



Measuring Mercury Trends in Freshwater Fish in Washington State: 2006 Sampling Results

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For more information contact:

Publications Coordinator
Environmental Assessment Program
P.O. Box 47600
Olympia, WA 98504-7600

E-mail: jlet461@ecy.wa.gov
Phone: (360) 407-6764

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Measuring Mercury Trends in Freshwater Fish in Washington State: 2006 Sampling Results

by
Chad Furl

Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington 98504-7710

September 2007

Waterbody Numbers: see Appendix A

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Abstract

This report presents results from the second year of a long-term monitoring effort by the Washington State Department of Ecology to measure mercury trends in fish tissue. The primary goal of this project is to monitor mercury levels in edible tissue from freshwater fish at six sites per year for five years (30 sites total) to characterize temporal trends.

In 2006, 85 individual fish and 30 fish composite samples, representing 10 species, were analyzed from seven lakes in Washington: American Lake, Mason Lake, Lake Meridian, Moses Lake, Newman Lake, Offut Lake, and Lake Sammamish. Water and sediment samples were collected to evaluate selected parameters that may influence mercury loading in tissues.

A total of 17% of individuals and 3% of composites sampled exceeded the U.S. Environmental Protection Agency (EPA) recommended water quality criterion of 300 ppb. Largemouth bass and northern pikeminnow were the only species exceeding EPA criterion. A single nine-year-old female bass from Mason Lake contained a mercury concentration of 952 ppb. This was the only sample exceeding the National Toxics Rule (NTR) criterion of 825 ppb.

Dissolved organic carbon (DOC), total organic carbon (TOC), pH, temperature, and percent anoxic water had the most significant correlations with mercury concentrations in individual bass.

A temporal analysis was performed for four lakes (Newman, Meridian, Long, and Moses) sampled in 2003 and again in either the 2005 or 2006 mercury trends report. Time between sampling events ranged from 49-59 months, and results estimated decreases in \log_{10} tissue concentrations of 13-31%.

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Introduction

Background

While mercury is a naturally occurring substance, human activity has greatly increased the release of mercury into the environment. Consequences of this include increased health risks to humans and wildlife due to the persistent, bioaccumulative, and toxic nature of this substance. Concerns about these risks have led governments at international, national, state, and local levels to recognize and address the problems associated with the use and disposal of mercury.

Mercury is widespread in the environment, being released to the atmosphere from varied sources and transported globally. Natural sources of mercury include weathering of mercury-bearing rocks and soil, volcanic activity, forest fires, and degassing from water and terrestrial surfaces. Anthropogenic (human-caused) sources include combustion of fossil fuels, metals production, and industrial processes. Lake sediment records show that atmospheric mercury has tripled over the last 150 years, suggesting that two-thirds of atmospheric mercury is of anthropogenic origin (Morel et al., 1998; Mason et al., 1994).

In humans, mercury can affect the nervous system, with children and developing fetuses being most at risk (EPA, 2000). Concern with these health risks resulted in the 2002 Washington State Legislature directing the Washington Departments of Ecology (Ecology) and Health (DOH) to develop a plan targeting mercury as the first chemical in the state's *Proposed Strategy to Continually Reduce Persistent, Bioaccumulative Toxins (PBTs) in Washington State* (Gallagher, 2000).

The *Washington State Mercury Chemical Action Plan* (Peele, 2003) was developed in 2003 by Ecology and DOH to address: mercury in Washington's environment, the Clean Water Act Section 303d listings of waterbodies impaired by mercury, a review of research projects looking at mercury in Washington, the regulatory structures and numerical criteria that address mercury, and recommendations for reducing mercury emissions in Washington.

Previous Studies on Mercury in Washington

Several studies have described the extent and severity of mercury contamination in fish and sediments throughout Washington, many of which led to issuance of fish consumption advisories.

Furl et al. (2007) examined mercury in individual bass as part of the first year of the current study. Mercury levels were within typical ranges (0-300 ppb) of previous fish tissue studies conducted within the state. Less than 10% of samples exceeded the EPA recommended criterion for mercury (300 ppb), and no samples exceeded the National Toxics Rule criterion (825 ppb).

Fischnaller et al. (2003) examined mercury in bass and sediment from 20 sites across Washington. Samples of muscle tissue from bass confirm that elevated levels of mercury are prevalent across Washington. The study recommended implementing a long-term monitoring plan for mercury in fish.

Mercury concentrations were correlated with size, age, weight, and length in about 90% of sites sampled. These findings were consistent with other studies, demonstrating that bioaccumulation of mercury occurs in upper trophic level predatory species, such as bass. A weak correlation was found between mercury concentrations and lipids, such that lipids analysis in future studies was deemed unnecessary.

Many fish exceeded one or more criteria for protection of human health. In this study, about 23% of 185 fish, representing 14 of 20 sites, exceeded the EPA Recommended Fish Tissue Criterion of 300 ug/kg wet weight (EPA, 2001). A single ten-year-old fish from Samish Lake had a muscle tissue mercury level of 1280 ug/kg wet weight. This result exceeded the NTR criterion of 825 ug/kg ww (CFR, 2004). This study was the basis of DOH's issuance of a statewide fish consumption advisory for largemouth and smallmouth bass (McBride, 2003).

Serdar et al. (2001) examined mercury concentrations in 273 fish from six finfish and one crayfish species in Lake Whatcom. Mercury levels were elevated in smallmouth bass. These data were used in developing a fish consumption advisory for Lake Whatcom (Lake Whatcom Cooperative Management Program, 2001). Serdar et al. (2001) recommended a monitoring program to routinely characterize mercury levels in fish throughout Washington.

Munn et al. (1995) investigated mercury and other metals in walleye, bass, and trout from Lake Roosevelt. Spatial differences in mercury concentrations in fish tissue were discovered throughout the lake. The report attributes these spatial differences to the unique areas of spawning and foraging where bioavailability of mercury differs due to local physical and chemical differences. Elevated mercury levels in walleye led DOH to issue a fish consumption advisory in Lake Roosevelt (USGS, 1997).

Furl (2007b) examined sediment cores from Lake Ozette, Lake Sammamish, and Lake St. Clair as part of the first year of long-term mercury monitoring. Mercury analyses throughout the cores indicated peak levels during the mid 1990s at Lake Ozette, and peak levels during the 1940s at Lake Sammamish and Lake St. Clair. Mercury concentrations at Lake Ozette have experienced a leveling off of mercury loading with possible slight declines. Mercury levels at Lake Sammamish have significantly declined, while concentrations at Lake St. Clair have increased during the past 15-20 years.

Norton (2004) investigated mercury levels in surface water, surficial sediments, and sediment cores of Lake Whatcom, in cooperation with the U.S. Geological Survey and Whatcom County Health Department (Paulson, 2004). Findings suggest that mercury levels began increasing around 1900, may have peaked in the late 1990s, and appear to be declining. This study recommended that mercury levels in fish from Lake Whatcom be monitored periodically to determine if mercury levels decline over time. This study also recommended monitoring bottom

waters for methylmercury and total mercury to help evaluate compliance with water quality target concentrations in the lake and to prevent excessive bioaccumulation of mercury in fish.

Paulson (2004) examined sources of mercury in sediments, water, and fish for eight lakes in Whatcom County. An atmospheric deposition model was developed to allow comparison of deposition patterns in the lakes sampled. Mercury emissions from known sources in the area (e.g. waste incinerators, a sewage-sludge incinerator, a chlor-alkali plant) were modeled as part of this effort. Relationships between point (discrete) source deposition and mercury concentrations in bass could not be established.

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Study Design

Goal and Objectives

In 2005, the Legislature began funding two long-term projects designed to monitor mercury in the environment:

1. Determine mercury levels in edible tissue from ten individual fish of the same species (bass and/or walleye) from six sites per year for long-term trend characterization. Sampling at each of these sites will be repeated every five years, such that a total of 30 sites will be sampled over a five-year period.
2. Collect sediment cores from three lakes per year to assess depositional history of mercury in Washington. The sediment coring effort began in 2006.

The primary goal of the fish tissue project is to monitor mercury levels in individual fish tissues for the purpose of determining temporal trends. Additional objectives of the project are to:

- Collect ancillary data on the sites where fish were collected to better understand patterns, dynamics, and changes in fish tissue mercury levels over space and time. Ancillary data will include:
 - Fish length, weight, sex, and age.
 - Morphological and drainage characteristics.
 - Alkalinity and dissolved organic carbon (DOC) from top and bottom waters; vertical profiles of temperature, dissolved oxygen, conductivity, and pH.
 - Three surficial sediment grabs analyzed for mercury, total organic carbon (TOC), and grain size.
- Determine mercury concentrations in composite samples from two other fish species that are present at the sites where bass and/or walleye are collected. For each species, three composite samples of 3-5 fish per composite sample will be collected. This objective is intended to aid DOH in crafting more informative recommendations for fish consumption advisories.

Site Information

Figure 1 displays the locations of American, Mason, Meridian, Moses, Newman, Offut, and Sammamish Lakes where fish were collected. Offut Lake was added after sampling had begun due to difficulties in fish collection at American Lake. Fish were collected from September - December, 2006, concurrent with efforts of Ecology's Washington State Toxics Monitoring Program (Seiders and Yake, 2002). American, Moses, Newman, Offut, and Meridian Lakes were sampled as part of an Ecology Mercury Screening Study (Fischnaller et al., 2003) in 2003.

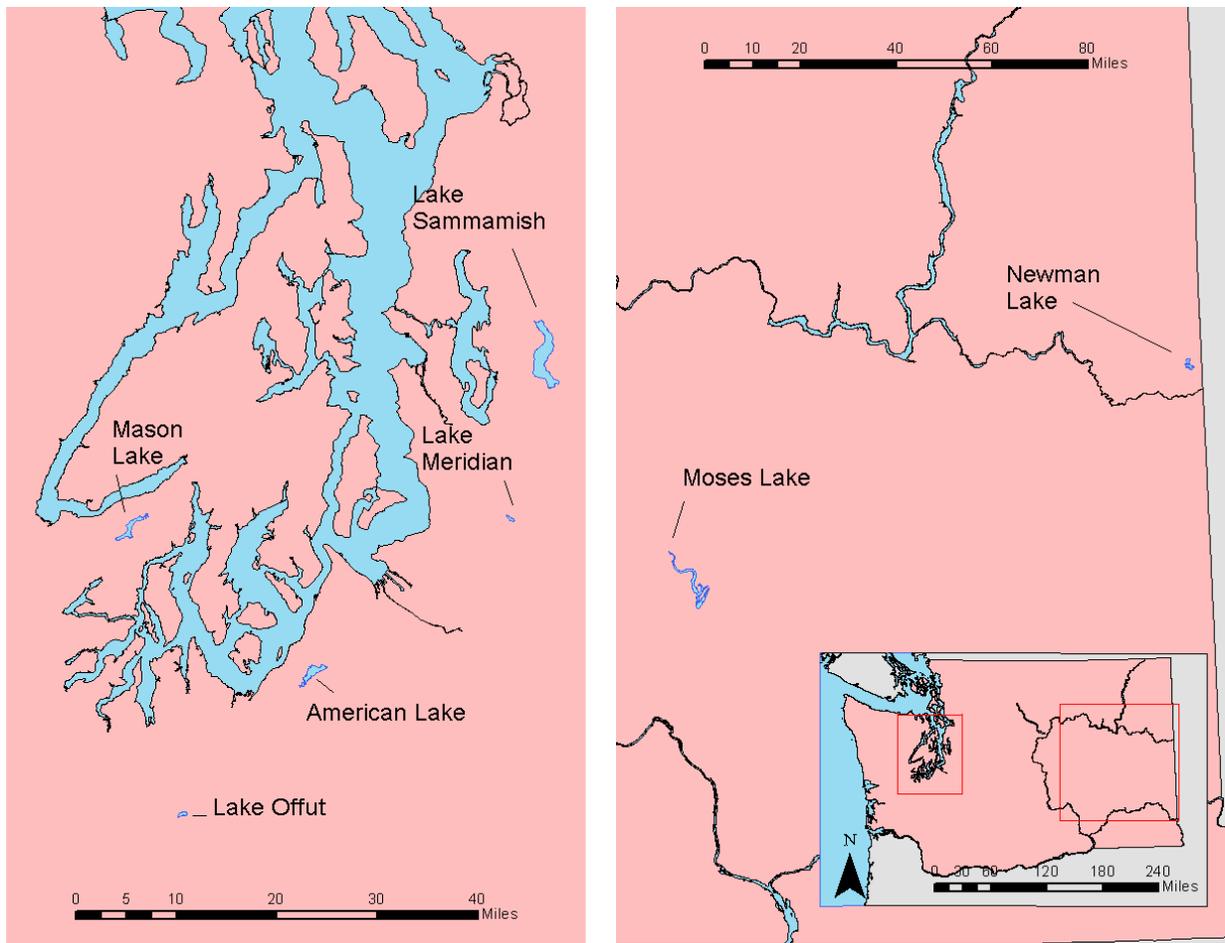


Figure 1. 2006 Study Lakes.

Lakes were selected considering numerous criteria including: proximity to known mercury sources, popularity among anglers, availability of target fish species, and availability of historical data. Table 1 gives more information for each of these sites. The project plan discusses complete site selection considerations (Seiders, 2006).

Table 1. 2006 Location and Physical Information.

Lake →	American*	Mason	Moses*	Newman*	Offut*	Sammamish	Meridian*
County	Pierce	Mason	Grant	Spokane	Thurston	King	King
Drainage (sq mi)	25.4	20.2	3080	28.6	2.7	98	1.16
Altitude (ft)	235	194	1046	2124	230	26	370
Surface area (acres)	1100	1000	6800	1200	200	4900	150
Lake volume (acre-ft)	60,000	49,000	130,000	23,000	2900	285,000	6100
Maximum depth (ft)	90	90	38	30	25	105	90
Mean depth (ft)	53	48	19	19	15	58	41

* Surveyed in the 2003 Mercury Screening Study (Fischnaller et al., 2003)

Methods

Sample Collection

Over 250 fish encompassing 10 species were collected from the 2006 study lakes. A total of 85 individual fish along with 30 composite samples were analyzed by Manchester Environmental Laboratory (MEL). Collection goals for each waterbody as outlined in the project plan (Seiders, 2006) were 10 individual bass or walleye, 3 composite samples of 3-5 fish for 2 additional species, 2 water samples, and 3 surface sediment grab samples.

Table 2 displays information on the collection efforts for each lake. Detailed information on all samples collected is included in Appendix C.

Table 2. 2006 Sampling Goals and Collections.

Collection Goal	Lake						
	American	Mason	Meridian	Moses	Newman	Offut	Sammamish
10 Individual bass or walleye	NA	NA	+	+	+	+	+
2 Additional species composites of 3-5 fish	NA	NA	NA	+	+	+	NA
3 Sediment grab samples	+	+	+	+	+	NA	+
2 Water samples	+	+	+	+	+	NA	+

NA = Collection goal not attained as outlined in project plan

+ = Collection goal met

Field Procedures

Fish

The collection, handling, and processing of fish tissue samples for analysis were guided by methods described in the EPA's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* (EPA, 2000). Fish were collected by Ecology or Washington State Department of Fish and Wildlife (WDFW) crews using boat electrofishing and netting (gill or fyke nets).

For the purpose of trends detection, ten largemouth bass or walleye within target size range (250-460 mm) were collected at each site when possible. Fish were inspected to ensure that they were acceptable for further processing (e.g., no obvious damage to tissues, skin intact). Acceptable fish were euthanized by a blow to the head with a dull object, rinsed in ambient water to remove foreign material from their exterior, weighed to the nearest gram, and their total lengths measured to the nearest millimeter. Individual fish were then double-wrapped in foil and placed in a plastic zip-lock bag along with a sample identification tag. The bagged specimens were placed on ice in the field. Fish remained on ice for a maximum of 24-72 hours and then

were frozen at -20°C and held at Ecology facilities in Lacey, Washington for processing at a later date.

For processing, fish were removed from the freezer, partially thawed, slime and scales removed, rinsed in tap water, and followed by a rinse in deionized water. Fish were then filleted with the skin left on. Fillets were cut into small cubes and passed three times through a Kitchen-Aid food grinder. The ground tissue was homogenized by stirring to a consistent texture and color. Subsamples from the homogenate were placed into 2- or 4-ounce glass containers (I-Chem 200®) that were previously cleaned. Sample jars were assigned a laboratory identification number and transported to the laboratory for analyses. Excess homogenate was placed in an appropriate container, labeled, and archived frozen at -20°C .

After fillets were removed, the sex of the fish was determined, when possible, and recorded. Otoliths and scales were removed from fish that were analyzed individually and sent to WDFW biologists to determine age.

All utensils used for processing tissue samples were cleaned to prevent contamination of the sample. Utensils included stainless steel bowls, as well as knives and tissue grinding appliances having plastic, wood, bronze, and stainless steel parts. All utensils for fish tissue sampling were cleaned with the following procedure: hand washed with soap (Liquinox) and hot water, hot tap water rinse, 10% nitric acid rinse, and a final deionized water rinse. Utensils were air-dried and wrapped in aluminum foil until used. Fish were filleted and tissues processed on the dull side of heavy-duty aluminum foil covering a nylon cutting board laid on the workbench. Each fish was processed on a new/clean sheet of aluminum foil with cleaned utensils to prevent contamination from one sample to the next.

Sediment

The collection, handling, and processing of sediment samples were guided by Puget Sound Estuary Protocol (PSEP, 1986). Profundal sediment samples were collected with a single grab using a 0.02 m^2 stainless steel petite ponar. The overlying water was siphoned away, and the top two centimeters were removed with a stainless steel spoon. Sediments coming in contact with the side of the ponar device were not retained.

Subsamples were homogenized on the boat using stainless steel bowls and spoons and then placed in the proper sized pre-cleaned jars according to MEL protocol (MEL, 2005). Samples were packed in ice and shipped to MEL within 96 hours. All utensils used to collect and prepare samples were cleaned in the same manner as utensils used in fish tissue processing.

Water

Two water samples were obtained at the deepest part of the lake using a one-liter Kemmerer sampler. The samples were obtained at the mid-points of the hypolimnion and epilimnion in stratified lakes. At well-mixed lakes, the samples were obtained at 10-15% and 85-90% of total depth. Samples were retrieved and placed in the proper pre-cleaned jars. Samples were placed on ice in the field and remained cooled until shipment to MEL.

Conductivity, pH, dissolved oxygen, and water temperature were measured at the water sample sites using a Hydrolab[®] following Ecology standard operating procedures (Swanson, 2007). All units were calibrated prior to field use, and Winkler titrations were performed as a measure of quality control for the dissolved oxygen readings.

Laboratory Procedures

All samples were analyzed at MEL excluding grain size which was performed by Analytical Resources Inc. Table 3 contains information on the analytical methods used to perform laboratory analysis.

Table 3. Analytes and Analytical Methods.

