Technical Report No. 22-09

Aquatic Biomonitoring at the Pebble Prospect, 2010-2013

by

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North Fork Koktuli River Monitoring Reach

March 2022

Alaska Department of Fish and Game **Habitat Section**

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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. 22-09

AQUATIC BIOMONITORING AT THE PEBBLE PROSPECT, 2010 - 2013

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March 2022

Cover: North Fork Koktuli Monitoring Reach, October 16, 2012. Photograph by Jeanette Alas.

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TABLE OF CONTENTS

Page

LIST OF TABLES III

LIST OF FIGURES III

LIST OF APPENDICES V

ACKNOWLEDGMENTS VI

EXECUTIVE SUMMARY VII

1. INTRODUCTION 1

2. GEOMORPHOLOGY AND HYDROLOGY 4

Overview 4
Methods 4
Results and Discussion 5

3. WATER QUALITY 9

Overview 9
Methods 9
Results and Discussion 9
- *Water Quality: Temperature* 9
- *Water Quality: Specific Conductance* 11
- *Water Quality: pH* 12
- *Water Quality: Dissolved Oxygen* 12
- *Water Quality: Turbidity* 13

4. PERIPHYTON 14

Overview 14
Methods 14
Results and Discussion 15

5. AQUATIC INVERTEBRATES 17

Overview 17
Methods 17
- *Drift Nets* 17
- *Surber Sampling* 18

Results and Discussion 19
- *Drift Net* 19
- *Surber Samplers* 25

6. ELEMENT CONCENTRATIONS IN FISH 32

Overview 32
Methods 32
Results and Discussion 34
- *Copper* 43
- *Cadmium* 43
- *Selenium* 43
- *Zinc* 44

7. FISH PRESENCE 45

Overview 45
Methods 46

Results and Discussion 47
8. SUMMARY AND CONCLUSIONS 58
9. LITERATURE CITED..59

LIST OF TABLES

Table **Page**

Table 1. Calculated and measured values for geomorphology parameters from stream monitoring reaches and riffle cross-sections. 5
Table 2. Particle size distribution in monitoring reaches. 6
Table 3. Range of specific conductance daily means recorded in NFK, SFK, and UT. 12
Table 4. Range of daily mean values recorded for pH in NFK, SFK, and UT. 12
Table 5. Range of daily means recorded for DO in NFK, SFK, and UT. 13
Table 6. Annual mean values for turbidity (NTUs) from NFK, SFK, and UT monitoring reaches for the years 2012 and 2013 with standard deviation in parentheses. 13
Table 7. Periphyton collection dates by sampling reach and year with number of samples analyzed in parentheses. 15
Table 8. Aquatic invertebrate sampling dates by monitoring reach. 19
Table 9. Drift net aquatic invertebrate sampling densities (mean density/m^3) by sampling reach with copepods and cladocerans removed (standard deviation shown in parenthesis). 20
Table 10. Percent composition and total abundance (in parenthesis) of EPT, and dominant taxon from drift net samples. 21
Table 11. Surber sampler aquatic invertebrate densities (mean density/m^2) by sampling reach (standard deviation shown in parenthesis). 26
Table 12. Percent composition and total abundance (in parenthesis) of EPT, and dominant taxon from Surber samplers. 27
Table 13. Fish sampling dates by sampling reach. 32
Table 14. Abundance of fish captured in minnow traps, by species 2010-2013 combined. 47
Table 15. Mean Fulton's condition factor, SD (in parenthesis), and sample size (*n*) for coho salmon and Dolly Varden from ADF&G monitoring reaches. 57

LIST OF FIGURES

Figure **Page**

Figure 1. Locations of Alaska Department of Fish and Game (ADF&G) aquatic biomonitoring sites and United States Geological Survey (USGS) stream gauges. 2
Figure 2. Particle size (mm) distribution for the NFK, SFK, and UT monitoring reaches. 6
Figure 3. NFK monitoring reach riffle cross-section. 7
Figure 4. SFK monitoring reach riffle cross-section. 7
Figure 5. UT monitoring reach riffle cross-section. 7
Figure 6. Water temperature daily mean values from the NFK for 2011, 2012, and 2013. 10
Figure 7. Water temperature daily mean values from the SFK for 2011, 2012, and 2013. 10
Figure 8. Water temperature daily mean values from the UT for 2011, 2012, and 2013. 11
Figure 9. Mean chlorophyll-a concentrations (±1 SD) for NFK, SFK, and UT monitoring reaches. 16
Figure 10. Drift net configuration for macroinvertebrate sampling and ADF&G staff recording water depth and velocity, NFK monitoring reach, June 27, 2012. 18
Figure 11. Aquatic invertebrate community composition in NFK monitoring reach (2010-2013, Drift Net Sampling). 23
Figure 12. Aquatic invertebrate community composition in SFK monitoring reach (2010-2013, Drift Net Sampling). 23
Figure 13. Aquatic invertebrate community composition in UT monitoring reach (2010-2013, Drift Net Sampling). 24
Figure 14. Percent Chironomidae and percent EPT in the NFK monitoring reach from drift net sampling (2010-2013). 24
Figure 15. Percent Chironomidae and percent EPT in the SFK monitoring reach from drift net sampling (2010-2013). 25
Figure 16. Percent Chironomidae and percent EPT in the UT monitoring reach from drift net sampling (2010-2013). 25

Figure 17. Aquatic invertebrate community composition in North Fork Koktuli River monitoring reach (2011-2013, Surber sampling). 28
Figure 18. Aquatic invertebrate community composition in South Fork Koktuli River monitoring reach (2011-2013, Surber sampling). 28
Figure 19. Aquatic invertebrate community composition in Upper Talarik Creek monitoring reach (2011-2013, Surber sampling). 29
Figure 20. Percent Chironomidae and percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) in North Fork Koktuli monitoring reach from surber sampling (2011-2013). 30
Figure 21. Percent Chironomidae and percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) in South Fork Koktuli monitoring reach from surber sampling (2011-2013). 30
Figure 22. Percent Chironomidae and percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) in Upper Talarik Creek monitoring reach from surber sampling (2011-2013). 30
Figure 23. Baited minnow trap in UT monitoring reach (August 26, 2013). 33
Figure 24. Mean whole body dry weight antimony (Sb) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches. 34
Figure 25. Mean whole body dry weight arsenic (As) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches. 35
Figure 26. Mean whole body dry weight beryllium (Be) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches. 35
Figure 27. Mean whole body dry weight boron (B) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches (not analyzed in 2010). 36
Figure 28. Mean whole body dry weight cadmium (Cd) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches. 36
Figure 29. Mean whole body dry weight chromium (Cr) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches. 37
Figure 30. Mean whole body dry weight copper (Cu) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches. 37
Figure 31. Mean whole body dry weight lead (Pb) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches. 38
Figure 32. Mean whole body dry weight mercury (Hg) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches. 38
Figure 33. Mean whole body dry weight molybdenum (Mo) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches. 39
Figure 34. Mean whole body dry weight nickel (Ni) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches. 39
Figure 35. Mean whole body dry weight selenium (Se) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches. 40
Figure 36. Mean whole body dry weight silver (Ag) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches. 40
Figure 37. Mean whole body dry weight thallium (Tl) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches. 41
Figure 38. Mean whole body dry weight tin (Sn) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches (not analyzed in 2010). 41
Figure 39. Mean whole body dry weight zinc (Zn) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches. 42
Figure 40. Mean percent solids (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches. 42
Figure 41. ADF&G biologists processing captured fish in UT monitoring reach (August 27, 2013). 45
Figure 42. Dolly Varden captured by minnow trap in SFK monitoring reach (August 27, 2013). 46
Figure 43. Length frequency distribution of coho salmon caught in the NFK monitoring reach (late summer surveys, 2010-2013). 48
Figure 44. Length frequency distribution of coho salmon caught in the SFK monitoring reach (late summer surveys, 2010-2013). 48
Figure 45. Length frequency distribution of coho salmon caught in the UT monitoring reach (late summer surveys, 2010-2013). 49
Figure 46. Length frequency distribution of Dolly Varden caught in the NFK monitoring reach (late summer surveys, 2010-2013). 49

Figure 47. Length frequency distribution of Dolly Varden caught in the SFK monitoring reach (late summer surveys, 2010-2013). 50
Figure 48. Length frequency distribution of Dolly Varden caught in the UT monitoring reach (late summer surveys, 2010-2013). 50
Figure 49. Length frequency distribution of Chinook salmon caught in the NFK monitoring reach (late summer surveys, 2010-2013). 51
Figure 50. Length frequency distribution of Chinook salmon caught in the SFK monitoring reach (late summer surveys, 2010-2013). 51
Figure 51. Length frequency distribution of Chinook salmon caught in the UT monitoring reach (late summer surveys, 2010-2013). 52
Figure 52. Length frequency distribution of sculpin species caught in the NFK, SFK, and UT monitoring reaches (late summer surveys, 2010-2013). 52
Figure 53. CPUE for coho salmon in the NFK, SFK, and UT monitoring reaches (late summer surveys, 2010-2013). 53
Figure 54. CPUE for Dolly Varden in the NFK, SFK, and UT monitoring reaches (late summer surveys, 2010-2013). 54
Figure 55. CPUE for Chinook salmon in the NFK, SFK, and UT monitoring reaches (late summer surveys, 2010-2013). 54
Figure 56. CPUE for sculpin species in the NFK, SFK, and UT monitoring reaches (late summer surveys, 2010-2013). 55
Figure 57. Coho salmon weight-length data and linear trendlines on the NFK, SFK, and UT monitoring reaches (late summer surveys, 2010-2013). 56
Figure 58. Dolly Varden weight-length data and linear trendlines on the NFK, SFK, and UT monitoring reaches (late summer surveys, 2010-2013). 56

LIST OF APPENDICES

Appendix **Page**
Appendix 1. Overview of ADF&G Monitoring Reaches 65
Appendix 2. Hydrology Data from USGS Stream Gauges 68
Appendix 3. Periphyton Standing Crop, 2010-2013 70
Appendix 4. Aquatic Invertebrate Samples 77
Appendix 5. Juvenile Dolly Varden Whole-Body Total Metals Concentrations 84

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EXECUTIVE SUMMARY

The Alaska Department of Fish and Game (ADF&G), Habitat, conducted an aquatic biomonitoring program in the Pebble Project area from 2010 through 2013. Monitoring sites were established on the North Fork Koktuli River (NFK), South Fork Koktuli River (SFK), and Upper Talarik Creek (UT), downstream of the proposed Pebble Prospect. At each site, channel morphology, hydrology, water quality, periphyton, macroinvertebrate, whole body element concentrations in fish, and fish data were collected. The goal of the biomonitoring program was to collect baseline data at long-term monitoring locations that can be used to assess biological conditions and monitor potential changes over time.

Based on the geomorphology data, all sample reaches were classified as Rosgen C4 stream types. Rosgen C4 stream types are described as slightly entrenched, meandering, gravel-dominated, riffle-pool channels with a developed floodplain, point bars and other depositional features present; and are susceptible to shifts in both lateral and vertical stability (Rosgen 1994). From a management perspective, C4 streams are typically very sensitive to disturbance with good recovery potential, have a high sediment supply, are very susceptible to streambank erosion, and are highly dependent on vegetation as a controlling influence (Rosgen 1994).

Streamflow in the NFK tends to be the most dynamic of the three streams, with peaks in flow during precipitation or runoff events, while UT streamflow is characterized by more stable flow throughout the year likely due to groundwater influences. All three streams exhibit a bimodal hydrograph with spring and late summer peaks.

Monitored water quality parameters were within Alaska Department of Environmental Conservation Water Quality Standards with few exceptions. Typically, water temperatures were highest in the SFK and lowest in the UT during the monitoring period (late May to early October). Specific conductance was consistently higher in the UT than the NFK and SFK, which had similar values. Dissolved oxygen and pH values were similar among streams with a tendency for lower values in the SFK. Turbidity tended to be relatively higher in the SFK and lower in the NFK.

Mean chlorophyll-a concentrations ranged from 1.6 mg/m^2 (SFK, 2012) to 22.7 mg/m^2 (UT, 2011). Chlorophyll-a concentrations were highest overall in UT, which had a mean concentration over four years of 17.27 mg/m^2. The NFK and SFK samples were similar, with mean chlorophyll-a concentrations over four years of 3.08 mg/m^2 and 2.53 mg/m^2, respectively.

Drift net samples were collected during all four years of monitoring while surber samples were collected for three years. Based on drift net samples, the mean density of aquatic invertebrates was highest in the SFK and lowest in the UT. The UT reach typically had the greatest percentage of pollution-sensitive taxa (Ephemeroptera, Plecoptera, and Trichoptera taxa - EPT), followed closely by the NFK. Chironomids, an important food source for fish, were most abundant in the NFK, closely followed by the UT. The NFK had the highest mean density of aquatic invertebrates based on surber samples, largely attributed to high counts of Diptera. The UT typically had the greatest percentage of EPT taxa and the NFK consistently had the highest number of EPT taxa in surber samples. Chironomids were most common in the NFK based on surber samples.

Juvenile Dolly Varden (*Salvelinus malma*) were sampled from each stream reach and analyzed for whole-body element concentrations. In general, UT fish showed lower concentrations of elements than NFK and SFK fish. UT reach fish had the lowest mean concentrations of all elements except tin.

A total of nine fish species were captured in the three biomonitoring reaches and species assemblages varied slightly by site. Coho salmon (*Oncorhynchus kisutch*), chinook salmon (*O. tshawytscha*), Dolly Varden, and sculpin species (*Cottus cognatus and C. aleuticus*) were present in all three reaches. Rainbow trout (*O. mykiss*) were captured only in the UT. Burbot (*Lota lota*) and northern pike (*Esox luscious*) were captured only in the SFK. Ninespine stickleback (*Pungitius pungitius*) were captured in both the NFK and UT. Catch per unit effort (CPUE), using minnow traps, was greatest for coho salmon in the UT, while CPUE for Dolly Varden and Chinook salmon was greatest in the NFK.

Species-specific condition factors were similar among streams. Fulton's condition factor for Dolly Varden ranged from 0.85 (SFK) to 0.93 (NFK). Coho salmon had a calculated condition factor range of 1.09 (SFK) and 1.38 (NFK).

1. INTRODUCTION

The Pebble Prospect is located about 32 km northwest of the village of Iliamna, Alaska, in the Lake and Peninsula Borough (Figure 1). More specifically, the Pebble Prospect is located at the headwaters of the Upper Talarik Creek and South Fork Koktuli River drainages, and adjacent to the headwaters of the North Fork Koktuli River drainage. This is a transitional area between two ecoregions, the Bristol Bay–Nushagak Lowlands and the Interior Forested Lowlands and Uplands (Gallant et al. 1995). The mean annual temperature is 34.9º F (July mean of 55.8º F and January mean of 16.4º F) as measured near Iliamna Lake (Alaska Climate Research Center 2012). The area has a mean precipitation of 25.09 inches and a mean snowfall of 55.2 inches (Alaska Climate Research Center 2012). The general vegetation consists of alder and willow stands, low shrub/scrub habitat, and various sedges and grasses, including tussock-forming species. The area is inhabited by a variety of large mammals, including brown bear, black bear, gray wolf, coyote, caribou, moose, wolverine, red fox, river otter, and beaver. Additionally, the streams in the area are home to all five species of Pacific salmon and numerous resident fish species, such as Dolly Varden (*Salvelinus malma*), rainbow trout (*Oncorhynchus mykiss*), Arctic grayling (*Thymallus arcticus*), and others.

The Pebble Prospect is a copper-gold-molybdenum porphyry deposit in the advanced exploration stage. The prospect is located on state land in the Bristol Bay Region of southwest Alaska, approximately 17 miles northwest of the community of Iliamna. Pebble Limited Partnership (PLP) has applied for federal permits to develop a portion of the Pebble deposit as an open-pit mine, along with an associated transportation corridor, port facility, and natural gas pipeline.

The Alaska Department of Fish and Game (ADF&G), Habitat Section, developed a monitoring program for the purpose of collecting baseline data on a select number of parameters that reflect stream conditions in 2010 and further refined the program through 2013. Three biomonitoring sites were established downstream of the potential mine site. Monitoring sites were established on the North Fork Koktuli River (NFK), South Fork Koktuli River (SFK), and Upper Talarik Creek (UT), at elevations ranging from 760–999 ft above sea level (Figure 1). Each monitoring site is a stream reach that was established using the Field Survey Procedures for Characterization of River Morphology by Rosgen (1996a). The Rosgen method calls for including a stream length that is equal to 20–30 channel widths (or two meander wavelengths). The following criteria were considered when selecting the location of the biomonitoring sites: located near an established stream gauge, located on a relatively stable stream reach, wadeable at all but the highest flows, and located outside and downstream of the anticipated mine footprint.

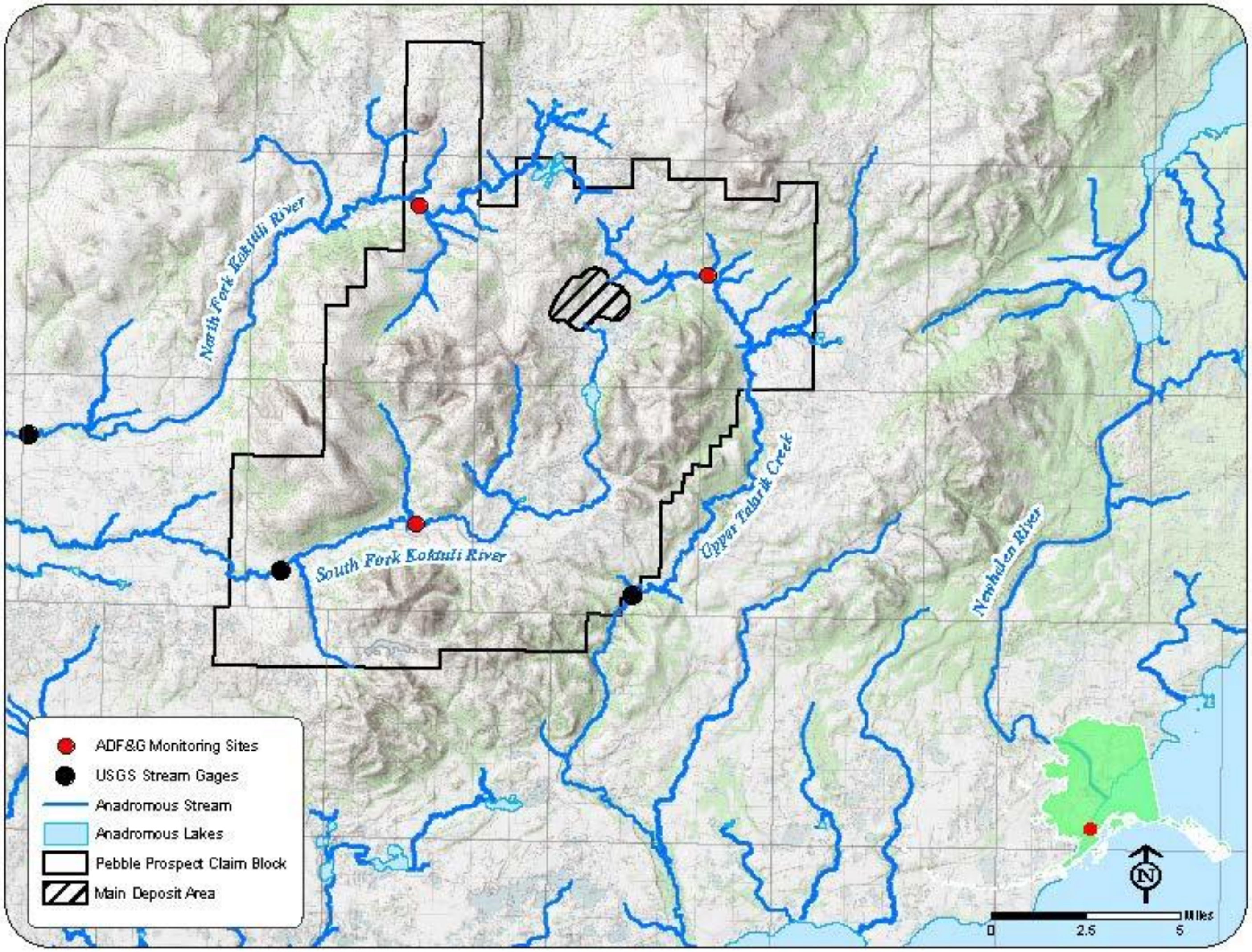


Figure 1. Locations of Alaska Department of Fish and Game (ADF&G) aquatic biomonitoring sites and United States Geological Survey (USGS) stream gauges.

The aquatic biomonitoring program includes the following parameters and associated metrics:

- Geomorphology (channel cross sections, particle-size distribution)
- Hydrology (stream discharge)
- Water quality (temperature, specific conductance, pH, dissolved oxygen, and turbidity)
- Periphyton (chlorophyll-a concentrations)
- Aquatic invertebrates (density and community composition)
- Element concentrations (whole-body element analysis of juvenile Dolly Varden)
- Fish presence (fork length, length frequency distribution, catch per unit effort, Fulton’s condition factor).

2. GEOMORPHOLOGY AND HYDROLOGY

OVERVIEW

Fluvial geomorphology is the study of rivers and streams and the processes that shape them. These processes can include natural events or human induced development activities. Rivers transport both water and sediment while dissipating energy. The channel size, shape, and pattern will adjust over time to accommodate the water and sediment load. By monitoring basic geomorphic characteristics, we can assess how stable the stream is and how it may respond to development activities or changes in the watershed (Leopold 1994; Rosgen 1994).

Changes in stream flow, width, velocity, depth, slope, roughness of channel materials, sediment volumes, and sediment sizes, brought on by activities in the watershed, can directly affect the stability of streams. This in turn may result in impaired water quality, reduction in diversity and quality of available fish habitat, and land loss through erosional processes (Meehan 1991; Waters 1995). Geomorphic monitoring can provide the ability to detect changes in these streams and rivers over time.

The Rosgen Stream Classification System is widely used, with literature available describing the methods (Rosgen 1994). The foundation of the Rosgen approach is to measure several variables in the field that allow for the determination of the stream type. The identification of the stream type assists managers in determining how stable the stream is, how it may respond to development activities, and what types of restoration activities have the highest likelihood of long-term success.

Monitoring stream discharge provides an empirical understanding of the volumetric effects of water withdrawal activities, as well as information which can be used to assess changes to stream geomorphology in the event of altered flow.

METHODS

During the 2010 monitoring season, a geomorphic evaluation of each site was conducted. A monitoring reach that is equal to 20-30 channel widths was established at each site per the Rosgen method. Each monitoring reach was classified to Level II of the Rosgen stream classification system (Rosgen 1994). The classification is determined from several field measured variables, such as the entrenchment ratio, width/depth ratio, sinuosity, and channel material. Riffle cross-sections and channel materials were measured at each monitoring reach to determine these values. See Appendix 1 for overview pictures/layout of monitoring reaches.

Riffle cross-sections were developed in 2010 by imbedding rebar stakes on opposite streambanks, adjacent to a riffle, forming a transect perpendicular to the channel. A temporary benchmark also was set on one side of the channel and used for relative elevation during the survey. Bankfull widths and cross-sectional depth profiles were measured between the rebar stakes using standard survey techniques (Harrelson et al. 1994) and plotted using Microsoft Excel® software. Bankfull area, mean bankfull depth, width/depth ratio, and maximum bankfull depth were calculated for each riffle cross-section from the profile data. Sinuosity was calculated using aerial photography

(2006 imagery) and measuring the stream length and related valley length for at least two meander wavelengths centered on each monitoring reach.

Channel material was assessed, and particle size distributions of the streambed were determined by conducting pebble counts (Wolman 1954). Sediment samples of the streambed material were taken from the surface layer of the streambed (bed armor). Particle size diameters are reported for the D_{16}, D_{50}, D_{84}, and D_{100} values. D_{50} represents the median particle size of the bed material, while the D_{100} represents the largest particle size measured. Rosgen stream channel classifications were determined for each sample reach using measurements obtained from cross-sections and particle size distribution.

Hydrology data from October 2004 through September 2014, in the form of means of daily mean stream discharge, were obtained from the USGS maintained stream gauges on NFK, SFK, and UT, located downstream from sample reaches (Appendix 2). Stream gauge information, including past archives and real time flow is available at http://waterdata.usgs.gov/.

RESULTS AND DISCUSSION

The stream length of each survey reach was approximately 355 m (1,165 ft) for NFK reach, 175 m (574 ft) for SFK reach, and 140 m (460 ft) for UT reach. An overview of the monitoring reaches is detailed in Appendix 1. Selected channel parameters are reported in Table 1. A summary of particle size diameter distribution is presented in Table 2 and the particle size distribution plots for all three sites are presented in Figure 2. Riffle cross-sections show a streambed profile of each sample reach (Figures 3-5). In the figures, the downstream view of the cross-sectional profile is depicted, and a temporary benchmark was used for relative elevation.

Table 1. Calculated and measured values for geomorphology parameters from stream monitoring reaches and riffle cross-sections.

	Waterbody		
Parameter	NFK	SFK	UT
Bankfull Width (ft)	38.6	28.1	22.25
Bankfull Depth (ft)	1.15	1.47	0.92
Bankfull X-Section Area (ft^2)	44.31	41.42	20.44
Width/Depth Ratio (ft/ft)	33.63	19.06	24.22
Maximum Depth (ft)	1.75	2.36	1.79
Flood Prone Area Width (ft) [1]	-	102.3	48.6
Entrenchment Ratio (ft/ft) [1]	-	2.21	3.64
Channel Materials - D50 (mm)	40	30	27
Channel Sinuosity	1.27	2.05	1.52

[1] Width of Flood Prone Area for NFK was not measured. This value feeds the calculation of the Entrenchment Ratio.

The NFK reach had the largest bankfull area, indicating it transports the most water through its reach. The UT reach had the smallest bankfull area. The NFK reach had the greatest bankfull width while the SFK reach was the deepest and had the highest sinuosity (Table 2).

The entrenchment ratio was not calculated for the NFK reach because the field crew had difficulties obtaining the width of the flood prone area needed for this calculation. The entrenchment ratio for the SFK and UT was greater than 2.2, classifying them as slightly entrenched (Rosgen 1996b). All three stream reaches are classified as having a moderate to high width/depth ratio (>12). The NFK reach (1.27) is classified as having a moderate to high sinuosity (>1.2) and the SFK reach (2.05) and UT reach (1.52) have high sinuosity (>1.5).

Table 2. Particle size distribution in monitoring reaches.

Stream reach	D_{16} (mm)	D_{50} (mm)	D_{84} (mm)	D_{100} (mm)
NFK	10	40	90	256
SFK	11	30	56	180
UT	10	27	53	90

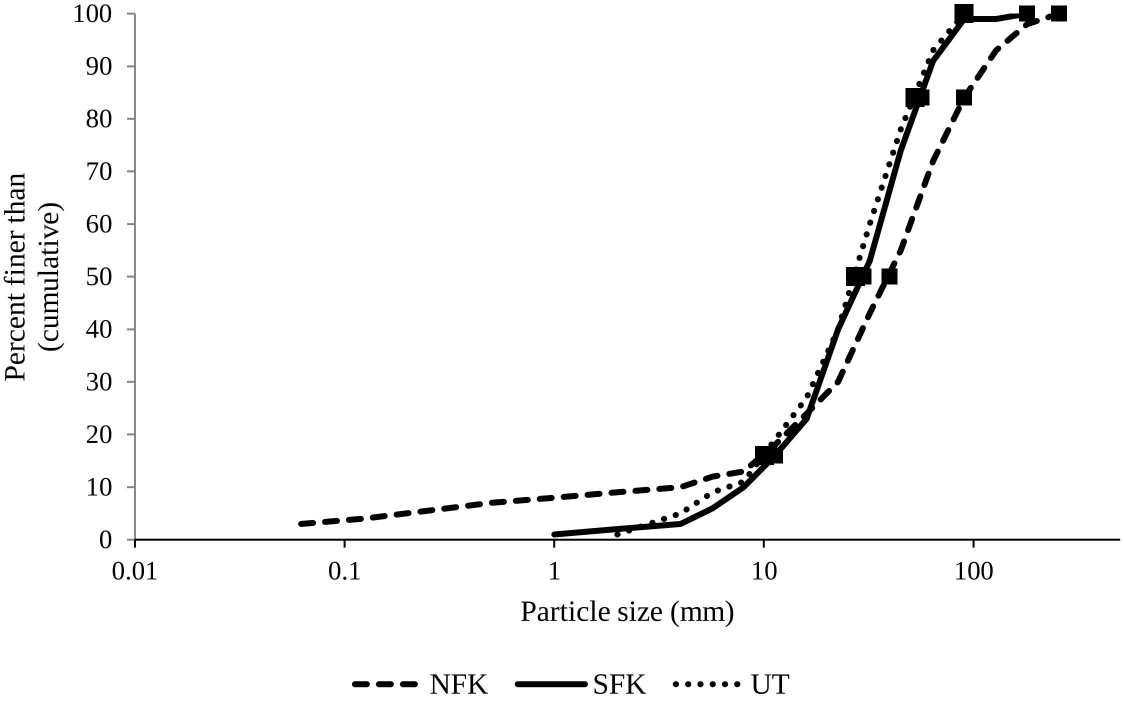


Figure 2. Particle size (mm) distribution for the NFK, SFK, and UT monitoring reaches.

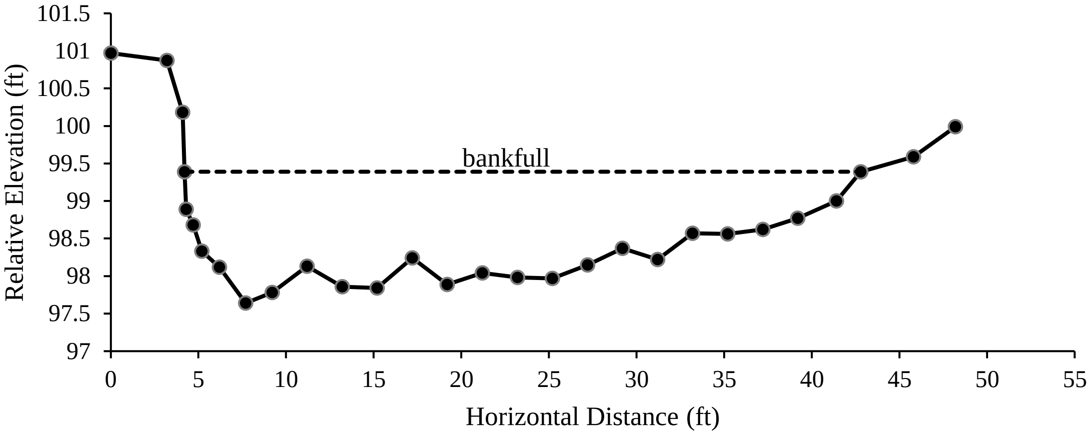


Figure 3. NFK monitoring reach riffle cross-section.

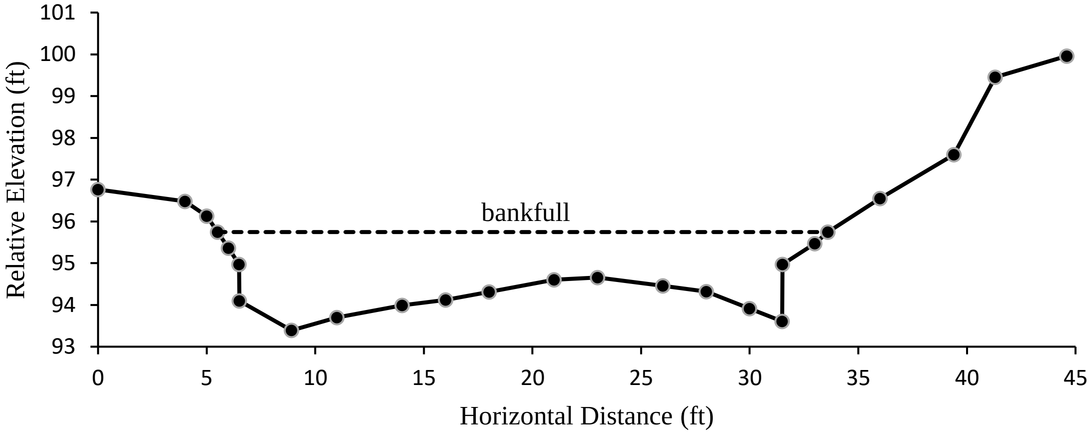


Figure 4. SFK monitoring reach riffle cross-section.

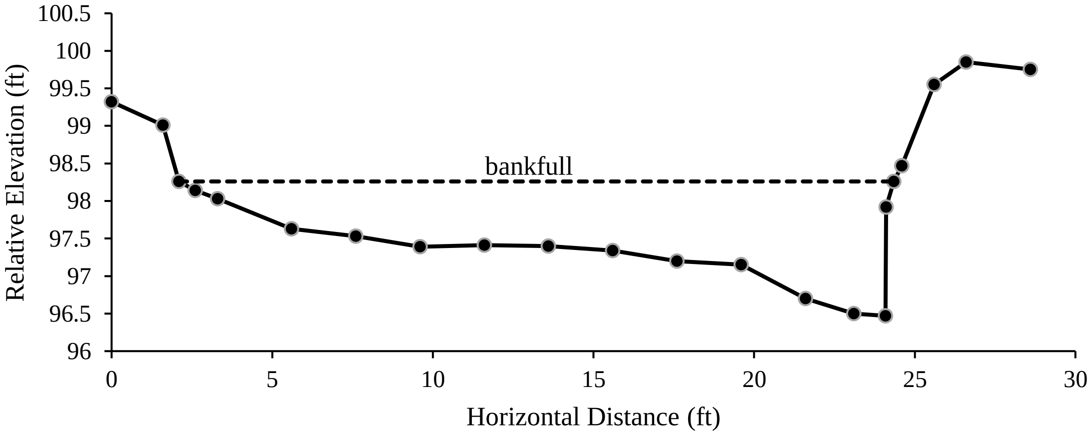


Figure 5. UT monitoring reach riffle cross-section.

Using the Rosgen stream channel classification system, all sample reaches were classified as C4 stream types in Glacial Trough valleys. The monitoring reaches used for the stream classifications are a short segment of the entire stream. However, overflights and foot surveys suggest that the Rosgen C4 classification at the reach level generally is characteristic of the streams on a larger scale, especially in adjacent stream segments upstream and downstream of the monitoring reaches. Since the streams occur in similar geologic landscapes and climate with similar vegetation patterns, it is not unusual that they have the same classification.

These alluvial C4 stream types are very susceptible to scour and erosion and can be significantly altered and rapidly de-stabilized by channel or landscape disturbances and changes in the flow or sediment regimes of the contributing watershed (Rosgen 1996b; Ward et al. 2008; Lord et al. 2009). For example, a net increase of flow in the streams will increase the sediment transport rate, alter deposition rates, and offset the stream’s equilibrium. Changes to sediment transport and deposition rates could alter spawning gravel quality and location (Meehan 1991; Waters 1995).

