Technical Report No. 11-09

Tulsequah Chief Mine Acid Rock Drainage: Whole Body Metals Concentrations in Dolly Varden Char

by

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April 2012

Alaska Department of Fish and Game — Division of Habitat

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

TECHNICAL REPORT NO. 11-09

TULSEQUAH CHIEF MINE ACID ROCK DRAINAGE: WHOLE BODY METALS CONCENTRATIONS IN DOLLY VARDEN CHAR

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April 2012

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Cover Photos: Lee Close (Alaska Department of Fish and Game) and Mark Connor (Taku River Tlingit First Nation) using a beach seine in the Tulsequah River, near the Tulsequah Chief Mine. Copyright Alaska Department of Fish and Game. Photo by Joseph Hitselberger.

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EXECUTIVE SUMMARY

The Tulsequah Chief Mine is an inactive copper, gold, lead, silver and zinc mine located in western British Columbia, Canada. The mine is under consideration for re-opening and the project proponent, Chieftain Metals, Inc., is currently completing permit transfers. The mine is adjacent to the Tulsequah River, which flows into the Taku River. The Taku River flows through Canada into Alaska, and is an important fish producer for sport and commercial fisheries.

Acid rock drainage (ARD) has been leaching from the Tulsequah Chief mine into the Tulsequah River for over 50 years. Lough and Sharpe (2003) document the leachate as acidic and high in metals including cadmium, copper, lead and zinc. In 2010, the United Fishermen of Alaska wrote to Governor Sean Parnell that acid drainage from the currently inactive Canadian mine "is destroying prime rearing habitat, threatening potential future harvests of multi gear commercial fishing groups" (Vinsel 2010). The United Southeast Alaska Gillnetters petitioned Representative Beth Kerttula for "an appropriation…to do a comprehensive study to determine the scope of the existing acid-leakage problem" (Knight 2010). The legislature provided ADF&G $35,000 to conduct a study of the acid leakage into the Tulsequah and Taku Rivers and the acid's effects on salmon and salmon habitat in the fiscal year 2011 capital budget. The legislature did not specify a study type or design.

We collaborated with U.S. and Canadian scientists and considered several aquatic studies to evaluate whether leachate was impacting water quality in the Tulsequah and Taku Rivers. We concluded a heavy metals investigation in resident fish tissues would provide the most meaningful information given the budget and the interests of the organizations that petitioned the Governor and legislature for funding.

We captured 41 resident juvenile Dolly Varden char (*Salvelinus malma)* from two sites on the Tulsequah River, upstream of the acid rock discharge site (Upper Tulsequah or UTR) and below the acid rock discharge site (below the Tulsequah Mine or TRM), and from the Taku River near the U.S./Canada border (Taku Border or TRB). We tested the resident juvenile Dolly Varden char for whole body metals concentrations of arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), mercury (Hg), selenium (Se), silver (Ag), and zinc (Zn). We compared the results with a 10 year resident juvenile Dolly Varden char whole body metals concentrations dataset for Cd, Cu, Pb, Se, Ag, and Zn from the Hecla Greens Creek Mine on Admiralty Island where we take samples above and below mine operations.

Mean concentrations of Zn, Pb, and Hg are highest in fish from the Upper Tulsequah, the sampling site nearest the Tulsequah Glacier. Zn and Pb concentrations are lower than samples taken above and below Greens Creek Mine operations, 2001–2011. We do not sample Hg at the Greens Creek Mine. This is the only site in which Ag was reported at the detection limit. Ag is often not detected at the reporting limit or is measured slightly above the limit in samples taken above and below Greens Creek Mine operations, 2001–2011.

Mean concentrations of As, Se and Cu are highest in fish from below the Tulsequah Mine site. Se and Cu concentrations are lower than samples taken above and below Greens Creek Mine operations, 2001–2011. We do not sample As at the Greens Creek Mine.

Mean concentrations of Cd were highest in the fish obtained from the Taku Border sampling site. Cd concentrations are lower than samples taken above and below Greens Creek Mine operations, 2001–2011.

INTRODUCTION

The Tulsequah River originates from the Tulsequah Glacier and drains into the Taku River, which flows through Canada and into Alaska. The Taku River is an important salmon producer for sport and commercial fisheries in both countries (Rescan 1997).

