Technical Report No. 23-04

Aquatic Biomonitoring at the Arctic-Bornite Prospect, 2022

by Chelsea M. Clawson

May 2023

Alaska Department of Fish and Game Habitat Section

Symbols and Abbreviations

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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)

Measures (fisheries)	
fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL
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. 23-04

AQUATIC BIOMONITORING AT THE ARCTIC-BORNITE PROSPECT, 2022

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May 2023

Cover: Subarctic Valley, July 21, 2022. Photograph by Audra Brase.

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INTRODUCTION

The Ambler mining district is located in northwest Alaska in the Kobuk River drainage along the southern end of the Brooks Range (Figure 1). There are two primary deposits currently being explored by Ambler Metals (formerly Trilogy Metals). The Bornite deposit is located about 17 km north of Kobuk in the Ruby Creek drainage, and the Arctic deposit is located approximately 37 km northeast of Kobuk in the upper end of the Subarctic Creek drainage. The Bornite deposit contains primarily copper and cobalt while the Arctic deposit contains copper, lead, zinc, silver and gold. Both Ruby and Subarctic creeks are tributaries to the Shungnak River, which flows into the Kobuk River. A large waterfall in the lower Shungnak River prevents upstream passage of fish, so no anadromous fish occur in the drainage above the falls (Figure 2). All fish around the Bornite and Arctic deposits complete their life cycle within the Shungnak River drainage.

All sample sites except Riley Creek are in the Shungnak River drainage. Riley Creek, which flows into the Kogoluktuk River, was selected to monitor as it is being considered as a possible location for a tailings storage facility.

Figure 1. Location of the Arctic and Bornite deposits in northwest Alaska.

Figure 2. Waterfall on the Shungnak River blocking fish passage upstream, July 21, 2016.

Aquatic baseline work conducted in the area in 2010 focused on macroinvertebrate and fish species presence (Tetra Tech 2011). The fish species documented in the 2010 survey were Arctic grayling (*Thymallus arcticus*), round whitefish (*Prosopium cylindraceum*), slimy sculpin (*Cottus cognatus*), and Dolly Varden (*Salvelinus malma*). Ambler Metals contracted the Alaska Department of Fish and Game (ADF&G) Habitat Section to continue aquatic sampling beginning in 2016. The ADF&G study plan is based on aquatic biomonitoring the Habitat Section conducts at various large hard rock mines in the state (Bradley 2017b). Three primary types of data are collected: periphyton, aquatic invertebrates, and fish, which included samples for whole body element analyses. Biomonitoring has been performed annually except for 2020 when all camp operations were suspended due to the Covid-19 pandemic.

This report summarizes the periphyton, aquatic invertebrate, and fish samples collected by ADF&G, and water quality data collected by Ambler Metals in 2022, with comparisons to prior years when appropriate. Sampling in 2022 included trips in late spring and early winter, in addition to the standard mid-summer sampling event. New in 2022, aquatic invertebrates and periphyton were collected at Center of the Universe Creek, where in previous years only fish sampling was conducted.

Location and Description of Monitoring Sites

The full suite of biomonitoring activities were performed at ten sites, and fyke net sampling was performed at one site in the drainages surrounding the Arctic and Bornite deposits during the standard mid-summer sampling trip (Table 1; Figure 3). Sunshine Creek was added in 2021 because it is in the vicinity of a new deposit being explored by Ambler Metals. Sampling efforts were concentrated in Ruby and Subarctic creeks as there may be changes to these aquatic systems based on projected mining development. Additional sampling for fish presence occurred in April 2022 (seven sites) and October 2022 (five sites) (Figure 4).

- **Upper Ruby Creek** is characterized by beaver pond habitats, deep water, dense vegetative cover, short channels between beaver dams, and minimal gravel/cobble. The sample site is in a channel between beaver dams and was chosen for its gravel/cobble substrate.

- **Lower Ruby Creek** is characterized by pool/riffle habitat, shallower water, gravel substrate, and grass riparian habitats.

