Prepared in cooperation with the Shoshone-Paiute Tribes of the Duck Valley Indian Reservation

Evaluation of Mercury in Rainbow Trout Collected from Duck Valley Indian Reservation Reservoirs, Southwestern Idaho and Northern Nevada, 2007, 2009, and 2013

Scientific Investigations Report 2015–5079

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

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SALLY JEWELL, Secretary

U.S. Geological Survey
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U.S. Geological Survey, Reston, Virginia: 2015

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Suggested citation:
Williams, M.L., MacCoy, D.E., and Maret, T.R., 2015, Evaluation of mercury in rainbow trout collected from Duck Valley Indian Reservation reservoirs, southwestern Idaho and northern Nevada, 2007, 2009, and 2013: U.S. Geological Survey Scientific Investigations Report 2015–5079, 18 p., http://dx.doi.org/10.3133/sir20155079.

ISSN 2328-0328 (online)

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
	Area	
acre	4,047	square meter (m^2)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Mass	
ounce, avoirdupois (oz)	28.35	gram (g)
pound, avoirdupois (lb)	0.4536	kilogram (kg)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
kilometer (km)	0.6214	mile (mi)
	Mass	
milligram (mg)	0.00003527	ounce, avoirdupois (oz)
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)

Abbreviations

ANOVA	analysis of variance
CRM	certified reference material
Hg	mercury
IDEQ	Idaho Department of Environmental Quality
IFCAP	Idaho Fish Consumption Advisory Program
IAEA	International Atomic Energy Agency
MDN	Mercury Deposition Network
MeHg	methylmercury
NADP	National Atmospheric Deposition Program
QC	quality-control
RPTE	reasonable potential to exceed
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
USGS MRL	U.S. Geological Survey Mercury Research Laboratory

Evaluation of Mercury in Rainbow Trout Collected from Duck Valley Indian Reservation Reservoirs, Southwestern Idaho and Northern Nevada, 2007, 2009, and 2013

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Abstract

The U.S. Geological Survey, in cooperation with the Shoshone-Paiute Tribes of the Duck Valley Indian Reservation, analyzed mercury (Hg) concentration in rainbow trout (*Oncorhynchus mykiss*) collected from three reservoirs on the reservation (Mountain View, Lake Billy Shaw, and Sheep Creek) during sampling events in 2007, 2009, and 2013, to determine the risk of Hg exposure to Tribal members and the general public.

Mercury concentration in predatory fish tends to increase with fish length, and this tendency was true for rainbow trout in the reservoirs on the reservation ($r^2 = 0.44–0.70$). Mean (average) and median Hg concentrations in fish tissue were determined for each reservoir for each sample year. All Hg concentrations were less than the U.S. Environmental Protection Agency's water-quality criterion of 0.30 milligram per kilogram (mg/kg wet weight [ww]) and the Idaho Department of Environmental Quality's reasonable potential to exceed threshold of 0.24 mg/kg. Idaho Department of Health and Welfare toxicologists determined that the Hg concentrations in rainbow trout in this study would not warrant a fish-consumption advisory for this species.

Throughout this report, statistical findings with a *p*-value of less than 0.05 are referred to as "significant." Mean Hg concentrations in fish-tissue samples collected from Mountain View Reservoir were higher in 2007 (0.12 mg/kg ww) than in 2009 and 2013 (0.07 and 0.06 mg/kg ww, respectively), indicating a significant mean decrease. Mean Hg concentrations in fish-tissue samples collected from Lake Billy Shaw showed no significant differences among sample years (2007, 0.12 mg/kg ww; 2009, 0.07 mg/kg ww; 2013, 0.09 mg/kg ww). Mean Hg concentrations in fish-tissue samples collected from Sheep Creek Reservoir significantly increased in 2013 (0.10 mg/kg ww) from concentrations in 2007 and 2009 (0.06 and 0.05 mg/kg ww, respectively). These temporal and spatial variations are not unexpected, as each body of water may differ in the factors and conditions affecting the rate of methylation and demethylation.

Coupled with the dynamic put-and-take fishery, the outcomes reflect the system complexities among reservoirs despite their fairly close proximity to one another. The influence of these other factors is evident when the analysis of atmospheric Hg deposition at Mercury Deposition Network site NV02 in northern Nevada showed no significant linear trend in wet Hg deposition rates for 2003–2013 (average 3.02 micrograms per square meter).

Introduction

The Duck Valley Indian Reservation spans the border of Idaho and Nevada (fig. 1). The reservation, established by executive order on April 16, 1877, is home to about 2,000 members of the Shoshone-Paiute Tribes (hereafter referred to as "the Tribes"). The Tribes manage three reservoirs (Mountain View, Lake Billy Shaw, and Sheep Creek Reservoirs) on the reservation as a subsistence fishery, and sport fishery for recreation and economic benefit. The Tribes have expressed concern about the potential for mercury (Hg) contamination of these reservoirs and their aquatic biota. Research conducted in 2005 by Abbot and others (2008) from the U.S. Department of Energy Idaho National Laboratory showed elevated levels of atmospheric Hg entering southern Idaho from gold processing sites in northern Nevada. Average Hg concentrations of trout sampled from nearby Nevada waters in 2005 and 2006 were 0.09–0.17 mg/kg ww (Nevada Department of Wildlife, 2007). Because of mercury's potential toxicity to humans, the Tribes needed more information on the occurrence of Hg concentrations in their fishery to help determine if those concentrations posed a risk to Tribal members and the general public. To determine the bioaccumulation of Hg in the Tribes' rainbow trout fishery and the potential risk to the consumers, the U.S. Geological Survey (USGS) began monitoring Hg concentrations in rainbow trout in the reservation's three reservoirs in 2007, with additional sampling conducted in the 2009 and 2013.