Mean daily discharges in cubic feet per second (cfs) from October 2004 (when gauges were established) through September 2014 (when monitoring ended) as measured by United States Geological Survey gauges located downstream of our stream monitoring reaches are depicted in Appendix 2.

3. WATER QUALITY

OVERVIEW

Water quality data were collected from the established NFK, SFK, and UT ADF&G monitoring reaches for three years (2011-2013). The objective was to document the naturally occurring conditions in the surface water at established monitoring sites. The physical parameters of temperature, specific conductance, pH, dissolved oxygen, and turbidity were recorded every two hours. Gaps in the data are the result of power loss (dead batteries), sensor malfunction/erroneous data, or Sonde removal from the water for maintenance and calibration.

METHODS

Physical parameters of water quality were recorded using Hydrolab DS5 Multiparameter Data Sondes. The water quality sondes were deployed during most of the open water season (i.e., late May to early October) at all three monitoring reaches in 2011, 2012, and 2013. The sondes were deployed in 2010, but a technical error prevented the loggers from recording data. In 2011 the water quality sondes were calibrated monthly, while in 2012 and 2013 the calibrations occurred at about two-week intervals after it was determined that some of the sensors (e.g., pH) required more frequent calibrations and to reduce dead battery occurrences.

The water quality sondes were placed inside polyvinyl chloride (PVC) housing that were anchored to and suspended above the stream bottom near the channel’s thalweg. Openings in the ends of the PVC housing allowed stream water to continuously flow through the housing and past the sonde sensors.

The water quality sondes were removed from the water at each site and transported back to Iliamna for calibration events. The water quality sondes were removed from the housings, cleaned, calibrated, downloaded, and, if needed, the batteries were replaced. Typically, the water quality sondes were returned to the stream on the same day they were calibrated.

RESULTS AND DISCUSSION

Water Quality: Temperature

The mean daily water temperatures from the NFK, SFK, and UT from 2011-2013 are presented in Figures 6-8. Typically, water temperatures were highest in the SFK and lowest in the UT during the monitoring period (late-May to early-October). The highest water temperatures typically occurred in mid to late July in all three reaches. Data gaps in the temperature data are due primarily to dead batteries or low water episodes that exposed the sondes to air temperatures.

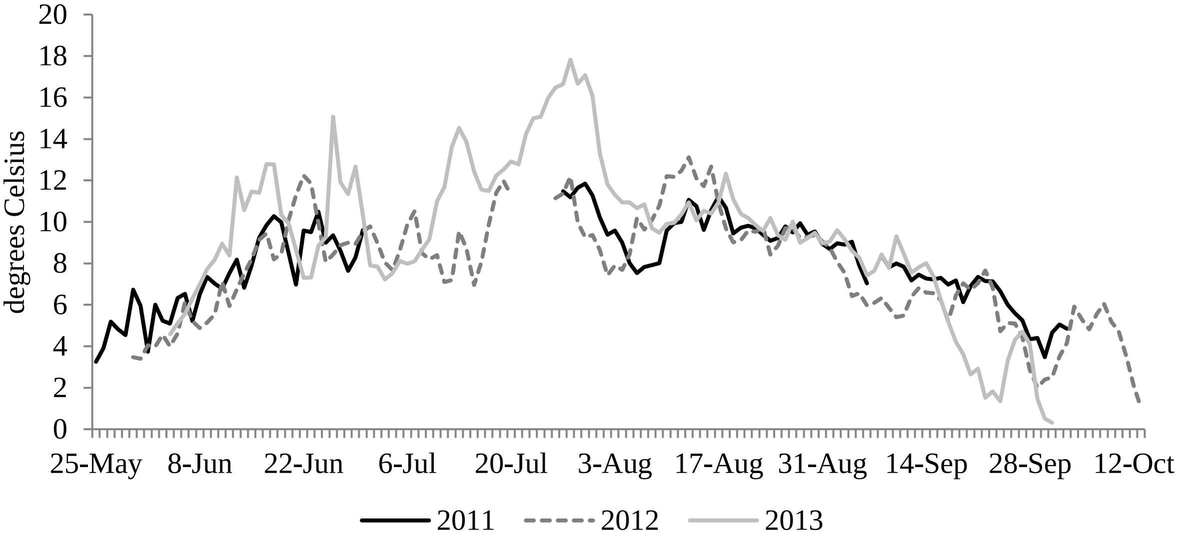


Figure 6. Water temperature daily mean values from the NFK for 2011, 2012, and 2013.

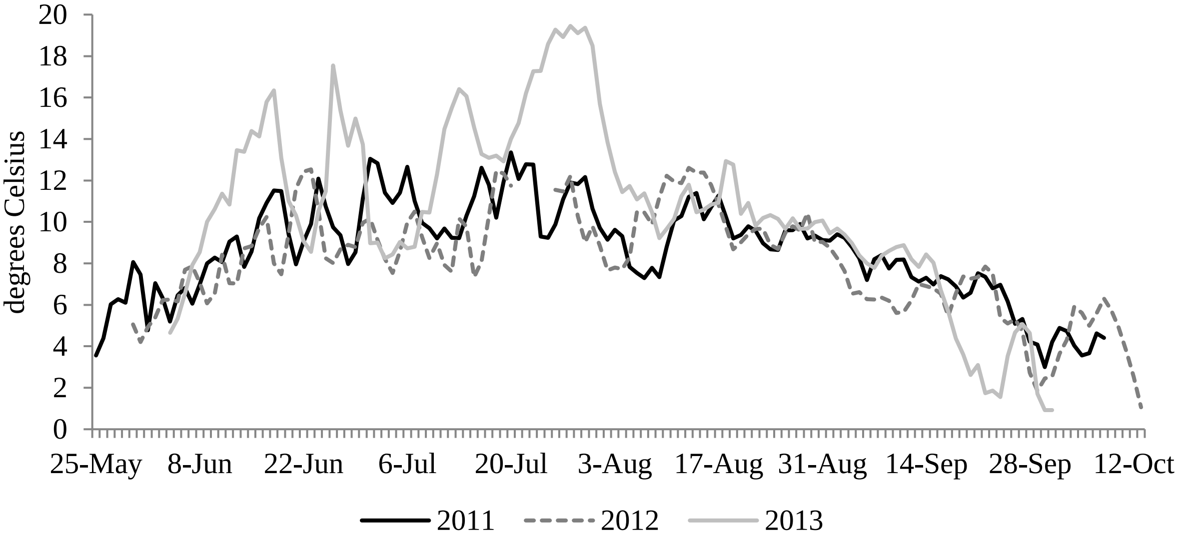


Figure 7. Water temperature daily mean values from the SFK for 2011, 2012, and 2013.

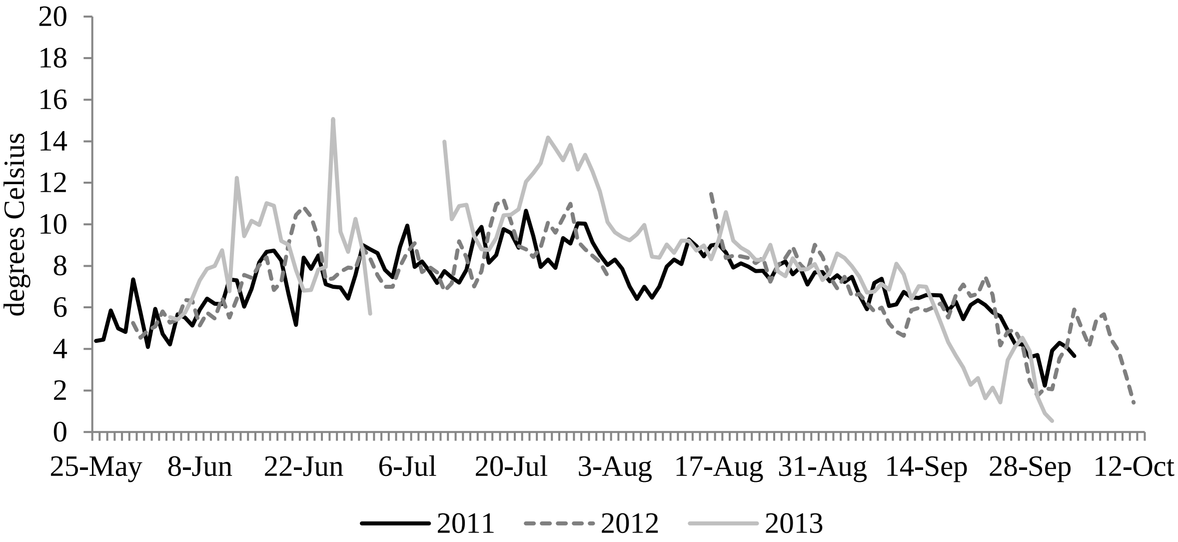


Figure 8. Water temperature daily mean values from the UT for 2011, 2012, and 2013.

Water Quality: Specific Conductance

Minimum and maximum daily means along with the annual median values for specific conductance in the NFK, SFK, and UT are presented in Table 3. The average specific conductance was consistently higher in UT when compared to the NFK and SFK, which had similar readings. The mean monthly values for specific conductance ranged from 35-50 µS/cm in the NFK, 40-54 µS/cm in the SFK, and 80-105 µS /cm in the UT. The higher specific conductance values in UT, especially during low water levels, indicate that the creek has a higher ion content, likely due to a higher inflow of groundwater. All three streams exhibited an inverse relationship with specific conductance and stream discharge; as streamflow decreases, specific conductance rises. Typically, streams had their highest specific conductance values in the middle of summer (July or August) and their lowest values early in the season.

Table 3. Range of specific conductance daily means recorded in NFK, SFK, and UT.

Minimum and maximum daily mean and annual median for specific conductance (µS/cm) (date recorded)			
	2011	2012	2013
NFK	**23.71** (6/1) **57.28** (10/2) **46**	**28.0** (6/1 & 9/19) **53.5** (8/8) **44**	**25.83** (6/4) **55.08** (7/24) **45**
SFK	**35.94** (5/25) **60.51** (7/30) **52**	**31.33** (5/30) **62.0** (8/15) **46**	**29.49** (6/4) **74.82** (7/10) **48**
UT	**60.89** (8/3) **122.08** (8/12) **91**	**58.0** (5/30) **117.42** (9/11) **92**	**66.5** (6/4) **115.58** (8/18) **94**

Water Quality: pH

Minimum and maximum daily means along with the annual median values for pH in the NFK, SFK, and UT are presented in Table 4. The pH in each stream tended to be lowest (more acidic) when discharge was high and highest (more alkaline) when discharges were lower. This is likely a result of runoff and sedimentation during higher flows due to the ionic content of the input. The SFK had slightly lower pH values than the other two monitored streams. Monthly mean values ranged from 7.1 – 7.7 in the NFK, 6.7 – 7.5 in the SFK, and 7.1 – 7.7 in the UT. All three streams generally had pH values (between 6.5 and 8.5) indicative of a healthy stream (Brabets 2002). Daily mean pH values were below this range during one occasion in late September 2012 in the SFK.

Table 4. Range of daily mean values recorded for pH in NFK, SFK, and UT.

Minimum and maximum daily mean and annual median values for pH (date recorded)			
	2011	2012	2013
NFK	**6.9** (6/2) **7.63** (9/10 & 7/27) **7.38**	**6.83** (6/13 & 6/14) **7.79** (10/13) **7.37**	**7.25** (6/4) **7.9** (8/1 & 8/27) **7.57**
SFK	**6.5** (7/24) **7.36** (7/1) **7.09**	**6.26** (9/29 – 10/1) **7.45** (7/26) **6.82**	**6.8** (6/20) **7.74** (6/26 & 8/1) **7.33**
UT	**6.71** (9/1) **7.97** (7/6) **7.44**	**6.77** (7/5) **7.95** (10/12) **7.43**	**7.19** (6/8) **7.92** (9/22) **7.67**

Water Quality: Dissolved Oxygen

Minimum and maximum daily means along with the median concentration for dissolved oxygen (DO) in the NFK, SFK, and UT are presented in Table 5. The DO concentrations in each stream were roughly the inverse of water temperatures and were typically lowest near the end of July and early August. The NFK had the highest mean daily concentrations, but the UT typically had the higher DO of the three streams. Values are typically between 10 and 14 mg/L DO with the SFK values slightly lower than the other two monitored streams, which is attributed to the higher water temperatures in the SFK system due in part to warmer water input from Frying Pan Lake. Streams with a saturation value of 90% or greater, or greater than 9 mg/L, are considered healthy (Bjornn and Reiser 1991).

Table 5. Range of daily means recorded for DO in NFK, SFK, and UT.

Minimum and maximum recorded daily mean concentrations and the annual median for DO (mg/L)
(date recorded)

	2011	2012	2013
NFK	**11.64** (6/13) **13.02** (5/25) **12.25**	**10.25** (7/19) **13.78** (6/4) **11.88**	**9.35** (7/28) **14.28** (9/30) **11.09**
SFK	**9.95** (7/20) **12.98** (5/25) **11.29**	**10.05** (9/23) **12.84** (10/13) **11.63**	**9.03** (6/25) **12.28** (6/4) **10.73**
UT	**10.07** (8/2) **12.86** (9/30) **11.6**	**9.02** (7/25) **13.61** (10/1 & 10/13) **12.06**	**10.23** (7/25) **13.92** (10/1) **11.29**

Water Quality: Turbidity

The turbidity probes in the Sondes proved to be unreliable and measurements were collected during calibration site visits using a HF Scientific Micro TPW portable turbidity meter. Turbidity annual means from the NFK, SFK, and UT are depicted for 2012 and 2013 in Table 6. The SFK had the highest mean turbidity while the NFK had the lowest. The highest recorded turbidity in 2012 and 2013 was in the SFK at 5.94 NTU (July) and 6.76 NTU (October) respectively. The lowest recorded turbidity in 2012 and 2013 was in the NFK at 0.7 (June) and 0.72 (October) respectively.

Table 6. Annual mean values for turbidity (NTUs) from NFK, SFK, and UT monitoring reaches for the years 2012 and 2013 with standard deviation in parentheses.

	NFK	SFK	UT
2012	1.23 (0.44)	2.50 (1.34)	1.91 (0.84)
2013	1.52 (0.54)	3.73 (1.64)	2.44 (0.91)

4. PERIPHYTON

OVERVIEW

Periphyton (attached microalgae) biomass samples were collected annually from 2010 to 2013. Periphyton are sensitive to changes in water quality and are often used in monitoring studies to detect changes in aquatic communities because of their short life cycles and rapid reproduction rates (Barbour et al. 1999). Measuring the chlorophyll-a concentrations over time allows for long-term comparisons and the detection of changes in primary productivity.

METHODS

Periphyton were sampled directly from submerged cobbles, located in a riffle section of the stream, within each monitoring reach. Sampling was scheduled during a time of moderate to low flow to ensure that the submerged cobble had been wetted continuously for the previous 30 days. The United States Environmental Protection Agency's (USEPA) Rapid Bioassessment Protocols for Streams and Wadeable Rivers were followed, but with more replicates per site to increase sample precision (Barbour et al. 1999). This modified approach is described below and follows the protocols as detailed in Ott et al. (2010).

Ten flat rocks, larger than 25 cm^2, were collected from a submerged riffle area of the streambed that was expected to have been underwater for the previous 30 days. A 5 cm x 5 cm square of high-density flexible foam was placed in the middle portion of the rock. All material around the foam square was scrubbed with a toothbrush and rinsed from the rock with clean water collected from the stream. This scrubbing process was repeated twice, with the toothbrush being rinsed clean between each step. The foam square was removed from the rock, and algae remaining on the rock were brushed with a clean toothbrush and rinsed with water into a filter receptacle with a 0.45 µm glass fiber filter. The material on the toothbrush was also rinsed onto the filter with clean stream water. The foam square and toothbrush were cleaned in between samples. Water was removed from the filter using a hand vacuum pump. After extracting most of the water (i.e., ¼ inch of water remains above the glass fiber filter), 3 to 5 drops of saturated $MgCO_3$ were added (no solid $MgCO_3$) while gently swirling the filter receptacle to ensure the entire sample received a light coating. Pumping continued until the water was gone and the filter was dry. The $MgCO_3$ was added to prevent acidification and additional conversion of chlorophyll-a to phaeophytin. If the water was not moved through the filter within a few minutes, then a second glass fiber filter with another vacuum pump was used and excess water transferred to the second filter receptacle. Each additional filter required to collect the sample was preserved with $MgCO_3$ as outlined above.

The receptacle on top of the vacuum pump was then removed and the glass filter folded over, so the sample material was protected on the inside of the filter. The glass fiber filter(s) were then placed on a paper coffee filter and the coffee filter was folded to entirely cover the fiber filter(s). The dry coffee filters were used to absorb any residual water that may have been present. The filters were then placed in a properly labeled, sealable plastic bag, and silica gel desiccant added. The sample bag was then placed in a cooler with ice. Immediately upon return to Iliamna, the samples were frozen and kept frozen until analyzed. Periphyton samples were sent to the ADF&G office in Fairbanks and were processed in the manner described in Ott et al. (2010). Samples were analyzed using a spectrophotometer and a standardized reference solution derived from fresh spinach leaves. Total chlorophyll-a, -b, and -c were calculated using the tri-chromatic equation (American Public Health Association 1992). Additionally, phaeophytin was calculated to determine if any chlorophyll-a conversion occurred, and to correct chlorophyll-a concentrations for the presence of phaeophytin. Phaeophytin-corrected chlorophyll-a (mg/m^2) results were used for data analysis.

RESULTS AND DISCUSSION

Periphyton biomass sampling dates are presented in Table 7. With some exceptions, 10 samples were collected and analyzed each year, at each site, during times of moderate to low flow. Phaeophytin-corrected chlorophyll-a (mg/m^2) results are presented for analysis.

Table 7. Periphyton collection dates by sampling reach and year with number of samples analyzed in parentheses.

Stream reach	2010	2011	2012	2013
NFK	August 4 (7)	July 1 (10)	June 27 (11)	June 25 (10)
SFK	August 5 (10)	June 30 (10)	June 28 (10)	June 25 (9)
UT	September 1 (10)	July 1 (10)	June 26 & 28 (21)	June 24 (10)

Mean chlorophyll-a concentrations for each sampling reach by year are presented in Figure 9. Mean chlorophyll-a concentrations ranged from 1.6 mg/m^2 (SFK, 2012) to 22.7 mg/m^2 (UT, 2011). Chlorophyll-a concentrations were highest overall in UT, and the NFK and SFK samples were lower and like each other. UT had the largest data set and the greatest variability of individual samples, with a low of 1.71 mg/m^2 (2010) and a high of 66.43 mg/m^2 (2012). Individual chlorophyll-a concentrations can be found in Appendix 3.

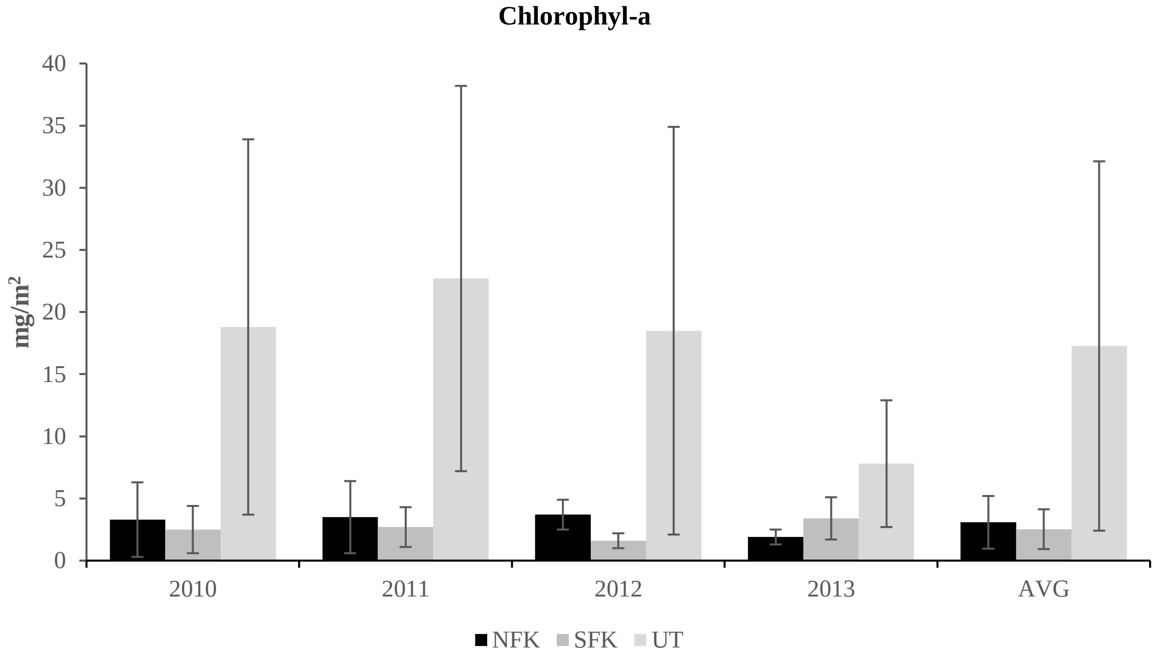


Figure 9. Mean chlorophyll-a concentrations (±1 SD) for NFK, SFK, and UT monitoring reaches.

Chlorophyll-a concentrations indicate primary production is highest in UT. This could be attributable to UT having a more stable hydrologic regime, likely due to the influence of groundwater in this system, which provides for more stable flows throughout the year. Other factors unique to UT (e.g., water temperatures, stream geomorphology) may also contribute to higher primary production.

5. AQUATIC INVERTEBRATES

OVERVIEW

Aquatic invertebrates are ubiquitous in almost all streams and rivers. These invertebrates are an important food supply for fish, including salmonids (Groot and Margolis 1991) and are useful indicators of environmental conditions that could affect fish populations (Barbour et al. 1999; Hodkinson and Jackson 2005).

METHODS

ADF&G deployed drift nets annually (2010-2013) at each monitoring reach to sample drifting invertebrates. A modified version of the rapid bioassessment technique developed by the USEPA (Barbour et al. 1999) was used. The modification consists of more replicates to retain more quantitative features in the sampling program. In 2011, surber samplers were added to the program to expand methods and account for invertebrates not drifting in the water column.

Drift Nets

At each of the three monitoring sites, five drift nets were installed in riffle habitat with the open end of the net facing upstream. Nets were placed along a transect perpendicular to the flow (Figure 12) and were numbered from right (1) to left (5) looking downstream. The drift nets used were 45.7 cm (18 in) wide by 30.5 cm (12 in) deep with 350 µm mesh size. The water depth at the inlet to the drift net and the mean water velocity in the mouth of each net were measured with a flow meter and recorded to allow for invertebrate density calculations (Figure 10).

Figure 10. Drift net configuration for macroinvertebrate sampling and ADF&G staff recording water depth and velocity, NFK monitoring reach, June 27, 2012.

After one hour, the drift nets were removed and placed along the stream margin with the open end on the streambank and the cod end in the water to keep the sample wetted. Materials in the net were flushed into the cod end by splashing water on the outside of the net. After all debris and insects were rinsed from the net into the cod end, the water was decanted, and the contents transferred to a labeled sample container. Ninety percent denatured ethanol was added to the containers to completely submerge and preserve the samples. Samples were packaged and brought back to Anchorage and then delivered to the University of Alaska, Alaska Natural Heritage Program – Aquatic Ecology lab for sorting and identification.

Surber Sampling

Aquatic invertebrate sampling with Surber samplers occurred at each monitoring reach in 2011, 2012, and 2013. Surber samples were collected on the same day as the drift samples. Sampling typically took place during medium to low-flow conditions and was conducted in the first shallow rifle downstream from the drift net sampling location. Riffles typically contain most species found in a particular stream and using Surber samplers only in shallow riffle habitat helps to standardize the sample method (Barbour et. al. 1999).

A shallow section (< 12-inches water depth) of the riffle was chosen for sampling and the first sample was collected near the right streambank where adequate flow was present. The Surber sampler was positioned in the riffle facing upstream with the horizontal sampling frame embedded in the gravel upstream of the net opening. The horizontal sampling frame measured 0.31-meter by

0.31-meter for a sampling area of 0.096 m^2 per sample. The net in the Surber samplers was 0.3 mm mesh.

ADF&G personnel approached the sampling location from downstream to avoid disturbing the sampling area. Starting with larger substrate (cobbles or large gravel), rocks were hand scrubbed in front of the net so that any invertebrates dislodged would flow into the collection net. These rocks were then placed away from the sampling area. After the larger rocks were scrubbed and removed, the entire area within the horizonal frame was disturbed with hands and fingers to a depth of 4 to 7 centimeters for about three minutes. After the entire area was scrubbed, the contents of the cod end of the net were washed into a sample jar. The surber sampler was moved towards the center of the stream and the process repeated two more times for a total of three samples at each site. Ninety percent denatured ethanol was added to the containers to completely submerge and preserve the samples. Samples were packaged and brought back to Anchorage and then delivered to the University of Alaska, Alaska Natural Heritage Program – Aquatic Ecology lab for sorting and identification.

Aquatic invertebrate sampling dates varied each year due to water conditions, weather, and scheduling and are listed in Table 8. Drift net samples were collected each year of monitoring (2010-2013) and surber samplers were used from 2011-2013. Invertebrate sampling typically took place during medium to low-flow conditions.

Table 8. Aquatic invertebrate sampling dates by monitoring reach.

Stream reach	2010[1]	2011[2]	2012[2]	2013[2]
NFK	August 31	July 1	June 27	June 25
SFK	August 3	June 30	July 13	June 25
UT	September 2	July 1	June 26	June 24

[1] Drift net sampling only

2 Drift nets and surber samplers used for sample collection.

RESULTS AND DISCUSSION

Drift Net

Aquatic invertebrate mean densities from drift net sampling for each sampling reach by year, with cladocerans and copepods removed, are presented in Table 9. Based on four years of drift net sampling from 2010 through 2013, the mean density of aquatic invertebrates, without cladocerans or copepods included, was highest in the SFK reach (5.31/m^3; SD = 7.42) and lowest in the UT reach (2.13/m^3; SD = 1.47). The mean density in the NFK was 4.25/m^3 (SD = 3.04), when cladocerans and copepods are removed.

Table 9. Drift net aquatic invertebrate sampling densities (mean density/m^3) by sampling reach with copepods and cladocerans removed (standard deviation shown in parenthesis).

Stream reach	2010	2011	2012	2013	Average
NFK	0.62 (0.31)	4.33 (0.79)	5.39 (1.92)	6.64 (3.76)	4.25 (3.04)
SFK	2.73 (0.96)	3.41 (1.29)	9.42 (14.96)	5.66 (0.84)	5.31 (7.42)
UT	0.45 (0.27)	3.37 (1.03)	1.17 (0.23)	3.52 (0.28)	2.13 (1.47)

The SFK reach drift nets contained large numbers of copepods and cladocerans, which were not present in high numbers in the other two systems (Appendix 4). For example, the SFK cumulative count of cladocerans and copepods in all samples from all four years of monitoring was 10,766, while the cumulative count of cladocerans and copepods in all samples from all four years in both the NFK and UT combined was 236.

The monitoring reach with the highest abundance of EPT organisms varied by year with the SFK reach having the highest abundance two out of the four years monitored (2010, 2012), but having the lowest percent composition all four years monitored (Table 10; Figure 11). The NFK reach and UT reach had the highest abundance of EPT organisms in 2011 and 2013, respectively. The UT reach had the highest percent of EPT organisms three out of four years monitored while the NFK reach had the highest percent in 2011 (Figure 12). The UT reach had both the highest count of EPT organisms, 619 (2013) and the lowest count, 224 (2010; Figure 13).

Table 10. Percent composition and total abundance (in parenthesis) of EPT, and dominant taxon from drift net samples.

NFK	2010	2011	2012	2013
EPT taxa	36.9% (255)	35.3% (438)	17.1% (415)	11.6% (311)
Ephemeroptera	23.3% (161)	13.6% (169)	13.0% (316)	6.6% (178)
Plecoptera	4.5% (31)	0.2% (3)	0.5% (12)	0.4% (12)
Trichoptera	9.1% (63)	21.4% (266)	3.6% (87)	4.5% (121)
Dominant taxon	19% (131)	18.3% (227)	24.9% (603)	23.2% (623)
SFK				
EPT taxa	6% (577)	14.9% (288)	4.4% (511)	3.1% (340)
Ephemeroptera	1.8% (169)	11.0% (212)	4.2% (488)	2.2% (236)
Plecoptera	3.7% (348)	0.4% (7)	0.1% (10)	0.5% (58)
Trichoptera	0.5% (50)	3.6% (69)	0.1% (13)	0.4% (46)
Dominant taxon	44.7% (4,239)	14.6% (282)	66.1% (7,725)	20.0% (2,158)
UT				
EPT taxa	38.6% (224)	20.0% (401)	22.3% (314)	20.2% (619)
Ephemeroptera	13.6% (79)	8.7% (175)	8.4% (118)	5.6% (173)
Plecoptera	5.7% (33)	0.3% (7)	1.0% (14)	0.6% (18)
Trichoptera	19.3% (112)	10.9% (219)	12.9% (182)	14.0% (428)
Dominant taxon	15.5% (90)	15.4% (309)	17.8% (250)	18.6% (572)

Taxa richness (number of unique taxa) from all four years of drift net sampling for all aquatic invertebrates ranged from 33 to 41 in the NFK, 31 to 33 in the SFK, and 32 to 41 in the UT. Although the SFK reach had the highest overall aquatic invertebrate abundance and average density, it had the lowest taxa richness Average taxa richness was 37 in the NFK, 36 in the UT, and 32 in the SFK. EPT taxa richness in drift net sampling was similar across sites ranging from 12 to 15 in the NFK and 10 to 14 in the both the SFK and UT reaches.

The SFK reach had the highest relative abundance of a single dominant aquatic taxa in three out of the four years monitored (2010, 2012, and 2013) with the highest count in 2012 of 7,725 organisms (class Copepoda). The relative abundance of a single dominant aquatic taxa was relatively consistent in the NFK and UT and similar across years between the two reaches while the SFK reach showed more variability (Table 10). The NFK reach and UT reach were similar in percent and number of dominant taxa which typically made up less than 20 percent of the aquatic invertebrate drift net samples and always less than 25 percent. The SFK reach showed much more variability in dominant taxa percentage with ranges from 14.6 percent to 66.1 percent.

The greatest percent composition of a single dominant aquatic taxon alternated by year between the NFK and the SFK reaches, however, in years when the NFK reach had a higher percent composition, the SFK reach still had higher numbers of organisms from a dominant taxon. The highest percent composition of a single dominant aquatic taxa occurred in the SFK reach at 66.1% in 2012 (Table 10).

The NFK reach’s dominant taxon was Podocopa, a subclass Ostracoda, in 2010 (107 organisms), order Trichoptera in 2011 (227), and order Diptera in 2012 (603) and 2013 (623). The SFK reach’s dominant taxon was the order Cladocera in 2010 (4,191 organisms), order Diptera in 2011 (282) and 2013 (2,158), and class Copepoda (unidentified) in 2012 (7,725). In the UT reach the dominant taxon was Orthocladinae, a subfamily of Chironomidae in 2010 (74 organisms) and 2012 (250), and order Diptera in 2011 (309) and 2013 (572).

EPT percent composition at the SFK reach are masked by high numbers of other taxa, such as cladocerans, copepods, and diptera. Ephemeroptera and Trichoptera taxa were found in relatively high numbers in all three reaches each year compared to Plecoptera taxa which were generally scarce in the samples (except for the SFK reach in 2010). Of the EPT taxa, the NFK and SFK reach was typically dominated by Ephemeroptera (mayflies) while the UT reach was dominated by Trichoptera (caddisflies). Plecoptera (stoneflies) dominated the SFK reach in 2010 and Trichoptera dominated the NFK in 2011.

Ephemeroptera made up the largest percentage of EPT community in both the NFK and SFK reaches three out of the four years of drift net sampling while Trichoptera had the largest percentage in the UT reach all four years (Table 10; Figures 11-13).

The SFK reach had the highest abundance of Ephemeroptera in all four years of monitoring yet the lowest percent composition of Ephemeroptera in three out of the four years of monitoring. The NFK reach had the highest percent composition of Ephemeroptera in all four years of monitoring. Plecoptera abundance was extremely low and similar across the three reaches in 2011 and 2012. The SFK had the highest abundance of Plecoptera but the UT had the highest percent composition of Plecoptera in 2010 and 2013. In general, however, all three sites had similar percent composition of Plecoptera in drift net samples. The UT reach had the highest abundance and percent composition of Trichoptera in three out of the four years of drift net sampling, while the NFK reach had the highest abundance and percent composition in 2011.

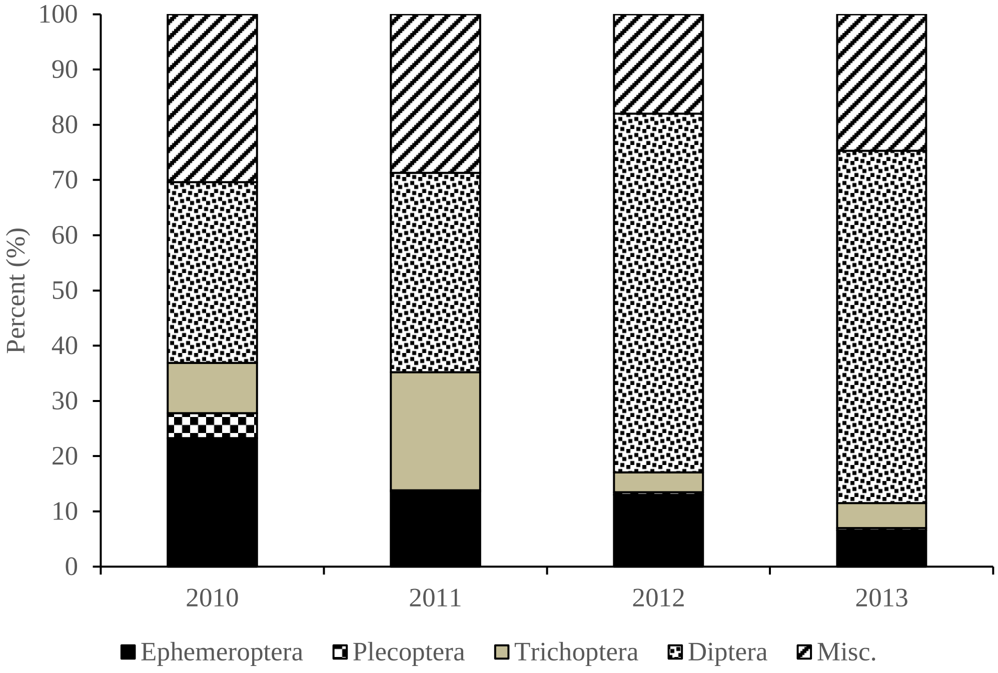


Figure 11. Aquatic invertebrate community composition in NFK monitoring reach (2010-2013, Drift Net Sampling).

