Technical Report No. 11-08

Aquatic Studies at Kensington Mine, 2011

by

Jackie Timothy and Katrina M. Kanouse

with Southeast Region Habitat Staff

February 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. 11-08

AQUATIC STUDIES AT KENSINGTON MINE, 2011

by
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Cover: Juvenile Dolly Varden char. Photo by Gordon Willson-Naranjo.

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Thank you all so very much. We could not have completed this without your help.

EXECUTIVE SUMMARY

On March 7, 2011, Coeur Alaska, Inc. requested the Alaska Department of Fish and Game (ADF&G) Division of Habitat (Habitat) conduct the aquatic studies required under the US Forest Service (USFS) Plan of Operations (Coeur 2005) and the Environmental Protection Agency National Pollutant Elimination Discharge System Permit No. AK-005057-1 (NPDES) for the Kensington Mine. Habitat has conducted aquatic studies at the Red Dog Mine near Kivalina, the Fort Knox Mine near Fairbanks, the Illinois Creek Mine southwest of Galena, the Greens Creek Mine on Admiralty Island, and the Pebble and Moneyknob prospects. This long-term collaboration with mine operators, which began in 1990 at the Red Dog Mine, provides Habitat the opportunity to gather and review biological information and cooperatively resolve issues as they arise.

The Alaska Department of Environmental Conservation (DEC) recently completed a transfer of federal permitting, compliance and enforcement authority for mining discharges to the State of Alaska and was soliciting public comments on a proposed Kensington Mine Alaska Pollutant Elimination System (APDES) permit. During Habitat's review of DEC's proposed APDES permit we recommended biological productivity and substrate composition studies in Slate, Johnson and Sherman Creeks to detect change outside the bounds of natural variation that may be attributed to mine operations.

Specifically, we recommended estimates of periphyton biomass, benthic macroinvertebrate density and richness, resident Dolly Varden char abundance and distribution in Slate Creek, concentrations of heavy metals in Dolly Varden char whole body tissues in Slate Creek, sediment toxicity and sediment metals concentrations (Weber Scannell and Ott, 2001). We recommended these studies to supplement DEC's primary water quality and quantity studies as most changes, if they occur, are most readily detected at the lower trophic levels. Fish, at the highest trophic level of these studies, are the least likely organism to reveal definitive information regarding changes from mine operations. Instead, we look to a combination of all assemblages to reveal information about stream health over the long term. On July 29, 2011, DEC issued APDES Permit No. AK0050571.

This document reports the aquatic studies completed for the Kensington Mine in 2011 to satisfy the requirements of the USFS Plan of Operations (Coeur 2005), and the NPDES and APDES permits.

We include the documents referenced in the Executive Summary in Appendix A.

INTRODUCTION

The Kensington Gold Mine is located in Berners Bay in Southeast Alaska; about 72.5 km north of Juneau by air and about 56 km south of Haines by air (Figure 1). The site, where mining began near the end of the 19^{th} century, is within the City and Borough of Juneau and the Tongass National Forest (USDA Forest Service Vol. 1 & 2, 2004). The mine is owned and operated by Coeur Alaska, Inc. (Coeur) under the Coeur d'Alene Corporation out of Coeur d'Alene, Idaho.

Mine infrastructure is located in three drainages that support anadromous fish (Figure 2):

- The tailing treatment facility (TTF) in the Slate Creek drainage;
- The camp and mill facilities in the Johnson Creek drainage, and;
- The mine water treatment facility in the Sherman Creek drainage.

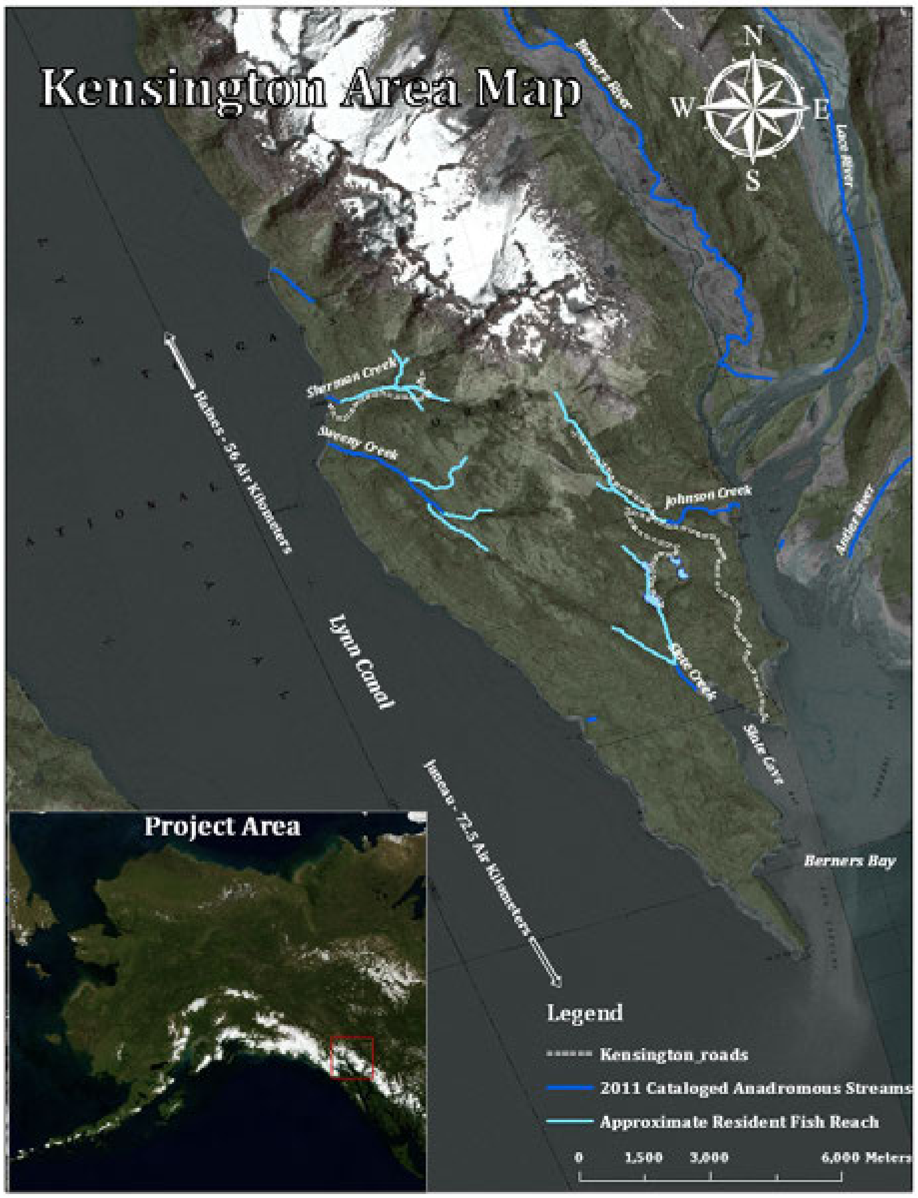

Figure 1. Kensington Area Map.

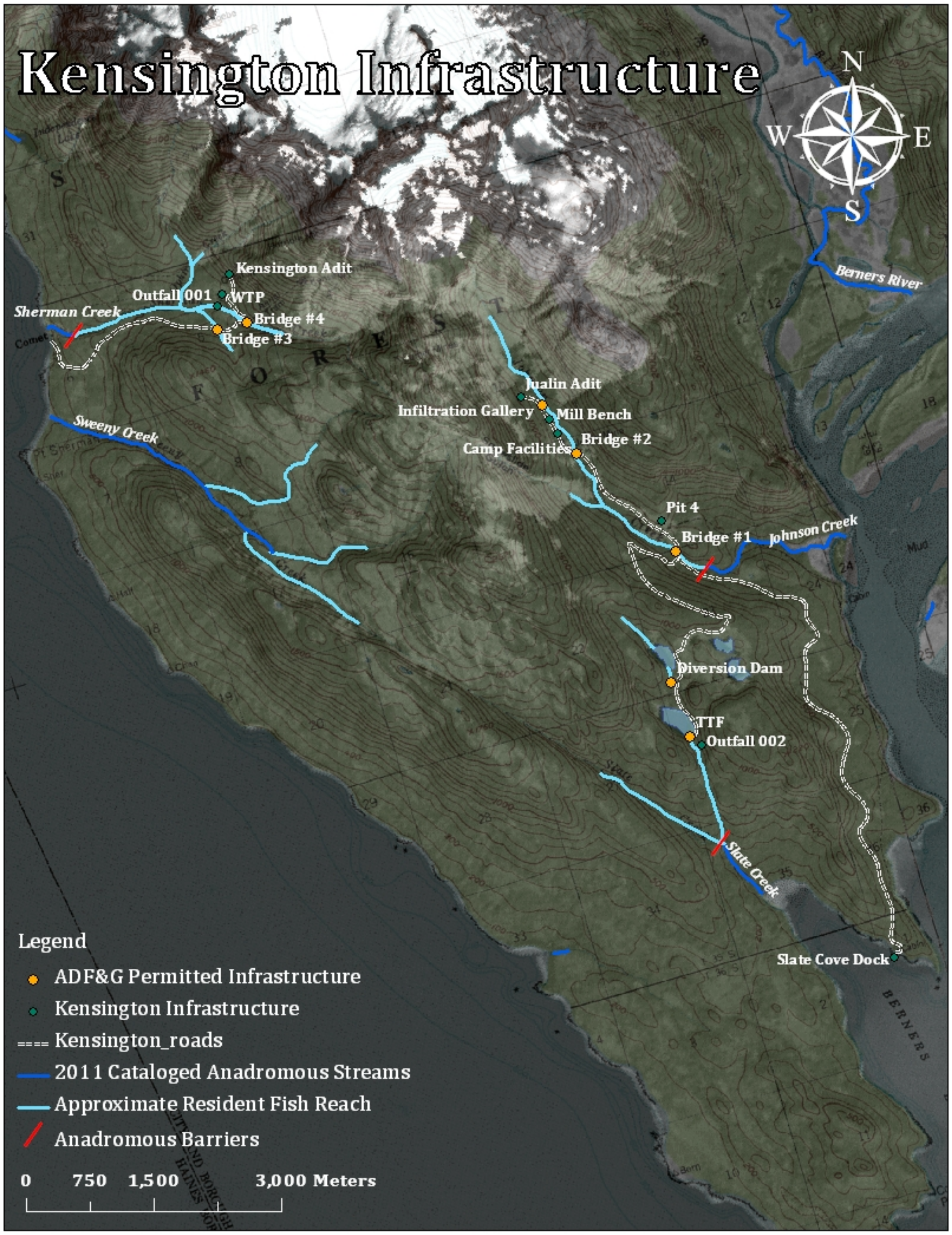

Figure 2. Kensington Mine Infrastructure.

The Kensington and Jualin adits were connected in July of 2007, making travel through the ore body between the Johnson and Sherman Creek drainages possible. The mine began production on June 24, 2010 and produces gold concentrate that is exported for processing. Tailings are disposed as slurry from the processing area through a pipeline into the TTF. ADF&G determined Lower Slate Lake is a suitable site for tailing disposal because exploratory rock appeared relatively inert and the resident Dolly Varden char are coming from Upper Slate Lake where spawning habitat is available. With final reclamation after mining, newly created littoral habitat seeded with Dolly Varden char from Upper Slate Lake, will increase Lower Slate Lake Dolly Varden char productivity. Therefore, under our authorities at Alaska Statute (AS) 16.05.841 and AS 16.05.871, Habitat permitted a dam and stream diversion in the Slate Creek drainage. Habitat also permitted activities in two other waterbodies, including an infiltration gallery and bridges at Johnson Creek, and bridges over tributaries to Sherman Creek. We include the Fish Habitat Permits for the Kensington Mine in Appendix B.

Contractors gathered data for the Kensington Mine from the late 1980s through 2010. Information from this earlier work is available in Archipelago Marine Research Ltd. (1991), Dames and Moore (1991), Earthworks Technology, Inc. (2002), EVS Environment Consultants (2000), Flory (1998-2011), HDR Alaska, Inc. (2003), Kline Environmental Research, LLC (2003, 2005), Konopacky Environmental (1992, 1993, 1995, 1996), Pentec Environmental (1990, 1991), and Steffen Robertson and Kirsten Consulting Engineers and Scientists (1997).

Habitat began the aquatic studies required under the NPDES permit in Slate, Johnson, Sherman and Sweeny Creeks in April 2011. NPDES requirements included sampling benthic macroinvertebrates (aquatic insects), resident Dolly Varden char populations and condition, outmigrating salmon fry, adult salmon escapement, spawning substrate composition, sediment toxicity, and sediment metals concentrations.

In 2011 we also collected samples for aquatic studies expected to be required under the APDES permit in Slate, Johnson, and Sherman Creeks. The APDES requirements include sampling periphyton (attached algae), benthic macroinvertebrates, resident Dolly Varden char populations, condition, and whole body metals concentrations, sediment toxicity, and sediment metals concentrations. Overall stream health is determined by estimates of periphyton biomass, benthic macroinvertebrate density and richness, resident Dolly Varden char abundance and condition in Slate Creek, concentrations of heavy metals in Dolly Varden char whole body tissues in Slate Creek, sediment toxicity and sediment metals concentrations.

PURPOSE

The purpose of this technical report is to summarize the data collected during the 2011 field season and document the condition of biological communities and sediment composition in the Slate, Johnson, and Sherman Creek drainages near mine development and operations. This report satisfies the aquatic studies required under the USFS Plan of Operations, NPDES and APDES permits.

STUDY AREA

We completed aquatic studies in the three drainages influenced by mine construction and operations (Figure 2):

- Four (4) sample sites in the Slate Creek drainage;
- Three (3) sample sites in the Johnson Creek drainage; and
- Three (3) sample sites in the Sherman Creek drainage.

We also completed aquatic studies in Sweeny Creek, a drainage outside the influence of mine construction and operations, as a control site required under the NPDES permit. Although previous contractors documented baseline data in all four systems, the current APDES permit does not require further aquatic studies in Sweeny Creek.

Slate Creek Drainage

Slate Creek drains 11.61 km^2 (Flory 2011) into Slate Cove on the northwest side of Berners Bay. Two waterfalls about 1 km upstream of the mouth prevent upstream anadromous fish passage to the East and West Forks. There are two lakes in this drainage; Lower Slate and Upper Slate Lakes, both in the East Fork. Plants and animals inhabiting lakes and rivers vary, so results of samples taken in Slate Creek below the lakes may naturally differ from those of the West Fork, and Sherman and Johnson Creeks, where lakes are not present. The Catalog of Waters Important for the Spawning, Rearing, or Migration of Anadromous Fishes (Catalog; Johnson and Blanche 2011) lists Slate Creek (Stream No. 115-20-10030) providing habitat for pink *Oncorhynchus gorbuscha*, chum *O. Keta*, and coho *O. kisutch* salmon, and eulachon *Thaleichthys pacificus*. Dolly Varden char *Salvelinus malma* and cutthroat trout *O. clarkii* are also present below the waterfall. Above the waterfall, Dolly Varden char are present in the East Fork drainage. We captured one Dolly Varden char in the West Fork about 100 m upstream of the waterfall on October 12, 2011, the only known fish sampling in the West Fork to date (Figure 3).

We access Slate Creek (Figure 4) by kayak from the Slate Cove dock when conditions permit. During inclement weather, we can access the creek hiking along the rocky shoreline, or through the woods to the mouth. Above the waterfall, East Fork Slate Creek is on river left and West Fork Slate Creek is on river right.[a] The East Fork Slate Creek reach is steep with cascade falls for 1 km, and is between the waterfall and the plunge pool where the diversion pipeline and TTF water treatment facility discharge on the river left. Above the plunge pool, an earthen dam contains the TTF where mine tailing slurry is deposited. Upstream of the TTF, a small concrete dam diverts water draining from Upper Slate Lake through a diversion pipeline and into East Fork Slate Creek, bypassing the TTF. Upper Slate Creek is the inlet creek to Upper Slate Lake and is outside the influence of current mine operations.

Figure 3. West Fork Slate Creek Dolly Varden char. Photo by Gordon Willson-Naranjo.

[a] The terms "river right" and "river left" are looking downstream in the direction water is flowing, per USGS convention.

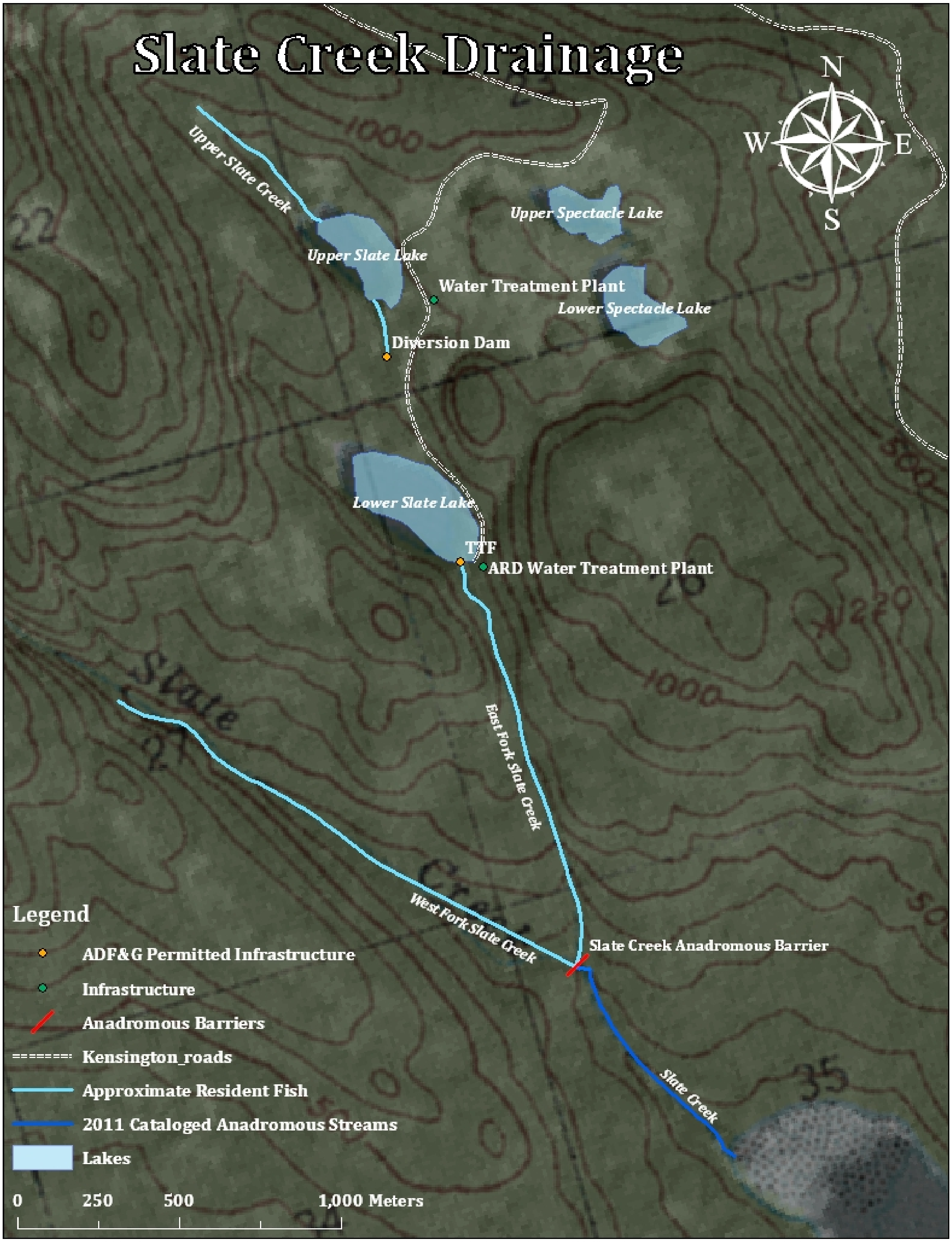

Figure 4. Slate Creek Drainage.

Johnson Creek Drainage

Johnson Creek (Figure 5) drains 19.97 km^2 (Flory 2011) into the north side of Berners Bay. A waterfall about 1.5 km upstream of the mouth prevents anadromous fish passage. The Catalog lists Johnson Creek (Stream No. 115-20-10070) providing habitat for pink, chum and coho salmon. Dolly Varden char and cutthroat trout are also present below the waterfall, and Dolly Varden char are present above the waterfall.

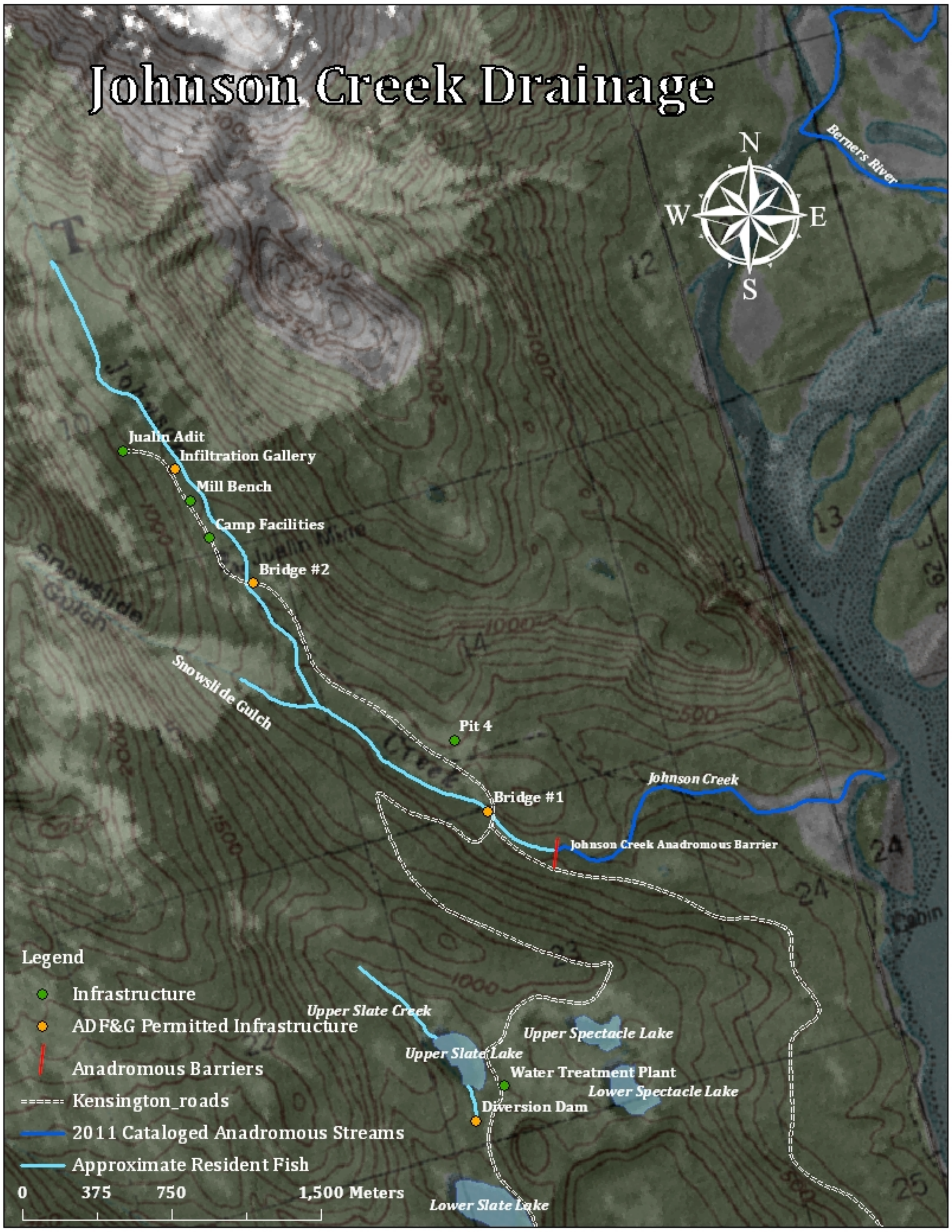

Figure 5. Johnson Creek Drainage.