- **Upper Shungnak River** is characterized by deep water, outside bend cut banks and inside bend gravel bars. The substrate is primarily gravel with some cobble.

- **Upper Subarctic Creek** is in alpine tundra and is characterized by high gradient with step pools and large boulders. There are some shrubby willows along the banks, but most vegetation is limited to ground cover. This sample site is located a few hundred meters below the origin of the creek, which abruptly forms when water transitions from subsurface to surface flow.

- **Lower Subarctic Creek** has a much lower gradient than the upper site, is wider, and is characterized by riffle/pool habitat with gravel/cobble substrate.

- **Riley Creek** is characterized by riffle/pool habitat with gravel and cobble.

- **Jay Creek** is characterized by riffle/run habitats with very dense vegetation and overhanging canopy.

- **Lower Red Rock Creek** has similar habitat to the Lower Subarctic Creek site, with riffle/pool habitat and gravel/cobble substrate. This drainage is directly north of Subarctic Creek drainage on the Shungnak River and may provide alternative fish habitat if Subarctic Creek is altered by future mining activity.

- **Center of the Universe Creek** is a tributary of Red Rock Creek that enters above the Upper Red Rock Creek sampling location. The creek is characterized by riffles and runs interspersed with pools. Substrate here is smaller gravel than at other downstream sites.

- **Sunshine Creek** is characterized by riffle/run habitats and gravel/cobble substrate. The sample site is just upstream of a large beaver pond. The upper reaches of Sunshine Creek are very high gradient.