ARD from the inactive Tulsequah Chief copper, gold, lead silver, and zinc mine in Canada has been leaching into the Tulsequah River for over 50 years (Office of the Auditor General of Canada 2005). ARD from the Tulsequah Chief Mine is documented as acidic and high in metals including Cu, Cd, Pb, and Zn, and contributes the greatest percentage of dissolved heavy metals into the Tulsequah River compared to other nearby mines (Lough and Sharpe 2003).

The Tulsequah Chief Mine is currently undergoing Canadian governmental review for re-authorization, and the project proponent, Chieftain Metals, Inc. is completing permit transfers. Chieftain Metals, Inc. installed an acid-water treatment plant which began operating at capacity in December 2011, about six months after we collected our fish and water samples.

Purpose

The purpose of this study is to compare whole body metals concentrations of As, Cd, Cu, Pb, Hg, Se, Ag, and Zn in juvenile Dolly Varden char captured in the receiving waters of Tulsequah Chief Mine ARD with juvenile Dolly Varden char collected upstream and downstream of the Tulsequah Chief mine site and the Hecla Greens Creek mine site.

Sample Sites

We flew an aerial survey on May 19, 2011 and selected sample sites where it appeared there was good fish habitat, including large woody debris. We relied on the expertise of ADF&G Division of Sport Fish staff that routinely capture fish for mark recapture studies on the Taku River. We located two sample sites on the Tulsequah River, one about 5 km upstream of the discharge site and the other about 1 km downstream of the discharge site. We sampled one location on the Taku River near the U.S./Canada border, about 26 km downstream of the Tulsequah Chief Mine (Figure 1).

