samples, respectively, but it was in detected in only 1 of 16 samples at Brookville Lake. Dissolved MeHg is the fraction of the dissolved Hg that is most available for transfer to the aquatic food web. Median and maximum ratios of dissolved MeHg to Hg concentrations in samples from the pools of Monroe Lake and Patoka Lake were considerably higher than in those from Brookville Lake (table 7). In Monroe Lake, ratios of dissolved MeHg to Hg higher than 25 percent were observed for samples below 8-m depths in the main lake and near the dam, as well as in the tailwater (fig. 11). In Patoka Lake, ratios of dissolved MeHg to Hg higher than 25 percent were observed for all samples below 9-m depths in the main lake, in the Lick Fork inlet, and near the dam (fig. 12).

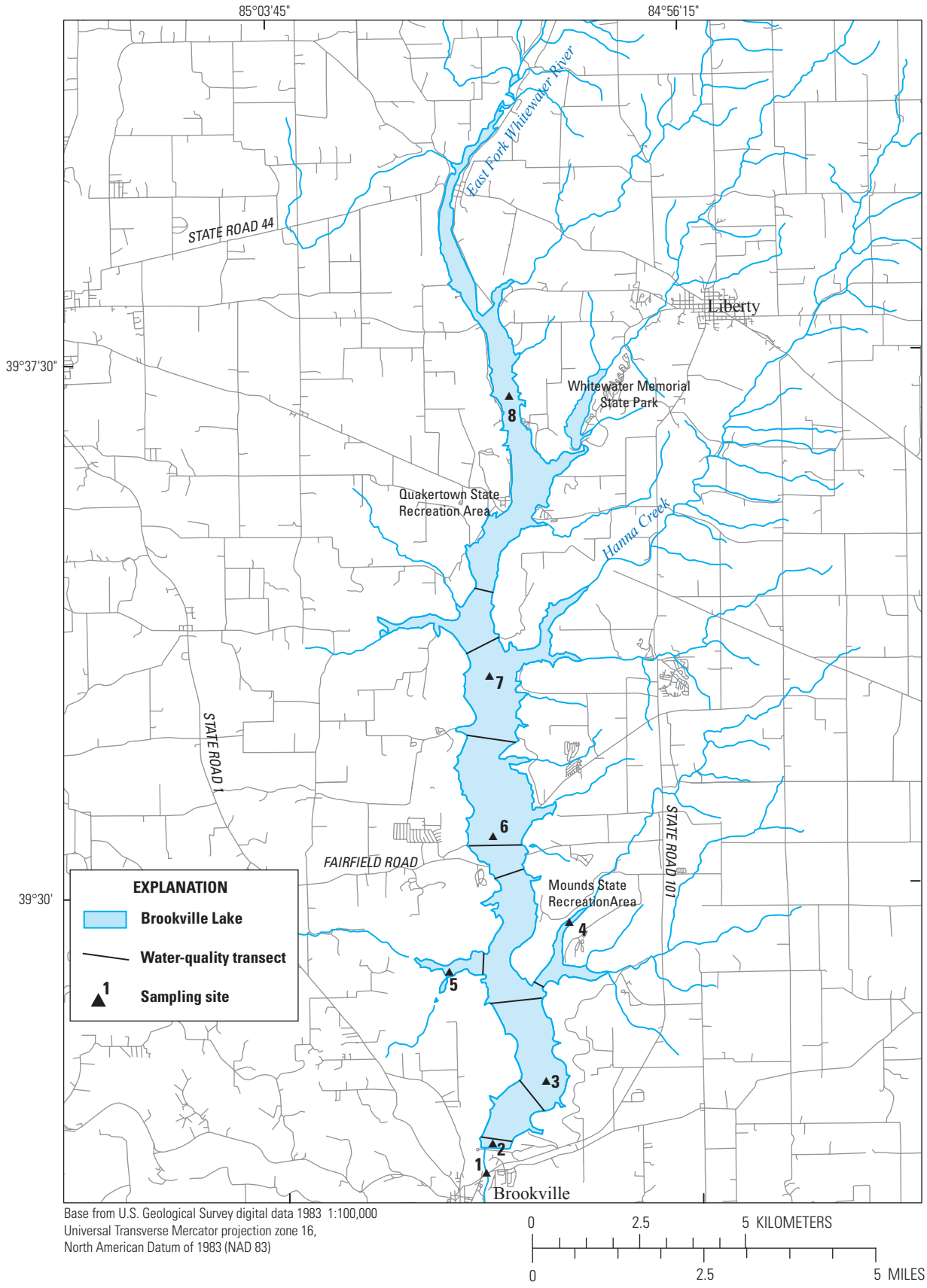

Figure 5. Sampling sites and water-quality transects for Brookville Lake.

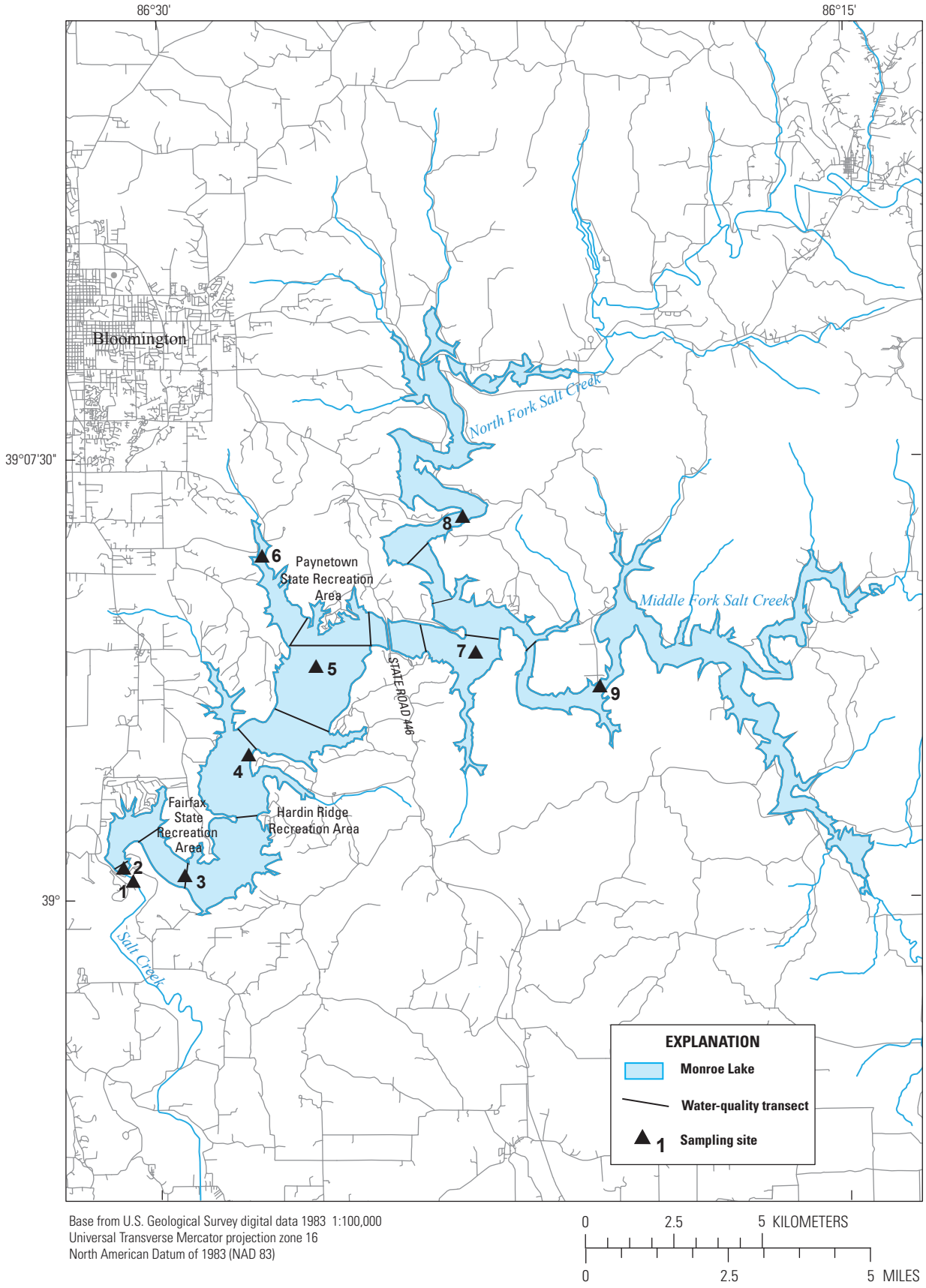

Figure 6. Sampling sites and water-quality transects for Monroe Lake (note variation in horizontal scale).

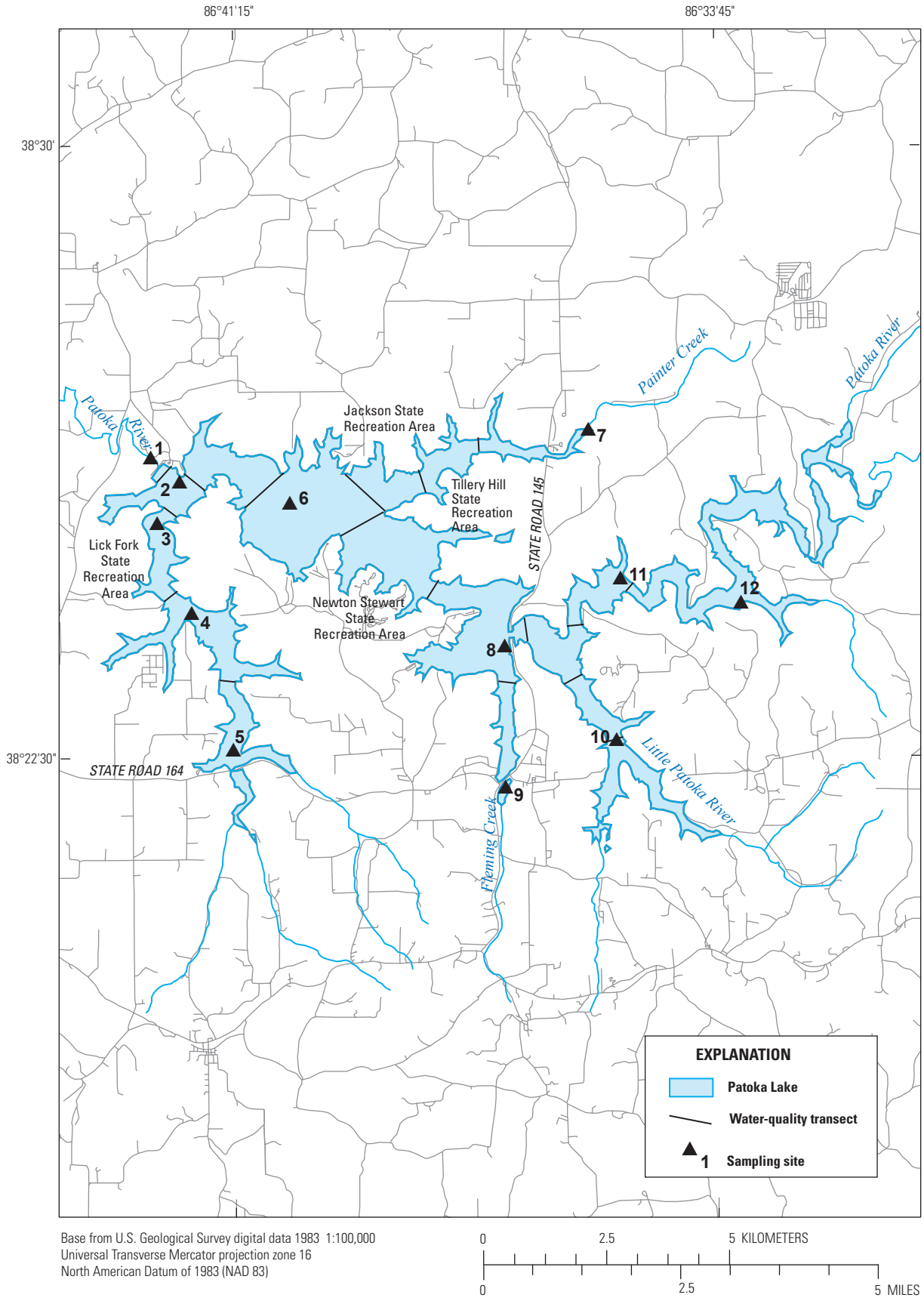

Figure 7. Sampling sites and water-quality transects for Patoka Lake (note variation in horizontal scale).

Table 6. Reservoir-pool and tailwater sampling-site information.

[NWIS, U.S. Geological Survey National Water Information System database; dms, degree, minute, second]

Reservoir	Site number	Descriptive site name	NWIS Site ID	Latitude (dms)	Longitude (dms)	Lake location
Brookville Lake	1	Tailwater in East Fork Whitewater River	USGS 03276000	39 26 02	85 00 12	Tailwater near gage
	2	Near dam	USGS 392628084595901	39 26 28	84 59 59	Near dam
	3	Near Bonwell Hill	USGS 392721084585901	39 27 21	84 58 59	Main lake, south
	4	Near Mounds Recreation Area	USGS 392935084583001	39 29 35	84 58 30	Inlet, west
	5	South of Fairfield Road	USGS 392855085004201	39 28 55	85 00 42	Inlet, east
	6	Near Fairfield Marina	USGS 393049084595101	39 30 49	84 59 51	Main lake, middle
	7	Near Hanna Creek Marina	USGS 393304084595101	39 33 04	84 59 51	Main lake, north
	8	Near Quakertown Recreation Area	USGS 393700084592301	39 37 00	84 59 23	Headwater
Monroe Lake	1	Tailwater in Salt Creek	USGS 03372500	39 00 16	86 30 31	Tailwater near gage
	2	Near dam	USGS 390034086304801	39 00 34	86 30 48	Near dam
	3	Near Fairfax Recreation Area	USGS 390026086292801	39 00 26	86 29 28	Main lake, south
	4	Near Hardin Ridge Recreation Area	USGS 390229086280401	39 02 29	86 28 04	Main lake, middle
	5	Near State Road 446 causeway	USGS 390359086263501	39 03 59	86 26 35	Main lake, north
	6	Near Paynetown Recreation Area	USGS 390552086274501	39 05 52	86 27 45	Inlet
	7	Near Cutright Recreation Area	USGS 390412086230601	39 04 12	86 23 06	Main lake, east
	8	Near Pine Grove Recreation Area	USGS 390631086232201	39 06 31	86 23 22	Headwater, north
	9	Middle Fork Waterfowl Area	USGS 390337086202401	39 03 37	86 20 24	Headwater, south
Patoka Lake	1	Tailwater in Patoka River	USGS 382618086423301	38 26 18	86 42 33	Tailwater
	2	Near dam	USGS 382553086420601	38 25 53	86 42 06	Near dam
	3	Near Lick Fork Boat Ramp	USGS 382523086422701	38 25 23	86 42 27	West branch, north
	4	Near Lick Fork Recreation Area	USGS 382417086415501	38 24 17	86 15 50	West branch, middle
	5	Near State Road 164	USGS 382237086411601	38 23 37	86 41 16	West branch, south
	6	Near Newton Stewart Recreation Area	USGS 382538086402301	38 25 38	86 40 23	Main lake, middle
	7	Near Jackson Recreation Area	USGS 382631086354401	38 26 31	86 35 44	Inlet, north
	8	Near Newton Stewart Marina	USGS 382352086370301	38 23 52	86 37 03	Main lake, south
	9	Near State Road 145 at Fleming Creek	USGS 382209086370201	38 22 09	86 37 02	Inlet, southwest
	10	Near Little Patoka River Boat Ramp	USGS 382243086351901	38 22 43	86 37 19	Inlet, southwest
	11	Near Wall's Lake Boat Ramp	USGS 382442086351401	38 24 42	86 35 14	Inlet, east
	12	Near King's Bridge Boat Ramp	USGS 382424086332201	38 24 24	86 33 22	Headwater

Table 7. Mercury data summary for pools and tailwaters at three reservoirs in Indiana.

[Hg, mercury; MeHg, methylmercury; ng/L, nanogram per liter; < less than percentage listed; n.d., not determined because dissolved MeHg reported in only one sample]

Reservoir	Number of samples[1]	Whole-water Hg[2]			Ratio of particulate Hg to Hg[3]			Ratio of dissolved MeHg to Hg[4]		
		Range in pool (ng/L)	Median in pool (ng/L)	Tailwater (ng/L)	Range in pool (ng/L)	Median in pool (ng/L)	Tailwater (ng/L)	Range in pool (ng/L)	Median in pool (ng/L)	Tailwater (ng/L)
Brookville Lake	16	0.33–1.91	0.56	0.31	<21–82	41	<29	18	n.d.	n.d.
Monroe Lake	17	0.42–4.84	1.36	1.92	30–79	62	55	<5–64	20	56
Patoka Lake	20	0.42–5.51	1.24	0.52	25–84	68	63	<3–82	31	<16

[1] Number of samples includes one tailwater sample and multidepth pool samples.

[2] Whole-water Hg is the sum of particulate and dissolved Hg concentrations.

[3] Ratio of particulate Hg to whole-water Hg concentration, multiplied by 100.

[4] Ratio of dissolved MeHg to whole-water MeHg concentration, multiplied by 100, where whole-water MeHg is the sum of the particulate and dissolved fractions. Dissolved MeHg reported in a single sample from Brookville Lake pool.

