A Department of Ecology Report

Mercury Concentrations in Lake Ozette Sockeye

Abstract

During 2010, the Washington State Department of Ecology analyzed total mercury in Lake Ozette sockeye salmon collected by the Makah Tribe in 2009. Mercury levels in 28 whole body samples ranged from 24 - 50 ug/kg. Levels in 10 fillet samples ranged from 25 - 43 ug/kg. Mercury levels in Lake Ozette sockeye were lower than levels in coho and chinook salmon from the Puget Sound and Columbia River basins. Mercury levels in Lake Ozette sockeye were within the range of levels recorded in Alaska.

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Introduction

Background

Exposure to mercury is a concern due to the negative effects it can have on ecosystems and human health. In Washington, mercury was chosen as the first pollutant to be addressed in the state's Persistent and Bioaccumulative Toxics (PBT) Reduction Strategy (Gallagher, 2000). This focus on mercury resulted in development of the *Washington State Mercury Chemical Action Plan* (Peele, 2003) which sought to reduce mercury releases and exposure to the state's residents.

The Washington State Department of Ecology (Ecology) began a long-term monitoring program in 2005 to detect mercury concentration trends in freshwater fish tissues (Seiders, 2006). The long-term monitoring effort, along with an exploratory monitoring study (Furl and Meredith, 2008; Seiders et al., 2007), found mercury concentrations in Lake Ozette fish were among the highest in the state.

Lake Ozette is a large, remote lake located in the coastal strip of the Olympic National Park in northwest Washington (Figure 1). Detailed descriptions of the environmental conditions present at the lake and its tributaries can be found in Haggerty et al. (2009). Over the past few years, Ecology has conducted several mercury studies within or near the Lake Ozette watershed: fish, sediment, stream cycling, and wet deposition. Results have shown high mercury levels in fish tissues, high flux rates of mercury to lake sediments, elevated export levels of mercury from the Umbrella Creek watershed, and atmospheric wet deposition levels of mercury on par with Seattle. Currently, the Olympic National Park has a fish consumption advisory for largemouth bass and yellow perch.

Of the 25 fish species found at Lake Ozette, mercury data are only available for 4 (largemouth bass, yellow perch, cutthroat trout, and northern pikeminnow). No data are available for any anadromous species found in the lake including the Lake Ozette sockeye (LOS) (*Oncorhynchus nerka*).

Lake Ozette Sockeye

The LOS are one of 6 sockeye salmon evolutionarily significant units (ESUs) present in Washington State. In March 1999 LOS were listed as a threatened ESU under the federal Endangered Species Act. It was concluded that the species was likely to become endangered in the foreseeable future if present conditions continue. Over the past decade considerable research has been conducted, and much has been written about the causes of the declining population. The following information is from the recovery plan and limiting factors analysis (Haggerty et al., 2008 and 2009, respectively).

Historical accounts of LOS escapement are sparse; however, returns were believed to be several thousand fish (based on 1940s estimates). In 1949 annual harvest by Makah Fisheries reached an estimated high of over 17,000. Since the mid-1990s LOS escapements have averaged around 2,000 with low years dropping to a few hundred. Hatchery operations have supported LOS restoration efforts since 1983. Currently, broodstock are collected from Umbrella Creek, and fry/fingerlings are released to Big River and Umbrella Creek.

Figure 1. Lake Ozette.

Life History

LOS return to Lake Ozette from the ocean from mid-April through mid-August primarily as 4-year-old adults. Their early return to the lake (peak returns occur in late May to early June) precludes them from being intercepted by commercial efforts aimed at the Fraser River sockeye. The fish hold in Lake Ozette for 2-10 months prior to spawning in November and December. Fish spawn at three tributaries (Umbrella Creek, Big River, and Crooked Creek) and two beaches (Olsen's Beach and Allen's Beach) (Figure 1). Fry emergence and dispersal in the lake occurs from February – May. Juvenile LOS rear in the lake for one summer before emigrating to the ocean during their second spring.

Limiting Factors Analysis

Several factors (Haggerty et al., 2009) suggested for the causes behind the LOS declines include:

1. Loss of adequate quality and quantity of spawning habitat.
2. Predation and disruption of natural predator-prey relationships.
3. Introduction of non-native fish and plant species.
4. Past over-exploitation in fisheries.
5. Poor ocean survival.
6. Synergistic and cumulative effects of these factors.