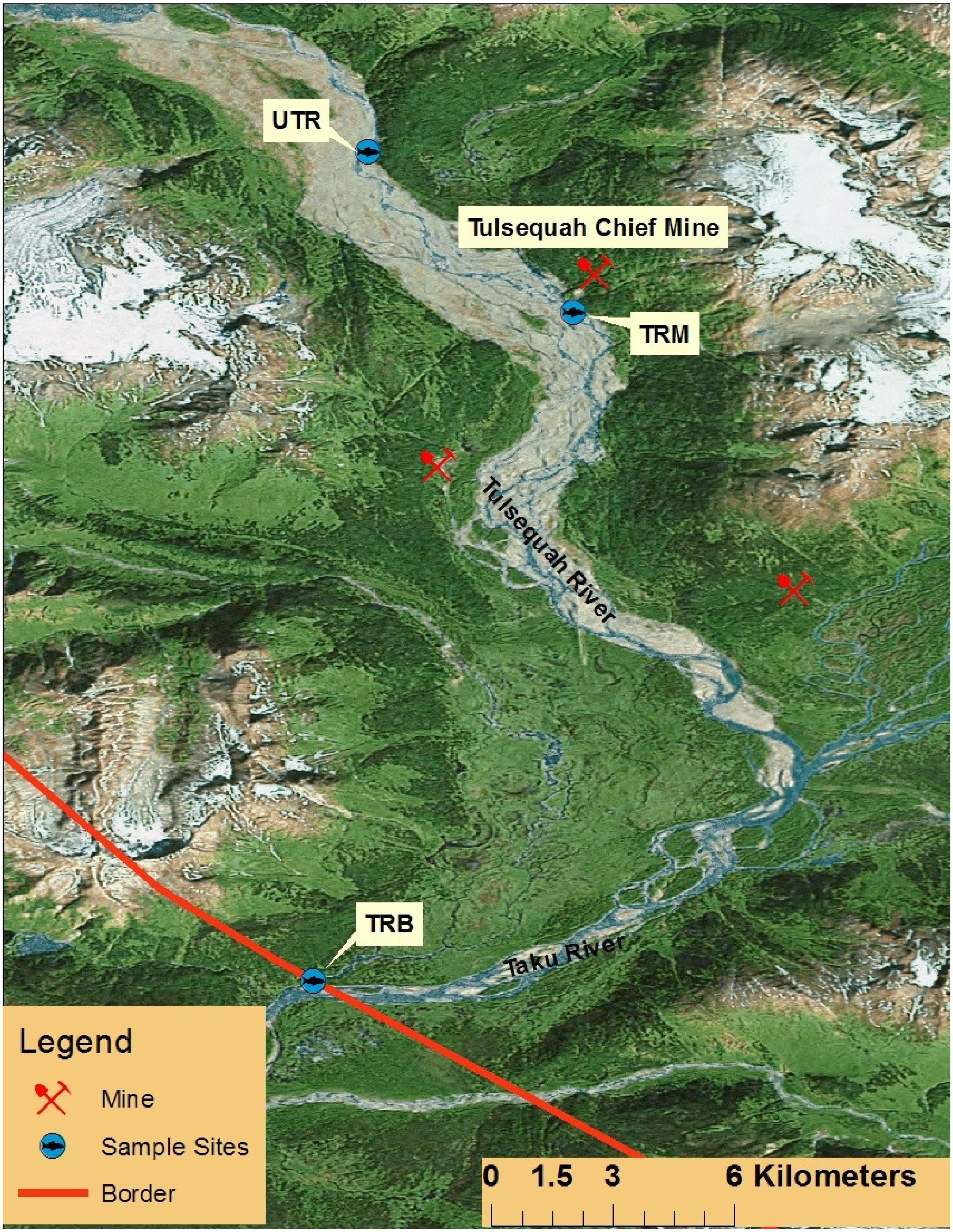

Figure 1.–Area map

METHODS

Data Collection

We accessed sample sites by jet boat and helicopter on five occasions between June 3 and June 16, 2011. We sampled basic water quality with an Extech Exstick II field meter and colorpHast PH indicator strips on June 15. We captured juvenile Dolly Varden char at all three sites using 0.635 cm (1/4 in) wire mesh minnow traps baited with whirl packs containing disinfected salmon eggs (Magnus 2006). Bait was contained to prevent eggs from entering the fish gut track, potentially affecting the whole body metals sample. We allowed traps to soak for a minimum of 24 h. We used a beach seine to capture fish at the Upper Tulsequah and below the Tulsequah Mine sampling sites. We proposed to keep fish that measured 90 mm to 140 mm as this size range improves the likelihood of sampling resident, rather than anadromous fish while meeting the minimum weight requirement of 5 g needed for testing.[a] Instead, we kept fish that measured between 58 mm and 170 mm FL as fish at the Upper Tulsequah and Taku Border sites were scarce. Each fish was placed individually in a labeled plastic bag and stored in a cooler containing gel packs until we returned to the Region I Douglas office where each sample was re-measured to FL and weighed in the sample bag, correcting for bag weight. We kept the samples frozen in a sealed cooler stored in a refrigerator/freezer and shipped the samples in the cooler with frozen gel ice packs to the lab via overnight air freight on June 20, 2011.

Laboratory Analyses

We chose Columbia Analytical Services to process the samples based on their experience testing metals concentrations in fish tissues. The Environmental Protection Agency (EPA) has approved the standards and qualifications. The lab received the samples on June 21, 2011 in good condition, stored the samples at –20°C, then individually freeze-dried, digested, and analyzed the samples for whole body metals concentrations of As, Cd, Cu, Pb, Hg, Se Ag, and Zn, on a dry-weight basis using EPA methods. A copy of the laboratory report is included in Appendix A.

Quality Assurance / Quality Control

We maintained written Chain of Custody Forms on each fish for metals testing. The laboratory provided Tier II quality assurance/quality control validation information for each analyte including matrix spikes, standard reference materials, laboratory calibration data, sample blanks, and sample duplicates.

Statistical Analyses and Data Presentation

We use Statistix® 9 (Analytical Software 2008) for statistical analyses. We used a One-Way Analysis of Variance to test for differences of means for each analyte and each site, and all-pairwise comparisons to identify differences between sites. Significant differences are reported when $p \leq 0.05$. We present graphs by analyte of mean metal concentration and whiskers illustrating the minimum and maximum values observed. We include whole body metals data collected near the Greens Creek Mine located on Admiralty Island, about 88 km southwest of the Tulsequah Chief Mine, for comparison of all metals except As and Hg. Greens Creek Mine currently produces concentrates of gold, lead, silver and zinc for export. We have 10 years of data using the methods described above, both upstream (Site 48) and downstream (Site 54) of mine and mill operations (Kanouse 2012).

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[a] Kensington mine 90 – 130 mm FL determined by historical length frequency data (Timothy and Kanouse 2012). Greens Creek mine 85 – 125 mm FL chosen by study authors in 2001 (Kanouse 2012)

RESULTS

We captured a total of 82 Dolly Varden char, three coho salmon (*Oncorhynchus kisutch*), and one threespine stickleback (*Gasterosteus aculeatus*), returning Dolly Varden char not meeting size criteria, and returning the coho salmon and threespine stickleback to the sample site. We retained 46 Dolly Varden char from all three samples sites then disposed of five undersized animals. We submitted 41 fish for laboratory analyses: 12 samples from the Upper Tulsequah, 20 samples from below the Tulsequah Mine, and 9 samples from the Taku Border.