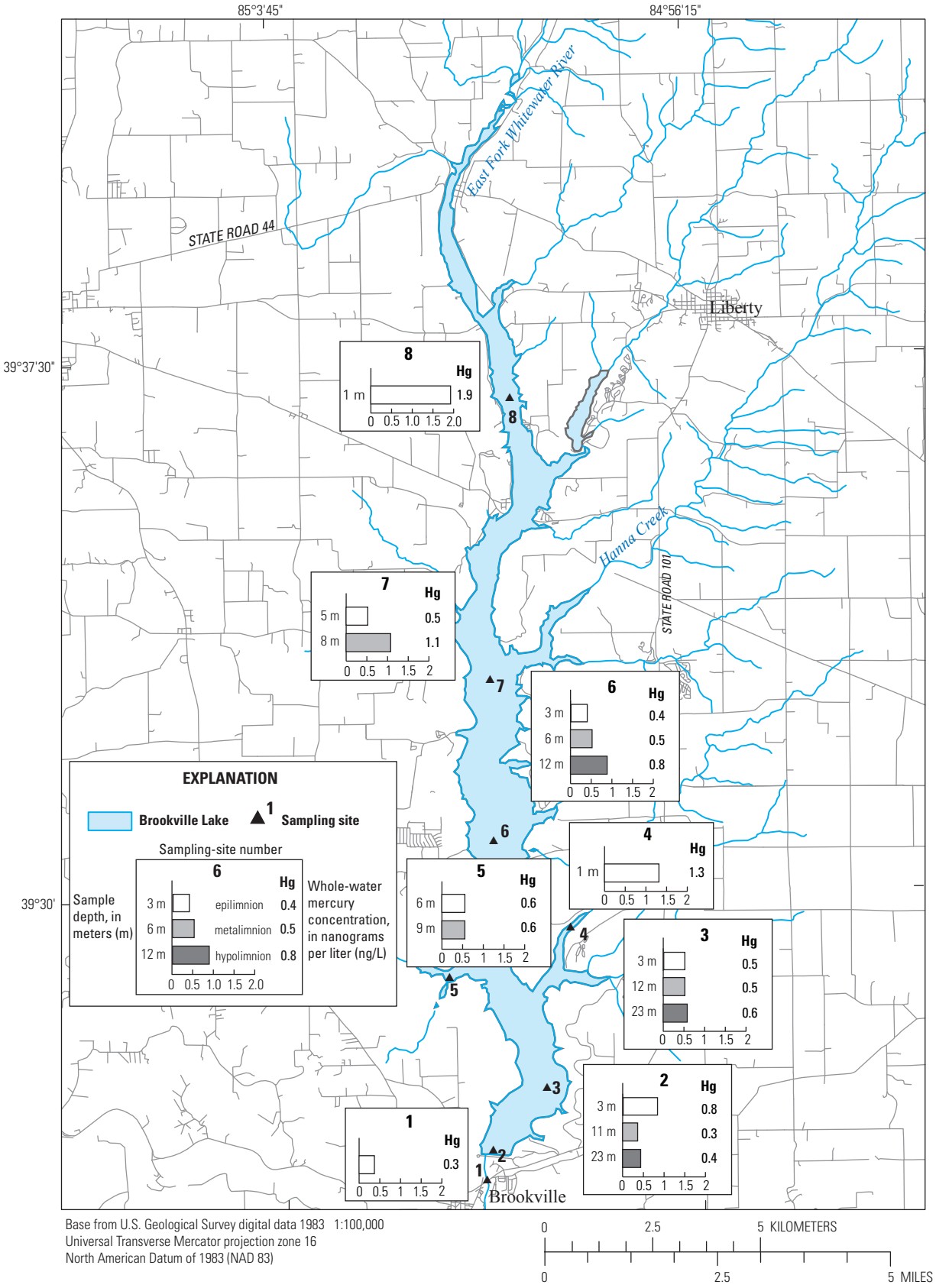

Figure 8. Whole-water mercury concentrations in water from Brookville Lake. (Site 1 was a tailwater site; sample depth not applicable.)

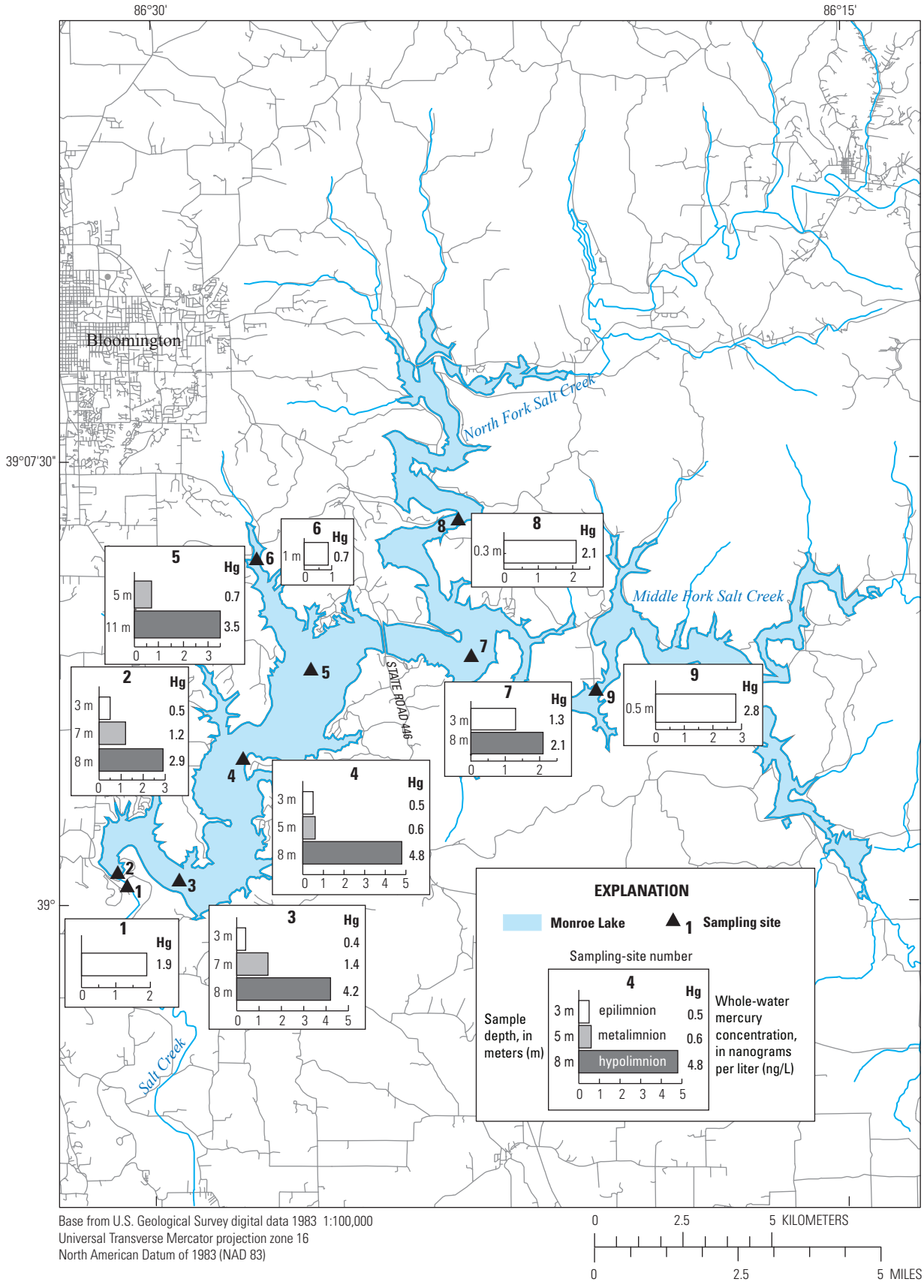

Figure 9. Whole-water mercury concentrations in water from Monroe Lake. (Site 1 was a tailwater site; sample depth not applicable; note variation in horizontal scale.)

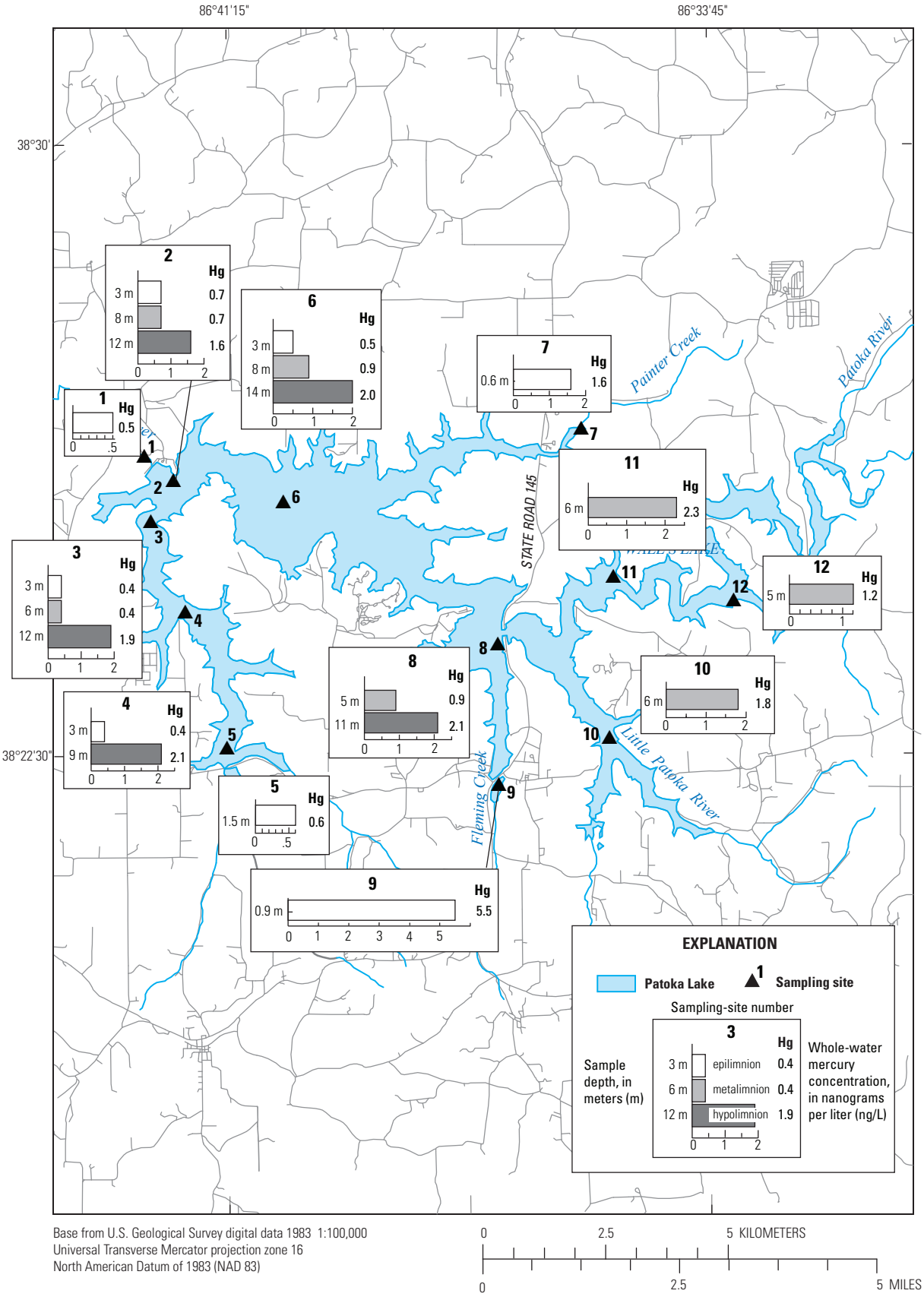

Figure 10. Whole-water mercury concentrations in water from Patoka Lake. (Site 1 was a tailwater site; sample depth not applicable; note variation in horizontal scale.)

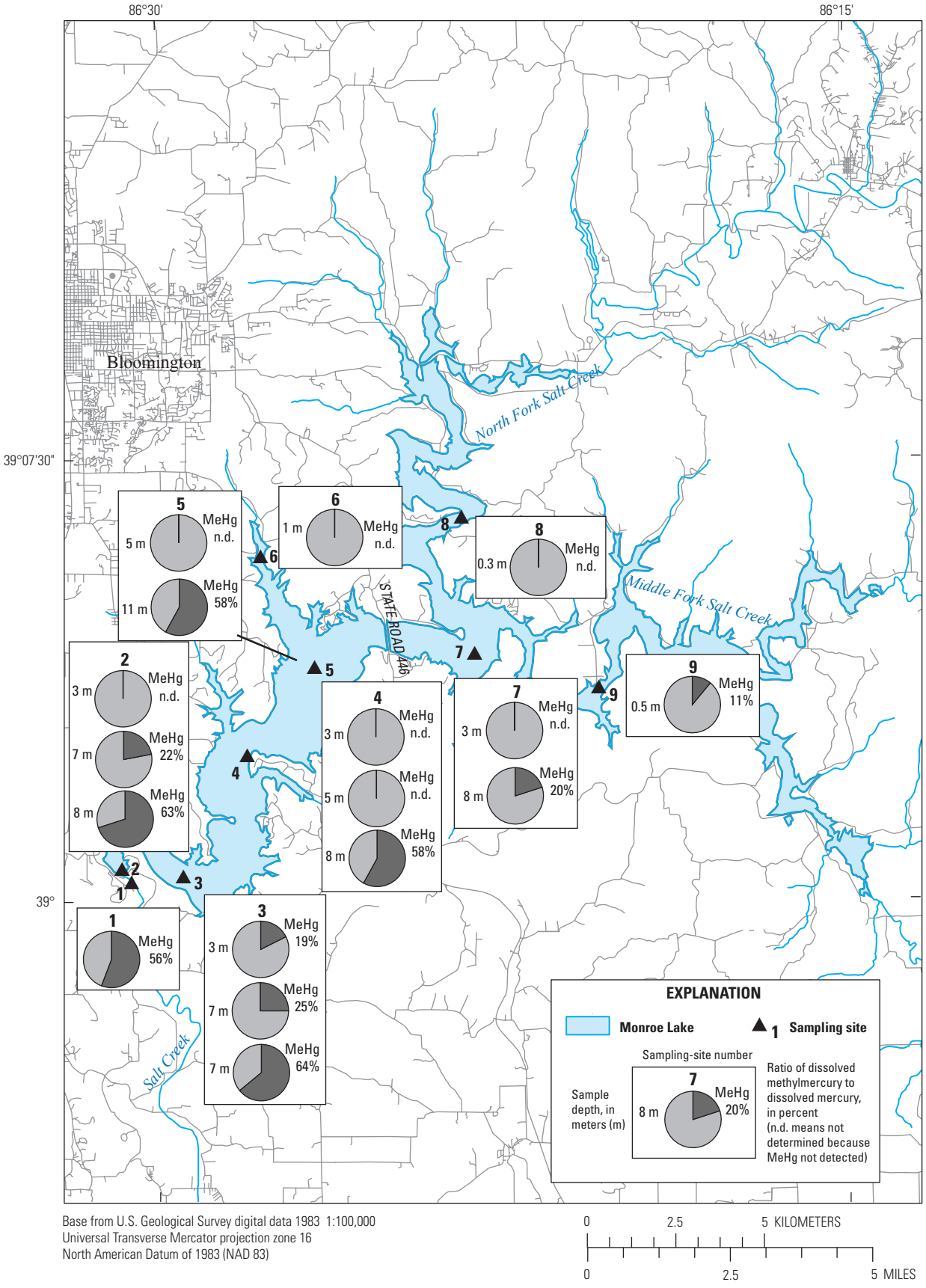

Figure 11. Ratio of dissolved methylmercury to mercury in water from Monroe Lake.

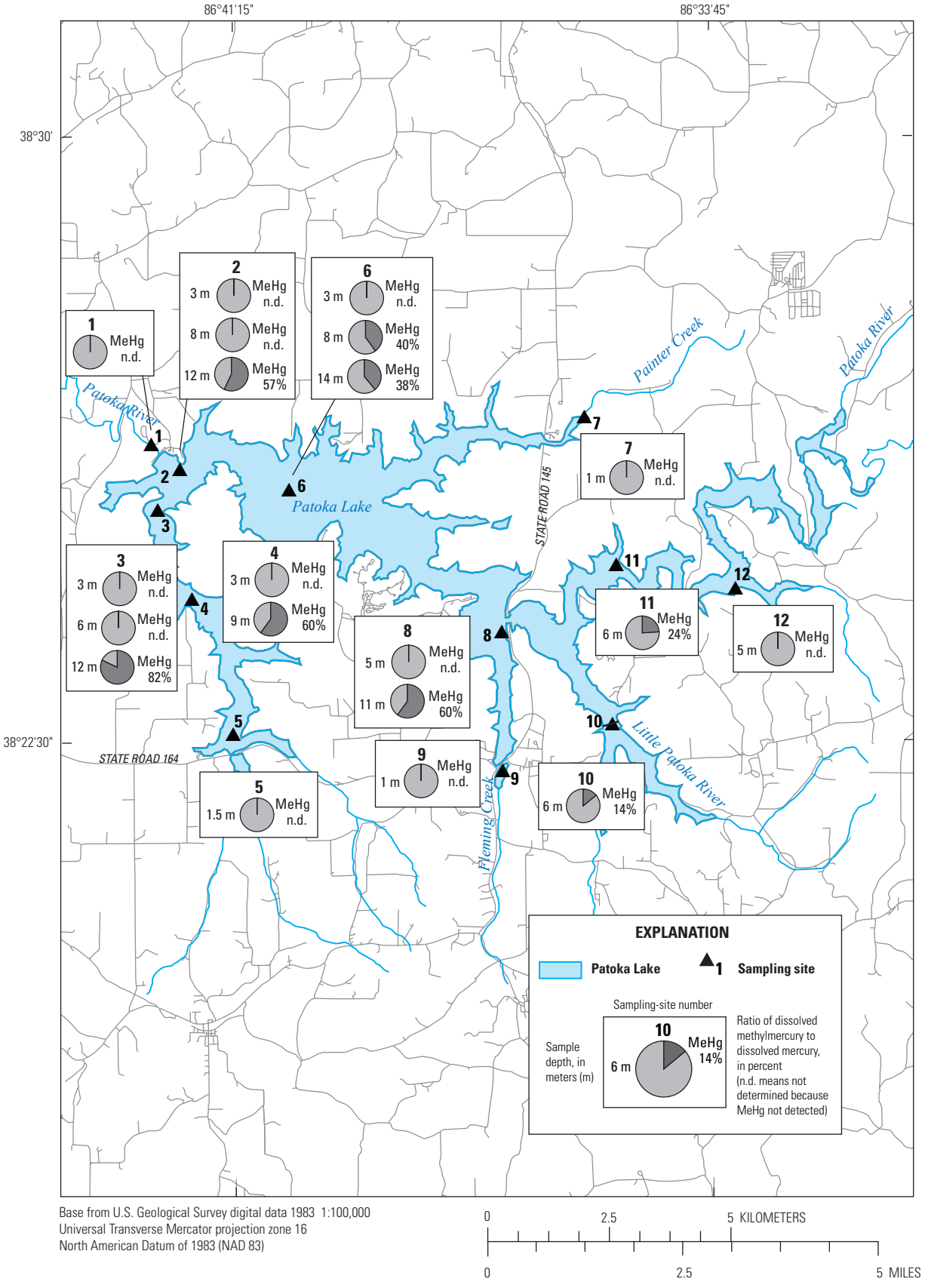

Figure 12. Ratio of dissolved methylmercury to mercury in water from Patoka Lake (note variation in horizontal scale).

Factors Affecting Mercury and Methylmercury in Reservoirs in Indiana

Factors affecting Hg and MeHg in reservoirs in Indiana are the transport of Hg and the conversion of Hg to MeHg. Wet and dry atmospheric deposition rates and landscape characteristics are related to the transport of Hg. Thermal strata and water chemistry are related to the potential for "methylation," which is the conversion of Hg to MeHg.

Transport of Mercury to Reservoirs

Wet and dry deposition of atmospheric Hg are primary pathways for Hg transport to reservoir watersheds and reservoir pools. For this study, mean annual wet and dry loads of atmospheric Hg deposited to the reservoir watersheds were computed separately and summed to get a total atmospheric Hg load to the watershed. The mean annual total Hg-deposition rate for each reservoir watershed was computed by dividing the total Hg load by the drainage area. StreamStats (U.S. Geological Survey, 2011) was used to delineate the watershed and quantify the drainage area upstream from each reservoir dam. Explanations of wet and dry Hg deposition follow.

Mean annual Hg wet-deposition rates in Indiana were mapped as the product of Hg concentrations in precipitation monitored at 9 sites in Indiana and 4 nearby states and precipitation amounts monitored at 151 sites in Indiana, 2001–2006, by using the method described in Risch and others (2010). Mean annual Hg wet-deposition loads for each reservoir watershed were computed as a product of the Hg-deposition rates on the map and the drainage area upstream from the reservoir.