Analyte	Matrix	Method
Mercury	Tissue	CVAA, EPA 245.6
Mercury	Sediment	CVAA, EPA 245.5
TOC	Sediment	PSEP-TOC
Grain Size	Sediment	PSEP, Sieve and Pipette
Alkalinity	Water	SM2320B
DOC	Water	EPA 415.1

TOC = Total Organic Carbon

DOC = Dissolved Organic Carbon

CVAA = Cold Vapor Atomic Absorption

PSEP = Puget Sound Estuary Protocol

In 2005 Ecology switched analytical laboratory methods for analyzing mercury in fish tissues from method EPA 245.5 to EPA 245.6. A study was conducted (Furl, 2007b) comparing the two methods. Method 245.5 was found to under-report mercury levels by 25 – 38% depending on the magnitude of concentration (Figure 2). Adjustments were made to data from the 2003 (Fischnaller et al., 2003) mercury report for trends analysis purposes. A detailed statistical account of how the methods differed and results amended is found in Furl 2007b.

Total mercury, as opposed to methylmercury, has been the target analyte used in other fish tissue studies in Washington due to the relative simplicity and lower cost of the total mercury analyses. Methylmercury, the bioaccumulative and toxic form of mercury in fish tissue, accounts for more than 95% of the mercury in fish tissue where it is associated with muscle proteins (Bloom, 1995; Driscoll et al., 1994).

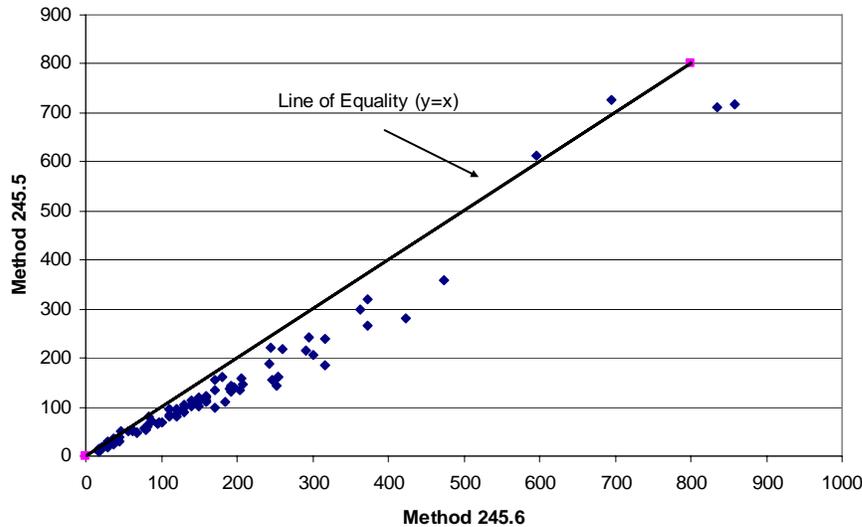


Figure 2. Laboratory Duplicates Analyzed by EPA M245.5 and EPA M245.6 (Furl, 2007b).

Data Quality Assessment

Results from MEL included a Case Narrative (Momohara, 2007) that described results from the quality control and quality assurance procedures used during sample analyses. These results included holding times, instrument calibration, method blanks, matrix spikes, laboratory duplicates, laboratory control samples, and Standard Reference Material 1946 (Lake Superior fish tissue) from the National Institute of Standards and Technology.

The Case Narrative and quality assessment indicated fish tissue data met all measurement quality objectives (MQOs) outlined by the project plan (Seiders et al., 2006). All MQOs for sediment analyses were met excluding a single lab duplicate which was qualified as an estimate. Two TOC analyses failed duplicate tests and were qualified as estimates. DOC and alkalinity quality control measures were within acceptable limits. However, several of the water samples were analyzed past their holding times and therefore qualified as estimates. The majority of grain size analyses were qualified due to either being frozen before analysis, abundant organic material, or an improper amount of fines for accurate pipette analysis. All grain size averages were qualified as estimates since no lake contained all three results without qualifiers.

Results for all samples are reported in Appendix C. Summary results from laboratory duplicates, matrix spikes, and standard reference material (SRM) analyses can be found in Appendix B.

Results

Fish, sediment, and water samples were collected and analyzed from all seven lakes except Offut Lake. Due to time constraints only fish were collected from Offut Lake. Water and sediment samples were also obtained from the 2005 study waterbodies that included Potholes Reservoir, Silver Lake, Liberty Lake, Loon Lake, Long Lake, and the Yakima River (Furl et al., 2007).

Fish

Trends Monitoring Samples

For the 2006 study, lakes where 10 largemouth bass were collected were the only lakes used for trends monitoring purposes. Figure 3 displays mercury concentrations of the individual largemouth bass, along with their age at the bottom of each bar. Table 4 contains summary statistics of their physical characteristics. Ten individual walleye were also collected in 2006 from Moses Lake, but this was the only lake where walleye collections occurred. As more individual walleye are collected in future years, trends monitoring will become possible.

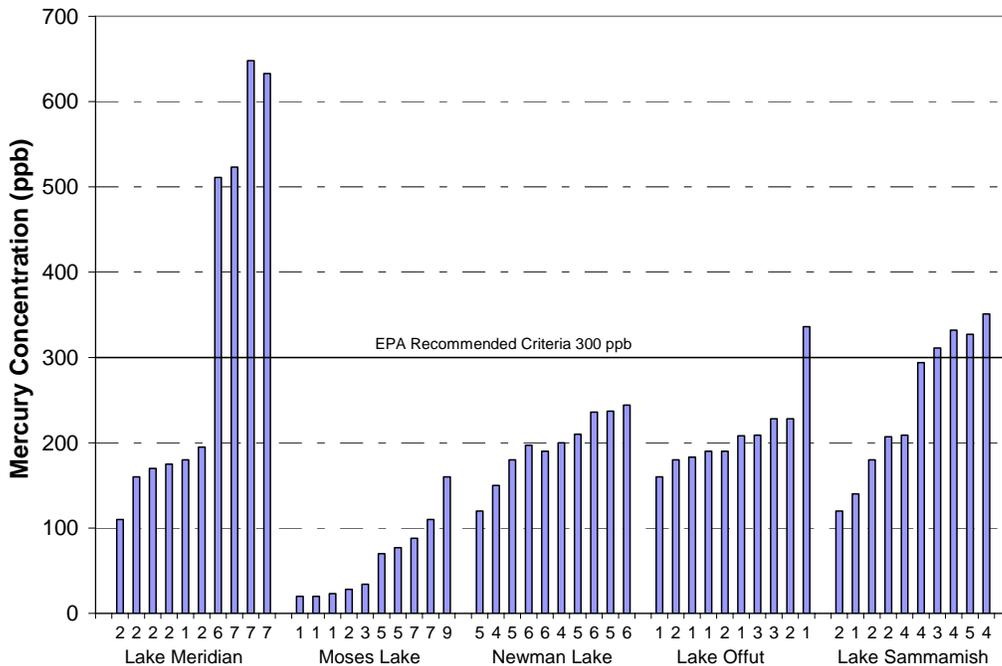


Figure 3. Mercury Concentrations and Age of Individual Largemouth Bass.

Table 4. Summary Statistics for Individual Largemouth Bass.

Lake	Statistic	Total Length (mm)	Weight (g)	Age (yr)	Mercury (ppb)
Meridian	Mean	384	1256	3.8	331
	Std. Dev.	105	1080	2.6	219
	Minimum	270	316	1.0	110
	Maximum	535	2955	7.0	648
Moses	Mean	416	1708	4.1	63
	Std. Dev.	94	1082	2.9	47
	Min	295	490	1.0	20
	Max	536	3260	9.0	160
Newman	Mean	391	925	5.2	196
	Std. Dev.	35	377	0.8	39
	Min	350	548	4.0	120
	Max	460	1825	6.0	244
Offut	Mean	319	626	1.7	211
	Std. Dev.	70	519	0.8	49
	Min	245	176	1.0	160
	Max	440	1575	3.0	336
Sammamish	Mean	376	977	3.1	247
	Std. Dev.	58	386	1.3	86
	Min	282	389	1.0	120
	Max	450	1530	5.0	351
All Lakes	Mean	377	1098	3.6	210
	Std. Dev.	28	362	1.0	75
	Min	28	176	0.8	20
	Max	536	3260	9.0	648

Std. Dev. – standard deviation

Mercury concentrations in bass from lakes where at least 10 fish were collected ranged from undetected at 20 ppb (Moses Lake) to 648 ppb (Lake Meridian). Eighteen percent (9) of the largemouth bass used for trends monitoring exceeded the EPA’s recommended mercury criteria of 300 ppb ww. Eight of the 9 fish exceeding the criteria were collected from Lake Meridian and Lake Sammamish.

Figure 4 is a boxplot graphically displaying the distribution of (minimum, 25th percentile, median, 75th percentile, and maximum) mercury concentrations for the individual bass.

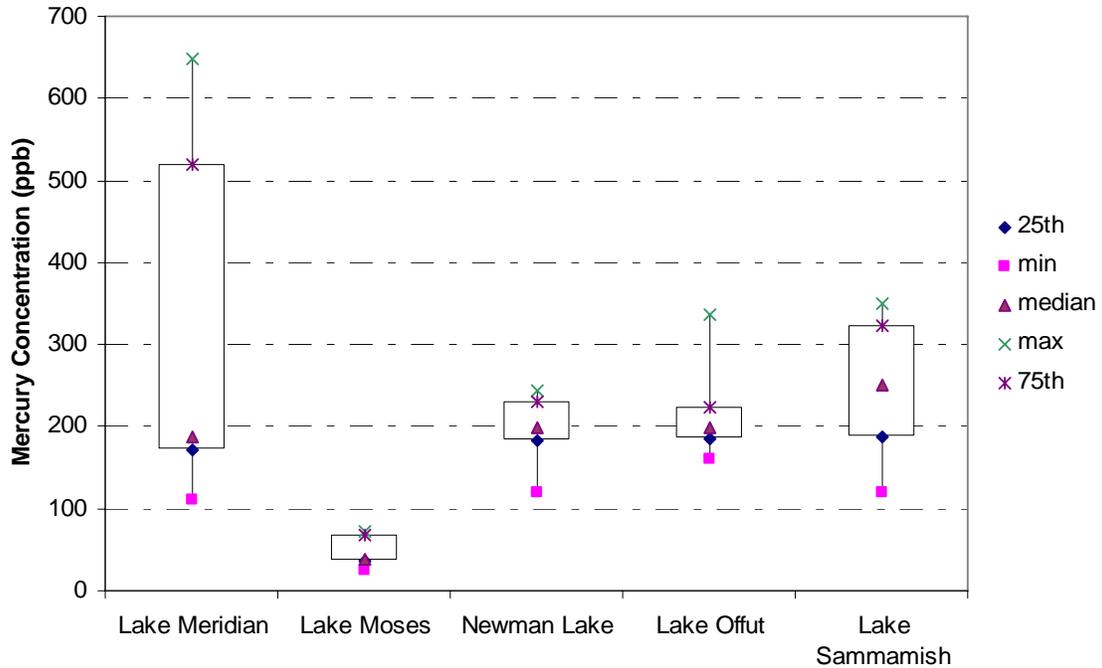


Figure 4. Boxplots of Mercury Concentrations in Individual Bass.

Distribution and variance of concentrations varied widely among lakes. No lakes were extremely skewed by a single outlier. Boxplots displaying distribution for weight and length for the individual bass are located in Appendix D.

Size Range

Target size ranges for individual fish used in trends monitoring were determined by considering historical data, usefulness for long-term monitoring, angler-preferred size ranges, and fishing regulations. The target size range is expressed in (1) total length of an individual fish (250 to 460 mm, or about 10 to 18 inches), and (2) terms of the spread or range of the group of fish collected: the length of the smallest fish should be at least 75% the length of the largest fish (Seiders, 2006).

Figure 5 displays the size ranges for the individual bass. The length of the smallest fish is expressed as a percentage of the largest fish for each lake above the bars.

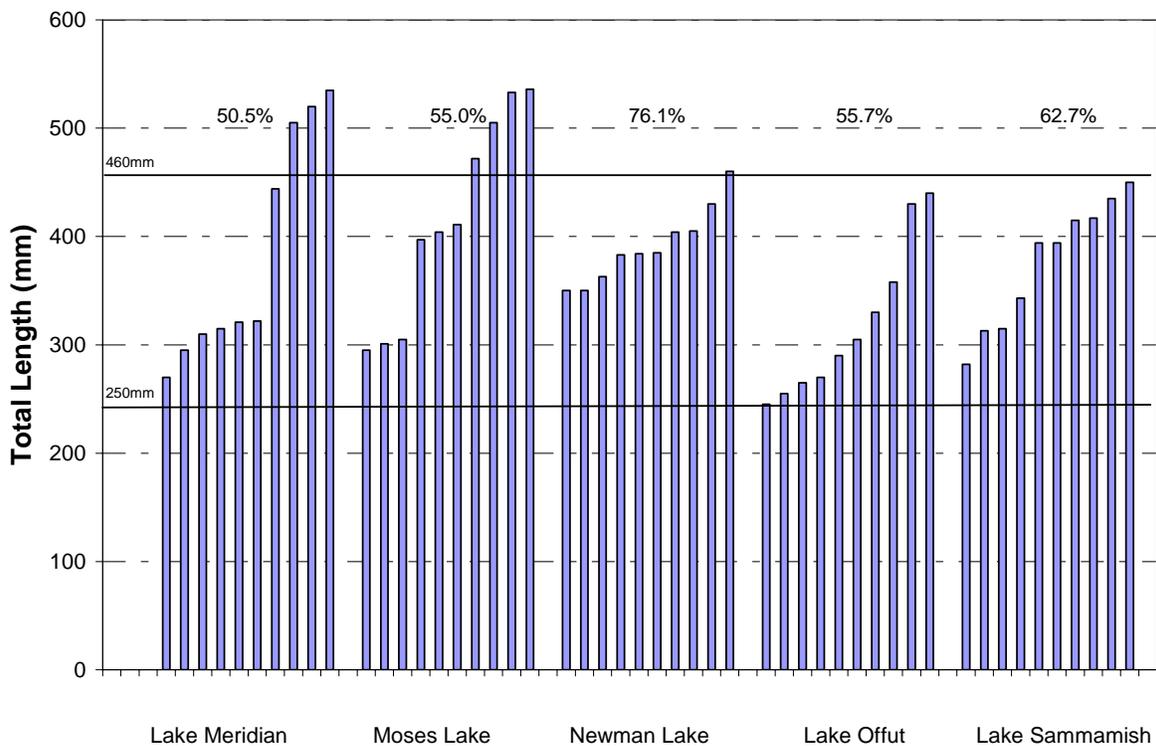
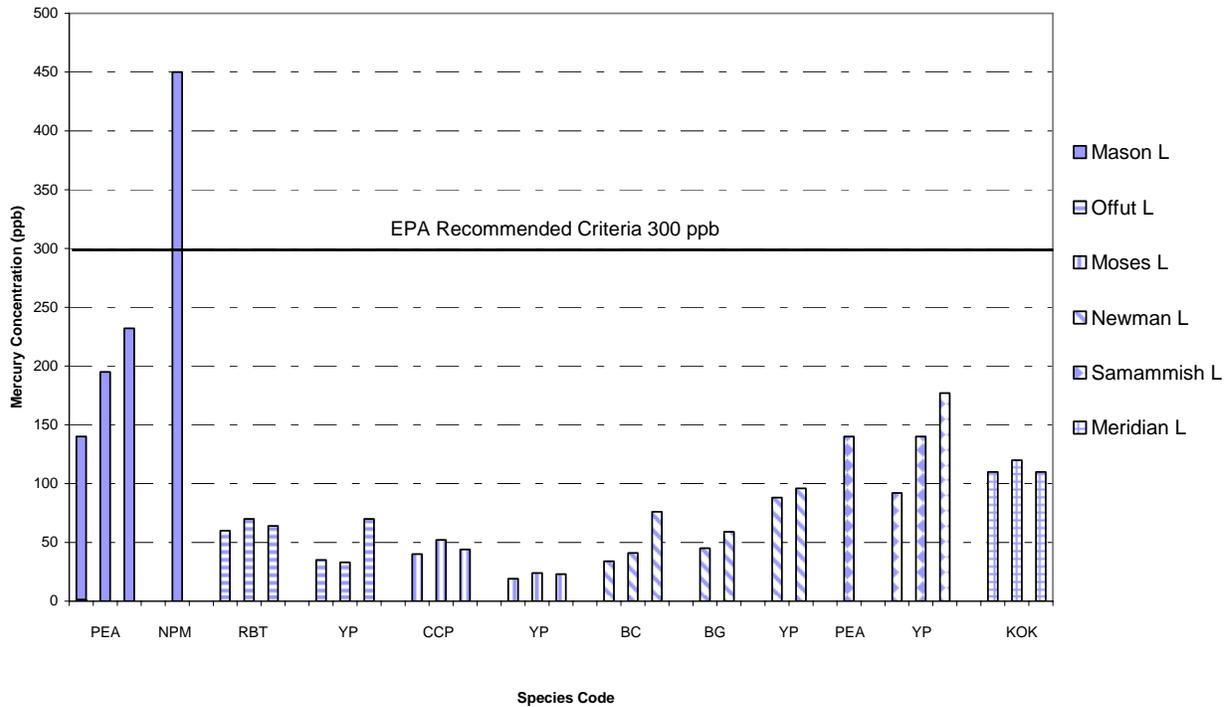


Figure 5. Total Lengths of Individual Fish used for Trends Monitoring.

Newman Lake was the only waterbody where fish collections met both size criteria. Lake Meridian, Moses Lake, and Offut Lake contained bass outside of the target size range and failed to meet the 75% rule. Lake Sammamish bass fell within desired size limits, but the length of the smallest fish was only 62.7% of the largest. All lakes where 10 bass were collected were used for trends monitoring. Future collection efforts will strive to meet target size criterion.

Composite samples were included as part of the second year (2006) of the study. Mercury concentrations for composites are graphed in Figure 7. Size information describing the composites can be found in Appendix C.



* Species codes listed in Appendix C

Figure 7. Mercury Concentrations in Composite Samples.

Mercury concentrations in the composite samples varied from 23 – 450 ppb. Excluding northern pikeminnow (NPM) from Mason Lake, mercury concentrations were relatively low when compared to concentrations in individual largemouth bass. Concentrations in composite samples varied in relation to the levels found in individuals. Meridian, Sammamish, and Mason Lakes were the only lakes containing composite samples over 100 ppb. All three of these lakes had largemouth bass above the EPA’s Recommended Criteria of 300 ppb.

Sediment

Three sediment grab samples were obtained from each 2005 and 2006 study lake excluding Offut Lake. Sediment analysis included mercury, total organic carbon (TOC), and grain size. Figure 8 below displays averaged mercury results. Grain size and TOC data are located in Figure 9. Averaged sediment data for Loon, Long, American, and Moses Lakes include field replicate analyses.

Mercury concentrations, grain size composition, and TOC varied widely between lakes. Mercury concentrations ranged from 9 – 266 ppb. TOC averaged 7.6%. Average grain size among the lakes was 50% fine grained material (< 62 micron (u)).