Goals and Objectives

Due to the elevated mercury concentrations in resident Lake Ozette fish, the Makah Tribe was concerned about elevated mercury levels in LOS. To investigate mercury concentrations in LOS, Ecology tested sockeye broodstock from the Makah Umbrella Creek hatchery for mercury during 2010. Objectives of the study were to:

- Examine mercury concentrations in whole fish and fillet samples.
- Compare mercury values to available literature and consumption criteria.

The project was completed following a Quality Assurance Project Plan (Furl, 2010).

Methods

Sample Collection

In fall 2009, Makah Fisheries retained 28 sockeye (17 males and 11 females) from the Umbrella Creek broodstock. Sockeye were wrapped in foil with a unique identifying tag and transferred to Ecology staff. Total lengths and weights of the fish were recorded by Makah Fisheries staff.

Sample Preparation

A total of 18 of the fish were prepared as whole body samples. The remaining 10 samples (5 male and 5 female) were processed as fillet and carcass (fillet already removed) samples.

Fish tissue samples were prepared following adapted guidelines from Ecology's *Standard Operating Procedures for Resecting Finfish Whole Body, Body Parts or Tissue Samples* (Sandvik, 2006). Fish were removed from the freezer and partially thawed before a tap water rinse followed by a deionized water rinse.

Fillet tissue was passed through a Kitchen-Aid food grinder 3 times, mixing the tissue after each pass. Whole fish and carcass samples were ground using a Hobart commercial meat grinder. The weight of the whole fish, fillet, and carcass were recorded to estimate whole body mercury concentrations on fish sampled for fillets.

Subsamples of the homogenate were placed into laboratory-provided clean glass jars. Samples were refrozen, assigned an identification number, and shipped to Ecology's Manchester Environmental Laboratory for analysis. Excess homogenate was labeled and archived at -20° C at Ecology Headquarters.

All utensils were cleaned prior to processing in order to prevent contamination of samples. Utensils include resecting tools, scalpels, bowls, spoons, and blender parts having plastic, wood, bronze, and stainless steel parts. The cleaning procedure included: hand-wash with soap (Liquinox) and hot tap water, hot tap water rinse, 10% nitric acid rinse, and a final deionized water rinse. Fish processing was carried out on the dull side of aluminum foil covering a nylon cutting board. New foil and clean processing utensils were used for each sample. All staff wore nitrile gloves during tissue processing.

Sample Analysis

In 2010, Manchester Laboratory analyzed samples for total mercury in 2 batches following U.S. Environmental Protection Agency (EPA) Method 245.6 (cold vapor atomic absorption).

Data Quality

Quality control tests for the 2 batches are shown in Table 1. Results met all measurement quality objectives outlined in the project plan (Furl, 2010).

Table 1. Quality control results.

Sample ID	Blank (ug/kg)	Laboratory Control Sample (% recovery)	Duplicate (RPD)	Matrix Spike (% recovery)
B10J175	17 U	106	4	93
B10K010	17 U	92	9	89

RPD - relative percent difference.
U - not detected at concentration shown.

Results and Discussion

Tables 2 and 3 display project data and summary statistics, respectively.

Table 2. Mercury data for Lake Ozette sockeye, 2009.

Field ID	Mercury concentration (ug/kg)			Length (mm)	Weight (g)	Sex		Field ID	Mercury concentration (ug/kg)			Length (mm)	Weight (g)	Sex
	Whole body	Fillet	Carcass						Whole body	Fillet	Carcass			
SOCK01	32.9			590	1592	f		SOCK15	31.8			590	1870	m
SOCK02	32.6*	38.0	29.1	590	1776	f		SOCK16	45.2			570	1951	m
SOCK03	36.1			590	1600	f		SOCK17	41.0			550	1660	m
SOCK04	38.1*	40.9	36.4	600	1793	f		SOCK18	31.1			590	1969	m
SOCK05	50.1			530	1295	f		SOCK19	40.8*	41.7	40.6	580	1878	m
SOCK06	29.4*	33.7	26.9	590	1810	f		SOCK20	34.2			620	2401	m
SOCK07	32.9			540	1249	f		SOCK21	34.3			590	2023	m
SOCK08	46.5			540	1248	f		SOCK22	28.3			620	2450	m
SOCK09	32.8*	39.6	28.1	550	1484	f		SOCK23	23.6*	25.3	22.3	640	2376	m
SOCK10	38.8			550	1358	f		SOCK24	34.1			630	2071	m
SOCK11	39.3*	44.3	37.8	510	1188	f		SOCK25	33.4			610	2047	m
SOCK12	28.6*	27.1	29.5	420	589	m		SOCK26	39.8*	43.2	37.9	610	2116	m
SOCK13	32.1			620	2125	m		SOCK27	30.9			630	2194	m
SOCK14	38.9*	38.1	39.4	520	1412	m		SOCK28	40.7			600	1976	m