Mean annual Hg dry-deposition rates were based on the 3-year mean annual litterfall Hg-deposition rate at four sites in Indiana, 2007–2009 (Risch and others, 2012). Studies have shown that forest canopies scavenge and retain Hg from the air and that forests are net sinks for dry deposition of atmospheric Hg (Kolka and others, 1999; Grigal, 2002; Hartman and others, 2009, Zhang and others, 2009). Annual litterfall Hg deposition in a deciduous forest is a conservative estimate of the Hg dry deposition to the forest canopy (Risch and others, 2012, Zhang and others 2012).

By use of ArcGIS software (Environmental Systems Research Institute, 2006), the watershed for each reservoir was overlain on the National Land Cover Database (NLCD; Homer and others, 2004) and the area in each of the NLCD land-cover classes was computed (appendix table 1–6). Deciduous, evergreen, and mixed NLCD forest classes were combined to get the area of forest land cover in the watershed. Mean annual Hg dry-deposition loads for each reservoir watershed were computed as a product of the mean annual litterfall Hg-deposition rate and the area of forest land cover in the reservoir.

For the reservoirs in Indiana, the mean annual total Hg-deposition rates ranged from 11.3 to 25.7 micrograms per square meter (mg/m^2) (appendix table 1–7) and were highest for Monroe Lake and Patoka Lake. Mercury wet deposition and litterfall Hg dry deposition tend to correlate spatially and statistically (Risch and others, 2012), and the same Hg emissions sources may affect Hg wet and dry deposition. Mean annual Hg wet-deposition rates were highest for Monroe Lake and Patoka Lake (12 to13 mg/m^2). Forest land cover was highest for Monroe Lake (for 82 percent) and Patoka Lake (67 percent), whereas forest in the other six reservoirs was less than 23 percent. A full comparison of Hg deposition and reservoir-pool Hg could not be made for all the reservoirs in Indiana with the available data.

Classifications of physiography, natural region, and surficial geology indicated that three reservoirs—Monroe Lake, Patoka Lake, and Cagles Mill Lake—are in landscapes with steep slopes and near-surface bedrock that promote high rates of precipitation runoff and low rates of infiltration. These landscapes have potentially higher rates of particulate and dissolved Hg transport to reservoirs than occurs in flat topography with glacial deposits. These three reservoirs also have the highest mean annual total Hg-deposition rates. Monroe Lake, Patoka Lake, and Cagles Mill Lake are in the Southern Hills and Lowlands physiographic region and the Shawnee Hills and Southern Bottomlands natural region; their surficial geology is primarily sandstone, shale, and limestone bedrock (table 8). The other five reservoirs are in the Central Till Plain physiographic and natural regions; the surficial geology is predominantly loamy till, outwash, and alluvium.

Conversion of Mercury to Methylmercury in Reservoirs

Three layers (called thermal strata) were defined for discussion in this study, based on water temperature, dissolved oxygen, and water depth determined from vertical profiles along 10 to 17 transects in each reservoir pool. The three thermal strata are the following:

1. The *epilimnion,* a surface layer with water temperatures greater than 23 degrees Celsius (°C), dissolved oxygen greater than 7 milligrams per liter (mg/L), and water depth less than 5 m.

2. The *metalimnion*, a transition layer with water temperatures 20 to 23 °C, dissolved oxygen 4 to 7 mg/L, and water depth 2 to 3 m below the epilimnion.

3. The *hypolimnion*, the layer extending to the lake bottom, with water temperatures less than 20 °C, dissolved oxygen less than 4 mg/L, and the greatest water depths.

Table 8. Physiographic region, natural region, and surficial geology in the vicinity of reservoirs in Indiana.

Reservoir	Physiographic region	Natural region	Surficial (Quaternary) geology
Brookville Lake	Central Till Plain	Bluegrass, Central Till Plain	Loam of Wisconsinan till; Ordovician shale and limestone
Cagles Mill Lake	Southern Hills and Lowlands	Shawnee Hills, Southwestern Lowlands	Loam to sandy loam of pre-Wisconsinan till and undifferentiated outwash
C.M. Harden Lake	Central Till Plain	Central Till Plain, Shawnee Hills	Loam to sandy loam of pre-Wisconsinan till; alluvium
Mississinewa Lake	Central Till Plain	Central Till Plain	Silty clay loam of Wisconsinan till
Monroe Lake	Southern Hills and Lowlands	Shawnee Hills, Highland Rim	Mississippian siltstone, limestone, shale, and terra rossa
Patoka Lake	Southern Hills and Lowlands	Shawnee Hills, Southern Bottomlands	Mississippian and Pennsylvanian sandstone, shale, and limestone
J.E. Roush Lake	Central Till Plain	Central Till Plain	Silty clay loam of Wisconsinan till
Salamonie Lake	Central Till Plain	Central Till Plain	Silty clay loam of Wisconsinan till

Information about the following classifications were obtained from metadata at Indiana Geological Survey (2011).

[1] Physiographic region from Indiana Geological Survey (Gray, 2000).

[2] Natural region from Indiana Department of Natural Resources, Division of Nature Preserves, Indiana Natural Heritage Data Center (Homoya and others, 1985).

[3] Quaternary geology from Indiana Geological Survey (Gray, 1989).

Reservoir-pool MeHg concentrations and ratios of dissolved MeHg to Hg in samples from Monroe Lake and Patoka Lake[9] demonstrated a significant correlation with sample depth (*rho*> 0.7), and a significant inverse correlation with dissolved oxygen (*rho*> −0.6) and water temperature (*rho*> −0.7) (fig. 13, table 9). These correlations indicate that deep, relatively cold, relatively low-dissolved-oxygen water, found primarily in the hypolimnion and in part of the metalimnion, coincided with the highest Hg and MeHg concentrations and ratios of MeHg to Hg. Water-sample data indicate that methylation probably was occurring in or near the hypolimnion because this stratum had the highest ratios of dissolved MeHg to Hg. The data do not confirm whether methylation was occurring in the water column, in the lake-bottom sediment, at the sediment-water interface, or some combination of these locations.

Statistical differences between Hg, MeHg, and water quality in the hypolimnion and epilimnion were observed in Monroe Lake and Patoka Lake. These differences were evaluated by grouping samples by the three thermal strata and tailwater.

In Monroe Lake, the hypolimnion had significantly higher concentrations of particulate Hg, dissolved Hg, particulate MeHg, and dissolved MeHg and a higher ratio of dissolved MeHg to Hg than the epilimnion (Kruskal-Wallis, $p < 0.05$). The hypolimnion had significantly lower dissolved oxygen, water pH, and dissolved sulfate than the epilimnion (Kruskal-Wallis, $p < 0.05$). The tailwater had dissolved Hg and MeHg, a ratio of dissolved MeHg to Hg, dissolved oxygen, water pH, and dissolved sulfate that were most similar to those of the hypolimnion (fig. 14).

In Patoka Lake, the hypolimnion had significantly higher concentrations of particulate and dissolved MeHg and a higher ratio of MeHg to Hg than the epilimnion (Kruskal-Wallis, $p < 0.05$). The hypolimnion had significantly lower dissolved oxygen, water pH, and dissolved sulfate than the epilimnion (Kruskal-Wallis, $p < 0.05$). The tailwater had dissolved Hg and MeHg, a ratio of dissolved MeHg to Hg, dissolved oxygen, and water pH that were most similar to those of the epilimnion (fig. 15).

Through the preceding analysis, the hypolimnions of Monroe Lake and Patoka Lake were found to have zones of high methylation potential—defined by water temperature less than 18.5 °C, dissolved oxygen less than 3.5 mg/L, and water depths greater than 8 m. The estimated areal extent of these zones involved nearly half of the summer pools in Monroe Lake (fig. 16) and Patoka Lake (fig. 17). The extents of these zones were estimated with values of water temperature and dissolved oxygen measured along the vertical profiles of the 31 water-quality transects and were processed with GIS software to interpolate the areal extent of similar values.

Alpers and others (2008) discussed (1) how seasonal thermal stratification in reservoirs with a hypolimnion that has low dissolved oxygen can promote MeHg formation in deep water and lake-bottom sediments and (2) how the MeHg becomes vertically mixed into all the water during thermal destratification. Gray and Hines (2009) confirmed that methylation is highly influenced by a eutrophic hypolimnion with low concentrations of dissolved oxygen, geochemically reducing conditions, high organic matter in bottom sediment, and high concentrations of dissolved plant nutrients that increases the activity of Hg-methylating anaerobic organisms and increases the MeHg flux at the water-sediment interface.

[9] Correlations were not computed for Brookville Lake because MeHg was detected once in the samples from the reservoir pool.

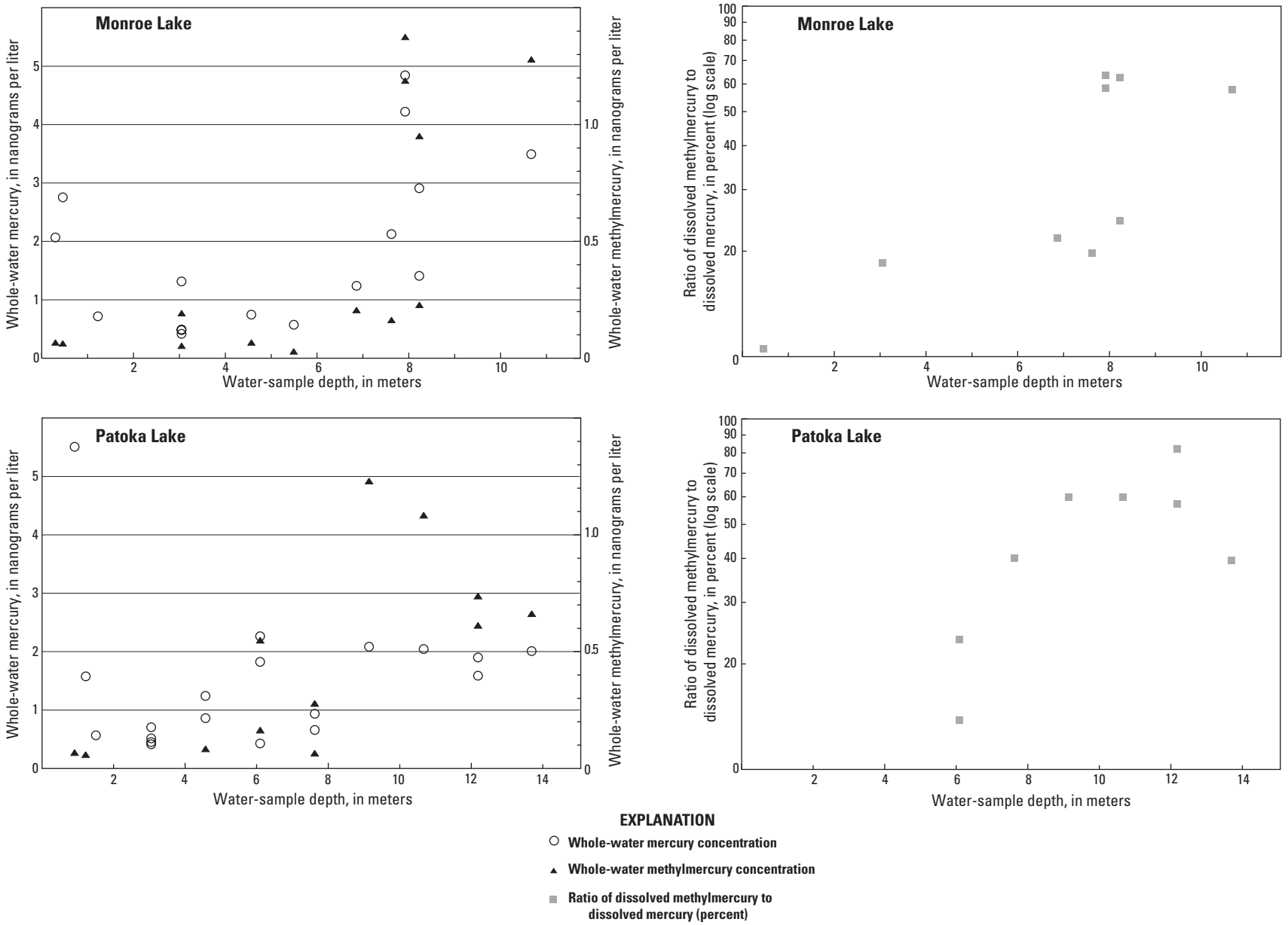

Figure 13. Relations between mercury and sample depth in Monroe Lake and Patoka Lake.

Table 9. Statistical correlations of reservoir pool mercury with sample depth and selected constituents in Monroe Lake and Patoka Lake.

[Spearman rank correlation test significance (p-value < 0.05) in bold; *rho*, Spearman rank correlation coefficient; Hg, mercury; MeHg, methylmercury; DOC, dissolved organic carbon]

Reservoir	Mercury determination	Sample depth		Dissolved oxygen		Water pH		Water temperature		Dissolved sulfate		DOC	
		p-value	*rho*	p-value	*rho*	p-value	*rho*	p-value	*rho*	p-value	*rho*	p-value	*rho*
Monroe Lake	Hg concentration[1]	**0.044**	0.521	0.156	–0.368	**0.001**	–0.822	**0.008**	–0.688	**<0.001**	–0.900	**0.007**	0.702
	MeHg concentration[2]	**0.003**	0.763	**0.020**	–0.600	**0.001**	–0.854	**0.001**	–0.935	**<0.001**	–0.872	0.070	0.470
	Ratio of MeHg to Hg[3]	**0.002**	0.818	**0.006**	–0.708	**0.002**	–0.783	**0.002**	–0.814	**0.004**	–0.749	0.181	0.347
	Ratio of dissolved MeHg to Hg[4]	**0.002**	0.787	**0.003**	–0.752	**0.002**	–0.791	**0.006**	–0.710	**0.005**	–0.731	0.083	0.449
Patoka Lake	Hg concentration[1]	0.120	0.368	**0.003**	–0.690	**0.002**	–0.731	**0.004**	–0.684	**0.009**	–0.617	0.064	0.437
	MeHg concentration[2]	**0.001**	0.757	**<0.001**	–0.790	**<0.001**	–0.827	**<0.001**	–0.849	**0.002**	–0.734	0.883	0.035
	Ratio of MeHg to Hg[3]	**<0.001**	0.792	**<0.001**	–0.800	**<0.001**	–0.855	**<0.001**	–0.852	**0.002**	–0.725	0.775	–0.068
	Ratio of dissolved MeHg to Hg[4]	**<0.001**	0.818	**0.002**	–0.714	**0.002**	–0.726	**<0.001**	–0.822	**0.004**	–0.674	0.893	–0.032

[1]Whole-water concentration determined as particulate plus dissolved concentration.

[2] Whole-water concentration determined as particulate plus dissolved concentration.

[3] Ratio of whole-water methylmercury to whole-water mercury concentration.

[4] Ratio of dissolved methylmercury to dissolved mercury concentration.

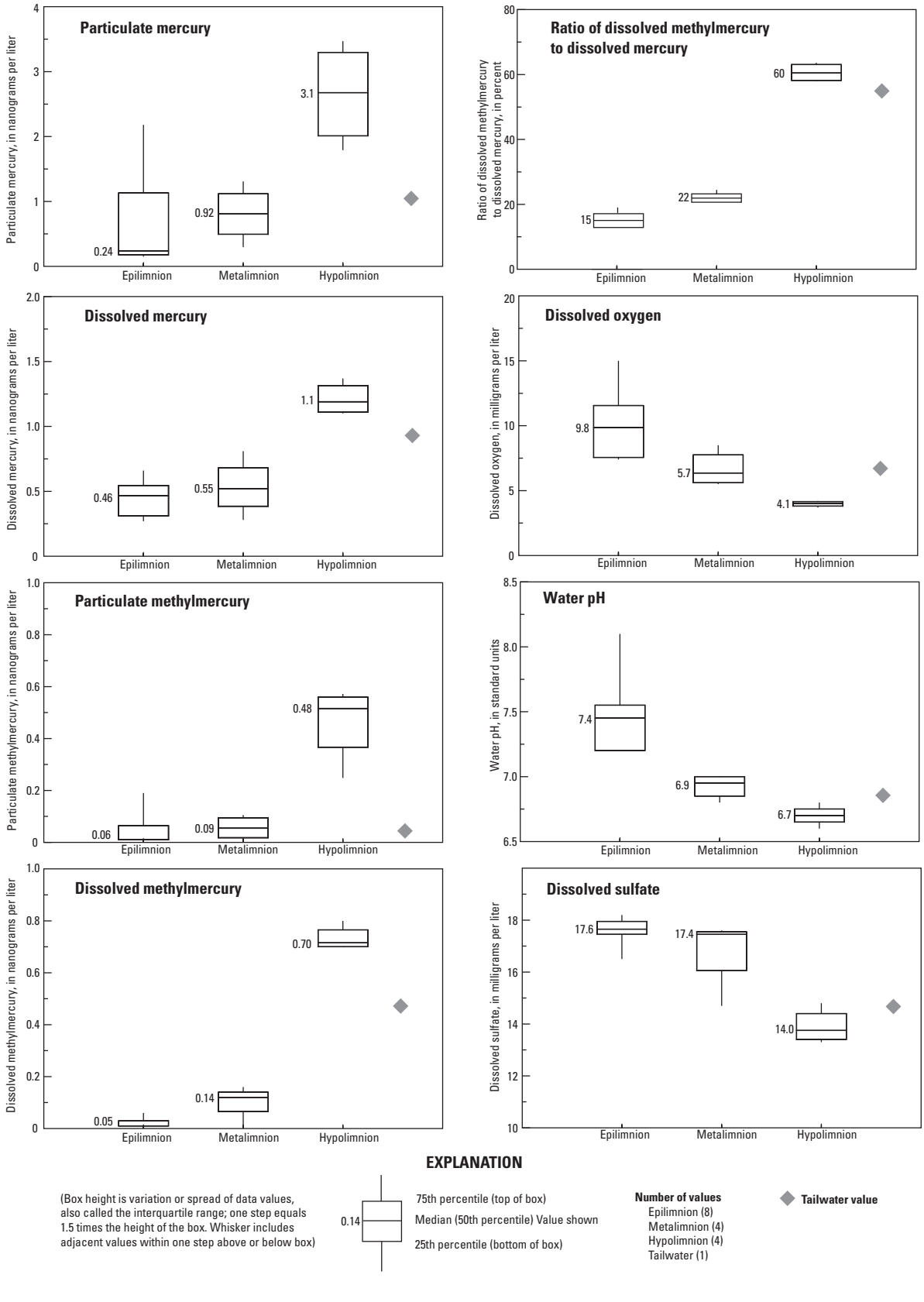

Figure 14. Distributions of mercury, methylmercury, dissolved oxygen, water pH, and dissolved sulfate in Monroe Lake.