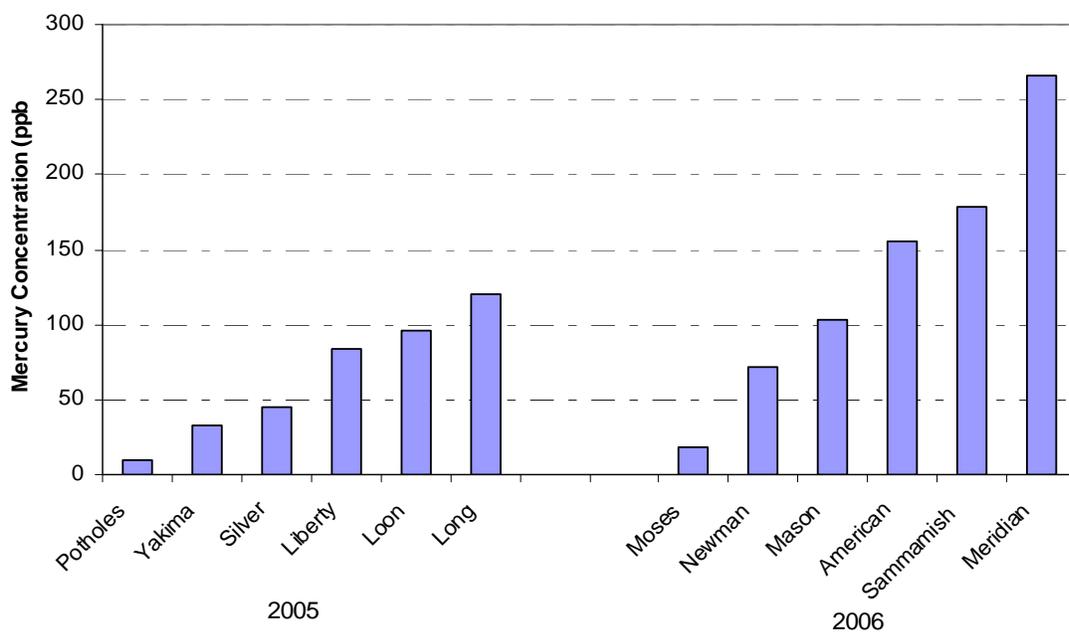


Figure 8. Average Mercury Concentrations in Sediments.

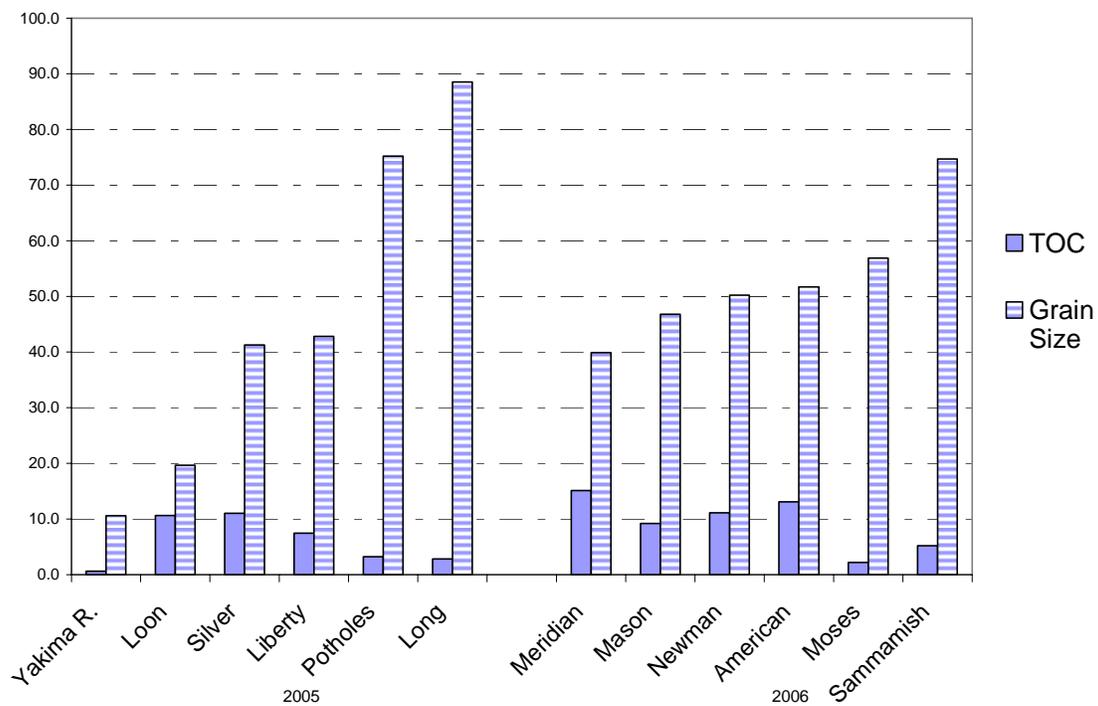


Figure 9. Grain Size (% Fines < 62u) and Total Organic Carbon (%).

Water

Two water samples were obtained from each 2005 and 2006 study lake excluding Offut Lake. Lab analysis for the water samples included alkalinity and dissolved organic carbon (DOC). Dissolved oxygen and temperature profiles taken from Hydrolab[®] measurements for the 2006 study lakes are included in Figure 10. Complete data for 2005 lakes are included in Appendix C.

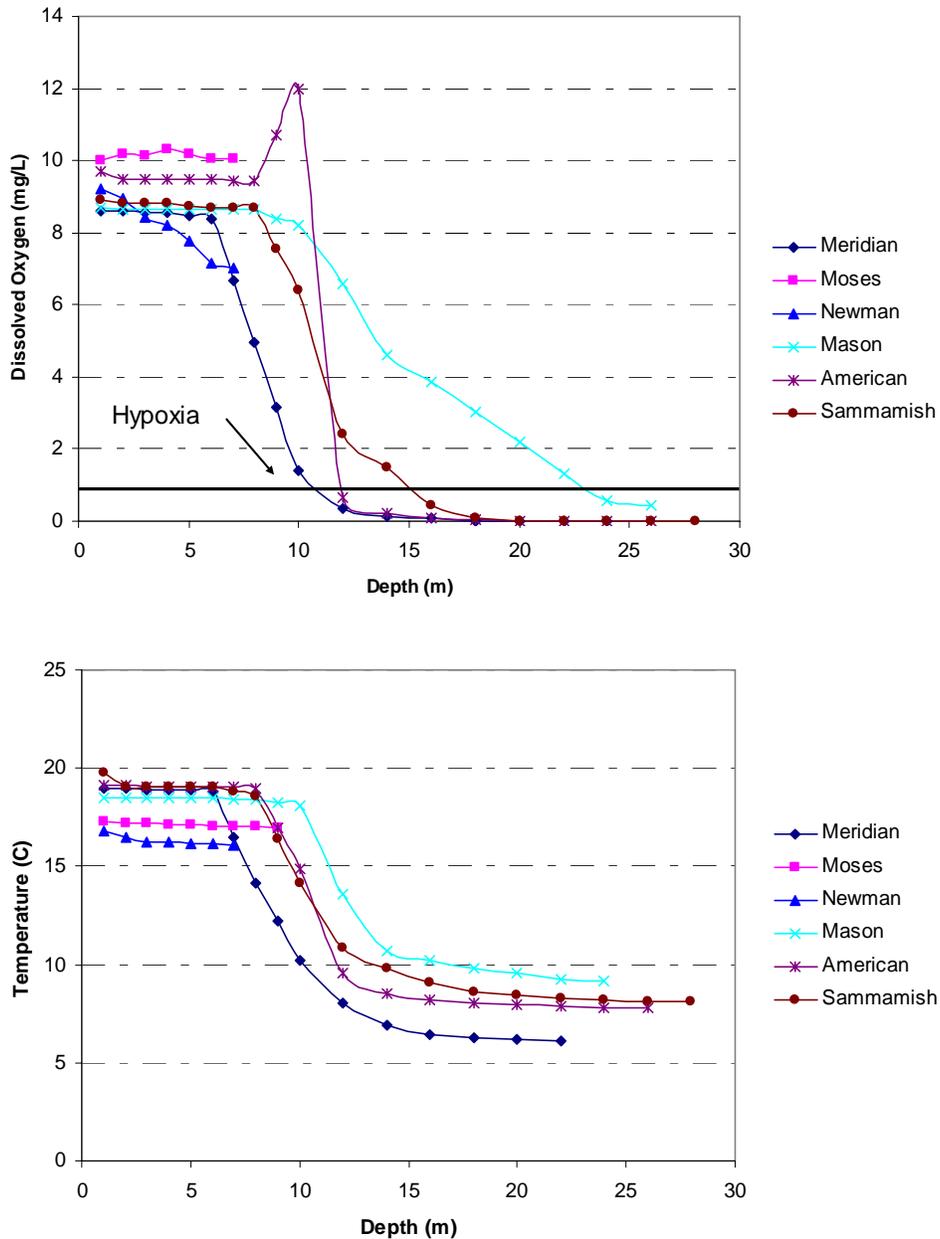


Figure 10. Dissolved Oxygen and Temperature Profiles for the 2006 Study Lakes.

Dissolved oxygen profiles were measured 1-2 times during a single day at lakes in late September to early October. In the 2006 study lakes, hypoxic bottom waters existed at Meridian, American, Sammamish, and Mason Lakes.

Dissolved oxygen depressions occurred at the same depth where temperature profiles revealed distinct thermoclines. Temperature and dissolved oxygen profiles for the 2005 study lakes are included in Appendix C.

DOC levels were similar among lakes with the exception of elevated levels at Newman Lake. Alkalinity measures were also similar among lakes except at Moses Lake where they were over 2.5 times higher. Complete information on all water chemistry measurements for 2005 and 2006 study sites are located in Appendix C.

Discussion

Relationships of Mercury Concentrations and Fish Size and Age

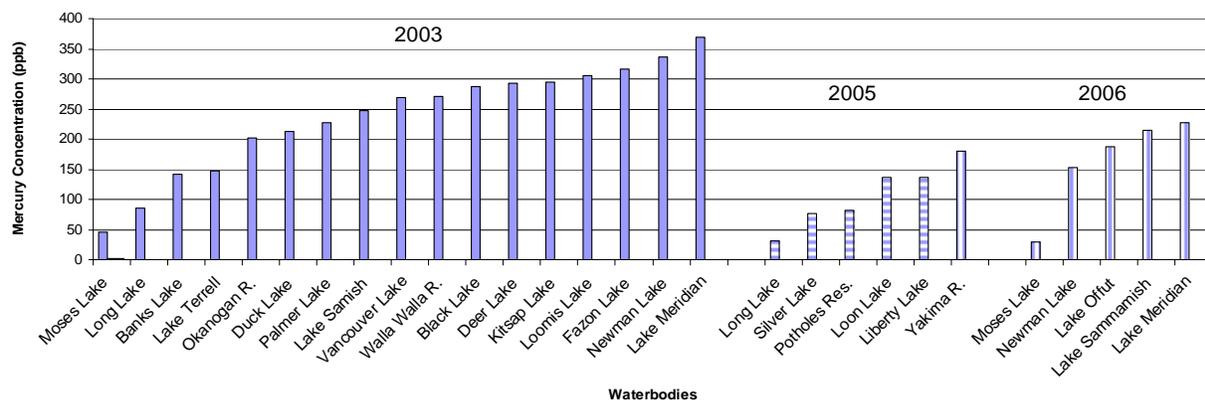
Scatterplots were constructed for mercury concentrations and fish size, weight, and age for species in which 10 individuals were collected (Appendix D). Positive relationships between mercury concentrations and fish size and age have been well established and previously documented in Washington State mercury reports (Furl et al., 2007; Fischnaller et al., 2003; Serdar et al., 2001).

Positive relationships of varying strength between mercury and length, weight, and age were identified in 7 of 8 fish groups (n=10) at the 6 lakes in the 2006 study. Offut Lake largemouth bass exhibited no relationship between mercury and length ($r^2 = .0041$, $p = .860$), weight ($r^2 = .0175$, $p = .716$), or age ($r^2 = .0003$, $p = .961$).

Moses Lake smallmouth bass and Mason Lake yellow perch mercury concentrations displayed no relationship with length or weight (Moses Lake $r^2 = .0407$, $p = .576$; $r^2 = .0175$, $p = .716$; Mason Lake $r^2 = .0595$, $p = .497$; $r^2 = .1562$, $p = .851$ length and weight, respectively).

Standard-Sized Fish and Factors Affecting Bioaccumulation

Multiple regression analysis was used to derive mercury concentrations for a standard-sized fish to allow for direct comparisons between lakes after length was considered (Figure 11). The same technique for calculating a standard-sized fish was used in previous Ecology reports examining mercury in fish (Furl et al., 2007 and Fischnaller et al., 2003).



* 2003 Values are Estimated (Furl 2007a)

Figure 11. Projected Mercury Concentrations for a 356-mm Bass.

Mercury in a standard-sized or 356-mm fish was estimated by calculating the following multiple regression formula:

$$\text{Log}_{10}(Hg) = M + \{B1 * \text{Log}_{10}(356 \text{ mm})\} + \{B2 * (\text{Log}_{10}(356 \text{ mm}))^2\}$$

$$10^{\text{Log}_{10}(Hg)} = \text{Hg Concentration at 356mm}$$

Regression coefficients (M, B1, B2), products, and standardized mercury concentrations are listed in Appendix D. Deer Lake, Loomis Lake, Loon Lake, and Offut Lake were estimated by extrapolating from existing mercury data because length did not serve as adequate independent variable.

Fish Tissue : Sediment Ratio

Sediment to fish tissue (FT:S) mercury ratios were calculated as a means of assessing biological uptake from sediment to a standard-sized 356-mm bass. The ratio was calculated by dividing the mercury concentration in a standardized 356-mm fish by the average mercury concentration in sediment grabs. Figure 12 displays the ratios on a bar graph for 2005 and 2006 study lakes where sediment data and standard-sized fish estimates were available.

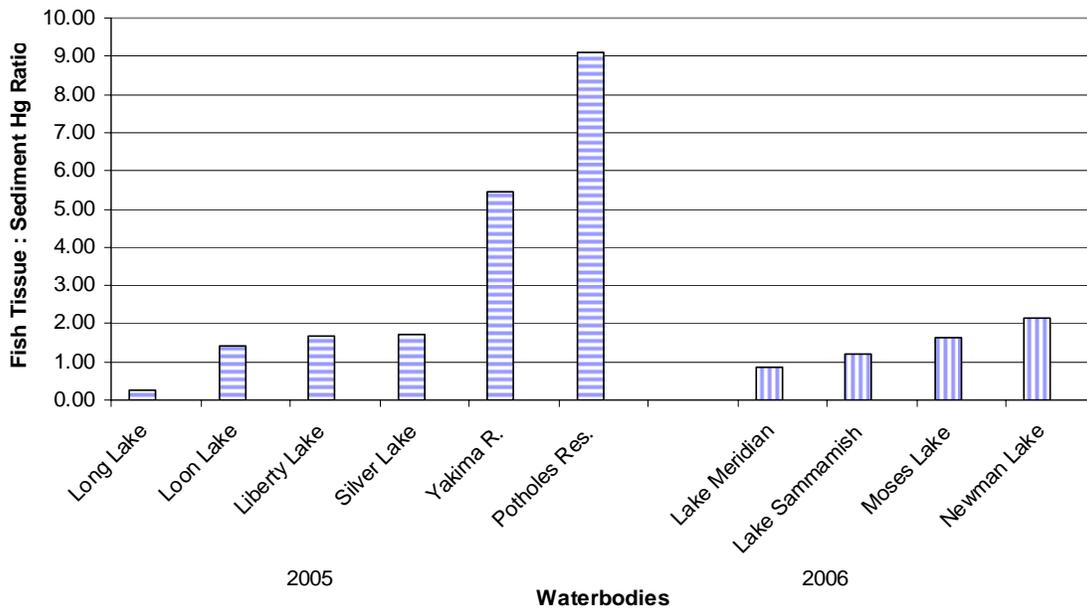


Figure 12. Standardized Fish-to-Sediment Mercury Ratio for 2005 and 2006 Study Lakes.

Potholes Reservoir and the Yakima River had the highest ratios (9.12 and 5.45, respectively). No other waterbody returned a FT:S higher than 3.

It is unknown how well 3 sediment grabs characterize mercury concentrations in sediments. Minimal variance existed between averaged grabs and averaged field replicates, but inflated relative percent differences (RPDs) between the 3 grab samples were encountered at several lakes (Appendix D).

Correlations

The Pearson and Spearman Rank correlations were examined to evaluate relationships between 20 lake variables and mercury concentrations in a standard-sized 356-mm bass and the FT:S ratio. Spearman Rank is a non-parametrical test, used when normality of the data is not known, which ranks data in order of increasing value before calculating coefficients.

In an attempt to reduce variability, lakes were the only type of waterbody analyzed. Excluding the Yakima River, nine lakes remained with enough information to calculate correlations.

Independent variables were grouped into sediment chemical composition, water chemical composition, and morphologic characteristics of the lake. Temperature and pH were divided into top and bottom waters due to the effects of lake stratification. All lake variables except percent anoxic waters were \log_{10} transformed to improve the normality of the data. Appendix D contains the correlation coefficients for all 20 lake variables.

Standard-Sized Bass

Table 5 displays correlation coefficients for the lake variables displaying strong relationships ($\geq .5$) with mercury concentrations in a standard-sized 356-mm bass.

Table 5. Correlations Describing Relationships with Mercury Concentration in a Standard-Sized 356-mm Bass.

Variable Grouping	Lake Variable	Pearson Correlation	Spearman Rank Correlation
Sediment Chemistry	Total organic carbon (TOC)	0.767	0.681
Water Chemistry	Alkalinity	-0.581	-0.519
	% Anoxic Waters	0.707	0.690
	Conductivity	-0.496	-0.500
	pH - Bottom Waters	-0.906	-0.885
	Temperature - Bottom Waters	-0.597	-0.597
Morphologic Characteristics	Surface Area	-0.709	-0.678

Several lake variables were highly correlated with mercury concentrations in a standard-sized 356-mm bass. Significant positive relationships existed between TOC and percent anoxic waters. Anoxic waters were reported as a percentage of surface acres and were estimated in ArcGIS using the dissolved oxygen profiles and bathymetric maps.

The enrichment of methylmercury in anoxic hypolimnetic lake volumes has been observed by several researchers (Herrin et al., 1998; Eckley et al., 2005). Oxygen concentrations have been found to vary spatially and temporally with methylmercury buildup in proportion with each other, and de-stratification is believed to be a key entry point of methylmercury to the food chain (Herrin et al., 1998). Meridian, American, Sammamish, Mason, Loon, and Potholes Lakes experience seasonally anoxic conditions.

Independent variables with negative correlations included bottom water pH levels, alkalinity, conductivity, bottom water temperature levels, and lake surface area.

Negative correlations between pH and alkalinity have been well established with elevated levels of mercury in fish (Hanten et al., 1998; Grieb et al., 1990; Hrabik and Watras, 2002). The increased accumulation of mercury in low-pH systems is attributed to increased microbial methylation in acidic waters (Xun et al., 1987). The inverse relationship with alkalinity and mercury levels is likely related to a waterbody’s inability to neutralize fluxes of acidic waters when alkalinity is very low. The Pearson correlation between alkalinity and pH revealed a strong positive relation in the study lakes (.72).

Conductivity (and other measures of water hardness) has been established to have negative correlations with mercury in fish tissue. Rodgers and Beamish (1983) found uptake of methylmercury from the water column through the gills was twice as high in soft water when compared to hard water.