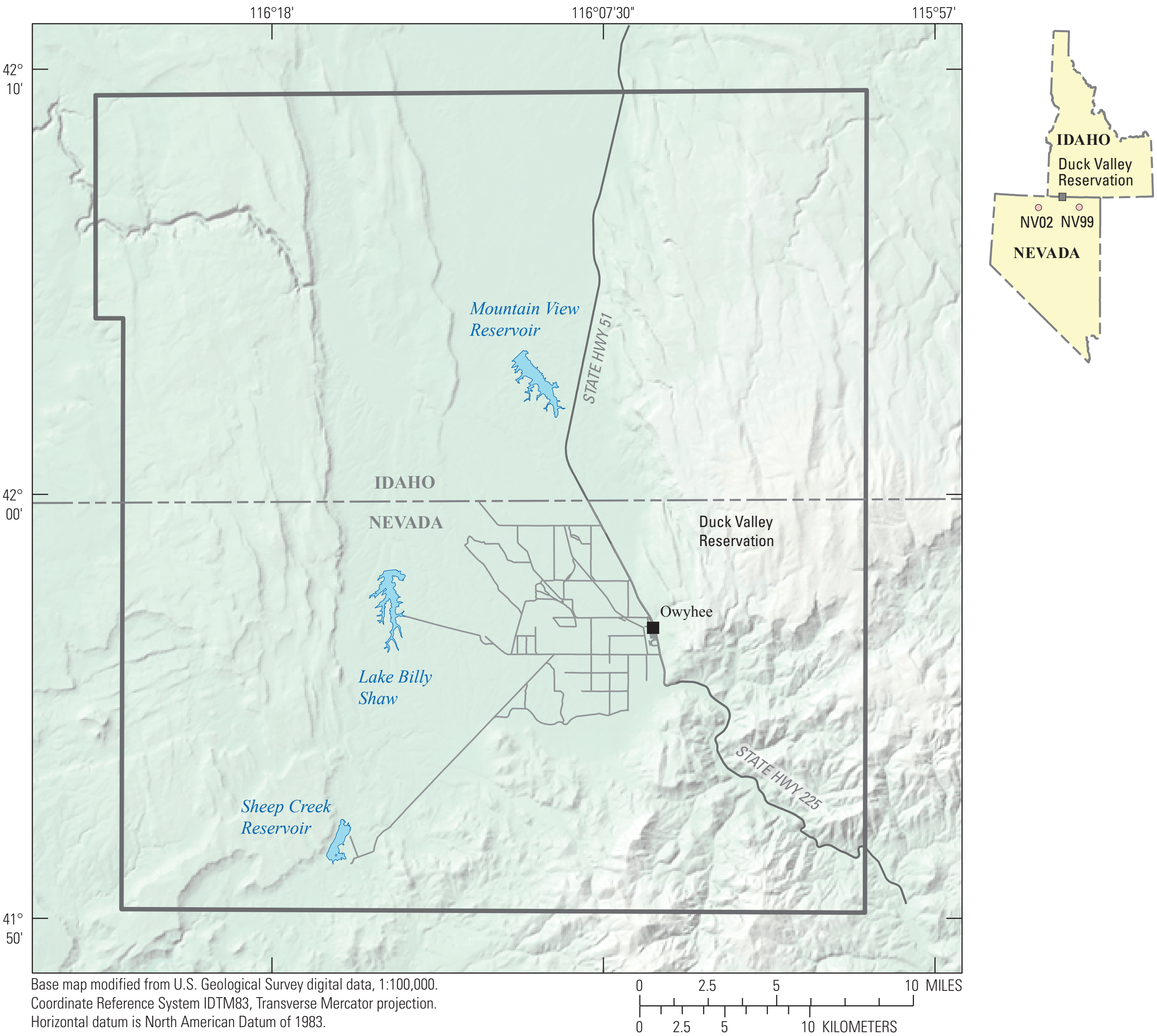

Figure 1. Location of Duck Valley Indian Reservation reservoirs and Mercury Deposition Network sites (NV02 and NV99), southwestern Idaho and northern Nevada.

Mercury is a global pollutant that ultimately makes its way into every aquatic ecosystem through the hydrologic cycle. Atmospheric deposition of inorganic Hg contributes the vast majority of Hg to aquatic systems as either dry fall or scavenged during precipitation events, although geologic sources and point-source pollution also may contribute to Hg loading (Rada and others, 1989; Fitzgerald and others, 1991; Kamman and Engstrom, 2002). Once it is in aquatic systems, inorganic Hg may become methylated through microbial sulfate and iron reduction (Fitzgerald and Lamborg, 2003; Fleming and others, 2006; Kerin and others, 2006). Reservoirs are particularly prone to Hg methylation because of increased microbial activity that results from water-level fluctuations; they can also respond quickly to direct Hg deposition (Sorensen and others, 2005; Wiener and others, 2007; Brigham and others, 2014). Methylmercury (MeHg) is the more bioavailable and toxic form of Hg; once Hg has moved through aquatic food chains into predatory fish, almost all Hg present in fish tissue is MeHg. In turn, sport fish that are most commonly captured and consumed by subsistence or recreational anglers tend to be predatory fish.

As a result of these dynamics, risks of human exposure to MeHg are primarily through consumption of fish (U.S. Environmental Protection Agency, 2001). Sources of Hg often are not well quantified. However, they likely include atmospheric deposition, historical gold mining operations, and natural sources. The U.S. Environmental Protection Agency (USEPA, 2015) Toxic Release inventory for data from 2001 to 2013 shows that most Hg (stack) emissions in Nevada come from gold mining and processing facilities. Mercury often is released from thermal processes where it enters the air during the gold extraction process (Jones and Miller, 2005). Air emissions from these mining and processing facilities may travel great distances, affecting States throughout the Intermountain West. In 2001, USEPA toxic release inventory data showed that Nevada metal mining companies reported releasing about 9 percent of total U.S. mercury compounds as point source (stack) emissions. This amount has steadily decreased, becoming 6.5 percent of the total U.S. emissions in 2002, 3.6 percent in 2003 (Jones and Miller, 2005), and 1.4 percent in 2013. Overall, reported Hg mass from stack emissions attributed to mines and mine processing in Nevada has decreased from about 11,800 lb in 2001 to 932 lb in 2013, a 92 percent decrease (U.S. Environmental Protection Agency, 2015).

Regulatory Guidance

The USEPA recommended a water-quality criterion for MeHg expressed as a fish-tissue residue value (MeHg in fish tissue) of 0.30 mg/kg ww (U.S. Environmental Protection Agency, 2001). The MeHg criterion is based on fresh weight, appropriately indicating the nature of fish destined for human consumption. This criterion is based on protecting an adult consumer who eats an average of 17.5 g of fish per day, equivalent to about one 8-ounce serving every other week (U.S. Environmental Protection Agency, 2001; Idaho Department of Environmental Quality, 2005).

The Idaho Department of Environmental Quality (IDEQ) adopted the USEPA fish-tissue criterion and established a reasonable potential to exceed (RPTE) threshold designed to protect consumers that is 20 percent lower than the criterion or Hg greater than 0.24 mg/kg ww based on an average concentration of 10 fish from a receiving waterbody (Idaho Department of Environmental Quality, 2005). The Idaho Fish Consumption Advisory Program (IFCAP) applies an even lower action level of 0.22 mg/kg ww Hg, which is compared to the geometric mean Hg concentration of 10 fish of a single species collected from a single water body (lake or stream). IFCAP compares the action level and angling usage of each water body to determine if a consumption advisory should be issued.

For this study, total Hg is analyzed in place of MeHg in fish tissue for two reasons: (1) total Hg is easier and less costly for laboratories to determine than MeHg, and (2) nearly all Hg present in fish muscle tissue is MeHg (Bloom, 1992; Hammerschmidt and others, 1999; Harris and others, 2003). In comparing fish-tissue results with the criterion, the analytical results for total Hg in the fish tissue should be interpreted as 100 percent MeHg. For the remainder of this report, total Hg analyzed in fish tissue will be referred to as “Hg”.

Purpose and Scope

This report presents the results of the fish tissue analysis from samples collected from three reservoirs on the Duck Valley Indian Reservation in 2007, 2009, and 2013 in order to identify changes in fish-tissue Hg concentration within and between reservoirs for different sampling periods. A summary of annual atmospheric deposition rates measured at one of two northern Nevada Mercury Deposition Network (MDN) sites also is included. The scope of the investigation is limited to rainbow trout in the range of sizes people are likely to catch and eat from the reservoirs on the reservation.