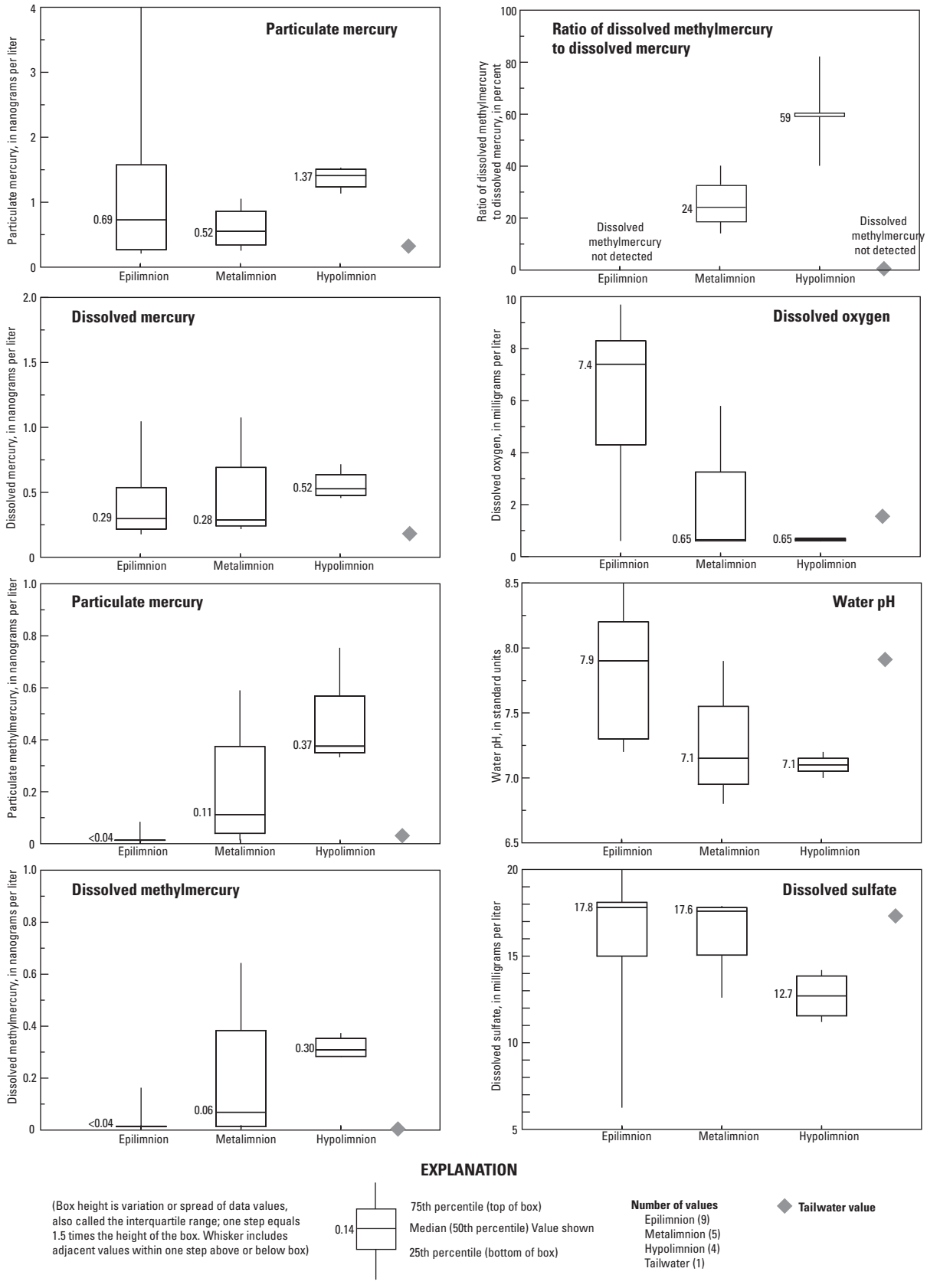

Figure 15. Distributions of mercury, methylmercury, dissolved oxygen, water pH, and dissolved sulfate in Patoka Lake.

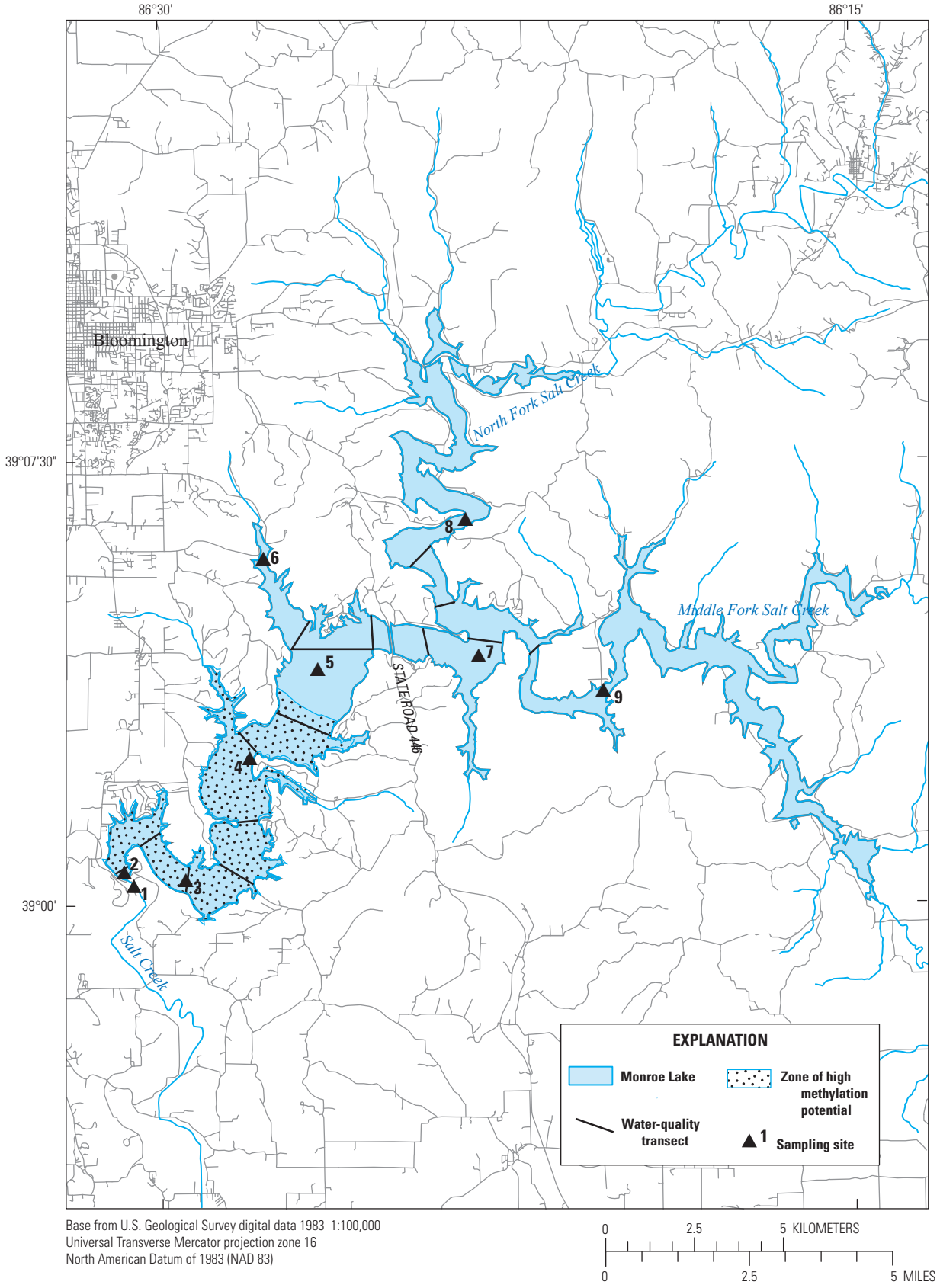

Figure 16. Areal extent of zone of high methylation potential in summer pool of Monroe Lake.

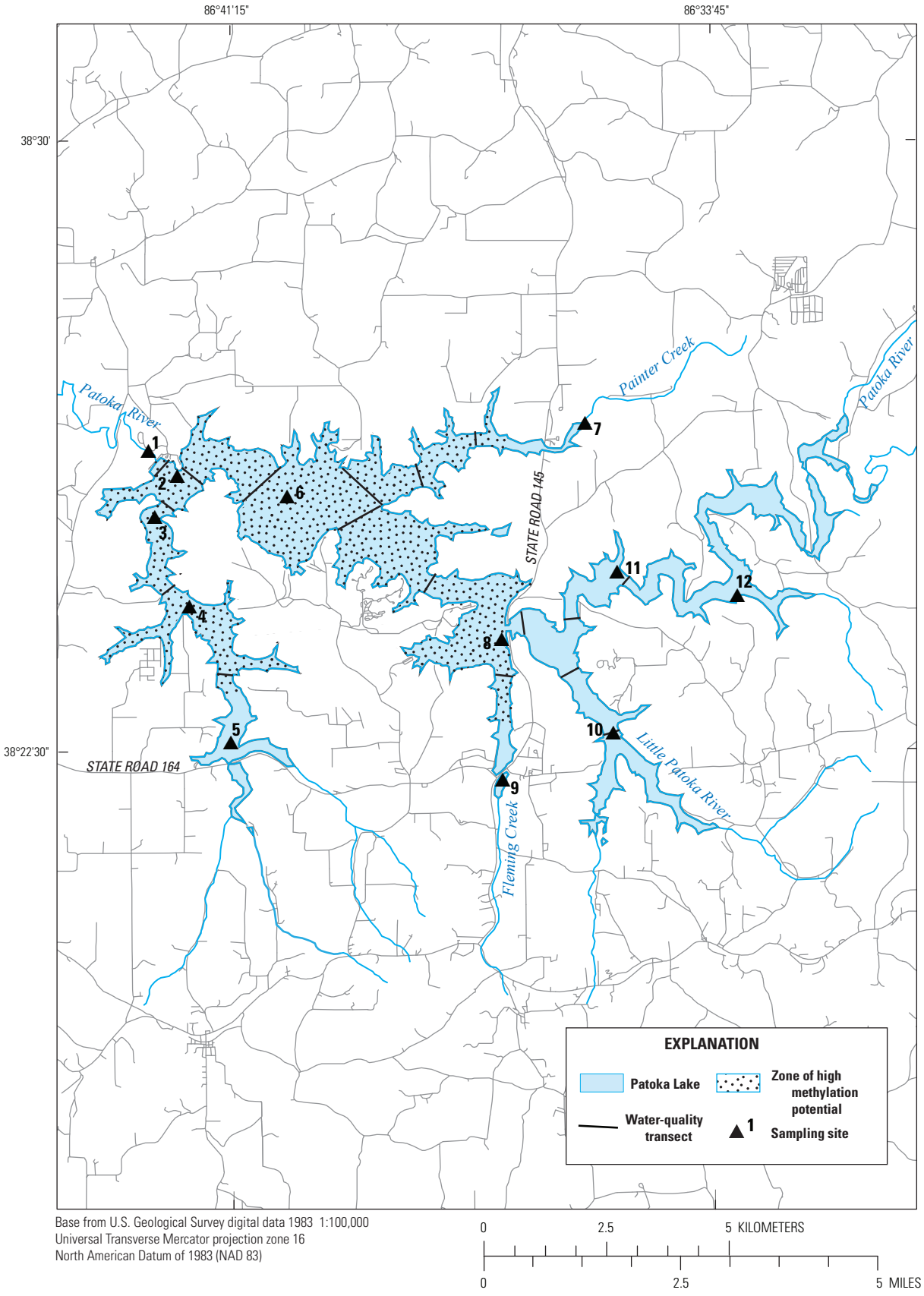

Figure 17. Areal extent of zone of high methylation potential in summer pool of Patoka Lake.

The summer pools of Monroe Lake (59.5 kilometers [km] long) and Patoka Lake (40.2 km long) are the longest in Indiana (table 1). The mean annual retention times, which are based on reservoirs outflows and pool volume for 1984–2007, index the time for water to move through each reservoir (table 1). The highest retention times in Indiana include Patoka Lake (556 days) and Monroe Lake (199 days). A long summer pool and high retention time apparently combine to retain Hg when the extensive zone of high methylation potential develops in Monroe Lake and Patoka Lake. These reservoir characteristics may be related to the maximum ratios of 64 to 82 percent dissolved MeHg to Hg measured in Monroe Lake and Patoka Lake.

The concentrations of Hg and MeHg and the ratios of whole-water MeHg to Hg and dissolved MeHg to Hg in Monroe Lake and Patoka Lake demonstrated a significant inverse correlation with water pH (*rho* > −0.7*)* and concentrations of dissolved sulfate (*rho* > −0.6) and dissolved oxygen (*rho* > −0.6, except *rho* > −0.37 for Hg in Monroe Lake) (table 9).[10] Values for water pH, dissolved sulfate, and dissolved oxygen were lower in the hypolimnion than the metalimnion and the epilimnion of both reservoirs (figs. 14 and 15). Decreased concentrations of dissolved sulfate and increased hydrogen sulfide are indications of sulfate reduction. The odor of hydrogen sulfide was reported in all water samples from the hypolimnions of Monroe Lake and Patoka Lake, which coincided with the lowest concentrations of dissolved sulfate. Microorganisms including bacteria that reduce sulfate to hydrogen sulfide are thought to facilitate Hg methylation.

The role of water pH for methylation potential in the reservoir pools is shown by comparing conditions at Brookville Lake with Monroe Lake and Patoka Lake. At Brookville Lake, MeHg was not detected in samples from the reservoir pool even though whole-water Hg was detected in all water samples. Water pH in Brookville Lake was statistically higher in all water samples compared to Monroe Lake and Patoka Lake and also was higher in the hypolimnion samples (median 7.6) compared to Monroe Lake and Patoka Lake (median 6.7 and 7.1, respectively). Dissolved sulfate in Brookville Lake was statistically higher in all water samples compared to Monroe Lake and Patoka Lake and also was higher in the hypolimnion samples (median 25.5 mg/L) compared to Monroe Lake and Patoka Lake (median 13.8 and 12.7 mg/L, respectively). These data indicate a potential relation of the lower sulfate reduction in the Brookville Lake hypolimnion with the relatively higher pH water.

Particulate organic carbon (POC) and dissolved organic carbon (DOC) provide a substrate for particulate Hg and sulfate-reducing microorganisms. Both POC and DOC were detected in water from both reservoirs. However, DOC was significantly correlated only with whole-water Hg in samples from Monroe Lake (table 9). The DOC concentrations in the Monroe Lake hypolimnion samples were significantly higher (median 4.4 mg/L) than those in Patoka Lake (median 3.1 mg/L). Concentrations of DOC in Brookville Lake water samples were not statistically different from those in Patoka Lake, whether all samples or hypolimnion samples are considered. Overall, POC and DOC were less important for explaining methylation potential in the reservoir pools than were dissolved sulfate and water pH.

[10] Correlations were not computed for Brookville Lake because MeHg was detected once in the samples from the reservoir pool.

Reservoir Fish

Concentrations in Fish Tissue

Methylmercury (reported as Hg) in fish-tissue samples was used to depict the effects of MeHg food-web accumulation and magnification in the reservoirs. Data for Hg concentrations in 203 fish-tissue samples were compiled for the eight reservoirs in Indiana (appendix table 1–8) and were compared with the reference benchmarks for human health and for wildlife. The wet-weight fish-tissue Hg concentrations in these 203 samples ranged from 0.02 to 0.91 mg/kg, and the median was 0.16 mg/kg. Concentrations in 19 percent of the samples exceeded 0.30 mg/kg—a percentage approximately equal to 1 out of every 5 fish samples, compared with 1 out of every 8 fish samples in rivers, streams, lakes, and reservoirs statewide (Risch and others, 2010).

Mercury concentrations that exceeded 0.30 mg/kg were reported in samples from all eight reservoirs and included species found in all eight reservoirs. The highest percentages of samples that exceeded 0.30 mg/kg were from Monroe Lake (38 percent), Patoka Lake (33 percent), and C.M. Harden Lake (27 percent); the lowest percentage was from Brookville Lake (5 percent). Mercury concentrations in fish from Monroe Lake (median 0.21 mg/kg) were statistically higher than those from J.E. Roush Lake, Brookville Lake, and Mississinewa Lake. Mercury concentrations in fish from C.M. Harden Lake (median 0.22 mg/kg) were statistically higher than those from Mississinewa Lake (Kruskal-Wallis, $p < 0.001$; Tukey). The Hg concentrations in 76 percent of the 203 fish-tissue samples exceeded the 0.10-mg/kg reference benchmark for wildlife. The highest percentages of samples that exceeded 0.10 mg/kg were from Monroe Lake (92 percent), Salamonie Lake (90 percent), and C.M. Harden Lake (87 percent).

Bioaccumulation

A bioaccumulation factor (BAF) is the ratio of MeHg in fish tissue to dissolved MeHg in the water and offers a comparison of the food-web effects among the six reservoirs in Indiana with MeHg data. The BAFs indicate that MeHg concentrations in water became a million times higher in fish because of food-chain accumulation and magnification. BAFs were computed with measured concentrations of fish-tissue MeHg (as Hg) data from all samples in the six reservoirs and the mean dissolved MeHg in water samples from the reservoirs. BAFs are presented as a range of values (table 10).

Table 10. Methylmercury bioaccumulation factors for five reservoirs in Indiana.

[Hg, mercury; wet wt., wet weight; mg/kg, milligram per kilogram; MeHg, methylmercury; ng/L, nanogram per liter; BAF, bioaccumulation factor; L/kg, liter per kilogram; 106, one million]

Reservoir name	Mean fish tissue Hg wet wt. (mg/kg)	Maximum fish tissue Hg wet wt. (mg/kg)	Mean dissolved MeHg in water (ng/L)	BAF[3] low (L/kg)	"BAF[4] high (L/kg)"
Misssinewa Lake[1]	0.126	0.322	0.07	1.80×10^6	4.60×10^6
Monroe Lake[2]	0.297	0.910	0.22	1.35×10^6	4.14×10^6
Patoka Lake[2]	0.233	0.634	0.12	1.94×10^6	5.28×10^6
J.E. Roush Lake[1]	0.160	0.440	0.15	1.07×10^6	2.95×10^6
Salamonie Lake[1]	0.170	0.395	0.15	1.15×10^6	2.63×10^6

[1]Dissolved MeHg in water based on non-censored values from tailwater samples (appendix table 1–3).

[2]Dissolved MeHg in water based on values from pool samples (appendix table 1–5).

[3]BAF-low computed as ratio of fish mean Hg concentration to mean dissolved MeHg concentration in water. Fish-tissue data from Indiana Department of Environmental Management Assessment Information Management System (appendix table 1–8).

[4]BAF-high computed as ratio of fish maximum Hg concentration to mean dissolved MeHg concentration in water. Fish-tissue data from Indiana Department of Environmental Management Assessment Information Management System (appendix table 1–8).

The low value in the range is the ratio of the mean fish tissue MeHg (as Hg) to the mean dissolved MeHg; this value includes Hg found in all species in a reservoir. The high value in the range is the ratio of the maximum fish tissue MeHg (as Hg) to the mean dissolved MeHg; this value includes the species at the top of the food web. BAFs for Monroe Lake and Patoka Lake were computed with reservoir-pool MeHg data. BAFs for J.E. Roush Lake, Mississinewa Lake, and Salamonie Lake were computed with reservoir-tailwater data because reservoir-pool water data were not available. Methylmercury was not detected in Brookville Lake pool or tailwater samples, and a BAF was not computed. All of the BAFs were a millionfold and differed by a factor of 5 or less. The highest BAFs were for Patoka Lake, ranging from 1.94×10^6 to 5.28×10^6 liters per kilogram.