We access Lower Johnson Creek by hiking downhill from mile 3 of the Jualin road, through the woods and across meadows to the mouth. About 0.5 km above the anadromous barrier, the creek runs beneath the Jualin Road Bridge 1. The Snowslide Gulch tributary is on river right about 1 km upstream of Jualin Road Bridge 1. Further upstream, the creek runs beneath the Jualin Road Bridge 2 with camp facilities, the mill and the Jualin adit on river right. Middle Johnson Creek is between the anadromous barrier and Jualin Road Bridge 2. An infiltration gallery collects water from Johnson Creek at the mill bench to support the camp. Johnson Creek above the Jualin adit to the headwaters is outside the influence of current mine operations.

Sherman Creek Drainage

Sherman Creek (Figure 6) drains 10.59 km^2 (Flory 2011) into the east shore of Lynn Canal. A waterfall about 360 m upstream from the mouth prevents anadromous fish passage. The Catalog lists Sherman Creek (Stream No. 115-31-10330) providing habitat for pink, chum and coho[b] salmon. Above the waterfall, Dolly Varden char are present.

Figure 6. Sherman Creek Drainage.

We access Sherman Creek by driving underground from the Jualin adit to the Kensington adit and then down the Comet Road to the beach where we walk north about 100 m to the mouth. Middle Sherman Creek is upstream of the waterfall and intercepts Ophir Creek on river right. Upstream of the Sherman and Ophir Creeks confluence, the South Fork of Sherman Creek is on river left. The mine water treatment plant Outfall 001 is upstream of the Sherman and South Fork

[b] Coho salmon have never been documented in Sherman Creek. We will submit a correction to the Catalog.

Creeks confluence. ADF&G did not issue a Fish Habitat Permit for the outfall hoses that discharge into Sherman Creek as the hoses do not block fish passage for resident fish (AS 16.05.841). Upper Sherman Creek above the Comet Road to the headwaters is outside the influence of current mine operations. The historic 2050 adit and a cabin are in this drainage.

Sweeny Creek Drainage

Sweeny Creek drains 10.57 km^2 (Konopacky 1992) into the east shore of Lynn Canal. A waterfall about 3 km upstream from the mouth prevents anadromous fish passage. The Catalog lists Sweeny Creek (Stream No. 115-31-10350) providing habitat for pink salmon. Cutthroat trout is documented in middle Sweeny Creek (Flory 2009).

We access Sweeny Creek driving underground from the Jualin to the Kensington adits and then down the Comet road to the beach where we walk south about 600 m to the mouth. Lower Sweeny Creek drains into Lynn Canal and is anadromous upstream for about 3 km at a barrier waterfall. Sweeny Creek is a control site outside the influence of mine operations. Baseline information has been gathered and 2011 is the final year of sampling in the Sweeny Creek drainage.

Sample Sites

We sample at sites sampled by Flory (2011) to the extent possible. We describe new or different sample sites in this report. Flory established stream sections using natural features, for example, all the lower creek sections include the mouth to the first anadromous fish barrier. We sample two other sections in the Slate Creek drainage; West Fork Slate Creek and the TTF (Table 1).

Table 1. Drainage sections.

Slate Creek	Johnson Creek	Sherman Creek
Lower Slate Creek	Lower Johnson	Lower Sherman
West Fork Slate Creek	Middle Johnson	Middle Sherman
East Fork Slate Creek	Upper Johnson	Upper Sherman
TTF (Lower Slate Lake)		
Upper Slate Creek		

AQUATIC STUDIES

In 2011, we completed the following studies (Figures 7, 8, 9, 10):

- Periphyton biomass estimated by chlorophyll *a*;
- Benthic macroinvertebrate density and richness;
- Resident fish population status by species and habitat type;
- Resident fish population condition;
- Resident Dolly Varden char whole body metals concentrations of Al, Ag, Cd, Cr, Cu, Pb, Hg, Ni, Se, and Zn;
- Sediment metals concentrations of Al, Ag, Cd, Cr, Cu, Pb, Hg, Ni, Se, and Zn;
- Sediment toxicity using *Hyalla azteca* and *Chironomus dilutus*;
- Emigrating salmon fry abundance;
- Adult salmon escapement; and
- Spawning substrate composition in cataloged anadromous fish streams.

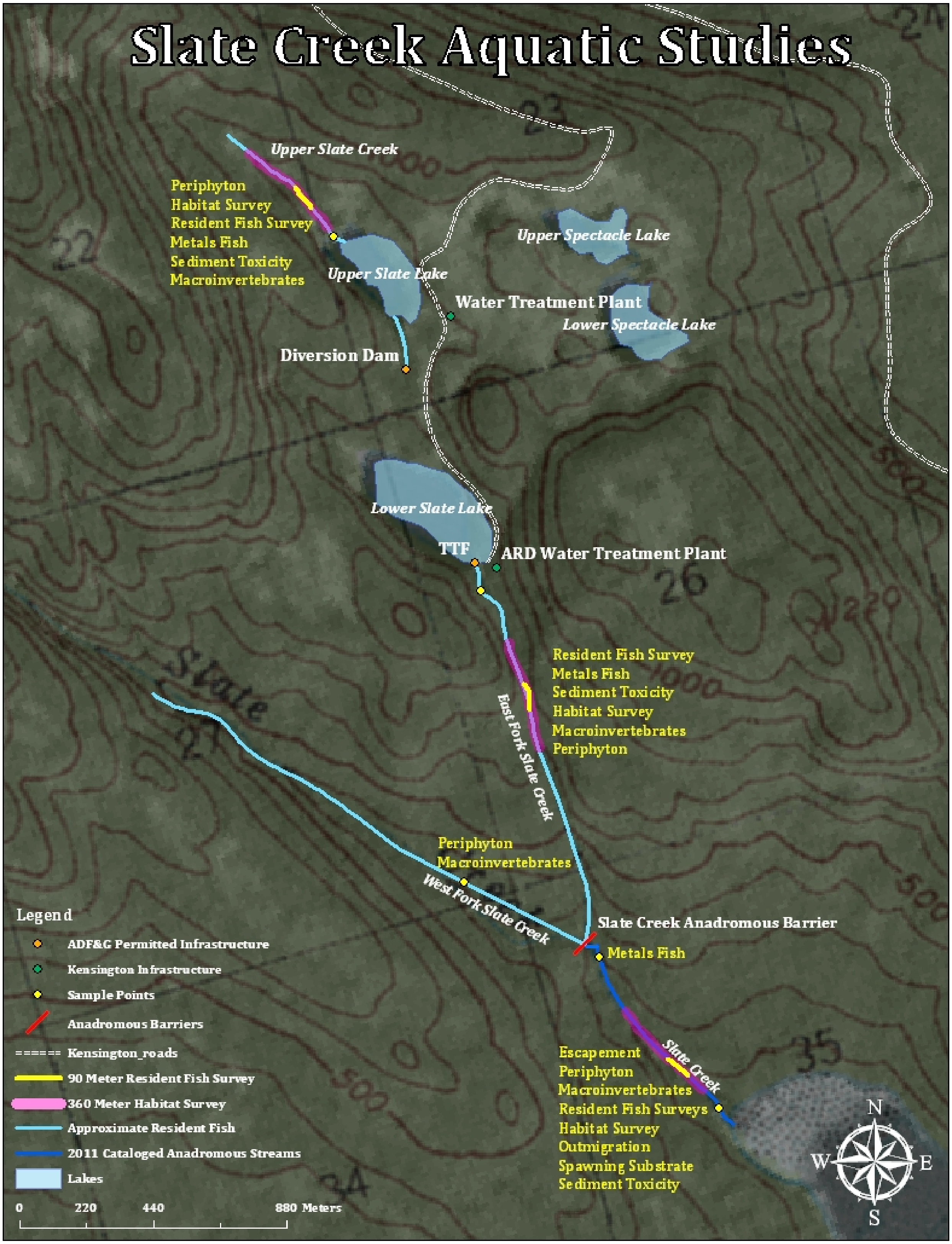

Figure 7. Slate Creek Aquatic Studies.

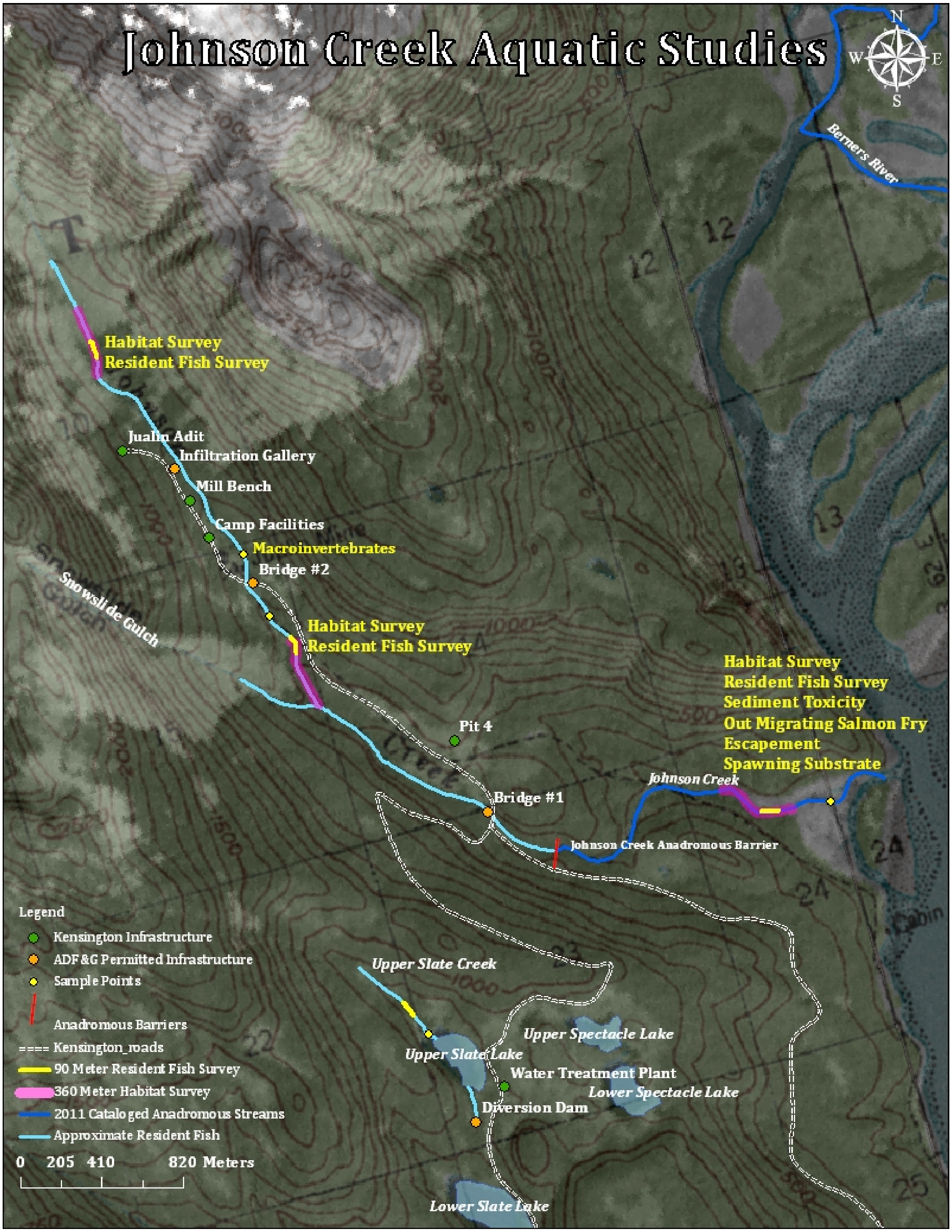

Figure 8. Johnson Creek Aquatic Studies.

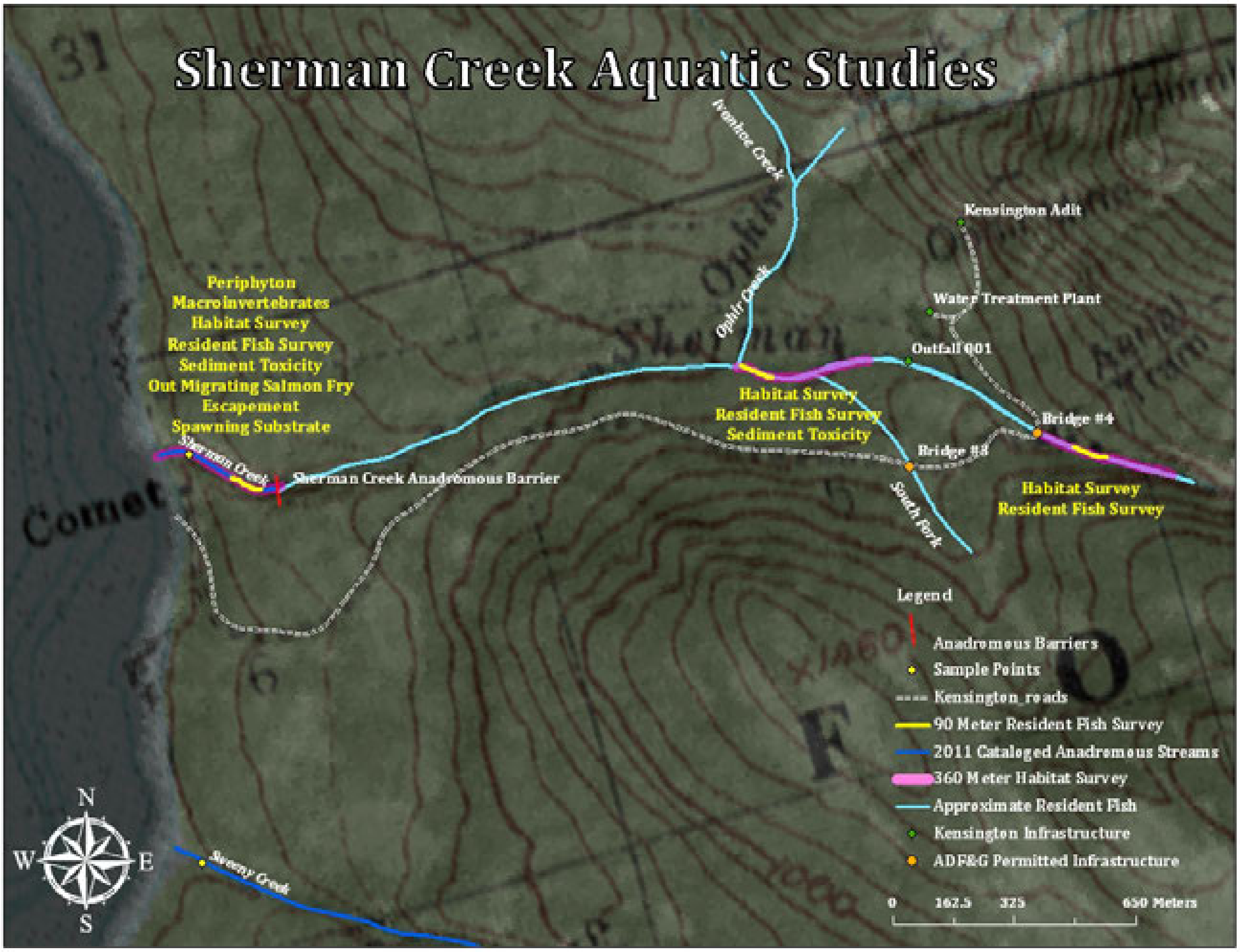

Figure 9. Sherman Creek Aquatic Studies.

Figure 10. Sweeny Creek Aquatic Studies.

MONITORING SCHEDULE

A general overview of the aquatic studies required in the USFS Plan of Operations, NPDES and APDES permits follows.

Plan of Operations Section 4.4 Freshwater Monitoring:

- Upper Slate Lake Dolly Varden spawning surveys (annually)
- Anadromous salmon escapement (annually)
- Photographs of anadromous fish habitat types (annually)

Plan of Operations TTF Ecological Monitoring Plan[c]:

- Tailings habitability studies (annually)
- TTF Dolly Varden population estimates (years 1,3,5)
- Upper Slate Lake Dolly Varden population estimates and spawning surveys (years 1,3,5)
- TTF threespine stickleback surveys (years 1,3,5)
- Upper Slate Lake and TTF invert surveys (years 1,3,5)
- Upper Slate Lake and TTF zooplankton surveys (years 1,3,5)
- Upper Slate Lake, TTF summer and winter habitat surveys (2 years total)

NPDES/APDES Permit Monitoring in Sherman, Slate and Johnson Creeks:

- Periphyton biomass and aquatic vegetation (July)
- Benthic macroinvertebrates (April/May)
- Dolly Varden char population (July/August)
- Dolly Varden char condition (July/August)
- Dolly Varden char whole body metal concentrations (July/Aug)
- Sediment composition (Aug/Sept)
- Sediment metals concentrations (Aug/Sept)
- Sediment toxicity (July)
- Emigrating fry (April/May)
- Anadromous salmon escapement (July–Oct)
- Spawning substrate quality (July)

We include an aquatic studies monitoring schedule and a 2011 timeline in Appendix C.

WATER QUALITY

We use an Extech Exstick II[d] field meter to measure basic water quality at each site during sampling, including temperature and conductivity. We use a Global Water Flow Probe FP101[e], USGS Pygmy Meter Model[f], or Marsh McBirney Flo-Mate[g] to measure stream flow.

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[c] Plan under review. Implementation scheduled for Spring 2012.
[d] Product names used in this publication are included for completeness but do not constitute product endorsement.
[e] Ibid
[f] Ibid
[g] Ibid

METHODS[h]

PERIPHYTON

Rationale

The presence of periphyton, as evidenced by concentrations of chlorophyll, affirms continued *in situ* productivity. We assess periphyton biomass and the proportion of chlorophyll pigments *a, b,* and *c* to detect changes over time.

Sample Collection and Laboratory Analysis

We sample periphyton at low flows when there have not been recent high flows. We collect 10 smooth, undisturbed, and perennially wetted rocks from the streambed in less than 0.45 m of water within each study reach using the collection methods described in Barbour et al. (1999) and Weber Scannell (2010). We place a 5 × 5 cm square of high-density foam on each rock and scrub the area around the foam with a toothbrush to remove all attached algae outside the covered area. We rinse the rock by dipping it with foam intact in the stream. We remove the foam square and scrub the sample area with a rinsed toothbrush over a 0.45 µm glass fiber filter attached to a vacuum pump. We use stream water in a wash bottle to rinse the loosened periphyton from the rock, the toothbrush, and the inside of the vacuum pump onto the filter. We pump most of the water through the filter then add a few drops[i] of saturated $MgCO_3$ to the filter before we pump the sample dry. This prevents acidification and conversion of chlorophyll to phaeophyton. We remove the dry glass fiber filter and wrap it in a coffee filter to absorb additional water and place the sample in a sealed, labeled plastic bag with desiccant and store the samples in a light-proof cooler containing frozen gel paks until we can freeze them. Once we return to the office, we keep the samples frozen at –20°C until processing.

We generally follow U.S. Environmental Protection Agency protocol (USEPA 1997) for chlorophyll extraction and measurement and instrument detection limit and error.[j] We remove the samples from the freezer, cut them into small pieces, and place them in a centrifuge tube with 10 ml of 90% buffered acetone. We cap the centrifuge tubes and place them in a metal rack, cover them with aluminum foil, and hold them in a refrigerator for not more than 24 hours to extract the chlorophyll. After extraction, we centrifuge the samples for 20 minutes at 1,600 rpm and then read them on a Shimadzu UV-1800 Spectrophotometer[k] at optical densities (OD) 664 nm, OD 647 nm, and OD 630 nm. We also take a reading at OD 750 nm to correct for turbidity. We use an acetone blank to correct for the solvent. We treat the samples with 80 µ1 of 0.1 N hydrochloric acid to convert chlorophyll to phaeophyton, and then read them again at OD 665 nm and OD 750 nm.

Data Presentation

We include a figure of stream flow three weeks prior to field sampling in the Slate Creek results section. Discharge data is not available in Johnson or Sherman Creeks. We present periphyton

[h] We will provide footnotes under each specific aquatic study in the *Results* section when we deviate from the methods described in this section.

[i] This measurement is not exact as the amount of water used to dilute the magnesium carbonate is not exact and fixes the sample regardless of the concentration and without affecting data integrity.

[j] There are two main deviations from EPA Method 446. Our sample storage exceeds 3.5 weeks. Our filters are cut rather than homogenized due to risk of acetone exposure (Weber Scannell and Ott 2001).