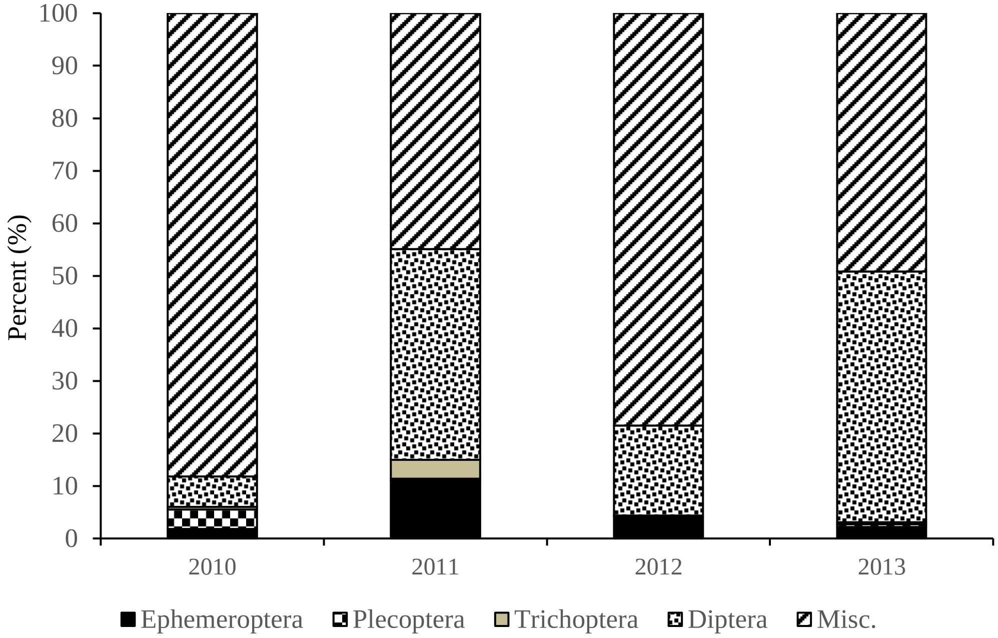


Figure 12. Aquatic invertebrate community composition in SFK monitoring reach (2010-2013, Drift Net Sampling).

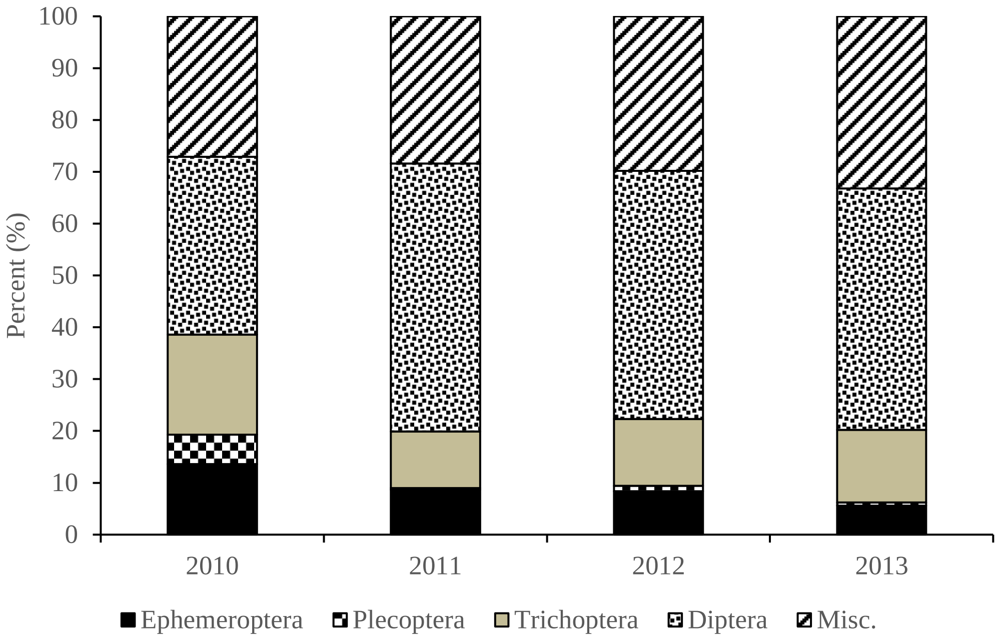


Figure 13. Aquatic invertebrate community composition in UT monitoring reach (2010-2013, Drift Net Sampling).

Chironomidae composed a greater percentage of the aquatic invertebrate community than EPT taxa except in 2010 (all three reaches) and in 2011 (NFK reach). SFK reach had the lowest percentages of both EPT (3.1%, 2013) and Chironomidae (5.4%, 2010). Chironomidae composition ranges were similar in the NFK reach (23.2% to 39.6 %) and UT reach (19.3% to 35.9%) (Figures 14-16). Chironomidae abundance and percent composition also were similar in the NFK and UT reaches with ranges typically between 20 and 40 percent. SFK reach chironomidae percent compositions were lower, ranging from 5 to 20 percent.

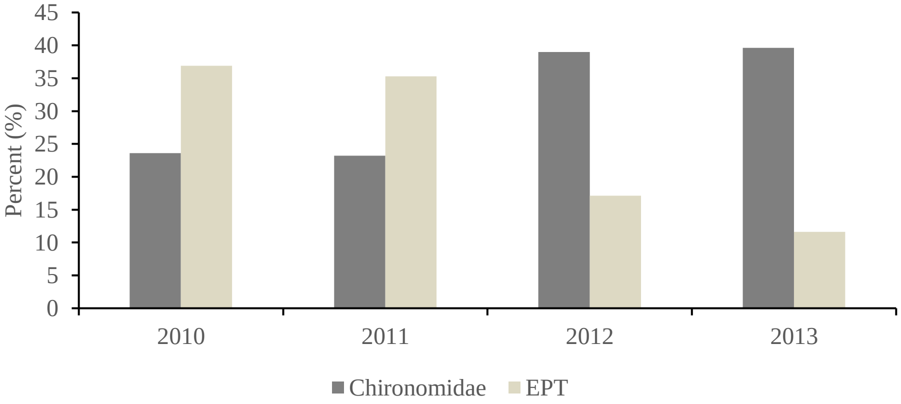


Figure 14. Percent Chironomidae and percent EPT in the NFK monitoring reach from drift net sampling (2010-2013).

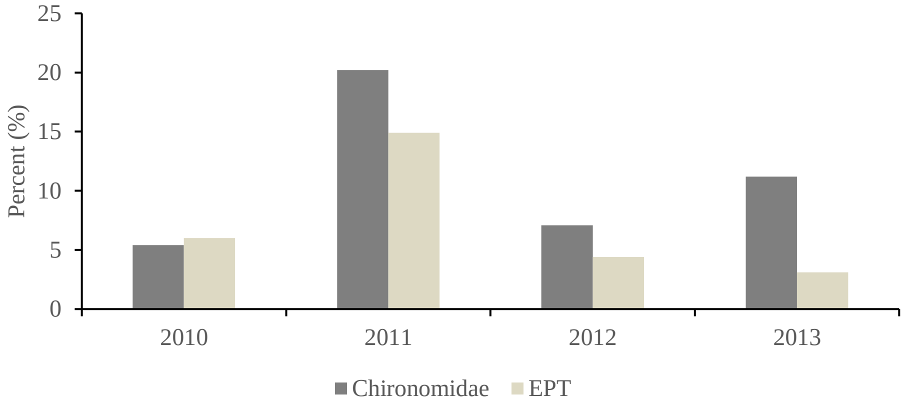


Figure 15. Percent Chironomidae and percent EPT in the SFK monitoring reach from drift net sampling (2010-2013).

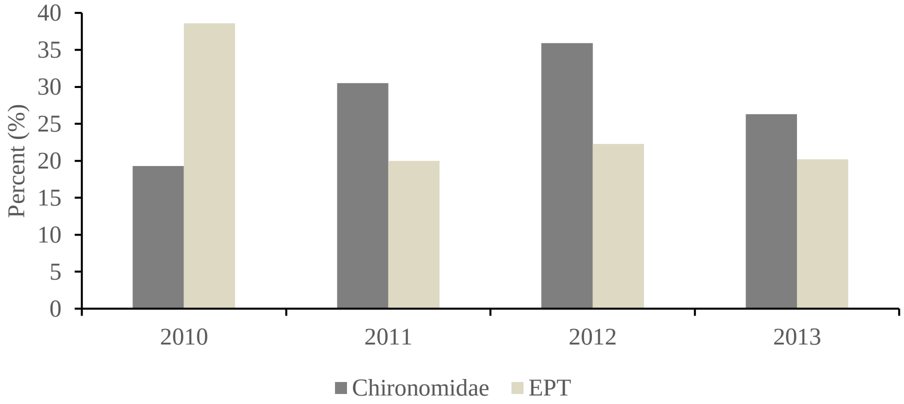


Figure 16. Percent Chironomidae and percent EPT in the UT monitoring reach from drift net sampling (2010-2013).

Surber Samplers

Based on Surber sampling results, the mean density of aquatic invertebrates was highest in the NFK monitoring reach and lowest in the SFK monitoring reach (Table 11). The higher density of aquatic invertebrates in the NFK monitoring reach was attributed to high counts of invertebrates from the Order Diptera (Flies) which comprised over 75% of the invertebrate counts in NFK samples. The Order Diptera was also the most prevalent order represented in SFK samples while the Order Ephemeroptera (mayflies) was the most common order represented in UT Surber samples. Cladocerans and copepods were not removed from the data set since they were captured very infrequently, likely a result of the sampling method as they were frequently captured in the drift net sampling. No cladocerans or copepods were captured in the Surber samplers with one exception, 14 copepods and 1 cladoceran were captured in the Surber samplers in the SFK in 2012.

Table 11. Surber sampler aquatic invertebrate densities (mean density/m^2) by sampling reach (standard deviation shown in parenthesis).

Stream reach	2011	2012	2013	Average
NFK	4,664 (3,307)	19,321 (10,977)	6,968 (5,591)	10,318 (9,342)
SFK	581 (424)	431 (372)	359 (167)	457 (310)
UT	1,790 (880)	1,672 (1,075)	502 (331)	1,322 (944)

Taxa richness (number of unique taxa) from all three years of Surber sampling for all aquatic invertebrates ranged from 28 to 33 in the NFK, 14 to 17 in the SFK, and 23 to 24 in the UT monitoring reaches. EPT taxa richness ranged from 14 to 16 in the NFK, 6 to 8 in the SFK, and 9 to 12 in the UT monitoring reaches. Based on Surber sampling results, the SFK had the lowest taxa richness of the three sites.

The monitoring reach with the highest abundance of EPT organisms using Surber samplers was consistently the NFK. However, the UT monitoring reach had the highest percent composition and the NFK monitoring reach had the lowest percent composition of EPT organisms in all three years of Surber sampling. The highest count of EPT organisms using Surber samplers was in 2012 in the NFK monitoring reach (671) and the lowest count was in 2013 in the SFK monitoring reach (42). Order Plecoptera accounted for the fewest EPT organisms while the Order Ephemeroptera were the most common EPT organisms in Surber samplers (Table 12).

The NFK reach had the highest abundance and greatest percent composition of a single dominant aquatic taxon for the three years of Surber sampling (Table 12). The dominant taxa in the NFK were *Chironomidae tanytarsini* in 2011 and *Chironomidae orthocladinae* in 2012 and 2013 (both Order Diptera). The dominant taxa in the SFK were *Chironomidae orthocladinae* in 2011 and *Simuliidae simulium* in 2012 and 2013 (both Order Diptera), and the dominant taxa in the UT reach were *Baetidae baetis* in 2011 and *Heptageniidae cinygmula* in 2012 and 2013 (both Order Ephemeroptera) (Appendix 4).

Table 12. Percent composition and total abundance (in parenthesis) of EPT, and dominant taxon from Surber samplers.

NFK	2011	2012	2013
EPT taxa	29.8% (387)	12.5% (671)	17.0% (330)
Ephemeroptera	21.4% (278)	6.3% (339)	13.2% (256)
Plecoptera	0.4% (5)	0.4% (19)	0.4% (8)
Trichoptera	8.0% (104)	5.8% (313)	3.4% (66)
Dominant taxon	29.4% (382)	41.2% (2,217)	36.8% (714)
SFK			
EPT taxa	43.2% (70)	39.2% (47)	42.0% (42)
Ephemeroptera	30.9% (50)	36.7% (44)	29.0% (29)
Plecoptera	7.4% (12)	0 % (0)	12.0% (12)
Trichoptera	4.9% (8)	2.5% (3)	1.0% (1)
Dominant taxon	27.8% (45)	21.7% (26)	20.0% (20)
UT			
EPT taxa	43.7% (218)	59.2% (276)	64.3% (90)
Ephemeroptera	31.9% (159)	40.6% (189)	35.7% (50)
Plecoptera	8.2% (41)	7.3% (34)	22.1% (31)
Trichoptera	3.6% (18)	11.4% (53)	6.4% (9)
Dominant taxon	19.8% (99)	21.7% (101)	25.0% (35)

The NFK monitoring reach had the highest abundance but the lowest percent composition of Ephemeroptera in all three years of monitoring. The UT reach had the highest percent composition and the SFK reach had the lowest abundance of Ephemeroptera in all three years of Surber sampling. The UT reach had the highest abundance and the highest percent composition of Plecoptera in all three years of surber sampling. Plecoptera were rare in NFK and SFK reach samples. In 2011, the NFK reach had the highest abundance and percent composition of Trichoptera while in 2012 and 2013 the highest abundance occurred in the NFK reach and the highest percent composition of Trichoptera occurred in the UT reach samples. Trichoptera were also rare in the SFK reach samples. The NFK reach had the highest abundance and percent composition of Diptera in all three years of surber sampling (Figures 17-19).

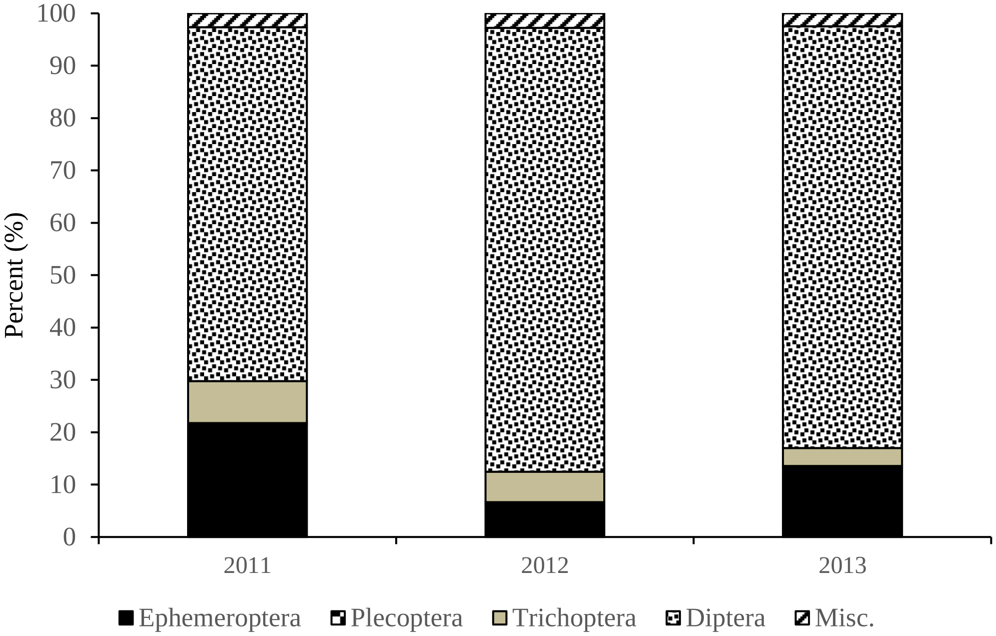


Figure 17. Aquatic invertebrate community composition in North Fork Koktuli River monitoring reach (2011-2013, Surber sampling).

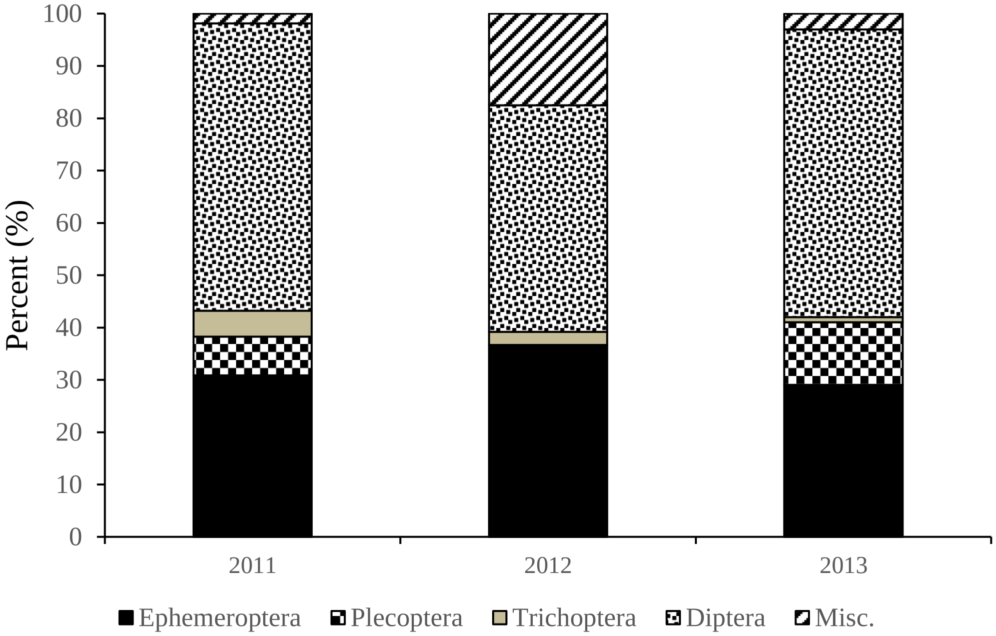


Figure 18. Aquatic invertebrate community composition in South Fork Koktuli River monitoring reach (2011-2013, Surber sampling).

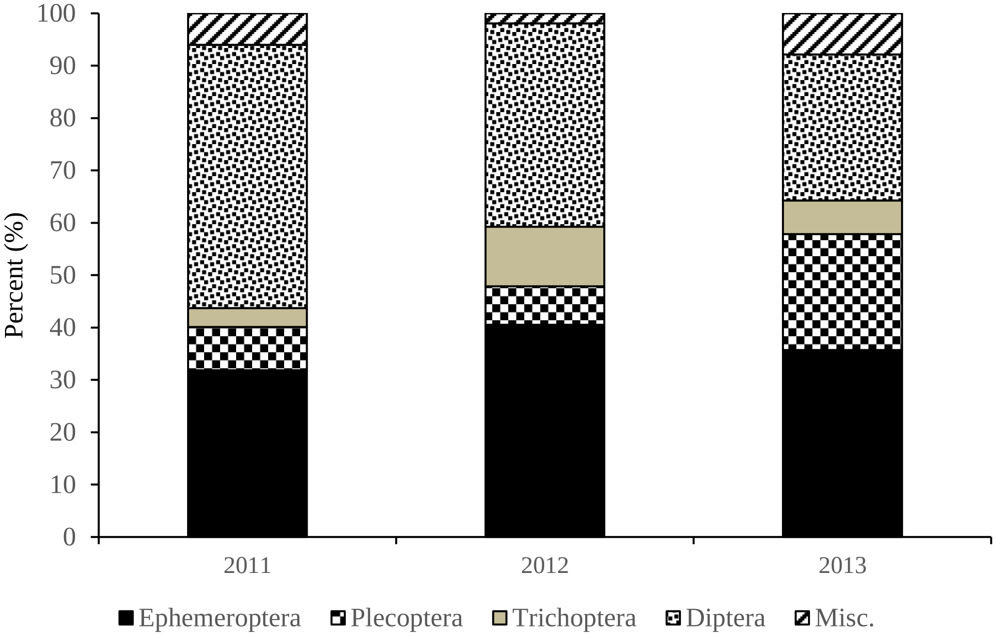


Figure 19. Aquatic invertebrate community composition in Upper Talarik Creek monitoring reach (2011-2013, Surber sampling).

Ephemeroptera had the highest abundance and made up the largest percentage of the EPT community in all three monitoring reaches for all three years of surber sampling. Trichoptera were the second most common member of the EPT community in the NFK (all three years) and in the SFK and UT in 2012. Plecoptera were the second most common member of the EPT community in the SFK and UT in 2011 and 2013 surber samples (Table 12 and Figures 17-19). In three years of Surber sampling, Chironomidae composed a greater percentage of the aquatic invertebrate community than EPT taxa in the NFK monitoring reach while EPT taxa were more common than Chironomidae in SFK and UT monitoring reaches (Figures 20-22).

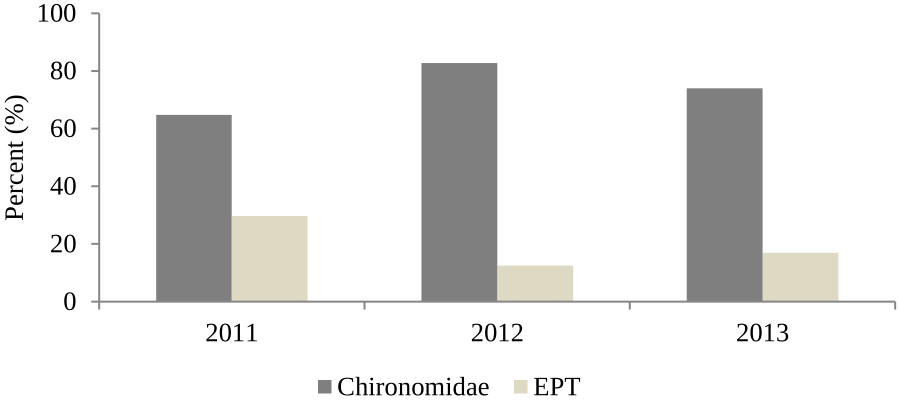


Figure 20. Percent Chironomidae and percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) in North Fork Koktuli monitoring reach from surber sampling (2011-2013).

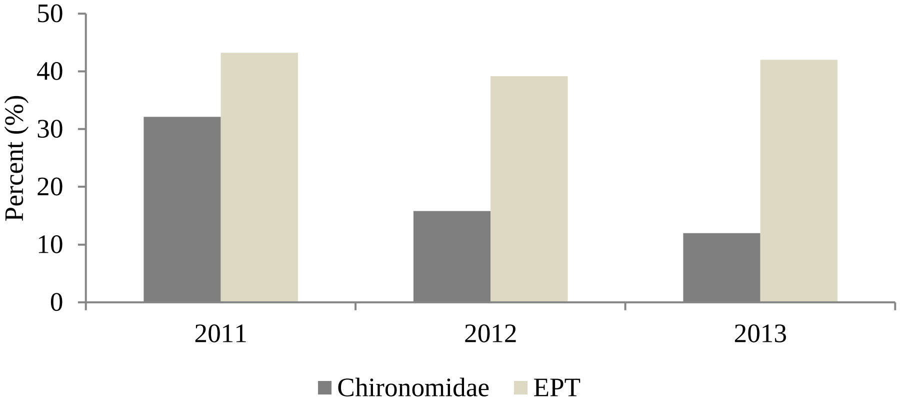


Figure 21. Percent Chironomidae and percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) in South Fork Koktuli monitoring reach from surber sampling (2011-2013).

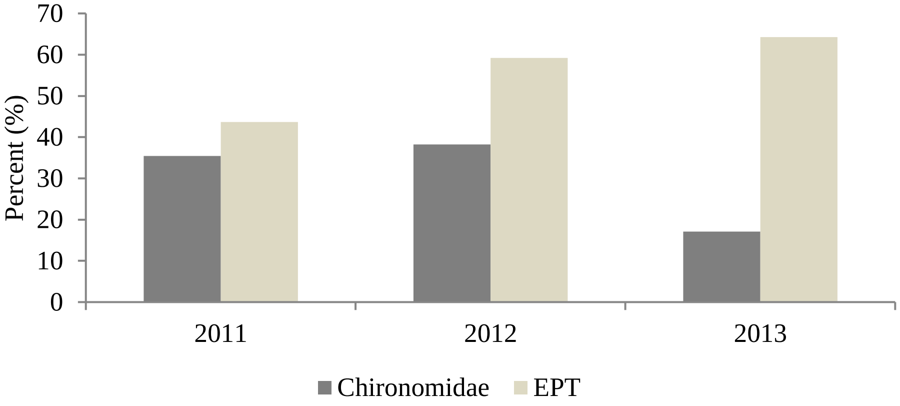


Figure 22. Percent Chironomidae and percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) in Upper Talarik Creek monitoring reach from surber sampling (2011-2013).

More detailed information on aquatic invertebrate sample results from the ADF&G monitoring reaches is included in Appendix 4. This includes results from both drift nets and surber sampling.

6. ELEMENT CONCENTRATIONS IN FISH

OVERVIEW

Water bodies in the region of an ore deposit can exhibit higher than normal background element concentrations. Element concentrations can be monitored through water quality, sediments, invertebrates, and fish. Sampling fish tissue provides a direct assessment of element concentrations and can be used to establish baseline concentrations in fish tissues. Fish tissue analysis also includes measures of fish condition, such as percent solids and percent lipids (Post and Parkinson 2001; Weber et al. 2003; Hanson et al. 2010; Rinella et al. 2012). Dry weight can be used as an index of fish condition because it directly relates to nutritional reserves of the fish (Sutton et al. 2000).

METHODS

Juvenile Dolly Varden were collected in each of the three monitoring reaches using minnow traps baited with salmon eggs (Figure 23). Whirl-paks® (with puncture holes) or nylons were used as bait sacks and filled with commercially available salmon roe. Traps were numbered, marked with flagging, and placed in the stream in slow-moving current. Seven to ten traps per monitoring reach were set during each survey/sampling event. Fish sampling dates with minnow traps are presented in Table 13. Late summer or early fall is the preferred time to sample, as it allows juvenile Dolly Varden to have the maximum residency time within the monitoring reach before moving to overwintering areas.

Table 13. Fish sampling dates by sampling reach.

Stream reach	2010	2011	2012	2013
NFK	Aug. 31-Sept. 1	Sept. 6-7	Aug. 29-30	June 13-14 Aug. 26-27
SFK	Aug. 30-31	Sept. 7-8	Aug. 29-30	June 13-14 Aug. 26-27
UT	Sept. 1-2	Sept. 6-7	Aug. 29-30	June 12-13 Aug. 26-28

Traps were fished as close to 24 hours as logistics allowed. Traps were checked starting with the most downstream trap to minimize the chance of recapturing the same fish in a subsequent trap. For each reach, a maximum of 15 juvenile Dolly Varden, between 90- and 140-mm fork length (FL), were retained for whole body element analyses. Fish were selected from this length range to ensure that minimum weight requirements for laboratory analyses were met, and to minimize age-related variability. Fish retained for element analyses were measured to the nearest mm (FL) using a measuring board and weighed individually with a digital scale to the nearest tenth of a gram. Retained fish were handled with nitrile gloves and each fish placed individually in a numbered sealable plastic bag and stored in an insulated cooler with an ice pack. Fish not retained were returned to the sample reach.

Figure 23. Baited minnow trap in UT monitoring reach (August 26, 2013).

Juvenile Dolly Varden were transported back to Iliamna where they were immediately frozen. Fish were then packaged and shipped to Anchorage where they were placed in the freezers at the ADF&G office. The fish were kept in their sealed bag in a sealed container in the freezer at ADF&G until prepared for shipment to Columbia Analytical Services, Inc. for analyses. ADF&G maintained written chain of custody for the samples. At the laboratory, whole body fish samples were homogenized, freeze dried, and ground prior to element analyses.

Whole body analyses of juvenile Dolly Varden tested for the following element concentrations: antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, silver, thallium, and zinc. Total percent solids and percent lipids were measured for each fish to assess body condition. Element concentrations were calculated on a dry weight basis, and percent lipids and solids were calculated on a wet weight basis. Columbia Analytical Services, Inc. performed the analyses according to their National Environmental Laboratory Accreditation Program-approved quality assurance program.

For samples with element concentrations below their respective Method Detection Limit (MDL), we used half the MDL during calculations and comparisons. Two-sample *t*-tests with Bonferonni's correction were conducted using Microsoft Excel® to compare the concentrations of certain elements among stream reaches.

RESULTS AND DISCUSSION

Fish sampling occurred between August 26 and September 8 from 2010 through 2013. The goal was to retain 15 juvenile Dolly Varden (90 to 140 mm FL) for analysis, but in some cases fewer than 15 fish were collected. Samples from 2013 were not analyzed due to a lab storage error resulting in the samples being lost.

Figures 24 through 39 depict mean concentrations of elements by monitoring reach by year. Mean concentrations of elements in Dolly Varden are variable within each reach by year. For example, mean concentration of copper in the SFK was 8.13 mg/kg in 2010, 10.36 mg/kg in 2011, and 4.40 mg/kg in 2012. Zinc concentrations appear to be the most consistent among reaches and across years. Several elements had their lowest concentrations in 2012 for each reach. Mean cadmium, selenium, and thallium concentrations were consistently highest in the SFK reach while concentrations were consistently highest for chromium, mercury, and silver in the NFK reach. With some exceptions, element concentrations tended to be lowest in UT. The UT reach had the highest mean concentration of only one of the analyzed elements (tin).

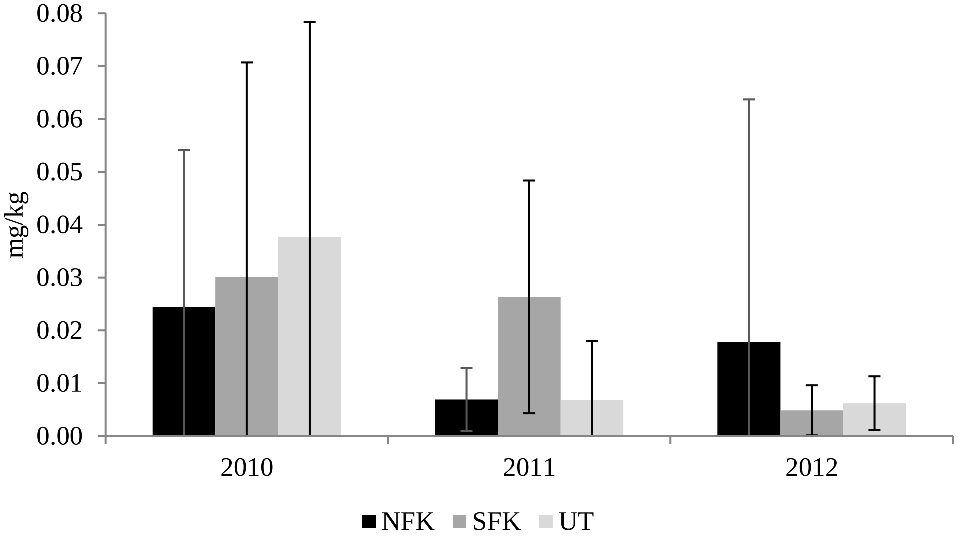


Figure 24. Mean whole body dry weight antimony (Sb) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches.

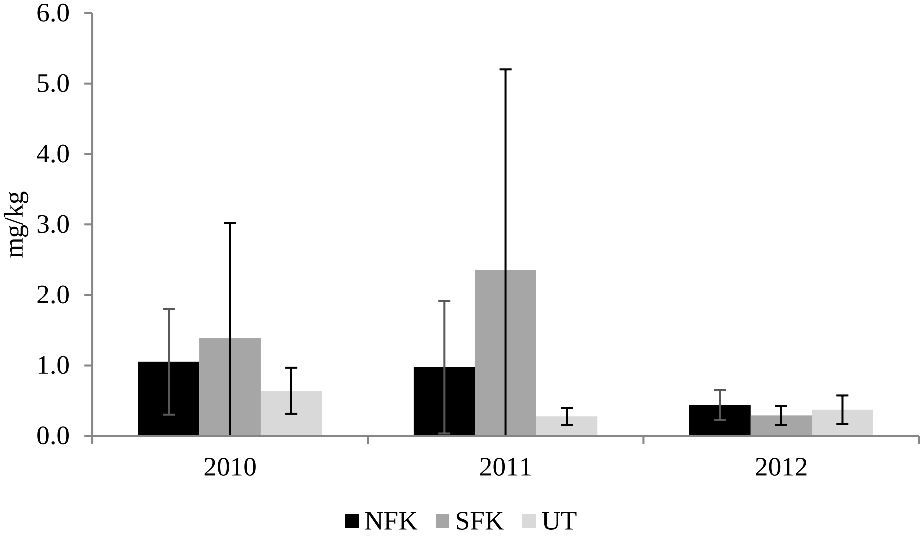


Figure 25. Mean whole body dry weight arsenic (As) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches.

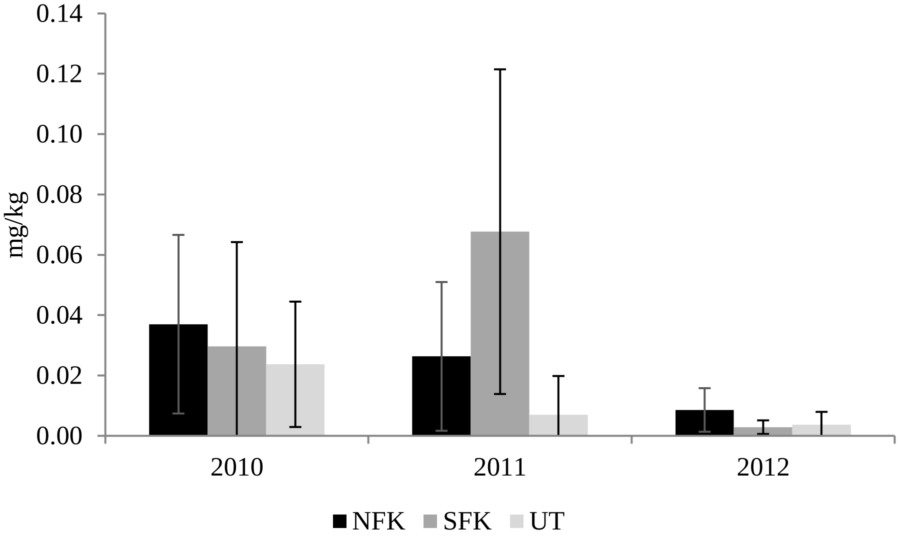


Figure 26. Mean whole body dry weight beryllium (Be) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches.