Implications for Fish Consumption

Reservoir fish-tissue data indicated the highest levels of Hg and MeHg were observed in Monroe Lake and Patoka Lake, and these findings have implications for fish consumption by humans. Approximately 104,000 anglers were recorded to have caught fish in the pools and tailwaters of these two reservoirs in 2007 (Carnahan, 2008; Kittaka, 2008). Many fish that are caught are released, so it is important to distinguish which fish were "harvested" (for potential human consumption). The fish species that were reported as harvested, when compared with the available fish-tissue Hg concentrations data for each reservoir, indicate that most of the fish harvested are species likely to have fish-tissue Hg concentrations below the reference benchmark for human health. On the other hand, the fish species most frequently targeted and caught typically were not harvested but were likely to have Hg fish-tissue sample concentrations that exceed the reference benchmark for human health. These implications for fish consumption by humans are detailed in the following discussions.

Monroe Lake creel surveys (Kittaka, 2008) during the April through October 2007 fishing season, including 30 bass tournament days, recorded 38,019 anglers who caught 85,248 fish and harvested 51,053 (60 percent). Of the fish harvested, 88 percent were crappie (*Pomoxis* species), bluegill (*Lepomis macrochirus*), and channel catfish (*Ictalurus punctatus*). Fish-tissue samples of these species from Monroe Lake, 1996–2007, had Hg concentrations ranging from 0.166 to 0.320 mg/kg ($n = 58$). These data indicate that most, but not all, fish of these three species harvested from Monroe Lake probably had Hg concentrations lower than the reference benchmark for human health.

Nearly half of the anglers at Monroe Lake targeted largemouth bass (*Micropterus salmoides*), striped bass (*Morone* species), and walleye (*Sander vitreus*). These three species accounted for 66 percent of the fish caught and 6.9 percent of the fish harvested. Comparing harvest to catch, 1.4 percent of largemouth bass, 27 percent of striped bass, and 66 percent of walleye were harvested. Mercury in fish-tissue samples from Monroe Lake, 1996–2007, had Hg concentrations ranging from 0.154 to 0.556 mg/kg in 11 largemouth bass samples and 0.175 to 0.910 mg/kg in 6 walleye samples. No data

were available for fish tissue Hg in hybrid striped bass. The data indicated average-length largemouth bass and above-average-length walleye harvested from Monroe Lake probably contained Hg concentrations that exceeded the reference benchmark for human health.[11,12]

Patoka Lake creel surveys (Carnahan, 2008) during the April through October 2007 fishing season, including 24 bass tournament days, recorded 65,860 anglers who caught 213,680 fish and harvested 117,007 (55 percent). Of the fish harvested, 97 percent were crappie, bluegill, and channel catfish. Fish-tissue samples of these species from Patoka Lake, 1996–2006, had Hg concentrations ranging from 0.023 to 0.221 mg/kg. These data indicate that most fish of these species harvested from Patoka Lake probably did not contain Hg concentrations that exceeded the reference benchmark for human health.

Many anglers at Patoka Lake targeted largemouth bass and striped bass, and these two species accounted for 46 percent of the fish caught and 2.2 percent of the fish harvested. Comparing harvest to catch, 2 percent of largemouth bass and 42 percent of striped bass were harvested. Fish-tissue samples from Patoka Lake, 1996–2006, had Hg concentrations ranging from 0.304 to 0.634 mg/kg in largemouth bass. No data were available for fish tissue Hg in hybrid striped bass. These data indicate that the average-length largemouth bass harvested from Patoka Lake probably contained Hg concentrations that exceeded the reference benchmark for human health.[13,14]

[11] Largemouth bass harvested from Monroe Lake were 356 to 559 millimeters (mm) long, with a mean of 419 mm. The largemouth bass samples from Monroe Lake exceeding 0.30 mg/kg Hg were 296 to 480 mm long, with a mean of 361 mm. Most of the largemouth bass harvested would be in the size range of samples exceeding 0.30 mg/kg Hg. Walleye harvested were 356 to 696 mm long, with a mean of 442 mm. The walleye samples exceeding 0.30 mg/kg Hg were 554 to 675 mm long, with a mean of 626 mm. The above-average-size walleye, more than 554 mm long, would be in the size range of samples exceeding 0.30 mg/kg Hg.

[12] The advisory and guidelines applicable to Monroe Lake state that women of childbearing years, nursing mothers, and all children under age 15 may eat one meal per month of largemouth bass larger than 13 inches (in.) (330 mm) and walleye 19 to 21 in. (483 to 533 mm) but should not eat walleye larger than 21 in. (533 mm).

[13] Largemouth bass harvested from Patoka Lake were a mean of 414 mm long. The largemouth bass samples from Patoka Lake exceeding 0.30 mg/kg Hg were 322 to 467 mm long, with a mean 371. The average-size largemouth bass, including those 414 mm, would be in the size range of samples exceeding 0.30 mg/kg Hg.

[14] The advisory and guidelines applicable to Patoka Lake state that women of childbearing years, nursing mothers, and all children under age 15 may eat one meal per month of largemouth bass larger than 13 in. (330 mm).

Limitations of Existing Information

Existing information limits a uniform comparison of Hg and MeHg in the eight flood-control reservoirs in Indiana. Mercury and MeHg data from reservoir tailwaters and pools do not include the same reservoirs for the same seasons over the same time period. Tailwater MeHg data provide an insight into reservoir-pool conditions at J.E. Roush Lake, Mississinewa Lake, and Cagles Mill Lake, but reservoir-pool data, collected at least during summer thermal stratification, would provide a better comparison with the findings from the pools at Brookville Lake, Monroe Lake, and Patoka Lake. Multiyear, seasonal tailwater data are not available for Monroe Lake and Patoka Lake.

Mercury and MeHg data have not been collected from tailwaters and pools at C.M. Harden Lake and Salamonie Lake. These two reservoirs have percentages of agricultural land cover similar to J.E. Roush Lake and Mississinewa Lake (more than 70 percent), and all four reservoirs are in the Central Till Plains physiographic region. Mercury was detected in 100 percent and MeHg was detected in more than 70 percent of the tailwater samples from J.E. Roush Lake and Mississinewa Lake. These similarities indicate a potential for Hg and MeHg to be detected in tailwater samples from C.M Harden Lake and Salamonie Lake.

The duration and areal extent of conditions favoring Hg methylation are likely related to thermal stratification, but current knowledge for the reservoirs in Indiana is limited to a single summer sampling during thermal stratification. Other investigators have noted the important role of thermal destratification in the cycling and transport of MeHg in a reservoir system (for example, Alpers and others, 2008; Gray and Hines, 2009). In addition, autumn drawdown of water levels mixes and removes water from the pool, potentially changing Hg and MeHg transport within the reservoir and to downstream locations. Current knowledge does not include the distance downstream from a dam that MeHg from tailwaters persists, the annual reservoir yield of MeHg in tailwaters, and the Hg in fish from reaches downstream from reservoirs compared to fish in the reservoirs.

Finally, collection of water from reservoir pools and tailwaters for Hg and MeHg analysis throughout the year for several years—if coordinated with periodic collection of fish tissue samples for Hg analysis from these same locations—would provide a more thorough understanding of Hg delivery, methylation, food-web bioaccumulation, and downstream transport.

Summary and Conclusions

Mercury (Hg) is an element that occurs naturally, but evidence suggests that human activities have resulted in increased amounts being released to the atmosphere and land surface. When Hg is converted to toxic methylmercury (MeHg) in aquatic ecosystems, MeHg accumulates and increases in the food web so that some fish contain levels which pose a health risk to humans and wildlife that consume these fish.

Reservoirs, unlike natural lakes, are a part of river systems that are managed for flood control, which has unintentional effects on mercury transport and methylmercury formation. A condition known as the reservoir effect highlights the importance of Hg and MeHg in reservoirs. Previous investigations in North America have shown that lakes and reservoirs during summer thermal stratification can develop conditions in the hypolimnion that promote MeHg formation. In this study, two sets of data from six flood-control reservoirs in Indiana were compiled and interpreted to evaluate how Hg transport and MeHg formation in the water were affected by physical factors and chemical and biological conditions. The data included water samples collected and processed with ultra-clean protocols and analyzed for Hg and MeHg by low-level methods, plus field determinations for water-quality characteristics and analysis of supplementary constituents.

One set of data was 66 seasonal samples from tailwaters downstream near the dams of four reservoirs—Brookville Lake, Cagles Mill Lake, J.E. Roush Lake, and Mississinewa Lake. In these samples, Hg ranged up to 15 nanograms per liter (ng/L), and the mean was 2.58 ng/L. Methylmercury was detected only once in the tailwaters of Brookville Lake. The concentration ratios of MeHg to Hg ranged up to 64.8 percent, and the mean for the four reservoirs was 9.1 percent. Statistical analysis indicated the median concentration ratio of MeHg to Hg in summer tailwater samples, 6.7 percent, was significantly higher than in other seasons.

The other set of data was 53 samples from summer pools and tailwaters of three reservoirs: Brookville Lake, Monroe Lake, and Patoka Lake. Water-quality characteristics data from 1,440 depth-specific measurements in vertical profiles along 10 to 17 transects in each reservoir were used to select the depths for the water samples in the epilimnion, metalimnion, and hypolimnion thermal strata. Examination of changes in water temperature and dissolved oxygen with depth shows that the pool of each reservoir was thermally stratified at many of the transects.

Whole-water Hg (particulate plus dissolved Hg) was reported in all samples from the three reservoir pools and concentrations ranged up to 5.51 ng/L; the mean was 1.34 ng/L. Mercury concentrations were highest in the hypolimnions of Monroe Lake and Patoka Lake. Water samples from Brookville Lake had considerably lower levels of whole-water Hg, particulate Hg, and MeHg than the other two reservoirs. Methylmercury was detected in 53 percent of the samples, including just a single sample from the Brookville Lake headwaters. Dissolved MeHg is the form that is most available for transfer to the aquatic food web. Concentration ratios of dissolved MeHg to Hg in the three reservoirs ranged up to 82 percent, and the median was 40 percent in Monroe Lake and 48 percent in Patoka Lake.

The hypolimnions of Monroe Lake and Patoka Lake were found to have zones with a high potential for conversion of Hg to MeHg—defined by water temperature less than 18.5 degrees Celsius and dissolved oxygen less than 3.5 milligrams per liter (mg/L), and water depths greater than 8 meters. These zones had the highest concentrations of Hg and MeHg, the highest concentration ratios of dissolved MeHg to Hg, and conditions favorable for sulfate reductions (water pH< 7, decreased dissolved sulfate concentrations, and observed hydrogen sulfide in water samples) compared to other strata. These zones extended through nearly half of the summer pools for these two reservoirs. Reservoir outflow came from this zone at Monroe Lake and contributed to a tailwater concentration ratio for dissolved MeHg to Hg of 56 percent. Reservoir outflow at Patoka Lake was not from this zone, and dissolved MeHg was not detected in the tailwater.

Factors affecting the transport of Hg to reservoirs favored Monroe Lake and Patoka Lake. These two reservoirs are in parts of Indiana with high Hg wet deposition so that the total wet plus dry atmospheric Hg-deposition rates at Monroe Lake and Patoka Lake were higher than at the other reservoirs. The drainage areas of these two reservoirs have the highest percentages of forest land cover supporting Hg dry deposition—82 percent for Monroe Lake and 67 percent for Patoka Lake. Furthermore, Monroe Lake and Patoka Lake are in landscapes with steep slopes and near-surface bedrock, which promote higher rates of precipitation runoff and potentially higher rates of Hg transport to streams and the reservoirs.

To depict food-web accumulation and magnification of MeHg, fish-tissue MeHg (as Hg) data for the reservoirs in Indiana were compiled from State records. Fish-tissue Hg concentrations from 203 samples ranged from 0.02 to 0.91 milligram per kilogram (mg/kg), and the median was 0.16 mg/kg; 19 percent exceeded the reference benchmark for human health, 0.30 mg/kg. Methylmercury (as Hg) concentrations in fish differed among reservoirs, and the highest percentages of samples that exceeded the reference benchmark were from Monroe Lake (38 percent) and Patoka Lake (33 percent); the lowest was from Brookville Lake (5 percent). Concentrations in 76 percent of the 203 fish-tissue samples exceeded the 0.10-mg/kg reference benchmark for wildlife. The highest percentage of samples that exceeded 0.10 mg/kg were from Monroe Lake (92 percent), Salamonie Lake (90 percent), and C.M. Harden Lake (87 percent).

Because fishing is a popular activity at Monroe Lake and Patoka Lake, the fish species harvested and Hg fish-tissue data were compared. The implications for human consumption were that the highest numbers of fish harvested were crappie, bluegill, and catfish, which are more likely to have MeHg levels lower than the 0.30-mg/kg reference benchmark for human health. Largemouth bass were typically caught and released at these reservoirs, but 66 percent of walleye caught were harvested. The

average-size largemouth bass harvested in both reservoirs and the above-average-size walleye harvested from Monroe Lake were likely to exceed the reference benchmark for human health.

Existing information limits a uniform comparison of Hg and MeHg in the eight flood-control reservoirs in Indiana. Mercury and MeHg data from tailwaters and pools at C.M. Harden Lake or Salamonie Lake have not been collected. Mercury and MeHg data from reservoir tailwaters and pools do not include the same reservoirs at the same intervals over the same time period. The duration and areal extent of conditions favoring Hg methylation are likely related to thermal stratification, but current knowledge is limited to a single time during thermal stratification. Currently unknown is the distance downstream that MeHg from tailwater outflow persists, the annual reservoir MeHg yields in tailwaters, or the associated fish Hg in downstream reaches.

In conclusion, this study has shown that MeHg is formed in six flood-control reservoirs in Indiana—Brookville Lake, Cagles Mill Lake, Mississinewa Lake, Monroe Lake, Patoka Lake, and J.E. Roush Lake. This MeHg accumulated and magnified to unsafe levels in the aquatic food web, including the food chains of fish caught in these lakes and consumed by anglers and wildlife. On the basis of information available, other reservoirs will have the highest rates of Hg transport and MeHg formation and the highest levels of MeHg in fish if they are located in forested landscapes with steep terrain and near-surface bedrock, if they receive moderate to high atmospheric Hg wet and dry deposition, and if the water pH is less than 7 and dissolved oxygen is less than 3.5 mg/L to promote sulfate reduction. These conditions will be most prevalent during thermal stratification in the summer, leading to the potential for MeHg to be released in tailwater—especially if the water that is released is from the hypolimnion or metalimnion. Additional multiseason studies of Hg and MeHg in water and fish from reservoir pools and tailwaters in Indiana and other states could provide the data needed to evaluate risks to humans and wildlife and to assess reservoir management options to mitigate these risks.

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Appendix 1. Supplemental Data

Table 1–1. Reservoir-pool and tailwater mercury quality-control field blank sample data.

[QC, quality control; Hg, mercury; ng/L, nanogram per liter; MeHg, methylmercury; n.a., not analyzed for; <, less than]

Field ID	Type of QC sample	USGS station ID	Sample date (month/day/ year)	Particulate Hg (ng/L)	Dissolved Hg (ng/L)[1]	Particulate MeHg (ng/L)	Dissolved MeHg (ng/L)	Unfiltered Hg (ng/L)[1]
FB1	Field equipment/filter blank	390034086304801	7/6/2009	<0.07	0.06	<0.01	<0.04	n.a.
FB2	Field equipment/filter blank	392628084595901	7/13/2009	<0.10	0.18	<0.02	<0.04	n.a.
FB3	Field equipment/filter blank	382553086420601	7/20/2009	<0.10	0.06	<0.02	<0.04	n.a.
BB1	Blank source water/bottle blank	390034086304801	7/6/2009	n.a.	n.a.	n.a.	n.a.	0.17
BB2	Blank source water/bottle blank	392628084595901	7/13/2009	n.a.	n.a.	n.a.	n.a.	0.48
BB3	Blank source water/bottle blank	382553086420601	7/20/2009	n.a.	n.a.	n.a.	n.a.	0.17

[1]Average unfiltered Hg concentration in three blank source-water samples (0.27 ng/L) exceeded average dissolved Hg concentration in field equipment/filter blanks (0.10 ng/L). Unfiltered Hg concentration in blank source water exceeded dissolved Hg concentration in field equipment/filter blank for each date.

Table 1–2. Quality-control data for reservoir-pool and tailwater mercury field duplicate samples.

[QC, quality control; Hg, mercury; ng/L, nanogram per liter; MeHg, methylmercury; n.a., not analyzed for; RPD, relative percent difference; <, less than; ND., no relative percent difference computed for two < values]

Field ID	USGS station ID	Sample date (month/ day/ year)	Particulate Hg (ng/L)			Dissolved Hg (ng/L)			Particulate MeHg (ng/L)			Dissolved MeHg (ng/L)		
			Sample	Duplicate	RPD (percent)[1]	Sample	Duplicate	RPD (percent)[1]	Sample	Duplicate	RPD (percent)[1]	Sample	Duplicate	RPD (percent)[1]
Monroe 5A-R	390359086263501	7/8/2009	0.23	0.23	0.9	0.52	0.33	44.7	0.06	<0.02	100.0	<0.04	<0.04	ND
Monroe 5B-R	390359086263501	7/8/2009	2.23	2.43	8.7	1.26	1.18	6.6	0.55	0.56	2.3	0.73	0.64	13.1
Monroe 6-R	390229086280401	7/8/2009	0.25	0.23	8.3	0.47	0.33	35.0	<0.03	<0.03	ND	<0.04	<0.04	ND
Brookville 3A-R	392721084585901	7/14/2009	0.16	0.15	7.8	0.36	0.26	32.3	<0.03	<0.02	ND	<0.04	<0.04	ND
Brookville 3B-R	392721084585901	7/14/2009	0.12	0.12	1.7	0.40	0.32	22.2	<0.03	<0.03	ND	<0.04	<0.04	ND
Brookville 3C-R	392721084585901	7/14/2009	0.23	0.21	8.1	0.35	0.32	9.0	<0.03	<0.03	ND	<0.04	<0.04	ND
Patoka 2A-R	382553086420601	7/20/2009	0.18	0.18	2.8	0.53	0.28	61.7	<0.03	<0.03	ND	<0.04	<0.04	ND
Patoka 2B-R	382553086420601	7/20/2009	0.40	0.42	3.7	0.26	0.66	87.0	0.06	0.06	0	<0.04	<0.04	ND
Patoka 2C-R	382553086420601	7/20/2009	1.10	1.02	7.3	0.49	0.44	10.8	0.33	0.29	13.2	0.28	0.34	19.4

[1]Relative percent difference is the nonnegative difference of the paired duplicate sample concentrations divided by the average of the concentrations, expressed as a percentage. For one pair of duplicate samples with a 0.06 concentration and a <0.02 value, the <0.02 value was set to 0.019 for calculating the RPD of 100.

Table 1–3. Reservoir-tailwater mercury data.