[k] Product names used in the publication are included for completeness but do not constitute product endorsement. The Alaska Department of Fish and Game does not endorse or recommend any specific company or their products.

biomass data in Appendix D. We present periphyton biomass data comparisons using box-and-whisker plots in the Sherman Creek results section and in Appendix L for all Slate Creek sampling sites. The box illustrates the interquartile range, the line bisecting the box represents the median value, and the vertical whiskers are the typical range of data in the sample. Whiskers end at a data point that is within 1.5 times the interquartile range. A star (∗) represents possible outliers lying outside the box by more than 1.5 times the interquartile range, and an open circle (○) represents probable outliers more than 3 times the interquartile range.[l] We also present a figure of mean proportions of chlorophyll *a*, *b*, and *c*.

We use Statistix® 9 (Analytical Software 2008[m]) for statistical analyses. We use Kruskal-Wallis One-Way Analysis of Variance by ranks, a nonparametric alternative to a one-way analysis of variance, to test for equality of population medians between sample sites and periods, and use all-pairwise comparisons on the mean ranks for each group to test for homogeneity between sample sites and periods. We report significant differences when $p \leq 0.05$.

BENTHIC MACROINVERTEBRATES

Rationale

We sample benthic macroinvertebrates, paying close attention to those classified in the Orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddis flies); collectively known as EPT taxa. EPT taxa have limited mobility, a short life cycle, and are sensitive to changes in water quality. We use macroinvertebrate density and richness data to detect changes over time.

Sample Collection and Laboratory Analysis

The NPDES permit requires sampling in East Fork Slate, Upper Johnson, Lower Sherman, and Lower Sweeny Creeks once during construction and annually between late March and the end of May. The APDES permit requires sampling annually in Upper Slate, East Fork Slate, West Fork Slate, and Lower Slate Creeks, Upper Johnson Creek, and Lower Sherman Creek between March and May.

We collect 6 benthic macroinvertebrate samples from each sample reach with a Surber[n] stream bottom sampler using a stratified random sample design (Barbour et al. 1999) in riffle areas where we observe the greatest amount of taxonomic density and richness. This sample design eliminates the variability that arises when sampling pools, for instance, where pollution-sensitive taxa are less likely to be present.

The Surber stream bottom sampler has a 300 micron mesh net and a frame that outlines a 0.093 m^2 sample area. After setting the frame in the substrate, we scrub large rocks with a brush and disturb gravels and silt manually, to about 10 cm depth, to dislodge insects into the net.

We remove each macroinvertebrate sample from the cod end of Surber sampler by rinsing the sample into a prelabeled 500 mL plastic bottle with minimum 70% denatured ethanol. We add additional ethanol to each bottle at four parts ethanol to one part sample. Habitat biologists sort macroinvertebrates from debris under a dissecting stereoscope and identify them to genus, when possible, using Merritt and Cummins (1996) and Stewart (2006).

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[l] We have no evidence to suggest that potential and probable outlier data values are not part of the data set's natural distribution, so they are retained and used in the data analysis.

[m] See footnote a.

[n] See footnote a.

We calculate the density of macroinvertebrates per square meter by dividing the number of aquatic insects per sample by 0.093 m^2, the Surber sampling area.

The Shannon Diversity (*H*) and Evenness (*E*) Indices are commonly applied measures of diversity (Magurran 1988). The Indices are calculated using the following equations:

$$H = -\sum (P_i \ \log_{10} P_i)$$

$$E = \frac{H}{\log_{10} S}$$

Where *Pi* is the number of invertebrates per genus divided by the total number of invertebrates in the sample, and *S* is the number of genera in the sample.[o]

A single insect community has an *H* value of 0 that increases with the insect number (richness) and insect evenness (abundance equality). Aquatic macroinvertebrate density is expressed as the mean number of invertebrates per m^2.

Data Presentation

We include benthic macroinvertebrate data in Appendix E. We present a figure for mean macroinvertebrate densities, a figure for community composition, a table for benthic macroinvertebrates by taxa, and a table of the Shannon Indices of Diversity and Evenness in the Johnson and Sherman Creek result sections and in Appendix L for Slate Creek. We use Statistix® 9 (Analytical Software 2008[p]) for statistical analyses as we describe in the periphyton section above.

RESIDENT FISH POPULATION STATUS

Rationale

We sample resident Dolly Varden char populations as another index of stream health. We compare current year population estimates to previous years' population estimates to detect change over time.

Sample Collection and Laboratory Analysis

We complete habitat surveys using the habitat type naming convention described by Bisson et al. (1981), in about the same 360 m reaches surveyed by Flory (2011). Though Bisson subdivides three main habitat types for precision to detect environmental change, we count the main habitat types—riffles, pools and glides—as we describe here.

- Riffles: steepest slopes and shallowest depths at flows below bankfull with a poorly defined thalweg.
- Pools: deepest areas where water surface slope below bankfull is near zero.
- Glides: located immediately downstream of pools with negative bed slope and positive water surface slope.

We use this information to quantify habitat types and then select a 90 m representative reach for each sampling site.

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[o] Assuming all species are represented in the sample.

[p] See footnote a.

We sample resident fish populations using a modification[q] of a depletion method developed by the USFS (Bryant 2000). We isolate sample reaches using fine mesh nets we secure to the stream bottom with large rocks on both ends. We saturate the 90 m reaches with 0.635 cm (1/4 in) and 0.317 cm (1/8 in) soft mesh and wire mesh minnow traps baited with whirl packs containing sterilized salmon roe (Magnus 2006). Biologists begin from the downstream end of each reach setting baited minnow traps opportunistically in all habitat types where water depth and flow permits. We record the habitat type in which each trap is set. We soak the traps for 1.5 h, then retrieve each trap, record species (Pollard 1997) and numbers of fish in each respective habitat type, rebait, and reset for another 1.5 h soak period. We retain salmonids in aerated buckets until processing; biologists anesthetize[r], measure each to FL to the nearest 5 mm, weigh each to the nearest 0.1 g, and identify to species. Fish are kept in a live well secured in the stream during the sampling period, and returned to the sample reach after all three passes are complete.

We estimate resident fish population status using the multiple-pass depletion calculation developed by Lockwood and Schneider (2000). The repetitive method produces a maximum likelihood estimate (MLE) of fish with a 95% confidence interval.

Let X represent an intermediate sum statistic where the total number of passes, k, is reduced by the pass number, i, and multiplied by the number of fish caught in the pass, $C_{i,}$, for each pass,

$$X = \sum_{i=1}^{k} (k-i)C_i$$

Let T represent the total number of fish captured in the minnow traps for all passes. Let n represent the predicted population of fish, using T as the initial value tested. Using X, the MLE, N, is calculated by repeated population predictions where the result must be closest to, and not exceed, 1.0, in the following equation,

$$\left[\frac{n+1}{n-T+1}\right] \prod_{i=1}^{k} \left[\frac{kn-X-T+1+(k-i)}{kn-X+2+(k-i)}\right]_i \leq 1.0$$

The probability of capture, p, is given by the total number of fish captured, divided by an equation where the number of passes is multiplied by the MLE and subtracted by the intermediate statistic, X,

$$p = \frac{T}{kN-X}$$

The variance of N, a measure of variability from the mean, is given by,

$$Variance\ of\ N = \frac{N(N-T)T}{T^2 - N(N-T)\left[\frac{(kp)^2}{(1-p)}\right]}$$

[q] Shorter reaches, more minnow traps and three passes instead of four.
[r] Clove oil (.5 ml/gl)

The SE of N is calculated by the square root of the Variance of N, and the 95% confidence interval for the MLE is given by: MLE $\pm$ 2(SE).

Data Presentation

We present Dolly Varden char population, condition and length frequency data in Appendix F. We present figures of Dolly Varden char population estimates and Dolly Varden char population estimates by habitat type in Appendix L. We present figures of cutthroat trout population estimates and cutthroat trout population estimates by habitat type, in Appendix L. Because this method does not effectively calculate populations for small samples, population estimates and confidence intervals are not available for all sample reaches and habitat types. In these cases, we present the projected number of fish captured. In addition, we adjust some habitat type population estimates so the sum of the habitat type estimates equal the total population estimates.

RESIDENT FISH POPULATION CONDITION

Rationale

We quantify individual fish condition to compare fish within a population and between populations. Age, sex, season, maturation, diet, gut fullness, fat reserve and muscular development are influences that affect fish condition.

Sample Collection and Laboratory Analysis

We weigh Dolly Varden char to the nearest 0.1 g and measure to the nearest 5 mm FL.

We use the lengths and weights to calculate Fulton's condition factor (K) using the equation given in Anderson & Neumann (1996) where the weight of each fish measured in grams (W) is divided by the cubed length of fish (L) measured in millimeters, and the product multiplied by 100,000,

$$K = \frac{W}{L^3} \times 100{,}000$$

Data Presentation

We include resident fish capture data and length/frequency data in Appendix F. We present a figure of Dolly Varden char population condition with whiskers showing the 95% confidence intervals calculated by 2 × the standard deviation in Appendix L. We present a figure of cutthroat trout population condition with whiskers showing the 95% confidence intervals calculated by 2 × the standard deviation in Appendix L.

RESIDENT FISH METALS CONCENTRATIONS

Rationale

At the Red Dog Mine in northwest Alaska, Dr. Al Ott has documented metals accumulation in juvenile fish tissues within two months of migration into mineralized tributaries (A. Ott, Ph.D, Deputy Director, ADF&G Division of Habitat, Fairbanks, personal communication, January 17, 2012.) We sample whole body metals concentrations in resident Dolly Varden char to detect both short-term and long-term changes in tissue metals concentrations. By examining the relationship of tissue data and water quality data, we may be able to determine whether the changes over time are related to mine operations or natural variability.

Sample Collection and Laboratory Analysis

The APDES permit requires sampling resident Dolly Varden char tissues for 10 metals concentrations in Upper Slate Creek, East Fork Slate Creek and Lower Slate Creek near the waterfall.

We collect 6 juvenile Dolly Varden char from each sampling site measuring 85–125 mm FL for whole body metals analyses. This size range improves the likelihood of sampling resident fish in Lower Slate Creek which is accessible to anadromous fish. We capture the fish in minnow traps baited with sterilized salmon roe, measure to 5 mm FL, and individually package them in clean, prelabeled bags. Samples are immediately frozen in a cooler containing gel ice packs, then stored in a camp freezer until we return to Juneau and weigh the fish in the sealed bags, correcting for bag weight. We freeze the samples until we ship them to a private analytical laboratory, where they are individually[s] digested, dried, and analyzed for Ag, Al, Cd, Cr, Cu, Pb, Hg, Ni, Se, and Zn on a dry-weight basis, with percent total solids also reported. The private analytical laboratory provides 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.

Data Presentation

We include the laboratory reports from Columbia Analytical Services in Appendix G. We present a table showing resident fish mean metals concentrations in each Slate Creek section, and a figure with mean metals concentrations in Appendix L.

SEDIMENT METALS CONCENTRATIONS

Rationale

Metals concentrations are influenced by a variety of factors, including mineralogy, grain size, organic content and human activity.

Sample Collection and Laboratory Analysis

We opportunistically collect 100 mL of fine sediment each from Lower, East Fork and Upper Slate Creeks, Lower Johnson Creek, and Lower and Middle Sherman Creek. We use stainless steel scoops to collect the samples, generally on the downstream end of large rocks where fine particles tend to settle-out, and avoid collecting organics to the extent possible. Samples are stored in clean glass jars provided by the lab, and shipped to a private lab in a cooler packed with frozen gel ice packs as soon as possible.

Data Presentation

We present sediment metals concentrations for each sampling site in a figure that illustrates the proportion of metals in the results section for each sampling site. We include the laboratory report from AECOM in Appendix H. We present a figure of sediment metals concentrations at all sample sites in Appendix L.

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[s] We made an error and samples from 2011 were homogenized. We will explain this in the results section.

SEDIMENT METALS TOXICITY

Rationale

Sediment, the habitat for many aquatic organisms, is a repository of metals introduced into surface waters. The toxicity of metals in sediments can be assessed in the lab using *Chironomus dilutus* (midges) and *Hyalella azteca* (amphipods). Survival of *Chironomus dilutus* is generally lower than survival of *Hyalella azteca* on all mediums including the lab control sand.

Sample Collection and Laboratory Analysis

We collect 2 L of fine sediment each from Lower, East Fork and Upper Slate Creeks, Lower Johnson Creek, and Lower and Middle Sherman Creek using the same collection methods we describe in the *Sediment Metals Concentrations* section above, shipping the samples in plastic containers the laboratory provides. A private lab tests for short-term chronic toxicity of sediment using the organisms *Hyalella azteca* and *Chironomus dilutus*, and removes debris and large sediment from the sample prior to homogenizing. The lab uses eight replicates of sediment for each treatment, and the lab control sediment is commercial grade sand.

Data Presentation

We include the laboratory reports from AECOM that list significant differences ($p \leq 0.05$) between control and individual samples in Appendix H. We present organism survival and growth for each sample site in a table in Appendix L.

ANADROMOUS FISH POPULATIONS

Adult pink salmon migrate into streams in Southeast Alaska from July to September to spawn. A returning female will select an area to build a redd where substrate composition, water velocities, and dissolved oxygen are sufficient to support embryos. The embryos develop over the fall and winter and emerge from their gravel redds as early as March, emigrating immediately to the estuary (Groot 1991). Freshwater survival of pink salmon from egg to emergent fry is about 11.5% while survival from fry to adult averages 2.8% (Quinn 2005).

EMIGRATING FRY

Sample Collection

The NPDES permit requires outmigrating salmon fry counts in April until population counts diminish in Slate, Johnson and Sherman Creeks. This study is not required again.

We install fyke nets and live-trap perforated metal boxes in the mouths of Slate, Johnson and Sherman Creeks to capture outmigrating salmon fry. We attach wing nets, the lengths of which are modified to best fit each stream, to the fyke net frames to maximize stream coverage. The live-trap boxes contain a partition to deflect flow and allow fry to pass underneath to a compartment of low flow. We adjust the height of the live-trap boxes instream to maintain moderate flow inside the box. We build rock weirs to redirect high flows when necessary to keep fry from being entrained against the perforated metal. We install debris screens upstream of the fyke nets to catch large debris and reduce debris-related mortalities inside the live-trap box.

We identify and count all species captured. We estimate high counts by volume, using aquarium nets, where biologists count the number of fry in a net and estimate the total number of fry by the number of scoops. We record the length of wings, percent stream coverage, and mortalities.

Twice per week we conduct a mark–recapture trial to estimate trap efficiency at each site. We immerse 150 pink fry in a solution of 0.25 g bismark brown dye per gallon of stream water for about 10 minutes. We rinse the pink salmon fry in stream water and release them about 30 m upstream of the traps after they recover. We determine trap efficiency by the number of marked fish recaptured in the fyke net.

Data Presentation

We include the pink salmon fry data in Appendix I. We present figures illustrating the actual number and estimate number of pink fry captured each day in the results section of Lower Slate, Lower Johnson and Lower Sherman Creeks. In addition, we present an estimate of egg-to-fry survival rates by creek, using escapement data from the year prior and the numbers of other species we captured.

ADULT SALMON ESCAPEMENT

Sample Collection

The NPDES permit and USFS Plan of Operations require weekly surveys of adult salmon in Slate, Johnson and Sherman Creeks throughout the spawning season. The APDES permit does not require escapement counts.

We conduct foot surveys in the anadromous reaches of Slate and Sherman Creeks once per week. We survey Johnson Creek from a helicopter once per week because of the steep terrain and dense bear activity. We verify helicopter survey results three times by following up with foot surveys. We record weather, flow conditions, and number of live fish and carcasses in each reach, each survey.

We section each creek to examine the distribution of adult fish according to Flory (2011). Sherman Creek is sectioned into 50 m reaches, Slate Creek into 100 m reaches, and Johnson Creek by landmarks. We begin escapement surveys at the stream mouth, ending at the anadromous fish barrier. A team of two biologists wearing polarized sunglasses independently records the number of live and dead fish by species during each foot and aerial survey. We use the average of the two biologists' counts to estimate the total number of fish, by species, for each survey.

Data Presentation

We present pink salmon escapement by week and distribution in figures in the results section of Lower Slate, Lower Johnson and Lower Sherman Creeks. We also present estimates for chum salmon in Slate and Johnson Creek and coho salmon in Johnson Creek. We estimate escapement using calculations developed by Neilson and Geen (1981), where the total number of fish counted in all surveys is divided by fish residence time. Pentec (1990) documented a 1–3 week pink salmon residence time in Sherman Creek, so we divide the sum of pink salmon weekly counts by two to avoid overestimating the pink salmon run. We did not adjust chum and coho salmon estimates. We include the pink salmon escapement data in Appendix J.

SPAWNING SUBSTRATE QUALITY

Sample Collection

The NPDES permit requires pink salmon spawning substrate sampling in the lower reaches of Slate, Johnson and Sherman Creeks during July prior to spawning activity. The APDES permit requires sampling in lower Slate Creek.

We collect four replicate samples from two locations in the lower reach in each creek (Flory 2011) using a McNeil sampler, which has a 15 cm basal core diameter and 25 cm core depth. We randomly choose sample sites within each reach selecting substrate measuring less than 10 cm, the maximum gravel size used by pink salmon (Lotspeich 1981, Kondolf 1993), and where the stream gradient is less than 3% at pool riffle breaks where flow begins to accelerate (Valentine, B. E. 2001. Unpublished. Stream substrate quality for salmonids: Guidelines for Sampling, Processing, and Analysis. California Department of Forestry and Fire Protection, Coast Cascade Regional Office, Santa Rosa, CA.) We push the McNeil sampler into the substrate until the sample core is buried, then transfer the sediments to a five gallon bucket using a stainless steel scoop. Samples are wet-sieved onsite using sieve sizes 101.6, 50.8, 25.4, 12.7, 6.35, 1.68, 0.42, and 0.15 mm. We measure the contents of each sieve to the nearest 5 mL[t] by the volume of displaced water in 600 mL and 1 L plastic beakers. We transfer the fines that pass through the 0.15 mm sieve to an Imhoff cone and allow them to settle for 10 minutes. Substrate quality is presented in Appendix K.

Data Presentation

We convert the wet weights to dry weights using a correction factor derived from Shirazi et. al (1979), assuming a gravel density of 2.6 g/cm^3 (Flory 2011). We calculate the geometric mean particle size (d_g) using methods developed by Lotspeich and Everest (1981), where the midpoint diameter of particles retained in each sieve (d) is raised to a power equal to the decimal fraction of volume retained by that sieve (w), and multiplied the products of each sieve size to obtain the final product,

$$d^g = d_1^{w1} \times d_2^{w2} \times d_3^{w3} \ldots d_n^{wn}$$

We present figures that illustrate the geometric mean particle size for each sample in the results section of Lower Slate, Lower Johnson and Lower Sherman Creeks. We include the data in Appendix K.

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[t] The contents of the 0.15 mm sieve are measured to the nearest mL.

RESULTS

SLATE CREEK

Lower Slate Creek

Periphyton Biomass (APDES 1.5.3.5.2.1)

The mean density of chlorophylls *a*, *b*, and *c* in Lower Slate Creek samples taken on July 29, 2011 is 5.16 mg/m^2 (*a*), 0.43 mg/m^2 (*b*), and 0.26 mg/m^2 (*c*). See Appendix L for periphyton biomass (Figure L1) and chlorophyll *a*, *b*, and *c* proportions (Figure L2).

Benthic Macroinvertebrates (NPDES I. E. 3. a. 1.) (APDES 1.5.3.2.1)

We identified 29 taxa (Appendix L, Figure L3) in our Lower Slate Creek samples, with about 2,057 aquatic macroinvertebrates per m^2, (Figure L4) of which 13.7% are EPT taxa (Figure L5). The Shannon Diversity score is 0.51 and Evenness score is 0.46 (Table L3). The dominant taxa is Chironomidae at 72%.We do not have baseline data we can use for comparison.

Resident Fish Population Status (NPDES I.E.3.b.1)

We conducted habitat surveys in Lower Slate Creek on July 11, 2011 and sampled resident fish on July 29, 2011. We did not retain 6 Dolly Varden char (80–125 mm) for laboratory analyses of whole body metals concentrations during this survey as four fish is not enough for the sample.

At 16 fish, the Lower Slate Creek Dolly Varden char population estimate is too small to calculate a 95% confidence interval (Figure L6). Flory (2011) reported Dolly Varden Char numbers in Lower Slate Creek in 2005 (0), 2008 (9) and 2009 (3).[u]

See Appendix L for Dolly Varden char population estimates by habitat type (Figure L7) and condition factors (Figure L8).

The 2011 cutthroat trout population estimate for Lower Slate Creek is 123±8 (Appendix L, Figure L9), the second highest recorded since 2005 (Flory 2011). The cutthroat trout population estimate by habitat type is presented in Figure L10 and condition factor is presented in L11.

We were surprised during our habitat surveys to see thousands of juvenile coho salmon in Lower Slate Creek, all the way to the anadromous barrier (Figure 11). Adult coho salmon sightings in Slate Creek are scarce. Flory conducted adult pink salmon escapement foot surveys from as early as July 26 to as late as August 29 for six years (2005–2010) and only mentions observing a few adult coho salmon in 2005 and 2007 at the mouth of Slate Creek (Flory 2006 and 2008). Kline (2003) conducted foot surveys in Slate Creek as early as July 15 and as late as November 25 for six years (1995–2000), documenting a few coho adults and suggesting they were strays or a small spawning population.

We confirmed our visual observations of age-0 and 1-year-old juvenile coho salmon during resident fish population studies, capturing over 200 juvenile coho salmon in a 90 m reach (Figure 12). The reach is above two barriers that prevent age-0 fish from passing upstream, suggesting Slate Creek is the natal stream.

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[u] Comparing our resident fish population estimates with previous estimates by other contractors is of interest though our methods differ. Flory (2011) conducted snorkel surveys and electrofished in addition to minnow trapping. We used minnow traps only.

Figure 11. Juvenile coho salmon in the upper portion of the anadromous reach of Lower Slate Creek. Photo by Jackie Timothy.