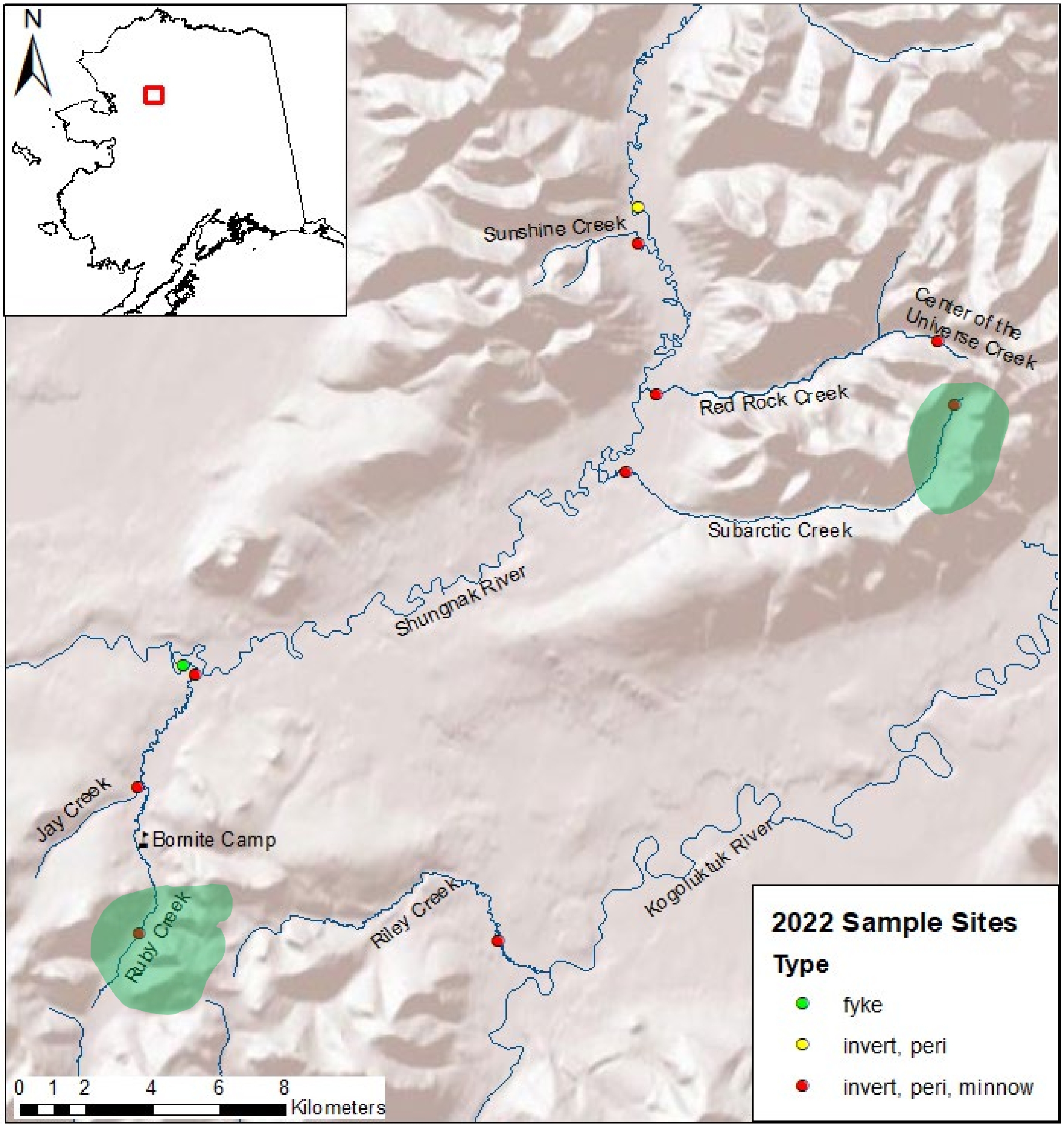

Figure 3. All locations sampled in July 2022. The approximate location of the Bornite and Arctic deposits are denoted by the green polygons.