[Hg, unfiltered mercury; ng/L, nanogram per liter; PHg, particulate mercury; MeHg, unfiltered methylmercury; <, less than reporting limit listed; n.d., not determined because PHg or MeHg was not reported]

Reservoir	Sample date (month/day/year)	Season	Hg (ng/L)[1]	PHg (ng/L)[1]	MeHg (ng/L)[1]	Ratio of PHg to Hg[2] (percent)	Ratio of MeHg to Hg (percent)[3]
Brookville Lake	3/11/2002	Winter	0.31	0.31	<0.3	100	n.d.
	6/10/2002	Spring	0.61	0.33	<0.3	54	n.d.
	9/9/2002	Summer	0.32	0.10	<0.3	31	n.d.
	12/16/2002	Fall	0.19	0.19	<0.3	100	n.d.
	4/21/2003	Spring	0.81	0.24	<0.3	30	n.d.
	7/21/2003	Summer	<0.3	<0.3	<0.3	n.d.	n.d.
	10/20/2003	Fall	0.55	0.33	<0.3	60	n.d.
	1/12/2004	Winter	1.02	0.78	<0.3	76	n.d.
	9/3/2004	Summer	0.54	0.14	<0.04	26	n.d.
	10/22/2004	Fall	1.02	0.61	<0.04	60	n.d.
	2/25/2005	Winter	1.85	0.64	<0.04	35	n.d.
	6/30/2005	Spring	0.34	0.11	<0.04	32	n.d.
	9/16/2005	Summer	0.32	0.10	<0.04	31	n.d.
	12/19/2005	Fall	0.24	0.07	<0.04	29	n.d.
	3/17/2006	Winter	1.21	0.56	<0.04	46	n.d.
	5/18/2006	Spring	0.64	0.20	<0.04	31	n.d.
	9/8/2006	Summer	0.26	0.04	0.04	15	15.4
Cagles Mill Lake	2/13/2002	Winter	2.23	1.41	<0.3	63	n.d.
	5/21/2002	Spring	2.34	1.51	<0.3	65	n.d.
	8/14/2002	Summer	0.71	0.50	0.46	70	64.8
	11/19/2002	Fall	0.95	0.71	<0.3	75	n.d.
	3/11/2003	Winter	3.34	2.17	<0.3	65	n.d.
	6/17/2003	Spring	1.73	0.40	<0.3	23	n.d.
	9/23/2003	Summer	1.83	1.31	0.32	72	17.5
	12/16/2003	Fall	1.74	1.59	<0.3	91	n.d.
	3/23/2004	Winter	1.31	1.31	<0.3	100	n.d.
	8/31/2004	Summer	1.36	0.99	0.32	73	23.5
	10/13/2004	Fall	1.17	0.85	0.12	73	10.3
	3/4/2005	Winter	3.26	0.81	<0.04	25	n.d.
	6/6/2005	Spring	2.18	1.22	0.14	56	6.4
	9/2/2005	Summer	2.32	0.15	0.57	6	24.6
	12/2/2005	Fall	1.39	0.65	<0.04	47	n.d.
	3/3/2006	Winter	1.67	0.77	<0.04	46	n.d.
	5/8/2006	Spring	1.94	1.00	0.06	52	3.1
	8/21/2006	Summer	1.56	1.25	0.23	80	14.7

[1] Concentrations in italics were higher than the method detection limit and lower than the reporting limit.

[2] Ratio of particulate Hg to unfiltered Hg, multiplied by 100.

[3] Ratio of unfiltered MeHg to unfiltered Hg, multiplied by 100.

Table 1–3. Reservoir-tailwater mercury data.—Continued

[Hg, unfiltered mercury; ng/L, nanogram per liter; PHg, particulate mercury; MeHg, unfiltered methylmercury; <, less than reporting limit listed; n.d., not determined because PHg or MeHg was not reported]

Reservoir	Sample date (month/day/year)	Season	Hg (ng/L)[1]	PHg (ng/L)[1]	MeHg (ng/L)[1]	Ratio of PHg to Hg[2] (percent)	Ratio of MeHg to Hg (percent)[3]
J.E. Roush Lake	4/22/2002	Spring	5.35	4.22	0.14	79	2.6
	7/8/2002	Summer	2.06	1.31	0.24	64	11.7
	10/21/2002	Fall	1.58	1.40	<0.3	89	n.d.
	1/13/2003	Winter	5.82	3.61	0.26	62	4.5
	5/19/2003	Spring	3.11	<0.3	<0.3	n.d.	n.d.
	8/18/2003	Summer	5.50	3.92	0.66	71	12.0
	2/23/2004	Winter	12.62	9.22	0.14	73	1.1
	8/26/2004	Summer	1.48	1.08	0.13	73	8.8
	10/25/2004	Fall	1.24	0.89	0.08	72	6.5
	3/7/2005	Winter	7.66	4.04	0.13	53	1.7
	6/20/2005	Spring	2.59	0.91	0.40	35	15.4
	8/29/2005	Summer	2.67	2.21	0.04	83	1.5
	12/5/2005	Fall	7.14	3.35	0.05	47	0.7
	3/13/2006	Winter	15.00	9.15	0.14	61	0.9
	5/22/2006	Spring	4.37	1.91	0.12	44	2.7
	8/28/2006	Summer	2.10	1.63	0.05	78	2.4
Mississinewa Lake	4/22/2002	Spring	4.96	3.32	<0.3	67	n.d.
	7/8/2002	Summer	2.89	2.42	<0.3	84	n.d.
	10/21/2002	Fall	1.14	1.14	<0.3	100	n.d.
	5/19/2003	Spring	5.13	2.97	<0.3	58	n.d.
	8/18/2003	Summer	3.42	2.73	0.16	80	4.7
	2/23/2004	Winter	6.65	4.56	0.11	69	1.7
	8/26/2004	Summer	2.38	1.39	0.16	58	6.7
	10/25/2004	Fall	2.31	1.99	0.05	86	2.2
	3/7/2005	Winter	1.74	0.73	0.05	42	2.9
	6/20/2005	Spring	1.12	0.44	0.18	39	16.1
	8/29/2005	Summer	1.19	0.81	0.12	68	10.1
	12/5/2005	Fall	3.25	1.09	0.05	34	1.5
	3/13/2006	Winter	3.39	1.63	0.06	48	1.8
	5/22/2006	Spring	3.33	1.24	0.06	37	1.8
	8/28/2006	Summer	1.38	0.69	0.09	50	6.5

[1] Concentrations in italics were higher than the method detection limit and lower than the reporting limit.

[2] Ratio of particulate Hg to unfiltered Hg, multiplied by 100.

[3] Ratio of unfiltered MeHg to unfiltered Hg, multiplied by 100.

Table 1–4. Hydrologic conditions at three Indiana reservoirs.

[ft, elevation in feet (National Geodetic Vertical Datum 1929) at 0600 or 0700; °C, degree Celsius; ft^3/s, cubic feet per second; in., inch in previous 24 hours]

Reservoir	Date (month/day/year)	Daily pool elevation (ft)	Tailwater temperature (°C)	Tailwater discharge (ft^3/s)	Precipitation (in.)
Brookville Lake	7/13/2009	748.17	17.1	181	0
	7/14/2009	748.13	17.1	104	0
	7/15/2009	748.12	16.9	72	0
	7/16/2009	748.12	17.0	72	0
	7/17/2009	748.09	17.1	72	0
Monroe Lake	7/6/2009	538.33	21.7	50	0
	7/7/2009	538.35	21.3	200	0
	7/8/2009	538.36	20.1	200	0.43
	7/9/2009	538.36	20.5	200	0.18
	7/10/2009	538.33	20.5	200	0.13
Patoka Lake	7/20/2009	537.48	26.7	200	0
	7/21/2009	537.43	27.2	200	0
	7/22/2009	537.45	26.7	200	1.27
	7/23/2009	537.58	26.2	50	1.76
	7/24/2009	537.59	26.4	50	0

Table 1–5. Reservoir-pool and tailwater data for mercury, water-quality characteristics, and supplementary constituents.

[m, meter; Hg, mercury; ng/L, nanogram per liter; whole water, sum of particulate and dissolved (nondetection assumed to be zero); MeHg, methylmercury; µS/cm; microsiemens per centimeter; mg/L, milligram per liter; °C, degree Celsius; NRTU, nephelometric turbidity ratio unit; n.a. not applicable (depth-integrated sample); <, less than reporting limit or percentage listed; n.d., not determined because particulate and dissolved MeHg were not detected]

Brookville Lake											
Sample ID	Sample date	Sample depth (m)	Particulate Hg (ng/L)	Dissolved Hg (ng/L)	Whole-water Hg (ng/L)	Ratio of particulate Hg to Hg[1]	Particulate MeHg (ng/L)	Dissolved MeHg (ng/L)	Whole-water MeHg (ng/L)	Ratio of dissolved MeHg to Hg[2]	Ratio of whole-water MeHg to Hg[3]
1	7/17/2009	n.a.	<0.10	0.31	0.31	<29	<0.03	<0.04	<0.04	n.d.	n.d.
2A	7/13/2009	3.05	0.16	0.60	0.76	21	<0.03	<0.04	<0.04	n.d.	n.d.
2B	7/13/2009	10.67	<0.10	0.43	0.33	<27	<0.02	<0.04	<0.04	n.d.	n.d.
2C	7/13/2009	22.86	<0.10	0.33	0.43	<21	<0.03	<0.04	<0.04	n.d.	n.d.
3A	7/14/2009	3.05	0.16	0.36	0.52	30	<0.03	<0.04	<0.04	n.d.	n.d.
3B	7/14/2009	12.19	0.12	0.40	0.52	24	<0.03	<0.04	<0.04	n.d.	n.d.
3C	7/14/2009	22.86	0.23	0.35	0.58	39	<0.03	<0.04	<0.04	n.d.	n.d.
4	7/15/2009	0.91	1.00	0.29	1.29	77	<0.03	<0.04	<0.04	n.d.	n.d.
5A	7/15/2009	6.1	0.26	0.37	0.63	42	<0.03	<0.04	<0.04	n.d.	n.d.
5B	7/15/2009	9.14	0.19	0.37	0.56	33	<0.03	<0.04	<0.04	n.d.	n.d.
6A	7/15/2009	3.05	0.19	0.23	0.42	46	<0.03	<0.04	<0.04	n.d.	n.d.
6B	7/15/2009	6.1	0.17	0.29	0.46	37	<0.03	<0.04	<0.04	n.d.	n.d.
6C	7/15/2009	12.19	0.45	0.34	0.79	57	<0.03	<0.04	<0.04	n.d.	n.d.
7A	7/16/2009	4.57	0.21	0.31	0.52	41	<0.03	<0.04	<0.04	n.d.	n.d.
7B	7/16/2009	7.62	0.82	0.29	1.11	74	<0.02	<0.04	<0.04	n.d.	n.d.
8	7/16/2009	1.22	1.57	0.34	1.91	82	0.07	0.06	0.13	18	7

Sample ID	pH (standard unit)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Water temperature (°C)	Turbidity (NRTU)	Suspended sediment (mg/L)	Dissolved sulfate (mg/L)	Particulate carbon (mg/L)	Particulate organic carbon (mg/L)	Dissolved organic carbon (mg/L)	Total particulate nitrogen (mg/L)	Seston chlorophyll *a* (mg/L)
1	7.9	479	9.3	16.9	1.5	<15	25.5	0.2	0.2	3.2	0.03	0.001
2A	8.4	423	9.5	25.2	2	<15	26.1	1.3	1.24	3.3	0.16	0.000
2B	7.7	479	0.4	18.6	2	<15	26.1	0.2	0.22	3.8	0.04	0.002
2C	7.7	478	1.3	12.0	1	<15	25.3	0.2	0.18	3.8	0.01	0.001
3A	8.4	419	10.0	25.1	3	<15	25.6	1.4	1.42	3.4	0.17	0.002
3B	7.5	482	0.5	17.0	2	<15	25.7	3.6	3.58	3.1	0.06	0.002
3C	7.6	483	0.6	12.3	4	<15	25.6	0.4	0.40	3.2	0.03	0.002
4	8.3	416	9.1	25.3	19	18	25.5	2.5	2.47	3.4	0.33	0.010
5A	7.9	431	5.4	24.2	7	<15	25.6	0.6	0.60	3.4	0.08	0.001
5B	7.4	480	0.4	19.8	4	<15	24.8	0.6	0.56	3.1	0.06	0.002
6A	8.2	426	9.0	25.0	3	<15	25.6	1.6	1.60	3.5	0.22	0.004
6B	7.5	445	1.6	23.7	3	<15	25.7	1	0.98	3.3	0.09	0.007
6C	7.4	496	0.4	17.0	8	<15	24.0	0.8	0.80	3.5	0.09	0.002
7A	8.2	423	9.6	25.0	5	<15	25.8	1.4	1.41	3.3	0.20	0.007
7B	7.4	491	0.6	26.8	15	<15	26.2	1.4	1.41	3.3	0.21	0.012
8	8.1	699	7.7	21.8	16	19	36.8	1	1.03	2.4	0.10	0.004

[1] Ratio of particulate Hg to whole-water Hg concentration, multiplied by 100. For particulate Hg concentrations <0.10 ng/L, the ratio was computed with particulate Hg set to 0.09 ng/L and the ratio of particulate Hg to Hg was determined to be less than the result.

[2] Ratio of dissolved MeHg to dissolved Hg concentration, multiplied by 100. For dissolved MeHg concentrations <0.04 ng/L, the ratio was computed with dissolved MeHg set to 0.03 ng/L and the ratio of dissolved MeHg to Hg was determined to be less than the result.

[3] Ratio of whole-water MeHg to whole-water Hg concentration, multiplied by 100.

Table 1–5. Reservoir-pool and tailwater data for mercury, water-quality characteristics, and supplementary constituents.—Continued

[m, meter; Hg, mercury; ng/L, nanogram per liter; whole water, sum of particulate and dissolved (nondetection assumed to be zero); MeHg, methylmercury; µS/cm; microsiemens per centimeter; mg/L, milligram per liter; °C, degree Celsius; NRTU, nephelometric turbidity ratio unit; n.a. not applicable (depth-integrated sample); <, less than reporting limit or percentage listed; n.d., not determined because particulate and dissolved MeHg were not detected]

Monroe Lake											
Sample ID	Sample date	Sample depth (m)	Particulate Hg (ng/L)	Dissolved Hg (ng/L)	Whole-water Hg (ng/L)	Ratio of particulate Hg to Hg[1]	Particulate MeHg (ng/L)	Dissolved MeHg (ng/L)	Whole-water MeHg (ng/L)	Ratio of dissolved MeHg to Hg[2]	Ratio of whole-water MeHg to Hg[3]
1	7/10/2009	n.a.	1.06	0.86	1.92	55	0.08	0.48	0.56	56	29
2A	7/6/2009	3.05	0.17	0.32	0.49	35	<0.02	<0.04	<0.04	n.d.	n.d.
2B	7/6/2009	7.01	0.69	0.55	1.24	56	0.08	0.12	0.20	22	16
2C	7/6/2009	8.23	1.79	1.12	2.91	61	0.25	0.70	0.95	63	33
3A	7/7/2009	3.05	0.15	0.27	0.42	36	<0.03	0.05	0.05	19	12
3B	7/7/2009	7.01	0.92	0.49	1.41	65	0.11	0.12	0.23	24	16
3C	7/7/2009	7.92	3.12	1.10	4.22	74	0.49	0.70	1.19	64	28
4A	7/7/2009	3.05	0.18	0.30	0.48	37	<0.03	<0.04	<0.04	n.d.	n.d.
4B	7/7/2009	5.49	0.30	0.28	0.58	51	0.03	<0.04	0.03	<11	5
4C	7/7/2009	7.92	3.47	1.37	4.84	72	0.57	0.80	1.37	58	28
5A	7/8/2009	4.57	0.23	0.52	0.75	30	0.06	<0.04	0.06	<6	9
5B	7/8/2009	10.67	2.23	1.26	3.49	64	0.55	0.73	1.28	58	37
6	7/8/2009	1.22	0.25	0.47	0.72	35	<0.03	<0.04	<0.04	n.d.	n.d.
7A	7/9/2009	3.05	0.85	0.46	1.31	65	0.19	<0.04	0.19	<7	14
7B	7/9/2009	7.62	1.31	0.81	2.13	62	<0.03	0.16	0.16	20	8
8	7/9/2009	0.30	1.41	0.66	2.07	68	0.06	<0.04	0.06	<5	3
9	7/9/2009	0.46	2.18	0.57	2.75	79	<0.03	0.06	0.06	11	2

Sample ID	pH (standard unit)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Water temperature (°C)	Turbidity (NRTU)	Suspended sediment (mg/L)	Dissolved sulfate (mg/L)	Particulate carbon (mg/L)	Particulate organic carbon (mg/L)	Dissolved organic carbon (mg/L)	Total particulate nitrogen (mg/L)	Seston chlorophyll *a* (mg/L)
1	6.8	129	5.9	21.3	13	<15	14.8	1.1	1.10	3.8	0.15	0.017
2A	7.5	116	7.6	25.0	2	<15	18.2	0.6	0.60	3.3	0.05	0.003
2B	7.0	117	7.0	24.3	5	<15	17.5	0.9	0.89	3.7	0.12	0.022
2C	6.8	122	4.1	19.5	14	<15	14.8	1.0	0.98	3.9	0.13	0.017
3A	7.5	116	7.5	25.1	3	<15	18.1	0.9	0.89	3.6	0.08	0.002
3B	7.0	124	5.5	22.0	6	<19	17.4	0.8	0.78	3.5	0.11	0.022
3C	6.6	138	3.7	19.3	27	38	14.0	1.6	1.54	4.4	0.18	0.018
4A	7.6	116	7.4	25.0	4	<15	17.8	0.9	0.92	3.8	0.07	0.004
4B	6.9	135	5.7	22.5	5	<15	17.6	0.6	0.58	4.1	0.05	0.004
4C	6.7	146	4.2	20.0	40	40	13.3	1.9	1.85	4.6	0.17	0.008
5A	7.4	118	9.0	24.8	6	<15	17.5	0.7	0.72	3.2	0.06	0.003
5B	6.7	147	3.9	18.1	31	36	13.5	1.5	1.44	4.4	0.16	0.004
6	8.1	120	10.7	26.6	6	<15	17.6	1.2	1.14	3.5	0.14	0.004
7A	7.2	129	11.0	23.9	25	21	16.5	1.0	1.00	3.9	0.09	0.008
7B	6.8	169	8.5	21.5	27	21	14.7	1.1	1.10	4.0	0.14	0.007
8	7.2	170	12.1	24.8	50	44	17.7	3.0	2.95	3.9	0.39	0.010
9	7.2	130	15.0	27.2	30	34	17.4	2.0	1.99	4.9	0.20	0.008

[1] Ratio of particulate Hg to whole-water Hg concentration, multiplied by 100. For particulate Hg concentrations <0.10 ng/L, the ratio was computed with particulate Hg set to 0.09 ng/L and the ratio of particulate Hg to Hg was determined to be less than the result.

[2] Ratio of dissolved MeHg to dissolved Hg concentration, multiplied by 100. For dissolved MeHg concentrations <0.04 ng/L, the ratio was computed with dissolved MeHg set to 0.03 ng/L and the ratio of dissolved MeHg to Hg was determined to be less than the result.