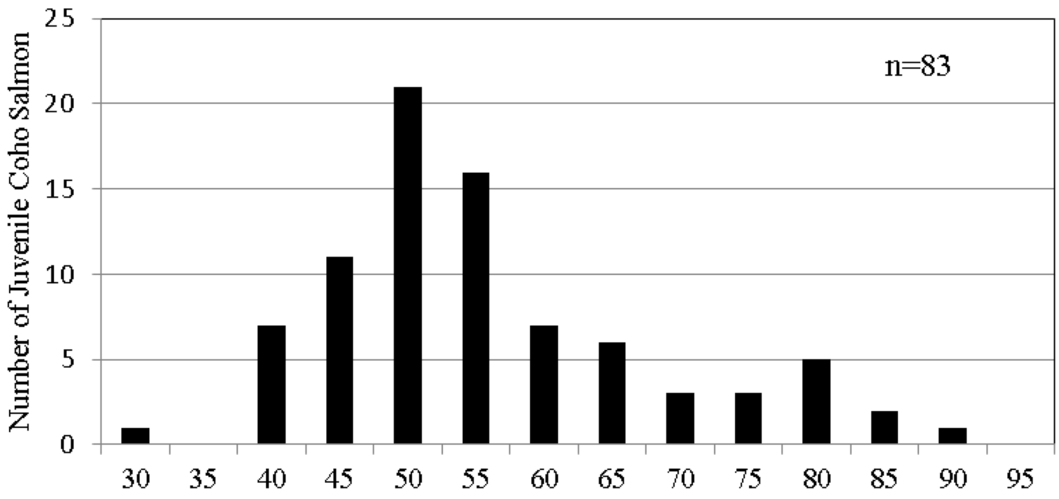


Figure 12. Lower Slate Creek juvenile coho salmon length and frequency.

We recommend additional foot surveys to document adult coho spawning in Slate Creek, into November. We will include this work in our upcoming monitoring schedule and will provide survey results in our 2012 technical report.

Metals Concentrations in Juvenile Fish (APDES 1.5.3.4.1)

We captured 6 Dolly Varden char on October 11, 2011 using baited minnow traps within the first 100 m downstream of the waterfall barrier; the area most likely to contain resident, rather than anadromous fish (Figure 3).

This is the first year we collected Dolly Varden char in Lower Slate Creek to test for whole body metals concentrations. Though we saved the fish individually as described in the methods section, we incorrectly completed the private laboratory's Chain of Custody form and the laboratory homogenized all 6 fish for Lower Slate Creek prior to testing. Thus, we only have one data point for 2011.

The fork lengths of the 6 fish tested are 110, 110, 110, 120, 125, and 130 mm. Table 2 shows the metals concentrations of whole body juvenile Dolly Varden char collected from Lower Slate Creek in 2011. Whole body metals concentrations in juvenile Dolly Varden char tissues in Lower, Middle and Upper Slate Creek, and data from Kline (2001) are presented in Appendix L (Figures L12 and L13).

Table 2. Lower Slate Creek Dolly Varden char whole body metals concentrations.

	Ag	Al	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
mg/Kg	0.05	2430	0.72	17.30	15.50	0.07	6.20	0.50	3.80	195

Sediment Metals Concentrations (NPDES I.E.2.a.) (APDES 1.5.2.1)

Lower Slate Creek sediment metals concentrations are shown in Figure 13. Metals concentrations at all sample sites are presented in Appendix L (Figure L14).

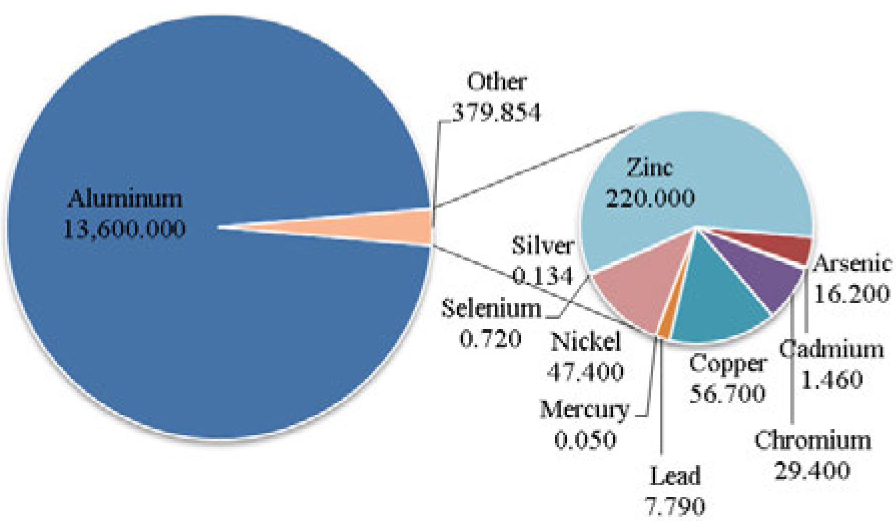


Figure 13. Lower Slate Creek 2011 sediment metals concentrations (mg/Kg).

Sediment Toxicity (NPDES I.E.2.e) (APDES 1.5.2.3.1)

There are no statistical differences in growth or survival of *Chironomus dilutus* or *Hyalella azteca* on the Lower Slate Creek sediment sample compared to the control (Appendix L, Tables L1 and L2).

Out-migrating Pink Salmon Fry (NPDES I.E.3.c.1.b.)

We installed the fyke nets and a live-trap box on April 12, 2011. We tended the nets daily to maintain them and to identify, count and release the fry, and fished in this manner through May 21, 2011 (Figure 14). During that time, we captured 130,230 pink fry in Lower Slate Creek, estimating a total outmigration 550,948 (Figure 15). We also captured 4 Dolly Varden char, 1 cutthroat trout, 320 sculpin *Cottus* sp., 6 juvenile coho salmon, and 158 juvenile chum salmon.

In 2010, Flory (2011) estimated adult pink salmon escapement in Lower Slate Creek at 3,000 fish. If we assume a sex ratio of 1:1, then about 1,500 females spawned. Quinn (2005) reports the average fecundity of female pink salmon is 1,648 eggs. Using these figures and the 2011 pink fry outmigration count (550,948), we estimate egg-to-fry survival in Slate Creek at 22.3%, similar to previous years documented by Flory (2011).

Figure 14. Art Chappel and Logan Miller maintain fyke net and live-trap box in Lower Slate Creek. Photo by Jackie Timothy.

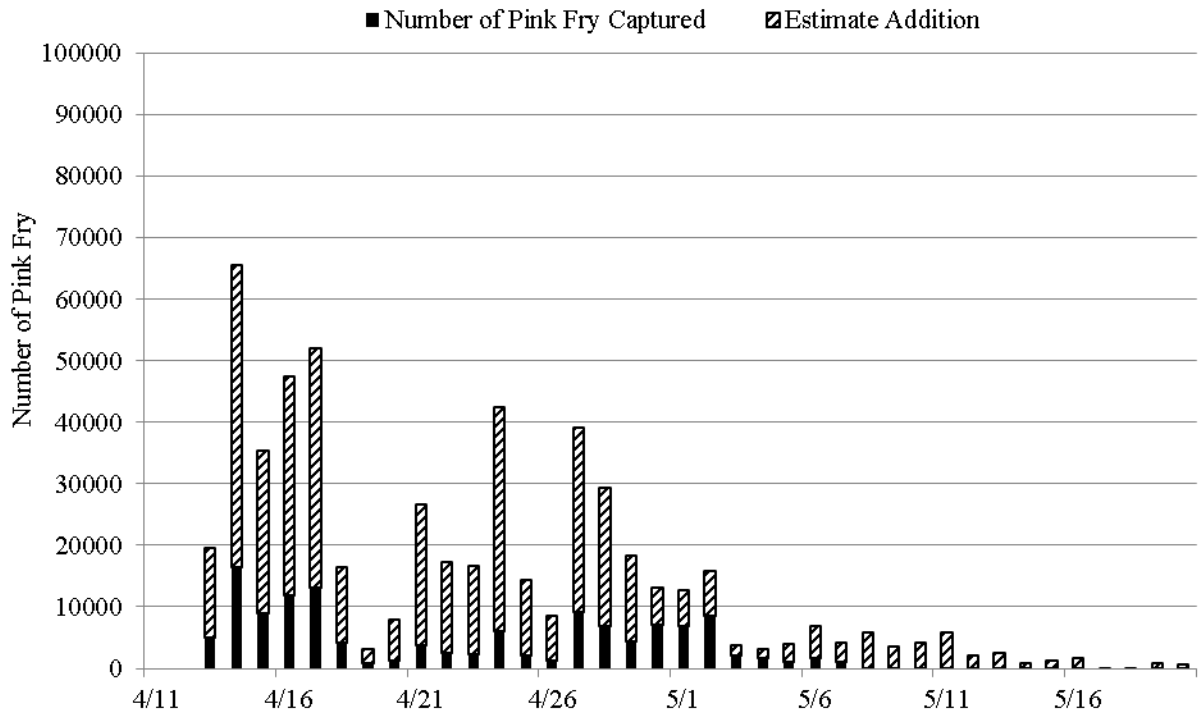


Figure 15. Lower Slate Creek daily pink fry outmigration estimates, April–May 2011.

We estimate sampling mortality at 9,212; approximately 6.6% of the captures for Lower Slate Creek. We attempted to adjust the fyke net wings to cover as much of the stream as possible for the most accurate estimate, but water levels varied hourly, decreasing the reliability of estimates. Though we adjusted live-trap box height and built rock weirs to deflect high flows, pink fry were entrained by flow against the box, entrapped by the 1/8 inch mesh net and holes in the trap (Figure 16), and impinged by debris (Figure 17). In fact, stream levels rose and fell so quickly on April 25 and April 26, and so much debris lodged in the nets, that we experienced unacceptable fry mortalities of 4000 on April 26, and 2700 on April 27. Mortalities were compounded by a river otter that repeatedly entered our live-trap box, despite our attempts to block entry, and by large Dolly Varden, cutthroat trout (Figure 18), and sculpin feasting on the captives. This study is discontinued under the APDES permit as the data gathered under the NPDES permit demonstrates the variability in the population cannot be tied to mine operations and the mortalities caused by sampling are not justified.

Anadromous Fish Escapement (NPDES I.E.3.c.1.a.)

We surveyed Lower Slate Creek for adult pink and chum salmon beginning July 19 and ending on September 20. We did not observe pink salmon during the first two surveys, or during the last survey (Figure 19). We estimate adult pink salmon escapement at 3,138 fish. The distribution of pink salmon in Lower Slate Creek is presented in Figure 20. We observed adult chum salmon on August 1 and August 9 and estimate escapement at 61 fish.

Figure 16. Fyke net entraps pink fry. Photo by Jackie Timothy.

Figure 17. Debris impinges pink fry. Photo by Jackie Timothy.

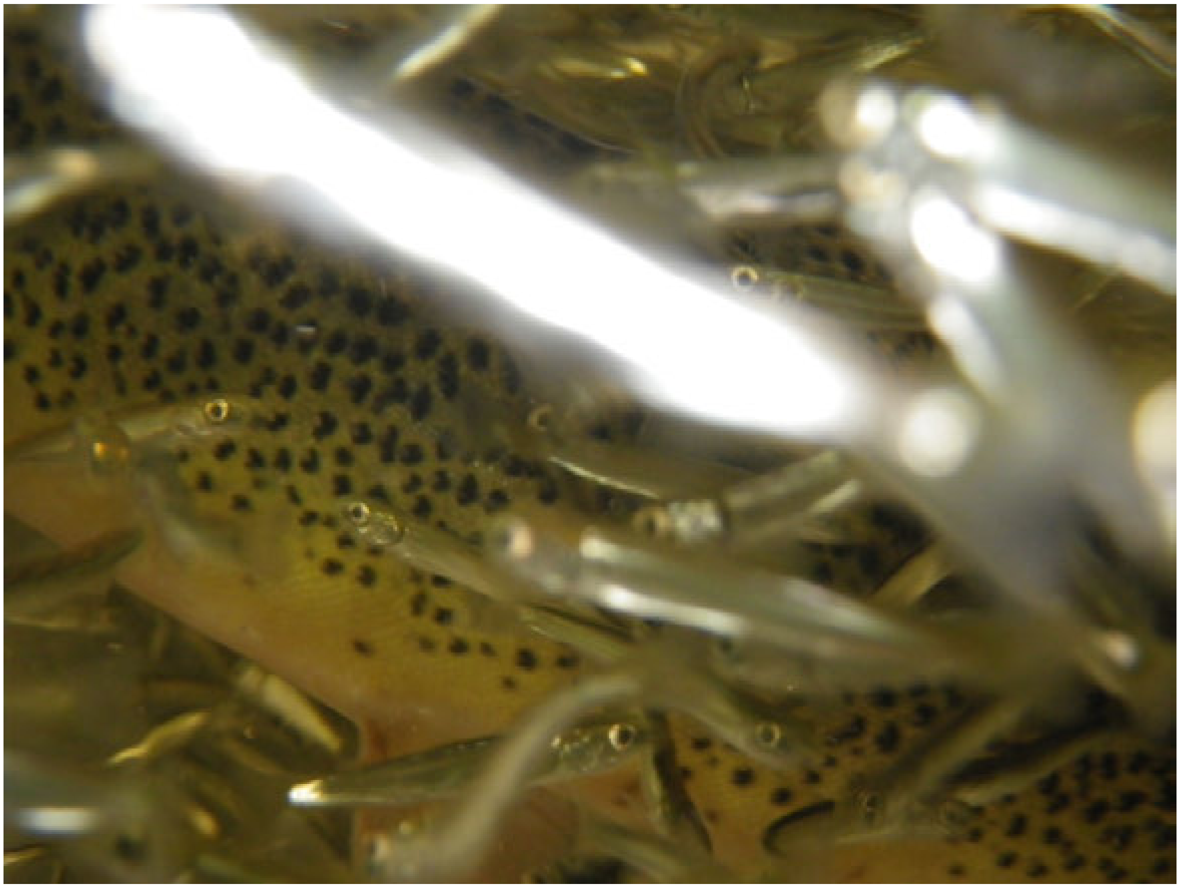


Figure 18. Pink salmon fry share space in a live-trap box with a cutthroat trout. Photo by Gordon Willson-Naranjo.

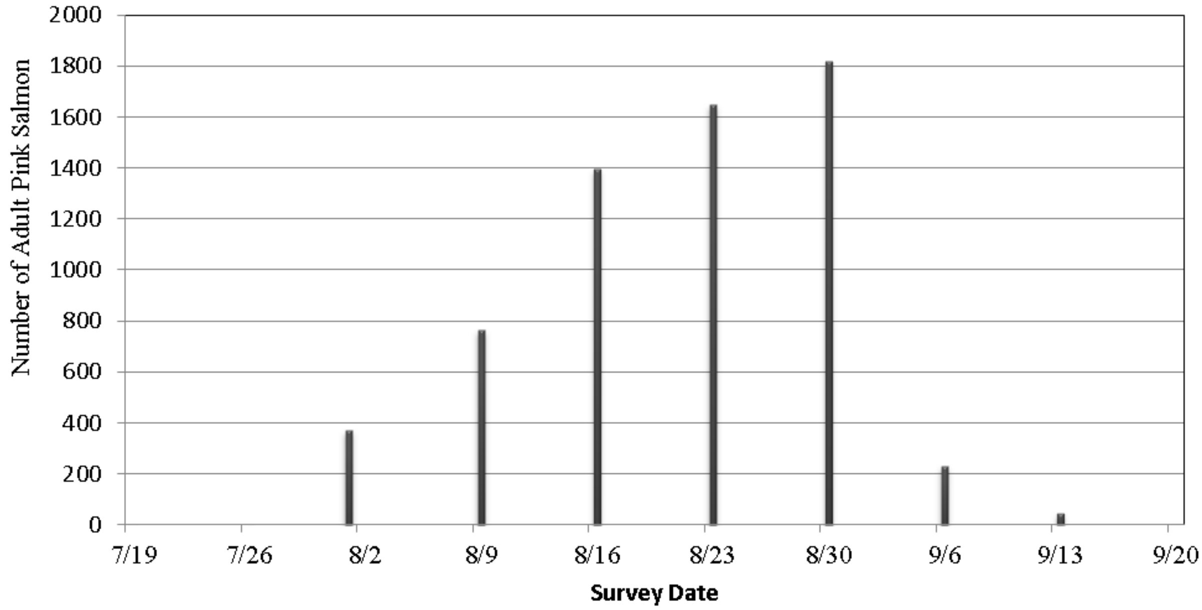


Figure 19. Lower Slate Creek pink salmon counts, July–September 2011.

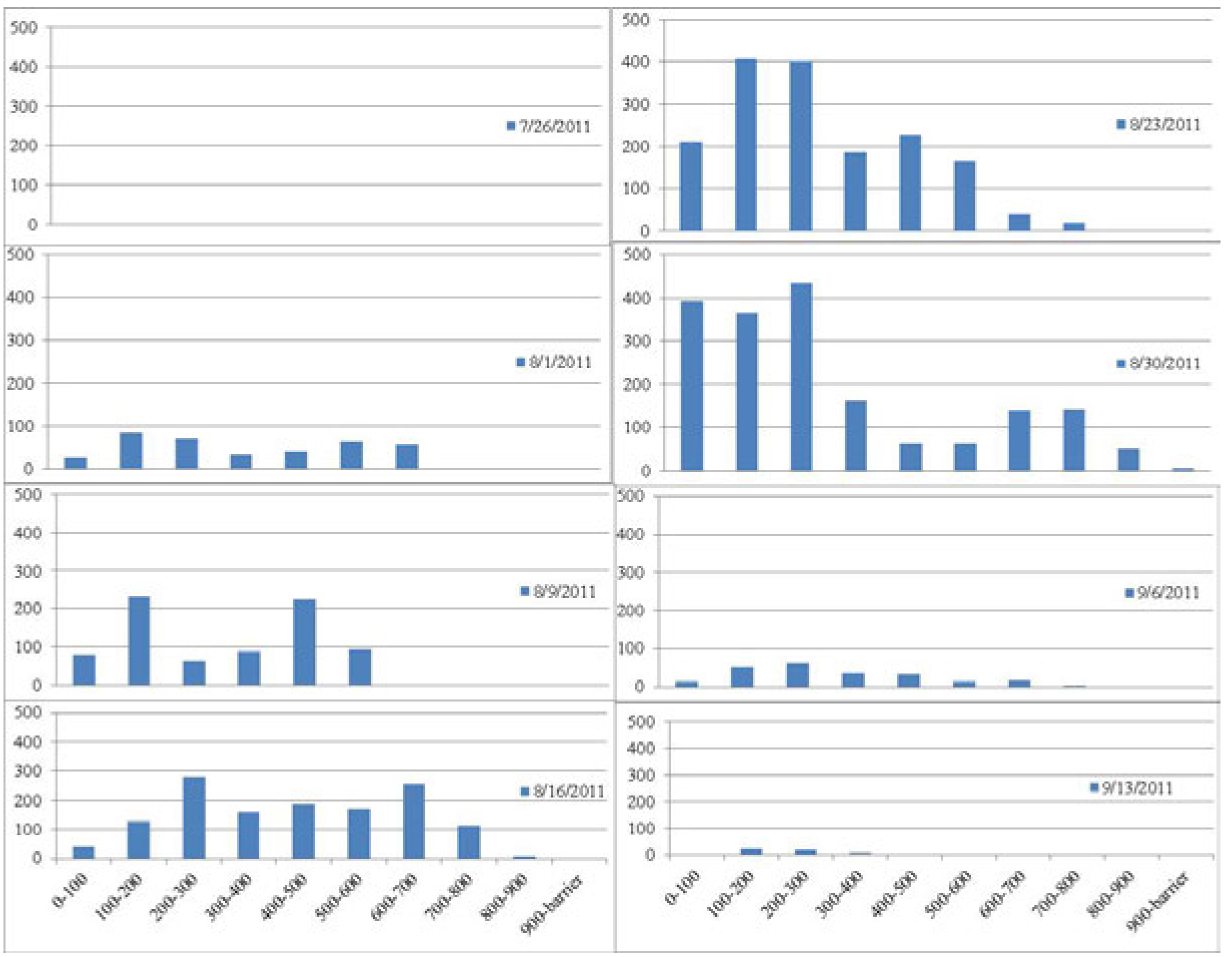


Figure 20. Lower Slate Creek adult pink salmon distribution, July–September 2011.

Spawning Substrate Composition (NPDES I.E.3.c.2.) (APDES 1.5.3.5.1.1)

The 2011 geometric mean particle size for substrate samples taken at Slate Creek on August 17, 2011, is 6.54 mm at Sample Point 1, and 9.33 mm at Sample Point 2 (Figure 21). This is finer than any year sampled since 2005 (Flory 2011).

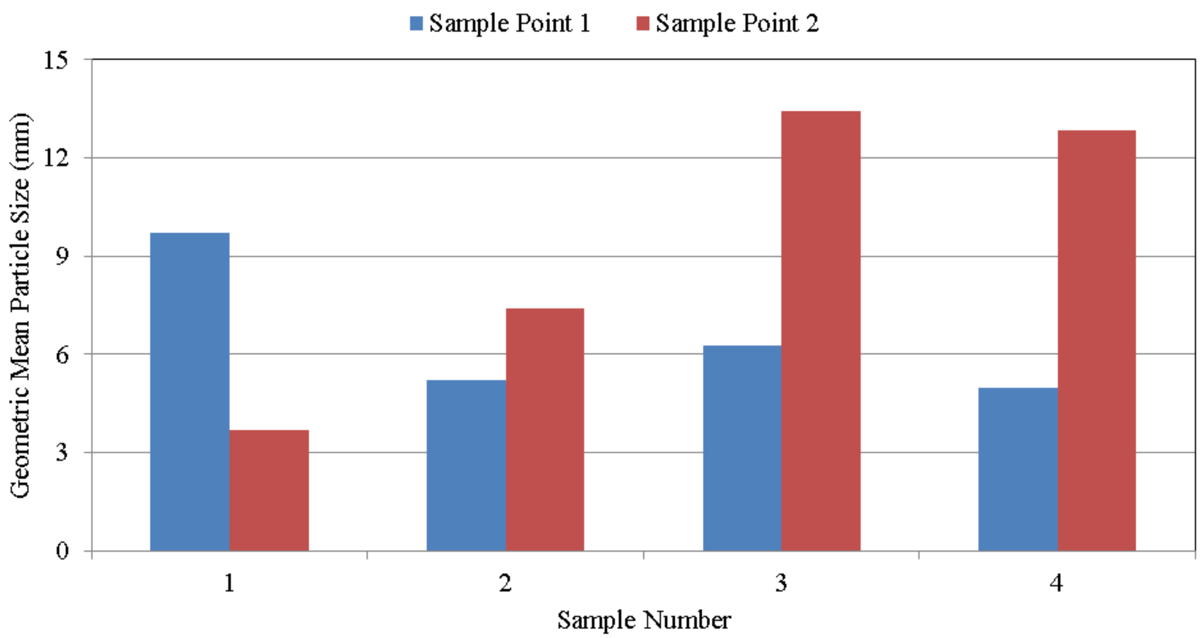


Figure 21. Lower Slate Creek geometric mean particle size.