We recorded water quality on June 15, 2011 and present temperature, pH and conductivity in Table 1.

Table 1.–Water quality recorded during sampling on 6/15/2011.

	UTR	TRM	TRB
Temperature (°C)	1.4	3.2	9.8
pH	5	6	7
Conductivity (μS/cm)	70.5	73.6	126.7

Arsenic

As concentrations in juvenile Dolly Varden char samples are displayed in Figure 2. Mean As concentrations are similar among sites, not significantly different when compared together (p = 0.500), and greatest below the Tulsequah Mine sample site. As concentrations were not detected at the Method Reporting Limit for six samples from the Upper Tulsequah site, three samples from below the Tulsequah Mine site, and one sample from the Taku Border site. For data comparison, we used the minimum reporting limit (0.5 mg As/Kg) for results reported as "not detected" and do not find any significant differences in mean concentrations among sample sites.

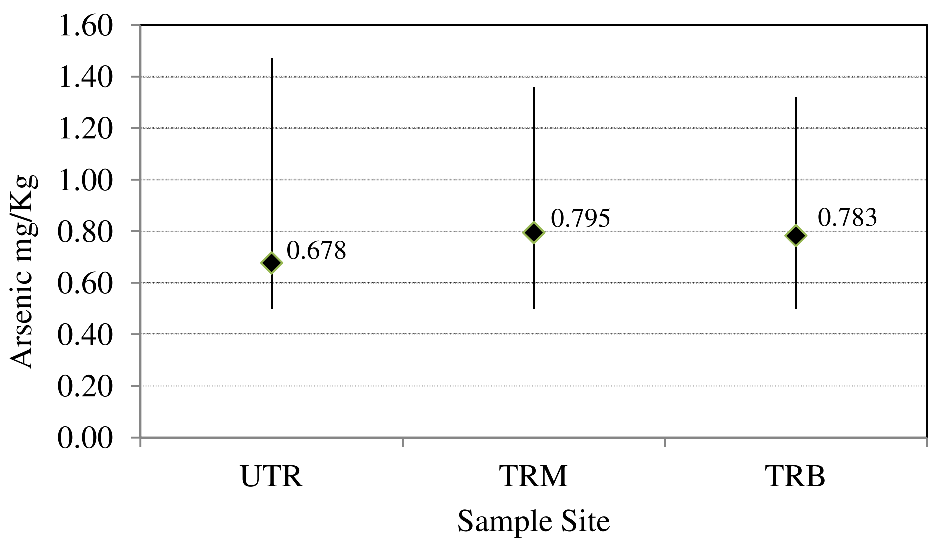

Figure 2.–Whole body As concentrations in juvenile Dolly Varden char.

Cadmium
Cd concentrations in juvenile Dolly Varden char samples are displayed in Figure 3. Mean Cd concentrations are similar among sites, not significantly different when compared together (p = 0.31), and greatest at the Taku Border sample site. The laboratory was not able to achieve a uniform distribution of Cd in one sample from site below the Tulsequah Mine, so we did not include the data in the statistical analyses or in Figure 4. Mean Cd concentrations in juvenile Dolly Varden char collected above and below Greens Creek Mine operations, 2001–2011, are greater than the mean concentrations for the Upper Tulsequah, Tulsequah Mine and Taku Border samples.

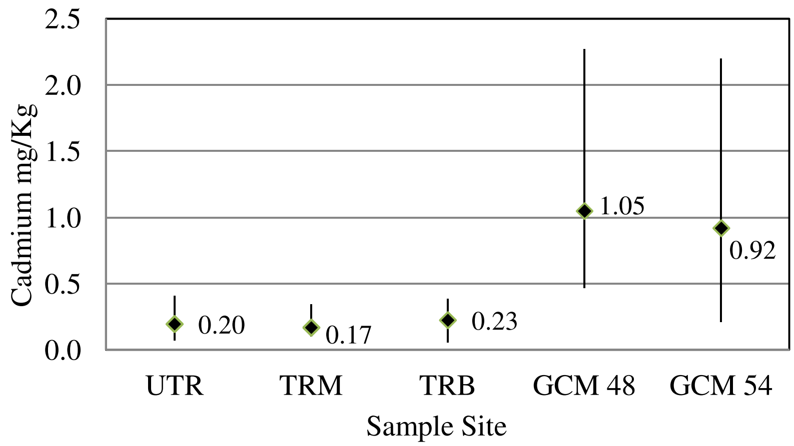

Figure 3.–Whole body Cd concentrations in juvenile Dolly Varden char.