* Calculated concentration = ((fillet weight x fillet concentration)+(carcass weight x carcass concentration))/ whole fish weight.

Table 3. Statistical summary of fish size and mercury concentrations.

Length (mm)					Weight (g)					
	Mean	(St. Dev.)	Range (min - max)	Median		Mean	(St. Dev.)	Min.	Max.	Median
All	578	(47)	420 - 640	590	All	1768	(429)	589 - 2450		1840
Males	588	(53)	420 - 640	600	Males	1948	(434)	589 - 2450		2023
Females	562	(31)	510 - 600	550	Females	1490	(237)	1188 - 1810		1484

Mercury (ug/kg) whole body						Mercury (ug/kg) fillet					
	Mean	(St. Dev.)	Min.	Max.	Median		Mean	(St. Dev.)	Min.	Max.	Median
All	36	(5.9)	24 - 50		34	All	37	(6.5)	25 - 44		39
Males	35	(5.6)	24 - 45		34	Males	35	(8.3)	25 - 43		38
Females	37	(6.3)	29 - 50		36	Females	39	(3.9)	34 - 44		40

St. Dev.: Standard deviation.

Mercury concentrations in whole body and fillet ranged from 24 - 50 ug/kg and 25 - 44 ug/kg, respectively. Concentrations were higher in fillets than carcasses with two exceptions. Mercury values were slightly higher in females despite males being larger. A cumulative frequency graph of whole body concentrations is shown in Figure 2.

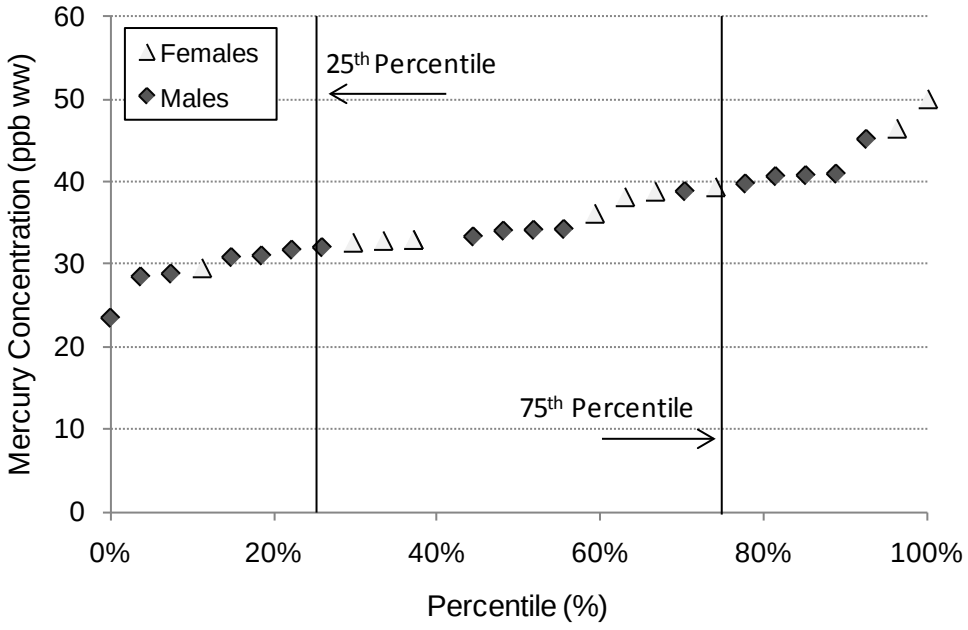

Figure 2. Cumulative frequency graph of sockeye whole body mercury concentrations.