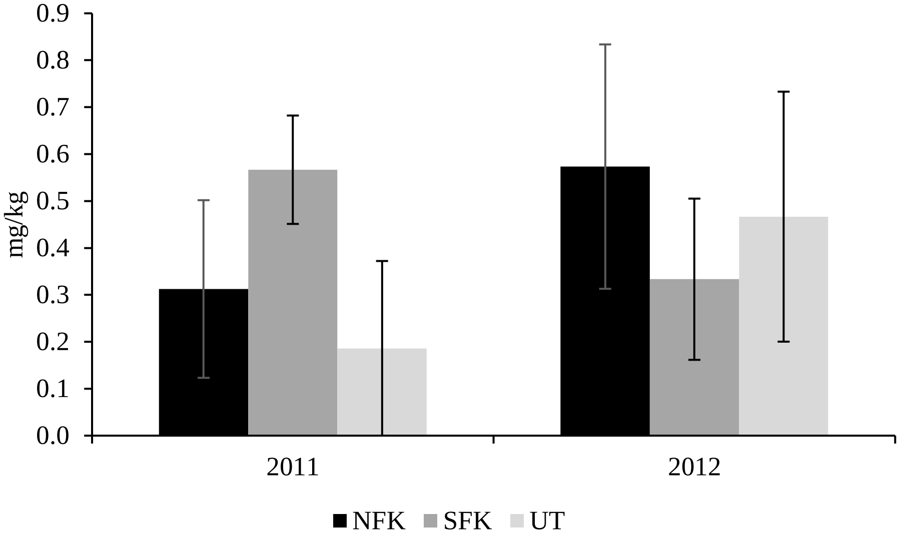


Figure 27. Mean whole body dry weight boron (B) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches (not analyzed in 2010).

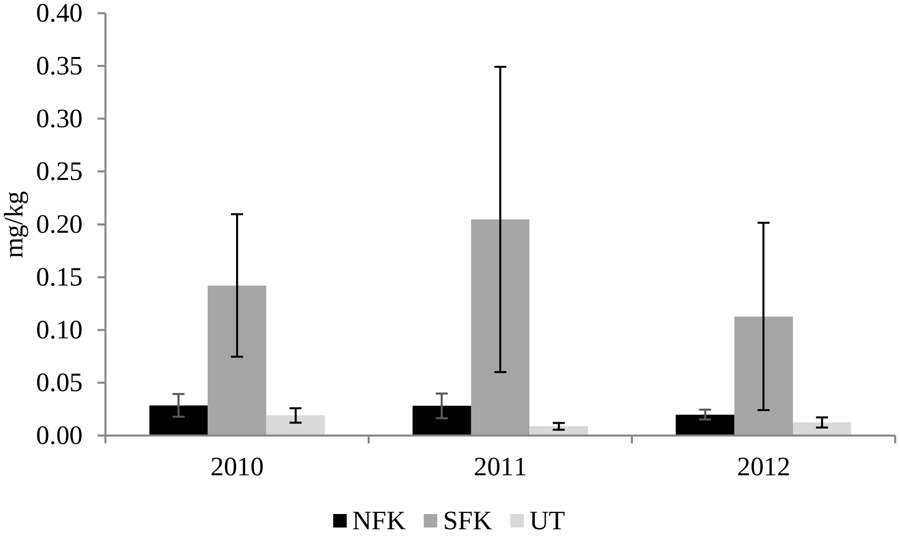


Figure 28. Mean whole body dry weight cadmium (Cd) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches.

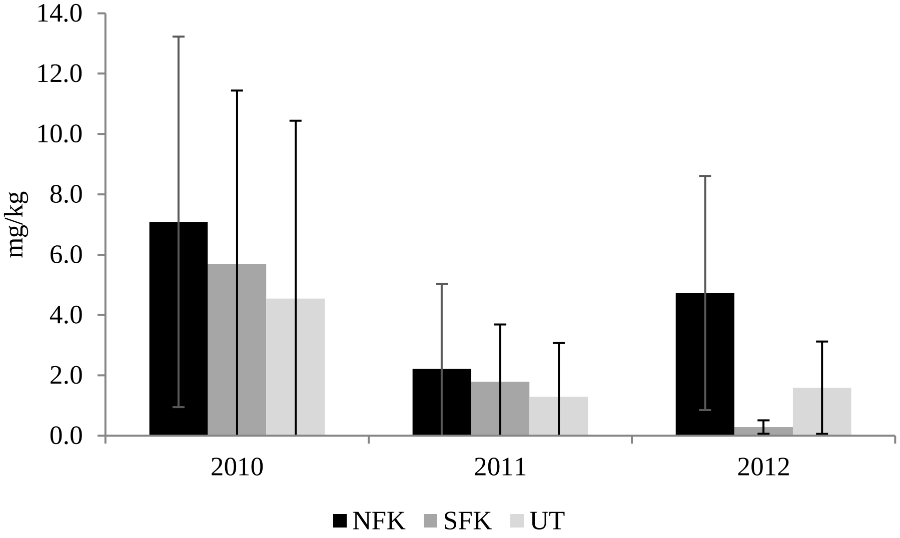


Figure 29. Mean whole body dry weight chromium (Cr) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches.

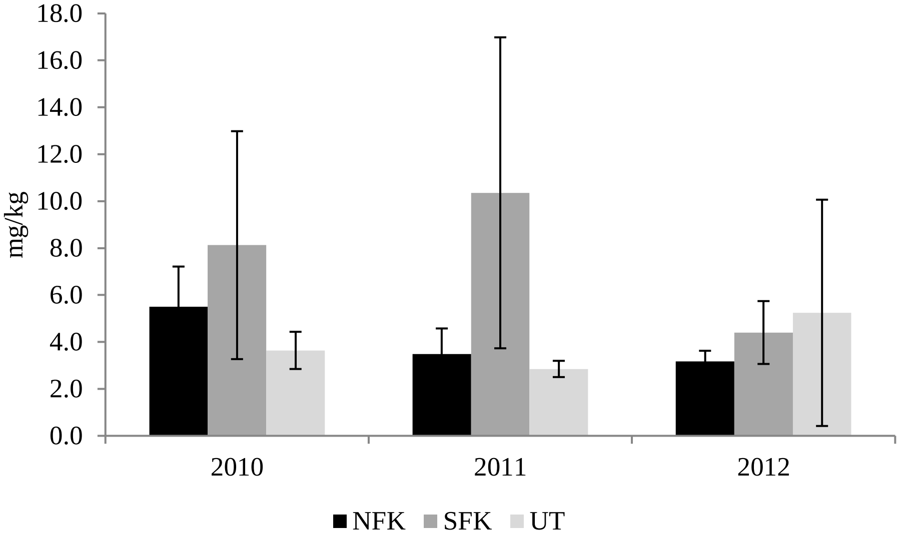


Figure 30. Mean whole body dry weight copper (Cu) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches.

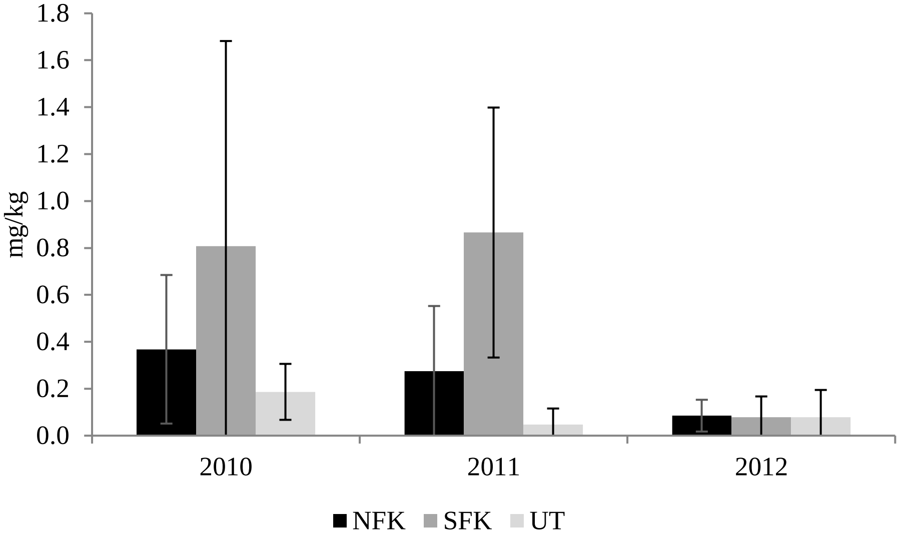


Figure 31. Mean whole body dry weight lead (Pb) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches.

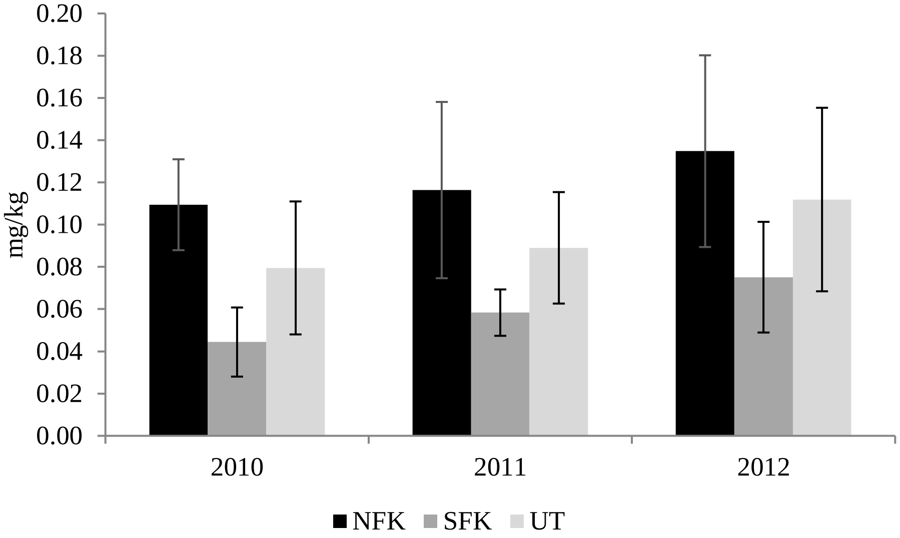


Figure 32. Mean whole body dry weight mercury (Hg) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches.

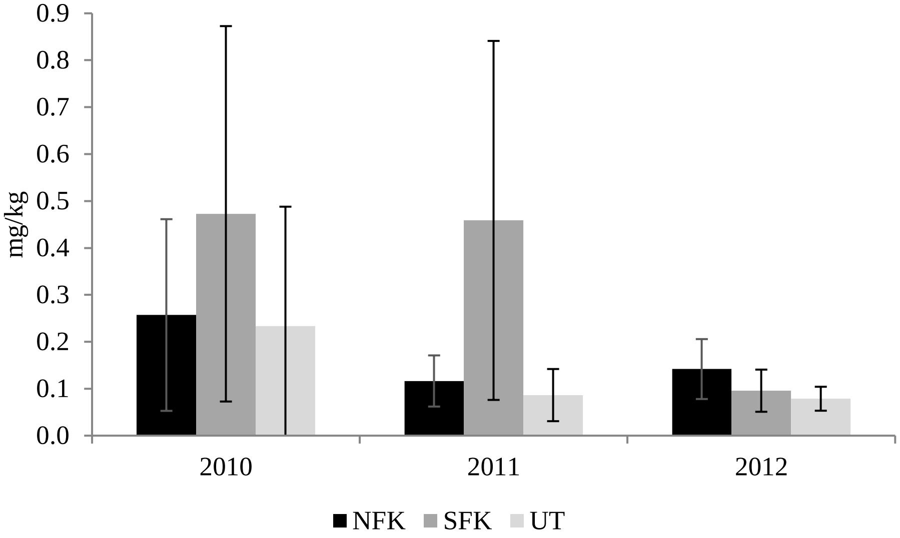


Figure 33. Mean whole body dry weight molybdenum (Mo) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches.

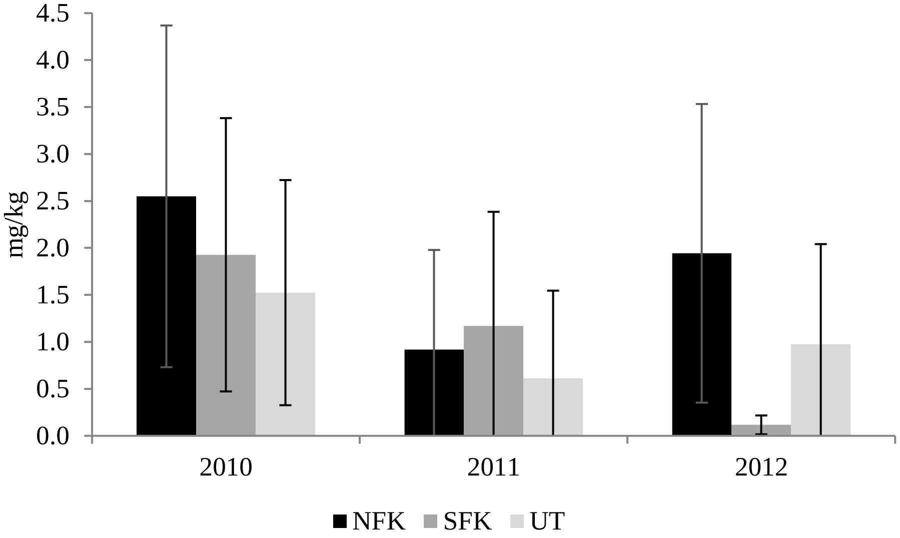


Figure 34. Mean whole body dry weight nickel (Ni) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches.

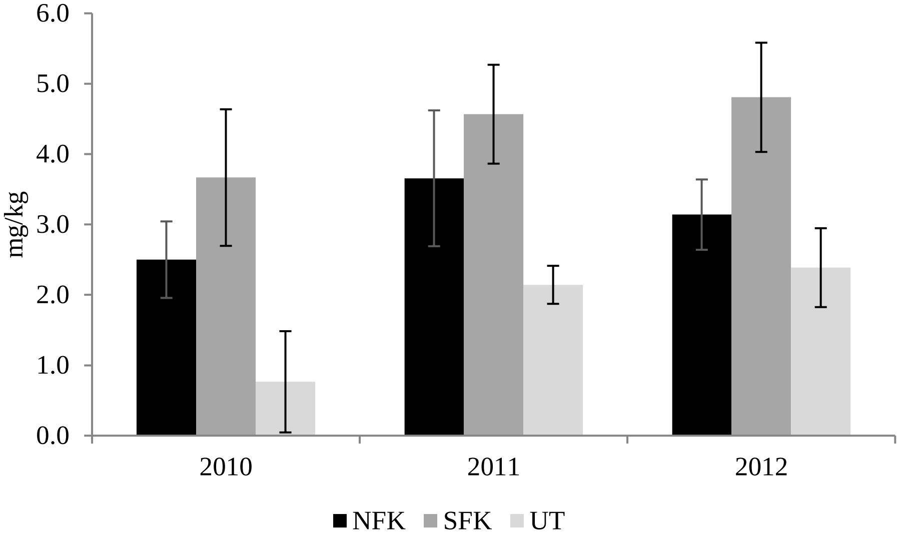


Figure 35. Mean whole body dry weight selenium (Se) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches.

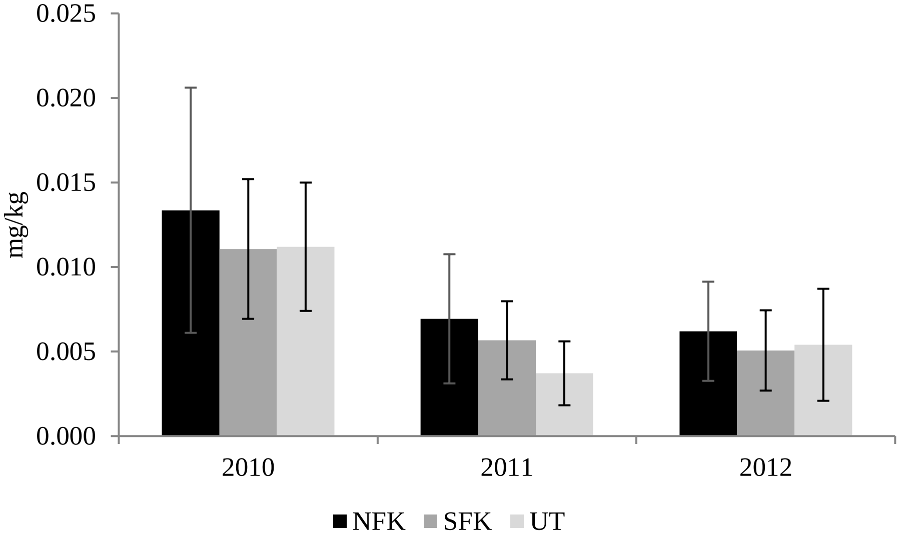


Figure 36. Mean whole body dry weight silver (Ag) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches.

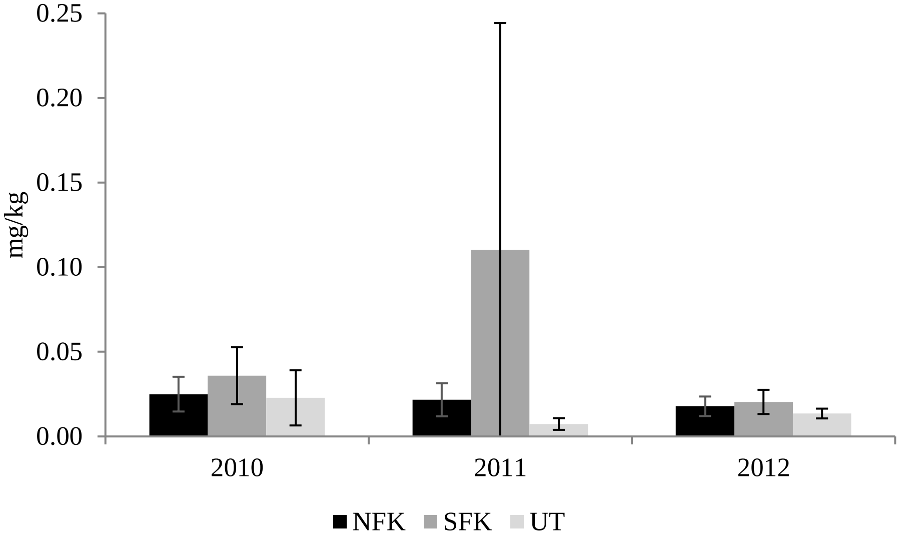


Figure 37. Mean whole body dry weight thallium (Tl) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches.

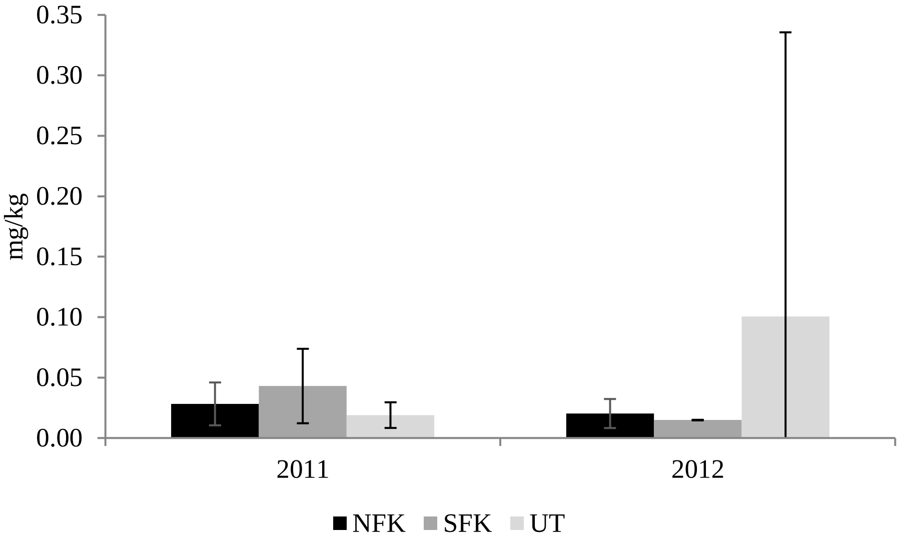


Figure 38. Mean whole body dry weight tin (Sn) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches (not analyzed in 2010).

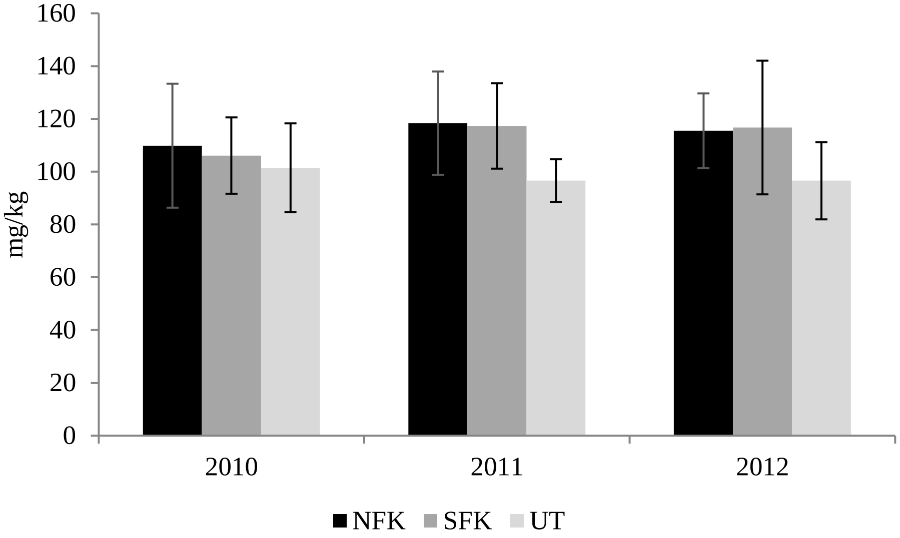


Figure 39. Mean whole body dry weight zinc (Zn) concentrations (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches.

Figure 40 depicts the mean percent solids and lipids content by monitoring reach. Mean percent solids content was nearly identical, ranging from 22.6% to 24.2%, for all three stream reaches across years.

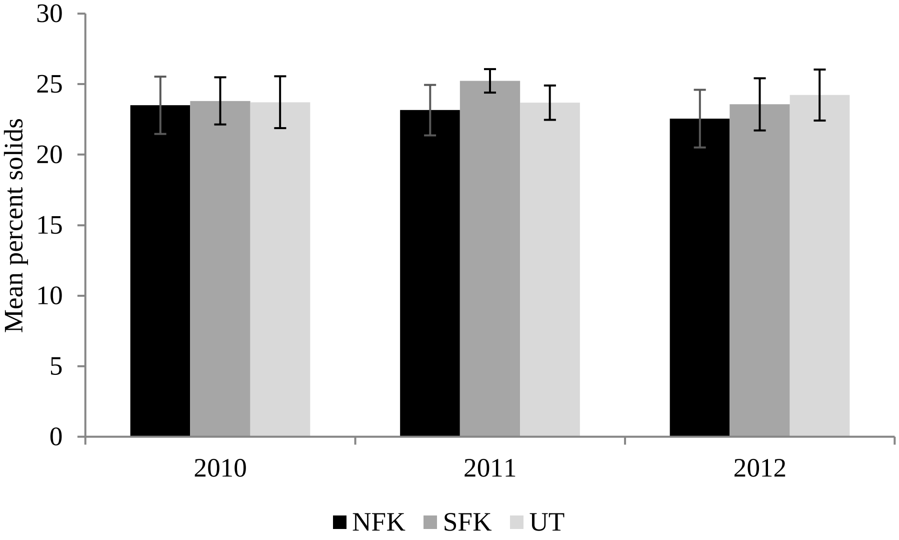


Figure 40. Mean percent solids (±1 SD) in juvenile Dolly Varden from NFK, SFK, and UT monitoring reaches.

There is particular concern with copper, cadmium, selenium, and zinc, because of their potential toxicity to salmonids and their potential to enter water bodies from mining activities. The USEPA lists each of these elements as Priority Pollutants (USEPA 2002), and mining activities can lead to increased concentrations in water (Eisler 1993; USEPA 2004; Mebane 2006). USEPA aquatic life criteria are reported as concentrations of pollutants in water and therefore cannot be directly compared to reported element concentrations based on whole body homogenizations of juvenile Dolly Varden. It does establish some baseline conditions that can be used to detect potential changes over time that may affect fish.

Copper

The Pebble Deposit is characterized as a porphyry copper deposit (PLP 2011, Chapter 1). The Pebble Environmental Baseline Document (EBD) reports the presence of copper-rich bedrock in the headwaters of South Fork Koktuli River (PLP 2011, Chapter 10). The Pebble EBD also reports an area rich in copper beneath a short reach near the headwaters of Upper Talarik Creek (PLP 2011, Chapter 10). Dolly Varden from the SFK reach had the highest copper concentrations in 2010 and 2011 while Dolly Varden from the UT reach had the highest concentration in 2012. Dolly Varden from the UT had the lowest copper concentrations in 2010 and 2011 while the NFK Dolly Varden had the lowest concentrations in 2012 (Figure 30).

Elevated concentrations of copper in surface waters can have negative effects on salmonids and macroinvertebrate communities. Effects on fish may include acute toxicity, decreased growth, behavior changes, reduced olfactory function, and changes in swimming ability (Scannell 2009). Most of these effects occur at levels above Alaska Water Quality Standards, but effects of copper on olfactory function occur at levels below Alaska Water Quality Standards.

Cadmium

Cadmium is a rare heavy metal that can often be found with copper and zinc (Mebane 2006). Dolly Varden from the SFK reach had the highest cadmium concentrations of the three monitoring reaches in 2010, 2011, and 2012. Dolly Varden from the UT reach had the lowest cadmium concentrations of the monitoring reaches for each year of analysis (Figure 28).

Acute toxicity from cadmium in fish largely effects ion regulation, whereas chronic toxicity is wide-ranging and can affect ion regulation, oxidation, growth, survival, reproduction, immunity, endocrine function, histopathology, and behavior (McGeer et al. 2012). The USEPA (2001) found salmonids to be among the most acutely sensitive freshwater animal species to cadmium.

Selenium

Selenium naturally occurs with sulfide minerals, including copper (Eisler 1985; USEPA 2004). Selenium concentrations in Dolly Varden were consistently highest in the SFK reach when compared to the other sites. Selenium concentrations were lowest in the Dolly Varden from the UT for all three years analyzed (Figure 35). Selenium concentrations at all three sites were consistently below EPA criterion (8.5 mg/kg dry weight) for fish tissue (whole body) concentrations in freshwater (USEPA, 2016).

Selenium is a naturally occurring chemical element that also is an essential micronutrient. Fish have a narrow range where selenium surpasses essential needs and becomes very toxic (USEPA 2016; Janz 2012). Selenium is one of the most toxic of the biologically essential elements (USEPA 2016). Egg-laying vertebrates have a lower tolerance than do mammals, but there is still debate regarding guidelines for when selenium concentrations will start to negatively affect freshwater fish (USEPA 2016; Hamilton 2003). Selenium uptake by fish is dietary, and it is known to bioaccumulate in aquatic ecosystems. Selenium can be transferred to eggs maternally where, at certain concentrations, it is known to negatively affect salmonid embryo and larval development (USEPA 2016; Janz 2012). The most severe toxic symptoms in fish are reproductive teratogenesis and larval mortality, but a variety of lethal and sublethal deformities can occur in the developing fish exposed to selenium. (USEPA 2016).

Zinc

Mean zinc concentrations in Dolly Varden from the UT reach were consistently lower than the other two reaches which had similar levels across the years analyzed (Figure 39). Zinc concentrations were like concentrations found in Dolly Varden tissue from other parts of the state (ADF&G, 2019; ADF&G, 2020).

Zinc is another of the metals listed by John et al. (2010) as being of concern for aquatic ecosystems from mining porphyry copper deposits. The toxicity of zinc to fish appears inversely related to water hardness (USEPA 1987; Hogstrand 2012). Toxicity is higher when uptake occurs from water through the gills, rather than from dietary means, and acute effects often concern the gills and its related functions (Hogstrand 2012).

7. FISH PRESENCE

OVERVIEW

Fish sampling was conducted to assess the use of streams by resident and anadromous species of fish (Figures 41-42). Collecting basic presence/absence data will help establish a baseline record of species composition and relative abundance. Weight and length measurement were collected to assess fish condition. Fish sampling was conducted with baited minnow traps and typically occurred in late summer or early fall, concurrent with collection of Dolly Varden for element analysis. Fish sampling also was conducted in early summer in 2013 to assess presence of fish species that may be absent during late summer sampling. Fish sampling dates with minnow traps are presented in Table 13.

Minnow traps were used as an easy, repeatable, and cost-effective way to obtain fish community and species data. Like all gear types, minnow traps are selective, and certain species or size classes may be absent or underrepresented in the data. However, most species of juvenile salmonids, which are indicators of habitat conditions and changes (Barbour et al. 1999), can be successfully captured using baited minnow traps (Bryant 2000). It should be noted that although sockeye salmon have been observed in all three of the monitored systems, they were not captured in any of our sampling events, likely due to gear type used and habitat selection.

Figure 41. ADF&G biologists processing captured fish in UT monitoring reach (August 27, 2013).

Figure 42. Dolly Varden captured by minnow trap in SFK monitoring reach (August 27, 2013).

METHODS

Fish were captured in each monitoring reach using baited minnow traps. Fish were identified, measured to the nearest mm (FL) using a measuring/viewing device (sculpin species were measured to total length), and weighed individually with a digital scale to the nearest tenth of a gram. All fish not retained for element analysis were returned to the sample reach. Identification of juvenile salmonids was carried out according to the Field Identification of Coastal Juvenile Salmonids (Pollard et al. 1997). Sculpin species (genus *Cottus*) were identified to species when possible but were considered as one group (sculpin species) for data analysis and presentation.

Within each stream, length frequency histograms and mean fork lengths were calculated for all species captured. Catch per unit effort (CPUE) was calculated for coho salmon (*Oncorhynchus kisutch*), Dolly Varden, and Chinook salmon (*O. tshawytscha*) by dividing the total catch per stream reach (C_t) by the total number of hours fished (cumulative of all traps; H_t) and multiplied by 24 for an average and normalized trap catch of fish per day (shown below). Data analyses were performed using Microsoft Excel®.

$$CPUE = \frac{Ct}{Ht} \times 24$$

Fork lengths (mm) and weights (g) of fish measured were used to calculate Fulton's condition factor (*K*) using the equation given in Anderson and Neumann (1996), where the weight of each fish measured in grams (W) is divided by the cubed fork length of fish (L) measured in millimeters, and the product multiplied by 100,000, as follows:

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

RESULTS AND DISCUSSION

Minnow traps soaked for 18 to 25 hours. A total of nine fish species were captured during the fish surveys, including coho salmon, Chinook salmon, Dolly Varden, rainbow trout, northern pike (*Esox lucius*), burbot (*Lota lota*), ninespine stickleback (*Pungitius pungitius*), slimy sculpin (*Cottus cognatus*), and coastrange sculpin (*C. aleuticus*). Some larger sculpin captured were positively identified as slimy sculpin or coastrange sculpin, but most sculpin captured, especially smaller ones, were not identified to species. All sculpin captured are considered sculpin species in this report.

Combined species composition varied by stream reaches. All three monitoring reaches contained coho and Chinook salmon as well as Dolly Varden and sculpin species. Rainbow trout were captured only in the UT monitoring reach and northern pike and burbot were captured only in the SFK reach. Ninespine stickleback were captured in the NFK and UT monitoring reach.

Based on minnow trapping results, Dolly Varden were the most common fish in the NFK while coho salmon were most common in the UT. Chinook salmon were captured at the highest frequency in the NFK monitoring reach. Overall, juvenile coho salmon captures were greatest in the UT reach (Table 14).

Table 14. Abundance of fish captured in minnow traps, by species 2010-2013 combined.

Fish Species	NFK	SFK	UT
Coho salmon	180	188	375
Chinook salmon	171	12	7
Dolly Varden	322	126	78
Rainbow trout	0	0	4
Sculpin species	20	33	74
Burbot	0	6	0
Northern pike	0	3	0
Ninespine stickleback	1	0	2

Coho salmon fork lengths from all three monitoring reaches ranged from 42 to 125 mm with most of the larger (>100 mm) fish captured in the UT reach (Figures 43-45). All coho salmon captured in the NFK reach were less than 100 mm. The three reaches showed variability in coho salmon size-class composition. From the histograms, inferences can be drawn for comparisons across the different stream reaches. Young of the year (0+) and age 1+ fish were captured at all three sites.

Captures of coho salmon at the NFK reach appear to be age 0+ fish and age 1+ fish. The SFK and UT reach captures were a mix of age 0+ and age 1+ fish and possibly some 2+ age fish.

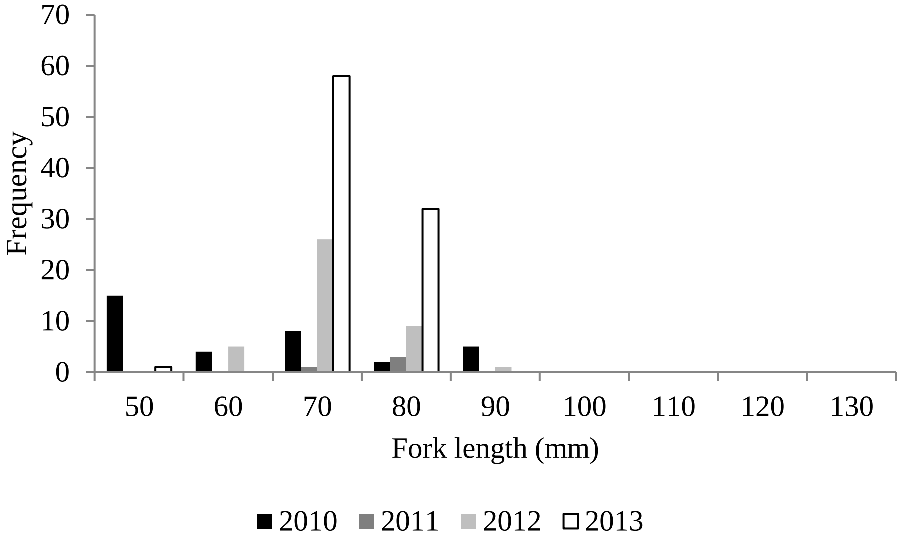


Figure 43. Length frequency distribution of coho salmon caught in the NFK monitoring reach (late summer surveys, 2010-2013).