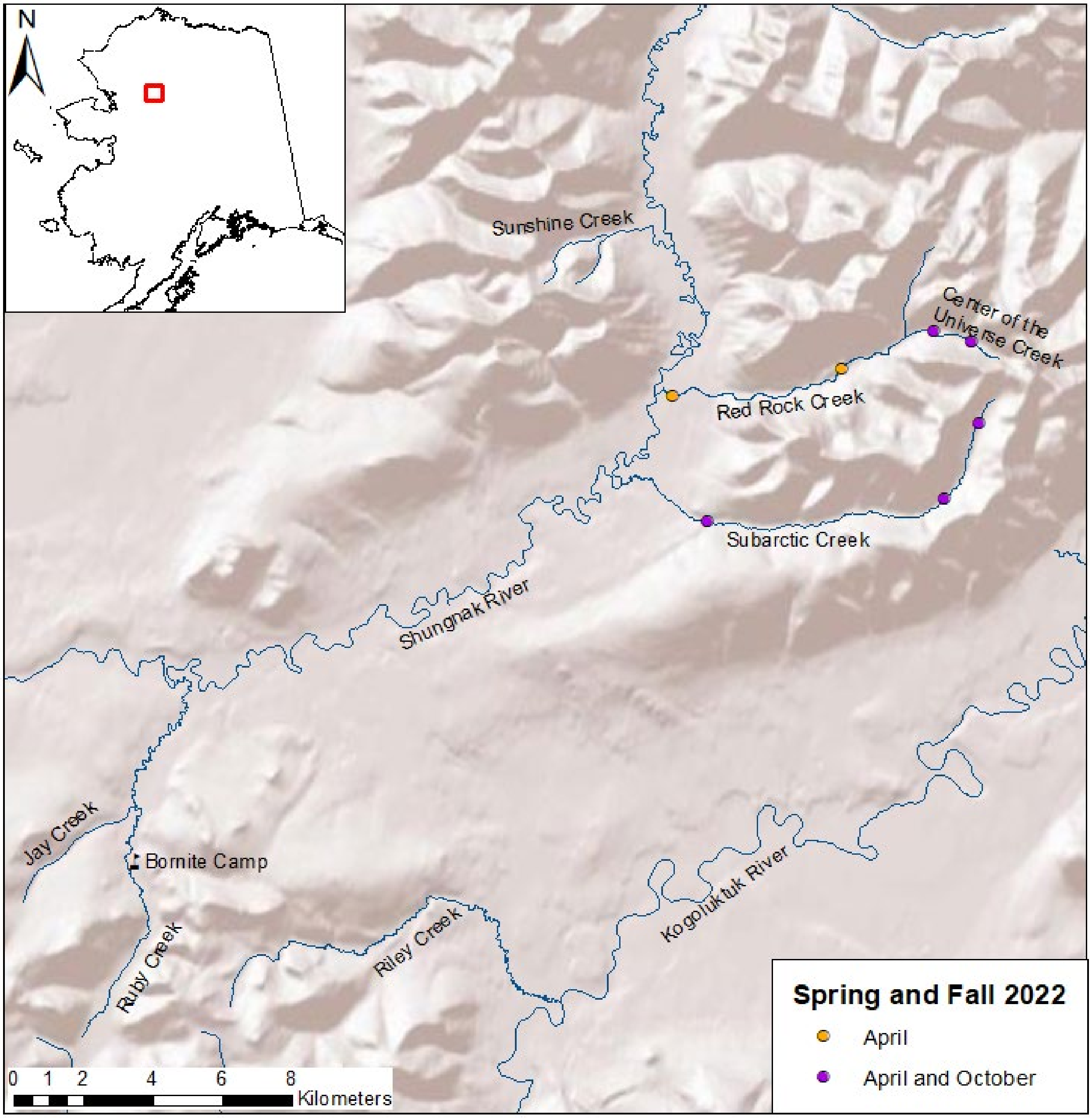

Figure 4. Locations sampled in April 2022 and October 2022.

Table 1. Arctic-Bornite sampling locations (WGS 84), 2022.

Sample Site	Latitude	Longitude	Invertebrates	Periphyton	July Minnow	Fyke Nets
Upper Subarctic	67.1926	-156.3911	X	X	X	
Lower Subarctic	67.1720	-156.6208	X	X	X	
Lower Red Rock	67.1932	-156.5991	X	X	X	
Upper Ruby	67.0408	-156.9394	X	X	X	
Lower Ruby	67.1114	-156.9084	X	X	X	
Mouth of Ruby	67.1140	-156.9167				X
Upper Shungnak	67.2440	-156.6160	X	X		
Riley	67.0426	-156.6923	X	X	X	
Jay	67.0804	-156.9445	X	X	X	
Upper Center of the Universe	67.2010	-156.4041	X	X	X	
Sunshine	67.2335	-156.6162	X	X	X	

METHODS

Sampling Overview

The objective of the biological monitoring program is to document in-situ productivity of aquatic communities at each sample site, and background levels of elements and metals in the vicinity and downstream of potential project facilities.

In 2022 there were three sampling events in the Arctic Bornite area. The first sampling event occurred from April 20 – 23. This sampling event was conducted to assess fish overwintering presence in Subarctic, Red Rock, and Center of the Universe creeks. The standard baseline sampling event took place from July 18 – 23. At each location replicate samples of the aquatic community were collected, including aquatic invertebrates, periphyton, and fish (Table 1). A subset of fish were retained for whole body element analysis. The final sampling event occurred from October 17 – 21. The purposes of this sampling event were to sample Subarctic and Center of the Universe creeks for Dolly Varden presence and spawning condition, and perform an aerial survey of the Kogoluktuk River for evidence of anadromous fish presence.

Beginning in 2021, aquatic invertebrates were collected with Hess samplers rather than drift nets to identify and quantify the in-situ macro invertebrate community. This change was made to better identify the benthic community, rather than the drifting invertebrate community. This provides a more accurate baseline for evaluating changes at each sampling location.

Water Quality

Ambler Metals has collected water quality data from many locations throughout the Arctic-Bornite Prospect project area. The 2016 ADF&G technical report summarized all water quality data collected from 2008 to 2016 (Bradley 2017a). This report summarizes only the water data collected in 2022. These data were provided to ADF&G and were compiled and graphed showing mean, minimum, and maximum values (Appendix 1). Only water quality data from locations near the 2022 sample sites were used. Between two and four water samples were collected at each sample site from January to December 2022.