Fish Tissue : Sediment Ratio

Table 6 presents correlation coefficients for the lake variables displaying strong relationships ($\geq .5$) with the FT:S ratio.

Table 6. Correlations Describing Relationships with the Ratio of Mercury in Fish Tissue to Sediment.

Variable Grouping	Lake Variable	Pearson Correlation	Spearman Rank Correlation
Water Chemistry	DOC	0.423	0.600
	Secchi Depth	-0.378	-0.723
Morphologic Characteristics	DA:SA	0.735	0.683
	Drainage Area	0.859	0.633

DOC – Dissolved organic carbon

DA/SA – Drainage Area : Lake Surface Area

Correlations between lake variables and the FT:S ratio were not as numerous as correlations between standardized fish mercury concentrations and the same variables. Significant correlations describing uptake by largemouth bass were found with DOC, secchi depth, DA:SA ratio, and drainage area. No sediment chemistry variables had a strong correlation with the FT:S ratio.

DA:SA and total drainage area positively correlated with the FT:S ratio. The same relationships were not found between the two independent variables and mercury in sediments or a standardized bass.

Secchi depth had a negative correlation with the FT:S ratio suggesting eutrophic systems support enhanced mercury uptake. This finding is in contrary to other studies which have hypothesized that vegetation and humic matter absorb mercury, lowering the burden on fish communities (Hanten et al., 1998; Grieb et al., 1990).

The effect of carbon on the mercury cycle appears to play a significant but poorly understood role. Total mercury and methylmercury levels in the water column appear to correlate positively with DOC (Watras et al., 1995; Driscoll et al., 1994). Using simple linear regression, Watras et al. (1995) found DOC to account for 82-92% of variability in total mercury in the water column. The report suggests high DOC in the water column favors the methylation of mercury over evasion into the atmosphere.

The relationships between carbon and mercury levels in fish tissue are inconsistent across numerous studies (Hanten et al., 1998; Watral et al., 1995; Grieb et al., 1990). The current (2006) study found a strong positive relation between TOC and mercury in a standard-sized fish, but a weak positive relationship with DOC. DOC had a strong positive relationship with the FT:S ratio, and no relation with TOC.

Trends Assessment

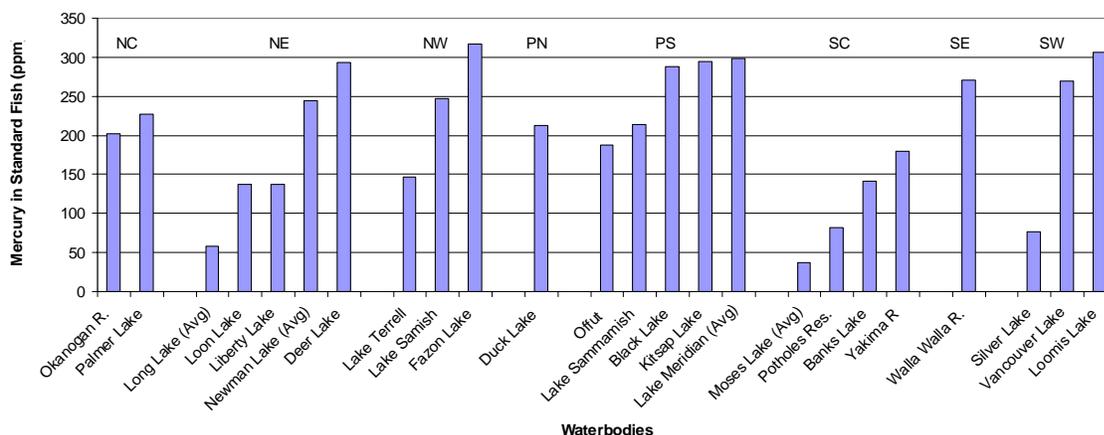
Spatial Analysis

Waterbodies from Figure 11 containing standardized 356-mm bass mercury levels were mapped (Figure 13) to examine spatial differences in mercury concentrations. Lakes sampled multiple times during different years (Meridian, Long, Newman, and Moses) were reported as averages.

To assess differences, Washington State was divided into 8 geographical regions along county lines (PN Peninsular, NW Northwest, PS Puget Sound, SW Southwest, NC Northcentral, SC Southcentral, NE Northeast, SE Southeast). Figure 14 displays mercury concentrations for a 356-mm bass for the 8 regions.

An analysis of variance (ANOVA) was performed to determine if differences exist between lakes in different geographical regions. The results of the ANOVA $F(7, 23) = 1.373, p = .282$ were insignificant. The South Central region – containing Moses Lake, Potholes Reservoir, Banks Lake, and the Yakima River – had the lowest average concentration (ppb = 110, n = 4) of the regions.

Fischnaller et al. (2003) hypothesized waterbodies receiving a large volume of water exchange could serve as a partial explanation of lower mercury levels in fish tissues. All waterbodies in the south central region experience large volumes of water exchange during a year when compared to seepage lakes. Lower mercury levels in the region could also result from: relative isolation from known point sources, possible shorter thermal stratification caused by the flushing, and elevated pH and alkalinity.



* 2003 Values are Estimated (Furl 2007b)

Figure 14. Mercury Concentrations for a 356-mm Bass for the 8 Regions.

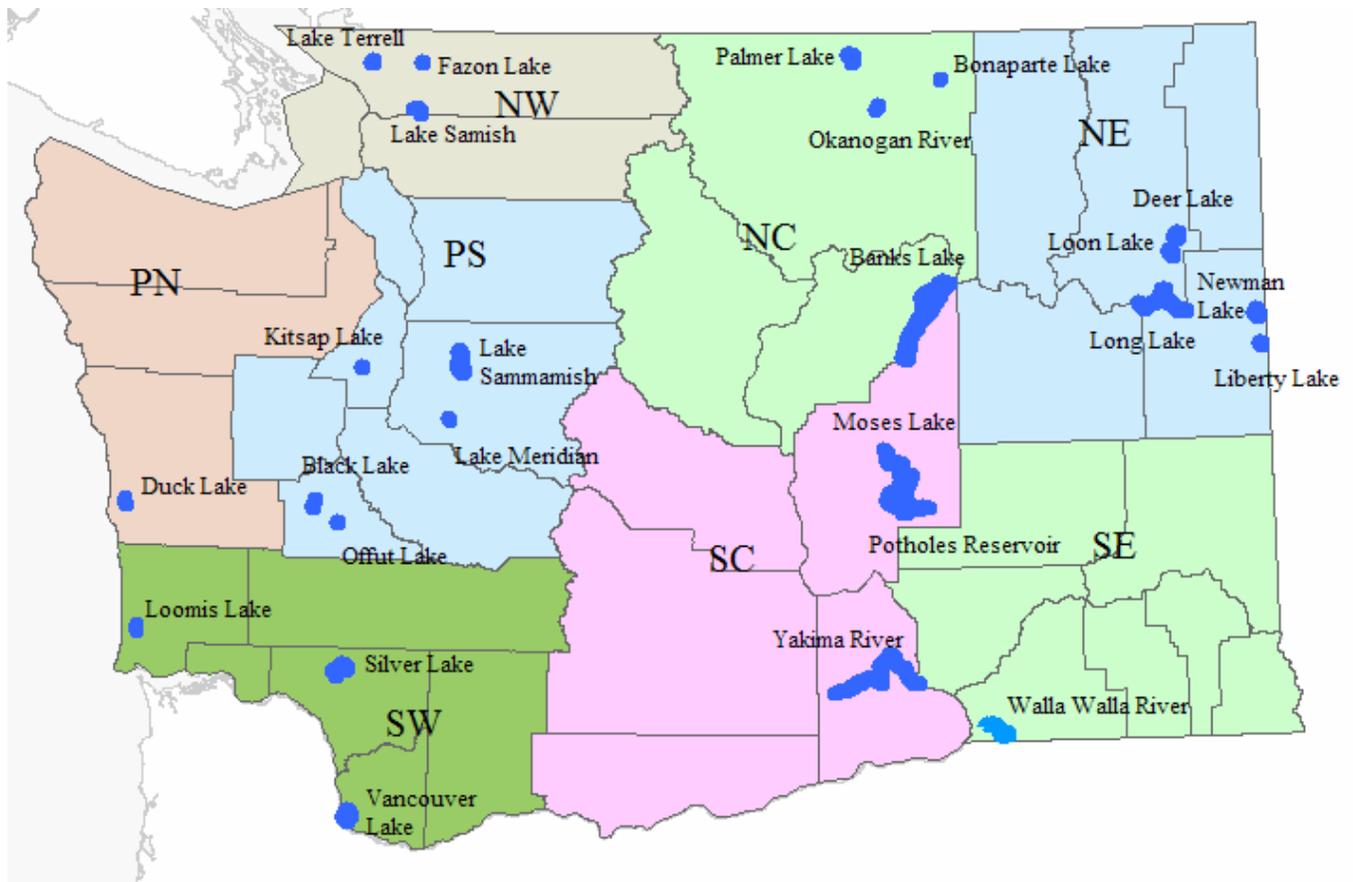


Figure 13. Mercury Sample Sites Categorized by 8 Geographical Regions.

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Temporal Analysis

Meridian, Newman, Long, and Moses Lakes were all sampled as part of the 2003 Fischnaller et al. (2003) study, and subsequently sampled as part of the 2005 or 2006 mercury trends studies. In order to estimate any shifts in trends and their magnitudes, a generalized linear model of mercury concentrations in tissues as a function of \log_{10} transformed lengths and a dummy variable representing collection year was generated.

$$1. \text{Log}_{10}(Hg) = M + B1(\log_{10} \text{Length}) + B2(\text{Year})$$

Year was assigned a value of 0 (Fischnaller et al., 2003) or 1 (Mercury Trends) corresponding with the study. The coefficient B2 and standard error associated with the variable were used to estimate the shift for each lake using the following equation:

$$2. g = 100 \{ \exp [B2(V(B2)/2)] - 1 \}$$

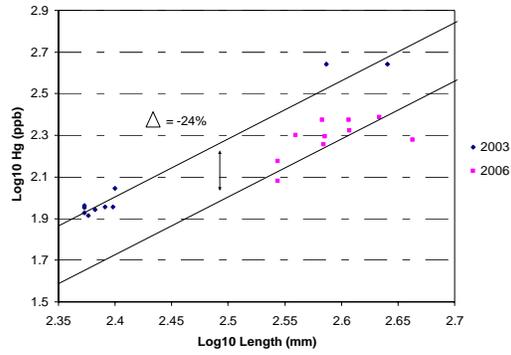
where $V(B2)$ is the estimated variance of B2 (Halvorsen and Palmquist, 1980; Kennedy, 1981).

Figure 15 displays the slopes of the lines calculated from the multiple regression model (equation 1) using the dummy variable alongside plotted data from both years and the estimated shift (g). Appendix D contains regression results for each of the lakes.

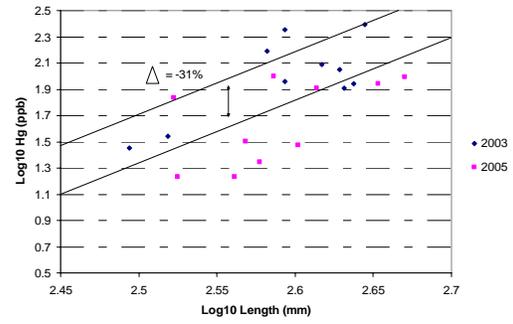
Time between sample recoveries ranged from 49-59 months, and in all four cases mercury levels in a standard-sized bass from the 2003 study were higher than levels found in the more recent studies.

The magnitude of decrease in \log_{10} mercury concentrations for fish at a given length ranged from 13% at Lake Meridian to 31% at Long Lake. Isolating and quantifying the relative effects responsible for the apparent mercury reduction in tissues at the lakes are difficult due to lack of standardized ancillary data from the 2003 study.

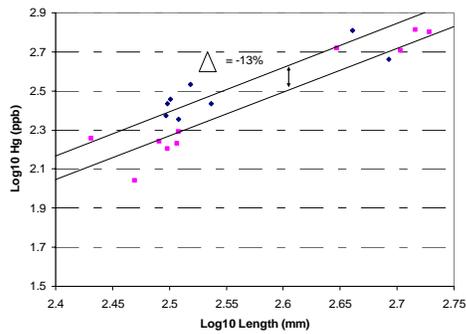
Fish collection from Long Lake occurred in different areas of the waterbody. It should be noted, Munn et al. (1995) reported spatial variances attributed to different feeding grounds in walleye tissues from Lake Roosevelt.



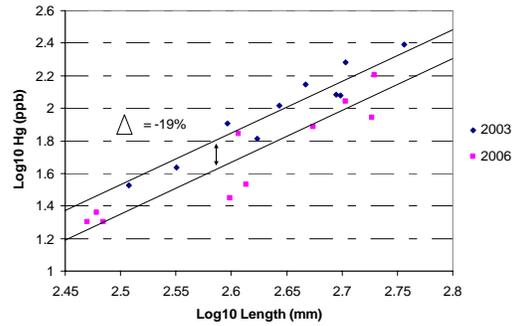
Newman Lake; 50 months



Long Lake; 53 months



Lake Meridian; 59 months



Moses Lake; 49 months

* 2003 Values are Estimated (Furl 2007b)

Figure 15. Temporal Analyses of Lakes Sampled during Multiple Years.

Criteria for Protection of Human Health

Criteria for Mercury

Various criteria have been developed for mercury in fish tissue in order to meet differing needs:

- EPA's recommended criterion of 300 ppb wet weight (ww) (based on 17.5 grams/day consumption rate).
- National Toxics Rule: 825 ppb ww (based on 6.5 grams/day consumption rate).
- EPA screening values which are 400 ppb ww for recreational fishers and 49 ppb ww for subsistence fishers (based on freshwater fish consumption rates of 17.5 and 142.4 grams/day, respectively).

These criteria are summarized below and compared with mercury levels found in fish collected in 2006. Appendix F discusses how the state Department of Ecology and state Department of Health (DOH) evaluate fish tissue data to meet the different mandates these agencies have.

EPA's recommended criterion

The EPA's current recommended water quality criterion for methylmercury is 300 ppb (EPA, 2001). This is the maximum advisable concentration of methylmercury in fish and shellfish to protect consumers among the general population. EPA expects the criterion to be used as guidance by states and authorized tribes, and EPA in establishing or updating water quality standards for waters of the United States.

National Toxics Rule

Washington State's water quality standards for toxic substances (WAC 173-201A-040[5]) define human-health-based water quality criteria by referencing 40 CFR 131.36, also known as the National Toxics Rule (NTR). Washington's water quality standards further state that risk-based criteria for carcinogenic substances be based on a risk level of 10^{-6} . A risk level is an estimate of the number of cancer cases that would be caused by exposure to a specific contaminant. At a risk level of 10^{-6} , one person in a million would be expected to contract cancer due to long-term exposure to a specific contaminant. These risks are upper-bound estimates, while true risks may be as low as zero. Exposure assumptions include an acceptable risk level and the consumer's body weight, length of exposure, and consumption rate. The NTR criteria are based on a consumption rate of 6.5 grams/day.

EPA Screening Values

Screening values (SVs) for carcinogenic and non-carcinogenic substances were developed by EPA to aid the prioritization of areas that may present risks to human populations from fish consumption. The EPA SVs are considered guidance only; they are not regulatory thresholds (EPA, 2000).

Assumptions about exposure to contaminants were also used in developing the EPA SVs. The SV approach is similar to that used for developing the NTR with two assumptions: the cancer risk level (10^{-5}) and the consumption rate (17.5 grams/day for recreational fishers and 142.4 grams per day for subsistence fishers). SVs for non-carcinogenic effects are calculated using toxicological data from a variety of tests.

Human Health Criteria Exceedances

While the criterion recommended by EPA in 2001 for mercury in freshwater fish is 300 ppb, the NTR criterion of 825 ppb ww remains to be the value used in Washington's water quality standards for regulatory purposes. DOH's process for establishing fish consumption advisories uses an approach similar to the EPA's *Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories Vol. 1-4*. Information about DOH's evaluation of fish toxics data are detailed in Appendix E.

Seventeen percent of individual fish analyzed and 3% of fish composites exceeded EPA's recommended criterion (300 ppb). Seventy-four percent of individual and 70% of composite samples were above the EPA Screening Values for subsistence fishermen (49 ppb). Eight percent of individual and 3% of composite samples exceeded the EPA Screening Values for recreational fisherman (400 ppb). A single nine-year-old female bass from Mason Lake contained a mercury concentration of 952 ppb. This sample was the only result in excess of the National Toxics Rule (825 ppb).

Conclusions

A total of 85 individual fish and 31 composite samples from 7 lakes were analyzed for the second year (2006) of a five-year study to gather information on mercury trends in Washington State. Total mercury was the target analyte for fish collected from American Lake, Mason Lake, Lake Meridian, Moses Lake, Newman Lake, Offut Lake, and Lake Sammamish.

Consistent with previous Ecology mercury reports, mercury concentrations were generally higher in older and larger fish (Furl et al., 2007; Fischnaller 2003). A total of 17% (14) of individuals and 3% (1) of composites sampled exceeded (were higher than) the EPA's recommended water quality criterion of 300 ppb. A single nine-year-old female bass from Mason Lake contained a mercury concentration of 952 ppb. This sample was the only result exceeding the National Toxics Rule of 825 ppb. Other significant findings included:

- A temporal analysis was performed for 4 lakes (Newman, Meridian, Long, and Moses) sampled in 2003 and again for the 2005 and 2006 mercury trends reports. Time between sampling events ranged from 49-59 months, and results estimated a decrease in \log_{10} mercury concentrations for fish at a given fish length, ranging from 13-31%.
- Correlations examining relationships between lake variables and mercury concentrations in bass tissue found carbon (dissolved organic and total organic), pH, temperature, and percent anoxic water to have the most significant correlations.
- A total of 24 waterbodies from the 2005 and 2006 mercury trends reports and the Fischnaller et al. (2003) mercury review were divided into 8 geographical areas. Standardized mercury concentrations were compared through an analysis of variance (ANOVA) to determine if any regions significantly differed from the others. Results of the ANOVA were insignificant, but the South Central region containing Moses Lake, Potholes Reservoir, Banks Lake, and the Yakima River contained the lowest average mercury concentration of all regions. Lower mercury levels in the region could result from relative isolation from known point (discrete) sources as well as increased flushing experienced by reservoirs and rivers.
- Field and laboratory measurements were taken for water and sediment samples to characterize chemical and physical composition from the 2005 and 2006 mercury trends study lakes. The 2005 study included Potholes Reservoir, Yakima River, Silver Lake, Liberty Lake, Loon Lake, and Long Lake. Average mercury concentrations in sediment samples from the lakes in both studies ranged from 9 ppb in Potholes Reservoir to 266 ppb in Lake Meridian. Lake Meridian was the only lake with average mercury concentration over 200 ppb.