East Fork Slate Creek

Periphyton Biomass (APDES 1.5.3.5.2.1)

The mean density of chlorophylls *a*, *b*, and *c* in East Fork Slate Creek samples taken on July 28, 2011 is 8.84 mg/m^2 (*a*), 1.56 mg/m^2 (*b*), and 0.24 mg/m^2 (*c*). See Appendix L for periphyton biomass (Figure L1) and chlorophyll *a*, *b*, and *c* proportions (Figure L2).

Benthic Macroinvertebrates (APDES 1.5.3.2.1)

We identified 27 taxa (Figure L3) in our East Fork Slate Creek samples, with about 4,679 aquatic macroinvertebrates per m^2 (Figure L4), of which 18.5% are EPT taxa (Figure L5). The Shannon Diversity score is 0.64 and Evenness score is 0.52 (Table L3). Of note, the East Fork Slate Creek samples included pea clams of the genus *Psidium* as 54.6% of the sample (Table L4). We will continue to investigate the abundance of this animal at this location.

In East Fork Slate Creek, the sampling site is downstream from the wastewater treatment plant outfall with most stream flow coming from the Upper Slate Lake diversion pipeline. The diversion pipeline was constructed in late 2006, removed in fall 2008 and rebuilt in fall 2009 which may have affected samples in 2007, 2008 and 2010 since all water to East Fork Slate Creek was delivered via the pipeline. Tailings placement began in the TTF on June 24, 2010. Treated water from the TTF WTP began discharging into East Fork Slate Creek in December 2010.

TTF Diversion Pipe Fish Passage

A diversion dam (Figure 22) and pipeline (Figure 23) routes water around the TTF to reduce water treatment and discharge volumes and provide downstream fish passage for resident Dolly Varden char in Upper Slate Lake. Habitat required Coeur to screen the pipeline intake until we evaluated downstream fish passage.

Figure 22. Diversion dam, pipeline, and TTF. Photo by Jackie Timothy.

Figure 23. Approximate diversion pipeline route. Photo and figure by Gordon Willson-Naranjo

In July 2010, habitat biologists captured 38 Dolly Varden char and 2 threespine stickleback in the plunge pool below the diversion pipeline (Figure 24). Two Dolly Varden char (185 and 240 mm FL) sustained external injuries from traveling the diversion pipeline system during low flow. The rest of the fish migrated unharmed (Kanouse 2010). In 2011, Habitat biologists placed minnow traps in the plunge pool at high flows, captured 23 Dolly Varden char, and weighed and measured them to FL. All fish were all in good condition (Willson-Naranjo 2011). Based on these investigations, safe downstream fish passage is occurring through the pipeline and Habitat no longer requires Coeur Alaska, Inc. to screen the intake. Trip reports of the fish passage investigations are available upon request.

We have not identified overwintering habitat and have not read of other contractors identifying overwintering habitat in East Fork Slate Creek. We will investigate overwintering habitat possibilities in East Fork Slate Creek in 2012. Previous contractors suggest the East Fork Slate Creek population may be dependent on Upper Slate Lake downstream migrants.

Resident Fish Population Status (NPDES I.E.3.b.1) (APDES 1.5.3.3.1)

We conducted habitat surveys in East Fork Slate Creek on August 18, 2011 and sampled resident fish on September 1, 2011. We did not retain 6 Dolly Varden char (80–125 mm) for laboratory analyses of whole body metals concentrations during this survey; rather we trapped and retained 6 fish on September 13.

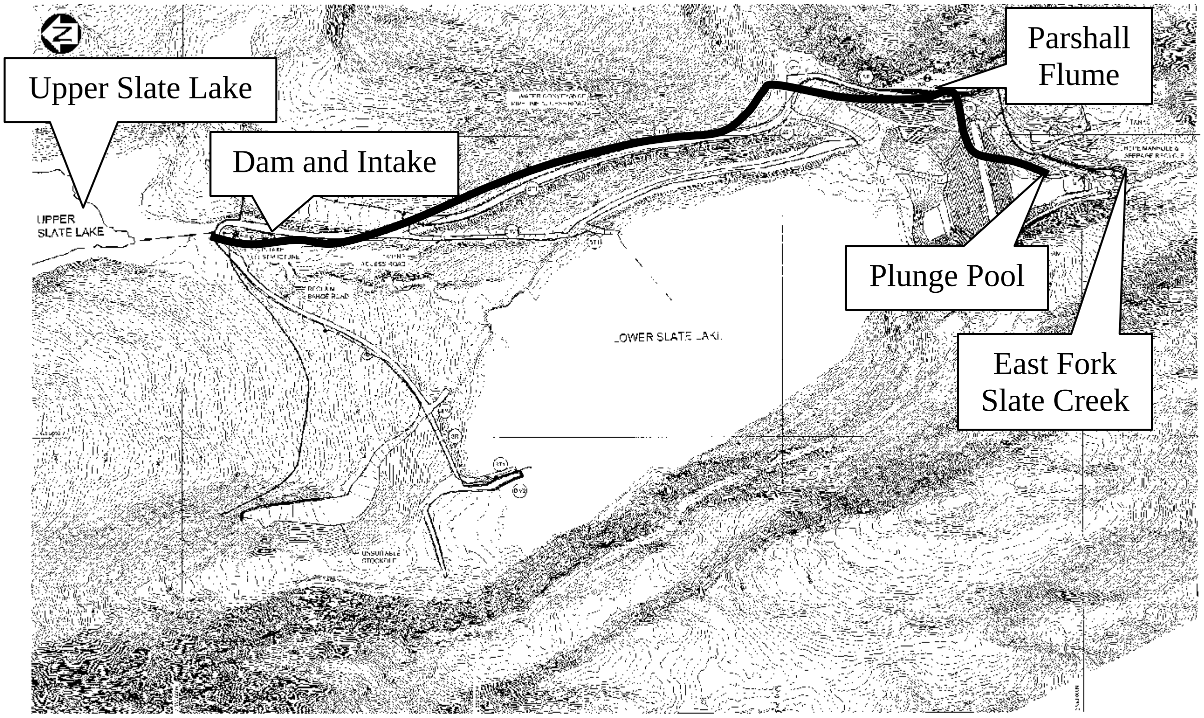


Figure 24. Diversion pipeline system (image courtesy of Coeur Alaska).

The 2011 population estimate for East Fork Slate Creek (44±6 Dolly Varden char) can be found in Appendix L (Figure L6). This number is similar to the previous three years (Flory 2011). Dolly Varden char population estimates by habitat type are presented in Figure L7 and condition factors are presented in Figure L8.

Metals Concentrations in Juvenile Fish (APDES 1.5.3.4.1)

This is the first year we collected Dolly Varden char in East Fork Slate Creek to test for whole body metals concentrations. Though we saved the fish individually as described in the methods section, we incorrectly completed the private laboratory's Chain of Custody form and the laboratory homogenized all 6 fish for East Fork Slate Creek prior to testing. Thus, we only have one data point for 2011.

The fork lengths of the 6 fish tested are 110, 115, 120, 120, 120, and 125 mm. Table 3 shows the metals concentrations of whole body juvenile Dolly Varden char collected from East Fork Slate Creek in 2011. Whole body metals concentrations in juvenile Dolly Varden char tissues in Lower, Middle and Upper Slate Creek, and data from Kline (2001), are presented in Appendix L (Figures L12 and L13).

Table 3. East Fork Slate Creek juvenile Dolly Varden char whole body metals concentrations.

	Ag	Al	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
mg/Kg	0.02	46.30	1.99	1.30	14.60	0.107	1.10	0.04	4.60	133

Sediment Metals Concentrations (NPDES I.E.2.a.) (APDES 1.5.2.1)

East Fork Slate Creek sediment metals concentrations are shown in Figure 25. Metals concentrations at all sample sites are presented in Appendix L (Figure L14).

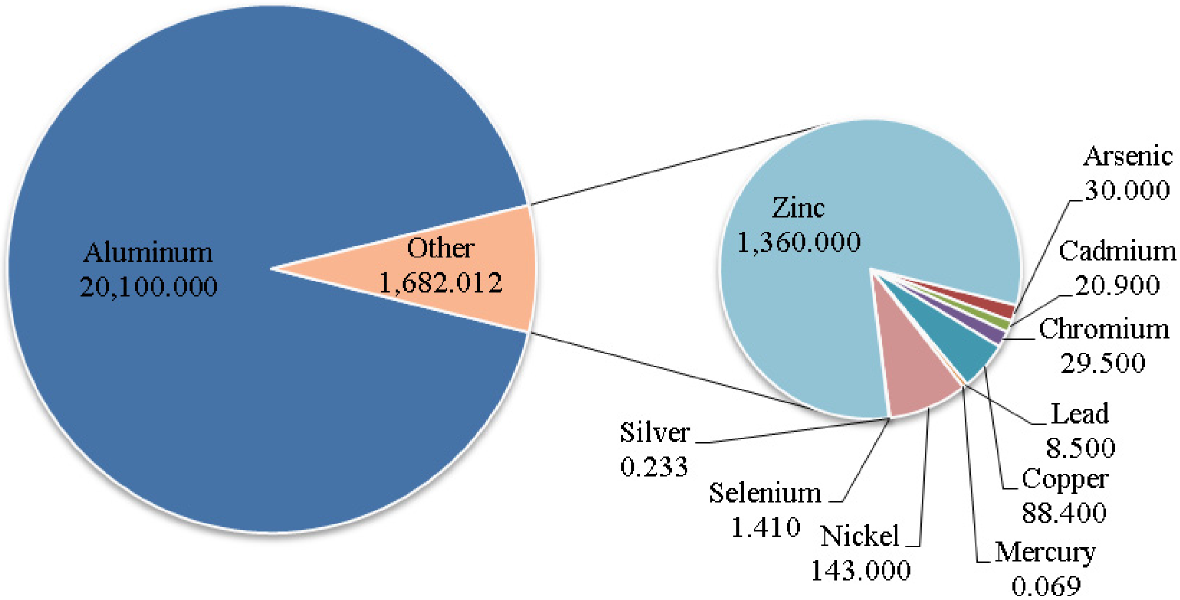


Figure 25. East Fork Slate Creek 2011 sediment metals concentrations (mg/Kg).

Sediment Toxicity (NPDES I.E.2.e) (APDES 1.5.2.3.1)

There is no statistical difference in survival of *Chironomus dilutus* or *Hyalella azteca* on the East Fork Slate Creek sediment sample compared to the control. Growth of both organisms is significantly less than growth on the control. 2011 sediment toxicity survival and growth results for *Chironomus dilutus* and *Hyalella azteca* are found in Appendix L, Tables L1 and L2.

Aquatic Vegetation Surveys (NPDES I.E.3.d)

Tailing discharge to the TTF began June 24, 2010.

Coeur Environmental staff noticed an algal bloom in the TTF at the beginning of July, 2011. During this time, habitat biologists observed an unusual stratified green and brown coloration on the surface waters of the estuary while kayaking across the cove to the mouth of Slate Creek. A commercial fisheries biologist took a picture of Slate Cove from the air (Figure 26). Habitat biologists noted filamentous green algae growing in the mouth of Slate Creek (Figure 27) and a smell in lower Slate Creek reminiscent of the mill. We photographed the algal bloom in the TTF (Figure 28). We sampled periphyton in East Fork Slate Creek below the TTF wastewater treatment plant effluent discharge site at the end of July and noticed unusually thick algal samples clogging our vacuum filters.

Coeur sampled to detect potassium (Figure 29), sulfur (Figure 30), nitrogen (Figure 31), phosphorus (Figure 32), total organic carbon (Figure 33), and chlorophyll *a* (Figure 34) at four locations: 1) upstream of the TTF (control site); 2) in the TTF; 3) the TTF water treatment plant effluent, and; 4) downstream of effluent discharge into East Fork Slate Creek.

Figure 26. Slate Cove algal bloom. Photo by Randy Bachman, Division of Commercial Fisheries.

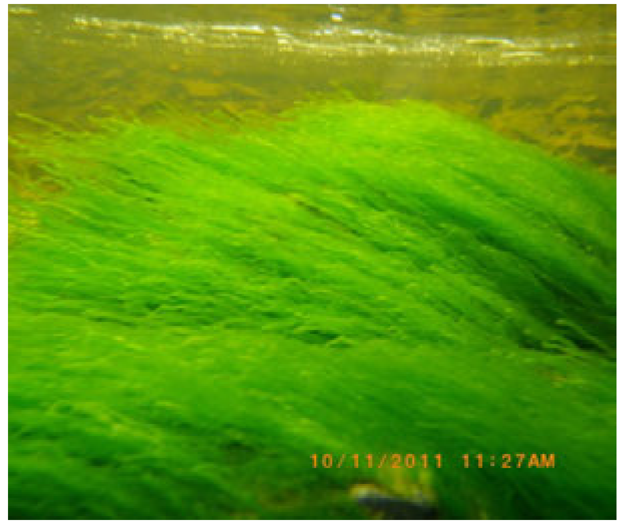


Figure 27. Vegetation in the mouth of Slate Creek. Photo by Gordon Willson-Naranjo.

Figure 28. TTF algal bloom in late July. Photo by Jackie Timothy.

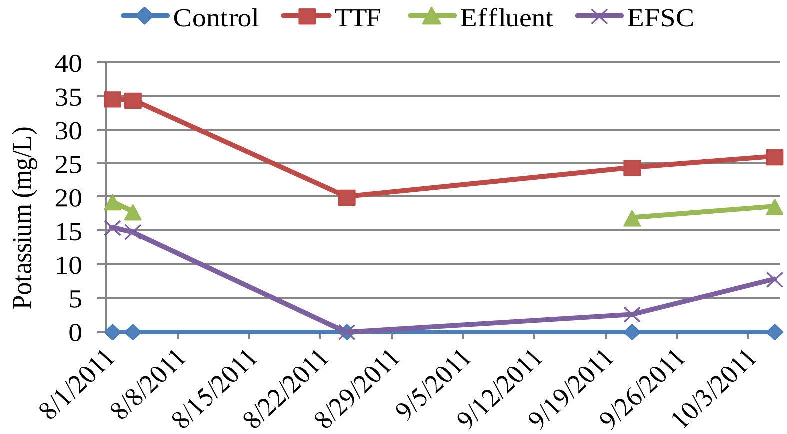


Figure 29. Potassium (mg/L) at four stations, 8/1/11 through 10/31/11.

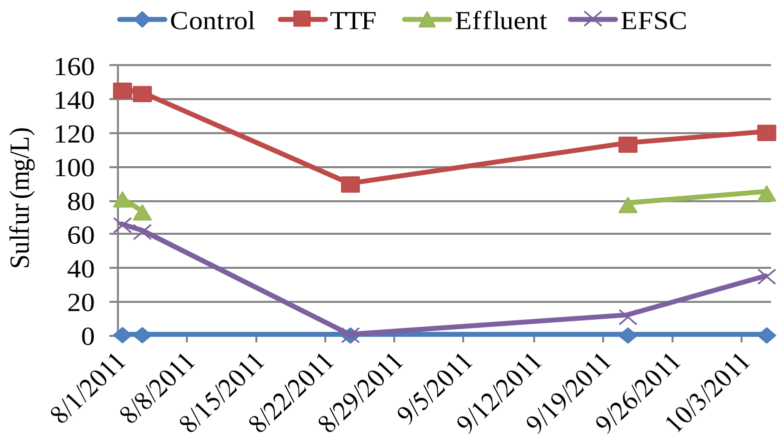


Figure 30. Sulfur (mg/L) at four stations, 8/1/11 through 10/31/11.

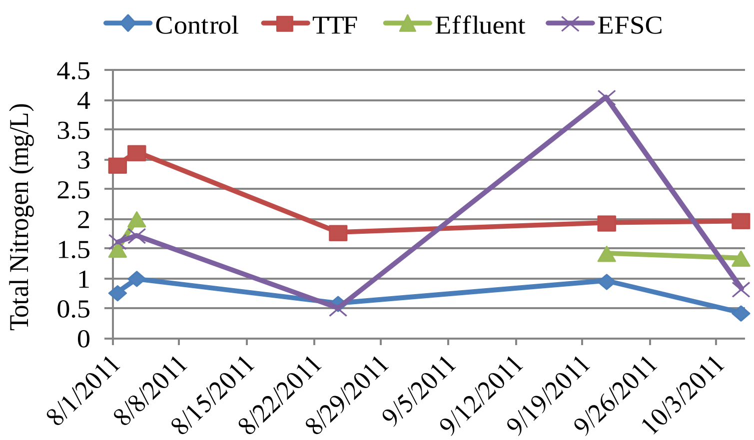


Figure 31. Nitrogen (mg/L) at four stations, 8/1/11 through 10/31/11.

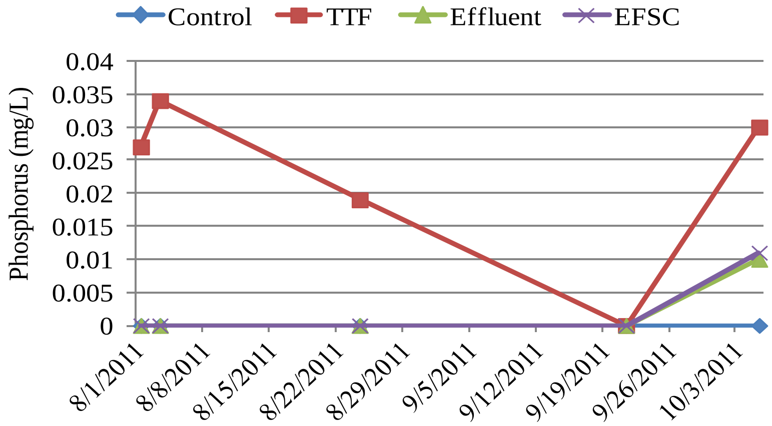


Figure 32. Phosphorus (mg/L) at four stations, 8/1/11 through 10/31/11.

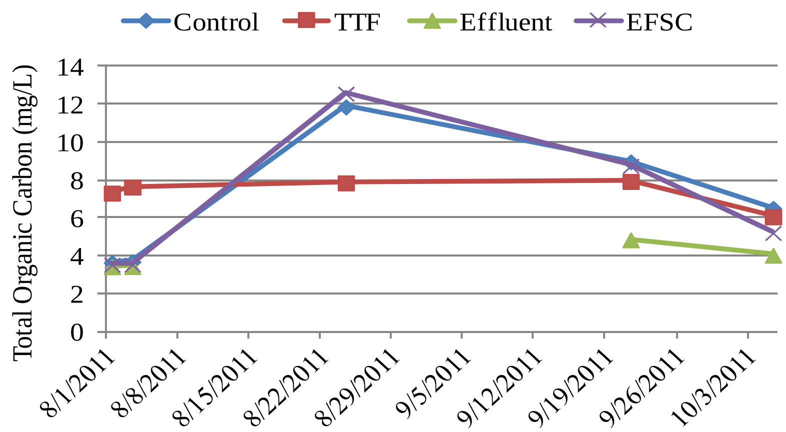


Figure 33. Total Organic Carbon (mg/L) at four stations, 8/1/11 through 10/31/11.

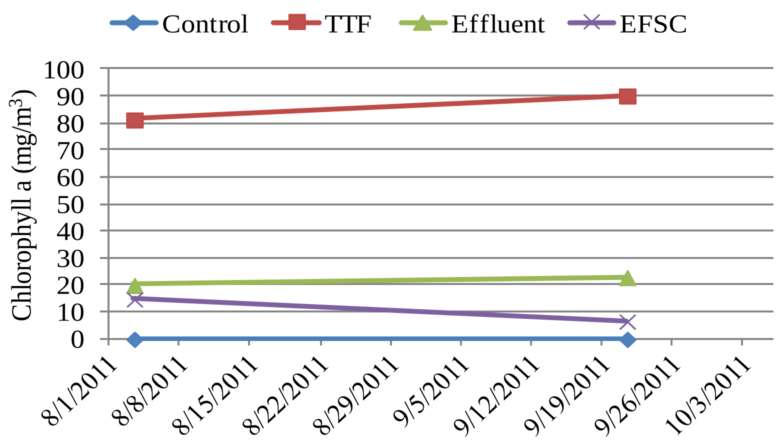


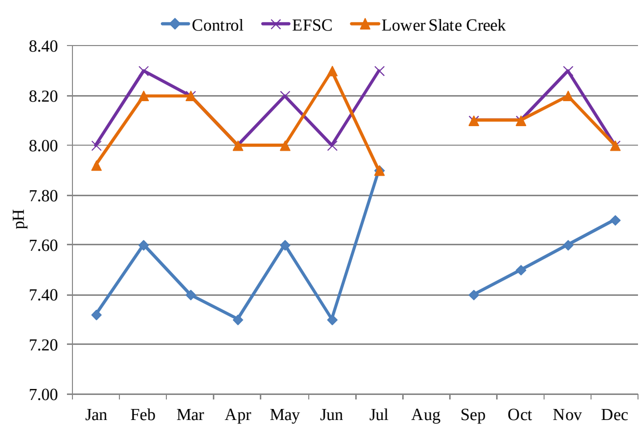
Figure 34. Chlorophyll *a* (mg/m^3) at four stations, 8/1/11 through 10/31/11.