Periphyton

Periphyton, or attached micro-algae, are sensitive to changes in water quality and are often used in monitoring studies to detect changes in aquatic communities (Ott and Morris 2010). The presence of periphyton in a stream system is evidence of in-situ productivity (Ott and Morris 2010). Periphyton samples were collected at ten locations around the Arctic-Bornite area (Table 1; Figure 3).

Ten flat rocks, each larger than 25 cm^2 were collected from submerged areas at each site. A 5 cm x 5 cm square of high-density flexible foam was placed on the rock. All the material around the foam was scrubbed off with a toothbrush and rinsed back into the stream. The foam square was then removed from the rock, and that section of the rock was brushed and rinsed onto a 0.45 µm glass fiber filter receptacle attached to a hand vacuum pump. Material from the toothbrush was also rinsed onto the filter. The water was extracted from the periphyton covered filter using a hand vacuum pump. Just before all the water was pumped through the filter, one to two drops of magnesium carbonate ($MgCO_3$) were added to the water to prevent acidification and additional conversion of chlorophyll-a to phaeophytin.

Filters from each rock were folded in half, with the sample material on the inside, and placed in individual dry paper coffee filters. All ten coffee filters were placed in a zip-lock bag containing desiccant to absorb remaining moisture. The bags were then wrapped in aluminum foil to prevent light from reaching the samples, placed in a cooler with ice packs, then transferred to a freezer at the Bornite camp. Samples were kept frozen until they were analyzed at the ADF&G laboratory in Fairbanks. Additional details regarding periphyton sampling and analysis methods can be found in ADF&G Technical Report No. 17-09 (Bradley 2017b).

Aquatic Invertebrates

At each sample site, five samples were collected using a Hess sampler (Table 1; Figure 5). The Hess stream bottom sampler has a 0.086 m^2 sample area and material is captured in a 200 mL cod end – both constructed with 300 µm mesh net. Rocks within the sample area were scoured by hand, and gravel, sand, and silt were disturbed to about 10 cm depth to dislodge macroinvertebrates into the net. The cod end contents were then removed and placed in individual pre-labeled Nalgene bottles with denatured ethyl alcohol to preserve the samples. Samples were sorted and invertebrates identified to the lowest taxonomic level, typically family or genus, by a private aquatic invertebrate lab in Fairbanks. Because invertebrates belonging to the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) are more sensitive to water quality, the total number of individual specimens of EPT was calculated and compared to groups of other invertebrates, which are less sensitive. Macroinvertebrate density was calculated for each sample by dividing the number of macroinvertebrates by 0.086 m^2, the Hess sampling area. Mean density was estimated for each site by calculating the mean density among the five samples.

Figure 5. Collecting invertebrate samples using a Hess sampler on Lower Subarctic Creek.

Fish

For the April sampling trip, five minnow traps were baited with cured salmon roe in a perforated plastic bag, and were set at the Lower Red Rock, Middle Red Rock, Lower Subarctic, and Middle Subarctic creeks. Four traps were set at Lower Center of the Universe and Upper Subarctic creeks, and one trap was set at Upper Center of the Universe. Trap locations were limited due to lack of water flow. The baited traps were set in sections of open water that were deep enough to submerge the throats of the traps. Traps were soaked overnight and checked about 24 hours later. All captured fish were measured for fork length then released.

During the July sampling trip, periphyton and aquatic invertebrates were collected at each baseline site and then ten baited minnow traps were placed upstream and downstream of the periphyton and aquatic invertebrate sampling locations (Table 1). Traps were placed in a variety of habitats, including cut banks, pools, and near submerged woody debris. Traps were soaked overnight and checked about 24 hours later. All captured fish were measured for fork or total length, depending on species. Some fish were retained for whole body element analyses. Those fish were handled wearing class 100 nitrile gloves and placed in individual pre-labeled plastic zip-lock bags. The bagged fish were placed in a cooler with ice packs in the field and then transferred to a freezer in the camp. The samples remained frozen until they were analyzed by ACZ Laboratories, Inc.