Table 4 displays simple Pearson correlations for mercury with fish length and weight. Mercury concentrations did not vary positively with fish size as seen with resident Lake Ozette species (Furl et al., 2010). The inverse relationship may be the result of mercury dilution by fish growth. Ward et al. (2010) found large, fast-growing Atlantic salmon had lower mercury concentrations than small, slow-growing fish.

Table 4. Pearson correlations for mercury and fish size.

	All	Male	Female
Length vs. Mercury	-0.29	-0.14	-0.54
Weight vs. Mercury	-0.31	-0.12	-0.58

Comparisons

Mercury concentrations in LOS were often lower by an order of magnitude than concentrations in other resident lake species. Large differences from resident species would be expected since sockeye stop feeding after entering freshwater. Figure 3 graphs fillet tissue concentrations from Lake Ozette.

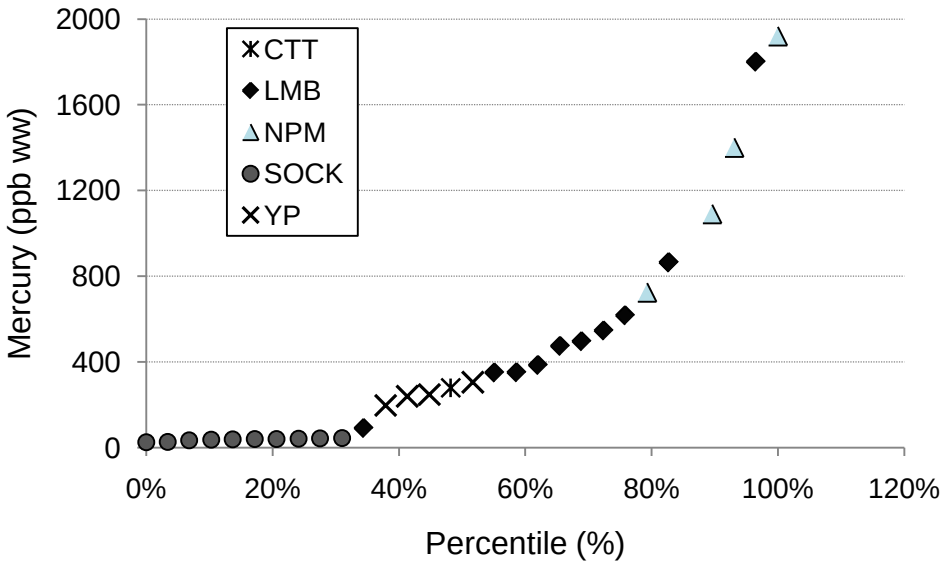

Figure 3. Mercury concentrations in fish (fillet samples only) collected from Lake Ozette.

CTT = cutthroat trout, LMB = largemouth bass, NPM = northern pikeminnow, SOCK = sockeye, YP = yellow perch.

Table 5 presents data on other salmon species in Washington State and Alaska. Mercury concentrations in LOS were lower than in coho and chinook collected from the Puget Sound and Columbia River basins. Concentrations in LOS were slightly lower than in juvenile sockeye collected from Lake Washington and within the range of sockeye values recorded in Alaska.

Table 5. Mercury concentrations in salmon from Washington and Alaska.

Location	Species	Number of Samples	Sample Type	Average (ug/kg)	Study
Puget Sound*	Chinook	106	Muscle	92	O'Neill and West, 2007
	Coho	108		52	
Columbia River system	Fall Chinook	30	Whole body and muscle	84	EPA, 2002
	Spring Chinook	48		100	
	Coho	6		120	
Lake Washington^	Sockeye	20	Whole body	46	McIntyre and Beauchamp, 2007
Alaska		30	Muscle	48	Zhang et al., 2001
		59	Whole body	24	Baker et al., 2009
Lake Ozette		28	Whole body	36	Present study
		10	Muscle	37	

* River sites included.
^ Juvenile sockeye.

Criteria for Human Consumption of Fish

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

- EPA's recommended criterion of 300 ppb ww, based on 17.5 grams/day fish consumption rate.
- National Toxics Rule (NTR): 770 ppb ww, based on 18.7 grams/day fish consumption rate.
- EPA screening values (SVs) 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.