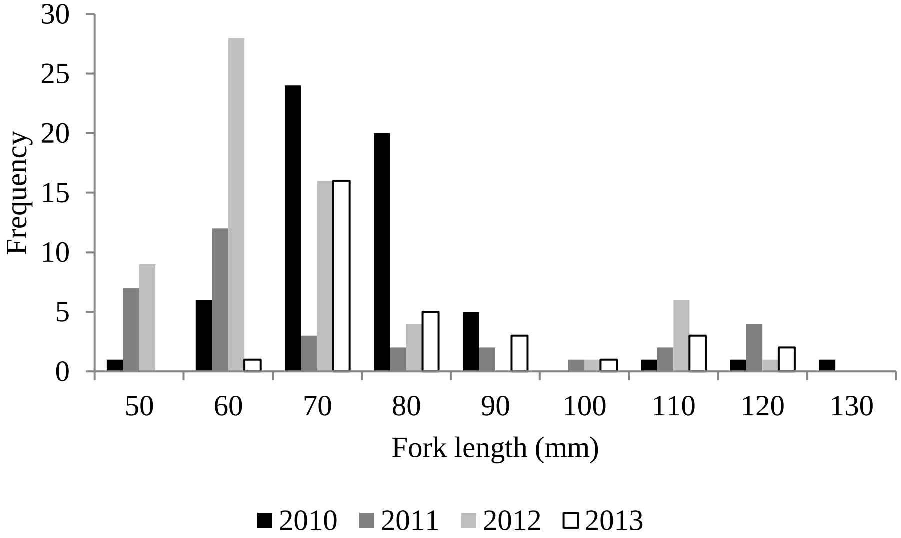


Figure 44. Length frequency distribution of coho salmon caught in the SFK monitoring reach (late summer surveys, 2010-2013).

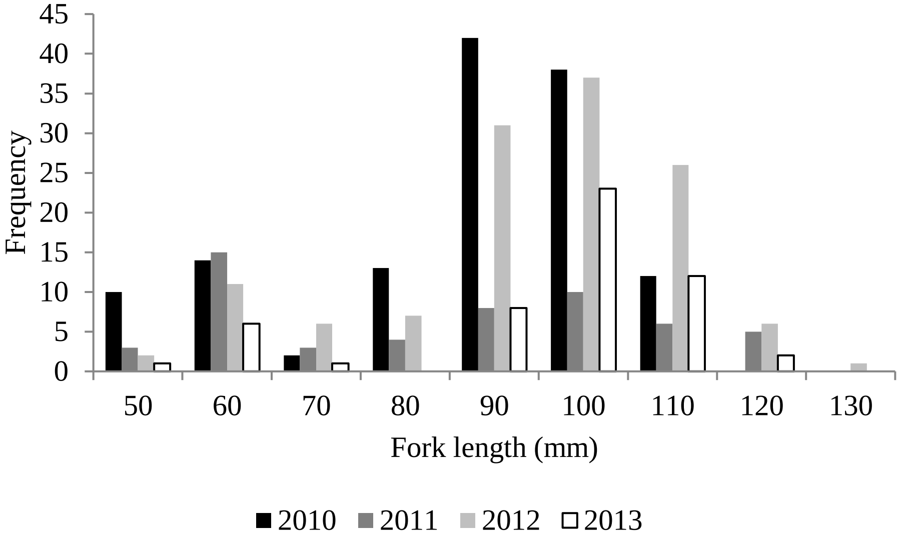


Figure 45. Length frequency distribution of coho salmon caught in the UT monitoring reach (late summer surveys, 2010-2013).

Dolly Varden fork lengths ranged from 42 to 170 mm and were relatively consistent between drainages, although no fish <90 mm were captured in the UT reach (Figures 46-48). Based on the histograms and knowledge of regional Dolly Varden age class composition, multiple age classes were captured in the monitoring reaches (Jaecks 2010; PLP 2011, Chapter 15). Young of the year (0+) Dolly Varden were captured in both the NFK and SFK reaches, but not the UT reach. The NFK reach catches were dominated by older age classes (1+ and 2+).

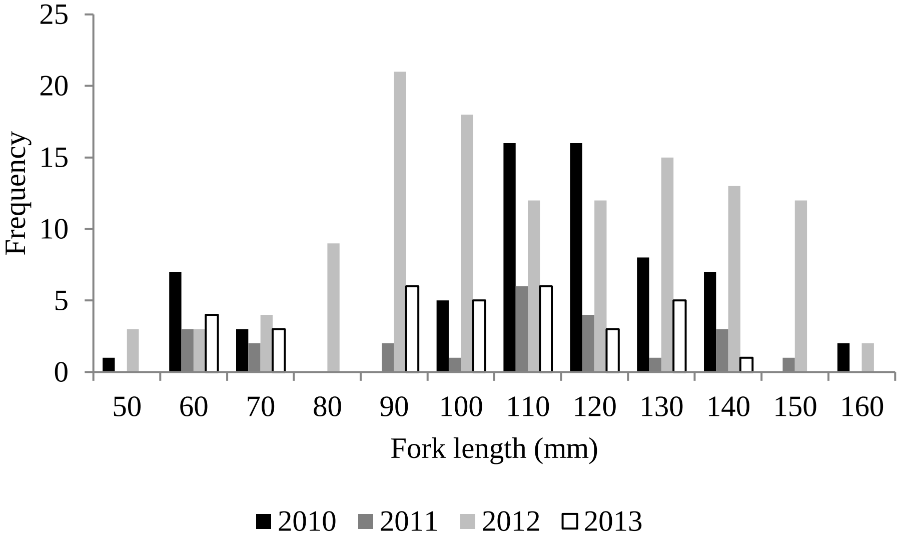


Figure 46. Length frequency distribution of Dolly Varden caught in the NFK monitoring reach (late summer surveys, 2010-2013).

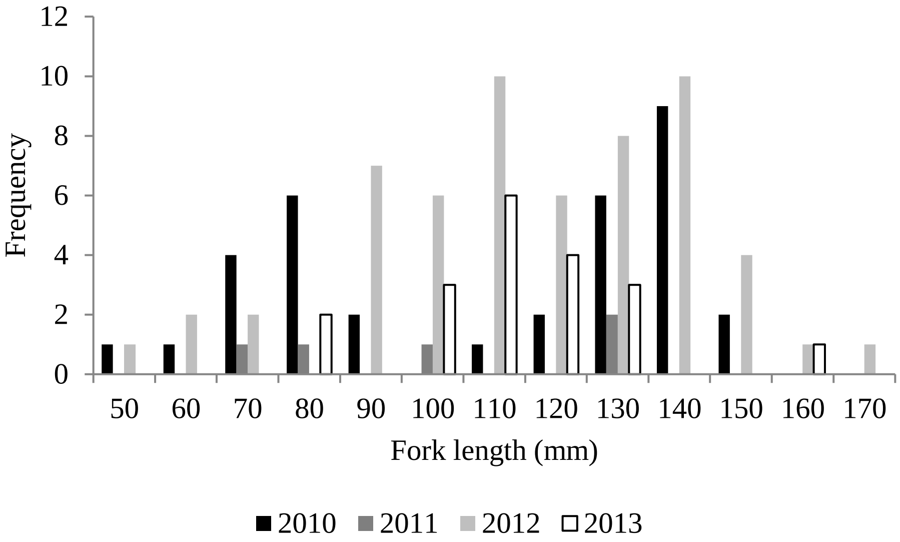


Figure 47. Length frequency distribution of Dolly Varden caught in the SFK monitoring reach (late summer surveys, 2010-2013).

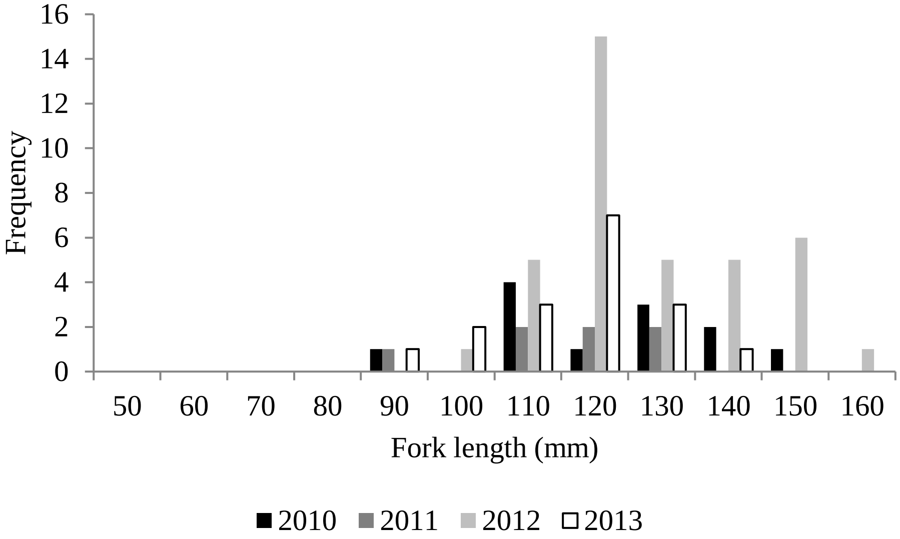


Figure 48. Length frequency distribution of Dolly Varden caught in the UT monitoring reach (late summer surveys, 2010-2013).

Most Chinook salmon had fork lengths of less than 100 mm, but values ranged from 47 to 144 mm (Figures 49-51). The data set is limited, but it appears that young of the year (0+) and 1+ fish are present in all three reaches with the possibility of some 2+ fish in the SFK.

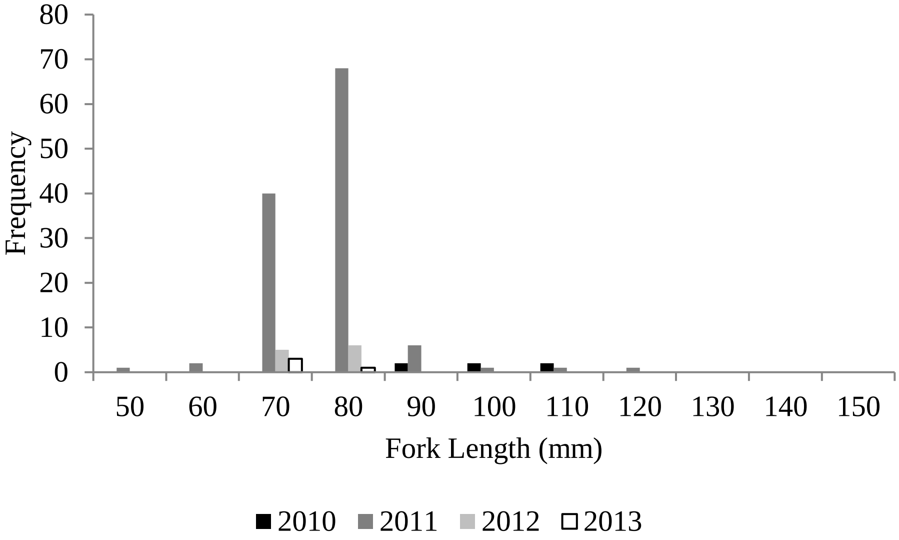


Figure 49. Length frequency distribution of Chinook salmon caught in the NFK monitoring reach (late summer surveys, 2010-2013).

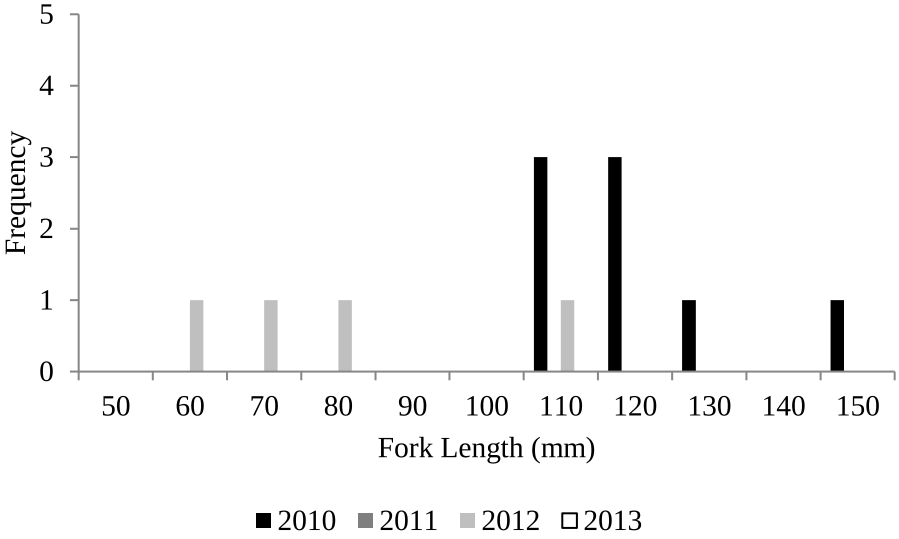


Figure 50. Length frequency distribution of Chinook salmon caught in the SFK monitoring reach (late summer surveys, 2010-2013).

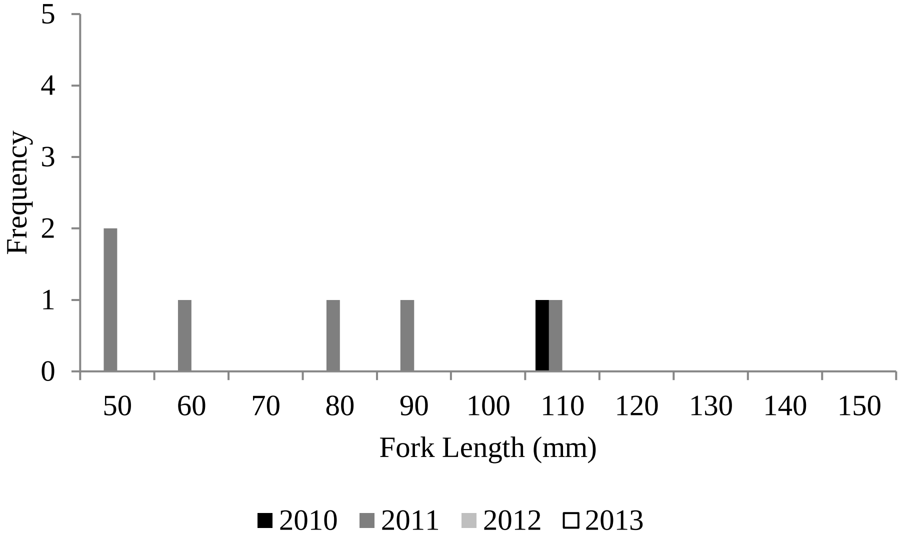


Figure 51. Length frequency distribution of Chinook salmon caught in the UT monitoring reach (late summer surveys, 2010-2013).

Combined (2010-2013) sculpin species fork length distribution from minnow trap captures in late summer are presented in Figure 52. Sculpin species, on average, were the largest in the UT reach.

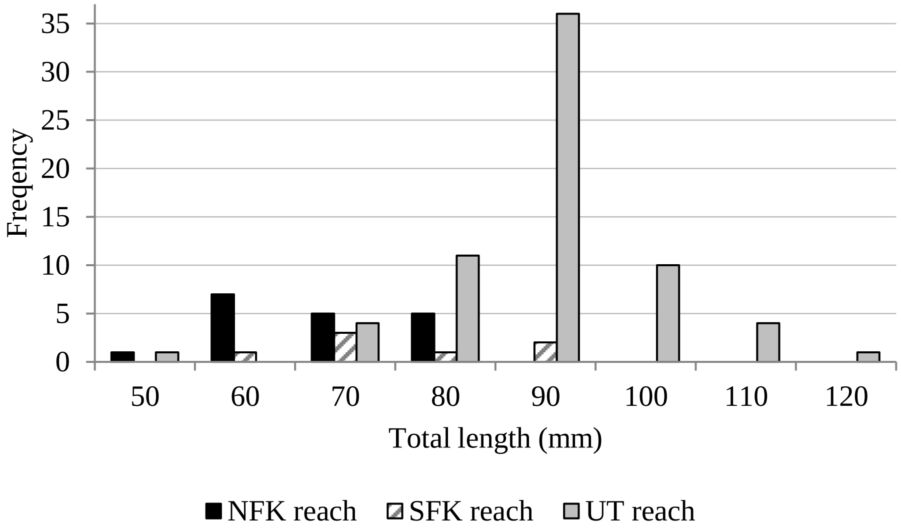


Figure 52. Length frequency distribution of sculpin species caught in the NFK, SFK, and UT monitoring reaches (late summer surveys, 2010-2013).

Coho salmon CPUE was the highest in the UT reach three out of the four years of minnow trapping. In 2013, the NFK reach had the highest CPUE for coho salmon (Figure 53). The combined average CPUE for coho salmon in the UT reach (10.80, 2010-2013) averaged about twice that of the coho salmon CPUE in the NFK and SFK reaches (5.98 and 5.63 respectively). The highest coho salmon CPUE was in the UT reach in 2010 (17.46) and the lowest was in the NFK reach in 2011 (0.54) which coincided with a very high CPUE for Chinook salmon (20.3) in the same reach. Juvenile coho salmon could be benefitting from the more moderate flows (with lower peak discharges) and pool habitat present in Upper Talarik Creek, compared to the other two streams, but several factors may be influencing the species composition of these stream reaches.

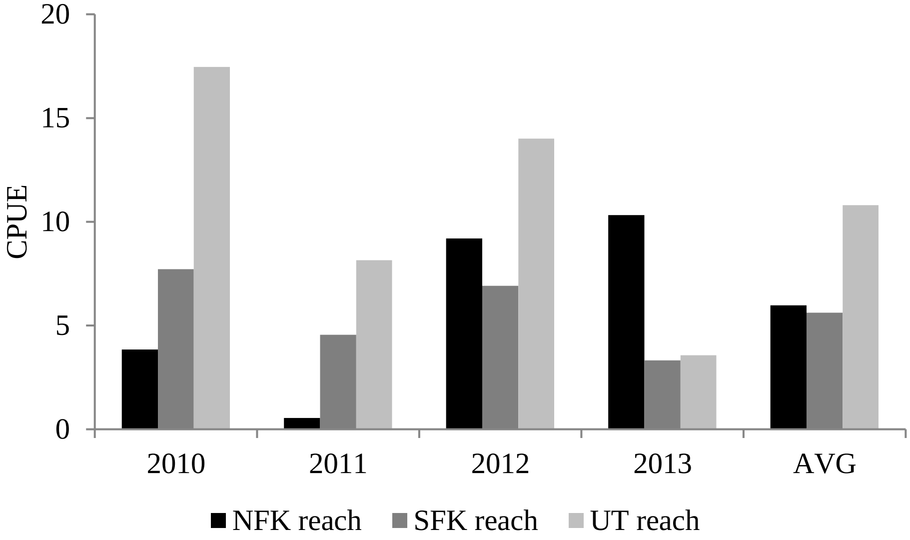


Figure 53. CPUE for coho salmon in the NFK, SFK, and UT monitoring reaches (late summer surveys, 2010-2013).

The NFK reach had the highest CPUE for Dolly Varden (average 10.39, 2010-2013) in each of the four years of minnow trapping, about three to five times higher than that of the SFK (average 3.39) and the UT reaches (average 2.18; Figure 54). The highest Dolly Varden CPUE occurred in 2012 in the NFK reach (25.44). Although pool and backwater habitat are present in the NFK reach, riffle habitat is more prevalent in the NFK monitoring reach compared to the other two reaches and may be a factor in the higher CPUE for Dolly Varden. The riffle habitat may be less desirable for juvenile coho salmon, which prefer calmer waters and the reduced competition provides a niche for the adaptable Dolly Varden (Morrow 1980; Quinn 2005).

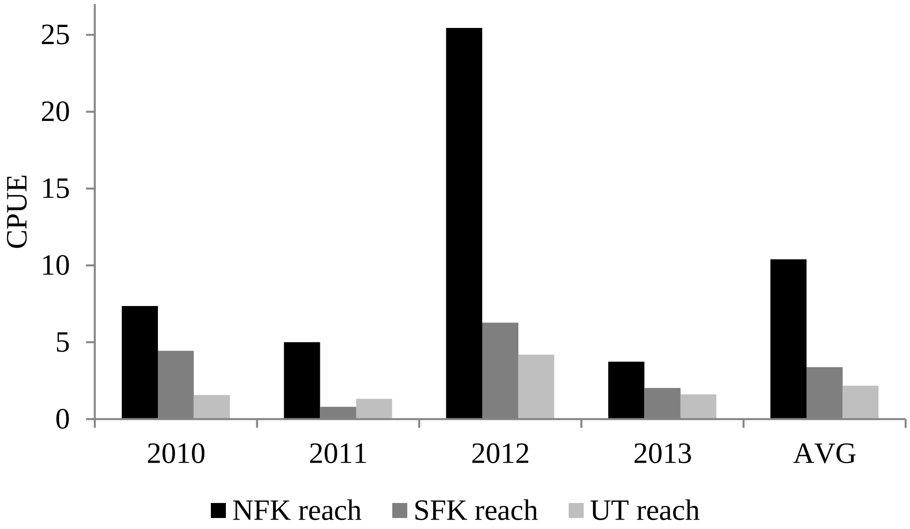


Figure 54. CPUE for Dolly Varden in the NFK, SFK, and UT monitoring reaches (late summer surveys, 2010-2013).

The NFK reach was the only reach in which juvenile Chinook salmon were captured every year and the reach had the highest CPUE each year except for 2010, when the Chinook salmon CPUE was higher in the SFK reach (Figure 55). The highest Chinook salmon CPUE was in the NFK reach in 2011 (20.3). CPUE for Chinook salmon was below 2.25 for all reaches in all other years. Chinook salmon were least common in the UT reach. The NFK experiences higher flows, has a higher gradient, and has larger substrate than the other two reaches. Chinook salmon are generally found rearing in larger rivers and higher gradients than coho salmon which prefer deeper, slower water characteristic of pools (Quinn 2005).

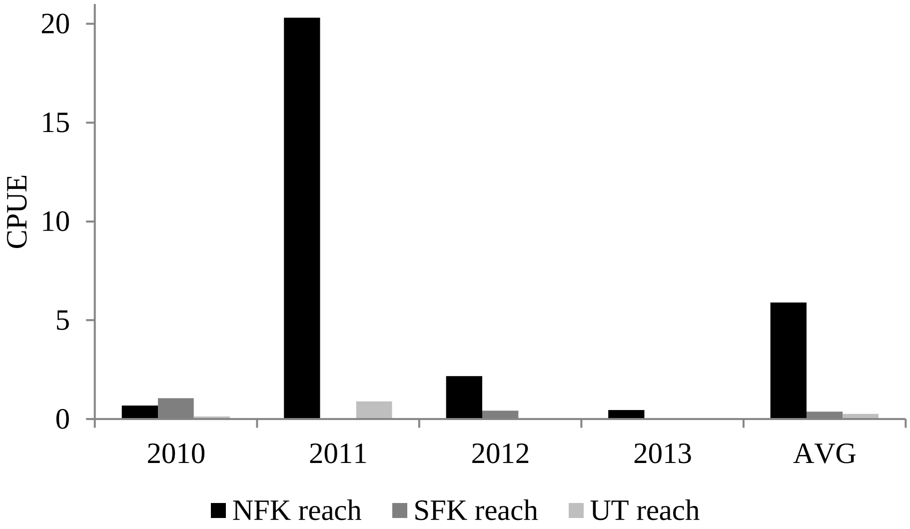


Figure 55. CPUE for Chinook salmon in the NFK, SFK, and UT monitoring reaches (late summer surveys, 2010-2013).

Sculpin species were most common in the UT reach with the highest CPUE for these species occurring in the UT reach each of the four years of trapping (Figure 56).

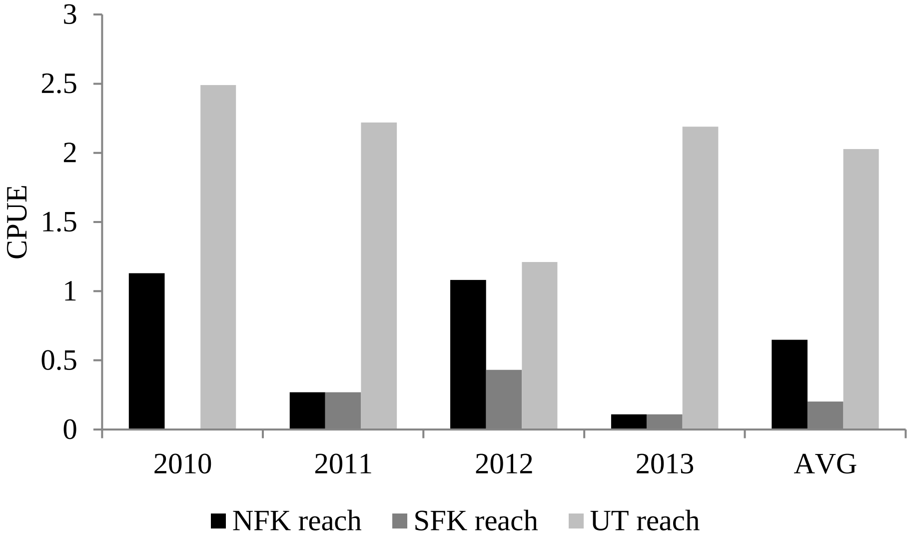


Figure 56. CPUE for sculpin species in the NFK, SFK, and UT monitoring reaches (late summer surveys, 2010-2013).

Coho salmon weight-length data, presented in Figure 57, show similar fitness among fish across drainages with values being highest in the NFK and lowest in the SFK reach. Dolly Varden weight-length data, presented in Figure 58, show nearly identical fitness between drainages. Fulton's condition factor (*K*) for juvenile coho salmon and Dolly Varden are presented in Table 15. Coho salmon and Dolly Varden *K* values were highest overall in the NFK reach (1.38 and 0.93) and lowest in the SFK reach (1.09 and 0.85). Weights were not obtained on all fish captured, and the data set is somewhat limited. No coho salmon were weighed in 2012 or from the SFK in 2010. Only Dolly Varden retained for element analysis were weighed in 2012.

The condition factor indicates the relative well-being of captured fish (i.e., higher *K* values indicate greater well-being) and allows for comparisons across seasons and drainages, however, comparisons between species is not possible because different fish species have different shapes. Larger size/higher condition may be a result of the stream productivity or a result of habitat selection as fish grow. Sampling gear may also be a factor with minnow traps set along streambanks. At a given size, salmonid species seem to prefer the same habitats, like creek margins with cover after emergence, but tend to move to progressively faster water as they grow (Quinn 2005, Meehan 1991). In general, *K* values of coho salmon were like values measured elsewhere. Milner and Bailey (1989) reported Fulton's condition factor values for juvenile coho salmon from five streams near Glacier Bay, Alaska, between 1.17 and 1.27, while values ranged from 0.84 to 1.14 from Southcentral Alaska watersheds (Hoem Neher et al. 2013). Dolly Varden K values from all three ADF&G monitoring reaches are generally lower than values reported elsewhere. York and Milner (1999) reported juvenile Dolly Varden *K* values of 1.13 and 1.14 from a Southcentral Alaska stream, and Milner and Bailey (1989) reported a *K* value of 1.18 from a stream in the Glacier Bay area. In general, a salmonid with a Fulton's *K* value greater than or equal to 1 indicates a fish in good condition.

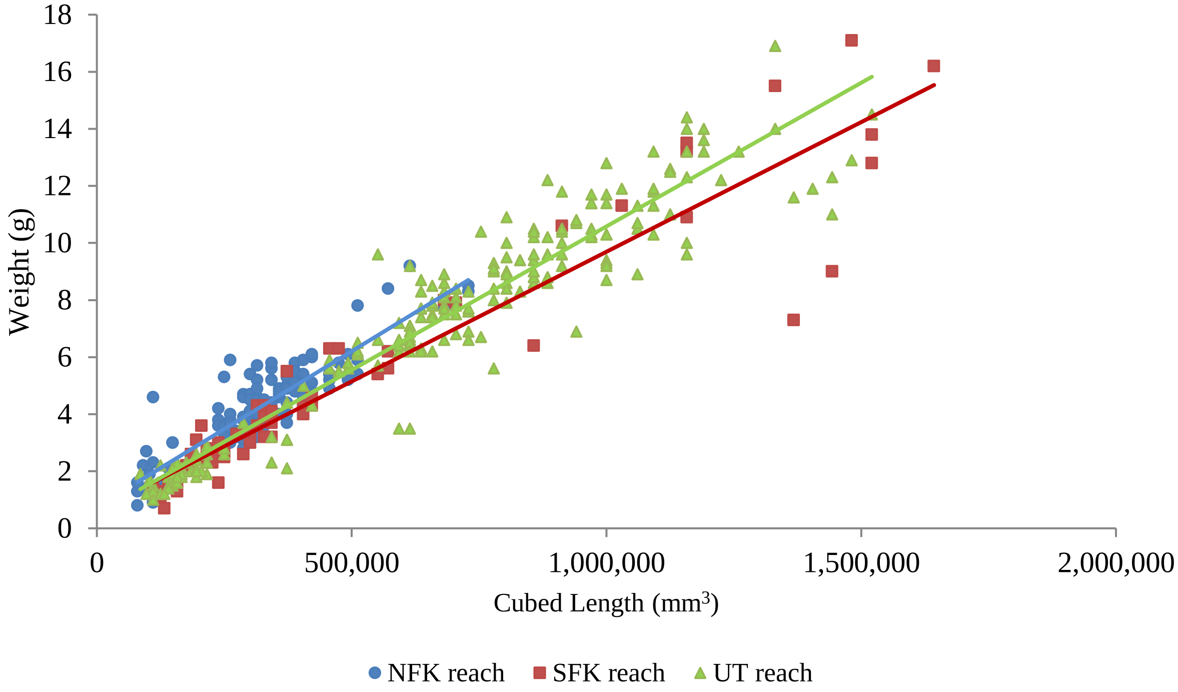


Figure 57. Coho salmon weight-length data and linear trendlines on the NFK, SFK, and UT monitoring reaches (late summer surveys, 2010-2013).

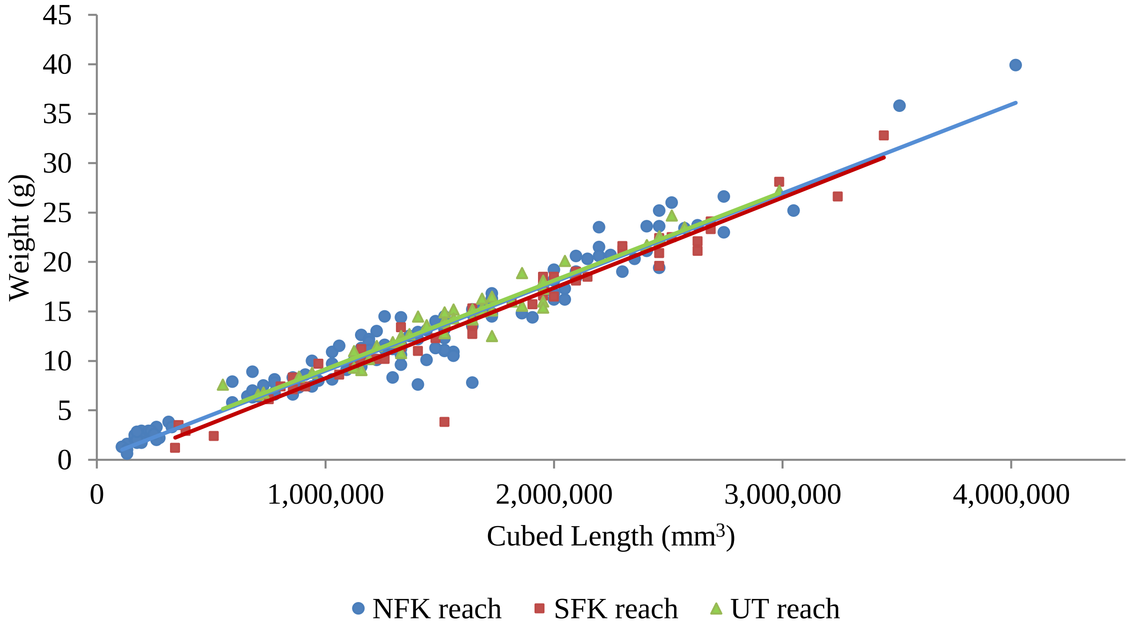


Figure 58. Dolly Varden weight-length data and linear trendlines on the NFK, SFK, and UT monitoring reaches (late summer surveys, 2010-2013).

Table 15. Mean Fulton's condition factor, SD (in parenthesis), and sample size (*n*) for coho salmon and Dolly Varden from ADF&G monitoring reaches.

Stream reach	Coho salmon	Dolly Varden
North Fork Koktuli	1.38 (0.38) (*n* = 129)	0.93 (0.18) (*n* = 134)
South Fork Koktuli	1.09 (0.22) (*n* = 64)	0.85 (0.14) (*n* = 54)
Upper Talarik	1.11 (0.18) (*n* = 222)	0.91 (0.09) (*n* = 51)

Fish sampling was conducted in early summer in 2013 to assess presence of fish species that may be absent during late summer sampling. These fish were not included in the length frequency distributions, weight-length data, or the condition factor data but they were included in CPUE data sets. Only one new fish species was captured with the early summer minnow trapping. Ninespine stickleback were captured in the NFK (1 fish) and UT (2 fish) monitoring reaches during early summer trapping but were not captured in late summer surveys. No salmon species were captured in the NFK or SFK reaches during the one-time early summer trapping effort (June 12-14, 2013).

8. SUMMARY AND CONCLUSIONS

This report contains the methods and results of four years (2010-2013) of aquatic biomonitoring for the Pebble Project at three selected sites located downstream from proposed project facilities. The objective of the biomonitoring program was to establish baseline data. Information was collected about the physical aquatic environment (geomorphology, hydrology, water quality) and different trophic levels of aquatic communities (periphyton, macro-invertebrates, and fish), using methods that are repeatable and can be used to compare conditions over time to assess potential changes at these sites.

Information collected in 2010 characterized these three streams in form, function, and productivity. All three streams are in a Glacial Trough valley (Type V) and are characterized as C4 under the Rosgen stream-channel classification system. C channel types are one of the most prevalent, natural stream types for a Glacial Trough valley. Rosgen (1994) describes the C4 stream type as "slightly entrenched, meandering, gravel-dominated, riffle-pool channel with a developed floodplain characterized by the presence of point bars and other depositional features, is very susceptible to shifts in both lateral and vertical stability caused by direct channel disturbance and changes in the flow and sediment regimes of the contributing watershed." C4 streams are interpreted as being very sensitive to disturbance with good recovery potential, have a high sediment supply, are very susceptible to streambank erosion, and are highly dependent on vegetation as a controlling influence (Rosgen 1994). Rosgen C channel types are generally considered stable in Glacial Trough valleys. Future geomorphology surveys documenting a shift from a C channel type to F or G channel type would indicate stream instability.

Primary production (as measured by chlorophyll-a concentrations) was greatest in UT. The SFK had the highest density of aquatic invertebrates based on drift net sampling while the NFK had the highest density based on surber sampling. Upper Talarik Creek had the highest proportion of pollution sensitive macroinvertebrates (EPT) based on drift net and Surber sampling.

UT has the most stable hydrologic regime throughout the year and across years (probably because of the greater influence of groundwater). The NFK has the highest volume, exhibits the most dynamic changes in flow, and has the largest bed material. Based on fish data, physical habitat data, and juvenile salmon habitat requirements, UT is valuable and productive rearing environment for juvenile coho salmon. NFK is an important headwater stream for rearing juvenile Chinook salmon.