Copper
Cu concentrations in juvenile Dolly Varden char samples are displayed in Figure 4. Mean Cu concentrations are similar among sites, not significantly different when compared together (p = 0.300), and greatest below the Tulsequah Mine sample site. Mean Cu concentrations in juvenile Dolly Varden char collected above and below Greens Creek Mine operations, 2001–2011, are greater than mean concentrations for the Upper Tulsequah, Tulsequah Mine and Taku Border samples.

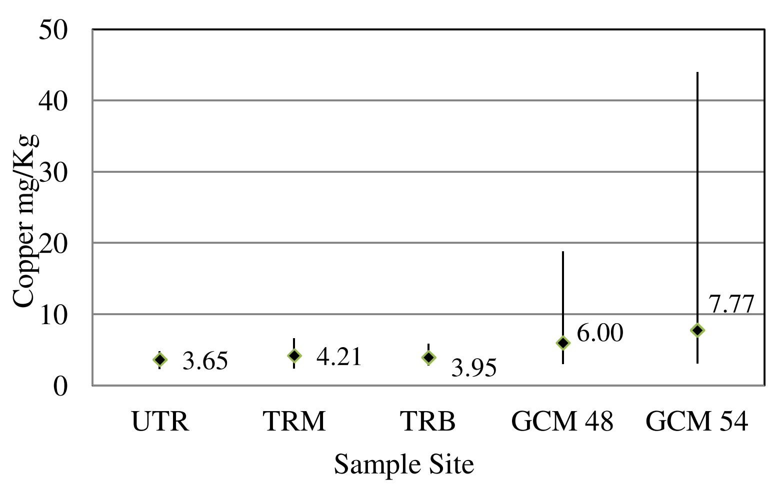

Figure 4.–Whole body Cu concentrations in juvenile Dolly Varden char.

Lead

Pb concentrations in juvenile Dolly Varden char samples are displayed in Figure 5. Mean Pb concentrations are similar among sites, not significantly different when compared together (p= 0.300), and greatest at the Upper Tulsequah sample site. Mean Pb concentrations in juvenile Dolly Varden char collected above and below Greens Creek Mine operations, 2001–2011, are greater than mean concentrations for the Upper Tulsequah, below the Tulsequah Mine, and the Taku Border samples.

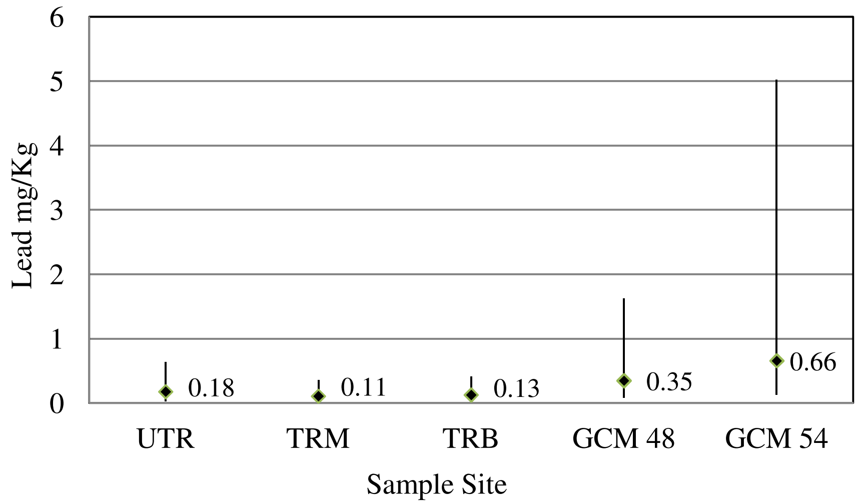

Figure 5.–Whole body Pb concentrations in juvenile Dolly Varden char.

Mercury

Hg concentrations in juvenile Dolly Varden char samples are displayed in Figure 6. Mean Hg concentrations are similar among sites, not significantly different when compared together (p = 0.444), and greatest at the Upper Tulsequah sample site.