Morris suggests the following regarding the nitrogen, phosphorus, potassium and sulfur in the TTF (W. Morris, Regional Supervisor, ADF&G Division of Habitat, Fairbanks, personal communication, August 19, 2011).

- Potassium (Figure 29) and sulfur (Figure 30) are present in potassium amyl xanthate ($C5H11OCSSK$) and are high downstream. As the potassium level increases, it can disrupt the sodium/potassium ratio, potentially becoming toxic to algae, so is not the source of the bloom. Increased sulfur can make the water more acidic (Figure 35).
- Additions of nitrogen (Figure 31) can enhance blooms if so much phosphorus is added that all of the naturally occurring nitrogen is used. There are cases where nitrogen is the limiting nutrient in aquatic systems; however, they have been infrequently studied.
- Phosphorous (Figure 32) concentrations measured in the TTF are consistent with those typically found in eutrophic (old, warm water, high productivity) lakes despite that the TTF is situated in a formerly oligotrophic (cold water, low productivity) lake. This finding alone suggests strongly that some source of phosphorous is the causal link to the algal bloom observed in the TTF during 2011.
- Normal phosphorus at all sites sampled except the TTF suggests that the downstream blooms are a function of organism transfer from the TTF through the water treatment facility rather than a chemical or nutrient transfer.

We collected periphyton samples in East Fork Slate Creek at the end of July as mentioned above, and again in October. There are no statistical differences in chlorophyll *a*, *b*, or *c* proportions[v] among the July and October 2011 East Fork Slate Creek samples (Figure 36). There is an increase in periphyton biomass (Figure 37).

Coeur took samples of algae for taxaomic identification. The algae *Synedra* and *Ankistrodesmus* are clogging the water treatment facility filters, which contributes to a TTF water level rise. A Coeur contractor conducted algaecide trials on TTF algae. Phycomycin, a sodium carbonate peroxyhydrate, is effective at controlling the growth of these species. Therefore, Coeur will watch to see how the lake is affected by cold winter temperatures, and see what spring brings in terms of temperature and precipitation. If conditions support another naturally unmanageable bloom, Coeur will request an authorization from DEC to treat the TTF with the algaecide.



[v] East Fork Slate Creek July and October sample differences: chlorophyll *a*, $p = 0.4114$; chlorophyll *b*, $p = 0.1475$; chlorophyll *c*, $p = 0.0735$.

Figure 35. Monthly receiving water quality monitoring pH data near the TTF during 2011.

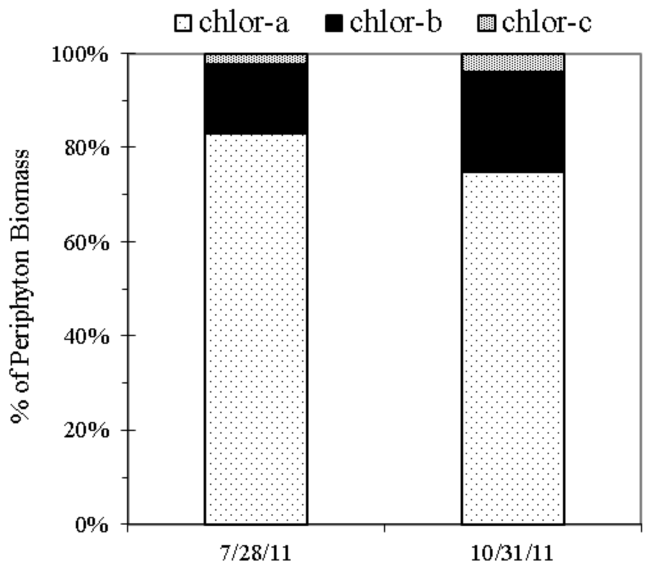


Figure 36. July and October East Fork Slate Creek chlorophyll *a*, *b*, and *c* proportions.

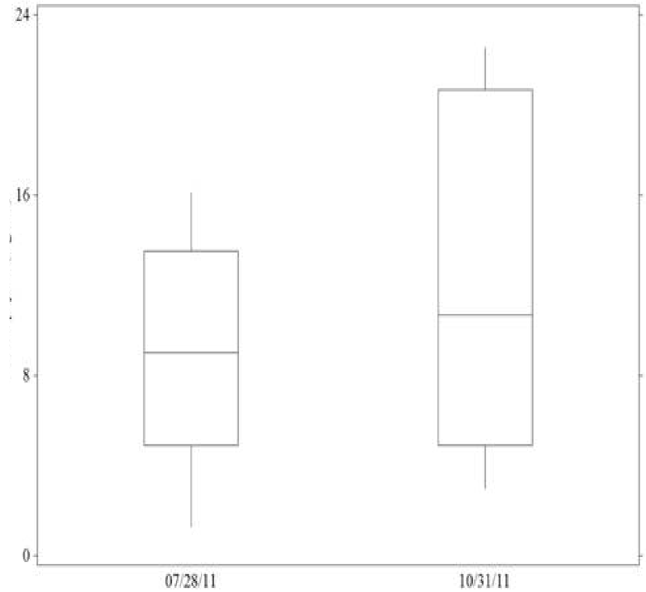


Figure 37. July and October East Fork Slate Creek periphyton biomass.

West Fork Slate Creek

Periphyton Biomass (APDES 1.5.3.5.2.1)

The mean density of chlorophylls *a*, *b*, and *c* in West Fork Slate Creek samples taken on July 29, 2011, is 3.92 mg/m^2 (*a*), 0.00 mg/m^2 (*b*) and 0.27 mg/m^2 (*c*). See Appendix L for periphyton biomass (Figure L1) and chlorophyll *a*, *b*, and *c* proportions (Figure L2).

Benthic Macroinvertebrates (APDES 1.5.3.2.1)

We identified 21 taxa (Figure L3) in our West Fork Slate Creek samples, with about 502 aquatic macroinvertebrates per m^2 (Figure L4) of which 80.3% are EPT taxa; Ephemeroptera dominated the EPT taxa (64.6%; Figure L5). The Shannon Diversity score is 0.63 and Evenness score is 0.74 (Table L3). Though West Fork Slate Creek has the highest proportion of EPT in the Slate Creek drainage, it has the lowest invertebrate density and number of taxa.

Upper Slate Creek

Periphyton Biomass (APDES 1.5.3.5.2.1)

The mean density of chlorophylls *a*, *b* and *c* in Upper Slate Creek samples taken on July 29, 2011 is 0.78 mg/m^2 (*a*), 0.00 mg/m^2 (*b*), and 0.05 mg/m^2 (*c*),. See Appendix L for periphyton biomass (Figure L1) and chlorophyll *a*, *b*, and *c* proportions (Figure L2).

Benthic Macroinvertebrates (APDES 1.5.3.2.1)

We observed 33 taxa (Figure L3) in our Upper Slate Creek samples, with about 2,523 aquatic macroinvertebrates per m^2 (Figure L4). 62.9% are EPT taxa (Figure L5) about 55% of those are Ephemeroptera and Plecoptera alone (Figure L5). The Shannon Diversity score is 0.97 and Evenness score is 0.74 (Table L3).

Resident Fish Population Status (APDES 1.5.3.3.1)

We conducted habitat surveys in Upper Slate Creek on August 10, 2011 and sampled resident fish on August 13, 2011. We retained eight Dolly Varden char (60–125 mm) for laboratory analyses of whole body metals concentrations; four of the fish were undersized, so we combined two for one composite sample, twice.

The 2011 Dolly Varden char population estimate for Upper Slate Creek is 124±12 fish (Figure L6). The 2011 population estimate is the third highest observed since 2005 (Flory 2011). Dolly Varden char population estimates by habitat type are presented in Figure L7 and condition factors are presented in Figure L8.

Metals Concentrations in Juvenile Fish (APDES 1.5.3.4.1)

This is the first year we collected Dolly Varden char in Upper Slate Creek to test for whole body metals concentrations. Though we saved the fish individually as described in the methods section, we incorrectly completed the private laboratory's Chain of Custody form and the laboratory homogenized all 6 fish for Upper Slate Creek prior to testing. Thus, we only have one data point for 2011.

The fork lengths of the eight fish tested are 55, 60, 65, 65, 85, 109, 124 and 125 mm. Table 4 shows the metals concentrations of whole body juvenile Dolly Varden char collected from Upper Slate Creek in 2011. Whole body metals concentrations in juvenile Dolly Varden char tissues in Lower, Middle and Upper Slate Creek, and data from Kline (2001), are presented Appendix L Figures L13 and L14.

Table 4. Upper Slate Creek juvenile Dolly Varden char whole body metals concentrations.

	Ag	Al	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
mg/Kg	0.02	1630	0.14	13.50	11.30	0.11	5.50	0.20	4.40	115

Sediment Metals Concentrations (NPDES I.E.2.a.) (APDES 1.5.2.1)

Upper Slate Creek sediment metals concentrations are shown in Figure 38. Metals concentrations at all sample sites are presented in Appendix L, Figures L12 and L13.

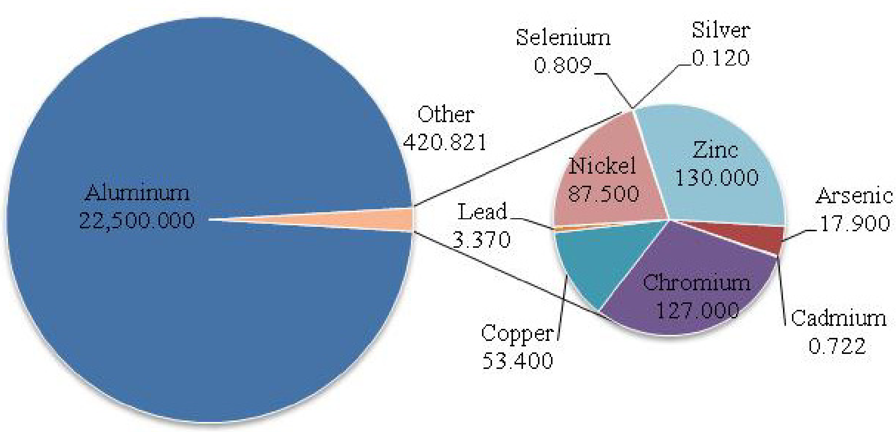


Figure 38. Upper Slate Creek 2011 sediment metals concentrations (mg/Kg).

Slate Creek Drainage Summary

Periphyton

We sampled Slate Creek periphyton on July 28 and 29. It rained while we were on site and flows were higher than they had been the previous three weeks.

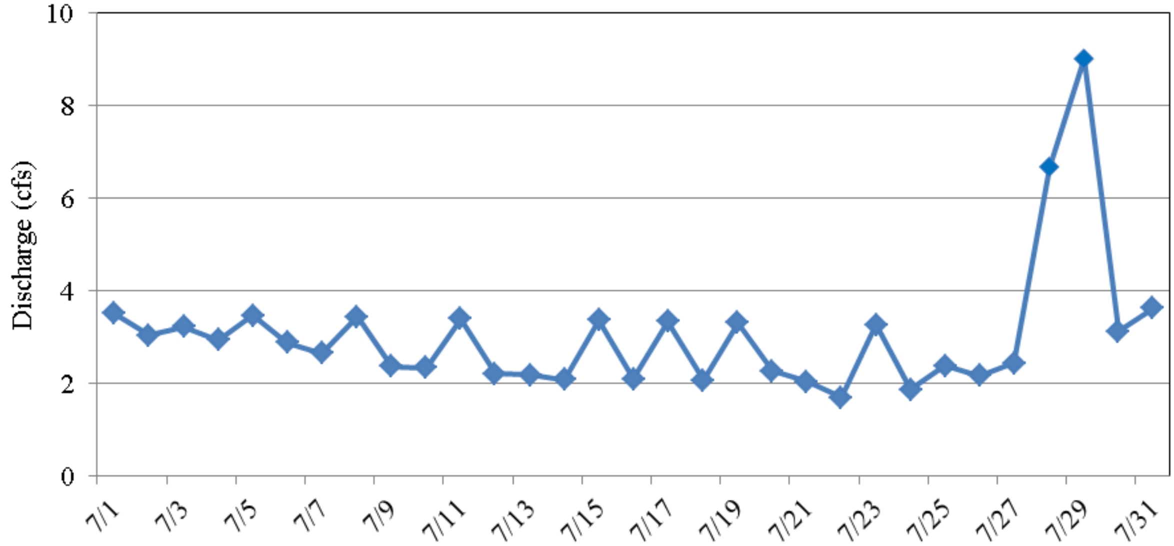


Figure 39. East Fork Slate Creek mean daily discharge July 2011.

The mean rank of chlorophyll *a* densities for the East Fork and West Fork samples are significantly greater ($\alpha \leq 0.05$) than the mean rank of densities for the Upper Slate samples. The mean rank of chlorophyll *b* densities for the East Fork and Lower Slate samples are significantly greater than the mean proportions of Upper Slate and West Fork samples. The mean rank of chlorophyll *c* densities for the Upper Slate and West Fork samples are significantly different. See Appendix L, Figures L1 and L2.

These differences are not surprising as West Fork and Upper Slate Creeks are headwater streams with dense cover and East Fork and Lower Slate Creeks are downstream of lakes. It will be valuable in future studies to compare within sample sites over time to detect any changes.

Benthic Macroinvertebrates

Some 2011 benthic macroinvertebrate results are suprising, as we describe in each Slate Creek section, which is why we use all assemblages in combination to assess stream health. In addition to water quality, the physical characteristics of a stream can influence diversity and evenness in macroinvertebrate communities. It will be valuable in future studies to look at change within sample sites over time.

Johnson Creek

Lower Johnson Creek

Resident Fish Population Status (NPDES I.E.3.b.1)

We conducted habitat surveys in Lower Johnson Creek on July 12, 2011 (Figure 4) and sampled resident fish on July 15, 2011. The 2011 Dolly Varden char population estimate is 193±22, the second highest estimate since 2005 (Flory 2011). Lower, Middle and Upper Johnson Creek population estimates are shown in Appendix L, Figure L16. Dolly Varden char population estimates by habitat type and condition factors are shown in Figures L17 and L18.

The 2011 cutthroat trout population estimate for Lower Johnson Creek is 12 fish. The number of fish captured is too low to estimate the 95% confidence interval. The cutthroat trout population estimate, population estimate by habitat type and condition factor is shown in Appendix L, Figures L9, L10, and L11.

Sediment Metals Concentrations (NPDES I.E.2.a.) (APDES 1.5.2.1)

Upper Slate Creek sediment metals concentrations are shown in Figure 40. Metals concentrations at all sample sites are presented in Appendix L, Figure L14.

Sediment Toxicity (NPDES I.E.2.e) (APDES 1.5.2.3.1)

Survival and growth of both *Chironomus dilutus* or *Hyalella azteca* on the Johnson Creek sediment sample are significantly less compared to the control (Appendix L, Tables L1 and L2).

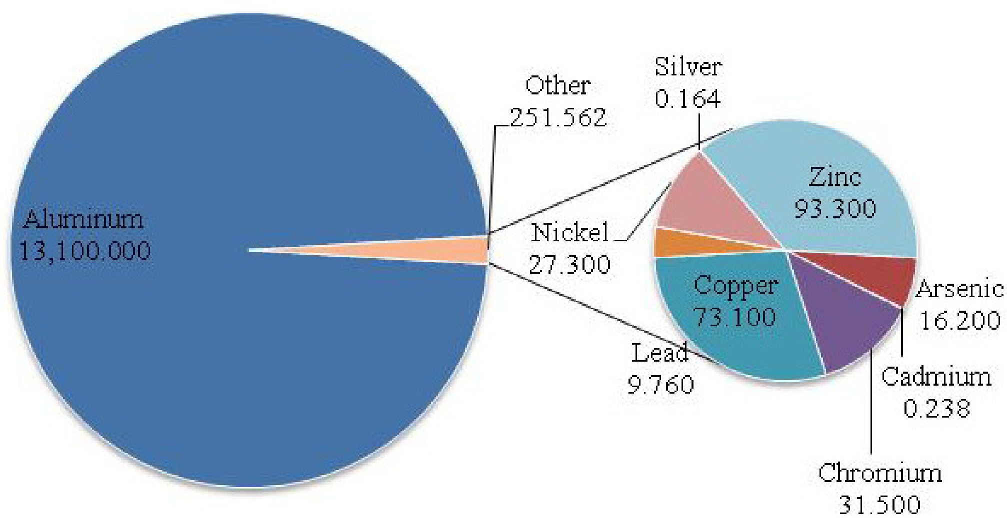


Figure 40. Lower Johnson Creek 2011 sediment metals concentrations (mg/Kg).

Out-migrating Pink Salmon Fry (NPDES I.E.3.c.1.b.)

We installed the fyke nets and a live-trap box on April 14, 2011(Figure 41). We tended the nets daily to maintain them and to identify, count and release the fry, and fished in this manner through May 21, 2011. During that time, we captured 121,328 pink fry in Johnson Creek (Figure 42), estimating a total outmigration of 820,746 (Figure 43). We experienced 1394 mortalities; about 1.1% of the sample. We also captured 73 Dolly Varden char, 2 cutthroat trout, 30 sculpin, 53 juvenile coho salmon, and 3394 juvenile chum salmon.

In 2010, Flory (2011) estimated adult pink salmon escapement in Lower Johnson Creek at 2,114 fish, of which about 1,057 fish would have been female. Using the 2011 pink fry outmigration count (820,746), we estimate egg-to-fry survival in Johnson Creek at 47.1%, greater than all previous years documented by Flory (2011).

Figure 41. Johnson Creek emigrating fry live-trap box. Photo by Jackie Timothy.

Figure 42. Pink fry; one marked with Bismark Brown. Photo by Kate Kanouse.

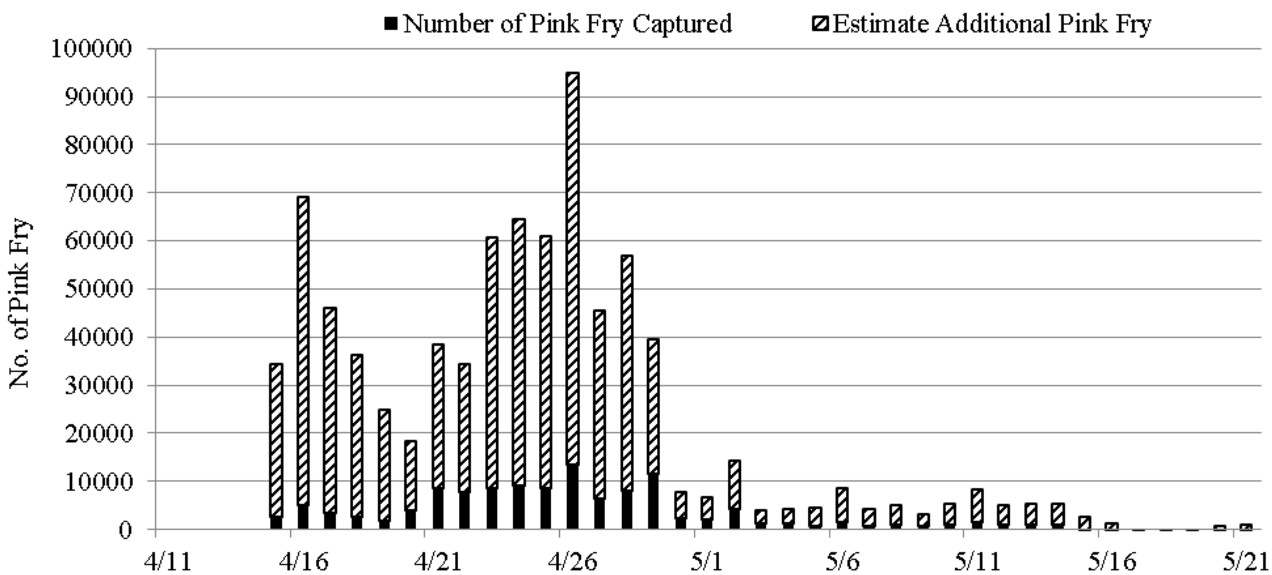


Figure 43. Lower Johnson Creek daily pink fry outmigration estimates, April–May 2011.

Returning Adult Pink Salmon (NPDES I.E.3.c.1.a.)

We surveyed Lower Johnson Creek for adult pink and chum salmon beginning July 18 and ending on September 19 (Figure 44). We observed pink salmon on all surveys and we estimate escapement at 21,218 fish. The distribution of pink salmon in Lower Johnson Creek is graphically presented in Figure 45. We observed chum salmon on July 18, July 26, August 8 and August 22 and estimate escapement at 81 fish. We also surveyed October 11 through November 15 for coho salmon, and observed live fish on October 19, October 24 and November 7. We estimate coho salmon escapement at 33 fish.