Figure 4 displays mercury concentrations in LOS fillets with consumption criteria thresholds. All fillet values for LOS were below published criterion.

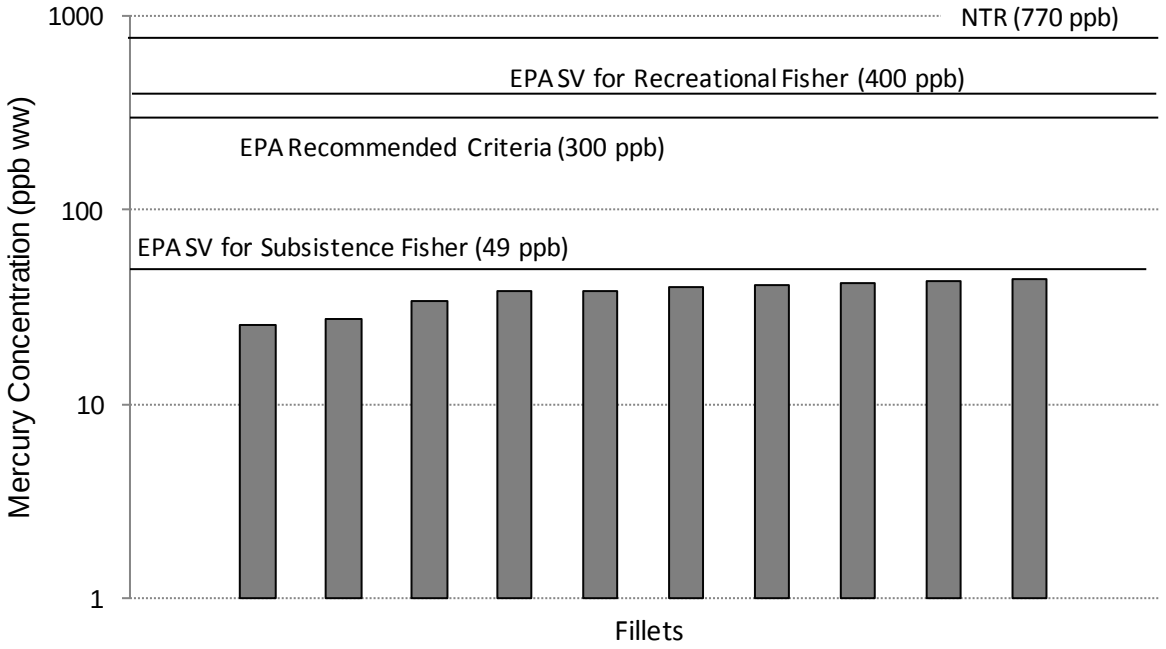

Figure 4. Mercury concentrations in Lake Ozette sockeye graphed with consumption criteria thresholds.

Conclusions and Recommendations

Results of this 2010 study support the following conclusions:

- Lake Ozette sockeye (LOS) do not contain elevated levels of mercury.
- Mercury levels in LOS are similar to levels in Alaskan sockeye and lower than levels found in other salmon species in Washington State.
- Mercury levels in LOS are well below the majority of criteria for human consumption of fish.

As a result of the study, the author recommends no further testing of returning LOS for mercury. If returning sockeye salmon as a pathway of mercury transport to the Lake Ozette system are of interest, future study designs must include analysis of juveniles exiting the lake.

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Appendix: Glossary, Acronyms, and Abbreviations

Glossary

Anadromous: Types of fish, such as salmon, that go from the sea to freshwater to spawn.

Broodstock: A group of sexually mature individuals of a cultured fish species that is kept separate for breeding purposes.

Escapement: Number of fish returning from the sea to freshwater to spawn.

Returning: Refers to fish returning from the sea to freshwater.

75th percentile: A statistical number obtained from a distribution of a data set, above which 25% of the data exists and below which 75% of the data exists.

Acronyms and Abbreviations

Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
LOS	Lake Ozette sockeye
MEL	Manchester Environmental Laboratory
NTR	National Toxics Rule
PBT	Persistent, bioaccumulative, and toxic substance
RPD	Relative percent difference
SOP	Standard operating procedures
SRM	Standard reference materials
ww	Net weight

Units of Measurement

g	gram, a unit of mass
mm	millimeters
ppb	parts per billion
ug/Kg	micrograms per kilogram (parts per billion)