Recommendations

As a result of this study, the following recommendations are made:

- Conduct Hydrolab measurements as close to peak lake stratification as possible (July-August) to measure the full extent of anoxic waters. Measure dissolved oxygen a second time in the fall before collecting fish to determine if de-stratification has occurred.
- Continue to test for differences between mercury concentrations in environmental media from waterbodies with wide-ranging levels of water exchange.
- Consider adding low-level mercury analysis to the water sampling plan to gain data on mercury accumulation in the water column of stratified and well-mixed lakes.
- Future efforts concerning trends analyses should continue to sample the same fish species whenever possible in these waterbodies: American Lake, Mason Lake, Lake Meridian, Moses Lake, Newman Lake, Offut Lake, and Lake Sammamish.
- Continue to sample lakes in diverse locations where temporal analysis may be executed to determine if mercury levels in bass have decreased statewide.
- Resample Mason Lake and American Lake to better characterize the extent of mercury contamination in largemouth bass.

References

- Bloom, N., 1995. Considerations in the Analysis of Water and Fish for Mercury. In National Forum on Mercury in Fish: Proceedings. U.S. Environmental Protection Agency, Office of Water, Washington D.C. Publication No. 823-R-95-002.
- CFR, 2004. Code of Federal Regulations, Title 40, Part 131, Section 36: Toxics Criteria for Those States Not Complying with Clean Water Act Section 303(3)(2)(B). Revised July 1, 2004. www.ecy.wa.gov/programs/wq/swqs/national_toxics_rule.pdf
- Driscoll, C., C. Yan, C. Schofield, R. Munson, and J. Holsapple, 1994. The Mercury Cycle and Fish in the Adirondack Lakes. Environment Science and Technology, Volume 28, No. 3. American Chemical Society.
- Eckley, C.S., C.J. Watras, H. Hintelmann, K. Morrison, A.D. Kent, and O. Regnell, 2005. Mercury Methylation in the Hypolimnetic Waters of Lakes with and without Connection to Wetlands in Northern Wisconsin. Canadian Journal of Fisheries and Aquatic Sciences, Vol. 62 400-411.
- EPA, 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories - Volume 1: Field Sampling and Analysis, Third Edition. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. Publication No. EPA-823-B-00-007. www.epa.gov/ost/fishadvice/volume1/
- EPA, 2001. Water Quality Criterion for the Protection of Human Health: Methylmercury. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, D.C. Publication No. EPA-823-R-01-001.
- Fischnaller, S., P. Anderson, and D. Norton, 2003. Mercury in Edible Fish Tissue and Sediments from Selected Lakes and Rivers of Washington State. Washington State Department of Ecology, Olympia, WA. Publication No. 03-03-026. www.ecy.wa.gov/biblio/0303026.html
- Furl, C., 2007a. History of Mercury in Selected Washington Lakes Determined from Age-Dated Sediment Cores: 2006 Sampling Results. Washington State Department of Ecology, Olympia, WA. Publication No. 07-03-019. www.ecy.wa.gov/biblio/0703019.html
- Furl, C., 2007b. A Comparison of Two Analytical Methods for Measuring Mercury in Fish Tissues. Washington State Department of Ecology, Olympia, WA. Publication No. 07-03-041. www.ecy.wa.gov/biblio/0703041.html
- Furl, C., K. Seiders, D. Alkire, and C. Deligeannis, 2007. Measuring Mercury Trends in Freshwater Fish in Washington State: 2005 Sampling Results. Washington State Department of Ecology, Olympia, WA. Publication No. 07-03-007. www.ecy.wa.gov/biblio/0703007.html

Gallagher, M., 2000. Proposed Strategy to Continually Reduce Persistent, Bioaccumulative Toxins (PBTs) in Washington State. Washington State Department of Ecology, Olympia, WA. Publication No. 00-03-054. www.ecy.wa.gov/biblio/0003054.html

Grieb, T.M., C.T. Driscoll, S.P. Gloss, C. L. Schofield, G.L. Bowie, and D.B. Porcella, 1990. Factors Affecting Mercury Accumulation in Fish in the Upper Michigan Peninsula. *Environmental Toxicology and Chemistry*, Vol. 9, 919-930.

Halvorsen, R. and P. Palmquist, 1980. The Interpretation of Dummy Variables in Semilogarithmic Equations. *American Economic Review*, Vol. 70, 1980, 474-475.

Hanten, R.P, R.M. Neuman, S.M. Ward, R.J. Carley, C.R. Perkins, and R. Pirrie, 1998. Relationships Between Concentrations of Mercury in Largemouth Bass and Physical and Chemical Characteristics of Connecticut Lakes. *Transactions of the American Fisheries Society*, Vol. 127, 807-818.

Herrin, R.T., R.C. Lathrop, P.R. Gorski, A.W. Andren, 1998. Hypolimnetic Methylmercury and its Uptake by Plankton During Fall Destratification: A Key Entry Point of Mercury Into Lake Food Chains? *Limnology and Oceanography*, Vol. 43, No. 7, 1476-1486.

Hrabik, T.R. and C.J. Watras, 2002. Recent Declines in Mercury Concentration in a Freshwater Fishery: Isolating the Effects of De-Acidification and Decreased Atmospheric Mercury Deposition in Little Rock Lake. *The Science of the Total Environment*, Vol. 297, 229-237.

Joslin, J.D., 1994. Regional Differences in Mercury Levels in Aquatic Ecosystems: A Discussion of Possible Causal Factors with Implications for the Tennessee River System and Northern Hemisphere. *Environmental Management*, Vol. 18, 559-567

Kennedy, P., 1981. Estimation with Correctly Interpreted Dummy Variables in Semilogarithmic Equations. *American Economic Review*, Vol. 71, 1981, 801.

Lake Whatcom Cooperative Management Program, 2001. Fish Advisory: Mercury in Lake Whatcom Smallmouth Bass and Yellow Perch. Whatcom County, City of Bellingham, and Water District #10. www.lakewhatcom.wsu.edu/lwhealthadv.html

Mason, R.P., W.F. Fitzgerald, and F.M. Morel, 1994. The Biogeochemical Cycling of Elemental Mercury: Anthropogenic Influences. *Geochim. Cosmochim. Acta*, Vol. 58 (15): 3191-3198.

McBride, D., 2003. Statewide Bass Advisory. Washington State Department of Health, Olympia, WA. www.doh.wa.gov/ehp/oehas/publications%20pdf/statewide_%20bass_%20advisory-2003.pdf

MEL, 2005. Manchester Environmental Laboratory Lab Users Manual. 8th Edition. Washington State Department of Ecology, Environmental Assessment Program, Olympia, WA.

- Momohara, D., 2007. Personal communication. Case Narrative for Laboratory Results for the Mercury Trends in Fish 2006 study. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA.
- Morel, F., A. Kraepiel, and M. Amyot, 1998. The Chemical Cycle and Bioaccumulation of Mercury. *Annual Reviews of Ecology and Systematics*. November 1998, Volume 29: 543-566. Annual Reviews, Palo Alto, CA.
- Munn, M., S. Cox, and C. Dean, 1995. Concentrations of Mercury and Other Trace Elements in Walleye, Smallmouth Bass, and Rainbow Trout in Franklin D. Roosevelt Lake and the Upper Columbia River, Washington, 1994. U.S. Geological Survey, Open-File Report 95-195, Tacoma, WA.
- Norton, D., 2004. Mercury in Lake Whatcom Sediments: Spatial Distribution, Depositional History, and Tributary Inputs. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-019. www.ecy.wa.gov/biblio/0403019.html
- Paulson, A. J., 2004. Sources of Mercury in Sediments, Water, and Fish of the Lakes of Whatcom County, Washington. U.S. Geological Survey Scientific Investigations Report 2004-5084. USGS, Reston, VA.
- Peele, C., 2003. Washington State Mercury Chemical Action Plan. Washington State Departments of Ecology and Health, Olympia, WA. Ecology Publication No. 03-03-001. www.ecy.wa.gov/biblio/0303001.html
- PSEP, 1986. Puget Sound Estuary Program: Recommended Protocols for Measuring Selected Variables in Puget Sound. U.S. Environmental Protection Agency, Region 10, Office of Puget Sound, Seattle, WA.
- Rodgers, D.W. and F.W.H. Beamish, 1983. Water Quality Modifies Uptake of Waterborne Methylmercury by Rainbow Trout, *Salmo Gairdneri*. *Canadian Journal of Fisheries and Aquatic Sciences*, Vol. 40, 824-828.
- Seiders, K., 2006. Measuring Mercury Trends in Freshwater Fish in Washington State: Quality Assurance Project Plan. Washington State Department of Ecology, Olympia, WA. Publication No. 06-03-103. www.ecy.wa.gov/biblio/0603103.html
- Seiders, K. and B. Yake, 2002. Washington State Toxics Monitoring Program: Exploratory Monitoring of Toxic Contaminants in Edible Fish Tissue and Freshwater Environments of Washington State: Quality Assurance Project Plan. Washington State Department of Ecology, Olympia, WA. Publication No. 02-03-065. www.ecy.wa.gov/biblio/0203065
- Sekerak, S., 2007. Personal communication. Case Narrative for Laboratory Results for the Mercury Trends in Fish 2006 study. Manchester Environmental Laboratory, Washington State Department of Ecology, Olympia, WA.

Serdar, D., J. Johnston, K. Mueller, and G. Patrick, 2001. Mercury Concentrations in Edible Muscle of Lake Whatcom Fish. Washington State Department of Ecology, Olympia, WA. Publication No. 01-03-012. www.ecy.wa.gov/biblio/0103012.html

Swanson, T., 2007. Standard Operating Procedures for Hydrolab[®], DataSonde[®], and MiniSonde[®] Multiprobes. Washington State Department of Ecology, Olympia, WA. www.ecy.wa.gov/programs/eap/qa/docs/ECY_EAP_SOP_Hydrolab_v1_0.pdf

USGS, 1997. Are Walleye from Lake Roosevelt Contaminated with Mercury? USGS Fact Sheet No. 102-97, August 1997. U.S. Government Printing Office.

Watras, C., K. Morrison, J. Host, and N. Bloom, 1995. Concentration of Mercury Species in Relationship to Other Site-Specific Factors in the Surface Waters of Northern Wisconsin Lakes. *Limnology and Oceanography*, 1995, Volume 40:556-565. American Society of Limnology and Oceanography, Inc. Canmore, Alberta, Canada.

Xun, L., N.E.R. Campbell, and J.W.M. Rudd, 1987. Measurements of Specific Rates of Net Methyl Mercury Production in the Water Column and Surface Sediments of Acidified and Circumneutral Lakes. *Canadian Journal of Fisheries and Aquatic Sciences*, Vol. 44, 750-757.

Appendices

- A. Sampling Sites
- B. Quality Assurance Data
- C. Biological, Sediment, and Water Quality Measures
- D. Statistical Comparisons
- E. Fish Tissue Data Evaluation by Ecology and DOH

Appendix A. Sampling Sites

Table A1. Sample Site Descriptions for the 2006 Study

Site Name	Latitude ¹	Longitude ¹	WBID	County	EIM "User Location ID"	WRIA
American Lake	47.13257	-122.563	WA-38-9005	Pierce	AMERICAN-F	12
Mason Lake	47.3364	-122.958	WA-14-9120	Mason	MASON-F	14
Lake Meridian	47.36252	-122.153	WA-09-9160	King	MERIDIAN-F	9
Moses Lake	47.15812	-119.342	WA-41-9250	Grant	MOSES-F	41
Newman Lake	47.77384	-117.101	WA-57-9020	Spokane	NEWMAN-F	57
Offut Lake	46.91722	-122.827	WA-13-9110	Thurston	OFFUT-F	13
Lake Sammamish	47.6031	-122.094	WA-08-9270	King	SAMMAMISH-F	8

¹ NAD83 HARN

WBID – Waterbody Identification

EIM – Ecology’s Environmental Information Management Database

WRIA – Water Resource Inventory Area

Appendix B. Quality Assurance Data

Fish

Fish tissue analyses for mercury were performed by Manchester Environmental Laboratory (MEL) between January 16 and February 15, 2007. Samples were received by the laboratory frozen and in good condition. Analyses were performed within EPA established holding times. Measurement quality objectives (MQOs) for fish tissue analysis are described in Table B1.

Table B1. Measurement Quality Objectives for Fish Tissue Analysis.

Parameter	Matrix	Reporting Limit	Accuracy	Check Standard (% recovery limit)	Duplicate Sample (RPD)	Matrix Spike (% recovery limit)
Mercury, total	tissue	0.017 mg/kg, wet	+/- 15% of SRM value	80-120%	<20%	75-125%

RPD – Relative Percent Difference
SRM – Standard Reference Material

Data quality for fish tissue was assessed through matrix spikes, laboratory blanks, standard reference material (Standard Reference Material 1946), laboratory control samples, and laboratory duplicates. All laboratory control measures met the above MQOs and are recorded in Tables B2 – B6.

Table B2. Matrix Spike Duplicates.

Sample Number	Recovery	RPD (%)
07024730 LMX1	94	5.5
07024730 LMX2	89	
07024750 LMX1	95	0.0
07024750 LMX2	95	
07024760 LMX1	102	3.0
07024760 LMX2	99	
07024780 LMX1	84	3.5
07024780 LMX2	87	
07024790 LMX1	92	1.1
07024790 LMX2	91	
07014255 LMX1	93	0.0
07014255 LMX2	93	
07014265 LMX1	86	3.4
07014265 LMX2	89	
Mean	92.1	2.4

RPD – Relative Percent Difference

Table B3. Laboratory Blanks.

Sample Number	Result (mg/Kg)
MB07016H1	0.017 U
MB07022H1	0.017 U
MB07022H2	0.017 U
MB07030H1	0.017 U
MB07030H2	0.017 U
MB07030H3	0.017 U
MB07008H2	0.017 U
MB07016H1	0.017 U

U = undetected at the level indicated

Table B4. Standard Reference Material.

Sample Number	Recovery (%)
ML07016H2	102
ML07022H3	95
MI07022H4	107
ML07030H3	98
ML07030H4	103
ML07030H6	102
ML07008H6	111
ML07016H2	102

Table B5. Laboratory Control Samples.

Sample Number	Recovery (%)
ML07016H1	103
ML07022H1	101
ML07022H2	100
ML07030H1	105
ML07030H2	103
ML07030H5	103
ML07008H4	109
ML07016H1	103

Table B6. Laboratory Duplicates.

Sample Number	Result (mg/Kg)	RPD (%)
07024730	0.228, 0.22	3.6
07024750	0.092, 0.089	3.3
07024760	0.048, 0.05	4.1
07024780	0.16, 0.15	6.5
07027490	0.034, 0.038	11.1
07014255	0.12, 0.13	8.0
07014265	0.326, 0.288	12.4
	Mean	7.0

RPD – Relative Percent Difference

Sediment

Sediment analyses were conducted from October – December 2006. Samples were received by the laboratory in proper condition. All analyses were performed by MEL staff except for grain size which was done by Analytical Resources Inc. All sediment analyses were performed within set holding times. MQOs as outlined by the project plan appear in Table B7.

Table B7. Measurement Quality Objectives for Sediment Analysis.

Parameter	Matrix	Reporting Limit	Accuracy	Check Standard (% recovery limit)	Duplicate Sample (RPD)	Matrix Spike (% recovery limit)
Mercury, total	Sediment	0.005 mg/kg, dry	N/A	85-115%	<20%	75-125%
Total Organic Carbon	Sediment	0.1%	N/A	80-120%	<20%	75-125%
Grain Size	Sediment	1%	N/A	N/A	<20%	N/A

RPD – Relative Percent Difference

Quality control with TOC and mercury analyses was assessed by examining matrix spikes, blanks, duplicates, and field replicates. Results appear in Tables B8 – B16. Quality assurance for grain size was assessed through triplicate samples. The triplicate samples met quality objectives (<20% RPD). The majority of grain size analyses were qualified due to either being frozen before analysis, abundant organic material, or an improper amount of fines for accurate pipette analysis. All grain size averages were qualified as estimates because no lake had all three samples with no qualifiers.

Table B8. Mercury Duplicates

Sample Number	Result (mg/Kg)	RPD (%)
06384248	0.229 0.239	4.3
06384249	0.357 J 0.282 J	23.5
06384250	0.212 0.238	11.6
06394270	0.084 0.093	10.2
06394271	0.120 0.110	8.7
06394272	0.14 0.20	35.3

J = qualified as estimate

Table B9. Mercury – Matrix Spikes

Sample Number	Recovery (%)	RPD (%)
06384243	90	6.2
06384248	121	
06394264	88	
06404306 - LMX1	78	
06404306 - LMX2	83	

Table B10. Mercury – Field Replicates

Sample Number	Field ID	Result (mg/Kg)	Sample Number	Field ID	Result (mg/Kg)
06384232	AMER-SED1	0.141	06384237	REP1-SED1	0.0818
06384233	AMER-SED2	0.162	06384238	REP1-SED2	0.153
06384234	AMER-SED3	0.194	06384239	REP1-SED3	0.204
	Mean	0.166		Mean	0.146
	RPD of results	31.6 %		RPD of results	85.5 %
				RPD of Means	12.4 %

Table B11. Mercury – Laboratory Blanks

Sample Number	Result (mg/Kg)
MB06279H1	.005 U
MB06286H1	.005 U
MB06286H2	.005 U
MB06296H1	.005 U

Table B12. Mercury – Laboratory Control Samples

Sample Number	Recovery (%)
ML06279H1	104
ML06286H1	103
ML06286H2	104
ML06296H1	99

All total organic carbon (TOC) data met objectives except for two duplicates that had a relative percent difference (RPD) > 20%.

Table B13. TOC – Duplicates

Sample Number	Result (%)	RPD (%)
06384260	7.22	54.3
	4.16	
	5.54	
06404291	1.39	53.1
	2	
	1.19	
06394263	2.83	1.1
	2.83	
	2.8	
06384232	9.05	0.1
	9.04	
06384233	12.4	0.8
	12.3	
06384234	15.8	1.9
	15.5	
06394270	8.41	1.6
	8.28	
06394271	11.2	6.5
	10.5	
06394272	12.8	2.4
	12.5	

Table B14. TOC – Matrix Spikes

Sample Number	Recovery (%)
GL06276T4-ERAN	87
GL06284T1-ERAN	87
GL06284T2-ERAN	100

Table B15. TOC – Blanks

Sample Number	Result (%)
GB06276T4	0.1 U
GB06284T1	0.1 U
GB06284T2	0.1 U

Table B16. TOC – Field Replicates

Sample Number	Field ID	Result (%)		Sample Number	Field ID	Result (%)
06384232	AMER-SED1	9.05		06384237	REP1-SED1	9.54
06384233	AMER-SED2	12.4		06384238	REP1-SED2	10.4
06384234	AMER-SED3	15.8		06384239	REP1-SED3	21.2
	Mean	12.4			Mean	13.7
	RPD of results	54.3			RPD of results	75.9
					RPD of Means	9.9

Tables B17-B18 display mercury results, the relative percent difference (RPD), and the relative standard deviation (RSD) of sample values from the three sediment grabs.

Of 6 mercury duplicates, sample 06384249 failed to meet established MQOs. The laboratory duplicate for sample 06394272 had a RPD greater than 20%, but the results were not qualified due to a result value less than 5 times the reporting limit. The elevated reporting limit was caused by sediment consistency (Sekerak, 2007).