Description of Study Area

Duck Valley Indian Reservation encompasses nearly 290,000 acres, of which 22,000 acres are wetlands. Three reservoirs were created on the reservation as a subsistence fishery, but they also provide the Tribes with a valued sport fishery for recreation and economic benefit (fig. 1). Mountain View Reservoir lies in the north-central part of the reservation and is about 2 mi long with a surface area of about 630 acres. Lake Billy Shaw is about 9 mi southwest of Mountain View Reservoir and covers about 430 surface acres near the central area of the reservation. Sheep Creek Reservoir is 6 mi south of Lake Billy Shaw in the south-west area of the reservation and covers about 855 surface acres. The perimeters of the reservoirs are shallow coves with riparian vegetation consisting of cattails, willows, and other aquatic vegetation; upland areas around the reservoirs primarily are sagebrush and grasses.

Data Quality Objectives

Data-quality objectives for sample collection, analysis, and reporting for this study are listed as follows, and provide Hg concentrations in fish-tissue data collected from Mountain View, Lake Billy Shaw, and Sheep Creek Reservoirs:

1. Collect fish that represent the size range (>25 cm) likely to be captured and consumed by recreational or subsistence anglers near the sampling sites (table 2, at back of report).
2. Analyze hatchery trout provided by the Tribes from the Black Canyon Trout Farm in Grace, Idaho, as background samples for Hg concentration in stocked fish (table 2).
3. Use sample processing, handling, storage, shipping, and quality-assurance protocols sufficient to avoid introducing sample contamination or bias to the data.
4. Use laboratory analytical techniques that have sufficiently low detection limits to quantify Hg concentrations in fish tissue at less than 0.24 mg/kg ww (Idaho RPTE threshold).
5. Analyze quality-control samples to provide accuracy and precision information for the fish-tissue samples collected (table 3, at back of report). Quality control included analysis of certified reference material (CRM) to verify instrument calibration (accuracy), and analyses of triplicate fish-tissue samples as an assessment of repeatability (precision) for all sample years. In 2009 and 2013, field duplicates were added as an additional measure of quality control.
6. Following review, provide fish-tissue data to the Tribes, to the general public through the USGS National Water Information System, and in this report.

Sampling and Analysis

Field Sampling Methods

Fifteen rainbow trout (*Oncorhynchus mykiss*) were collected from each of the reservoirs (Mountain View, Lake Billy Shaw, and Sheep Creek Reservoirs) for each sample year (2007, 2009, and 2013). One fish from Lake Billy Shaw in 2013 was not analyzed because of an external injury. Sampling in 2007 was conducted in late May, and samples in 2009 and 2013 were collected during the first week of June. Because one of the objectives was to sample a range of fish in sizes people are likely to catch and eat, experimental gill nets (mesh with several size openings) were used to reduce the effect of size selection based on a single mesh size (Hubert, 1983). These nets were used to collect samples, with the exception of fish collected on Sheep Creek Reservoir in 2007 when electrofishing was used. Fish were collected and stored in a live well on the boat during daily sampling events. Each fish was then measured, weighed, euthanized, and placed in separate clean, clear, zip-seal bags on wet ice; all fish were frozen within 24 hours of capture. Sample preparation followed guidelines in U.S. Environmental Protection Agency (2000) and Scudder and others (2008); final sample processing was conducted at the USGS Idaho Water Science Center's sample preparation area in Boise, Idaho. Individual samples, consisting of a 1-in. skinless fillet, were taken from each fish just below the dorsal fin (Goldstein and others, 1996). The samples were placed in self-sealing plastic bags, labeled, and frozen; they later were packed on dry ice for shipment to the USGS Mercury Research Laboratory (USGS MRL) in Middleton, Wisconsin, for analysis.

Fish-Tissue Laboratory Analysis

The USGS MRL provided analysis of Hg in fish tissue consistent with USEPA Method 7473 (U.S. Environmental Protection Agency, 2007). This method provides a minimum detection limit of 0.008 mg/kg dry weight (dw), based on a 20–50 mg sample size. The detection limit is sufficiently low to quantify Hg concentrations in fish tissue at less than 0.22 mg/kg ww required for IFCAP fish consumption advisory assessments.

Atmospheric Mercury Deposition Data Analysis

The USEPA operates two mercury wet deposition sites in northern Nevada (NV02 and NV99), upwind of the Duck Valley Indian Reservation as part of the National Atmospheric Deposition Program's (NADP) Mercury Deposition Network (MDN) (fig. 1). Wind vector and frequency analysis from a remote automated weather station on the reservation (Western Regional Climate Center, 2014) indicates that 44 percent of the prevailing winds are from the southwest compass quadrant, making site NV02, about 68 mi southwest of Sheep Creek Reservoir—the obvious choice for comparison of the Hg deposition rates in relation to reservoir fish samples. Details of the NADP methods and quality-assurance information are available online (National Atmospheric Deposition Program, 2014a). In general, Hg deposition data are collected at the MDN site and analyzed weekly for mercury deposition, summarized and normalized by precipitation, and reported to the public as an annual precipitation weighted wet Hg deposition rate (National Atmospheric Deposition Program, 2014b). Data from NADP for 2003–2013 were used to assess trends in Hg deposition on the reservation. Analysis of data outside of the tissue sampling year is helpful because elemental Hg may take years to enter into an aquatic system (Harris and others, 2007). Temporal trend testing was done through simple linear regression procedures using NCSS 10 data analysis software (NCSS Statistical Software, 2015). The annual depositional rate at site NV02 was regressed against year; a slope that is significant ($p<0.05$) indicates a trend.

Statistical Analysis

Analysis of variance (ANOVA) one-way parametric analysis was used to test the significance of difference in mean fish-tissue Hg concentrations for individual reservoirs among years. Because Hg concentration was positively correlated to fish length (fig. 2), Hg concentration was normalized by fish length, and then log transformed to remove much of the heteroscedasticity (unequal variance) of residuals. Data were assumed to be normally distributed. Significant differences were determined if the F-ratio exceeded the critical value ($p < 0.05$). For tests that indicated a significant difference, a multiple comparison test (Fisher's LSD, $\alpha = 0.05$) was used to determine which years were significantly different. All ANOVA and multiple comparison statistical tests were done using NCSS 10 data analysis software (NCSS Statistical Software, 2015). A Mann-Kendall test also was run on the normalized and transformed data to determine monotonic change (trend) of Hg concentration in relation to time. The null hypothesis of "no change" is rejected if the S statistic is significantly different from 0 ($p < 0.05$). The Mann-Kendall statistical test was performed with a USGS software package (Helsel and others, 2006).