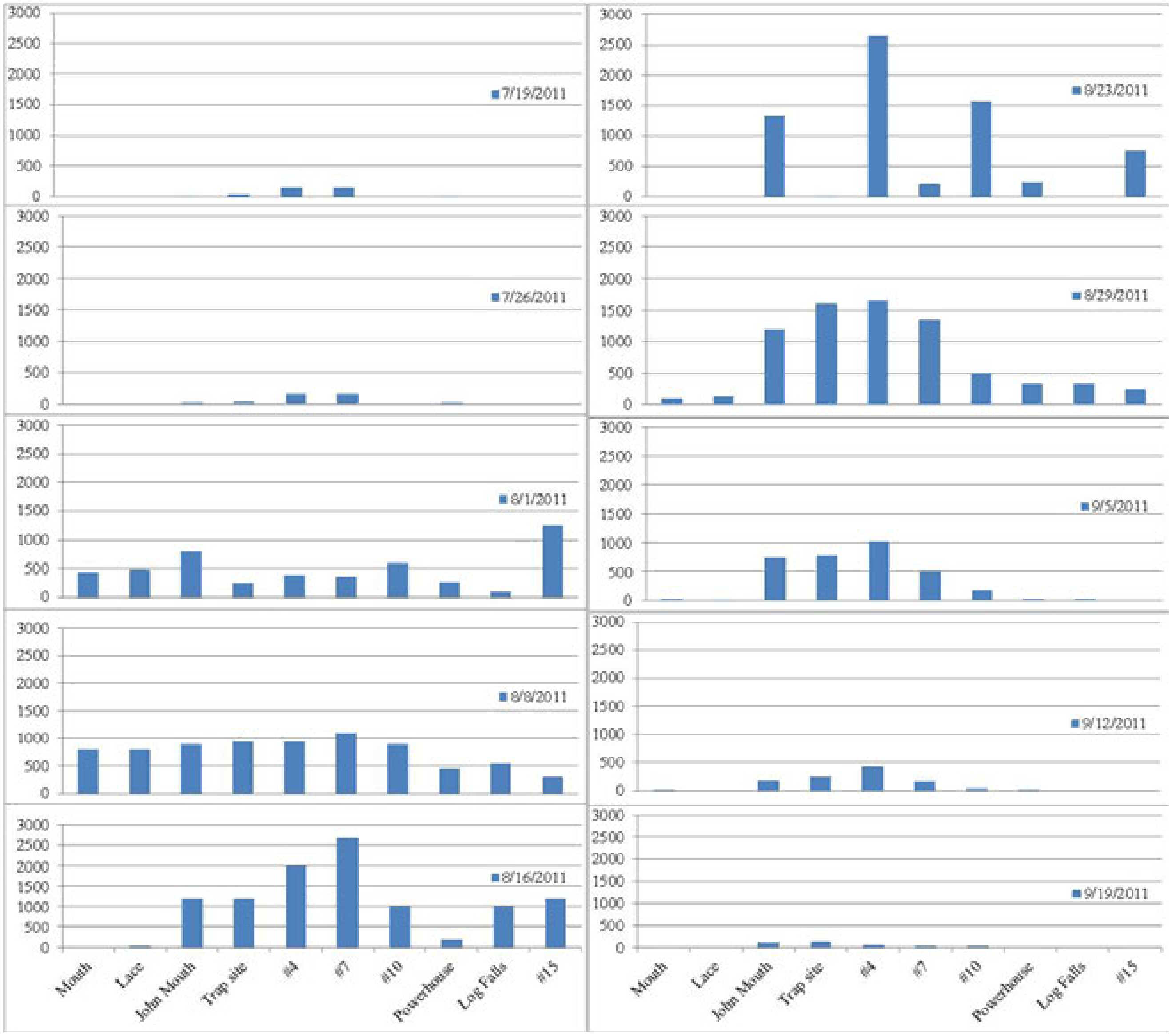


Figure 44. Lower Johnson Creek adult pink salmon distribution, July–September 2011.

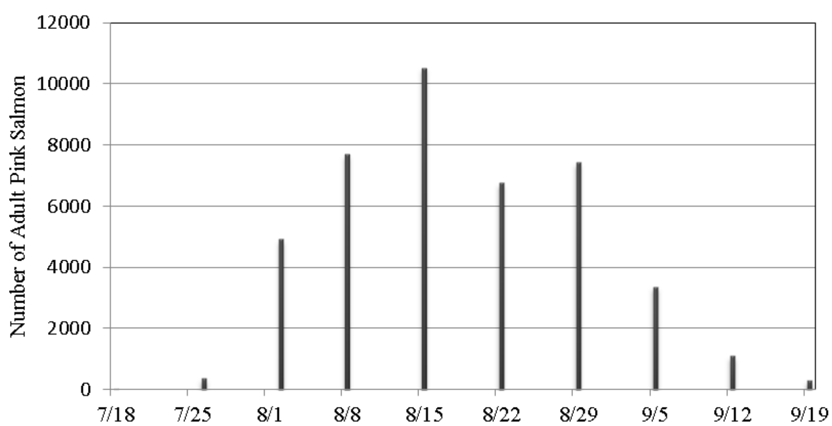


Figure 45. Lower Johnson Creek pink salmon counts, July–September 2011.

Spawning Substrate Composition (NPDES I.E.3.c.2.) (APDES 1.5.3.5.1.1)

The 2011 geometric mean particle size for substrate samples taken in Sample Point 1 and Sample Point 2 of Lower Johnson Creek on August 15, 2011 is 5.21 mm at Sample Point 1 and 6.34 mm at Sample Point 2. Figure 46 illustrates the geometric mean particle size calculated for each sample taken in each reach.

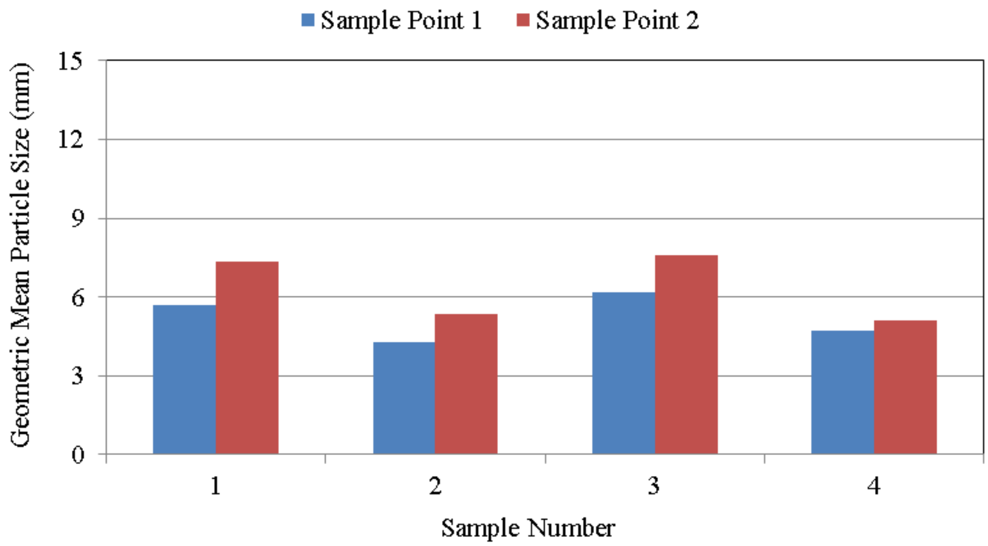


Figure 46. Lower Johnson Creek geometric mean particle sizes.

Middle Johnson Creek

Resident Fish Population Status (NPDES I.E.3.b.1)

We conducted habitat surveys in Middle Johnson Creek on August 19, 2011 and sampled resident fish on September 19, 2011. We did not use a block net on the lower end of the Middle Johnson Creek reach due to high flows. Instead, we set four baited minnow traps across the lower end to capture possible migrants. Fish captured in the block traps are not included in the population estimate.

The Dolly Varden char population estimate in Middle Johnson Creek for 2011 is 332±36, the highest recorded in the 7-year sampling period (Appendix L, Figure L16). Dolly Varden char population estimates by habitat type and condition factor are shown in Figures L17 and L18.

Upper Johnson Creek

Benthic Macroinvertebrates (NPDES I. E. 3. a. 1) (APDES 1.5.3.2.1)

We identified 24 taxa in our Upper Johnson Creek samples, with about 3,735 aquatic macroinvertebrates per m^2, of which 54.5% are EPT taxa (Figure 47). The Shannon Diversity score is 0.76 and Evenness score is 0.64 (Table 5). Taxa proportions are in Table 6. We do not have baseline data in this waterbody.

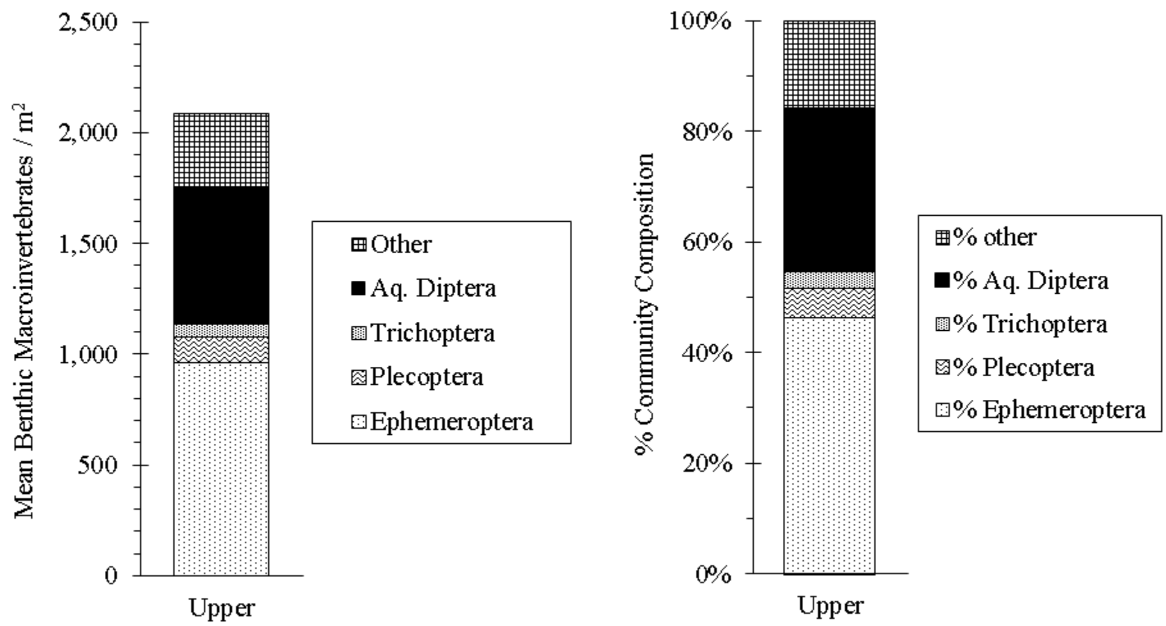


Figure 47. Upper Johnson Creek macroinvertebrate density and community composition.

Table 5. Upper Johnson Creek Shannon Diversity and Evenness Indices.

Johnson Creek	Shannon Diversity (H)	Evenness (E)
Upper Johnson	0.76	0.64

Table 6. Upper Johnson Creek taxa proportions.

Taxon	Upper Johnson
Ephemeroptera	46.2%
Plecoptera	5.5%
Trichoptera	2.8%
Aquatic Diptera	28.6%
Acari	0.4%
Oligochaeta	1.3%
Ostracoda	14.0%
Amphipoda	0.0%
Bivalvia	0.0%

Resident Fish Population Status (NPDES I.E.3.b.1)

We conducted habitat surveys in Upper Johnson Creek on August 19, 2011 and sampled resident fish on August 31, 2011.

The Dolly Varden char population estimate in Upper Johnson Creek for 2011 is 58±32 (Appendix L, Figure L16), similar to the previous six years except in 2010 (171±28) (Flory 2011). Dolly Varden char population estimates by habitat type and condition factor are shown in Figures L17 and L18.

SHERMAN CREEK

Lower Sherman Creek

Periphyton Biomass (APDES 1.5.3.5.2.1)

The mean density of chlorophylls *a*, *b*, and *c* in samples taken from sample site 1 in Sherman Creek on July 28, 2011 is 7.60 mg/m^2 (*a*), 0.69 mg/m^2 (*b*) and 0.49 mg/m^2 (*c*). The mean density of chlorophylls *a*, *b*, and *c* in samples taken from sample site 2 the same day is 5.61 mg/m^2 (*a*), 0.02 mg/m^2(*b*), and 0.32 mg/m^2 (*c*). There are no statistical differences between the mean rank of chlorophylls *a*, *b*, or *c* densities among site 1 and site 2 samples. Periphyton biomass is shown in Figure 48 and chlorophyll *a*, *b*, and *c* proportions are shown in Figure 49.

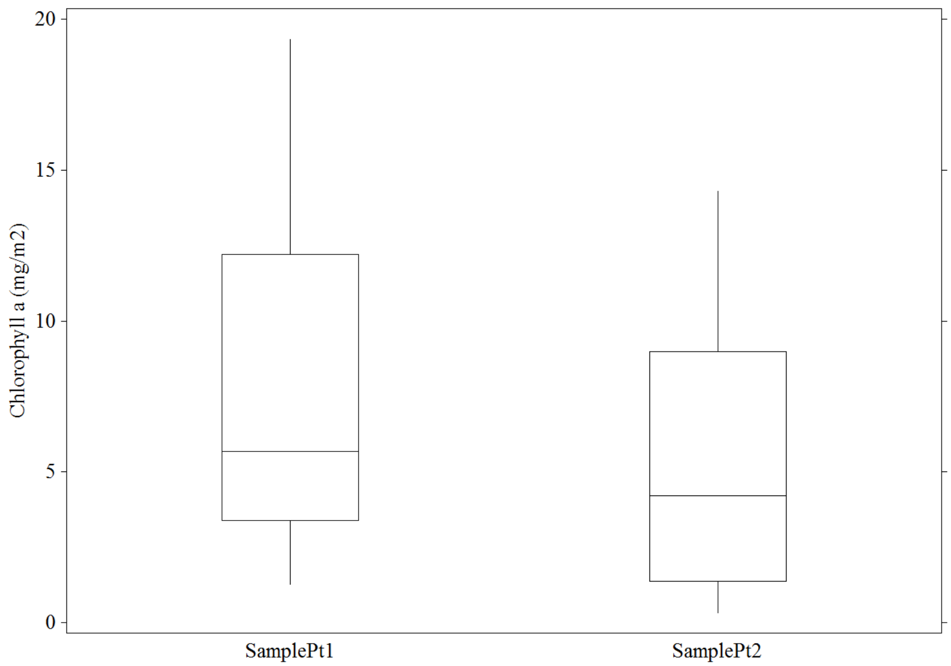


Figure 48. Sherman Creek drainage periphyton biomass.

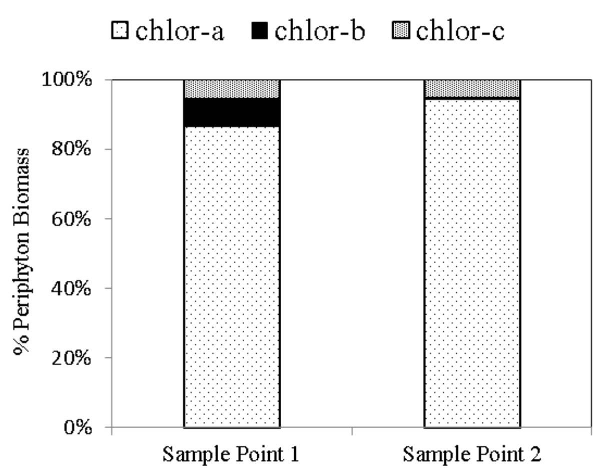


Figure 49. Sherman Creek drainage chlorophylls *a*, *b*, and *c* proportions.

Benthic Macroinvertebrates (NPDES I. E. 3. a. 1.) (APDES 1.5.3.2.1)

Sherman Creek Sample Site 1: We identified 26 taxa in our Sherman Creek site 1 samples (Figure 50) with about 1,118 aquatic macroinvertebrates per m^2, of which 32.1% are EPT taxa (Table 7). The Shannon Diversity score is 0.67 and Evenness score is 0.61 (Table 8).

Figure 50. Jackie Timothy collects benthic macroinvertebrates with Logan Miller. Photo by Kate Kanouse.

Sherman Creek Sample Site 2: We identified 30 taxa in our Sherman Creek site 2 samples, with about 1,651 aquatic macroinvertebrates per m^2, of which 75.9% are EPT taxa (Table 7). The Shannon Diversity score is 0.93 and Evenness score is 0.76 (Table 8).

Table 7. Sherman Creek taxa proportions.

Order	Sample Point 1	Sample Point 2
Ephemeroptera	25.2%	59.5%
Plecoptera	5.8%	14.9%
Trichoptera	1.1%	1.5%
Aquatic Diptera	6.1%	10.6%
Acari	1.5%	1.0%
Oligochaeta	50.7%	3.9%
Ostracoda	1.3%	1.8%
Amphipoda	0.5%	1.6%
Bivalvia	0.0%	0.0%

Table 8. Sherman Creek Shannon Diversity and Evenness Indices.

Sherman Creek	Shannon Diversity (H)	Evenness (E)
Sample Point 1	0.67	0.61
Sample Point 2	0.93	0.76

Mean macroinvertebrate densities and community composition for both Sherman Creek sample sites are shown in Figures 51 and 52.

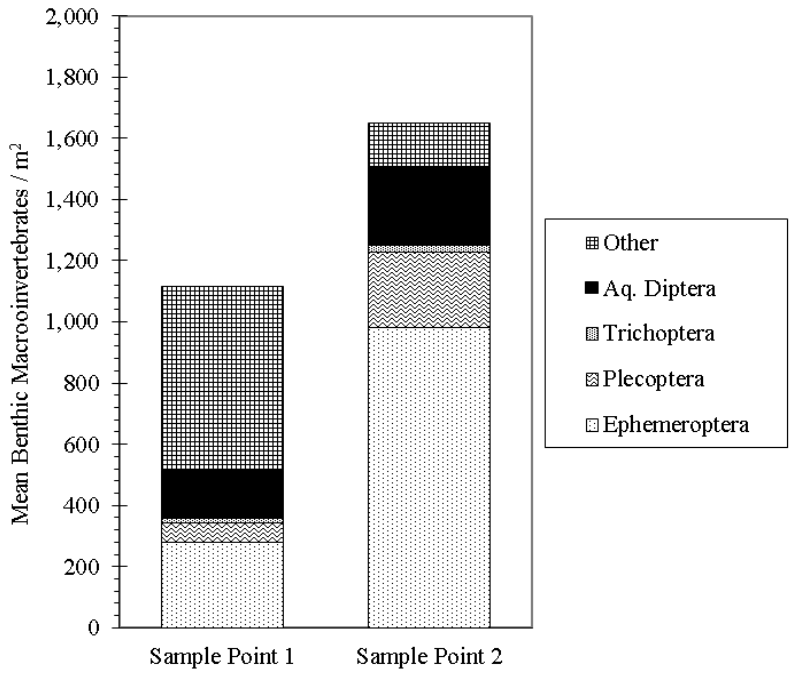


Figure 51. Sherman Creek macroinvertebrate densities.

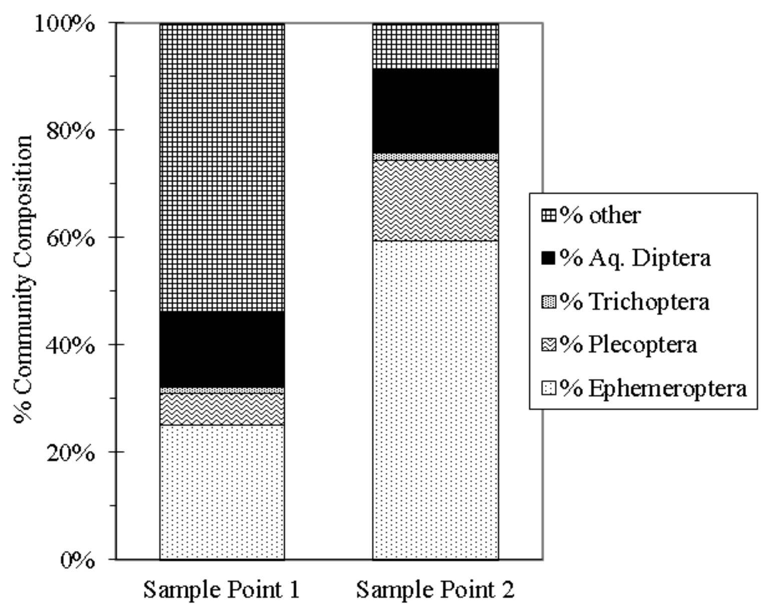


Figure 52. Sherman Creek macroinvertebrate community composition.

Resident Fish Population Status (NPDES I.E.3.b.1)

We conducted habitat surveys in Lower Sherman Creek on July 12, 2011 and sampled resident fish on July 13, 2011 (Figure 53). The 2011 Dolly Varden char population estimate is 280±12, the highest observed in seven years of sampling (Flory 2011).

Sherman Creek population estimates are shown in Appendix L, Figure L19. Dolly Varden char population estimates by habitat type and condition factors are shown in Figures L20 and L21.

The 2011 cutthroat trout population estimate for Lower Sherman Creek is 12 fish. 95% confidence intervals can not be determined as we did not catch a sufficient number of cutthroat trout. The cutthroat trout population estimate, population estimate by habitat type and condition factor is shown in Figures L9, L10, and L11.

Figure 53. Ben Brewster and Tess Quinn on Sherman Creek resident fish surveys.

Sediment Metals Concentrations (NPDES I.E.2.a.) (APDES 1.5.2.1)

Lower Sherman Creek sediment metals concentrations are shown in Figure 54. Metals concentrations at all sample sites are presented in Figure L14.

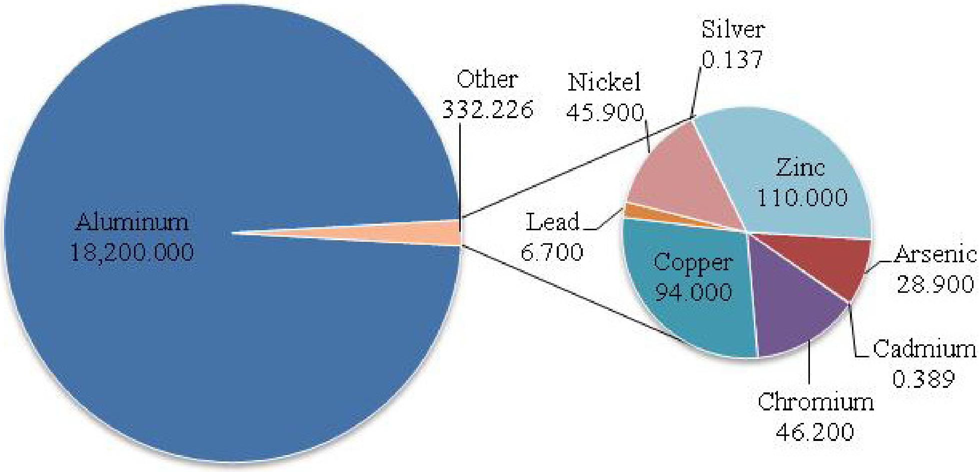


Figure 54. Lower Sherman Creek 2011 sediment metals concentrations (mg/Kg).

Sediment Toxicity (NPDES I.E.2.e) (APDES 1.5.2.3.1)

There are no statistical differences in growth or survival of *Chironomus dilutus* or *Hyalella azteca* on the Lower Sherman Creek sediment sample compared to the control (Appendix L, Tables L1 and L2).

Out-migrating Pink Salmon Fry (NPDES I.E.3.c.1.b.)