The SFK is unique because of Frying Pan Lake, a large, relatively shallow, lake upstream of the monitoring reach. The SFK generally had the lowest primary production (chlorophyll-a concentrations) and a different invertebrate community dominated by lake dwelling taxa such as cladocerans and copepods, and lower fish CPUE and fitness. Additionally, the SFK reach Dolly Varden had higher concentrations of several elements (i.e., antimony, arsenic, cadmium, copper, lead, molybdenum, selenium, and thallium), likely due to the monitoring site's proximity to the Pebble Project ore body.

Headwater streams in Alaska serve as critical rearing habitats for juvenile salmonids and affect overall stream productivity (Walker et al. 2007, 2009). By annually monitoring each of the three trophic levels detailed here, we hope to build a strong foundation for understanding the biological resources present and gather sufficient data to detect and evaluate changes to these systems in the future.

9. LITERATURE CITED

ADF&G (Alaska Department of Fish and Game). 2019. Baseline Aquatic Biomonitoring for the Anarraaq and Aktigiruq Prospects near the Red Dog Mine, 2019. Technical Report No. 20-06.

ADF&G. 2020. Aquatic Biomonitoring at the Arctic-Bornite Prospect, 2019. Technical Report No. 20-01.

ADNR (Alaska Department of Natural Resources). 2013. Pebble Project. Division of Mining, Land, and Water, Alaska Department of Natural Resources. http://dnr.alaska.gov/mlw/mining/largemine/pebble/.

Alaska Climate Research Center. 2012. Climatological data for Iliamna: http://climate.gi.alaska.edu/Climate/Location/BristolBay/Iliamna.html (Accessed February 22, 2012, site access changed to http://climate.gi.alaska.edu/acis_data).

Allan, J. D. 1995. Stream ecology: Structure and function of running waters. Chapman and Hall, London.

Allan, J. D., and M. M. Castillo. 2007. Stream ecology: Structure and function of running waters, Second Edition. Springer, Dordrecht, Netherlands.

American Public Health Association. 1992. Standard methods for the examination of water and waste water. Section 10300.B.2. 18th Edition. American Public Health Association, Washington D.C.

Anderson, N. H., and D. M. Lehmkuhl. 1968. Catastrophic drift insects in a woodland stream. Ecology 49: 198–206.

Anderson, R. O., and R. M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447–482 [*In]* B. R. Murphy and D. W. Willis, editors. Fisheries techniques. Second Edition. American Fisheries Society, Bethesda, MD.

Baldwin, D. H., J. F. Sandahl, J. S. Labenia, and N. L. Scholz. 2003. Sublethal effects of copper on coho salmon: Impacts on nonoverlapping receptor pathways in the peripheral olfactory nervous system. Environmental Toxicology and Chemistry 22: 2266–2274.

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. Available: http://water.epa.gov/scitech/monitoring/rsl/bioassessment/index.cfm.

Biro, P. A., A. E. Morton, J. R. Post, and E. A. Parkinson. 2004. Over-winter lipid depletion and mortality of age-0 rainbow trout (*Oncorhynchus mykiss*). Canadian Journal of Fisheries and Aquatic Sciences 61: 1513–1519.

Bogan, D., R. Shaftel, and D. Rinella. 2012. Baseline biological surveys in wadeable streams of the Kvichak and Nushagak watersheds, Bristol Bay, Alaska. Alaska Department of Environmental Conservation, Anchorage, Alaska. Available: www.dec.alaska.gov/water/wqsar/monitoring/documents/ADEC_BristolBay_biological monitoringreport.pdf.

Bjornn, T. C., and Reiser, D. W. 1991. Habitat Requirements of Salmonids in Streams. American Fisheries Society Special Publication 19:83-138.

Brabets, T. P. 2002. Water Quality of the Tlikakila River and Five Major Tributaries to Lake Clark, Lake Clark National Park and Preserve, Alaska, 1999-2001. Water-Resources Investigations Report 02-4127.

Brittain, J. E., and T. J. Eikeland. 1988. Invertebrate drift – A review. Hydrobiologia 166: 77–93.

Brumbaugh, W. G., T. W. May, J. M. Besser, A. L. Allert, and C. J. Schmitt. 2007. Assessment of elemental concentrations in streams of the New Lead Belt in southeastern Missouri, 2002–05. U.S. Geological Survey, Scientific Investigations Report 2007–5057. Available: http://pubs.usgs.gov/sir/2007/5057/.

Bryant, M. D. 2000. Estimating fish populations by removal methods with minnow traps in southeast Alaska streams. North American Journal of Fisheries Management 20(4): 923–930.

Cooke, S. J., S. G. Hinch, G. T. Crossin, D. A. Patterson, K. K. English, J. M. Shrimpton, G. Van Der Kraak, and A. P. Farrell. 2006. Physiology of individual late-run Fraser River sockeye salmon (*Oncorhynchus nerka*) sampled in the ocean correlates with fate during spawning migration. Canadian Journal of Fisheries and Aquatic Sciences 63:1469–1480.

Cunjak, R. A. 1988. Physiological consequences of overwintering in streams: The cost of acclimatization? Canadian Journal of Fisheries and Aquatic Sciences 45: 443–452.

Cunjak, R. A., T. D. Prowse, and D. L. Parrish. 1998. Atlantic salmon (*Salmo salar*) in winter: "The season of parr discontent"? Canadian Journal of Fisheries and Aquatic Sciences 55 (Suppl. 1): 161–180.

Davies, P. E., and L. S. J. Cook. 1993. Catastrophic macroinvertebrate drift and sublethal effects on brown trout, *Salmo trutta*, caused by cypermethrin spraying on a Tasmanian stream. Aquatic Toxicology 27: 201–224.

Durst, J. D., and L. L. Jacobs. 2010. Aquatic biomonitoring at Greens Creek Mine, 2009. Alaska Department of Fish and Game, Division of Habitat, Technical Report No. 10-03, Juneau. Available: http://www.adfg.alaska.gov/index.cfm?adfg=habitat_publications.main.

Eisler, R. 1985. Cadmium hazards to fish, wildlife, and invertebrates: A synoptic review. U.S. Fish and Wildlife Service Biological Report 85 (1.2), Contaminant Hazard Reviews Report No. 2.

Eisler, R. 1993. Zinc hazards to fish, wildlife, and invertebrates: A synoptic review. U.S. Fish and Wildlife Service Biological Report 10, Contaminant Hazard Reviews Report No. 26.

Farag, A. M., D. Skaar, D. A. Nimick, E. MacConnell, and C. Hogstrand. 2003. Characterizing aquatic health using salmonid mortality, physiology, and biomass estimates in streams with elevated concentrations of arsenic, cadmium, copper, lead, and zinc in the Boulder River Watershed, Montana. Transactions of the American Fisheries Society 132: 450–467.

Flecker, A. S. 1992. Fish predation and the evolution of invertebrate drift periodicity: Evidence from neotropical streams. Ecology 73: 438–448.

Gallant, A. L., E. F. Binnian, J. M. Omernik, and M. B. Shasby. 1995. Ecoregions of Alaska. U.S. Geological Survey Professional Paper 1567. Available: http://pubs.er.usgs.gov/publication/pp1567.

Graham, G. E., and K. D. Kelley. 2009. The Drenchwater deposit, Alaska: An example of a natural low pH environment resulting from weathering of an undisturbed shale-hosted Zn–Pb–Ag deposit. Applied Geochemistry 24: 232–245.

Groot, C., and L. Margolis. 1991. Pacific salmon life histories. Department of Fisheries and Oceans Biological Sciences Branch. British Columbia, Canada.

Hamilton, S. J. 2003. Review of residue-based selenium toxicity thresholds for freshwater fish. Ecotoxicology and Environmental Safety 56: 201–210.

Hanson, K. C., K. G. Ostrand, A. L. Gannam, and S. L. Ostrand. 2010. Comparison and validation of nonlethal techniques for estimating condition in juvenile salmonids. Transactions of the American Fisheries Society 139: 1733–1741.

Harper, D. D., A. M. Farag, C. Hogstrand, and E. MacConnell. 2009. Trout density and health in a stream with variable water temperatures and trace element concentrations: Does a cold-water source attract trout to increased metal exposure? Environmental Toxicology and Chemistry 28: 800–808.

Harrelson, C. C., C. L. Rawlins, and J. P. Potyondy. 1994. Stream channel reference sites: An illustrated guide to field technique. General Technical Report RM-245. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. Available: http://www.fs.fed.us/rm/pubs_rm/rm_gtr245.pdf.

Hildebrand, S. G. 1974. The relation of drift to benthos density and food level in an artificial stream. Limnology and Oceanography 19(6): 951–957.

Hodkinson, I. D., and J. K. Jackson. 2005. Terrestrial and aquatic invertebrates as bioindicators for environmental monitoring, with particular reference to mountain ecosystems. Environmental Management 35(5): 649–666.

Hoem Neher, T. D., A. E. Rosenberger, C. E. Zimmerman, C. M. Walker, and S. J. Baird. 2013. Estuarine Environments as Rearing Habitats for Juvenile Coho Salmon in Contrasting South-Central Alaska Watersheds. Transactions of the American Fisheries Society. 142(6): 1481-1494.

Hogstrand, C. 2012. Zinc. Pages 135–200 [*In*] C. M. Wood, A. P. Farrell, and C. J. Brauner, editors. Homeostasis and toxicology of essential metals, Fish Physiology, Volume 31A. Elsevier/Academic Press, Oxford, UK.

Holm, J., V. Palace, P. Siwik, G. Sterling, R. Evans, C. Baron, J. Werner, and K. Wautier. 2005. Developmental effects of bioaccumulated selenium in eggs and larvae of two salmonid species. Environmental Toxicology and Chemistry 24: 2373–2381.

Jaecks, T. A. 2010. Population dynamics and trophic ecology of Dolly Varden in the Iliamna River, Alaska: Life history of freshwater fish relying on marine food subsidies. Master's thesis. University of Washington, Seattle.

Janz, D. M. 2012. Selenium. Pages 327–374 [*In*] C. M. Wood, A. P. Farrell, and C. J. Brauner, editors. Homeostasis and toxicology of essential metals, Fish Physiology, Volume 31A. Elsevier/Academic Press, Oxford, UK.

John, D. A., R. A. Ayuso, M. D. Barton, R. J. Blakely, R. J. Bodnar, J. H. Dilles, F. Gray, F. T. Graybeal, J. C. Mars, D. K. McPhee, R. R. Seal, R. D. Taylor, and P. G. Vikre. 2010. Porphyry copper deposit model, Chapter B of Mineral deposit models for resource assessment. U.S. Geological Survey Scientific Investigations Report 2010–5070–B. Available: http://pubs.usgs.gov/sir/2010/5070/b/.

Kanouse, K. M. 2012. Aquatic biomonitoring at Greens Creek Mine, 2011. Alaska Department of Fish and Game, Division of Habitat, Technical Report No. 12-03, Juneau. Available: http://www.adfg.alaska.gov/index.cfm?adfg=habitat_publications.main.

Kelley, K. D., and C. D. Taylor. 1997. Environmental geochemistry of shale-hosted Ag-Pb-Zn massive sulfide deposits in northwest Alaska: Natural background concentrations of metals in water from mineralized areas. Applied Geochemistry 12: 397–409.

Lagarrigue, T., R. Cereghino, P. Lim, P. Reyes-Marchant, R. Chappaz, P. Lavandier, and A. Belaud. 2002. Diel and seasonal variations in brown trout (*Salmo trutta*) feeding patterns and relationship with invertebrate drift under natural and hydropeaking conditions in a mountain stream. Aquatic Living Resources 15: 129–137.

Leopold, L. B. 1994. A view of the river. Harvard University Press. Cambridge, MA.

Lord, M. L., D. Germanoski, and N. E. Allmendinger. 2009. Fluvial geomorphology: Monitoring stream systems in response to a changing environment. Pages 69–103 [*In]* R. Young and L. Norby, editors. Geological monitoring. Geological Society of America, Boulder, Colorado.

Lowe, R. L., and G. D. LaLiberte. 2006. Benthic stream algae: Distribution and structure. Pages 327-339 [*In*] F. R. Hauser and G .A. Lamberti, editors. Methods in stream ecology, Second Edition. Academic Press/Elsevier, Oxford, UK.

McGeer, J. C., S. Niyogi, and D. S. Smith. 2012. Cadmium. Pages 125–184 [In] C. M. Wood, A. P. Farrell, and C. J. Brauner, editors. Homeostasis and toxicology of non-essential metals, Fish Physiology, Volume 31B. Elsevier/Academic Press, Oxford, UK.

McIntyre, J. K., D. H. Baldwin, D. A. Beauchamp, and N. L. Scholz. 2012. Low-level copper exposures increase visibility and vulnerability of juvenile coho salmon to cutthroat trout predators. Ecological Applications 22: 1460–1471.

Mebane, C. A. 2006 (2010 rev.). Cadmium risks to freshwater life: Derivation and validation of low-effect criteria values using laboratory and field studies. U.S. Geological Survey Scientific Investigations Report 2006-5245, version 1.2. Available: http://pubs.usgs.gov/sir/2006/5245/.

Meehan, W. R. 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19.

Miller, M. C., J. R. Stout, and V. Alexander. 1986. Effects of a controlled under-ice spill on invertebrates of an arctic and subarctic stream. Environmental Pollution 42: 99–132.

Milner, A. M., and R. G. Bailey. 1989. Salmonid colonization of new streams in Glacier Bay National Park, Alaska. Aquaculture and Fisheries Management 20: 179-192.

Morrow, J. E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publishing Company, Anchorage, Alaska

Nabi Bidhendi, G. R., A. R. Karbassi, T. Nasrabadi, and H. Hoveidi. 2007. Influence of copper mine on surface water quality. International Journal of Environmental Science and Technology 4**:** 85–91.

Oswood, M. W. 1989. Community structure of benthic invertebrates in interior Alaskan (USA) streams and rivers. Hydrobiologia 172: 97–110.

Ott, A. G., and W. A. Morris. 2012. Aquatic biomonitoring at Red Dog Mine, 2011. Alaska Department of Fish and Game, Division of Habitat, Technical Report No. 12-02, Fairbanks. Available: http://www.adfg.alaska.gov/index.cfm?adfg=habitat_publications.main.

Ott, A. G., W. A. Morris, and L. L. Jacobs. 2010. Methods for aquatic life monitoring to satisfy requirements of 2010 NPDES permit, Red Dog Mine site (Revision #1). Alaska Department of Fish and Game, Division of Habitat, Technical Report No. 10-04, Fairbanks. Available: http://www.adfg.alaska.gov/index.cfm?adfg=habitat_publications.main.

Peckarsky, B. L. 1979. Biological interactions as determinants of distributions of benthic invertebrates within the substrate of stony streams. Limnology and Oceanography 24(1): 59–68.

Peckarsky, B. L. 1980. Predator-prey interactions between stoneflies and mayflies: Behavioral observations. Ecology 61: 932–943.

Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish. EPA/440/4-89/001 (previously published as EPA/444/4-89-001). United States Environmental Protection Agency, Office of Water, Assessment and Watershed Protection Division, Washington, D.C. Available: http://nepis.epa.gov.

PLP (Pebble Limited Partnership). 2011. Pebble Project Environmental Baseline Document 2004 through 2008.

Pollard, W. R., G. F. Hartman, C. Groot, and P. Edgell. 1997. Field identification of coastal juvenile salmonids. Harbour Publishing, Madeira Park, BC.

Post, J. R., and E. A. Parkinson. 2001. Energy allocation strategy in young fish: Allometry and survival. Ecology 82: 1040–1051.

Quinn, T. P. 2005. The behavior and ecology of Pacific salmon and trout. University of Washington Press, Seattle.

Resh, V. H. 2008. Which group is best? Attributes of different biological assemblages used in freshwater biomonitoring programs. Environmental Monitoring and Assessment 138: 131–138.

Resh, V. H., and J. K. Jackson. 1993. Rapid assessment approaches in benthic macroinvertebrate biomonitoring studies. Pages 195–233 [I*n]* D. M. Rosenberg and V. H. Resh, editors. Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall, New York.

Rinella, D. J., M. S. Wipfli, C. A. Stricker, R. A. Heintz, and M. J. Rinella. 2012. Pacific salmon (*Oncorhynchus* spp.) runs and consumer fitness: Growth and energy storage in stream-dwelling salmonids increase with salmon spawner density. Canadian Journal of Fisheries and Aquatic Sciences 69: 73–84.

Ripley, E. A., R. E. Redmann, and A. A. Crowder. 1996. Environmental effects of mining. St. Lucie Press, Delray Beach, FL.

Rosgen, D. L. 1994. A classification of natural rivers. Catena 22: 169–199.

Rosgen, D. 1996a. Field survey procedures for characterization of river morphology. http://www.wildlandhydrology.com/assets/Field_Survey_Procedures_for_Characterization_of_River_Morph.pdf (accessed July 30, 2013).

Rosgen, D. L. 1996b. Applied river morphology. Second Edition. Wildland Hydrology Books, Pagosa Springs, CO.

Runnels, D. D., T. A. Shepherd, and E. E. Angino. 1992. Metals in water: Determining natural background concentrations in mineralized areas. Environmental Science and Technology 26: 2316–2323.

Scannell, P. W. 2009. Effects of copper on aquatic species: A review of the literature. Alaska Department of Fish and Game, Division of Habitat, Technical Report No. 09-04, Fairbanks. Available: http://www.adfg.alaska.gov/index.cfm?adfg=habitat_publications.main.

Schulz, R., and M. Liess. 1999. A field study of the effects of agriculturally derived insecticide input on stream macroinvertebrate dynamics. Aquatic Toxicology 46: 155–176.

Shearer, K. D., and P. Swanson. 2000. The effect of whole body lipid on early sexual maturation of 1+ age male Chinook salmon *Oncorhynchus tshawytscha*. Aquaculture 190: 343–367.

Silverstein, J. T., H. Shimma, and H. Ogata. 1997. Early maturity in amago salmon (*Oncorhynchus masu ishikawai*): An association with energy storage. Canadian Journal of Fisheries and Aquatic Sciences 54: 444–451.

Sutton, S. G., T. P. Bult, and R. L. Haedrich. 2000. Relationships among fat weight, body weight, water weight, and condition factors in wild Atlantic salmon parr. Transactions of the American Fisheries Society 129: 527–538.

Thompson, J. M., E. P. Bergersen, C. A. Carlson, and L. R. Kaeding. 1991. Role of size, condition, and lipid content in the overwinter survival of age-0 Colorado squawfish. Transactions of the American Fisheries Society 120: 346–353.

Timothy, J., and K. M. Kanouse. 2012. Aquatic studies at Kensington Mine, 2011. Alaska Department of Fish and Game, Division of Habitat, Technical Report No.11-08, Douglas. Available: http://www.adfg.alaska.gov/index.cfm?adfg=habitat_publications.main.

USEPA (United States Environmental Protection Agency). 1987. Ambient water quality criteria for zinc – 1987. Office of Water, EPA-440/5-87-003. Office of Research and Development, Duluth, MN. Available: http://nepis.epa.gov.

USEPA (United States Environmental Protection Agency). 2001. 2001 Update of ambient water quality criteria for cadmium. Office of Water, EPA-822-R-01-001 (April 2001). Office of Science and Technology, Washington, D.C. Available: http://water.epa.gov/scitech/swguidance/standards/upload/2001_04_13_criteria_cadmium_cad2001upd.pdf.

USEPA (United States Environmental Protection Agency). 2002. National recommended water quality criteria: 2002. Office of Water, EPA-822-R-02-047 (November 2002). Office of Science and Technology (4304T). Available: http://nepis.epa.gov.

USEPA (United States Environmental Protection Agency). 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA 910-B-03-002. Region 10 Office of Water, Seattle, WA.

USEPA (United States Environmental Protection Agency). 2004. Draft aquatic life water quality criteria for selenium - 2004. Office of Water, draft EPA-822-D-04-001 (November 2004). Office of Science and Technology, Washington, D.C. Available: http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/selenium/upload/complete-2.pdf.

USEPA (United States Environmental Protection Agency). 2016. Final Aquatic Life Ambient Water Quality Criterion for Selenium - Freshwater 2016. Office of Water, EPA 822-R-16-006 (June 2016). Office of Science and Technology, Washington, D.C.

USGS (United States Geological Survey). 1996. Environmental studies of mineral deposits in Alaska. Survey Bulletin 2156. United States Government Printing Office, Washington. Available: http://pubs.er.usgs.gov/publication/b2156.

USGS (United States Geological Survey). 2013. USGS water data for USA. U.S Department of the Interior, U.S. Geological Survey. http://waterdata.usgs.gov/nwis.

USGS (United States Geological Survey). 2020. USGS Current Water Data for Alaska: https://waterdata.usgs.gov/ak/nwis/rt. Access May 24, 2020.

Walker, C., R. King, D. Whigham, and S. Baird. 2007. Wetland geomorphic linkages to juvenile salmonids and macroinvertebrate communities in headwater streams of the Kenai Lowlands, Alaska. U.S. EPA Region 10 Wetland Program Development Program, Final Report.

Walker, C., R. King, M. C. Rains, D. Whigham, S. Baird, and J. Bellino. 2009. Headwater stream wetland settings and shallow ground water influence: Relationships to juvenile salmon habitat on the Kenai Peninsula, Alaska. U.S. EPA Region 10 Wetland Program Development Program Final Report.

Ward, A., J. L. D'Ambrosio, and D. Mecklenburg. 2008. Stream classification. Agricultural and Natural Resources Fact Sheet AEX-445-01. The Ohio State University. Available: http://ohioline.osu.edu/aex-fact/.

Waters, T. F. 1995. Sediment in streams: Sources, biological effects, and control. American Fisheries Society, Monograph 7, Bethesda, MD.

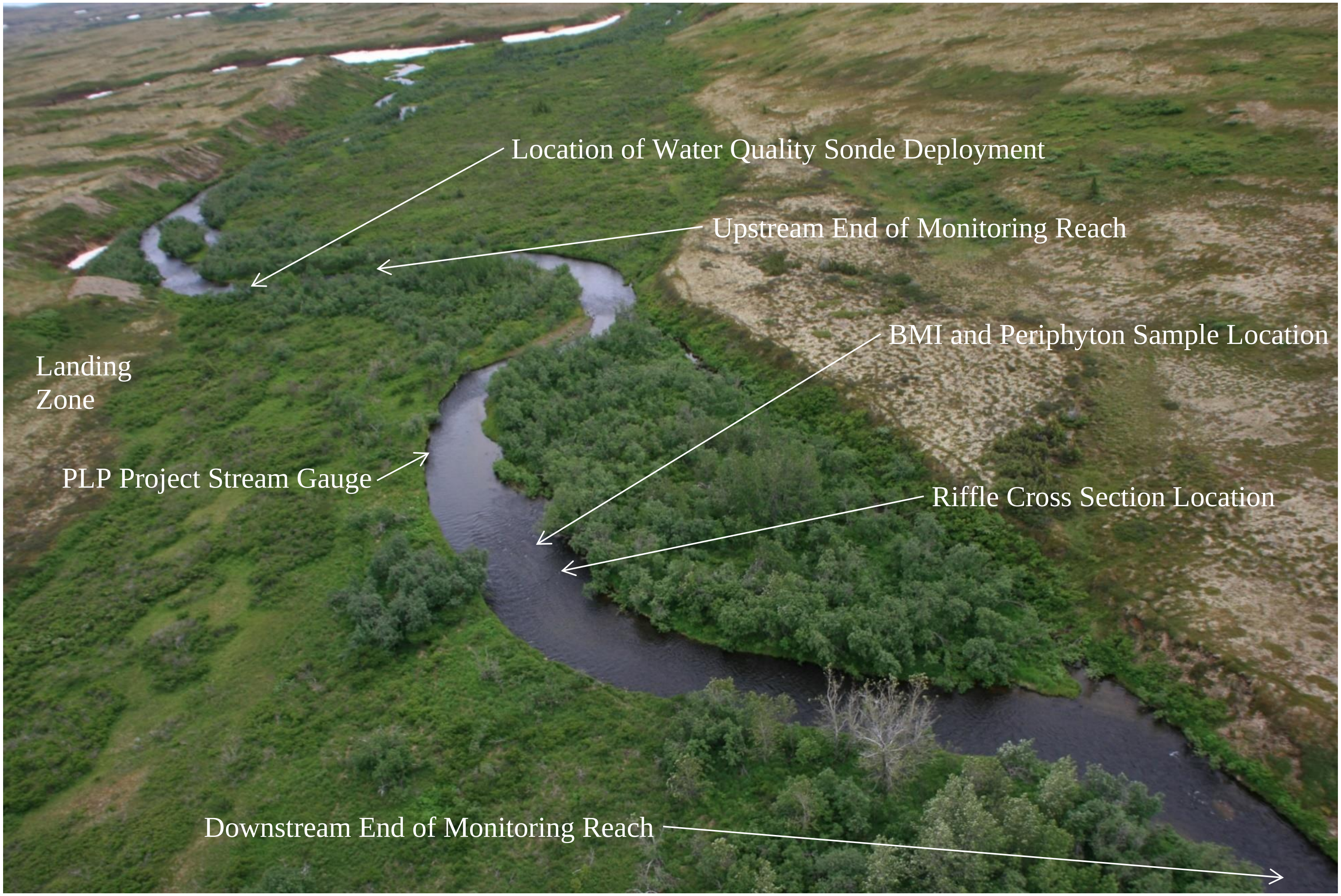
Weber, L. P., P. S. Higgins, R. I. Carlson, and D. M. Janz. 2003. Development and validation of methods for measuring multiple biochemical indices of condition in juvenile fishes. Journal of Fish Biology 63: 637–658.

Wolman, M. G. 1954. A method of sampling coarse river-bed material. Transactions, American Geophysical Union 35: 951–956.

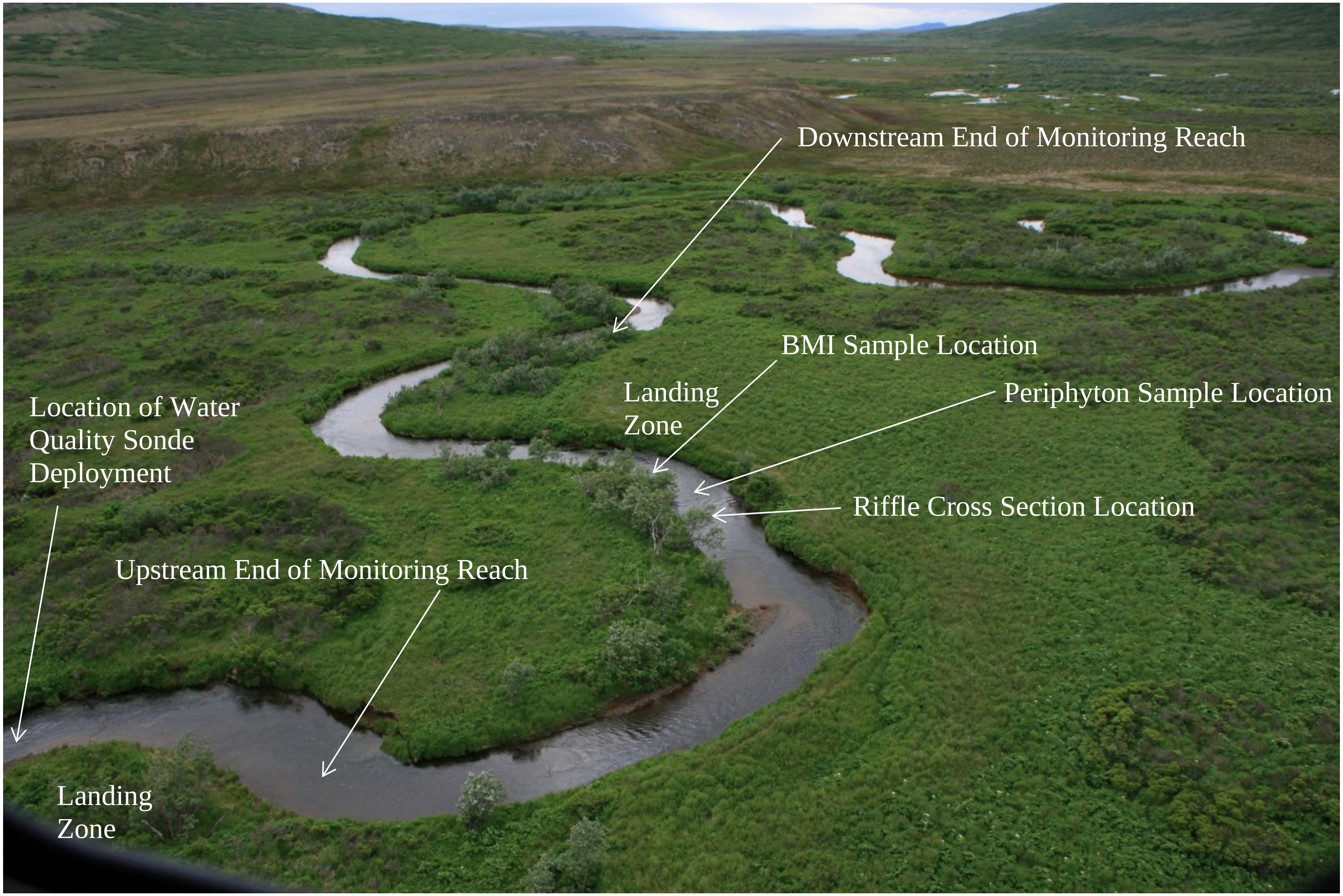
Woody, C. A., Shaftel, R., Rinella, D., Bogan, D. 2014. Long Term Monitoring Plan for Wadeable Streams, Lime Hills Ecoregion, Kvichak and Nushagak River Watersheds. March 2014.

York, G., and A. Milner. 1999. Colonization and community development of salmonids and benthic macroinvertebrates in a new stream within Kenai Fjords National Park, Alaska. Environment and Natural Resources Institute, University of Alaska Anchorage.

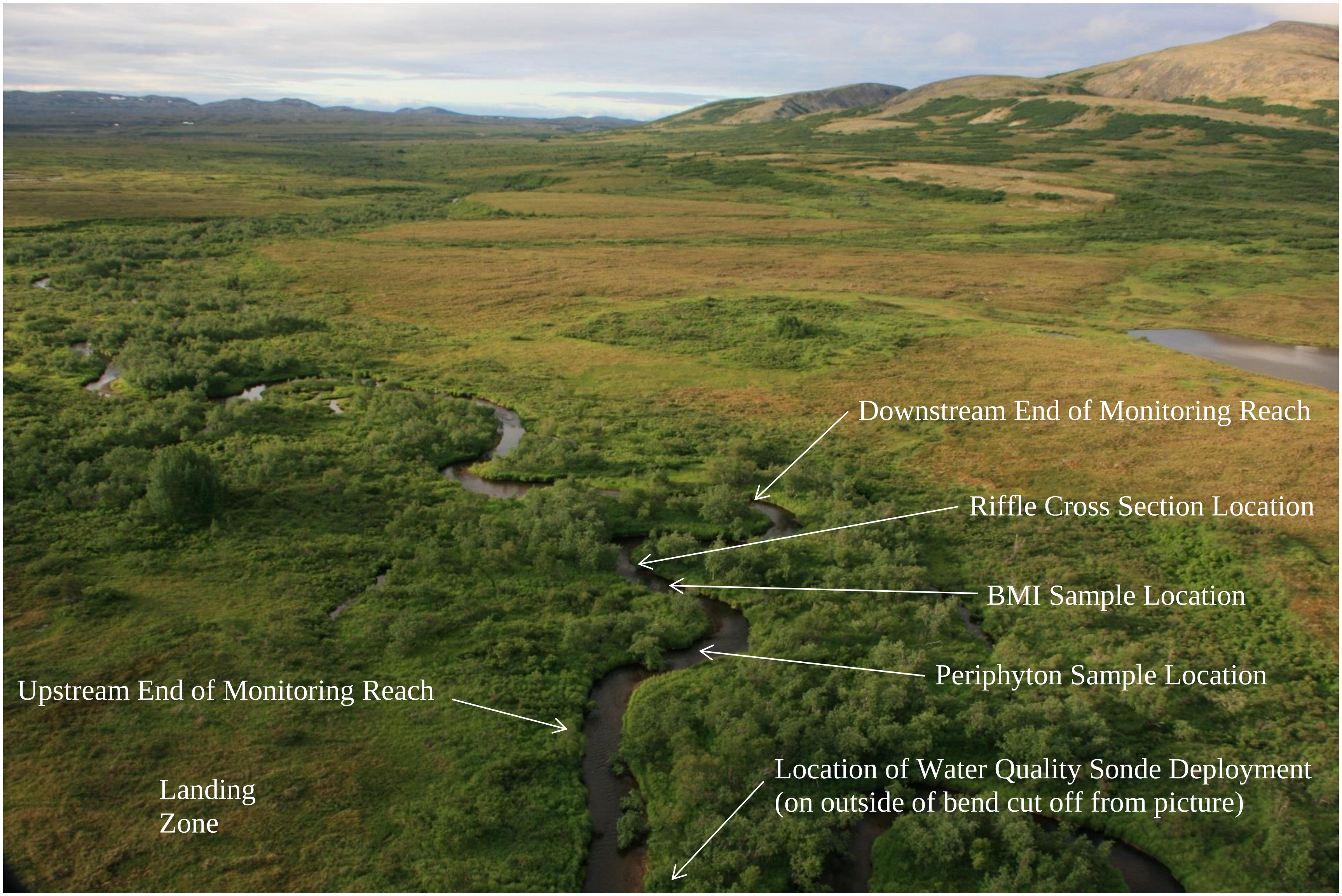
Appendix 1. Overview of ADF&G Monitoring Reaches



North Fork Koktuli ADF&G Monitoring Reach (view is upstream to the east)
July 12, 2012 – Flow at 334 cfs (USGS gauge downstream)



South Fork Koktuli ADF&G Monitoring Reach (view is downstream to the west)
July 12, 2012 – Flow at 228 cfs (USGS gauge downstream)



Upper Talarik ADF&G Monitoring Reach (view is downstream to the south)
July 13, 2012 – Flow at 200 cfs (USGS gauge downstream)

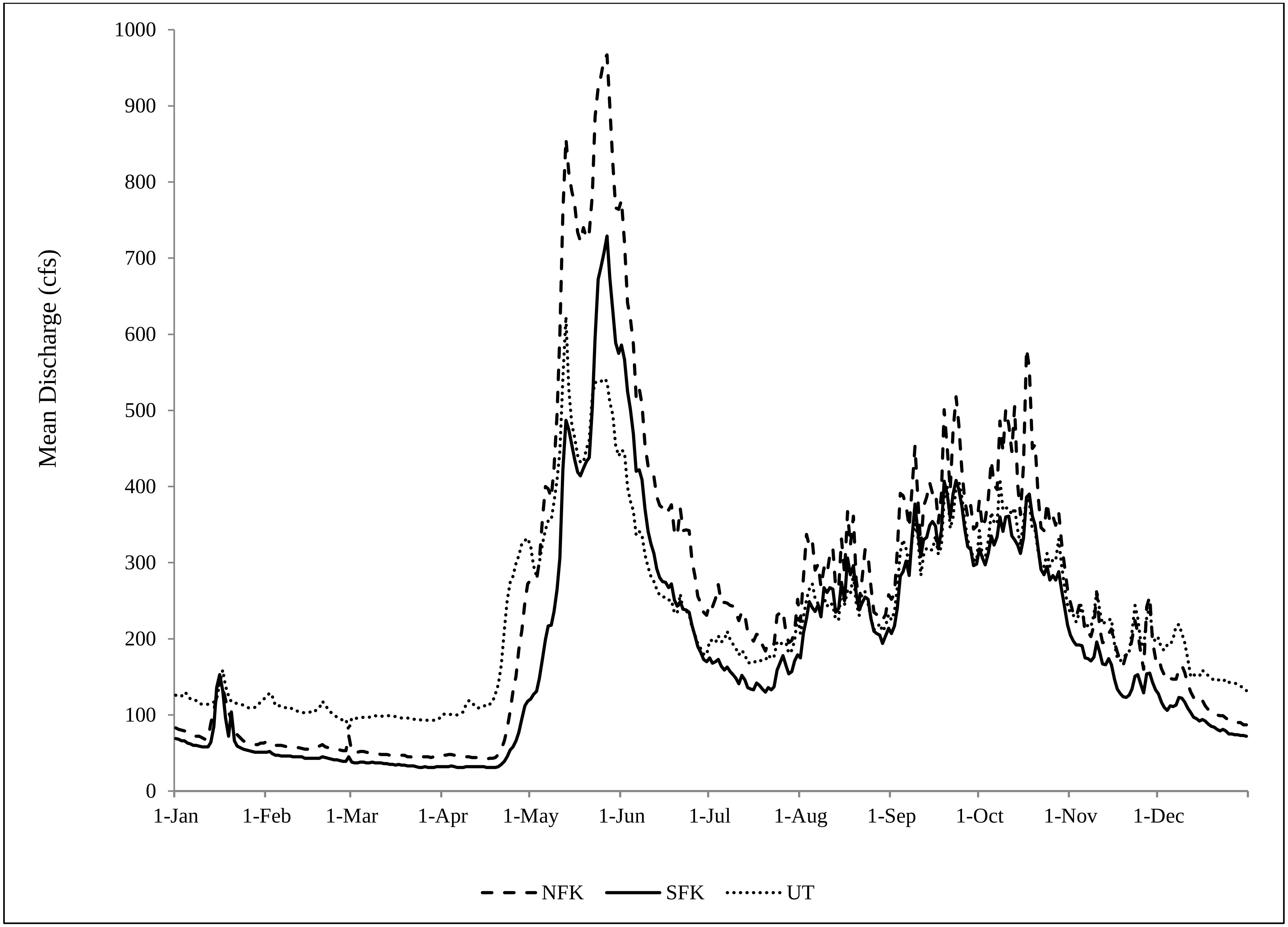
Appendix 2. Hydrology Data from USGS Stream Gauges

Stream	USGS gauge no.	Drainage area (m^2)	Elevation (ft)
North Fork Koktuli River	15302250	105.62	613
South Fork Koktuli River	15302200	69.1	775
Upper Talarik Creek	15300250	86.6	425

United States Geological Survey (USGS) stream gauge details. *Source*: USGS 2014.