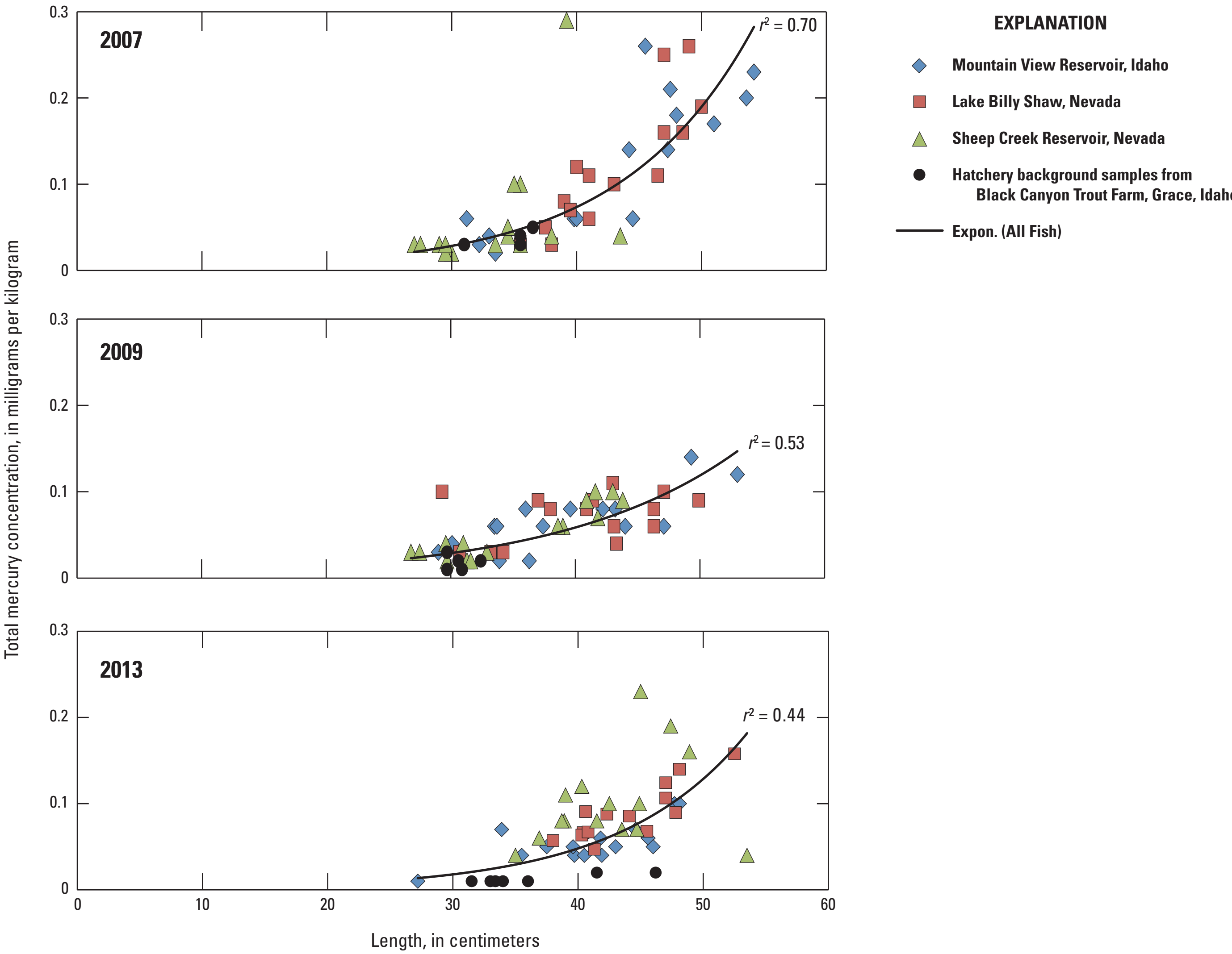

Figure 2. Mercury concentration in fish tissue by length from Duck Valley Indian Reservation reservoirs and hatchery background samples from the Black Canyon Trout Farm, southwestern Idaho and northern Nevada, 2007, 2009, and 2013.

Results and Discussion

Rainbow Trout Mercury Concentrations

Predatory fish generally tend to bioaccumulate Hg, with larger fish having higher Hg concentrations. Graphs of Hg concentration by fish length (fig. 2) show this principle for each of the sample years and each of the reservoirs. In aggregate, the correlation between fish length and Hg concentration was highest in 2007 ($r^2=0.70$), and decreased in subsequent years to $r^2=0.53$ (2009) and $r^2=0.44$ (2013).

Mean fish-tissue Hg concentrations significantly decreased in Mountain View Reservoir ($p=0.01$) between 2007 (0.12 mg/kg ww) and 2009 (0.07 mg/kg ww) (table 1) and changed little between 2009 (0.07 mg/kg ww) and 2013 (0.06 mg/kg ww). Results of the Mann-Kendall trend test showed a significant decreasing trend in Hg concentration in Mountain View Reservoir between 2007 and 2013 ($p<0.001$). Mean Hg concentration among the sample years in Lake Billy Shaw showed variance in Hg concentrations between sample years (2007, 0.12 mg/kg ww; 2009, 0.07 mg/kg ww; 2013, 0.09 mg/kg ww) with no significant difference between means ($p=0.14$), and no temporal trend observed ($p=0.31$). Mean Hg concentrations increased in Sheep Creek Reservoir ($p<0.01$) between 2009 (0.05 mg/kg ww) and 2013 (0.10 mg/kg ww), with minimal change in concentration between 2007 (0.06 mg/kg ww) and 2009 (0.05 mg/kg ww) (table 1); this reservoir showed an increasing trend in Hg concentration ($p<0.01$).

Hg concentrations exceeded the RPTE threshold of 0.24 mg/kg ww in only 3 of the 134 fish sampled in the reservoirs during the 3 sampling years, and did not exceed the IDEQ water-quality criterion of 0.30 mg/kg ww in any of the fish sampled in the reservoirs for any of the sampled years. In 2007, Hg concentrations exceeded the RPTE threshold in one fish from each of the reservoirs—Mountain View Reservoir (0.26 mg/kg ww); Lake Billy Shaw (0.26 mg/kg ww); and Sheep Creek Reservoir (0.29 mg/kg ww) (table 1, fig. 3). Hg concentrations did not exceed the RPTE threshold limit in any of the fish sampled in 2009 or 2013 (fig. 3). Idaho Department of Health and Welfare toxicologists determined that the Hg concentrations in rainbow trout in this study would not warrant a fish consumption advisory (Jim Vannoy, Idaho Department of Health and Welfare, written commun., December 11, 2009, and March 11, 2014).

Table 1. Statistical summary of annual sampling events for Duck Valley Indian Reservation reservoirs, southwestern Idaho and northern Nevada, 2007, 2009, and 2013.