Matrix spikes and laboratory control samples were all recovered at acceptable limits. No detectable amounts of mercury were found in method blanks. The RPDs for the concentrations of mercury in grabs varied widely from 31.6 and 85.5%. However, the RPDs between the means of the 3 grabs were low (12.4%). The low RPD suggests 3 samples accurately represent mercury levels in sediments although individual grabs can vary widely.

Table B17. 2006 Mercury in Sediments Results.

Moses Lake		American Lake		Newman Lake		Lake Sammamish		Lake Meridian		Mason Lake	
Field ID	Result (ppb)	Field ID	Result (ppb)	Field ID	Result (ppb)	Field ID	Result (ppb)	Field ID	Result (ppb)	Field ID	Result (ppb)
MOS-SED1	13	AMER-SED1	141	NEW-SED1	59	SAM-SED1	121	MERD-SED1	229	MASN-SED1	127
MOS-SED2	16	AMER-SED2	162	NEW-SED2	86	SAM-SED2	163	MERD-SED2	357	MASN-SED2	121
MOS-SED3	25	AMER-SED3	194	NEW-SED3	69	SAM-SED3	250	MERD-SED3	212	MASN-SED3	63
MOS-SED4	12	REP1-SED1	82								
MOS-SED5	11	REP1-SED2	153								
MOS-SED6	17	REP1-SED3	204								
Mean	15.7		156.0		71.3		178.0		266.0		103.7
RPD ¹	89.4%		78.2%		37.9%		72.5%		54.5%		55.9%
RSD ²	32.7		27.9		19.1		37		29.8		34.1

¹ RPD = (max - min) / ((mean) * 100)

² RSD = 100 * (sd / mean)

Table B18. 2005 Mercury in Sediments Results.

Loon Lake		Long Lake		Potholes Reservoir		Yakima River		Silver Lake		Liberty Lake	
Field ID	Result (ppb)	Field ID	Result (ppb)	Field ID	Result (ppb)	Field ID	Result (ppb)	Field ID	Result (ppb)	Field ID	Result (ppb)
LOON-SED1	84	LLSP-SED1	120	POT-SED1	9.5	YAK-SED1	32	SLVR-SED1	51	LIB-SED1	98
LOON-SED2	120	LLSP-SED2	120	POT-SED2	9.2	YAK-SED2	40	SLVR-SED2	37	LIB-SED2	80
LOON-SED3	140	LLSP-SED3	110	POT-SED2	8.9	YAK-SED3	26	SLVR-SED3	48	LIB-SED3	72
REP2-SED1	57	EXT-SED1	120								
REP2-SED2	86	EXT-SED2	130								
REP2-SED3	90										
Mean	96.2		120.0		9.2		32.7		45.3		83.3
RPD ¹	86.3%		20.4%		6.5%		42.9%		30.9%		31.2%
RSD ²	30.5		5.9		3.3		21.5		16.3		16

¹ RPD = (max - min) / ((mean) * 100)

² RSD = 100 * (sd / mean)

Water

Measurement quality objectives for water analysis are presented in Table B19.

Table B19. Measurement Quality Objectives for Water Analysis.

Parameter	Matrix	Reporting Limit	Accuracy	Check Standard (% recovery limit)	Duplicate Sample (RPD)	Matrix Spike (% recovery limit)
Dissolved Organic Carbon	water	1 mg/L	N/A	80-120%	<20%	75-125%
Alkalinity	water	5 mg/L	N/A	80-120%	<10%	N/A
Dissolved Oxygen	water	0.2 mg/L	+/- 0.2 mg/L	N/A	< 10%	N/A
pH	water	1.0 SU	+/- 0.3 pH units	N/A	< 10%	N/A
Conductivity	water	5 uS/cm	+/- 5 uS/cm	N/A	< 10%	N/A
Temperature	water	0.0 C	+/- 0.2 C	N/A	< 10%	N/A
Secchi Disc (20 cm dia)	water	1/4 foot	+/- 1/4 foot	N/A	< 10%	N/A

Quality criteria outlined in the project plan was met for dissolved organic carbon (DOC). One of 4 field replicates contained an elevated RPD relative to the other replicates. Six DOC samples were analyzed past their holding times and qualified as estimates. Tables B20-24 display results of quality assurance tests conducted for DOC analysis.

Table B20. DOC – Laboratory Duplicates

Sample Number	Result (mg/L)	RPD (%)
06384230	2.10	0.0
	2.10	
06384231	1.80	0.0
	1.80	

Table B21. DOC – Laboratory Blanks

Sample Number	Result (mg/L)
06384240	1 U
06394278	1 U
GB06279T2	1 U
GB06299T2	1 U
GB06297T1	1 U
GB06298T1	1 U
GB06298T2	1 U

Table B22. DOC – Laboratory Control Samples

Sample Number	Recovery (%)
GL06279T2	103
GL06299T2	102
GL06297T1	102
GL06298T1	101
GL06298T2	101

Table B23. DOC – Laboratory Matrix Spike

Sample Number	Recovery (%)
06384235	101

Table B24. DOC – Field Replicates

Sample Number	Result (mg/L)	Sample Number	Result (mg/L)	RPD (%)
06384230-T (American Lake)	2.1	06384235-T (American Lake)	1.6	27.0
06384231-B (American Lake)	1.8	06384236-B (American Lake)	2	10.5
06394268-T (Loon Lake)	3.4	06394273-T (Loon Lake)	3.8	11.1
06394269-B (Loon Lake)	3.1	06394274-B (Loon Lake)	3.5	12.1

Ten alkalinity samples were analyzed past their holding times and qualified as estimates. Tables B25-28 display the results of quality assurance tests for alkalinity.

Table B25. Alkalinity – Laboratory Duplicates

Sample Number	Result (mg/L)	RPD (%)
06384230	47 J 47 J	0.0
06384231	47 J 47 J	0.0
06394268	86.8 86.7	0.1
06394269	86.7 86.1	0.7
06394284	24.50 24.60	0.4

Table B26. Alkalinity – Laboratory Blanks

Sample Number	Result (mg/L)
GB06277K1	5 U
GB06276K3	5 U
GB06288K1	5 U
GB06283K1	5 U
GB06285K1	5 U
GB06288K2	5 U

Table B27. Alkalinity – Laboratory Control Samples

Sample Number	Recovery (%)
GL06277K1	100
GL06276K3	101
GL06288K1	103
GL06283K1	99
GL06285K1	100
GL06288K2	101

Table B28. Alkalinity – Field Replicates

Sample Number	Result (mg/L)	Sample Number	Result (mg/L)	RPD (%)
06384230-T	47 J	06384235-T	47 J	0.0
06384231-B	47 J	06384236-B	47 J	0.0
06394268-T	86.8	06394273-T	86.9	0.1
06394269-B	86.7	06394274-B	87.2	0.1

Appendix C. Biological, Sediment, and Water Quality Measures

Table C1. Individual Fish Data by Lake

Lake	Collection Date	Species	Total Length (mm)	Weight (gm)	Age	Fulton's Fish Condition Index	Sex	Mercury (ppb)
American	9/14/2006	LMB	474	2287	7	2.15	F	334
American	9/14/2006	LMB	530	3069	12	2.06	F	499
American	9/14/2006	LMB	550	4330	9	2.60	F	595
Mason	10/24/2006	YP	230	150	3	1.23	F	48
Mason	10/24/2006	YP	240	182	3	1.32	F	75
Mason	9/19/2006	YP	222	131	4	1.20	M	77
Mason	10/24/2006	YP	250	203	4	1.30	F	92
Mason	9/19/2006	YP	225	138	4	1.21	M	93
Mason	10/24/2006	YP	225	134	4	1.18	F	99
Mason	10/24/2006	YP	240	162	4	1.17	F	100
Mason	9/19/2006	YP	227	120	4	1.03	F	130
Mason	10/24/2006	YP	230	145	4	1.19	F	130
Mason	10/24/2006	YP	245	184	4	1.25	F	170
Mason	9/20/2006	LMB	366	864	4	1.76	M	364
Mason	9/20/2006	LMB	481	1971	9	1.77	F	952
Meridian	10/5/2006	LMB	295	354	2	1.38	F	110
Meridian	10/23/2006	LMB	315	500	2	1.60	F	160
Meridian	10/5/2006	LMB	321	568	2	1.72	F	170
Meridian	10/5/2006	LMB	310	494	2	1.66	M	175
Meridian	10/5/2006	LMB	270	316	1	1.61	M	180
Meridian	10/6/2006	LMB	322	635	2	1.90	M	195
Meridian	10/5/2006	LMB	505	2423	6	1.88	F	511
Meridian	10/5/2006	LMB	444	1483	7	1.69	M	523
Meridian	10/5/2006	LMB	535	2955	7	1.93	F	633
Meridian	10/23/2006	LMB	520	2836	7	2.02	F	648
Moses	10/9/2006	LMB	295	490	1	1.91	M	20
Moses	10/9/2006	LMB	305	554	1	1.95	F	20
Moses	11/6/2006	LMB	301	521	1	1.91	M	23
Moses	11/6/2006	LMB	397	1329	2	2.12	F	28
Moses	10/9/2006	LMB	411	1434	3	2.07	M	34
Moses	11/6/2006	LMB	404	1347	5	2.04	F	70
Moses	10/9/2006	LMB	472	2168	5	2.06	M	77
Moses	11/6/2006	LMB	533	3173	7	2.10	F	88
Moses	11/6/2006	LMB	505	2800	7	2.17	M	110
Moses	11/6/2006	LMB	536	3260	9	2.12	F	160
Moses	10/9/2006	SMB	329	568	2	1.59	F	24
Moses	10/10/2006	SMB	369	780	2	1.55	F	25
Moses	10/9/2006	SMB	343	745	2	1.85	M	26
Moses	10/9/2006	SMB	363	773	2	1.62	F	28
Moses	10/9/2006	SMB	369	848	2	1.69	F	30
Moses	10/9/2006	SMB	371	858	2	1.68	M	30
Moses	10/9/2006	SMB	355	739	2	1.65	F	32
Moses	10/9/2006	SMB	408	1225	3	1.80	M	34
Moses	10/9/2006	SMB	396	1049	3	1.69	F	40
Moses	10/9/2006	SMB	350	665	2	1.55	F	54

Table C1 (cont.)

Lake	Collection Date	Species	Total Length (mm)	Weight (gm)	Age	Fulton's Fish Condition Index	Sex	Mercury (ppb)
Moses	10/9/2006	WAL	458	996	2	1.04	M	21
Moses	10/9/2006	WAL	448	885	2	0.98	M	24
Moses	10/9/2006	WAL	455	1078	2	1.14	F	24
Moses	10/9/2006	WAL	467	897	2	0.88	M	34
Moses	10/9/2006	WAL	492	1073	2	0.90	M	38
Moses	10/9/2006	WAL	481	1090	2	0.98	M	39
Moses	10/9/2006	WAL	524	1591	2	1.11	F	40
Moses	10/9/2006	WAL	494	1332	4	1.10	M	66
Moses	10/9/2006	WAL	550	1721	6	1.03	M	72
Moses	10/9/2006	WAL	490	1070	2	0.91	M	73
Newman	9/27/2006	LMB	350	588	5	1.37	M	120
Newman	9/27/2006	LMB	350	548	4	1.28	M	150
Newman	9/27/2006	LMB	384	765	5	1.35	F	180
Newman	9/27/2006	LMB	460	1825	6	1.87	F	190
Newman	9/27/2006	LMB	385	813	6	1.42	M	197
Newman	9/27/2006	LMB	363	656	4	1.37	F	200
Newman	9/27/2006	LMB	405	1003	5	1.51	F	210
Newman	9/27/2006	LMB	383	796	6	1.42	M	236
Newman	9/27/2006	LMB	404	1133	5	1.72	M	237
Newman	9/27/2006	LMB	430	1123	6	1.41	M	244
Offut	10/30/2006	LMB	265	261	1	1.40	M	160
Offut	10/30/2006	LMB	330	652	2	1.81	M	180
Offut	10/30/2006	LMB	270	253	1	1.29	F	183
Offut	10/30/2006	LMB	245	176	1	1.20	F	190
Offut	10/30/2006	LMB	358	823	2	1.79	M	190
Offut	10/30/2006	LMB	290	348	1	1.43	F	208
Offut	10/30/2006	LMB	440	1575	3	1.85	F	209
Offut	10/30/2006	LMB	305	455	2	1.60	M	228
Offut	10/30/2006	LMB	430	1490	3	1.87	F	228
Offut	10/30/2006	LMB	255	228	1	1.38	M	336
Sammamish	10/4/2006	LMB	313	566	2	1.85	M	120
Sammamish	10/4/2006	LMB	282	389	1	1.73	F	140
Sammamish	10/4/2006	LMB	315	583	2	1.87	M	180
Sammamish	10/4/2006	LMB	343	775	2	1.92	F	207
Sammamish	10/4/2006	LMB	394	959	4	1.57	M	209
Sammamish	10/4/2006	LMB	450	1530	4	1.68	F	294
Sammamish	10/4/2006	LMB	394	1234	3	2.02	F	311
Sammamish	10/4/2006	LMB	435	1412	5	1.72	M	327
Sammamish	10/4/2006	LMB	415	1123	4	1.57	M	332
Sammamish	10/4/2006	LMB	417	1197	4	1.65	M	351

U = The analyte was not detected at or above the reported value

Table C2. Composite Fish Data

Lake	Collection Date	Species Code	Total Length (mm)	Weight (gm)	Fulton's Fish Condition Index	Number of Fish in Composite	Mercury (ppb)	Individual or Composite
Mason	9/19/06	PEA	264.8	151.2	0.81	5	140	C
Mason	9/19/06	PEA	270.0	159.2	0.81	5	195	C
Mason	9/19/06	PEA	282.8	182.6	0.81	5	232	C
Mason	9/19/06	NPM	373.0	475.6	0.81	5	450	C
Mason	10/24/06	YP	241.0	176.2	1.25	5	99	C
Meridian	10/5/06	KOK	295.8	224.2	0.86	5	110	C
Meridian	10/5/06	KOK	315.8	253.0	0.80	5	120	C
Meridian	10/5/06	KOK	327.6	279.8	0.80	5	110	C
Meridian	10/6/06	LMB	465.2	2066.4	1.88	5	512	C
Moses	10/9/06	CCP	538.0	2238.0	1.44	3	40	C
Moses	10/9/06	CCP	567.7	2541.3	1.39	3	52	C
Moses	10/9/06	CCP	604.7	3117.3	1.41	3	44	C
Moses	10/9/06	YP	234.0	175.6	1.37	5	19	C
Moses	10/9/06	YP	242.0	186.2	1.31	5	24	C
Moses	10/9/06	YP	267.4	239.0	1.24	5	23 U	C
Newman	9/27/06	BC	197.8	123.4	1.60	5	34	C
Newman	9/27/06	BC	211.8	149.2	1.57	5	41	C
Newman	9/27/06	BC	252.2	257.0	1.56	5	76	C
Newman	9/27/06	BG	163.3	88.3	2.03	4	45	C
Newman	9/27/06	BG	180.0	126.4	2.14	5	59	C
Newman	9/27/06	LMB	416.8	1179.4	1.59	5	262	C
Newman	9/27/06	YP	188.5	71.0	1.06	4	88	C
Newman	9/27/06	YP	200.8	82.0	1.01	5	96	C
Offut	10/30/06	LMB	372.6	999.0	1.79	5	209	C
Offut	10/30/06	RBT	217.2	112.2	1.10	5	60	C
Offut	10/30/06	RBT	221.0	116.2	1.08	5	70	C
Offut	10/30/06	RBT	230.0	121.6	1.00	5	64	C
Offut	10/30/06	YP	222.2	132.2	1.20	5	35	C
Offut	10/30/06	YP	242.6	158.0	1.22	5	33	C
Offut	10/30/06	YP	304.0	371.4	1.32	5	70	C
Sammamish	10/4/06	LMB	370.8	940.6	1.79	5	326	C
Sammamish	10/4/06	LMB	380.8	1013.0	1.72	5	262	C
Sammamish	10/4/06	PEA	290.0	260.8	1.00	5	140	C
Sammamish	10/4/06	YP	209.4	99.4	1.08	5	92	C
Sammamish	10/4/06	YP	238.0	142.6	1.05	5	140	C
Sammamish	10/5/06	YP	268.4	233.6	1.20	5	177	C