Stream reach	Minimum cfs	Maximum cfs
NFK	42 (April 15)	967 (May 27)
SFK	31 (March 24)	729 (May 27)
UT	80 (Feb. 29)	623 (May 13)

Minimum and maximum mean daily discharge from October 2004 through September 2014. *Source*: USGS 2014.



Mean daily discharge for the North Fork Koktuli River, South Fork Koktuli River, and Upper Talarik Creek, Oct. 2004–Sept. 2014. Source: USGS 2020.

Appendix 3. Periphyton Standing Crop, 2010-2013

Daily vial no.	Site	Date collected	Date analyzed	Vial chl-a	Chl-a (mg/ m^2)	Below instrument detection limit[a] or above linear check[b]	Chl-a[c] (mg/m^2)	664/665 Ratio	Chl-b (mg/m^2)	Chl-c (mg/m^2)	Notes[d]
2010											
1	BLANK		12/9/2010	0.00	-	Below detection	-	-	-	-	
2	NFK reach	8/5/2010	12/9/2010	0.41	1.64	-	1.60	1.71	0.00	0.14	1
3	NFK reach	8/5/2010	12/9/2010	0.30	1.19	-	1.07	1.63	0.00	0.01	1
4	NFK reach	8/5/2010	-	-	-	-	-	-	-	-	2
5	NFK reach	8/5/2010	12/9/2010	0.75	3.00	-	2.67	1.61	0.11	0.23	3
6	NFK reach	8/5/2010	12/9/2010	1.08	4.32	-	4.06	1.66	0.73	0.23	1, 4
7	NFK reach	8/5/2010	12/9/2010	2.79	11.15	-	9.72	1.59	0.85	0.83	1, 4
8	NFK reach	8/5/2010	12/9/2010	0.68	2.71	-	2.56	1.67	0.34	0.14	1, 4
9	NFK reach	8/5/2010	12/9/2010	0.37	1.48	-	1.39	1.65	0.30	0.07	1, 4
10	NFK reach	8/5/2010	-	-	-	-	-	-	-	-	2
11	NFK reach	8/5/2010	-	-	-	-	-	-	-	-	2
12	UT reach	9/1/2010	12/9/2010	7.75	30.99	-	28.94	1.67	0.00	2.49	1
13	UT reach	9/1/2010	12/9/2010	4.15	16.61	-	15.70	1.68	0.00	1.27	1
14	UT reach	9/1/2010	12/9/2010	9.90	39.59	-	37.70	1.69	0.00	3.04	1, 5
15	UT reach	9/1/2010	12/9/2010	0.47	1.87	-	1.71	1.64	0.02	0.24	1
16	UT reach	9/1/2010	12/9/2010	0.62	2.47	-	2.35	1.69	0.00	0.29	1
17	UT reach	9/1/2010	12/9/2010	2.69	10.77	-	10.15	1.67	0.00	0.76	1, 6
18	UT reach	9/1/2010	12/9/2010	9.83	39.34	-	36.21	1.65	0.00	3.07	1, 7
19	UT reach	9/1/2010	12/9/2010	10.42	41.66	-	38.98	1.67	0.00	3.33	1, 8
20	UT reach	9/1/2010	12/9/2010	1.93	7.72	-	7.37	1.69	0.00	1.03	1
21	UT reach	9/1/2010	12/9/2010	2.44	9.78	-	9.18	1.67	0.00	1.06	1
22	SFK reach	8/4/2010	12/9/2010	0.24	0.96	-	0.85	1.62	0.00	0.17	9
23	SFK reach	8/4/2010	12/9/2010	0.81	3.24	-	2.99	1.64	0.53	0.37	10
24	SFK reach	8/4/2010	12/9/2010	0.57	2.26	-	1.82	1.50	0.69	0.99	10
25	SFK reach	8/4/2010	12/9/2010	0.17	0.67	-	0.64	1.67	0.14	0.11	10
26	SFK reach	8/4/2010	12/9/2010	1.17	4.67	-	4.06	1.58	0.77	1.23	10

-continued-

Daily vial no.	Site	Date collected	Date analyzed	Vial chl-a	Chl-a (mg/m^2)	Below instrument detection limit[a] or above linear check[b]	Chl-a [c] (mg/m^2)	664/665 Ratio	Chl-b (mg/m^2)	Chl-c (mg/ m^2)	Notes[d]
27	SFK reach	8/4/2010	12/9/2010	0.81	3.24	-	3.10	1.69	0.00	0.32	10
28	SFK reach	8/4/2010	12/9/2010	0.53	2.13	-	2.03	1.68	0.13	0.21	10
29	SFK reach	8/4/2010	12/9/2010	2.05	8.21	-	6.84	1.53	1.99	3.20	10
30	SFK reach	8/4/2010	12/9/2010	0.44	1.77	-	1.28	1.43	0.53	1.02	10
31	SFK reach	8/4/2010	12/9/2010	0.39	1.55	-	1.39	1.62	0.04	0.06	10
32	BLANK		12/9/2010	0.00	-	Below detection	-	-	-	-	-
12d	UT DBL	9/1/2010	12/9/2010	7.76	31.04	-	29.58	1.69	0.00	2.48	-
2011											
1	BLANK		12/29/2011	0.00	0.00	Below detection					
2	NFK	7/1/2011	12/29/2011	3.08	12.30	-	11.32	1.63	1.97	0.60	11
3	NFK	7/1/2011	12/29/2011	0.84	3.37	-	2.88	1.56	0.72	0.16	11
4	NFK	7/1/2011	12/29/2011	0.31	1.23	-	1.17	1.69	0.03	0.07	11
5	NFK	7/1/2011	12/29/2011	0.85	3.40	-	2.99	1.60	0.23	0.24	11
6	NFK	7/1/2011	12/29/2011	0.74	2.95	-	2.67	1.63	0.13	0.23	11
7	NFK	7/1/2011	12/29/2011	1.08	4.33	-	3.84	1.60	0.56	0.29	11
8	NFK	7/1/2011	12/29/2011	0.58	2.32	-	2.03	1.59	0.13	0.15	11
9	NFK	7/1/2011	12/29/2011	0.63	2.53	-	2.35	1.65	0.26	0.13	11
10	NFK	7/1/2011	12/29/2011	0.60	2.40	-	2.14	1.61	0.17	0.11	11
11	NFK	7/1/2011	12/29/2011	1.02	4.07	-	3.52	1.58	0.46	0.22	11
12	SFK	6/30/2011	12/29/2011	1.42	5.68	-	5.13	1.62	0.25	0.92	11
13	SFK	6/30/2011	12/29/2011	0.33	1.32	-	1.17	1.61	0.06	0.12	11
14	SFK	6/30/2011	12/29/2011	0.80	3.21	-	2.88	1.61	0.38	0.43	11
15	SFK	6/30/2011	12/29/2011	0.46	1.83	-	1.71	1.67	0.00	0.28	11

-continued-

Daily vial no.	Site	Date collected	Date analyzed	Vial chl-a	Chl-a (mg/m^2)	Below instrument detection limit[a] or above linear check[b]	Chl-a [c] (mg/m^2)	664/665 Ratio	Chl-b (mg/m^2)	Chl-c (mg/m^2)	Notes[d]
12	SFK	6/30/2011	12/29/2011	1.42	5.68	-	5.13	1.62	0.25	0.92	11
13	SFK	6/30/2011	12/29/2011	0.33	1.32	-	1.17	1.61	0.06	0.12	11
14	SFK	6/30/2011	12/29/2011	0.80	3.21	-	2.88	1.61	0.38	0.43	11
15	SFK	6/30/2011	12/29/2011	0.46	1.83	-	1.71	1.67	0.00	0.28	11
16	SFK	6/30/2011	12/29/2011	0.30	1.19	-	1.07	1.63	0.00	0.10	11
17	SFK	6/30/2011	12/29/2011	1.36	5.44	-	4.91	1.63	0.00	0.59	11
18	SFK	6/30/2011	12/29/2011	0.49	1.95	-	1.71	1.59	0.12	0.46	11
19	SFK	6/30/2011	12/29/2011	0.92	3.69	-	3.10	1.56	0.06	0.59	11
20	SFK	6/30/2011	12/29/2011	0.31	1.24	-	1.07	1.59	0.00	0.10	11
21	SFK	6/30/2011	12/29/2011	1.23	4.93	-	4.27	1.59	0.00	0.43	11
22	UT	7/1/2011	12/29/2011	4.19	16.76	-	15.59	1.66	0.00	1.62	11
23	UT	7/1/2011	12/29/2011	16.49	65.95	Above Check	60.77	1.65	0.00	5.40	11, 12
24	UT	7/1/2011	12/29/2011	4.84	19.35	-	17.62	1.64	0.00	2.17	11
25	UT	7/1/2011	12/29/2011	3.11	12.46	-	11.32	1.64	0.00	1.22	11
26	UT	7/1/2011	12/29/2011	3.16	12.63	-	11.53	1.64	0.00	1.13	11
27	UT	7/1/2011	12/29/2011	2.28	9.11	-	8.12	1.62	0.00	0.85	11
28	UT	7/1/2011	12/29/2011	7.56	30.23	-	26.49	1.60	0.00	2.42	11
29	UT	7/1/2011	12/29/2011	8.86	35.43	-	32.36	1.64	0.00	2.57	11
30	UT	7/1/2011	12/29/2011	7.62	30.47	-	27.02	1.61	0.00	2.58	11
31	UT	7/1/2011	12/29/2011	4.48	17.92	-	15.70	1.60	0.00	1.43	11
32	BLANK		12/29/2011	0.01	0.05	Below detection					
6d	NFK DBL	7/1/2011	12/29/2011	0.73	2.91	-	2.56	1.6	0.08	0.17	11
						2012					
1	BLANK		1/18/2013	0.00	0.00	Below detection					
12	SFK	6/28/2012	1/18/2013	0.24	0.96	-	0.85	1.62	0.00	0.10	

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Daily vial no.	Site	Date collected	Date analyzed	Vial chl-a	Chl-a (mg/m^2)	Below instrument detection limit[a] or above linear check[b]	Chl-a[c] (mg/m^2)	664/665 Ratio	Chl-b (mg/m^2)	Chl-c (mg/m^2)	Notes[d]
13	SFK	6/28/2012	1/18/2013	0.45	1.82	-	1.71	1.67	0.06	0.15	
14	SFK	6/28/2012	1/18/2013	0.27	1.10	-	0.96	1.60	0.00	0.05	
15	SFK	6/28/2012	1/18/2013	0.66	2.64	-	2.56	1.71	0.04	0.27	
16	SFK	6/28/2012	1/18/2013	0.39	1.55	-	1.50	1.70	0.00	0.19	
17	SFK	6/28/2012	1/18/2013	0.42	1.69	-	1.60	1.68	0.00	0.14	
18	SFK	6/28/2012	1/18/2013	0.69	2.74	-	2.35	1.56	0.41	0.76	
19	SFK	6/28/2012	1/18/2013	0.55	2.20	-	2.03	1.66	0.00	0.10	
20	SFK	6/28/2012	1/18/2013	0.29	1.14	-	1.17	1.79	0.00	0.11	
21	SFK	6/28/2012	1/18/2013	0.40	1.60	-	1.39	1.59	0.00	0.18	
22	NFK	6/27/2012	1/18/2013	1.38	5.54	-	5.23	1.66	0.90	0.53	
23	NFK	6/27/2012	1/18/2013	1.36	5.46	-	5.13	1.67	0.17	0.46	
24	NFK	6/27/2012	1/18/2013	1.35	5.39	-	5.23	1.70	0.54	0.24	
25	NFK	6/27/2012	1/18/2013	1.10	4.41	-	4.06	1.64	0.23	0.21	
26	NFK	6/27/2012	1/18/2013	0.84	3.37	-	1.55	1.64	0.08	0.31	
27	NFK	6/27/2012	1/18/2013	0.87	3.46	-	3.20	1.65	0.04	0.29	
28	NFK	6/27/2012	1/18/2013	1.36	5.42	-	2.56	1.67	0.65	0.47	
29	NFK	6/27/2012	1/18/2013	0.87	3.49	-	3.20	1.64	0.24	0.49	
30	NFK	6/27/2012	1/18/2013	0.82	3.27	-	3.20	1.71	0.20	0.39	
30d	NFK DBL	6/27/2012	1/18/2013	0.85	3.40	-	3.31	1.70	0.28	0.50	
31	NFK	6/27/2012	1/18/2013	1.01	4.05	-	3.74	1.65	0.06	0.38	
32	UT	6/26/2012	1/18/2013	1.61	6.45	-	6.19	1.70	0.00	0.61	
33	UT	6/26/2012	1/18/2013	2.17	8.68	-	8.33	1.70	0.00	0.91	
34	UT	6/26/2012	1/18/2013	0.68	2.74	-	2.46	1.62	0.00	0.26	

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Daily vial no.	Site	Date collected	Date analyzed	Vial chl-a	Chl-a (mg/m^2)	Below instrument detection limit[a] or above linear check[b]	Chl-a[c] (mg/m^2)	664/665 Ratio	Chl-b (mg/m^2)	Chl-c (mg/m^2)	Notes[d]
35	UT	6/26/2012	1/18/2013	11.07	44.28	-	41.65	1.67	0.00	3.53	
36	UT	6/26/2012	1/18/2013	3.40	13.61	-	13.14	1.70	0.00	1.24	
37	UT	6/26/2012	1/18/2013	4.31	17.26	-	16.55	1.70	0.00	1.50	
38	UT	6/26/2012	1/18/2013	4.37	17.49	-	16.55	1.68	0.25	1.68	
39	UT	6/26/2012	1/18/2013	18.06	72.22	-	66.43	1.65	0.00	6.20	
40	UT	6/26/2012	1/18/2013	5.20	20.81	-	19.86	1.69	0.00	1.85	
41	UT	6/26/2012	1/18/2013	6.78	27.11	-	25.42	1.67	0.00	3.04	
42	UT	6/28/2012	1/18/2013	6.71	26.83	-	25.53	1.69	0.00	2.91	
43	UT	6/28/2012	1/18/2013	1.23	4.93	-	4.70	1.69	0.00	0.52	
44	UT	6/28/2012	1/18/2013	1.20	4.79	-	4.49	1.67	0.00	0.48	
45	UT	6/28/2012	1/18/2013	5.01	20.02	-	19.12	1.69	0.00	1.96	
46	UT	6/28/2012	1/18/2013	2.37	9.49	-	9.08	1.69	0.00	1.10	
47	UT	6/28/2012	1/18/2013	12.47	49.87	-	47.42	1.68	0.03	5.11	
48	UT	6/28/2012	1/18/2013	3.07	12.28	-	11.75	1.69	0.33	1.42	
49	UT	6/28/2012	1/18/2013	2.36	9.45	-	8.76	1.66	0.00	1.10	
50	UT	6/28/2012	1/18/2013	1.07	4.28	-	4.06	1.68	0.02	0.51	
51	UT	6/28/2012	1/18/2013	7.43	29.73	-	28.52	1.70	0.00	3.05	
52	UT	6/28/2012	1/18/2013	2.09	8.35	-	7.90	1.68	0.00	1.08	
53	BLANK		1/18/2013	0.00	0.00	Below detection					
2013											
B1	BLANK		1/8/2014	0.00	0.00	Below detection					
2	SFK	6/25/2013	1/8/2014	0.66	2.64	-	2.35	1.61	0.05	0.17	11
3	SFK	6/25/2013	1/8/2014	0.90	3.62	-	3.52	1.72	0.00	0.14	
4	SFK	6/25/2013	1/8/2014	0.57	2.29	-	2.14	1.67	0.00	0.09	
5	SFK	6/25/2013	1/8/2014	1.12	4.49	-	4.38	1.72	0.00	0.15	

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Daily vial no.	Site	Date collected	Date analyzed	Vial chl-a	Chl-a (mg/m^2)	Below instrument detection limit[a] or above linear check[b]	Chl-a[c] (mg/m^2)	664/665 Ratio	Chl-b (mg/m^2)	Chl-c (mg/m^2)	Notes[d]
6	SFK	6/25/2013	1/8/2014	3.95	7.90	-	7.42	1.67	0.00	0.41	13
7	SFK	6/25/2013	1/8/2014	0.57	2.29	-	2.24	1.72	0.00	0.15	
9	SFK	6/25/2013	1/8/2014	0.46	1.83	-	1.71	1.67	0.00	0.08	
10	SFK	6/25/2013	1/8/2014	0.91	3.63	-	3.31	1.63	0.18	0.37	
11	SFK	6/25/2013	1/8/2014	0.99	3.97	-	3.63	1.64	0.00	0.36	
12	NFK	6/25/2013	1/8/2014	0.46	1.85	-	1.71	1.64	0.20	0.09	
13	NFK	6/25/2013	1/8/2014	0.95	3.78	-	3.31	1.60	0.06	0.19	
14	NFK	6/25/2013	1/8/2014	0.45	1.81	-	1.60	1.60	0.15	0.02	
15	NFK	6/25/2013	1/8/2014	0.48	1.92	-	2.03	1.79	0.44	0.44	
16	NFK	6/25/2013	1/8/2014	0.27	1.10	-	0.96	1.60	0.00	0.00	
17	NFK	6/25/2013	1/8/2014	0.61	2.45	-	2.24	1.64	0.22	0.17	
18	NFK	6/25/2013	1/8/2014	0.45	1.82	-	1.71	1.67	0.07	0.05	
19	NFK	6/25/2013	1/8/2014	0.56	2.24	-	2.14	1.69	0.00	0.16	
20	NFK	6/25/2013	1/8/2014	0.40	1.60	-	1.60	1.75	0.02	0.05	
21	NFK	6/25/2013	1/8/2014	0.33	1.32	-	1.28	1.71	0.06	0.12	
22	UT	6/24/2013	1/8/2014	1.30	5.22	-	5.02	1.70	0.00	0.51	
23	UT	6/24/2013	1/8/2014	2.17	8.69	-	8.44	1.71	0.00	0.87	
24	UT	6/24/2013	1/8/2014	1.95	7.81	-	7.48	1.69	0.00	0.47	
25	UT	6/24/2013	1/8/2014	1.04	4.17	-	3.84	1.65	0.00	0.16	
26	UT	6/24/2013	1/8/2014	1.85	7.40	-	7.16	1.71	0.00	0.55	
27	UT	6/24/2013	1/8/2014	5.61	22.44	-	21.47	1.69	0.06	1.22	
28	UT	6/24/2013	1/8/2014	1.05	4.21	-	3.95	1.67	0.00	0.32	
29	UT	6/24/2013	1/8/2014	1.90	7.59	-	7.48	1.73	0.00	0.40	
30	UT	6/24/2013	1/8/2014	1.86	7.45	-	6.94	1.66	0.00	0.35	
31	UT	6/24/2013	1/8/2014	1.61	6.45	-	6.19	1.70	0.00	0.51	

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Daily vial no.	Site	Date collected	Date analyzed	Vial chl-a	Chl-a (mg/m^2)	Below instrument detection limit[a] or above linear check[b]	Chl-a[c] (mg/m^2)	664/665 Ratio	Chl-b (mg/m^2)	Chl-c (mg/m^2)	Notes[d]
32	BLANK		1/8/2014	0.00	0.00	Below detection					
5d	SFK DBL	6/25/2013	1/8/2014	1.13	4.53	-	4.38	1.71	0.00	0.15	

Notes:

[a] 0.06 Vial chlorophyll-a (Method detection limit = 0.02 vial chlorophyll-a).

[b] 21.19 Vial chlorophyll-a.

[c] Phaeophytin corrected.

[d] 1 - Glass fiber filter not folded in half sample to sample, in contact with outer filter; filters generally in poor condition, crushed, crumpled, etc.
2 - Not processed—excessive algal macrophytes
3 - 2 strands of macrophyte
4 - Significantly damaged filtered
5 - ¼ of sample stuck to outer filter, cut and processed
6 - Damp
7 - Much of sample lost to filter
8 - Wet
9 - 1 strand of algae/plant material; sample in good condition
10 - Sample in good condition
11 - High $MgCO_3$
12 - High sediment content
13 - Two samples combined, already averaged

Appendix 4. Aquatic Invertebrate Samples

Drift Nets - 2010

	Monitoring sites		
	NFK reach	SFK reach	UT reach
Sample date	8/31/2010	8/3/2010	9/2/2010
Aquatic invertebrate taxa richness/site	33	31	33
EPT taxa richness/site	13	12	13
% EPT	36.9%	6.0%	38.6%
% Ephemeroptera	23.3%	1.8%	13.6%
% Plecoptera	4.5%	3.7%	5.7%
% Trichoptera	9.1%	0.5%	19.3%
% Aquatic Diptera	32.7%	5.8%	34.3%
% Aquatic Chironomidae	23.6%	5.4%	19.3%
% Miscellaneous aquatic species	30.4%	88.2%	27.1%
% Dominant aquatic taxon	15.5%	44.2%	12.8%
Volume of water (m^3)	1228	754	1470
Average volume of water/net (m^3)	246	151	294
Standard deviation of water volume/net	73	20	99
Estimated total invertebrates/volume water (m^3)	0.8	13.0	0.5
Estimated aquatic invertebrates/volume water (m^3)	0.6	12.6	0.4
Average invertebrates/volume water (m^3)	0.9	13.5	0.5
Average aquatic invertebrates/volume water (m^3)	0.62	13.04	0.46
Standard deviation of aquatic invertebrate density	0.31	5.87	0.27
Total abundance of aquatic invertebrates[a]	691	9486	580
Total abundance Ephemeroptera[a]	161	169	79
Total abundance Plecoptera[a]	31	348	33
Total abundance Trichoptera[a]	63	50	112
Total abundance aquatic Diptera[a]	226	548	199
Total abundance miscellaneous aquatic species[a]	210	8371	157
Total abundance terrestrial invertebrates[a]	268	309	118
Total abundance all invertebrates[a]	959	9795	698
% Sample aquatic	72.1%	96.8%	83.1%
% Sample terrestrial	27.9%	3.2%	16.9%
Average number aquatic invertebrates/net[b]	138	1897	116
Average number Ephemeroptera/net[b]	32	34	16
Average number Plecoptera/net[b]	6	70	7
Average number Trichoptera/net[b]	13	10	22
Average number aquatic Diptera/net[b]	45	110	40
Average number miscellaneous aquatic species/net[b]	42	1674	31
Standard deviation aquatic invertebrates/net	36	671	29
Average number terrestrial invertebrates/net[b]	54	62	24
Average number invertebrates/net[b]	192	1959	140
Standard deviation of invertebrates/net	42	684	22
Total larval fish/net[b]	0	0	0

Notes:
[a] Corrected for subsampling.
[b] Five nets per site.

Drift Nets - 2011

	Monitoring sites		
	NFK reach	SFK reach	UT reach
Sample date	7/1/2011	6/30/2011	7/1/2011
Aquatic invertebrate taxa richness/site	33	32	32
EPT taxa richness/site	12	14	12
% EPT	35.3%	14.9%	20.0%
% Ephemeroptera	13.6%	11.0%	8.7%
% Plecoptera	0.2%	0.4%	0.3%
% Trichoptera	21.4%	3.6%	10.9%
% Aquatic Diptera	36.1%	40.1%	51.7%
% Aquatic Chironomidae	30.5%	20.2%	30.5%
% Miscellaneous aquatic species	28.6%	45.0%	28.3%
% Dominant aquatic taxon	18.5%	19.3%	19.1%
Volume of water (m^3)	285	525	627
Average volume of water/net (m^3)	57	105	125
Standard deviation of water volume/net	12	66	53
Estimated total invertebrates/volume water (m^3)	5.3	6.3	4.6
Estimated aquatic invertebrates/volume water (m^3)	4.3	3.7	3.2
Average invertebrates/volume water (m^3)	5.5	7.5	4.8
Average aquatic invertebrates/volume water (m^3)	4.48	4.43	3.45
Standard deviation of aquatic invertebrate density	0.81	1.75	1.10
Total abundance of aquatic invertebrates[a]	1,241	1,934	2,006
Total abundance Ephemeroptera[a]	169	212	175
Total abundance Plecoptera[a]	3	7	7
Total abundance Trichoptera[a]	266	69	219
Total abundance aquatic Diptera[a]	448	776	1,038
Total abundance miscellaneous aquatic species[a]	355	870	567
Total abundance terrestrial invertebrates[a]	268	1372	883
Total abundance all invertebrates[a]	1,509	3,306	2,006
% Sample aquatic	82.2%	58.5%	69.4%
% Sample terrestrial	17.8%	41.5%	30.6%
Average number aquatic invertebrates/net[b]	248	387	401
Average number Ephemeroptera/net[b]	34	42	35
Average number Plecoptera/net[b]	1	1	1
Average number Trichoptera/net[b]	53	14	44
Average number aquatic Diptera/net[b]	90	155	208
Average number miscellaneous aquatic species/net[b]	71	174	113
Standard deviation aquatic invertebrates/net	21	104	85
Average number terrestrial invertebrates/net[b]	54	274	177
Average number invertebrates/net[b]	302	661	578
Standard deviation of invertebrates/net	14	163	169
Total larval fish/net[b]	0	0	0

Notes:

[a] Corrected for subsampling.

[b] Five nets per site.

Drift Nets - 2012

	Monitoring sites		
	NFK reach	SFK reach	UT reach
Sample date	6/27/2012	7/13/2012	6/26/2012
Aquatic invertebrate taxa richness/site	41	33	37
EPT taxa richness/site	15	10	10
% EPT	17.1%	4.4%	22.3%
% Ephemeroptera	13.0%	4.2%	8.4%
% Plecoptera	0.5%	0.1%	1.0%
% Trichoptera	3.6%	0.1%	12.9%
% Aquatic Diptera	64.9%	17.1%	47.9%
% Aquatic Chironomidae	39.0%	7.1%	35.9%
% Miscellaneous aquatic species	18.0%	78.5%	29.8%
% Dominant aquatic taxon	24.9	66.1%	19.4%
Volume of water (m^3)	513	923	1,214
Average volume of water/net (m^3)	103	185	243
Standard deviation of water volume/net	53	115	79
Estimated total invertebrates/volume water (m^3)	5.6	13.4	1.5
Estimated aquatic invertebrates/volume water (m^3)	4.7	12.7	1.2
Average invertebrates/volume water (m^3)	6.5	28.0	1.6
Average aquatic invertebrates/volume water (m^3)	5.42	26.6	1.23
Standard deviation of aquatic invertebrate density	1.94	35.38	0.27
Total abundance of aquatic invertebrates[a]	2,425	11,696	1,408
Total abundance Ephemeroptera[a]	316	488	118
Total abundance Plecoptera[a]	12	10	14
Total abundance Trichoptera[a]	87	13	182
Total abundance aquatic Diptera[a]	1,573	2,001	675
Total abundance miscellaneous aquatic species[a]	437	9,184	419
Total abundance terrestrial invertebrates[a]	437	641	386
Total abundance all invertebrates[a]	2,862	12,337	1,794
% Sample aquatic	84.7%	94.8%	78.5%
% Sample terrestrial	15.3%	5.2%	21.5%
Average number aquatic invertebrates/net[b]	485	2,339	282
Average number Ephemeroptera/net[b]	63	98	24
Average number Plecoptera/net[b]	2	2	3
Average number Trichoptera/net[b]	17	3	36
Average number aquatic Diptera/net[b]	315	400	135
Average number miscellaneous aquatic species/net[b]	87	1,837	84
Standard deviation aquatic invertebrates/net	105	35.38	37
Average number terrestrial invertebrates/net[b]	87	128	77
Average number invertebrates/net[b]	572	2,467	359
Standard deviation of invertebrates/net	102	504	55
Total larval fish/net[b]	0	0	0

Notes:

[a] Corrected for subsampling.

[b] Five nets per site.

Drift Nets - 2013

	Monitoring sites		
	NFK reach	SFK reach	UT reach
Sample date	6/25/2013	6/25/2013	6/24/2013
Aquatic invertebrate taxa richness/site	40	32	41
EPT taxa richness/site	13	11	11
% EPT	11.6%	3.1%	20.2%
% Ephemeroptera	6.6%	2.2%	5.6%
% Plecoptera	0.4%	0.5%	0.6%
% Trichoptera	4.5%	0.4%	14.0%
% Aquatic Diptera	63.8%	47.7%	46.6%
% Aquatic Chironomidae	39.6%	11.2%	26.3%
% Miscellaneous aquatic species	24.6%	49.1%	33.2%
% Dominant aquatic taxon	25.8%	25.1%	20.7%
Volume of water (m^3)	468	1,463	858
Average volume of water/net (m^3)	94	293	172
Standard deviation of water volume/net	57	86	33
Estimated total invertebrates/volume water (m^3)	10.5	11.9	5.2
Estimated aquatic invertebrates/volume water (m^3)	5.7	7.4	3.6
Average invertebrates/volume water (m^3)	11.8	10.9	5.1
Average aquatic invertebrates/volume water (m^3)	6.78	7.3	3.56
Standard deviation of aquatic invertebrate density	3.82	1.11	0.28
Total abundance of aquatic invertebrates[a]	2,684	10,802	3,068
Total abundance Ephemeroptera[a]	178	236	173
Total abundance Plecoptera[a]	12	58	18
Total abundance Trichoptera[a]	121	46	428
Total abundance aquatic Diptera[a]	1,712	5,154	1,431
Total abundance miscellaneous aquatic species[a]	661	5,308	1,018
Total abundance terrestrial invertebrates[a]	2,235	6,630	1,377
Total abundance all invertebrates[a]	4,919	17,432	4,445
% Sample aquatic	54.6%	62.0%	69.0%
% Sample terrestrial	45.4%	38.0%	31.0%
Average number aquatic invertebrates/net[b]	537	2,160	614
Average number Ephemeroptera/net[b]	36	47	35
Average number Plecoptera/net[b]	2	12	4
Average number Trichoptera/net[b]	24	9	86
Average number aquatic Diptera/net[b]	342	1,031	286
Average number miscellaneous aquatic species/net[b]	132	1,062	204
Standard deviation aquatic invertebrates/net	3.82	1.11	139
Average number terrestrial invertebrates/net[b]	447	1,326	275
Average number invertebrates/net[b]	984	3,486	889
Standard deviation of invertebrates/net	627	2,522	272
Total larval fish/net[b]	0	0	0

Notes:

[a] Corrected for subsampling.

[b] Five nets per site.

Surber Samples - 2011

	Monitoring sites		
	NFK reach	SFK reach	UT reach
Sample date	7/1/2011	6/30/2011	7/1/2011
Aquatic invertebrate taxa richness/site	28	14	24
EPT taxa richness/site	14	8	11
% EPT	29.8%	43.2%	43.7%
% Ephemeroptera	21.4%	30.9%	31.9%
% Plecoptera	0.4%	7.4%	8.2%
% Trichoptera	8.0%	4.9%	3.6%
% Aquatic Diptera	67.6%	54.9%	50.3%
% Aquatic Chironomidae	64.8%	32.1%	35.3%
% Miscellaneous aquatic species	2.6%	1.9%	6.0%
% Dominant aquatic taxon	30.9%	28.4%	27.7%
Surber area (m^2)	0.28	0.28	0.28
Area/Surber (m^2)	0.9	0.09	0.09
Standard deviation of area/Surber	0.0	0.0	0.0
Estimated total invertebrates/m^2	4,707	649	1,816
Estimated aquatic invertebrates/m^2	4,664	581	1,790
Average invertebrates/m^2	4,707.4	649.4	1,815.5
Average aquatic invertebrates/m^2	4,664.4	581.3	1,790.4
Standard deviation of aquatic invertebrate density	3306.7	423.5	880.4
Total abundance of aquatic invertebrates[a]	1,300	162	499
Total abundance Ephemeroptera[a]	278	50	159
Total abundance Plecoptera[a]	5	12	41
Total abundance Trichoptera[a]	104	8	18
Total abundance aquatic Diptera[a]	879	89	251
Total abundance miscellaneous aquatic species[a]	34	3	30
Total abundance terrestrial invertebrates[a]	12	19	7
Total abundance all invertebrates[a]	1,312	181	506
% Sample aquatic	99.1%	89.5%	98.6%
% Sample terrestrial	0.9%	10.5%	1.4%
Average number aquatic invertebrates/Surber[b]	433	54	166
Average number Ephemeroptera/Surber[b]	93	17	53
Average number Plecoptera/Surber[b]	2	4	14
Average number Trichoptera/Surber[b]	35	3	6
Average number aquatic Diptera/Surber[b]	293	30	84
Average number misc. aquatic species/Surber[b]	11	1	10
Standard deviation aquatic invertebrates/Surber	307	39	82
Average number terrestrial invertebrates/Surber[b]	4	6	2
Average number invertebrates/Surber[b]	437	60	169
Standard deviation of invertebrates/Surber	308	42	80
Total larval fish/site[b]	0	0	0

Notes:

[a] Corrected for subsampling.