[Site locations are shown in figure 1. mg/kg, milligram per killogram]

Sample year	Mercury (mg/kg wet weight) Geometric mean per site	Median per site	Mean per site	Standard deviation	Minimum	Maximum	Number of samples
Mountain View Reservoir, Idaho							
2007	0.10	0.14	0.12	0.08	0.02	0.26	15
2009	0.06	0.06	0.07	0.03	0.02	0.14	15
2013	0.05	0.05	0.06	0.02	0.01	0.10	15
Lake Billy Shaw, Nevada							
2007	0.10	0.11	0.12	0.07	0.03	0.26	15
2009	0.07	0.08	0.07	0.03	0.03	0.11	15
2013	0.08	0.09	0.09	0.03	0.05	0.16	14
Sheep Creek Reservoir, Nevada							
2007	0.04	0.03	0.06	0.07	0.02	0.29	15
2009	0.05	0.04	0.05	0.03	0.02	0.10	15
2013	0.09	0.08	0.10	0.05	0.04	0.23	15

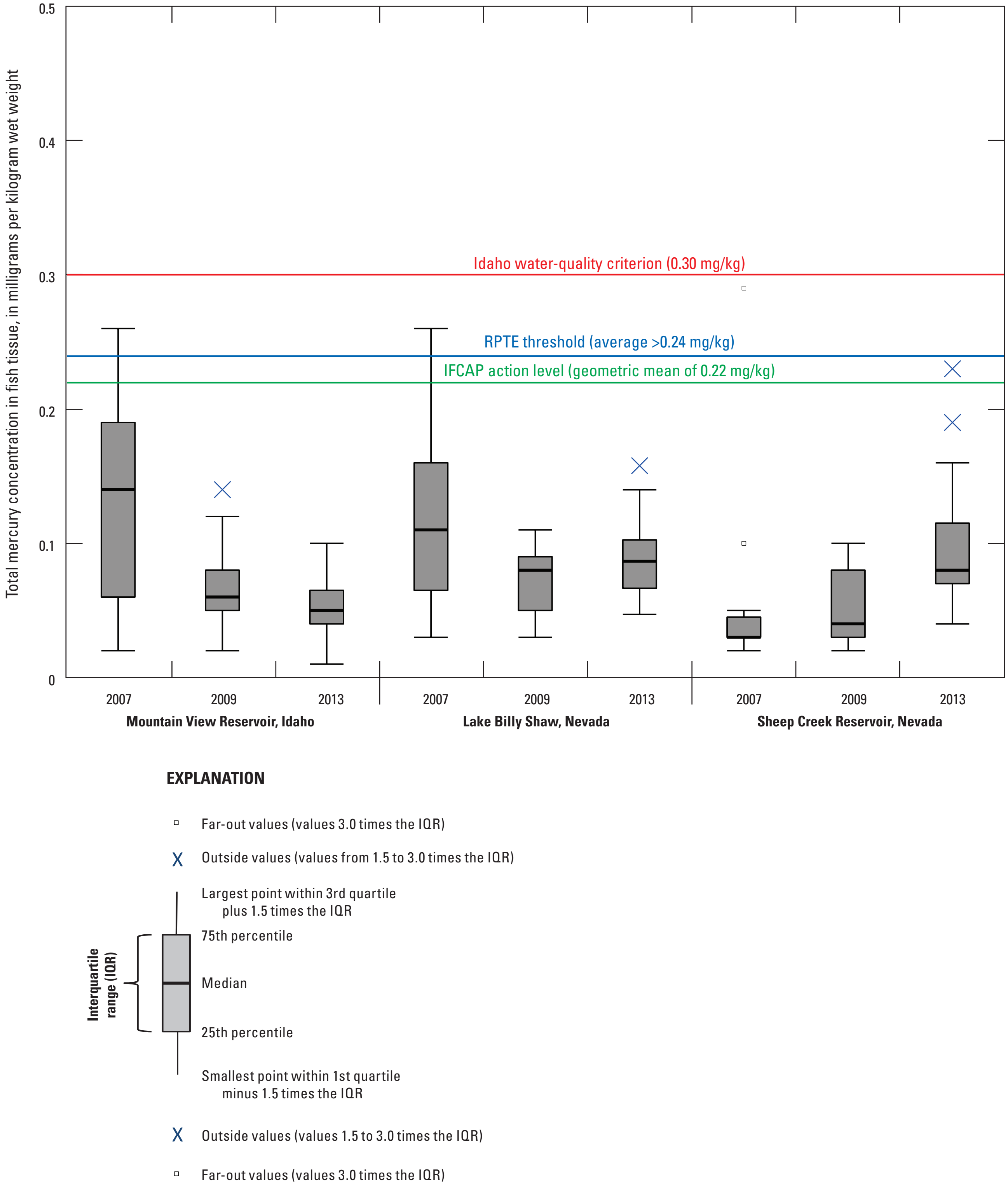

Figure 3. Sample concentration by year for rainbow trout sampled from Duck Valley Indian Reservation reservoirs, southwestern Idaho and northern Nevada, 2007, 2009, and 2013. RPTE threshold, reasonable potential to exceed 80 percent of the Idaho mercury water-quality criterion of 0.30 milligram per kilogram (mg/kg) wet weight mercury or greater than 0.24 mg/kg in an average of 10 fish; IFCAP action level, Idaho Fish Consumption Advisory Project recommends consideration of issuing a fish advisory when the geometric mean of mercury in 10 fish exceeds 0.22 mg/kg wet weight).

The variation in Hg concentrations in fish tissue between years in each reservoir may be due to confounding factors such as water-level fluctuations, light penetration limitations due to turbidity from suspended sediments or an abundance of organic matter, or other factors affecting methylation and demethylation rates (Wiener and others, 2007). Changes in fish population because of fish stocking practices and fish harvesting also may create an artifact in data and exemplifies the complexity of the systems (Wiener and others, 2007). The Tribes also stock the reservoirs with large hatchery trout to reduce predation from bass in the reservoirs (Edmond Murrell, Shoshone-Paiute Tribes then-Director of Fish, Wildlife and Parks Department, oral commun., 2012). These hatchery trout have low Hg concentrations, and may be the reason there is variability in the Hg concentration in larger fish (fig. 2). Information provided by the Tribes shows that they stocked 24,000 lb of catchable fish in late April and early May in each of the sample years. In 2007 and 2013, the hatchery stock was distributed equally among the three reservoirs, and ranged from 254 to 355 mm (10–14 in.) in length; in 2009, 16,000 lb was placed in Mountain View Reservoir, and 8,000 lb in Sheep Creek Reservoir, ranging from 254 to 330 mm (10–13 in.) in length (Jinwon Seo and Richard Edwards, Shoshone-Paiute Tribes Fish, Wildlife and Parks Department, written commun., 2015). The lengths should be considered estimates only, as one hatchery trout provided to the USGS for analysis in 2013 was 462 mm (18 in.) in length.

Atmospheric Wet Mercury Deposition

From 2003 to 2013, the rate of wet Hg deposition at site NV02 (average 3.02 μg/m^2) showed no significant temporal linear trend ($p = 0.79$). Despite the decrease in total reported Hg compounds as point source (stack) emissions from Nevada mine operations from 2001 to 2013, there does not seem to be a decrease in the annual mercury deposition rate at site NV02 between 2003 and 2013 (fig. 4) (National Atmospheric Deposition Program, 2014b). This finding may be due to factors such as the locations of active gold processing sites in relation to regional wind patterns, or that the primary source of Hg to site NV02 may be from the global atmospheric Hg pool. Although there was an elevated wet Hg deposition rate measured in 2009 (5.66 μg/m^2), there was no significant linear trend between 2003 and 2013 (fig. 4).