U = The analyte was not detected at or above the reported value

Table C3. Water and Sediment Results

Waterbody	Study Year	Collection Date	Field ID	Sediment				Water		
				Depth (m)	Mercury (ppb)	TOC (%)	Grain Size (% fines) ¹	Chl-a (ug/L)	Alkalinity (mg/L)	DOC (mg/L)
Yakima R.	2005	10/5/2006	YAK-SED1	3.0	32	1.39 J	7.5 J	-	-	-
			YAK-SED2	0.9	40	0.9	15.2 J	-	-	-
			YAK-SED3	0.6	26	0.32	9.1	-	-	-
			YAK-T2	1.5	-	-	-	0.16	119	1.5
Loon	2005	9/26/2006	LOON-SED1	30.5	84	8.41	42.4 J	-	-	-
			LOON-SED2	18.6	120	11.2	17.3 J	-	-	-
			LOON-SED3	14.6	140	12.8	15.4 J	-	-	-
			REP2-SED1	21.0	57	10.6	15.6 J	-	-	-
			REP2-SED2	13.7	86	9.62	15 J	-	-	-
			REP2-SED3	19.8	90	11.2	12.1 J	-	-	-
			LOON-T	4.0	-	-	-	2.5	86.8	3.4
			LOON-B	20.0	-	-	-	0.28	86.7	3.1
			REP2-T	4.0	-	-	-	2.3	86.9	3.8
			REP2-B	20.0	-	-	-	0.43	87.2	3.5
REP4 (BLK)	-	-	-	-	0.05 U	-	1 U			
Silver	2005	9/20/2006	SLVR-SED1	3.0	51	9.56	44.9 J	-	-	-
			SLVR-SED2	2.4	37	11	40.8 J	-	-	-
			SLVR-SED3	1.8	48	12.5	38.1 J	-	-	-
			SLVR-T	1.5	-	-	-	48.4 J	34	7.2 J
Liberty	2005	9/28/2006	LIB-SED1	7.6	98	6.73	43.2 J	-	-	-
			LIB-SED2	7.9	80	10.2	46.9 J	-	-	-
			LIB-SED3	7.6	72	5.42	38.4 J	-	-	-
			LIB-T	2.5	-	-	-	.25 J	24.5	3.9
			LIB-B	6.5	-	-	-	.41 J	24.3	3.8
Potholes	2005	8/3/2006	POT-SED1	30.5	9.5	3.02	78.2 J	-	-	-
			POT-SED2	13.7	9.2	2.75	66.4 J	-	-	-
			POT-SED2	19.5	8.9	3.82	81 J	-	-	-
			POT-T	4.0	-	-	-	.26 J	153	2.9
			POT-B	16.0	-	-	-	.05 UJ	162	2.7
			LLSP-SED1	32.0	120	2.83	89.3 J	-	-	-
Long	2005	9/25/2006	LLSP-SED2	21.3	120	2.83	91.5 J	-	-	-
			LLSP-SED3	30.5	110	2.75	89 J	-	-	-
			EXT-SED1	36.6	120	3.08	83.7 J	-	-	-
			EXT-SED2	47.2	130	2.49	89.2 J	-	-	-
			LLSP-T	4.5	-	-	-	5.9	98.5 J	1.6 J
			LLSP-B	20.0	-	-	-	1.9	88.3 J	1.5 J
			MERD-SED1	24.7	229	14.8	49.3 J	-	-	-
Meridian	2006	9/19/2006	MERD-SED2	8.8	357	14.9	33.4 J	-	-	-
			MERD-SED3	15.2	212	15.6	37.1 J	-	-	-
			MERD-T	3.0	-	-	-	2.4	39	3.1 J
			MERD-B	18.0	-	-	-	0.65	41	3 J
			MASN-SED1	25.9	127	9.74	66.6 J	-	-	-
Mason	2006	9/20/2006	MASN-SED2	18.3	121	10.6	48.3 J	-	-	-
			MASN-SED3	15.2	63	7.22 J	25.6 J	-	-	-
			MASN-T	5.0	-	-	-	1.7	22	1.5 J
			MASN-B	20.0	-	-	-	0.67	21	1.3 J
			NEW-SED1	7.6	59	8.26	65.5 J	-	-	-
Newman	2006	9/27/2006	NEW-SED2	5.2	86	11.9	45.3 J	-	-	-
			NEW-SED3	5.2	68.8	13.1	39.7 J	-	-	-
			NEW-T	2.5	-	-	-	13.8	15 J	4.8
			NEW-B	5.5	-	-	-	12.6	16 J	4.8
			AMER-SED1	26.8	141	9.05	67.3 J	-	-	-
American	2006	9/18/2006	AMER-SED2	21.6	162	12.4	52.1 J	-	-	-
			AMER-SED3	13.7	194	15.8	32.4 J	-	-	-
			REP1-SED1	29.0	81.8	9.54	65.6 J	-	-	-
			REP1-SED2	21.6	153	10.4	60 J	-	-	-
			REP1-SED3	12.5	204	21.2	32.9 J	-	-	-
			AMER-T	4.0	-	-	-	1.7 J	47 J	2.1
			AMER-B	18.0	-	-	-	2.8 J	47 J	1.8
			REP1-T	4.0	-	-	-	0.72 J	47 J	1.6
			REP1-B	18.0	-	-	-	1.9 J	47 J	2
			REP3 (BLK)	-	-	-	-	0.05	-	1 U
Moses (N)	2006	10/4/2006	MOS-SED1	8.2	13	2.9	81.5 J	-	-	-
			MOS-SED2	5.5	16	1.07	10	-	-	-
			MOS-SED3	3.0	25	2.6	79.1 J	-	-	-
			MOS-NT	3.0	-	-	-	0.09	128	2.4
			MOS-NG	5.5	-	-	-	0.2	129	2.9
Moses (S)	2006	10/4/2006	MOS-SED4	10.1	12	3.02	73.8 J	-	-	-
			MOS-SED5	5.2	11	0.75	11.9	-	-	-
			MOS-SED6	3.7	17	1.58	65.5 J	-	-	-
			MOS-ST	3.5	-	-	-	0.36	123	2.6
			MOS-SB	7.0	-	-	-	0.3	123	2.8
Sammamish	2006	9/19/2006	SAM-SED1	28.7	121	4.14	87.63	-	-	-
			SAM-SED2	25.9	163	5.07	67.2 J	-	-	-
			SAM-SED3	16.8	250	6.51	69.4 J	-	-	-
			SAM-T	4.0	-	-	-	2.7	47	2.4
			SAM-B	23.0	-	-	-	0.22	46	2.1

¹ Results qualified as estimates, (% fines = < 62u)

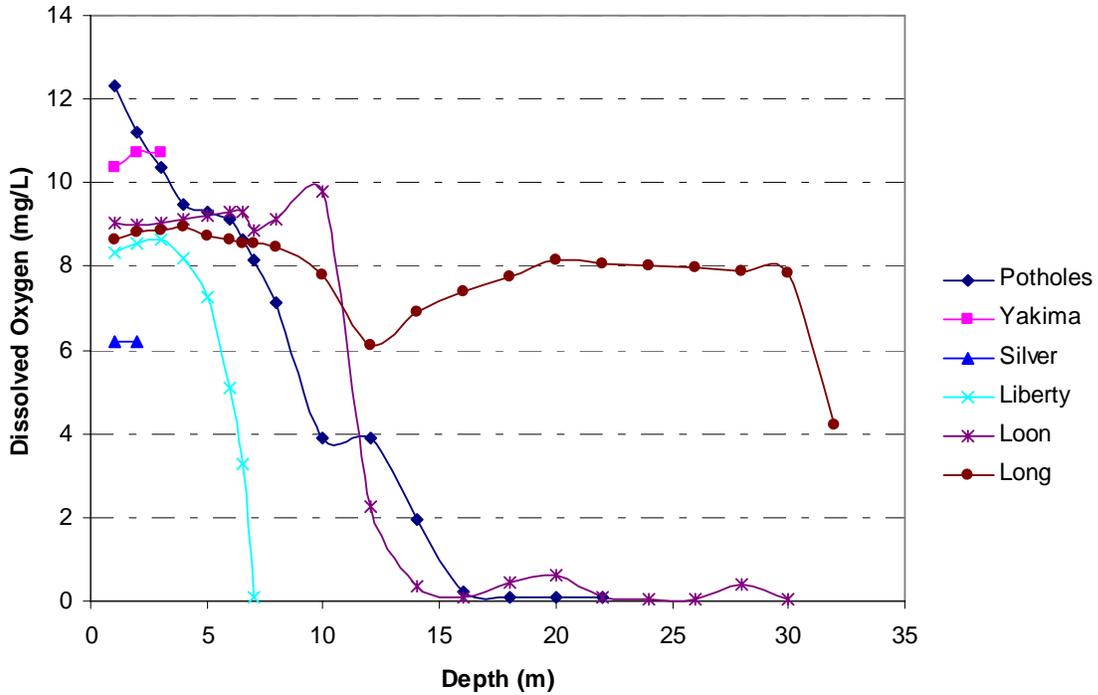


Figure C1. Dissolved Oxygen Profiles for 2005 Study Lakes between September 15 – October 15.

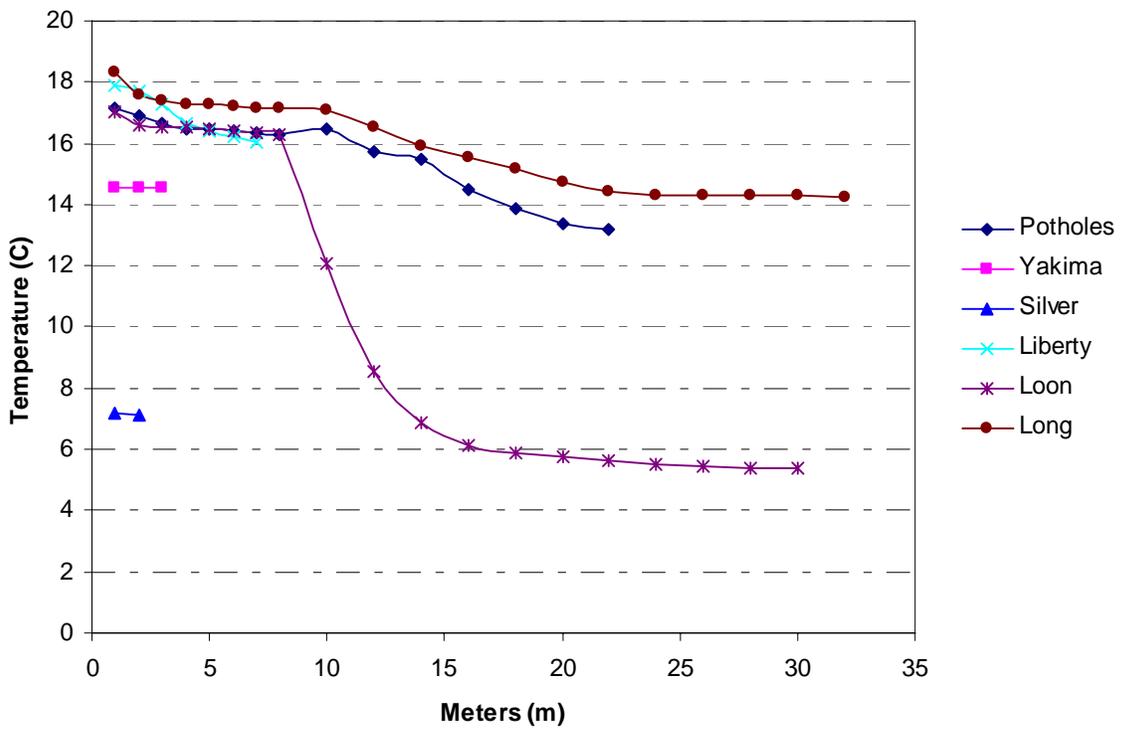


Figure C2. Temperature Profiles for 2005 Study Lakes between September 15 – October 15.

Table C4. Species Code List used by the Department of Ecology

Common name	Scientific name	Ecology Species Code
Black crappie	<i>Pomoxis nigromaculatus</i>	BC
Bluegill	<i>Lepomis macrochirus</i>	BG
Bridgelip sucker	<i>Catostomus columbianus</i>	BLS
Brook trout	<i>Salvelinus fontinalis</i>	BKT
Brown bullhead	<i>Ameiurus nebulosus</i>	BBH
Brown trout	<i>Salmo trutta</i>	BNT
Burbot	<i>Lota lota</i>	BUR
Channel catfish	<i>Ictalurus punctatus</i>	CC
Chiselmouth	<i>Arocheilus alutaceus</i>	CLM
Common carp	<i>Cyprinus carpio</i>	CCP
Cutthroat trout	<i>Oncorhynchus clarki</i>	CTT
Green sturgeon	<i>Acipenser medirostris</i>	GST
Green sunfish	<i>Lepomis cyanellus</i>	GS
Kokanee salmon	<i>Oncorhynchus nerka</i>	KOK
Lake trout	<i>Salvelinus namaycush</i>	LT
Lake whitefish	<i>Coregonus clupeaformis</i>	LWF
Largemouth bass	<i>Micropterus salmoides</i>	LMB
Largescale sucker	<i>Catostomus macrocheilus</i>	LSS
Longnose sucker	<i>Catostomus catostomus</i>	LNS
Mountain sucker	<i>Catostomus platyrhynchus</i>	MS
Mountain whitefish	<i>Prosopium williamsoni</i>	MWF
Northern pikeminnow	<i>Ptychocheilus oregonensis</i>	NPM
Peamouth	<i>Mylocheilus caurinus</i>	PEA
Pumpkinseed	<i>Lepomis gibbosus</i>	PMP
Rainbow trout	<i>Oncorhynchus mykiss</i>	RBT
Rock bass	<i>Ambloplites rupestris</i>	RKB
Sculpins	<i>Cottus sp.</i>	COT
Smallmouth bass	<i>Micropterus dolomieu</i>	SMB
Starry flounder	<i>Platichthys stellatus</i>	STF
Walleye	<i>Stizostedion vitreum</i>	WAL
Warmouth	<i>Lepomis gulosus</i>	WM
White crappie	<i>Pomoxis annularis</i>	WC
White sturgeon	<i>Acipenser transmontanus</i>	WST
Yellow bullhead	<i>Ameiurus natalis</i>	YBH
Yellow perch	<i>Perca flavescens</i>	YP

Appendix D. Statistical Comparisons

Table D1. Adjusted Mercury Levels for a Standardized Length and Weight.

Waterbody	Species	Study	Regression Coefficients			Mercury Concentration at 356mm	p	r ²
			Constant	B1	B2			
Moses Lake	LMB	Fischnaller et al. 2003	-5.289	2.044	0.267	46	0.000	0.905
Long Lake	LMB		-346.551	266.766	-51.024	85	0.021	0.573
Banks Lake	LMB		158.016	-125.669	25.311	141	0.012	0.634
Lake Terrell	LMB		140.926	-111.341	22.323	146	0.014	0.62
Okanogan R.	LMB		69.509	-54.893	11.191	202	0.000	0.872
Duck Lake	LMB		114.056	-91.727	18.788	212	0.000	0.905
Palmer Lake	LMB		55.528	-44.418	9.241	227	0.015	0.614
Lake Samish	LMB		44.475	-36.499	7.841	248	0.017	0.597
Vancouver Lake	LMB		-12.586	7.99	-0.825	269	0.000	0.878
Walla Walla R.	LMB		-44.898	35.237	-6.54	271	0.002	0.772
Black Lake	LMB		16.325	-12.908	2.929	287	0.000	0.981
Deer Lake	LMB		-	-	-	293 J	-	-
Kitsap Lake	LMB		17.415	-14.298	3.308	295	0.008	0.673
Loomis Lake	LMB		-	-	-	306 J	-	-
Fazon Lake	LMB		-107.609	81.578	-15.059	317	0.098	0.661
Newman Lake	LMB		-46.616	36.281	-6.671	335	0.000	0.976
Lake Meridian	LMB		-81.584	63.255	-11.865	370	0.016	0.729
Long Lake	SMB	Mercury trends 2005	177.068	-139.095	27.546	31	0.180	0.212
Silver Lake	LMB		127.366	-103.162	21.157	76	0.028	0.539
Potholes Res.	SMB		19.756	-16.15	3.589	82	0.013	0.628
Loon Lake	LMB		-	-	-	137 J	-	-
Liberty Lake	SMB		-41.8	32.241	-5.887	137	0.323	0.069
Yakima R.	SMB		-197.42	154.535	-29.895	180	0.341	0.054
Moses Lake	LMB	Mercury trends 2006	38.322	-31.337	6.62	29	0.001	0.842
Newman Lake	LMB		-271.292	209.038	-39.92	152	0.009	0.67
Lake Offut	LMB		-	-	-	188 J	-	-
Lake Sammamish	LMB		-11.735	8.868	-1.315	214	0.003	0.752
Lake Meridian	LMB		17.004	-13.679	3.111	226	0.000	0.898

Regression Equation: $\text{Log}_{10}(\text{Mercury}) = \text{Constant} + \{B1 * \text{Log}_{10}(\text{Length})\} + \{B2 * (\text{Log}_{10}(\text{Length}))^2\}$

J - Mercury concentrations are not estimated using the multiple regression equation above. Loon Lake did not contain any fish within the specified size range, while positive relationships between mercury concentration and size did not exist at Offut, Deer, and Loomis. Estimates for Loon Lake were extrapolated from existing data, while Offut, Deer, and Loomis estimates were based off of fish as close to 356 mm and 750 g as the data set would allow.

Table D2. Regression Results using Year as Dummy Variable.

Lake	Coefficient			Standard Error of B(2)	p	Adjusted r ²
	Constant	B(1) Length	B(2) Year			
Newman	-4.557	2.738	-0.252	0.051	< 0.05	0.896
Meridian	-3.237	2.251	-0.118	0.043	< 0.05	0.860
Long	-8.868	4.185	-0.317	0.108	< 0.05	0.532
Moses	-6.443	3.189	-0.188	0.049	< 0.05	0.896

Regression Equation: $\text{Log}_{10}(\text{Mercury}) = M + B1(\text{Log}_{10} \text{Length}) + B2(\text{Year})$

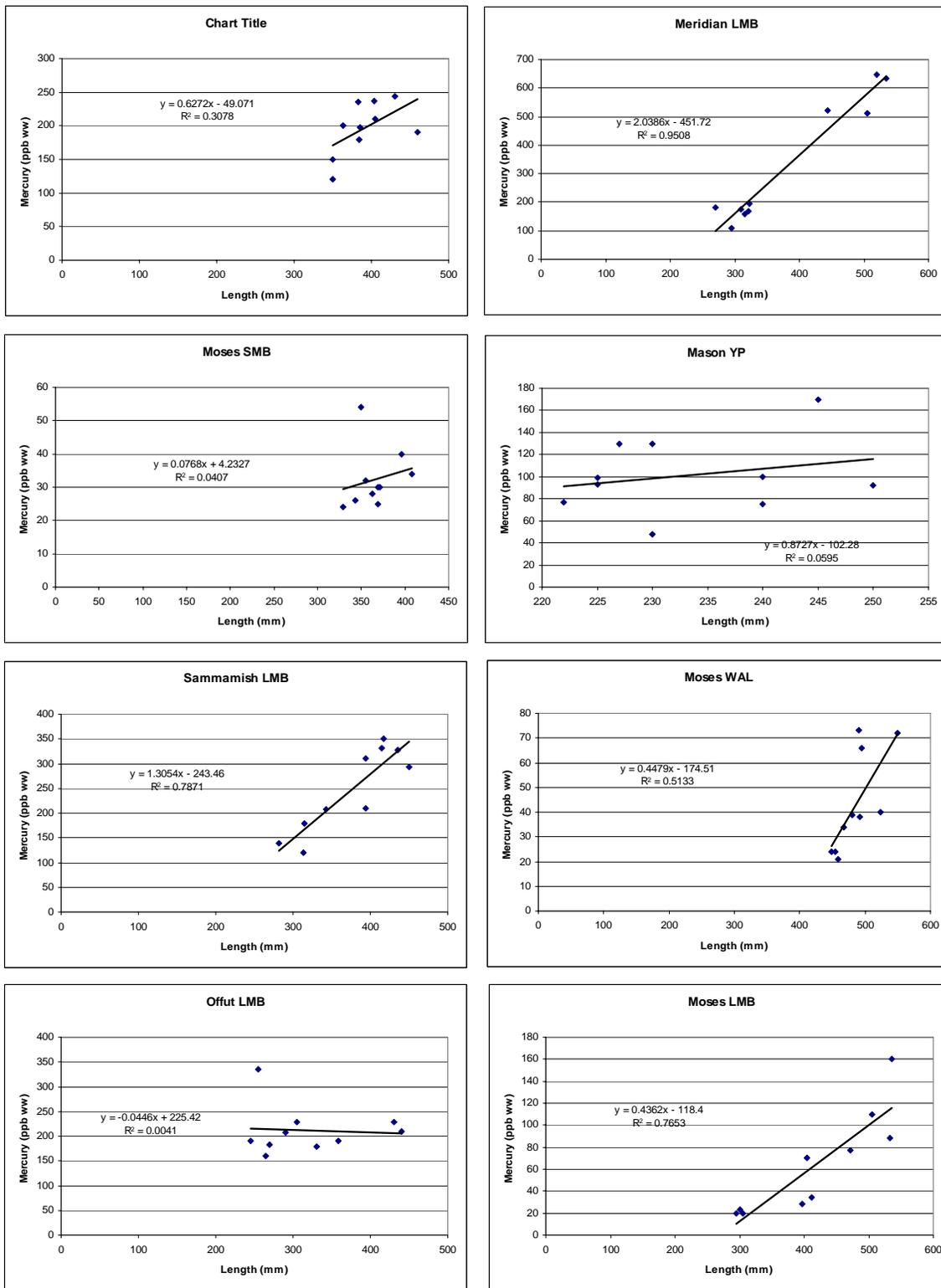


Figure D1. Simple Linear Regression Plots for Mercury and Length.