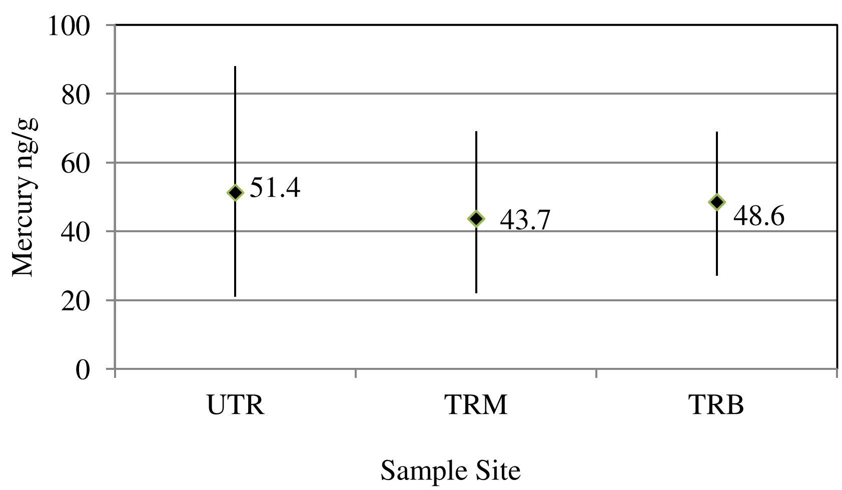

Figure 6.–Whole body Hg concentrations in juvenile Dolly Varden char.

Selenium

Se concentrations in juvenile Dolly Varden char samples are displayed in Figure 7. Mean Se concentrations are similar among sites, significantly different between the Tulsequah Mine and Taku Border samples sites ($p = 0.025$), and greatest at the sample site below the Tulsequah Mine. Mean Se concentrations in juvenile Dolly Varden char collected above and below Greens Creek Mine operations, 2001–2011, are greater than mean concentrations for the Upper Tulsequah, below the Tulsequah Mine and at the Taku Border samples.

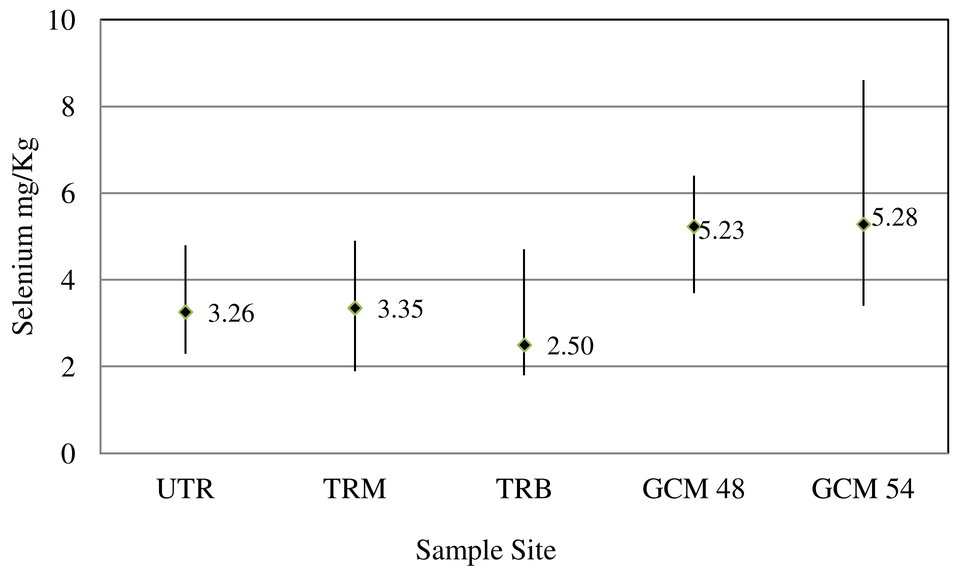

Figure 7.–Whole body Se concentrations in juvenile Dolly Varden char.

Silver

Ag concentrations are not detected at the Method Reporting Limit except for two samples from the Upper Tulsequah site that were both 0.02 Ag mg/Kg. For data comparison, we used the minimum reporting limit (0.02 mg Ag/Kg) for results reported as "not detected" and do not find any significant differences in mean concentrations among sample sites. Whole body Ag concentrations in juvenile Dolly Varden char samples collected above and below Greens Creek Mine operations, 2001–2011, are often not detected at the reporting limit or measured slightly above the limit.