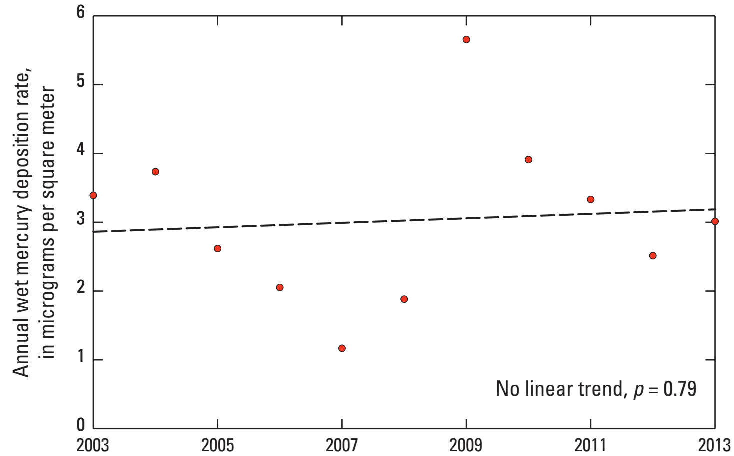

Figure 4. Annual wet mercury deposition rate at Mercury Deposition Network site NV02, Lesperance Ranch, Nevada, 2003–2013. Only complete data meeting National Atmospheric Deposition Program standards for data completion are plotted.

Quality Control for Fish Analysis

The USGS MRL has extensive quality-assurance and quality control procedures (U.S. Geological Survey, 2014). Briefly, the USGS MRL uses International Atomic Energy Agency certified reference material 407, or Institute for National Measurement Standards certified reference material DORM-2, to verify laboratory instrument calibration before each daily sample run (Institute for National Measurement Standards, 1993; International Atomic Energy Agency, 2003). To determine instrument accuracy, CRM is analyzed at the beginning of the sample processing day, after every 10 samples, and again at the end of the sample run. The relative percentage of difference of duplicates required by the USEPA is less than 24 percent (U.S. Environmental Protection Agency, 2002). Triplicates of sample material are analyzed to determine repeatability (precision) and should be within 15 percent of the relative standard deviation for replicate analysis to meet USGS MRL standards. For this project, field replicates were analyzed to determine bias in sample processing. The goal for relative percentage of difference in field replicates was established at less than 20 percent.

Hg concentrations in QC samples are presented with the environmental sample results (table 3). Table 3 also includes laboratory CRM results used to verify equipment calibration (accuracy), and triplicate sample results from individual fish to assess repeatability (precision) for all sample years. The accuracy of the data was within the USEPA standard of less than 24 percent of the most probable value for certified reference material for Hg (U.S. Environmental Protection Agency, 2002).

Certified reference material recovery of Hg in QC samples ranged from 84.8 to 122 percent, within the required recovery of 76–124 percent of the theoretical value. The precision of the triplicate sample material was within 15 percent relative standard deviation in laboratory replicate analyses and ranged from 0.474 to 4.31 percent. Field duplicates also were analyzed as a measure of quality control, ranging from 0 to 14.7 percent, below the project goal of less than 20 percent relative percent difference.

Summary

The U.S. Geological Survey, in cooperation with the Shoshone-Paiute Tribes of the Duck Valley Indian Reservation, monitored mercury (Hg) concentrations in rainbow trout to determine the risk of Hg exposure to Tribal members and the general public. Mean and median Hg concentrations were determined for 2007, 2009, and 2013, and all were less than the U.S. Environmental Protection Agency water-quality criterion of 0.30 milligram per kilogram (mg/kg) (wet weight, ww), and the Idaho Department of Environmental Quality reasonable potential to exceed threshold of 0.24 mg/kg ww. Idaho Department of Health and Welfare toxicologists determined that the Hg concentrations in rainbow trout in this study would not warrant a fish-consumption advisory for this species.

Analysis of fish-tissue samples from Mountain View Reservoir indicated a significant decrease ($p = 0.01$, analysis of variance test) in mean Hg concentrations between 2007 (0.12 mg/kg ww) and 2009 (0.07 mg/kg ww), and no significant difference between 2009 (0.07 mg/kg ww) and 2013 (0.06 mg/kg ww). Results of the Mann-Kendall trend test showed a decreasing trend in Hg concentration over time ($p < 0.001$) for this reservoir. Mean Hg concentrations in Lake Billy Shaw indicated no significant difference between sample years ($p = 0.14$) and no significant trend ($p = 0.31$). Mean Hg concentrations in Sheep Creek Reservoir indicated little change between 2007 (0.06 mg/kg ww) and 2009 (0.05 mg/kg ww), whereas there was a significant difference ($p < 0.01$) between 2009 (0.05 mg/kg ww) and 2013 (0.10 mg/kg ww); Hg concentration in this reservoir showed an increasing trend ($p < 0.01$). There was no statistically significant linear trend indicating a relationship between a regional atmospheric source of Hg as measured at Mercury Deposition Network site NV02 and the Hg concentration increase in fish collected from Sheep Creek Reservoir during 2009 and 2013. However, there was an elevated annual atmospheric deposition rate in 2009 (5.66 micrograms per square meter [$\mu g/m^2$]), and terrestrial sources of Hg can take years or decades to enter aquatic ecosystems. Determining the source of Hg in Duck Valley Reservation's reservoirs would require additional study. Without attributing cause, or identifying a source, Hg concentrations in trout tend to follow a pattern of increasing Hg concentrations in fish tissue from north to south on the reservation. A decreasing trend was noted in Mountain View Reservoir ($p < 0.00$), no trend was found in Lake Billy Shaw ($p = 0.31$), and an increasing Hg trend was found in Sheep Creek Reservoir ($p < 0.01$). Overall, management of the fishery as well as other factors may affect the bioaccumulation of Hg in fish tissue. It was beyond the scope of this study to identify methylation processes that may be unique to each reservoir. Further study of Hg processing in the reservoirs may provide important clues for future management decisions concerning the Shoshone-Paiute Tribes fishery.

Acknowledgments

We would like to thank the Shoshone-Paiute Tribes and, in particular, Heather Lawrence, Director for the Tribal Environmental Program, and John Crum, a former staff member, for their contributions to this investigation. This project would not have been possible without their untiring effort over many years. We also would like to express our appreciation to the former Director of Fish, Wildlife and Parks, Edmond Murrell, the current Director, Dr. Jinwon Seo, and their respective staff personnel for the assistance they provided.

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Table 2. Individual fish size, weight, and mercury concentration data, and statistical summaries for Duck Valley Indian Reservation reservoirs and hatchery background samples from the Black Canyon Trout Farm, southwestern Idaho and northern Nevada, 2007, 2009, and 2013.