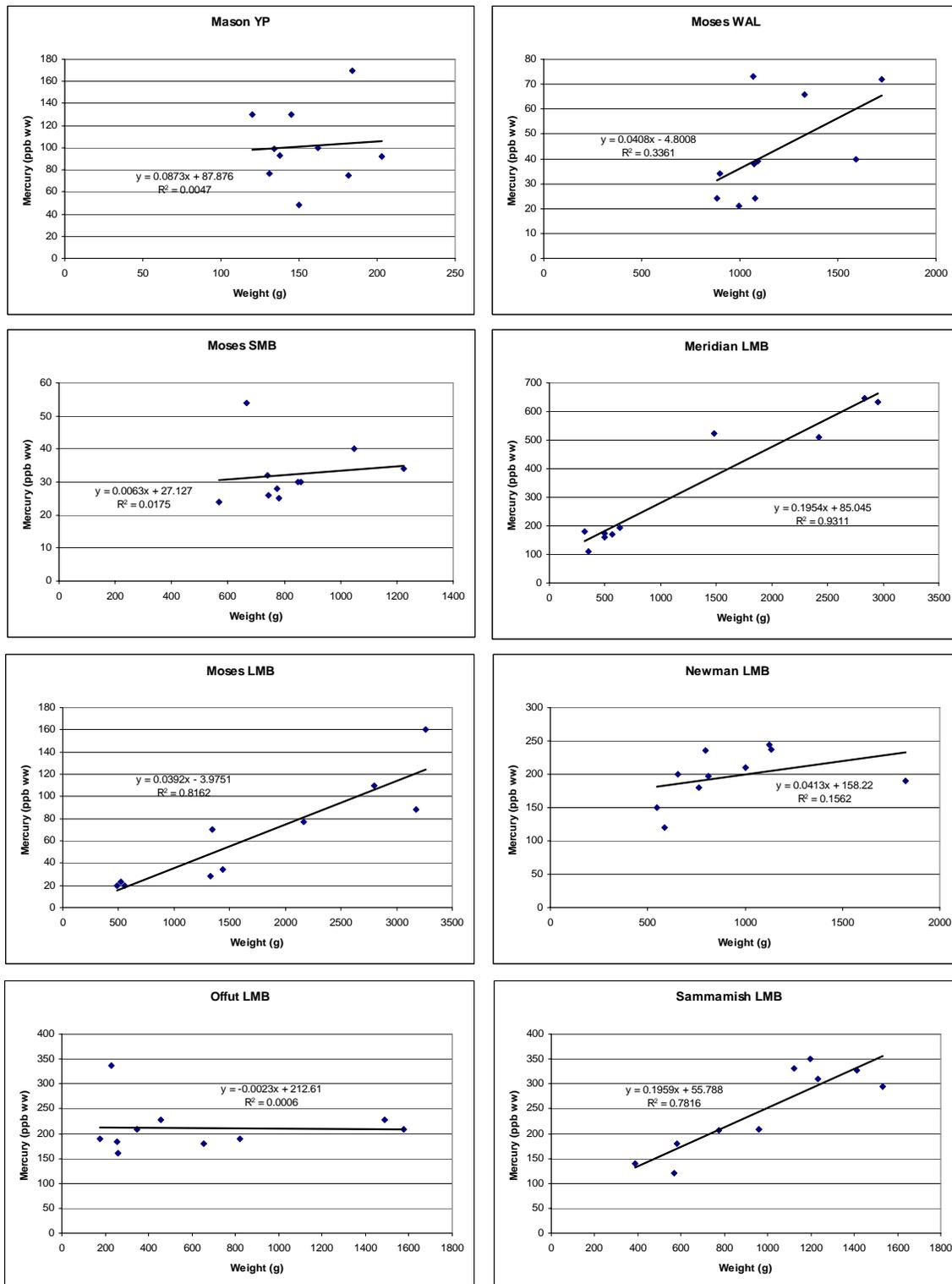


Figure D2. Simple Linear Regression Plots for Mercury and Weight.

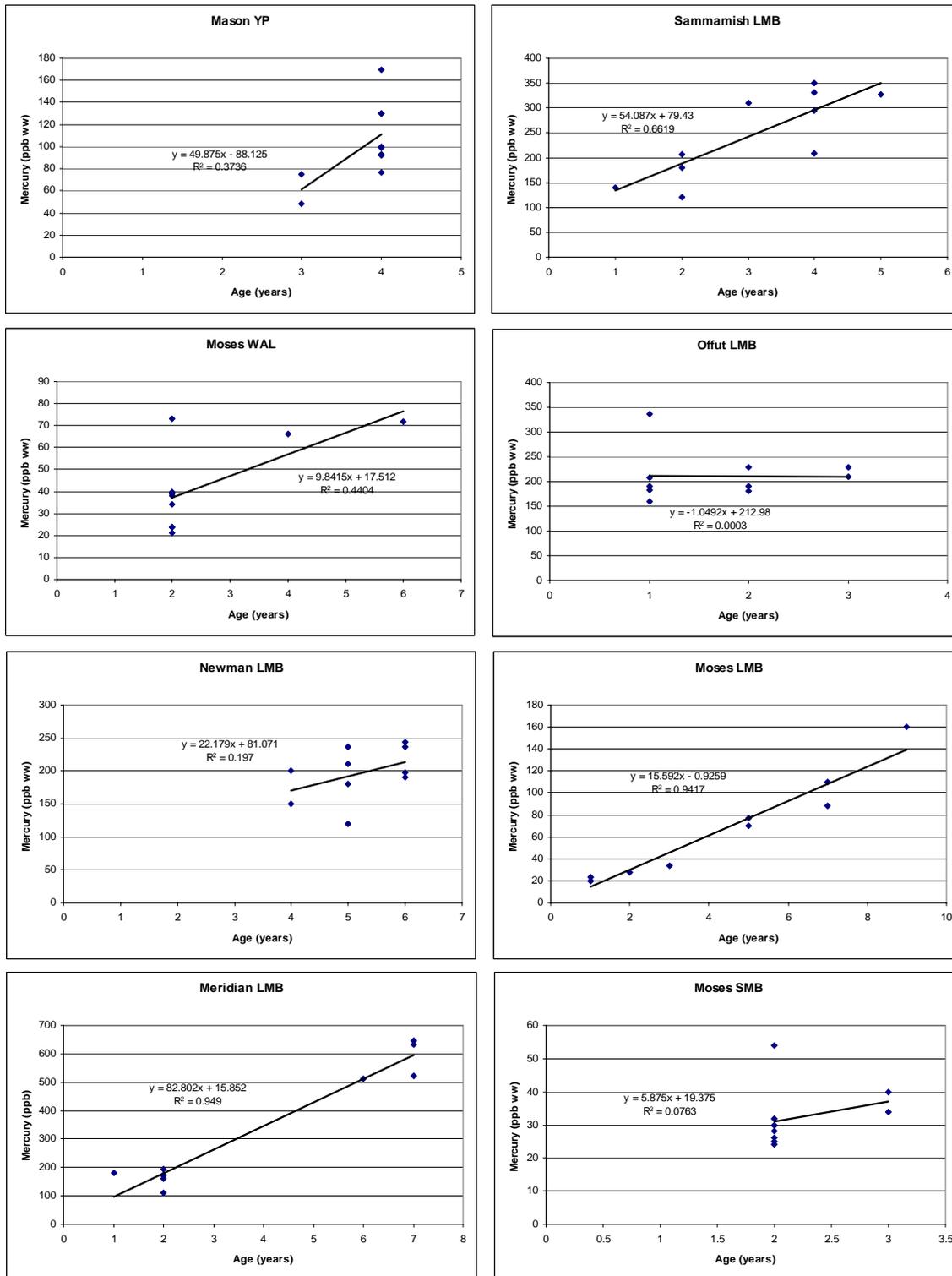


Figure D3. Simple Linear Regression Plots for Mercury and Age.

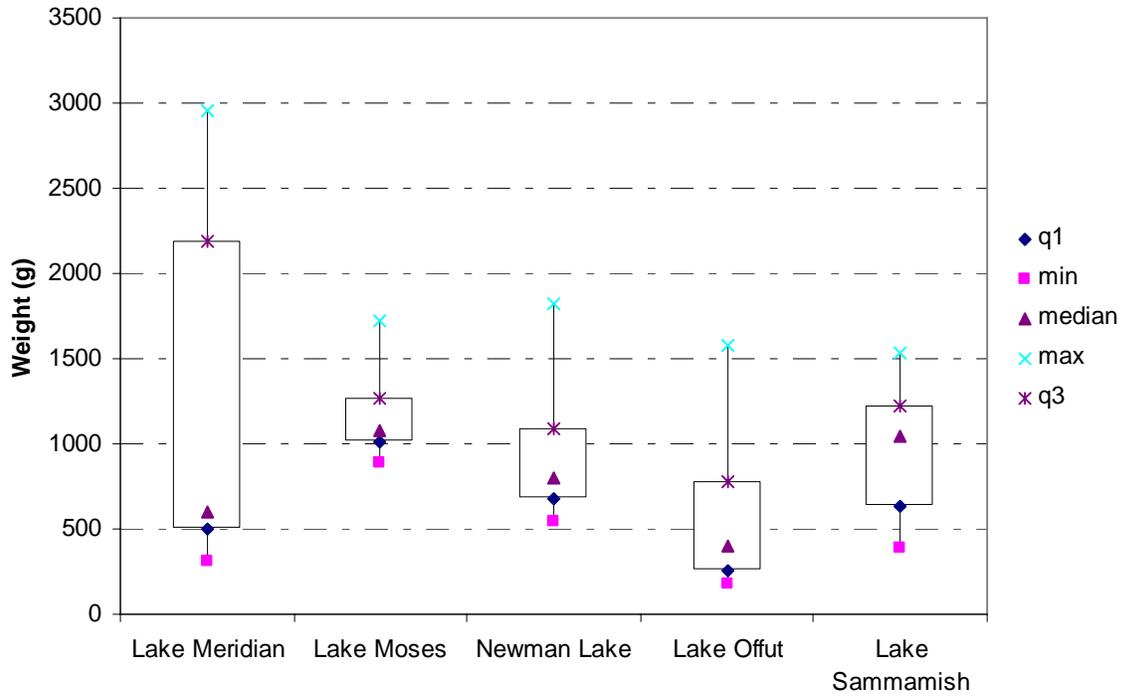


Figure D4. Boxplots of Weight in Individual Bass.

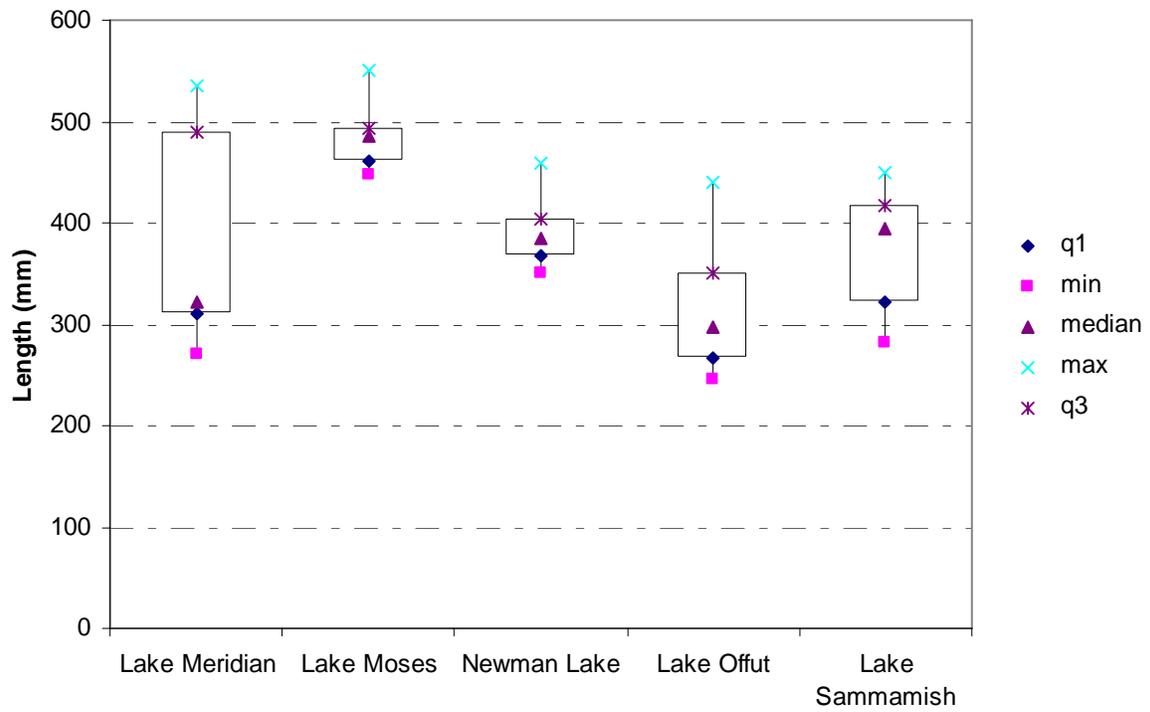


Figure D5. Boxplots of Length in Individual Bass.

Table D3. Correlation Matrix Describing Relationships with a Standard-Sized 356-mm Bass.

Variable Grouping	Lake Variable	Pearson Correlation	Spearman Rank Correlation
Sediment Chemistry	Mercury in Sediment	0.543	0.628
	Total Organic Carbon (TOC)	0.767	0.681
	Grain Size	-0.392	-0.393
Water Chemistry	Dissolved Organic Carbon	0.301	0.192
	Alkalinity	-0.581	-0.519
	Anoxic Waters	0.707	0.69
	pH - Top Waters	-0.474	-0.323
	Temperature - Top Waters	-0.145	0.277
	Conductivity	-0.496	-0.5
	pH - Bottom Waters	-0.906	-0.885
	Temperature - Bottom Waters	-0.597	-0.597
Secchi Depth	0.239	0.401	
Morphologic Characteristics	Lake Volume	-0.438	-0.301
	Surface Area	-0.709	-0.678
	DA:SA	-0.219	-0.184
	Drainage Area	0.079	-0.226
	Maximum Depth	0.002	-0.046
	Mean Depth	0.253	0.37

DA:SA - Drainage Area : Lake Surface Area

Table D4. Correlation Matrix Describing Relationships with the Mercury Sediment-to-Fish-Tissue Ratio.

Variable Grouping	Lake Variable	Pearson Correlation	Spearman Rank Correlation
Sediment Chemistry	Mercury in Sediment	-0.728	-0.833
	Total Organic Carbon (TOC)	-0.017	0.092
	Grain Size	-0.054	0
Water Chemistry	Dissolved Organic Carbon	0.423	0.6
	Alkalinity	0.113	-0.15
	Anoxic Waters	-0.067	-0.322
	pH - Top Waters	0.123	-0.17
	Temperature - Top Waters	-0.022	-0.455
	Conductivity	0.261	-0.159
	pH - Bottom Waters	-0.037	0.179
	Temperature - Bottom Waters	0.187	0.452
Secchi Depth	-0.378	-0.723	
Morphologic Characteristics	Lake Volume	0.149	0.05
	Surface Area	0.037	0.033
	DA:SA	0.735	0.683
	Drainage Area	0.859	0.633
	Maximum Depth	-0.193	-0.452
	Mean Depth	-0.491	-0.828

DA:SA - Drainage Area : Lake Surface Area

Appendix E. Fish Tissue Data Evaluation by Ecology and DOH

Several state and federal agencies collect and evaluate fish tissue data in Washington State: Ecology, the state Department of Health (DOH), state Department of Fish & Wildlife (WDFW), U.S. Environmental Protection Agency (EPA), and the U.S. Geological Survey (USGS). Tissue data are evaluated differently by these agencies because their mandates and roles are varied. These multiple evaluations often lead to confusion and misunderstanding among agencies and the public on how fish tissue data are used and interpreted. Most fish tissue contaminant data from Washington fish, regardless of who conducted the study, are forwarded to DOH for evaluating the safety of consuming contaminated fish. The following is an overview of how Ecology and DOH evaluate fish tissue data to meet different needs.

For many Ecology studies, fish tissue data are evaluated primarily to determine if (1) Washington State water quality standards are being met, and (2) potential risks to human health from consuming contaminated fish warrant further study and/or development of a fish consumption advisory. Ecology's role is to determine whether water quality standards are met and to begin the process to correct problems where standards are not met. The DOH and local health departments are responsible for developing fish consumption advisories in Washington. There is some overlap in these evaluations because the water quality standards that fish tissue data are compared to were developed for the protection of human health.

Washington's water quality standards criteria for toxic contaminants were issued to the state in EPA's 1992 National Toxics Rule (NTR) (40CFR131.36). The human-health-based NTR criteria are designed to minimize the risk of effects occurring to humans from chronic (lifetime) exposure to substances through the ingestion of drinking water and consumption of fish obtained from surface waters. The NTR criteria, if met, will generally ensure that public health concerns do not arise, and that fish advisories are not needed.

The NTR criteria are thresholds that, when exceeded, may lead to regulatory action. When water quality criteria are exceeded, the federal Clean Water Act requires that the waterbody be put on a list and a water cleanup plan be developed for the pollutant causing the problem. This list is known as the "303(d) list," and the water cleanup plan results from a Total Maximum Daily Load (TMDL) study and public involvement process. Ecology uses the TMDL program to control sources of the particular pollutant in order to bring the waterbody back into compliance with the water quality standards.

While DOH supports Ecology's use of the NTR criteria for identifying problems and controlling pollutant sources so that water quality will meet standards, DOH does not use the NTR criteria to establish fish consumption advisories. DOH uses an approach similar to that in EPA's *Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories Vol. 1-4* for assessing mercury, PCBs, and other contaminants (EPA, 2000). These guidance documents provide a framework from which states can evaluate fish tissue data to develop fish consumption advisories based on (1) sound science and (2) established procedures in risk assessment, risk management, and risk communication. Neither the NTR criteria, nor the screening values found

in the EPA guidance documents above, incorporate the varied risk management decisions essential to developing fish consumption advisories.

- *Risk Assessment* involves calculating allowable meal limits based on known fish contaminant concentrations. These calculations are conducted for both non-cancer and cancer endpoints using the appropriate Reference Dose (RfD) or Cancer Slope Factor (CSF), if available. These initial calculations are the starting point for evaluating contaminant data to determine whether a fish advisory is warranted. Additionally, known or estimated consumption rates help determine the potential magnitude of exposure and also highlight the sensitive groups or populations that may exist due to elevated consumption rates.
- *Risk Management* includes (but is not limited to) consideration of contaminant background concentrations, reduction in contaminant concentrations through preparation and cooking techniques, known health benefits from fish consumption, contaminant concentrations or health risks associated with replacement foods, and cultural importance of fish. Other considerations are the possible health endpoints associated with a contaminant, the strength or weaknesses of the supporting toxicological or sampling data, and whether effects are transient or irreversible.
- *Risk Communication* is the outreach component of the fish advisory. The interpretation of the data from the risk assessment and risk management components drives how and when the fish advisory recommendations are issued to the public. DOH's dual objective is how best to provide guidance to the public (1) on increasing consumption of fish low in contaminants to gain the benefits of eating fish, and (2) steering the public away from fish that have high levels of health-damaging contaminants.