Zinc

Zn concentrations in juvenile Dolly Varden char samples are displayed in Figure 8. Mean Zn concentrations are similar among sites, not significantly different when compared together ($p = 0.072$), and greatest at the Upper Tulsequah sample site. The lab reported that a matrix spike recovery of Zn for one sample from the Taku Border site was significantly higher than the added spike concentration, preventing accurate evaluation of the spike recovery. Therefore, we do not include the Zn concentration of this sample in the data analysis or present it in Figure 8. Mean Zn concentrations in juvenile Dolly Varden char collected above and below Greens Creek Mine operations, 2001–2011, are greater than mean concentrations in the samples from the Upper Tulsequah, below the Tulsequah Mine and at the Taku Border sites.

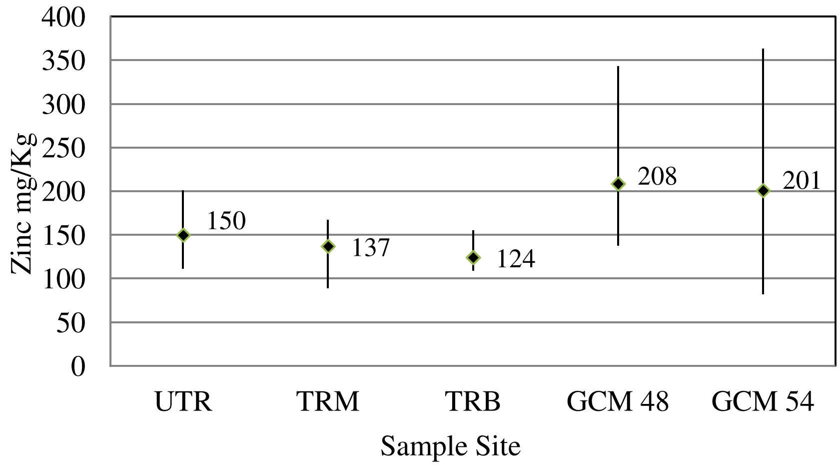

Figure 8.– Whole body Zn concentrations in juvenile Dolly Varden char.

CONCLUSIONS

Although water quality is not the focus of this study, the results of our testing provide valuable information. Water temperature, pH, and conductivity increase moving downstream. The Tulsequah River originates from the Tulsequah Glacier and the Upper Tulsequah sample site is located approximately 5 km downstream of the glacier, explaining the low water temperature (1.4°C) recorded at the Upper Tulsequah site. The temperature increased to 3.2°C below the Tulsequah Mine site, and 9.8°C at the Taku Border site.

On average, freshwater systems have a pH range between 6 and 8 (Helfman et al. 2009), while a pH of 5 is recorded at the Upper Tulsequah site. This suggests that the Tulsequah River is a naturally acidic system during certain times of the year. Our pH measurement taken below the Tulsequah Mine site, influenced by Tulsequah Chief Mine ARD drainage, is 6. The pH measured at the Taku Border site is 7.

Gartner Lee Limited reported baseline water quality levels in their 2008 report (Ford 2008). The report summarized water quality data collected between May and September, 2007. Four established sample sites in the mainstem of the Tulsequah River, including one sample site near the Upper Tulsequah site (W10), had pH values between 6.2 and 8.0. Site W10 had pH values between 6.2 and 7.67. The report also notes that the minimum pH (6.2) at site W10 is not within the preferred range suggested in the British Columbia Approved Water Quality Guidelines (British Columbia Ministry of Environment 2006). Water quality data collected during this project is used as reference and not a key element of this study.

Fish collected from the Upper Tulsequah site had the highest average concentrations of Zn, Pb and Hg. Fish collected from below the Tulsequah Mine site had the highest average concentrations of As, Se and Cu. Fish collected from the Taku Border site had the highest average concentration of Cd. Statistical analysis of the sample means did not find any statistical significance among the metals tested, except for Se ($P = 0.0253$) between the Tulsequah Mine and the Taku Border sites. Nevertheless, average values of Se concentration from all sample sites are below the EPA draft numeric criteria for Se concentrations in freshwater fishes (EPA 2004).

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APPENDIX

Appendix A.–Columbia Analytical Services Analytical Report for Service Request No: K1105585 Fish Tissue Metals Analysis