[Site locations are shown in figure 1. **Abbreviations:** g, gram; mm, millimeter; mg/kg, milligram per kilogram]

Sample date	Time	Total length (mm)	Weight (g)	Mercury (mg/kg wet weight)	Mercury (mg/kg wet weight)		
					Geometric mean per site	Median per site	Mean per site
			Mountain View Reservoir, Idaho				
05-21-07	0830	400	747	0.06	0.10	0.14	0.12
	0831	398	651	0.06			
	0832	510	1,522	0.17			
	0833	536	1,642	0.19			
	0834	480	1,376	0.19			
	0835	455	1,075	0.26			
	0836	442	884	0.14			
	0837	445	946	0.06			
	0838	473	1,195	0.14			
	0839	542	1,601	0.23			
	0840	475	1,207	0.22			
	0841	330	446	0.04			
	0842	335	412	0.02			
	0843	322	373	0.03			
	0844	312	337	0.06			
06-01-09	1200	471	1,153	0.06	0.06	0.06	0.07
	1201	493	1,289	0.14			
	1202	374	576	0.06			
	1203	396	711	0.08			
	1204	530	1,912	0.12			
	1205	363	529	0.02			
	1206	339	406	0.02			
	1207	360	495	0.08			
	1208	337	486	0.06			
	1209	335	460	0.06			
	1210	422	757	0.08			
	1211	301	318	0.04			
	1212	290	359	0.03			
	1213	440	846	0.05			
	1214	432	944	0.08			
06-04-13	928	272	298	0.01	0.05	0.05	0.06
	929	481	1,174	0.10			
	930	418	894	0.06			
	931	477	1,368	0.10			
	932	419	890	0.04			
	933	396	730	0.05			
	934	355	575	0.04			
	935	405	805	0.04			
	936	375	646	0.05			
	937	460	1,080	0.05			
	938	446	1,079	0.07			
	939	339	810	0.07			
	940	456	1,224	0.06			
	941	430	1,022	0.05			
	942	397	882	0.04			

Table 2. Individual fish size, weight, and mercury concentration data, and statistical summaries for Duck Valley Indian Reservation reservoirs and hatchery background samples from the Black Canyon Trout Farm, southwestern Idaho and northern Nevada, 2007, 2009, and 2013.—Continued

Sample date	Time	Total length (mm)	Weight (g)	Mercury (mg/kg wet weight)	Mercury (mg/kg wet weight)		
					Geometric mean per site	Median per site	Mean per site
Lake Billy Shaw, Nevada							
05-22-07	1400	395	605	0.07	0.10	0.11	0.12
	1401	490	958	0.26			
	1402	470	1,150	0.25			
	1403	410	724	0.06			
	1404	430	830	0.10			
	1405	465	940	0.11			
	1406	485	1,030	0.16			
	1407	380	604	0.03			
	1408	355	462	0.03			
	1409	375	600	0.05			
	1410	400	665	0.12			
	1411	410	745	0.10			
	1412	500	1,150	0.19			
	1413	470	1,060	0.16			
	1414	390	675	0.08			
06-02-09	1200	499	1,349	0.09	0.07	0.08	0.07
	1201	414	685	0.09			
	1202	463	922	0.08			
	1203	431	805	0.06			
	1204	409	688	0.08			
	1205	293	292	0.10			
	1206	380	498	0.08			
	1207	370	405	0.09			
	1208	433	775	0.04			
	1209	342	438	0.03			
	1210	471	973	0.10			
	1211	332	380	0.03			
	1212	463	1,053	0.06			
	1213	307	329	0.03			
	1214	430	1,099	0.11			
06-05-13	946	455	894	0.07	0.08	0.09	0.09
	947	470	1,073	0.07			
	949	380	1,190	0.12			
	951	403	630	0.06			
	952	478	880	0.06			
	953	413	1,196	0.09			
	954	481	792	0.05			
	956	525	1,345	0.14			
	957	404	1,400	0.16			
	958	423	680	0.07			
	959	470	825	0.09			
	1000	441	1,094	0.11			
	1001	406	887	0.09			
	1003	272	837	0.09			

Table 2. Individual fish size, weight, and mercury concentration data, and statistical summaries for Duck Valley Indian Reservation reservoirs and hatchery background samples from the Black Canyon Trout Farm, southwestern Idaho and northern Nevada, 2007, 2009, and 2013.—Continued

Sample date	Time	Total length (mm)	Weight (g)	Mercury (mg/kg wet weight)	Mercury (mg/kg wet weight)		
					Geometric mean per site	Median per site	Mean per site
Sheep Creek Reservoir, Nevada							
05-22-07	1600	335	418	0.03	0.04	0.03	0.06
	1601	392	568	0.29			
	1602	295	315	0.03			
	1603	345	430	0.05			
	1604	380	646	0.04			
	1605	345	464	0.04			
	1606	350	386	0.10			
	1607	435	834	0.03			
	1608	355	418	0.10			
	1609	335	390	0.03			
	1610	295	270	0.02			
	1611	300	294	0.02			
	1612	290	252	0.03			
	1613	275	228	0.03			
	1614	270	210	0.03			
06-03-09	1200	409	693	0.09	0.05	0.04	0.05
	1201	430	867	0.10			
	1202	418	761	0.07			
	1203	416	873	0.10			
	1204	386	607	0.06			
	1205	329	409	0.03			
	1206	390	723	0.06			
	1207	310	357	0.04			
	1208	316	372	0.02			
	1209	275	205	0.02			
	1210	297	276	0.02			
	1211	268	216	0.03			
	1212	313	326	0.02			
	1213	296	264	0.04			
	1214	438	806	0.09			
06-06-13	957	425	762	0.10	0.09	0.08	0.10
	959	447	1,010	0.07			
	1000	535	1,258	0.04			
	1001	450	1,069	0.23			
	1002	390	704	0.11			
	1003	387	584	0.08			
	1004	403	638	0.12			
	1006	350	398	0.04			
	1007	489	1,340	0.16			
	1008	389	565	0.08			
	1009	449	887	0.10			
	1010	435	783	0.07			
	1011	369	552	0.06			
	1012	474	1,155	0.19			
	1013	415	710	0.08			

Table 2. Individual fish size, weight, and mercury concentration data, and statistical summaries for Duck Valley Indian Reservation reservoirs and hatchery background samples from the Black Canyon Trout Farm, southwestern Idaho and northern Nevada, 2007, 2009, and 2013.—Continued

Sample date	Time	Total length (mm)	Weight (g)	Mercury (mg/kg wet weight)	Mercury (mg/kg wet weight)		
					Geometric mean per site	Median per site	Mean per site
Black Canyon Trout Farm, Grace, Idaho							
05-04-07	1215	355	500	0.03	0.04	0.04	0.04
	1216	310	326	0.03			
	1217	355	532	0.04			
	1218	355	548	0.04			
	1219	365	586	0.05			
04-22-09	1200	297	240	0.01	0.02	0.02	0.02
	1201	324	275	0.02			
	1202	309	245	0.01			
	1203	297	235	0.03			
	1204	306	245	0.01			
05-21-13	1125	330	365	0.01	0.01	0.01	0.01
	1130	360	505	0.01			
	1131	315	290	0.01			
	1132	334	450	0.01			
	1133	415	690	0.02			
	1134	462	1,070	0.02			
	1135	340	425	0.01			

Table 3. Quality-control results for analysis of total mercury in fish from Duck Valley Indian Reservation reservoirs and hatchery background samples from the Black Canyon Trout Farm, southwestern Idaho and northern Nevada, 2007, 2009, and 2013.