We installed the fyke nets and a live-trap box on April 11, 2011 (Figure 55). We tended the nets daily to maintain them and to identify, count and release the fry, and fished in this manner through May 20, 2011 (Figure 56). During that time, we captured 54,079 pink fry in Sherman Creek, estimating a total outmigration of 421,343 pink fry. We experienced 1,288 mortalities; about 2.3% of the sample. We also captured 2 Dolly Varden char, 4 sculpin and 11 juvenile chum salmon.

In 2010, Flory (2011) estimated pink salmon escapement in Lower Sherman Creek at 1,750 fish, suggesting about 875 females spawned. Using the 2011 pink fry outmigration count (421,343), we estimate pink salmon egg-to-fry survival in Sherman Creek at 29.2%, similar to previous years documented by Flory (2011).

Figure 55. Lower Sherman Creek fish trap. Photo by Jackie Timothy.

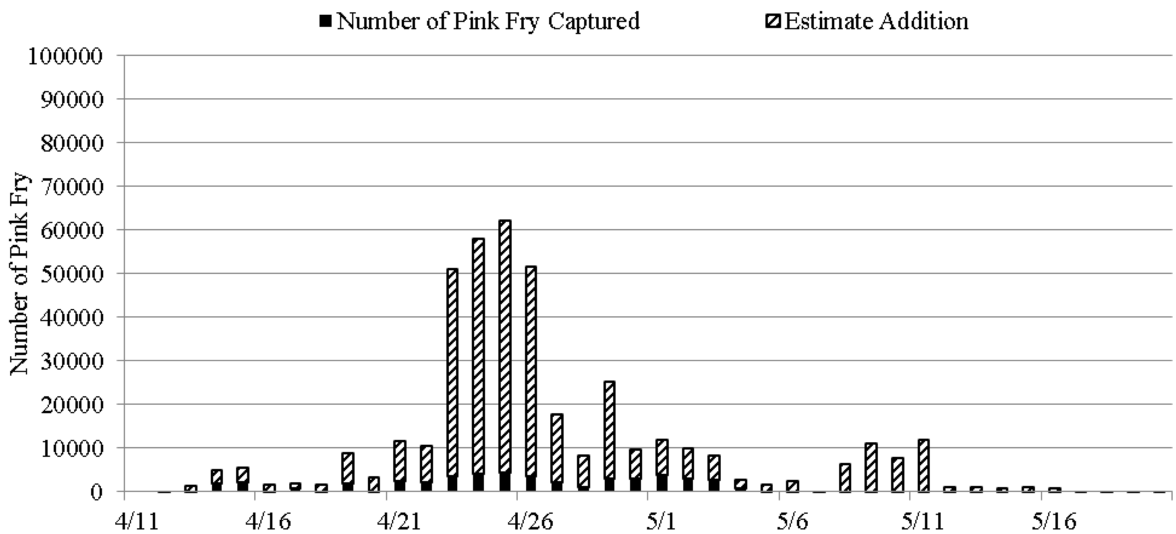


Figure 56. Lower Sherman Creek daily pink fry outmigration estimates, April–May 2011.

Returning Adult Pink Salmon (NPDES I.E.3.c.1.a.)

We surveyed Lower Sherman Creek for adult pink and chum salmon beginning July 19 and ending on September 20 (Figure 57). We observed pink salmon on all surveys and we estimate escapement at 2,312 fish. The distribution of pink salmon in Lower Sherman Creek is graphically presented Figure 58. We did not observe any chum salmon. We did not survey for adult coho salmon as no coho life stage has ever been observed in Sherman Creek.

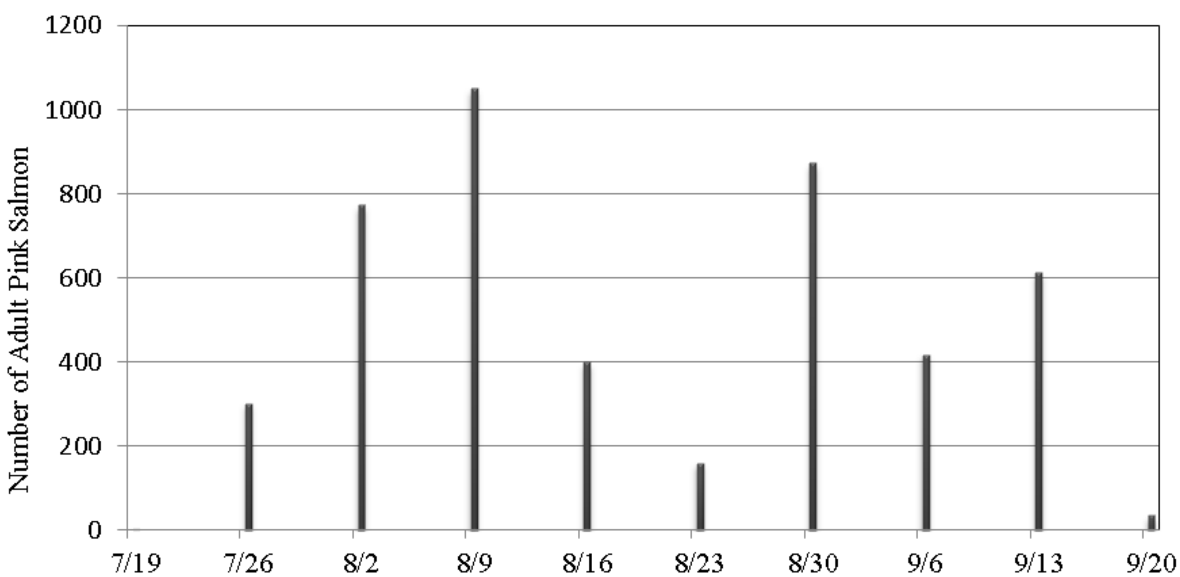


Figure 57. Lower Sherman Creek pink salmon counts, July–September 2011.

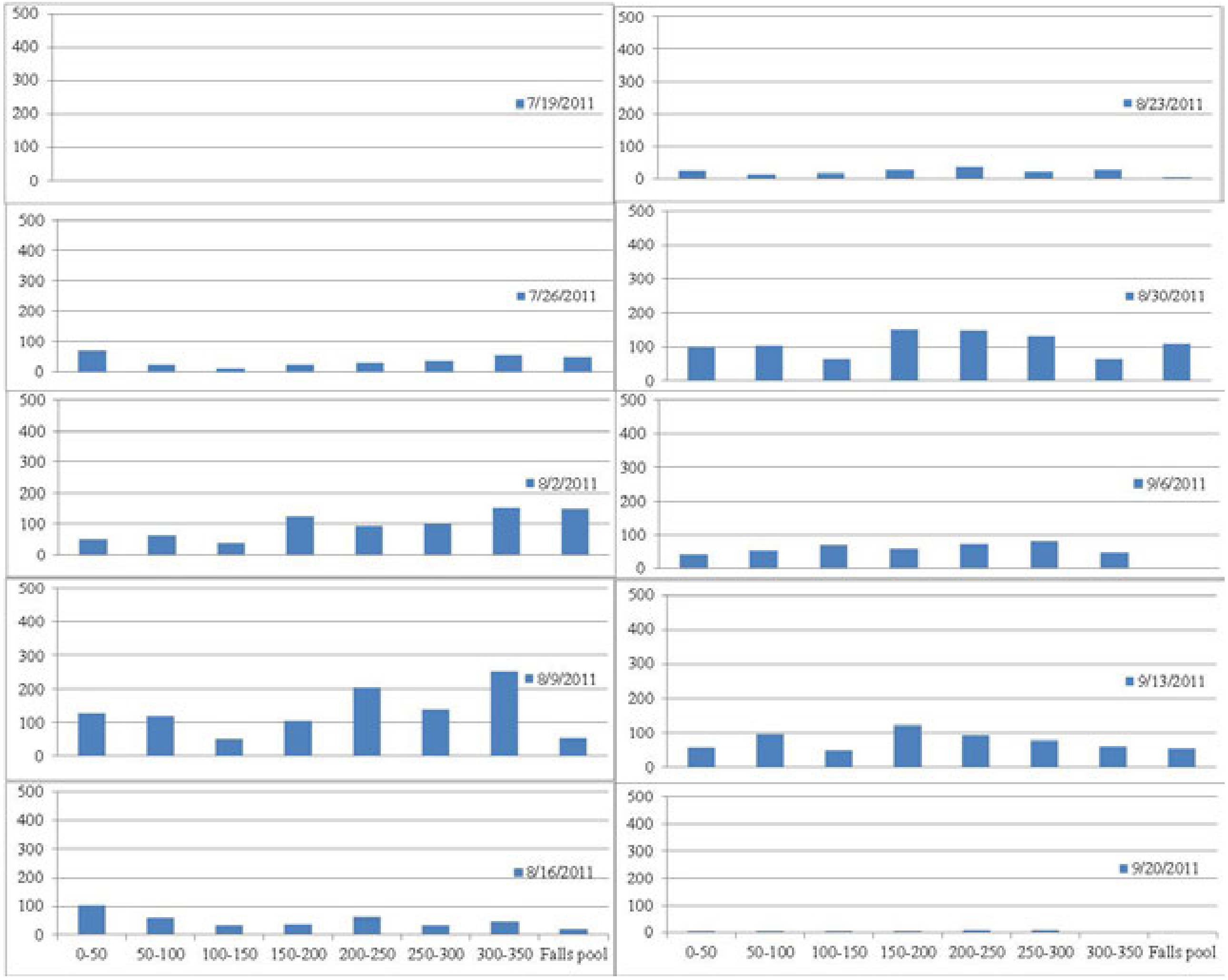


Figure 58. Lower Sherman Creek adult pink salmon distribution, July–September 2011.

Spawning Substrate Composition (NPDES I.E.3.c.2.) (APDES 1.5.3.5.1.1)

The 2011 geometric mean particle size for substrate samples taken at Samples Sites 1 and 2 of Lower Sherman Creek on August 11, 2011 (Figure 59) is 6.07 mm at Sample Site 1and 5.18 mm at Sample Site 2. Figure 59 also illustrates the geometric mean particle size calculated for samples taken at each site.

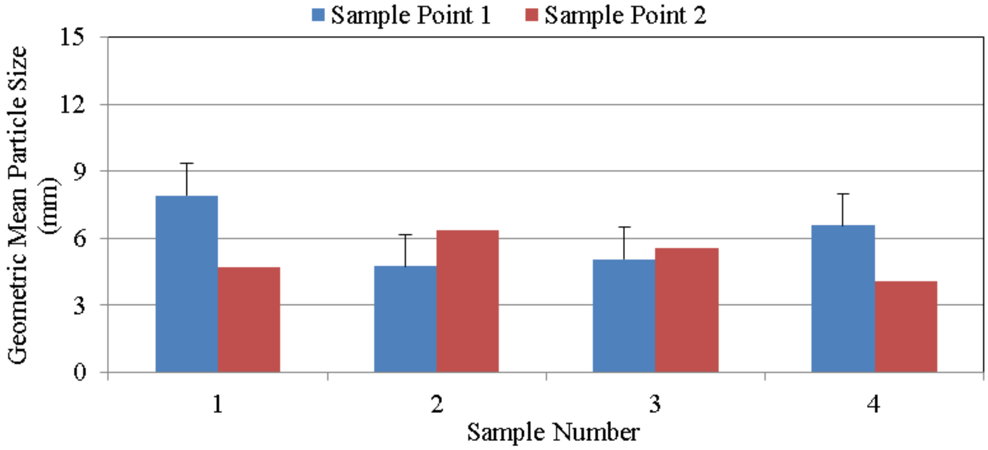


Figure 59. Lower Sherman Creek geometric mean particle sizes.

Middle Sherman Creek

Resident Fish Population Status (NPDES I.E.3.b.1)

We conducted habitat surveys in Middle Sherman Creek on August 18, 2011 and sampled resident fish on September 26, 2011. The Dolly Varden char population estimate in Middle Sherman Creek is 103±30, similar to previous years (Flory 2011). Population estimates are shown in Appendix L, Figure L19. Dolly Varden char population estimates by habitat type and condition factors are shown in Figures L20 and L21.

Sediment Metals Concentrations (NPDES I.E.2.a.) (APDES 1.5.2.1)

Upper Slate Creek sediment metals concentrations are shown in Figure 60. Metals concentrations at all sample sites are presented in Figure L14.

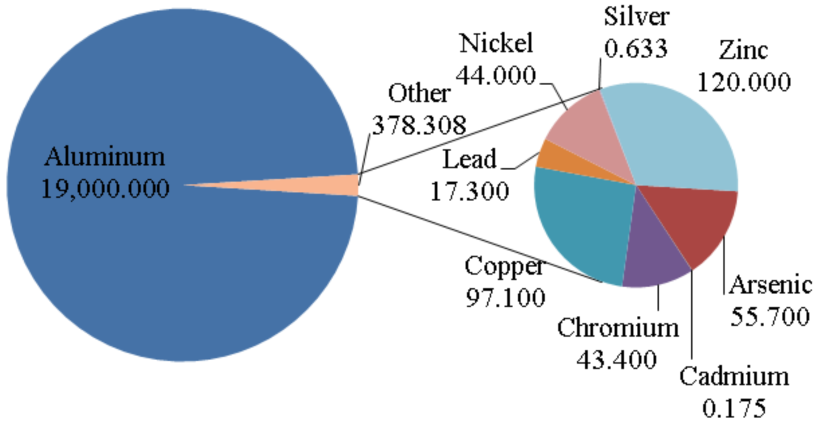


Figure 60. Middle Sherman Creek 2011 sediment metals concentrations.

Sediment Toxicity (NPDES I.E.2.e) (APDES 1.5.2.3.1)

Survival and growth of both *Chironomus dilutus* or *Hyalella azteca* on the Middle Sherman Creek sediment sample are significantly less compared to the control (Appendix L, Tables L1 and L2).

Upper Sherman Creek

Resident Fish Population Status (NPDES I.E.3.b.1)

We conducted habitat surveys in Upper Sherman Creek on August 18, 2011 and sampled resident fish on September 19, 2011. The Dolly Varden char population estimate in Upper Sherman Creek is 182±57, highest observed in 7-year sampling period (Flory 2011). Population estimates are shown in Appendix L, Figure L19. Dolly Varden char population estimates by habitat type and condition factors are shown in Figures L20 and L21.

SWEENY CREEK

Lower Sweeny Creek

Benthic Macroinvertebrate Density and Richness (NPDES I. E. 3. a. 1.)

Sweeny Creek Sample Site 1: We identified 25 taxa in our Sweeny Creek Site 1 samples (Figure 61) with about 419 aquatic macroinvertebrates per m^2, of which 44.4% are EPT taxa (Figure 62). The Shannon Diversity score is 0.80 and Evenness score is 0.82 (Table 9). Chironomidae are the dominant taxa at 32.9% (Table 10).

Sweeny Creek Sample Site 2: We identified 23 taxa in our Sweeny Creek Site 2 samples (Figure 61) with about 790 aquatic macroinvertebrates per m^2, of which 56.2% are EPT taxa (Figure 62). The Shannon Diversity score is 0.73 and Evenness score is 0.72 (Table 9). *Ephemeroptera* is the dominant taxa at 35.8% (Table 10).

Table 9. Sweeny Creek Shannon Diversity and Evenness Indices.

Sherman Creek	Shannon Diversity (H)	Evenness (E)
Sample Point 1	0.80	0.82
Sample Point 2	0.73	0.72

Table 10. Sweeny Creek taxa proportions.

Order	Sample Point 1	Sample Point 2
Ephemeroptera	18.8%	43.8%
Plecoptera	24.4%	12.2%
Trichoptera	1.3%	0.2%
Aquatic Diptera	32.9%	25.6%
Acari	1.7%	2.9%
Oligochaeta	6.9%	5.7%
Ostracoda	6.9%	4.3%
Amphipoda	0.9%	0.0%
Bivalvia	0.0%	0.0%

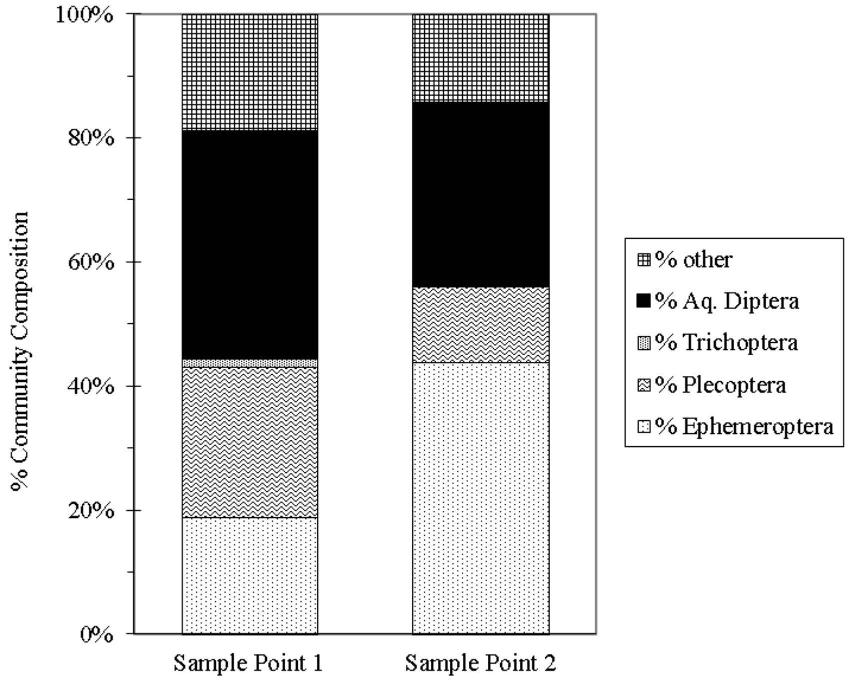


Figure 61. Sweeny Creek drainage macroinvertebrate densities.

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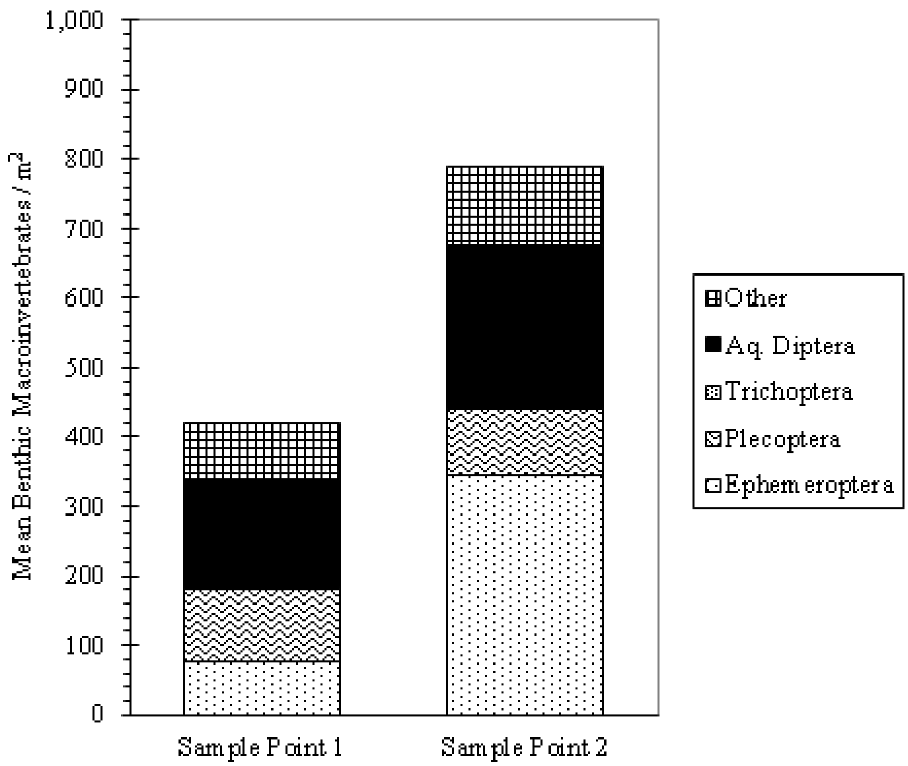

Figure 62. Sweeny Creek drainage macroinvertebrate community composition.

CONCLUSIONS

Our work at the Kensington Mine in 2011 is the first year in which Habitat Division designed and conducted the field work and wrote this technical report. The aquatic studies program is scientifically valid and cost effective, has environmentally benign procedures, and provides opportunity for many site investigations. We can analyze results quickly and use these in our management and permitting decisions.

In 2011, the mine discharge authorization was passed from the Environmental Protection Agency to the State of Alaska, requiring Coeur Alaska to monitor and report under two authorities. The overlap required more work than is anticipated in subsequent years. It did provide the opportunity for us to identify those studies most useful to the program and where we will place future emphasis. It also allowed us to add new components based on field work.

As we reviewed data from this field season, we saw less value in comparisons amongst drainages and more value within drainages. We observed the physicochemical habitat characteristics of each sample site are distinct. Our focus forward will be evaluating stream health by assessing all the biotic assemblages in relation to the physical and chemical constituents within a sample site over the long term. These are complex relationships with inherent high variability.

For example, here are a few of our notable findings in Lower Slate Creek:

- Chlorophyll *a* densities are significantly higher than in pristine sections of the drainage.
- Only 13.7% of the invertebrates in this section are EPT taxa.
- The dominant EPT taxa are E. Baetis (sensitive to water changes) and P. Suwallia (extremely sensitive to water quality changes; Barbour 1999).
- Chironomids are the overwhelmingly dominant taxa at 72% (moderately tolerant of water quality changes; Barbour 1999).
- There are few Dolly Varden char.
- There are lots of cutthroat trout.
- There are lots of coho salmon juveniles.

Water quality parameters, habitat characteristics, and even the weather are some of the components we consider in addition to our findings when we evaluate stream health. The previously undocumented and healthy population of juvenile coho salmon we identified in Lower Slate Creek introduces additional predator/prey, competition and diet preference relationships.

We learned a lot in 2011, and there is a lot more to learn. We look forward to the 2012 field season.

We have endeavored to present a technical report that is easily translated to Coeur management and to the public. We welcome comments, and especially comments that will help us improve the aquatic studies program at the Kensington mine.

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[w] Resident Fish Survey Report.
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