[b] Three Surbers per site.

Surber Samples - 2012

	Monitoring sites		
	NFK reach	SFK reach	UT reach
Sample date	6/27/2012	7/13/2012	6/26/2012
Aquatic invertebrate taxa richness/site	33	17	23
EPT taxa richness/site	16	6	12
% EPT	12.5%	39.2%	59.2%
% Ephemeroptera	6.3%	36.7%	40.6%
% Plecoptera	0.4%	0.0%	7.3%
% Trichoptera	5.8%	2.5%	11.4%
% Aquatic Diptera	84.8%	43.3%	38.8%
% Aquatic Chironomidae	82.8%	15.8%	38.2%
% Miscellaneous aquatic species	2.8%	17.5%	1.9%
% Dominant aquatic taxon	41.2%	26.7%	23.6%
Surber area (m^2)	0.28	0.28	0.28
Area/Surber (m^2)	0.9	0.9	0.9
Standard deviation of area/Surber	0.0	0.0	0.0
Estimated total invertebrates/m^2	19,368	466	1,715
Estimated aquatic invertebrates/m^2	19,321	431	1,672
Average invertebrates/m^2	19,367.9	466.4	1,715.1
Average aquatic invertebrates/m^2	19,321.2	430.6	1,672
Standard deviation of aquatic invertebrate density	10,976.9	372.4	1,075
Total abundance of aquatic invertebrates[a]	5,385	120	466
Total abundance Ephemeroptera[a]	339	44	189
Total abundance Plecoptera[a]	19	0	34
Total abundance Trichoptera[a]	313	3	53
Total abundance aquatic Diptera[a]	4,565	52	181
Total abundance miscellaneous aquatic species[a]	149	21	9
Total abundance terrestrial invertebrates[a]	13	10	12
Total abundance all invertebrates[a]	5,398	130	478
% Sample aquatic	99.8%	92.3%	97.5%
% Sample terrestrial	0.2%	7.7%	2.5%
Average number aquatic invertebrates/Surber[b]	1,795	40	155
Average number Ephemeroptera/Surber[b]	113	15	63
Average number Plecoptera/Surber[b]	6	0	11
Average number Trichoptera/Surber[b]	104	1	18
Average number aquatic Diptera/Surber[b]	1,522	17	60
Average number misc. aquatic species/Surber[b]	50	7	3
Standard deviation aquatic invertebrates/Surber	1,020	35	100
Average number terrestrial invertebrates/Surber[b]	4	3	4
Average number invertebrates/Surber[b]	1,799	43	159
Standard deviation of invertebrates/Surber	1,023	33	101
Total larval fish/site[b]	0	0	0

Notes:

[a] Corrected for subsampling.

[b] Three Surbers per site.

Surber Samples - 2013

	Monitoring sites		
	NFK reach	SFK reach	UT reach
Sample date	6/25/2013	6/25/2013	6/24/2013
Aquatic invertebrate taxa richness/site	32	14	23
EPT taxa richness/site	15	7	9
% EPT	17.0%	42.0%	64.3%
% Ephemeroptera	13.2%	29.0%	35.7%
% Plecoptera	0.4%	12.0%	22.1%
% Trichoptera	3.4%	1.0%	6.4%
% Aquatic Diptera	80.5%	55.0%	27.9%
% Aquatic Chironomidae	74.0%	12.0%	17.1%
% Miscellaneous aquatic species	2.5%	3.0%	7.9%
% Dominant aquatic taxon	37.5%	27.0%	25.0%
Surber area (m^2)	0.28	0.28	0.28
Area/Surber (m^2)	0.9	0.9	0.9
Standard deviation of area/Surber	0.0	0.0	0.0
Estimated total invertebrates/m^2	6,989	366	527
Estimated aquatic invertebrates/m^2	6,968	359	502
Average invertebrates/m^2	6,989.4	366.0	527.4
Average aquatic invertebrates/m^2	6,967.8	358.8	502.3
Standard deviation of aquatic invertebrate density	5591.3	167.2	331.0
Total abundance of aquatic invertebrates[a]	1,942	100	140
Total abundance Ephemeroptera[a]	256	29	50
Total abundance Plecoptera[a]	8	12	31
Total abundance Trichoptera[a]	66	1	9
Total abundance aquatic Diptera[a]	1,564	55	39
Total abundance miscellaneous aquatic species[a]	48	3	11
Total abundance terrestrial invertebrates[a]	6	2	7
Total abundance all invertebrates[a]	1,948	102	147
% Sample aquatic	99.7%	98.0%	95.2%
% Sample terrestrial	0.3%	2.0%	4.8%
Average number aquatic invertebrates/Surber[b]	647	33	47
Average number Ephemeroptera/Surber[b]	85	10	17
Average number Plecoptera/Surber[b]	3	4	10
Average number Trichoptera/Surber[b]	22	0	3
Average number aquatic Diptera/Surber[b]	521	18	13
Average number misc. aquatic species/Surber[b]	16	1	4
Standard deviation aquatic invertebrates/Surber	519	16	31
Average number terrestrial invertebrates/Surber[b]	2	1	2
Average number invertebrates/Surber[b]	649	34	49
Standard deviation of invertebrates/Surber	519	15	29
Total larval fish/site[b]	0	0	0

Notes:

[a] Corrected for subsampling.

[b] Three Surbers per site.

Appendix 5. Juvenile Dolly Varden Whole-Body Total Metals Concentrations

2010

					Results (mg/kg)														Results (%)	
				Method	200.8	200.8	200.8	200.8	6010C	200.8	200.8	7471B	200.8	200.8	7010	200.8	200.8	200.8	Freeze dry	NOAA
				MRL	≤0.050	≤0.50	0.020	0.020	0.20	0.10	0.020	≤0.020	≤0.050	0.20	1.0	0.020	0.020	≤0.50	-	≤0.249
				MDL	0.020	0.04	0.004	0.005	0.08	0.03	0.005	0.004	0.007	0.02	0.3	0.020	0.002	0.08	-	≤0.249
Sample no.	Date collected	Length (mm)	Weight (g)	Analyte	Sb	As	Be	Cd	Cr	Cu	Pb	Hg	Mo	Ni	Se	Ag	Tl	Zn	Solids	Lipids
NFK1	8/31/10	130	21.5		ND	0.29	ND	0.012	0.39	3.10	0.023	0.147	0.072	0.40	2.3	ND	0.011	102	24.3	3.5
NFK1[a]	-	-	-		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.9
NFK2	8/31/10	128	18.4		ND	0.29	ND	0.022	0.73	7.06	0.053	0.146	0.069	0.72	2.5	ND	0.015	128	20.0	1.8
NFK2[a]	-	-	-		ND	0.27	ND	0.022	0.70	7.11	0.050	NA	0.070	0.79	1.6	ND	0.016	138	NA	NA
NFK3	8/31/10	105	11.1		0.090	0.34	0.014	0.036	0.40	3.59	0.116	0.141	0.097	0.94	3.4	ND	0.045	135	20.7	2.1
NFK4	8/31/10	120	14.6		ND	0.45	0.013	0.027	1.39	3.96	0.191	0.096	0.098	0.96	3.0	ND	0.016	137	21.2	1.7
NFK5	8/31/10	105	9.5		ND	1.52	0.032	0.026	3.17	6.73	0.252	0.094	0.223	1.75	3.0	ND	0.019	160	23.1	2.7
NFK6	8/31/10	120	14.5		ND	1.13	0.040	0.024	8.43	5.38	0.339	0.117	0.243	2.69	2.1	ND	0.026	122	23.1	2.4
NFK7	8/31/10	120	16.3		0.055	1.22	0.049	0.039	13.9	6.88	1.020	0.107	0.335	5.36	2.4	0.034	0.029	84.8	23.3	2.6
NFK8	8/31/10	107	10.1		ND	0.17	ND	0.019	2.41	4.39	0.055	0.085	0.084	1.38	2.2	ND	0.014	112	22.1	2.5
NFK9	8/31/10	115	14.5		ND	0.96	0.037	0.020	17.5	4.23	0.517	0.121	0.394	6.77	2.4	ND	0.019	96.7	27.4	5.1
NFK10	8/31/10	118	13.5		0.087	2.20	0.086	0.047	12.1	9.46	0.905	0.093	0.335	3.51	1.9	0.022	0.040	94.0	25.7	2.4
NFK11	8/31/10	125	17.4		ND	2.25	0.071	0.031	9.38	5.22	0.704	0.104	0.366	2.71	1.6	0.021	0.024	86.6	24.7	2.5
NFK12	8/31/10	104	10.0		ND	2.22	0.090	0.049	9.12	6.62	0.359	0.095	0.233	3.35	3.3	ND	0.036	102	24.0	1.0
NFK13	8/31/10	105	10.5		ND	0.85	0.045	0.028	3.78	4.69	0.416	0.096	0.206	2.03	2.9	ND	0.031	99.0	24.1	2.3
NFK14	8/31/10	112	12.9		ND	0.78	0.035	0.020	16.5	5.62	0.203	0.090	0.844	3.12	2.0	ND	0.025	78.7	25.3	2.8
SFK1	8/30/10	135	22.1		ND	1.06	0.027	0.115	5.36	6.69	0.678	0.055	0.449	1.41	3.7	ND	0.025	96.7	25.6	4.4
SFK2	8/30/10	114	12.3		ND	0.33	ND	0.174	1.03	4.57	0.079	0.052	0.257	0.95	3.8	ND	0.023	104	22.0	2.7
SFK3	8/30/10	136	22.5		ND	1.79	0.035	0.177	12.6	14.2	1.950	0.038	0.612	4.48	2.7	ND	0.030	108	25.2	3.5
SFK4	8/30/10	135	22.4		ND	0.62	0.013	0.076	2.76	6.06	0.254	0.048	0.262	1.16	4.8	ND	0.027	108	23.1	3.3
SFK5	8/30/10	144	28.1		ND	1.71	0.039	0.149	16.4	9.15	1.380	0.042	0.742	4.93	4.1	ND	0.039	98.2	25.5	2.6
SFK5[a]	-	-	-		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.6
SFK6	8/30/10	126	18.5		ND	6.57	0.110	0.227	8.51	20.3	2.780	0.034	1.110	3.16	2.0	0.026	0.068	129	25.5	2.7
SFK7	8/30/10	138	21.1		0.027	1.44	0.022	0.125	1.29	9.72	0.376	0.026	0.559	1.20	3.0	ND	0.036	121	23.7	3.1
SFK8	8/30/10	128	19.0		ND	0.77	0.015	0.222	2.56	5.12	0.644	0.043	0.183	1.39	3.4	ND	0.045	111	22.6	5.5
SFK9	8/30/10	138	22.1		0.031	0.47	0.006	0.063	2.97	5.78	0.204	0.035	0.213	0.81	2.3	ND	0.012	73.0	25.6	2.4

-continued-

2010 (cont.)

					Results (mg/kg)														Results (%)	
				Method	200.8	200.8	200.8	200.8	6010C	200.8	200.8	7471B	200.8	200.8	7010	200.8	200.8	200.8	Freeze dry	NOAA
				MRL	≤0.050	≤0.50	0.020	0.020	0.20	0.10	0.020	≤0.020	≤0.050	0.20	1.0	0.020	0.020	≤0.50	-	≤0.249
				MDL	0.020	0.04	0.004	0.005	0.08	0.03	0.005	0.004	0.007	0.02	0.3	0.020	0.002	0.08	-	≤0.249
Sample no.	Date collected	Length (mm)	Weight (g)	Analyte	Sb	As	Be	Cd	Cr	Cu	Pb	Hg	Mo	Ni	Se	Ag	Tl	Zn	Solids	Lipids
SFK10	8/30/10	129	18.5		ND	0.58	0.007	0.139	2.61	4.54	0.325	0.048	0.306	1.13	4.5	ND	0.040	108	20.6	1.1
SFK11	8/30/10	132	21.2		0.151	3.23	0.110	0.298	18.1	15.1	2.280	0.085	1.540	3.72	5.0	ND	0.063	131	25.9	2.7
SFK12	8/30/10	148	26.6		ND	0.60	0.014	0.077	3.65	5.34	0.324	0.053	0.262	1.17	4.7	ND	0.029	106	22.4	2.2
SFK12[a]	-	-	-		ND	0.96	0.014	0.088	3.09	5.86	1.570	0.053	0.265	1.42	4.9	0.024	0.028	122	22.6	NA
SFK13	8/30/10	135	20.9		0.033	1.10	0.030	0.128	6.77	7.86	0.707	0.038	0.386	2.39	4.3	ND	0.034	101	22.4	2.4
SFK14	8/30/10	128	18.1		0.099	0.35	0.013	0.083	0.50	3.54	0.104	0.057	0.139	0.58	4.2	ND	0.057	106	22.8	3.4
SFK15	8/30/10	118	13.5		ND	0.29	ND	0.079	0.24	3.92	0.034	0.012	0.071	0.43	2.5	ND	0.011	90.3	24.3	5.1
UT1	9/2/10	105	9.1		0.069	0.42	0.015	0.025	2.08	3.52	0.171	0.065	0.200	1.17	0.4	ND	0.019	111	22.4	1.6
UT2	9/2/10	110	12.5		0.062	0.90	0.038	0.013	2.51	3.52	0.215	0.056	0.222	1.41	0.5	ND	0.015	95.1	23.9	3.0
UT3	9/2/10	125	17.3		0.025	0.53	0.008	0.015	1.34	3.96	0.095	0.095	0.133	0.77	0.8	ND	0.016	100	24.5	4.7
UT4	9/2/10	109	11.9		0.022	0.33	0.008	0.015	1.92	2.97	0.093	0.034	0.132	0.71	ND	ND	0.016	93.5	26.1	4.4
UT5	9/2/10	106	10.2		0.022	0.47	0.011	0.020	1.40	3.52	0.095	0.063	0.092	1.11	ND	ND	0.019	145	19.7	1.1
UT6	9/2/10	135	22.2		ND	0.94	0.008	0.027	0.71	3.54	0.160	0.149	0.109	0.82	2.0	ND	0.016	95.0	22.8	2.5
UT6[a]	9/2/10	-	-		ND	0.95	0.008	0.024	0.40	3.49	0.052	0.179	0.100	0.70	2.1	ND	0.016	92.9	22.2	NA
UT7	9/2/10	125	18.1		0.136	0.77	0.048	0.031	16.0	5.50	0.308	0.078	0.273	4.53	ND	0.022	0.068	91.1	23.8	3.9
UT8	9/2/10	123	15.6		ND	0.13	ND	0.009	0.30	2.73	0.089	0.068	0.042	0.53	1.3	ND	0.012	86.1	24.1	4.8
UT9	9/2/10	135	22.6		ND	0.70	0.037	0.017	4.07	2.97	0.177	0.104	0.205	1.77	ND	ND	0.024	93.8	26.0	3.8
UT10	9/2/10	119	15.3		ND	1.22	0.062	0.018	15.1	4.20	0.463	0.083	0.930	2.42	1.9	ND	0.023	104	23.9	2.1

2011

					Results (mg/kg)																Results (%)	
				Method	200.8	200.8	200.8	200.8	200.8	200.8	200.8	200.8	1631E	200.8	200.8	200.8	200.8	200.8	200.8	200.8	Freeze dry	NOAA
				MRL	≤0.05	≤0.5	0.02	0.5	0.02	0.2	0.1	0.02	≤5.0	≤0.05	≤0.2	1.0	0.02	≤0.02	≤0.05	≤0.5	-	≤0.249
				MDL	0.002	0.02	0.003	0.2	0.002	0.02	0.02	0.0005	≤1.5	0.008	0.02	0.2	0.02	0.0009	≤0.03	0.06	-	≤0.249
Sample no.	Date collected	Length (mm)	Weight (g)	Analyte	Sb	As	Be	B	Cd	Cr	Cu	Pb	Hg	Mo	Ni	Se	Ag	Tl	Sn	Zn	Solids	Lipids
NFK1	9/7/11	124	14.4		0.006	0.64	0.013	ND	0.025	0.26	3.58	0.220	153	0.092	0.30	3.1	ND	0.0149	ND	114	20.3	NA
NFK2	9/7/11	103	9.1		0.021	2.04	0.043	0.4	0.045	4.45	4.24	0.305	177	0.179	2.42	3.0	0.011	0.0406	0.065	122	21.9	NA
NFK3	9/7/11	131	20.7		0.003	0.50	0.015	ND	0.031	7.84	3.09	0.110	93.0	0.095	0.40	2.9	0.015	0.0326	0.039	144	23.3	NA
NFK4	9/7/11	109	8.3		0.007	0.41	0.013	ND	0.020	0.31	3.56	0.172	155	0.089	0.27	3.6	0.006	0.0220	ND	143	22.8	NA
NFK5	9/7/11	95	6.6		0.015	1.99	0.062	0.7	0.027	3.48	5.21	0.647	97.3	0.146	2.89	3.2	0.006	0.0227	ND	108	23.7	NA
NFK6	9/7/11	112	7.6		0.004	0.61	0.027	0.4	0.016	0.29	3.34	0.122	105	0.064	0.41	2.8	ND	0.0185	ND	106	24.5	NA
NFK7	9/7/11	110	10.6		0.008	0.62	0.016	0.2	0.022	0.30	3.35	0.194	65.8	0.127	0.41	4.7	ND	0.0231	ND	133	21.2	NA
NFK8	9/7/11	134	21.1		0.005	0.80	0.029	0.3	0.029	6.77	3.23	0.180	135	0.154	2.63	3.0	0.011	0.0232	0.062	91.8	25.2	NA
NFK9	9/7/11	110	11.2		0.003	0.43	0.009	ND	0.014	0.15	2.45	0.116	92.4	0.078	0.28	3.6	ND	0.0093	ND	86.2	25.4	NA
NFK10	9/7/11	101	8.1		0.012	1.74	0.045	0.4	0.028	6.93	3.98	0.574	100	0.139	2.31	2.4	0.009	0.0220	0.032	133	23.6	NA
NFK11	9/7/11	118	7.8		ND	0.13	ND	0.3	0.010	0.11	2.41	0.017	108	0.051	0.03	4.7	ND	0.0073	ND	97.0	22.7	NA
NFK12	9/7/11	101	9.7		ND	0.25	0.004	0.3	0.015	0.30	2.26	0.038	211	0.065	0.06	4.4	ND	0.0064	0.032	90.2	23.0	NA
NFK13	9/7/11	120	14.7		ND[b]	0.24	0.004	0.3	0.041	0.24	2.84	0.062	142	0.072	0.06	5.0	0.009	0.0328	ND	138	20.9	NA
NFK14	9/7/11	90	7.5		ND[b]	0.24	ND	0.2	0.036	0.34	2.7	0.028	71.1	0.084	0.04	5.8	0.007	0.0142	ND	126	22.4	NA
NFK15	9/7/11	115	13.2		0.009[b]	1.37	0.054	0.7	0.044	0.55	3.17	0.925	87.6	0.179	0.47	3.3	0.011	0.0248	0.040	130	22.4	NA
NFK16	9/7/11	135	19.4		0.014[b]	3.59	0.084	0.4	0.046	3.11	6.44	0.688	68.7	0.250	1.71	3.0	0.008	0.0322	0.047	132	27.2	NA
NFK16[a]	-	-	-		0.008	1.58	0.113	0.7	0.050	2.45	6.01	0.740	268	0.192	1.30	2.8	0.009	0.0309	0.1	127	29.8	-
SFK1	9/8/11	124	15.7		0.041[b]	1.12	0.022	0.5	0.347	1.20	11.40	0.740	68.8	0.829	0.92	5.3	0.007	0.0345	0.038	109	25.9	NA
SFK2	9/8/11	97	7.4		0.037[b]	5.61	0.054	0.5	0.209	3.91	16.40	1.450	46.9	0.482	2.49	3.9	0.007	0.0314	0.076	136	252.5	NA
SFK3	9/8/11	125	16.6		ND	0.34	0.127	0.7	0.058	0.26	3.27	0.407	59.3	0.065	0.10	4.5	ND	0.2650	ND	107	24.3	NA
UT2	9/7/11	125	16.0		0.032	0.48	0.036	0.6	0.012	3.84	3.48	0.200	55.6	0.205	2.19	2.0	0.008	0.0135	0.043	100	22.4	NA
UT3	9/7/11	90	6.8		0.002	0.18	ND	ND	0.005	3.95	2.34	0.008	59.5	0.100	1.74	2.4	ND	0.0055	ND	84.0	22.0	NA
UT4	9/7/11	120	15.1		0.003	0.17	ND	ND	0.013	0.37	2.84	0.011	78.0	0.052	0.04	2.0	ND	0.0056	ND	87.4	23.4	NA
UT5	9/7/11	105	9.1		0.002	0.17	ND	ND	0.009	0.18	2.73	0.016	122	0.053	0.05	2.2	ND	0.0063	ND	101	24.3	NA
UT6	9/7/11	125	15.4		0.002	0.40	0.004	ND	0.007	0.32	3.01	0.048	109	0.057	0.11	1.9	ND	0.0092	ND	99.7	24.0	NA
UT7	9/7/11	110	10.8		0.003	0.29	0.003	0.2	0.010	0.19	2.85	0.030	113	0.053	0.06	2.6	ND	0.0086	ND	97.5	24.1	NA
UT8	9/7/11	120	12.5		0.005	0.23	ND	ND	0.005	0.16	2.70	0.014	86.0	0.085	0.08	1.9	ND	0.0028	ND	107	25.6	NA

2012

					Results (mg/kg)																Results (%)	
				Method	200.8	200.8	200.8	200.8	200.8	200.8	200.8	200.8	1631E	200.8	200.8	200.8	200.8	200.8	200.8	200.8	Freeze dry	NOAA
				MRL	≤0.05	≤0.5	≤0.02	0.5	≤0.02	≤0.02	0.1	≤0.02	≤5.0	≤0.05	≤0.2	1.0	0.02	≤0.02	≤0.05	≤0.5	-	≤0.249
				MDL	0.002	0.02	0.003	0.1	0.002	0.02	0.02	0.0005	≤1.5	0.008	0.02	0.2	0.02	0.0009	≤0.03	0.06	-	≤0.249
Sample no.	Date collected	Length (mm)	Weight (g)	Analyte	Sb	As	Be	B	Cd	Cr	Cu	Pb	Hg	Mo	Ni	Se	Ag	Tl	Sn	Zn	Solids	Lipids
NFK1	8/30/12	133	20.3		0.004	0.29	ND	0.6	0.016	0.23	3.35	0.0185	0.157	0.075	0.12	3.5	0.009	0.0147	ND	116	23.6	NA
NFK2	8/30/12	115	11.1		0.018	0.38	0.011	0.4	0.017	0.8	2.77	0.0804	0.101	0.069	0.25	3.4	0.01	0.0176	ND	112	24.0	NA
NFK3	8/30/12	126	16.8		0.183	0.2	ND	0.4	0.018	0.22	2.62	0.171	0.217	0.073	0.05	4.0	ND	0.0175	ND	112	21.1	NA
NFK4	8/30/12	116	10.5		0.004	0.39	0.007	0.4	0.016	7.63	2.98	0.064	0.071	0.195	3.19	2.4	ND	0.012	0.048	102	24.3	NA
NFK5	8/30/12	106	10.2		0.007	0.8	0.024	1.1	0.03	1.34	3.82	0.128	0.124	0.092	0.61	3.7	0.007	0.0191	ND	120	23.5	NA
NFK6	8/30/12	127	16.2		0.009	0.76	0.014	0.7	0.027	8.52	3.02	0.183	0.105	0.193	3.18	3.1	0.011	0.0223	ND	107	20.6	NA
NFK7	8/30/12	114	14.0		0.01	0.61	0.016	0.5	0.023	11.8	3.49	0.17	0.097	0.265	5.01	3.6	0.007	0.0159	ND	134	20.9	NA
NFK8	8/30/12	138	23.7		0.004	0.32	0.003	0.2	0.024	5.27	3.44	0.0328	0.110	0.145	2.08	3.5	0.008	0.021	ND	121	20.6	NA
NFK9	8/30/12	118	14.7		0.003	0.34	ND	0.4	0.02	5.92	3.45	0.0336	0.195	0.154	2.4	3.4	ND	0.0066	ND	130	23.1	NA
NFK10	8/30/12	140	23.0		ND	0.15	ND	0.3	0.023	5.43	2.26	0.0144	0.227	0.164	2.17	2.8	0.007	0.0311	ND	150	18.3	NA
NFK11	8/30/12	137	23.4		0.007	0.75	0.014	0.5	0.02	6.43	3.54	0.215	0.116	0.152	2.92	2.9	ND	0.0235	ND	92.6	25.5	NA
NFK12	8/30/12	105	9.4		0.009	0.48	0.016	0.7	0.018	8.86	3.93	0.129	0.111	0.217	3.67	2.8	0.009	0.0187	ND	107	21.5	NA
NFK13	8/30/12	126	19.2		0.005	0.55	0.012	0.9	0.017	7.82	3.01	0.119	0.122	0.194	3.03	2.9	0.007	0.0181	0.048	108	25.7	NA
NFK14	8/30/12	106	10.2		0.002	0.32	0.004	1.0	0.014	0.46	2.82	0.0599	0.139	0.079	0.42	2.9	ND	0.0186	0.031	114	22.2	NA
NFK15	8/30/12	106	11.9		ND	0.2	ND	0.5	0.015	0.19	2.97	0.0135	0.131	0.062	0.04	2.2	ND	0.0107	ND	107	23.4	NA
SFK1	8/30/12	125	17.7		0.004	0.25	ND	0.5	0.284	0.25	6.43	0.0617	0.101	0.153	0.23	5.3	ND	0.028	ND	146	23.2	NA
SFK2	8/30/12	118	15.3		ND	0.33	ND	0.3	0.045	0.19	3.51	0.0159	0.074	0.06	0.04	4.9	ND	0.0152	ND	130	22.0	NA
SFK3	8/30/12	105	11.2		0.003	0.18	ND	0.7	0.262	0.13	5.51	0.0275	0.028	0.1	0.08	4.5	ND	0.0188	ND	105	25.4	NA
SFK4	8/30/12	139	23.3		ND	0.17	ND	0.3	0.08	0.17	3.38	0.0207	0.062	0.057	0.05	4.6	ND	0.0179	ND	122	23.5	NA
SFK4[a]	-	-	-		0.004	0.19	ND	0.3	0.076	0.18	3.43	0.0172	NA	0.070	0.03	5.0	ND	0.0175	ND	118.83	24.3	NA
SFK5	8/30/12	135	19.6		0.019	0.34	ND	0.7	0.034	0.28	3.68	0.102	0.058	0.066	0.12	3.5	0.007	0.0073	ND	66.8	26.9	NA
SFK6	8/30/12	99	9.7		0.008	0.3	0.003	0.4	0.129	0.2	7.57	0.0539	0.043	0.135	0.1	4.4	0.008	0.0268	ND	106	24.1	NA
SFK7	8/30/12	126	16.5		0.002	0.19	ND	0.3	0.032	0.13	3.22	0.0219	0.075	0.062	0.02	4.3	ND	0.0136	ND	99.6	24.5	NA
SFK8	8/30/12	95	8.3		0.009	0.62	0.008	0.2	0.069	0.95	4.64	0.286	0.077	0.149	0.32	4.6	0.006	0.0255	ND	163	21.7	NA
SFK9	8/30/12	132	21.6		0.006	0.28	0.007	0.2	0.116	0.35	4.26	0.102	0.059	0.111	0.1	4.1	0.008	0.0231	ND	112	23.5	NA
SFK10	8/30/12	139	24.1		0.004	0.22	ND	0.2	0.042	0.14	3.38	0.0365	0.060	0.052	0.04	4.1	ND	0.0115	ND	92.9	26.1	NA

2012 (cont.)

					Results (mg/kg)																Results (%)	
				Method	200.8	200.8	200.8	200.8	200.8	200.8	200.8	200.8	1631E	200.8	200.8	200.8	200.8	200.8	200.8	200.8	Freeze dry	NOAA
				MRL	≤0.05	≤0.5	≤0.02	0.5	≤0.02	≤0.2	0.1	≤0.02	≤5.0	≤0.05	≤0.2	1.0	0.02	≤0.02	≤0.05	≤0.5	-	≤0.249
				MDL	0.002	0.02	0.003	0.1	0.002	0.02	0.02	0.0005	≤1.5	0.008	0.02	0.2	0.02	0.0009	≤0.03	0.06	-	≤0.249
Sample no.	Date collected	Length (mm)	Weight (g)	Analyte	Sb	As	Be	B	Cd	Cr	Cu	Pb	Hg	Mo	Ni	Se	Ag	Tl	Sn	Zn	Solids	Lipids
SFK11	8/30/12	125	17.6		0.007	0.31	0.005	0.2	0.056	0.55	3.77	0.118	0.104	0.096	0.28	5.3	ND	0.0171	ND	155	20.7	NA
SFK12	8/30/12	107	10.2		0.005	0.55	0.005	0.2	0.277	0.45	5.22	0.273	0.078	0.199	0.24	6.5	0.007	0.0347	ND	123	21.6	NA
SFK13	8/30/12	110	13.4		0.002	0.15	ND	0.3	0.102	0.21	5.18	0.0249	0.083	0.07	0.05	5.1	0.007	0.0262	ND	107	23.4	NA
SFK14	8/30/12	105	10.1		ND	0.25	ND	0.2	0.102	0.17	3.25	0.0247	0.135	0.075	0.06	6.1	0.009	0.0214	ND	127	21.5	NA
SFK15	8/30/12	125	18.0		ND	0.21	ND	0.3	0.062	0.11	3.03	0.0106	0.090	0.052	0.02	4.8	ND	0.0192	ND	95.7	25.4	NA
SFK15[a]	-	-	-		ND	0.21	ND	0.3	0.052	0.11	3.65	0.0168	NA	0.064	0.03	4.9	ND	0.0199	ND	94.22	25.3	NA
UT1	8/30/12	110	12.0		0.012	0.77	0.011	0.6	0.019	2.32	19.8	0.463	0.232	0.09	3.94	1.9	0.011	0.0188	0.487	102	24.4	NA
UT2	8/30/12	115	14.1		0.005	0.47	ND	0.2	0.008	0.74	13.4	0.164	0.082	0.064	1.79	2.1	0.008	0.0138	0.828	104	26.3	NA
UT3	8/30/12	119	15.0		0.004	0.3	0.004	0.2	0.012	1.39	3.12	0.055	0.112	0.075	0.27	3.2	ND	0.0168	ND	103	24.7	NA
UT4	8/30/12	134	21.7		0.017	0.84	0.016	0.4	0.018	1.25	3.95	0.155	0.170	0.111	1.13	2.1	0.006	0.0186	ND	90.1	23.7	NA
UT5	8/30/12	136	24.7		ND	0.16	ND	0.2	0.008	0.27	2.84	0.0179	0.109	0.045	0.16	2.6	ND	0.0099	ND	67.9	23.8	NA
UT6	8/30/12	119	16.3		ND	0.29	ND	0.3	0.01	0.75	2.8	0.0096	0.114	0.054	0.31	2.8	ND	0.0114	ND	86.3	27.1	NA
UT7	8/30/12	122	16.0		0.004	0.47	0.005	0.2	0.013	0.82	3.0	0.0376	0.072	0.077	0.38	2.1	ND	0.0121	ND	119	22.5	NA
UT8	8/30/12	115	14.9		0.005	0.35	ND	0.5	0.007	3.76	2.97	0.0652	0.101	0.106	1.62	1.9	ND	0.015	ND	91.9	22.6	NA
UT9	8/30/12	112	14.5		0.007	0.37	0.004	0.3	0.013	0.35	3.84	0.0508	0.075	0..086	0.23	2.0	0.009	0.0143	ND	92.6	24.4	NA
UT10	8/30/12	137	23.5		0.004	0.4	ND	0.2	0.013	0.39	4.21	0.0396	0.125	0.056	0.15	2.5	ND	0.0125	ND	103	23.3	NA
UT10[a]	-	-	-		ND	0.38	ND	0.1	0.011	0.27	4.11	0.0229	NA	0.059	0.30	2.4	ND	0.0132	ND	106.11	23.3	NA
UT11	8/30/12	116	15.2		0.017	0.22	ND	0.9	0.007	2.58	3.32	0.0142	0.075	0.088	1.1	2.0	0.008	0.0099	ND	85.7	22.9	NA
UT12	8/30/12	127	20.1		0.006	0.18	ND	0.6	0.01	0.26	3.26	0.0207	0.106	0.056	0.06	3.9	ND	0.0153	ND	79.5	26.2	NA
UT13	8/30/12	120	16.5		0.004	0.23	ND	0.9	0.024	3.67	3.16	0.0292	0.061	0.093	1.47	2.2	0.012	0.0125	ND	103	26.6	NA
UT14	8/30/12	135	22.5		0.003	0.32	ND	0.7	0.011	0.27	3.28	0.0251	0.112	0.047	0.12	2.5	ND	0.011	ND	94.5	24.5	NA
UT15	8/30/12	115	13.9		0.003	0.18	ND	0.8	0.013	5.03	5.66	0.0312	0.133	0.132	1.93	2.0	ND	0.0112	ND	126	20.4	NA

Notes: NFK = North Fork Koktuli monitoring reach; SFK = South Fork Koktuli monitoring reach; UT = Upper Talarik monitoring reach; NA = Not analyzed; MRL = Method Reporting Limit; MDL = Method Detection Limit; ND = Not detected at or above MDL; Sb = Antimony; As = Arsenic; Be = Beryllium; Cd = Cadmium; Cr = Chromium; Cu = Copper; Pb = Lead; Hg = Mercury; Mo = Molybdenum; Ni = Nickel; Se = Selenium; Ag =Silver; Tl = Thallium; Zn = Zinc.

[a] Sample duplicate.

[b] Matrix Spike sample recovery is not within control limits.