[Certified reference material from the International Atomic Energy Agency (IAEA), laboratory identification number beginning with International Atomic Energy Agency (2003); a description of IAEA-407 is available at http://www.iaea.org/nael/refmaterial/iaea407.pdf. Certified reference material from the Institute for National Measurement Standards, National Research Council of Canada, laboratory identification number beginning with DORM-2; a description of DORM-2 is available at http://www.nrc-cnrc.gc.ca/obj/doc/solutions-solutions/advisory-consultatifs/crm-mrc/dorm_2_e.pdf. Triplicate samples from a single fish at a sampling site (laboratory identification samples beginning with MSC) were analyzed separate from the original sample for laboratory method repeatability (precision) and reported as relative standard deviation (RSD), RSD = Standard deviation of the three replicate concentrations divided by the average of those replicates. Field duplicates are samples from a single specimen collected as an assessment of quality control. Results are reported as relative percent difference (RPD), where $\{(x_1 - x_2)/[x_1 + x_2)/2]100$, and x = sample concentration. **Abbreviation:** ng/g, nanograms per gram]

Laboratory identification	Date of analysis	Mercury, ng/g dry weight	Certified reference material recovery (percent)
Certified — 2007			
IAEA 407	08-10-07	226	102
		222	100
		231	104
IAEA 407	08-13-07	226	102
		239	108
		244	110
		232	105
		236	106
		256	115
IAEA 407	08-14-07	232	105
		238	107
		270	122
		237	107
		238	107
		250	113
IAEA 407	08-15-07	239	107
		247	111
		254	114
IAEA 407	08-16-07	243	110
		244	110
		232	105
		242	109

Laboratory identification	Date of analysis	Mercury, ng/g dry weight	Triplicate relative standard deviation (percent)
Laboratory triplicate — 2007			
MSC603D	08-13-07	148	0.474
		148	
		147	
MSC617D	08-13-07	117	1.11
		115	
		115	
MSC631D	08-14-07	510	1.48
		496	
		507	
MSC645D	08-14-07	286	0.698
		290	
		287	
MSC659D	08-15-07	133	1.18
		133	
		130	

Laboratory identification	Date of analysis	Mercury, ng/g dry weight	Certified reference material recovery (percent)
Certified — 2007			
DORM-2	08-10-07	4,440	95.7
		4,480	96.5
		4,480	96.6
DORM-2	08-13-07	4,240	91.4
		4,480	96.6
		4,600	99.1
		4,690	101.0
		4,400	94.8
		4,660	100.0
DORM-2	08-14-07	4,310	92.9
		4,490	96.8
		4,510	97.3
		4,750	102.0
		4,680	101.0
		4,520	97.4
DORM-2	08-15-07	4,430	95.6
		4,380	94.3
		4,500	97.0
DORM-2	08-16-07	4,480	96.6
		4,560	98.4
		4,460	96.1
		4,620	99.6

Table 3. Quality-control results for analysis of total mercury in fish from Duck Valley Indian Reservation reservoirs and hatchery background samples from the Black Canyon Trout Farm, southwestern Idaho and northern Nevada, 2007, 2009, and 2013.—Continued

Certified – 2009			
Laboratory identification	Date of analysis	Mercury, ng/g dry weight	Certified reference material recovery (percent)
IAEA 407	09-22-09	201	90.5
		222	100.0
		225	101.0
		219	98.8
		220	99.0
		224	101.0
	09-25-09	222	99.9
		218	98.2
		220	99.0
		217	97.7
		219	98.8
		208	93.7
		220	99.2

Field duplicate — 2009			
Laboratory identification	Sample date	Mercury, ng/g dry weight	Relative percent difference
MSC316I	04-22-09	0.01	10.8
MSC315I	04-22-09	0.01	
MSC327I	06-02-09	0.03	5.47
MSC326I	06-02-09	0.04	
MSC364I	06-01-09	0.12	3.68
MSC363I	06-01-09	0.13	
MSC353I	06-01-09	0.08	4.9
MSC352I	06-01-09	0.09	
MSC342I	06-03-09	0.02	0.00439
MSC341I	06-03-09	0.02	

Laboratory triplicate — 2009			
Laboratory identification	Date of analysis	Mercury, ng/g dry weight	Triplicate relative standard deviation (percent)
MSC335I	09-25-09	406	3.93
		433	
		404	
		306	2.58
		292	
		306	
MSC356I	09-25-09	183	3.93
		171	
		183	
MSC348I	09-22-09	490	4.31
		506	
		534	
MSC340I	09-25-09	118	1.77
		122	
		121	
MSC338I	09-22-09	211	2.06
		219	
		212	

Table 3. Quality-control results for analysis of total mercury in fish from Duck Valley Indian Reservation reservoirs and hatchery background samples from the Black Canyon Trout Farm, southwestern Idaho and northern Nevada, 2007, 2009, and 2013.—Continued

Certified — 2013			
Laboratory identification	Date of analysis	Mercury, ng/g dry weight	Certified reference material recovery (percent)
IAEA 407	10-23-13	243	109.0
		241	108.0
		250	113.0
		251	113.0
		263	118.0
	10-24-13	229	103.0
		231	104.0
		248	111.0
		230	104.0
		233	105.0
		240	108.0
	10-25-13	224	101.0
		228	103.0
		227	102.0
		238	107.0
		233	105.0
	10-29-13	212	95.5
		226	102.0
		216	97.4
		233	105.0
	10-31-13	204	91.8
		198	89.0
		199	89.5
		188	84.8

Field duplicate — 2013			
Laboratory identification	Sample date	Mercury, ng/g dry weight	Relative percent difference
MSC849S	06-04-13	0.10	2.9
MSC848S	06-04-13	0.11	
MSC861S	06-04-13	0.05	14.7
MSC844S	06-04-13	0.06	
MSC336U	06-05-13	0.07	4.72
MSC337U	06-05-13	0.06	
MSC834S	06-05-13	0.05	6.48
MSC828S	06-05-13	0.05	
MSC835S	06-05-13	0.09	4.1
MSC838S	06-05-13	0.08	
MSC888S	06-06-13	0.10	1.97
MSC889S	06-06-13	0.10	
MSC882S	06-06-13	0.12	0.796
MSC883S	06-06-13	0.11	
MSC881S	06-06-13	0.08	7.49
MSC893S	06-06-13	0.09	

Laboratory triplicate — 2013			
Laboratory identification	Date of analysis	Mercury, ng/g dry weight	Triplicate relative standard deviation (percent)
MSC829S	10-23-13	307.0	0.529
		304.0	
		305.0	
MSC889S	10-23-13	530.0	3.49
		561.0	
		565.0	
MSC837S	10-24-13	752.0	0.416
		748.0	
		754.0	
MSC862S	10-24-13	171.0	0.932
		169.0	
		172.0	
MSC881S	10-24-13	377.0	1.27
		383.0	
		387.0	
MSC890S	10-25-13	495.0	3.89
		535.0	
		520.0	
MSC894S	10-25-13	266.0	0.53
		265.0	
		268.0	
MSC870S	10-29-13	814.0	1.71
		820.0	
		841.0	
MSC850S	10-31-13	56.7	3.96
		54.1	
		52.5	

Publishing support provided by the U.S. Geological Survey
Science Publishing Network, Tacoma Publishing Service Center

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Williams and others—**Mercury in Rainbow Trout, Duck Valley Indian Reservation Reservoirs, Southwest Idaho and Northern Nevada, 2007, 2009, and 2013**—Scientific Investigations Report 2015–5079

ISSN 2328-0328 (online)
http://dx.doi.org/10.3133/sir20155079