[3] Ratio of whole-water MeHg to whole-water Hg concentration, multiplied by 100.

Table 1–5. Reservoir-pool and tailwater data for mercury, water-quality characteristics, and supplementary constituents.—Continued

[m, meter; Hg, mercury; ng/L, nanogram per liter; whole water, sum of particulate and dissolved (nondetection assumed to be zero); MeHg, methylmercury; µS/cm; microsiemens per centimeter; mg/L, milligram per liter; °C, degree Celsius; NRTU, nephelometric turbidity ratio unit; n.a. not applicable (depth-integrated sample); <, less than reporting limit or percentage listed; n.d., not determined because particulate and dissolved MeHg were not detected]

Patoka Lake												
Sample ID	Sample date	Sample depth (m)	Particulate Hg (ng/L)	Dissolved Hg (ng/L)	Whole-water Hg (ng/L)	Ratio of particulate Hg to Hg[1]	Particulate MeHg (ng/L)	Dissolved MeHg (ng/L)	Whole-water MeHg (ng/L)	Ratio of dissolved MeHg to Hg[2]	Ratio of whole-water MeHg to Hg[3]	
1	7/24/2009	n.a.	0.33	0.19	0.52	63	0.03	<0.04	0.03	<16	6	
2A	7/20/2009	3.05	0.18	0.53	0.71	25	<0.03	<0.04	<0.03	n.d.	n.d.	
2B	7/20/2009	7.62	0.40	0.26	0.66	61	0.06	<0.04	0.06	<12	9	
2C	7/20/2009	12.19	1.10	0.49	1.59	69	0.33	0.28	0.61	57	38	
3A	7/21/2009	3.05	0.21	0.21	0.42	49	<0.02	<0.04	<0.02	n.d.	n.d.	
3B	7/21/2009	6.10	0.22	0.21	0.43	51	<0.02	<0.04	<0.02	n.d.	n.d.	
3C	7/21/2009	12.19	1.45	0.45	1.90	76	0.37	0.37	0.74	82	39	
4A	7/21/2009	3.05	0.23	0.22	0.45	52	<0.03	<0.04	<0.03	n.d.	n.d.	
4B	7/21/2009	9.14	1.02	1.07	2.09	49	0.59	0.64	1.23	60	59	
5	7/21/2009	1.52	0.28	0.29	0.57	49	<0.03	<0.04	<0.03	n.d.	n.d.	
6A	7/22/2009	3.05	0.34	0.18	0.52	65	<0.02	<0.04	<0.02	n.d.	n.d.	
6B	7/22/2009	7.62	0.64	0.30	0.94	68	0.16	0.12	0.28	40	29	
6C	7/22/2009	13.72	1.30	0.71	2.01	65	0.38	0.28	0.66	39	33	
7	7/22/2009	0.61	1.33	0.25	1.58	84	0.06	<0.04	0.06	<12	4	
8A	7/22/2009	4.57	0.69	0.17	0.86	80	0.08	<0.04	0.08	<18	9	
8B	7/22/2009	10.67	1.50	0.55	2.05	73	0.75	0.33	1.08	60	53	
9	7/23/2009	0.91	4.47	1.04	5.51	81	<0.03	<0.04	0.07	<3	1	
10	7/23/2009	6.10	1.54	0.29	1.83	84	<0.03	0.04	0.16	14	9	
11	7/23/2009	6.10	1.59	0.68	2.27	70	<0.03	0.16	0.55	24	24	
12	7/24/2009	4.57	0.95	0.29	1.24	77	<0.03	<0.04	<0.04	n.d.	n.d.	

Sample ID	pH (standard unit)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Water temperature (°C)	Turbidity (NRTU)	Suspended sediment (mg/L)	Dissolved sulfate (mg/L)	Particulate carbon (mg/L)	Particulate organic carbon (mg/L)	Dissolved organic carbon (mg/L)	Total particulate nitrogen (mg/L)	Seston chlorophyll *a* (mg/L)
1	7.8	170	8.0	23.7	4	<15	17.5	0.8	0.75	3.1	0.10	0.003
2A	7.9	166	7.7	24.5	3	<15	17.8	0.7	0.65	2.3	0.07	0.003
2B	7.1	175	0.6	18.0	4	<15	17.5	1.0	1.00	2.6	0.20	0.008
2C	7.0	189	0.6	13.8	9	21	14.2	0.8	0.74	2.9	0.12	0.005
3A	8.2	167	8.6	25.7	3	<15	18.0	0.7	0.68	3.1	0.08	0.002
3B	7.9	166	5.8	24.1	8	<15	17.9	0.3	0.32	3.1	0.05	0.003
3C	7.2	192	0.7	13.9	7	20	13.5	1.3	1.33	3.0	0.19	0.008
4A	8.3	163	8.3	25.3	1	<15	18.1	0.8	0.80	3.2	0.09	0.020
4B	6.8	185	0.6	16.0	8	<15	12.6	0.8	0.77	3.4	0.13	0.004
5	8.9	161	9.7	25.8	5	<15	19.1	1.5	1.48	3.1	0.21	0.007

[1] Ratio of particulate Hg to whole-water Hg concentration, multiplied by 100. For particulate Hg concentrations <0.10 ng/L, the ratio was computed with particulate Hg set to 0.09 ng/L and the ratio of particulate Hg to Hg was determined to be less than the result.

[2] Ratio of dissolved MeHg to dissolved Hg concentration, multiplied by 100. For dissolved MeHg concentrations <0.04 ng/L, the ratio was computed with dissolved MeHg set to 0.03 ng/L and the ratio of dissolved MeHg to Hg was determined to be less than the result.

[3] Ratio of whole-water MeHg to whole-water Hg concentration, multiplied by 100.

Table 1–5. Reservoir-pool and tailwater data for mercury, water-quality characteristics, and supplementary constituents.—Continued

[m, meter; Hg, mercury; ng/L, nanogram per liter; whole water, sum of particulate and dissolved (nondetection assumed to be zero); MeHg, methylmercury; µS/cm; microsiemens per centimeter; mg/L, milligram per liter; °C, degree Celsius; NRTU, nephelometric turbidity ratio unit; n.a. not applicable (depth-integrated sample); <, less than reporting limit or percentage listed; n.d., not determined because particulate and dissolved MeHg were not detected]

Patoka Lake—continued												
Sample ID	pH (standard unit)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Water temperature (°C)	Turbidity (NRTU)	Suspended sediment (mg/L)	Dissolved sulfate (mg/L)	Particulate carbon (mg/L)	Particulate organic carbon (mg/L)	Dissolved organic carbon (mg/L)	Total particulate nitrogen (mg/L)	Seston chlorophyll *a* (mg/L)
6A	7.9	170	7.7	24.5	4	<15	18.1	0.7	0.68	3.0	0.07	0.002
6B	7.2	178	0.7	17.9	4	<15	17.7	0.6	0.59	2.5	0.11	0.013
6C	7.1	199	0.7	13.7	12	<30	11.9	0.9	0.92	3.1	0.18	0.019
7	7.3	165	6.4	25.1	17	21	16.4	1.2	1.24	3.5	0.20	0.007
8A	8.0	174	7.4	24.5	8	<15	15.0	1.4	1.42	2.4	0.26	0.008
8B	7.1	201	0.6	15.9	10	17	11.2	0.8	0.75	3.1	0.14	0.013
9	7.2	217	5.4	21.9	88	94	22.2	2.8	2.82	3.9	0.42	0.006
10	7.3	209	0.6	22.7	31	22	16.9	1.9	1.82	3.3	0.26	0.010
11	7.2	237	0.6	21.2	21	25	6.3	2.5	2.49	4.0	0.30	0.061
12	7.4	191	4.3	23.7	11	<15	12.9	1.2	1.20	3.8	0.13	0.005

[1] Ratio of particulate Hg to whole-water Hg concentration, multiplied by 100. For particulate Hg concentrations <0.10 ng/L, the ratio was computed with particulate Hg set to 0.09 ng/L and the ratio of particulate Hg to Hg was determined to be less than the result.

[2] Ratio of dissolved MeHg to dissolved Hg concentration, multiplied by 100. For dissolved MeHg concentrations <0.04 ng/L, the ratio was computed with dissolved MeHg set to 0.03 ng/L and the ratio of dissolved MeHg to Hg was determined to be less than the result.

[3] Ratio of whole-water MeHg to whole-water Hg concentration, multiplied by 100.

Table 1–6. Percentages of land-cover categories in reservoir drainage areas.

[<, less than; km², square kilometer]

Land-cover category[1]	Percentage of drainage area							
	Brookville Lake	Cagles Mill Lake	C.M. Harden Lake	Mississinewa Lake	Monroe Lake	Patoka Lake	J.E. Roush Lake	Salamonie Lake
Forest, shrubland[2]	22.5	22.8	12.9	9.1	82.4	67.2	6.1	9.4
Cultivated crops	53.1	61.4	73.0	76.3	3.6	3.8	78.6	79.6
Pasture hay	9.0	7.8	5.5	2.5	4.3	12.0	3.9	1.7
Developed[3]	11.9	5.5	5.8	9.6	2.2	3.9	8.0	6.9
Grassland, barren[4]	0.8	1.3	1.1	1.0	3.1	4.9	1.0	0.8
Open water	2.5	1.1	1.6	0.9	4.3	8.1	1.8	1.1
Wetland[5]	0.2	0.1	0.1	0.5	<0.1	<0.1	0.5	0.6
Drainage area (km²)	984	761	562	2,093	1,119	440	1,867	1,443

[1] Land-cover categories derived from combining area of some land-cover classes in National Land Cover Database (Homer and others, 2004).

[2] Deciduous, evergreen, and mixed forest land-cover and shrubland classes combined.

[3] High, medium, and low intensity and open space combined.

[4] Grassland and barren land-cover classes combined.

[5] Woody and herbaceous wetland combined.

Table 1–7. Mercury wet- and dry-deposition rates and loads to reservoir watersheds in Indiana.

[km², square kilometer; Hg, mercury; mg/m², microgram per square meter; g, gram].

Reservoir watershed	Drainage area (km²)	Hg wet deposition rate[1] (µg/m²)	Hg wet deposition load[2] (g)	Percent forest cover	Forest cover area[3] (km²)	Hg dry deposition rate[4] (µg/m²)	Hg dry deposition load[2] (g)	Total Hg load[5] (g)	Total Hg deposition rate[6] (µg/m²)
Brookville Lake	984	11.5	11,318	22.5	221	16.0	3,543	14,861	15.1
Cagles Mill Lake	761	11.5	8,757	22.8	173	17.4	3,014	11,771	15.5
C.M. Harden Lake	562	11.5	6,463	12.9	73	17.4	1,265	7,728	13.8
Mississinewa Lake	2,093	10.5	21,973	9.1	190	13.9	2,647	24,621	11.8
Monroe Lake	1,119	12.5	13,986	82.4	922	16.0	14,751	28,737	25.7
Patoka Lake	440	12.5	5,504	67.2	296	16.0	4,734	10,238	23.3
J.E. Roush Lake	1,867	10.5	19,607	6.1	114	13.9	1,583	21,191	11.3
Salamonie Lake	1,443	11.5	16,590	9.4	136	13.9	1,885	18,475	12.8

[1] Value is the middle of the range, based on mean annual rate for 2001–2006.

[2] Watershed mean annual atmospheric mercury load for 2001–2006 computed as drainage area multiplied by deposition rate.

[3] Forest drainage area computed as drainage area multiplied by percent forest cover from table 1–6 (as decimal).

[4] Dry deposition rate based on 3-year mean litterfall Hg dry deposition rates for 3 sites in Indiana (Risch and others, 2012). Brookville, Monroe, and Patoka are based on IN21 Clifty Falls; Cagles Mill and Harden are based on IN26 Fort Harrison; and Mississinewa, J.E. Roush, and Salamonie are based on IN20 Roush Lake.

[5] Sum of Hg wet and dry deposition loads.

[6] Total Hg deposition rate for watershed is total Hg load divided by drainage area.

Table 1–8. Reservoir fish-tissue sample and mercury data.

[g, gram; mm, millimeter; Hg conc., mercury concentration; mg/kg, milligram per kilogram; wt., weight; bold indicates wet weight concentration >0.30 mg/kg]

Reservoir	Sample location	Sample date	Number of fish	Genus	Species	Common name	Sample type[1]	Mean fish weight (g)	Mean fish length (mm)	Hg conc. (mg/kg, wet wt.)
Brookville Lake	Dam end	2002	3	*Lepomis*	*macrochirus*	bluegill	2	113	180	0.067
	Dam end	2002	5	*Cyprinus*	*carpio*	carp	2	1,661	512	0.230
	Dam end	2002	4	*Ictalurus*	*punctatus*	channel catfish	1	721	435	0.110
	Dam end	2002	5	*Micropterus*	*salmoides*	largemouth bass	2	663	364	0.130
	Dam end	2002	5	*Pomoxis*	*annularis*	white crappie	2	207	248	0.057
	Dam end	2007	4	*Cyprinus*	*carpio*	carp	2	1,382	471	0.157
	Dam end	2007	1	*Ictalurus*	*punctatus*	channel catfish	1	1,928	545	0.162
	Dam end	2007	5	*Micropterus*	*salmoides*	largemouth bass	2	795	358	0.126
	Dam end	2007	3	*Micropterus*	*dolomieu*	smallmouth bass	2	404	305	0.174
	Dam end	2007	3	*Sander*	*vitreus*	walleye	2	631	402	0.090
	Quakerstown SRA	2002	5	*Lepomis*	*macrochirus*	bluegill	2	91	166	0.024
	Quakerstown SRA	2002	5	*Cyprinus*	*carpio*	carp	2	1,350	482	0.210
	Quakerstown SRA	2002	5	*Micropterus*	*salmoides*	largemouth bass	2	700	368	0.140
	Quakerstown SRA	2002	2	*Micropterus*	*salmoides*	largemouth bass	2	2,141	495	**0.320**
	Quakerstown SRA	2002	5	*Morone*	*chrysops*	white bass	2	707	384	0.200
	Quakerstown SRA	2007	4	*Pomoxis*	*nigromaculatus*	black crappie	2	271	246	0.059
	Quakerstown SRA	2007	2	*Cyprinus*	*carpio*	carp	2	1,928	521	0.118
	Quakerstown SRA	2007	4	*Ictalurus*	*punctatus*	channel catfish	1	1,023	443	0.091
	Quakerstown SRA	2007	3	*Micropterus*	*salmoides*	largemouth bass	2	602	314	0.073
	Quakerstown SRA	2007	4	*Morone*	*chrysops*	white bass	2	551	329	0.119
Cagles Mill Lake	Near dam	1996	4	*Cyprinus*	*carpio*	carp	2	957	417	0.119
	Near dam	1996	1	*Micropterus*	*salmoides*	largemouth bass	2	912	398	0.195
	Near dam	1996	1	*Micropterus*	*salmoides*	largemouth bass	2	564	341	0.168
	Near dam	2001	10	*Lepomis*	*macrochirus*	bluegill	2	123	181	0.051
	Near dam	2001	3	*Cyprinus*	*carpio*	carp	2	1,351	493	0.240
	Near dam	2001	1	*Ictalurus*	*punctatus*	channel catfish	1	1,106	521	0.130
	Near dam	2001	4	*Micropterus*	*salmoides*	largemouth bass	2	579	352	0.180
	Near dam	2001	1	*Morone*	*saxatilis*	striped bass	2	255	291	0.052
	Near dam	2001	2	*Pomoxis*	*annularis*	white crappie	2	226	308	0.022
	Near dam	2006	4	*Lepomis*	*macrochirus*	bluegill	2	83	161	0.056
	Near dam	2006	3	*Cyprinus*	*carpio*	carp	2	1,068	441	0.216
	Near dam	2006	1	*Aplodinotus*	*grunniens*	freshwater drum	2	252	299	0.261
	Near dam	2006	3	*Micropterus*	*salmoides*	largemouth bass	2	851	379	**0.376**
	Near dam	2006	2	*Micropterus*	*salmoides*	largemouth bass	2	323	284	0.065
	Near dam	2006	6	*Pomoxis*	*annularis*	white crappie	2	113	206	0.058

[1]Sample type code: 1=skin-off fillet; 2=skin-on, scaleless fillet.

Table 1–8. Reservoir fish-tissue sample and mercury data.—Continued

[g, gram; mm, millimeter; Hg conc., mercury concentration; mg/kg, milligram per kilogram; wt., weight; bold indicates wet weight concentration >0.30 mg/kg]

Reservoir	Sample location	Sample date	Number of fish	Genus	Species	Common name	Sample type[1]	Mean fish weight (g)	Mean fish length (mm)	Hg conc. (mg/kg, wet wt.)
Cecil M. Harden Lake	Main lake	1999	3	*Lepomis*	*macrochirus*	bluegill	2	60	151	0.092
	Main lake	1999	3	*Micropterus*	*salmoides*	largemouth bass	2	737	375	0.270
	Main lake	1999	4	*Micropterus*	*salmoides*	largemouth bass	2	312	288	0.140
	Main lake	1999	1	*Carpiodes*	*cyprinus*	quillback	2	946	420	0.160
	Main lake	2004	4	*Pomoxis*	*nigromaculatus*	black crappie	2	159	224	0.079
	Main lake	2004	9	*Lepomis*	*macrochirus*	bluegill	2	78	162	0.126
	Main lake	2004	5	*Cyprinus*	*carpio*	carp	2	1,049	453	**0.421**
	Main lake	2004	2	*Ictalurus*	*punctatus*	channel catfish	1	755	458	0.253
	Main lake	2004	1	*Ictalurus*	*punctatus*	channel catfish	1	2,892	700	**0.426**
	Main lake	2004	3	*Micropterus*	*salmoides*	largemouth bass	2	1,314	433	**0.350**
	Main lake	2004	1	*Morone*	*saxatilis*	striped bass	2	2,693	590	0.155
	Main lake	2004	2	*Morone*	*saxatilis*	striped bass	2	7,201	849	0.242
	Main lake	2004	3	*Morone*	*chrysops*	white bass	2	460	338	0.198
	Main lake	2004	4	*Pomoxis*	*nigromaculatus*	black crappie	2	159	224	0.079
	Main lake	2004	9	*Lepomis*	*macrochirus*	bluegill	2	78	162	0.126
	Main lake	2004	5	*Cyprinus*	*carpio*	carp	2	1,049	453	**0.421**
	Main lake	2004	2	*Ictalurus*	*punctatus*	channel catfish	1	755	458	0.253
	Main lake	2004	1	*Ictalurus*	*punctatus*	channel catfish	1	2,892	700	**0.426**
	Main lake	2004	3	*Micropterus*	*salmoides*	largemouth bass	2	1,314	433	**0.350**
	Main lake	2004	1	*Morone*	*saxatilis*	striped bass	2	2,693	590	0.155
	Main lake	2004	2	*Morone*	*saxatilis*	striped bass	2	7,201	849	0.242
	Main lake	2004	3	*Morone*	*chrysops*	white bass	2	460	338	0.198

[1]Sample type code: 1=skin-off fillet; 2=skin-on, scaleless fillet.

Table 1–8. Reservoir fish-tissue sample and mercury data.—Continued

[g, gram; mm, millimeter; Hg conc., mercury concentration; mg/kg, milligram per kilogram; wt., weight; bold indicates wet weight concentration >0.30 mg/kg]

Reservoir	Sample location	Sample date	Number of fish	Genus	Species	Common name	Sample type[1]	Mean fish weight (g)	Mean fish length (mm)	Hg conc. (mg/kg, wet wt.)
J. Edward Roush Lake	Main lake	1998	4	*Cyprinus*	*carpio*	carp	2	593	347	0.065
	Main lake	1998	5	*Cyprinus*	*carpio*	carp	2	1,656	494	0.149
	Main lake	1998	1	*Cyprinus*	*carpio*	carp	2	2,551	577	0.179
	Main lake	1998	4	*Micropterus*	*salmoides*	largemouth bass	2	196	239	0.064
	Main lake	1998	3	*Pomoxis*	*annularis*	white crappie	2	144	223	0.048
	Main lake	2004	3	*Ictiobus*	*cyprinellus*	bigmouth buffalo	2	1,200	420	0.067
	Main lake	2004	3	*Cyprinus*	*carpio*	carp	2	2,079	533	0.211
	Main lake	2004	2	*Ictalurus*	*punctatus*	channel catfish	1	2,850	673	0.280
	Main lake	2004	2	*Micropterus*	*salmoides*	largemouth bass	2	957	411	**0.442**
	Main lake	2004	8	*Micropterus*	*salmoides*	largemouth bass	2	184	240	0.154
	Main lake	2004	1	*Sander*	*vitreus*	walleye	2	600	397	0.128
	Main lake	2004	4	*Pomoxis*	*annularis*	white crappie	2	396	306	0.190
	Main lake	2004	9	*Pomoxis*	*annularis*	white crappie	2	180	236	0.091
	Main lake	2004	3	*Ictiobus*	*cyprinellus*	bigmouth buffalo	2	1,200	420	0.067
	Main lake	2004	3	*Cyprinus*	*carpio*	carp	2	2,079	533	0.211
	Main lake	2004	2	*Ictalurus*	*punctatus*	channel catfish	1	2,850	673	0.280
	Main lake	2004	2	*Micropterus*	*salmoides*	largemouth bass	2	957	411	**0.442**
	Main lake	2004	8	*Micropterus*	*salmoides*	largemouth bass	2	184	240	0.154
	Main lake	2004	1	*Sander*	*vitreus*	walleye	2	600	397	0.128
	Main lake	2004	4	*Pomoxis*	*annularis*	white crappie	2	396	306	0.190
	Main lake	2004	9	*Pomoxis*	*annularis*	white crappie	2	180	236	0.091
	Main lake	2008	3	*Cyprinus*	*carpio*	carp	2	2,410	580	0.155
	Main lake	2008	3	*Cyprinus*	*carpio*	carp	2	1,030	426	0.115
	Main lake	2008	2	*Aplodinotus*	*grunniens*	freshwater drum	2	403	330	0.121
	Main lake	2008	1	*Aplodinotus*	*grunniens*	freshwater drum	2	1,021	457	0.272
	Main lake	2008	3	*Micropterus*	*salmoides*	largemouth bass	2	759	355	0.068
	Main lake	2008	3	*Micropterus*	*salmoides*	largemouth bass	2	394	286	0.048
	Main lake	2008	5	*Pomoxis*	*annularis*	white crappie	2	399	294	0.062

[1]Sample type code: 1=skin-off fillet; 2=skin-on, scaleless fillet.

Table 1–8. Reservoir fish-tissue sample and mercury data.—Continued

[g, gram; mm, millimeter; Hg conc., mercury concentration; mg/kg, milligram per kilogram; wt., weight; bold indicates wet weight concentration >0.30 mg/kg]

Reservoir	Sample location	Sample date	Number of fish	Genus	Species	Common name	Sample type[1]	Mean fish weight (g)	Mean fish length (mm)	Hg conc. (mg/kg, wet wt.)
Mississinewa Lake	Dam end	1998	3	*Ictalurus*	*punctatus*	channel catfish	1	0	443	0.071
	Dam end	1998	1	*Micropterus*	*dolomieu*	smallmouth bass	2	516	338	0.093
	Dam end	1998	2	*Sander*	*vitreus*	walleye	2	289	323	0.054
	Dam end	1998	3	*Pomoxis*	*annularis*	white crappie	2	0	267	0.093
	Dam end	2008	6	*Lepomis*	*macrochirus*	bluegill	2	92	164	0.040
	Dam end	2008	3	*Cyprinus*	*carpio*	carp	2	1,701	516	0.106
	Dam end	2008	3	*Ictalurus*	*punctatus*	channel catfish	1	1,833	565	0.126
	Dam end	2008	5	*Micropterus*	*salmoides*	largemouth bass	2	1,134	412	0.221
	Dam end	2008	5	*Micropterus*	*salmoides*	largemouth bass	2	611	346	0.097
	Upper end	1998	3	*Micropterus*	*salmoides*	largemouth bass	2	419	309	0.100
	Upper end	1998	3	*Micropterus*	*salmoides*	largemouth bass	2	901	391	0.126
	Red Ridge SRA	2004	5	*Cyprinus*	*carpio*	carp	2	1,576	484	0.259
	Red Ridge SRA	2004	2	*Aplodinotus*	*grunniens*	freshwater drum	2	996	432	**0.322**
	Red Ridge SRA	2004	5	*Micropterus*	*salmoides*	largemouth bass	2	639	342	0.166
	Red Ridge SRA	2004	5	*Micropterus*	*salmoides*	largemouth bass	2	834	379	0.211
	Red Ridge SRA	2004	6	*Morone*	*chrysops*	white bass	2	254	266	0.048
	Red Ridge SRA	2004	5	*Cyprinus*	*carpio*	carp	2	1,576	484	0.259
	Red Ridge SRA	2004	2	*Aplodinotus*	*grunniens*	freshwater drum	2	996	432	**0.322**
	Red Ridge SRA	2004	5	*Micropterus*	*salmoides*	largemouth bass	2	639	342	0.166
	Red Ridge SRA	2004	5	*Micropterus*	*salmoides*	largemouth bass	2	834	379	0.211
	Red Ridge SRA	2004	6	*Morone*	*chrysops*	white bass	2	254	266	0.048
	Pearson Mill Public Access	2008	2	*Ictiobus*	*cyprinellus*	bigmouth buffalo	2	1,588	482	0.035
	Pearson Mill Public Access	2008	5	*Lepomis*	*macrochirus*	bluegill	2	111	174	0.045
	Pearson Mill Public Access	2008	4	*Cyprinus*	*carpio*	carp	2	1,758	504	0.139
	Pearson Mill Public Access	2008	5	*Micropterus*	*salmoides*	largemouth bass	2	504	336	0.104
	Pearson Mill Public Access	2008	4	*Micropterus*	*salmoides*	largemouth bass	2	204	243	0.038
	Pearson Mill Public Access	2008	5	*Carpiodes*	*carpio*	river carpsucker	2	640	372	0.110

[1]Sample type code: 1=skin-off fillet; 2=skin-on, scaleless fillet.

Table 1–8. Reservoir fish-tissue sample and mercury data.—Continued

[g, gram; mm, millimeter; Hg conc., mercury concentration; mg/kg, milligram per kilogram; wt., weight; bold indicates wet weight concentration >0.30 mg/kg]

Reservoir	Sample location	Sample date	Number of fish	Genus	Species	Common name	Sample type[1]	Mean fish weight (g)	Mean fish length (mm)	Hg conc. (mg/kg, wet wt.)
Monroe Lake	Salt Creek Boat Ramp	1996	2	*Ameiurus*	*melas*	black bullhead	1	400	295	0.098
	Salt Creek Boat Ramp	1996	2	*Cyprinus*	*carpio*	carp	2	3,363	599	0.122
	Salt Creek Boat Ramp	1996	3	*Cyprinus*	*carpio*	carp	2	2,204	551	0.146
	Salt Creek Boat Ramp	1996	2	*Micropterus*	*salmoides*	largemouth bass	2	332	296	**0.480**
	Salt Creek Boat Ramp	2002	8	*Lepomis*	*macrochirus*	bluegill	2	97	171	0.300
	Salt Creek Boat Ramp	2002	3	*Cyprinus*	*carpio*	carp	2	2,457	575	0.140
	Salt Creek Boat Ramp	2002	2	*Ictalurus*	*punctatus*	channel catfish	1	720	442	0.190
	Salt Creek Boat Ramp	2002	4	*Micropterus*	*salmoides*	largemouth bass	2	338	307	**0.460**
	Salt Creek Boat Ramp	2002	2	*Sander*	*vitreus*	walleye	2	1,120	497	0.230
	Salt Creek Boat Ramp	2002	1	*Morone*	*chrysops*	white bass	2	380	632	**0.700**
	Salt Creek Boat Ramp	2002	1	*Pomoxis*	*annularis*	white crappie	2	784	370	**0.320**
	Dam end	1996	5	*Lepomis*	*macrochirus*	bluegill	2	92	175	0.159
	Dam end	1996	1	*Micropterus*	*salmoides*	largemouth bass	2	780	405	**0.446**
	Dam end	1996	3	*Micropterus*	*salmoides*	largemouth bass	2	339	301	**0.415**
	Dam end	1996	3	*Micropterus*	*salmoides*	largemouth bass	2	563	352	**0.403**
	Dam end	2002	5	*Lepomis*	*macrochirus*	bluegill	2	102	177	0.120
	Dam end	2002	3	*Cyprinus*	*carpio*	carp	2	1,587	497	0.130
	Dam end	2002	2	*Micropterus*	*salmoides*	largemouth bass	2	1,077	405	**0.310**
	Dam end	2002	9	*Micropterus*	*salmoides*	largemouth bass	2	418	324	**0.320**
	Dam end	2002	4	*Lepomis*	*megalotis*	longear sunfish	2	65	145	0.180
	Dam end	2002	2	*Lepomis*	*microlophus*	redear sunfish	2	121	190	0.100
	Dam end	2002	1	*Sander*	*vitreus*	walleye	2	3,175	675	**0.910**
	Pinegrove SRA	2007	9	*Lepomis*	*macrochirus*	bluegill	2	70	155	0.130
	Pinegrove SRA	2007	3	*Cyprinus*	*carpio*	carp	2	2,183	527	0.210
	Pinegrove SRA	2007	1	*Ictalurus*	*punctatus*	channel catfish	1	1,474	540	0.155
	Pinegrove SRA	2007	3	*Micropterus*	*salmoides*	largemouth bass	2	964	375	**0.355**
	Pinegrove SRA	2007	5	*Micropterus*	*salmoides*	largemouth bass	2	414	310	0.154
	Pinegrove SRA	2007	2	*Sander*	*vitreus*	walleye	2	1,418	524	0.210
	Pinegrove SRA	2007	2	*Pomoxis*	*annularis*	white crappie	2	432	307	0.159
	Pinegrove SRA	2007	1	*Morone*	*chrysopsxsaxatilis*	wiper	2	2,155	535	**0.481**
	Allens Creek SRA	2007	10	*Lepomis*	*macrochirus*	bluegill	2	87	166	0.068
	Allens Creek SRA	2007	3	*Cyprinus*	*carpio*	carp	2	2,901	582	0.116
	Allens Creek SRA	2007	3	*Micropterus*	*salmoides*	largemouth bass	2	2,003	480	**0.556**
	Allens Creek SRA	2007	5	*Micropterus*	*salmoides*	largemouth bass	2	526	336	0.175
	Allens Creek SRA	2007	2	*Sander*	*vitreus*	walleye	2	2,835	648	**0.848**
	Allens Creek SRA	2007	3	*Sander*	*vitreus*	walleye	2	1,729	554	**0.698**
	Allens Creek SRA	2007	3	*Sander*	*vitreus*	walleye	2	983	464	0.175
	Allens Creek SRA	2007	4	*Pomoxis*	*annularis*	white crappie	2	163	223	0.152
	Allens Creek SRA	2007	3	*Morone*	*mississippiensis*	yellow bass	2	155	226	0.248

[1]Sample type code: 1=skin-off fillet; 2=skin-on, scaleless fillet.

Table 1–8. Reservoir fish-tissue sample and mercury data.—Continued

[g, gram; mm, millimeter; Hg conc., mercury concentration; mg/kg, milligram per kilogram; wt., weight; bold indicates wet weight concentration >0.30 mg/kg]

Reservoir	Sample location	Sample date	Number of fish	Genus	Species	Common name	Sample type[1]	Mean fish weight (g)	Mean fish length (mm)	Hg conc. (mg/kg, wet wt.)
Patoka Lake	Lick Fork Branch	1996	1	*Cyprinus*	*carpio*	carp	2	3,490	607	0.154
	Lick Fork Branch	1996	1	*Cyprinus*	*carpio*	carp	2	829	387	0.098
	Lick Fork Branch	1996	5	*Micropterus*	*salmoides*	largemouth bass	2	382	322	0.509
	Lick Fork Branch	2001	8	*Lepomis*	*macrochirus*	bluegill	2	53	151	0.024
	Lick Fork Branch	2001	3	*Cyprinus*	*carpio*	carp	2	2,136	555	0.140
	Lick Fork Branch	2001	3	*Micropterus*	*salmoides*	largemouth bass	2	1,247	412	0.190
	Lick Fork Branch	2006	2	*Cyprinus*	*carpio*	carp	2	2,197	534	0.158
	Lick Fork Branch	2006	2	*Aplodinotus*	*grunniens*	freshwater drum	2	556	361	0.060
	Lick Fork Branch	2006	5	*Micropterus*	*salmoides*	largemouth bass	2	869	378	**0.304**
	Lick Fork Branch	2006	1	*Micropterus*	*dolomieu*	smallmouth bass	2	808	387	0.195
	Lick Fork Branch	2006	2	*Minytrema*	*melanops*	spotted sucker	2	782	406	0.207
	Patoka River, upper end	1996	2	*Micropterus*	*salmoides*	largemouth bass	2	412	327	**0.634**
	Patoka River, upper end	2001	8	*Lepomis*	*macrochirus*	bluegill	2	47	140	0.023
	Patoka River, upper end	2001	3	*Cyprinus*	*carpio*	carp	2	2,315	560	**0.470**
	Patoka River, upper end	2001	3	*Micropterus*	*salmoides*	largemouth bass	2	1,493	467	**0.500**
	Patoka River, upper end	2006	5	*Lepomis*	*macrochirus*	bluegill	2	58	147	0.073
	Patoka River, upper end	2006	3	*Cyprinus*	*carpio*	carp	2	2,637	602	0.198
	Patoka River, upper end	2006	2	*Ictalurus*	*punctatus*	channel catfish	1	3,147	636	0.221
	Patoka River, upper end	2006	1	*Aplodinotus*	*grunniens*	freshwater drum	2	848	400	0.098
	Patoka River, upper end	2006	2	*Micropterus*	*salmoides*	largemouth bass	2	933	379	**0.324**
	Patoka River, upper end	2006	2	*Micropterus*	*salmoides*	largemouth bass	2	609	353	**0.308**

[1]Sample type code: 1=skin-off fillet; 2=skin-on, scaleless fillet.

Table 1–8. Reservoir fish-tissue sample and mercury data.—Continued

[g, gram; mm, millimeter; Hg conc., mercury concentration; mg/kg, milligram per kilogram; wt., weight; bold indicates wet weight concentration >0.30 mg/kg]

Reservoir	Sample location	Sample date	Number of fish	Genus	Species	Common name	Sample type[1]	Mean fish weight (g)	Mean fish length (mm)	Hg conc. (mg/kg, wet wt.)
Salamonie Lake	Lost Bridge SRA	2004	1	*Cyprinus*	*carpio*	carp	2	1,814	501	0.245
	Lost Bridge SRA	2004	4	*Ictalurus*	*punctatus*	channel catfish	1	980	490	0.173
	Lost Bridge SRA	2004	1	*Aplodinotus*	*grunniens*	freshwater drum	2	487	344	0.195
	Lost Bridge SRA	2004	5	*Micropterus*	*salmoides*	largemouth bass	2	364	292	0.122
	Lost Bridge SRA	2004	3	*Micropterus*	*salmoides*	largemouth bass	2	1,125	410	**0.395**
	Lost Bridge SRA	2004	1	*Pomoxis*	*annularis*	white crappie	2	346	374	0.100
	Lost Bridge SRA	2004	6	*Pomoxis*	*annularis*	white crappie	2	121	213	0.141
	Lost Bridge SRA	2004	1	*Cyprinus*	*carpio*	carp	2	1,814	501	0.245
	Lost Bridge SRA	2004	4	*Ictalurus*	*punctatus*	channel catfish	1	980	490	0.173
	Lost Bridge SRA	2004	1	*Aplodinotus*	*grunniens*	freshwater drum	2	487	344	0.195
	Lost Bridge SRA	2004	5	*Micropterus*	*salmoides*	largemouth bass	2	364	292	0.122
	Lost Bridge SRA	2004	3	*Micropterus*	*salmoides*	largemouth bass	2	1,125	410	**0.395**
	Lost Bridge SRA	2004	1	*Pomoxis*	*annularis*	white crappie	2	346	374	0.100
	Lost Bridge SRA	2004	6	*Pomoxis*	*annularis*	white crappie	2	121	213	0.141
	Dam end	1998	2	*Lepomis*	*macrochirus*	bluegill	2	140	181	0.100
	Dam end	1998	4	*Cyprinus*	*carpio*	carp	2	2,297	551	0.161
	Dam end	1998	4	*Cyprinus*	*carpio*	carp	2	1,595	484	0.180
	Dam end	1998	3	*Micropterus*	*salmoides*	largemouth bass	2	807	385	0.212
	Dam end	1998	2	*Micropterus*	*salmoides*	largemouth bass	2	1,021	418	**0.310**
	Dam end	1998	2	*Micropterus*	*salmoides*	largemouth bass	2	1,215	441	0.253
	Dam end	1998	1	*Sander*	*vitreus*	walleye	2	992	475	0.100
	Dam end	1998	1	*Morone*	*chrysops*	white bass	2	554	355	0.213
	Dam end	1998	2	*Pomoxis*	*annularis*	white crappie	2	210	256	0.125
	Dam end	1998	12	*Pomoxis*	*annularis*	white crappie	2	74	180	0.102
	Lost Bridge SRA	2008	1	*Ictiobus*	*cyprinellus*	bigmouth buffalo	2	5,982	654	0.116
	Lost Bridge SRA	2008	3	*Cyprinus*	*carpio*	carp	2	3,119	607	0.169
	Lost Bridge SRA	2008	1	*Aplodinotus*	*grunniens*	freshwater drum	2	1,758	490	**0.336**
	Lost Bridge SRA	2008	3	*Aplodinotus*	*grunniens*	freshwater drum	2	243	289	0.105
	Lost Bridge SRA	2008	6	*Micropterus*	*salmoides*	largemouth bass	2	511	325	0.055
	Lost Bridge SRA	2008	4	*Micropterus*	*salmoides*	largemouth bass	2	300	271	0.041
	Lost Bridge SRA	2008	10	*Pomoxis*	*annularis*	white crappie	2	174	229	0.020

[1]Sample type code: 1=skin-off fillet; 2=skin-on, scaleless fillet.

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