In addition to the minnow traps, fyke nets were set at the mouth of Ruby Creek during the July sampling event (Table 1). Fyke nets are used at this location due to the presence of large adult fish, and species that do not typically respond to baited minnow traps (e.g., Arctic grayling and round whitefish). Two nets were set to capture fish moving both upstream and downstream. Nets were fished for approximately 36 hours and checked twice a day. All captured fish were measured for fork or total length, depending on species. Some fish were retained for whole body element analyses. Captured fish received an upper caudal fin clip to prevent double counting recaptures.

During the October sampling event, ten baited minnow traps each were set at the Upper Subarctic, Middle Subarctic, and Lower Subarctic sample sites, as well as the Upper Center of the Universe and Lower Center of the Universe sample sites. Traps were soaked overnight and checked about 24 hours later. All captured fish were measured for fork or total length, depending on species. Dolly Varden were checked for maturity and all fish were released. An aerial survey using a helicopter was performed to look for anadromous fish, evidence of redds, and/or carcasses on the Kogoluktuk River from the confluence of the Kogoluktuk with the Kobuk River upstream approximately 10 river miles until sheet ice obscured the channel.

RESULTS AND DISCUSSION

Water Quality

A summary of sample dates and water quality results are shown in Appendix 1. Alaska Department of Environmental Conservation (ADEC) water quality standards are presented for some metals for both acute (24 hr) and chronic (one month) aquatic life exposure limits (Appendix 1). Most of the water quality sites are at the same location as the periphyton, aquatic invertebrate, and fish sampling. However, the water quality data from the Shungnak River used in these results were collected just upstream of the mouth of Subarctic Creek, not at the biomonitoring reference site further upstream (Upper Shungnak River).

In general, mean cadmium concentrations in 2022 were low and similar to previous years (Figure 6; Appendix 1). Upper Ruby, Lower Ruby, and Riley were all at or below the detection limit (0.025 µg/L). The highest mean concentration occurred in the Shungnak River, consistent with past years. Water quality acute and chronic exposure standards for aquatic life for cadmium depend on water hardness. Cadmium concentrations were below the acute and chronic water quality standards at all sites for all sampling events except the August sample on the Shungnak River, which exceeded chronic exposure standards but were well below acute exposure standards. (Appendix 1). In past years, the dissolved cadmium concentrations at the Shungnak River site have also slightly exceeded the chronic cadmium exposure standard.

Mean selenium concentrations were very low among all sample sites (Figure 6; Appendix 1). Samples were below the detection limit for all samples at Upper Ruby, Upper Subarctic, and Riley creeks. All concentrations were well below the current water quality standard for aquatic life which is 20 µg/L for acute exposure and 5 µg/L for chronic exposure.

Mean copper concentrations ranged from 1.91 µg/L at the Shungnak River site to below the detection limit at the Upper Subarctic and Upper Ruby sites (Figure 6; Appendix 1). The highest maximum concentration for copper was 2.17 µg/L and occurred at Shungnak River in August. Acute and chronic water quality standards for aquatic life for copper depend on water hardness. Copper concentrations were below the acute and chronic exposure standards at all sites for all sampling events (Appendix 1).

Mercury concentrations were below the detection limit for all sites and samples except the October sample at Upper Ruby Creek (Figure 6; Appendix 1). This concentration was 2.35 ng/L on October 18, 2022. All mercury concentrations were well below the water quality standards for aquatic life for mercury which are 2,400 ng/L for acute exposure and 12 ng/L for chronic exposure.

No zinc was detected at Riley Creek (Figure 6). The highest maximum zinc concentration occurred at Shungnak River in April (35.30 µg/L). Overall, zinc concentrations were very low and well below the acute and chronic water quality standards for aquatic life, which depend on water hardness (Appendix 1).

Total Dissolved Solids (TDS) concentrations in 2022 followed a pattern very similar to past years (Appendix 1). Lowest mean concentrations occurred in Lower Subarctic Creek (63 mg/L) and Upper Subarctic Creek (74.5 mg/L), and the highest mean concentrations occurred in Upper Ruby Creek (205 mg/L) (Figure 6; Appendix 1).

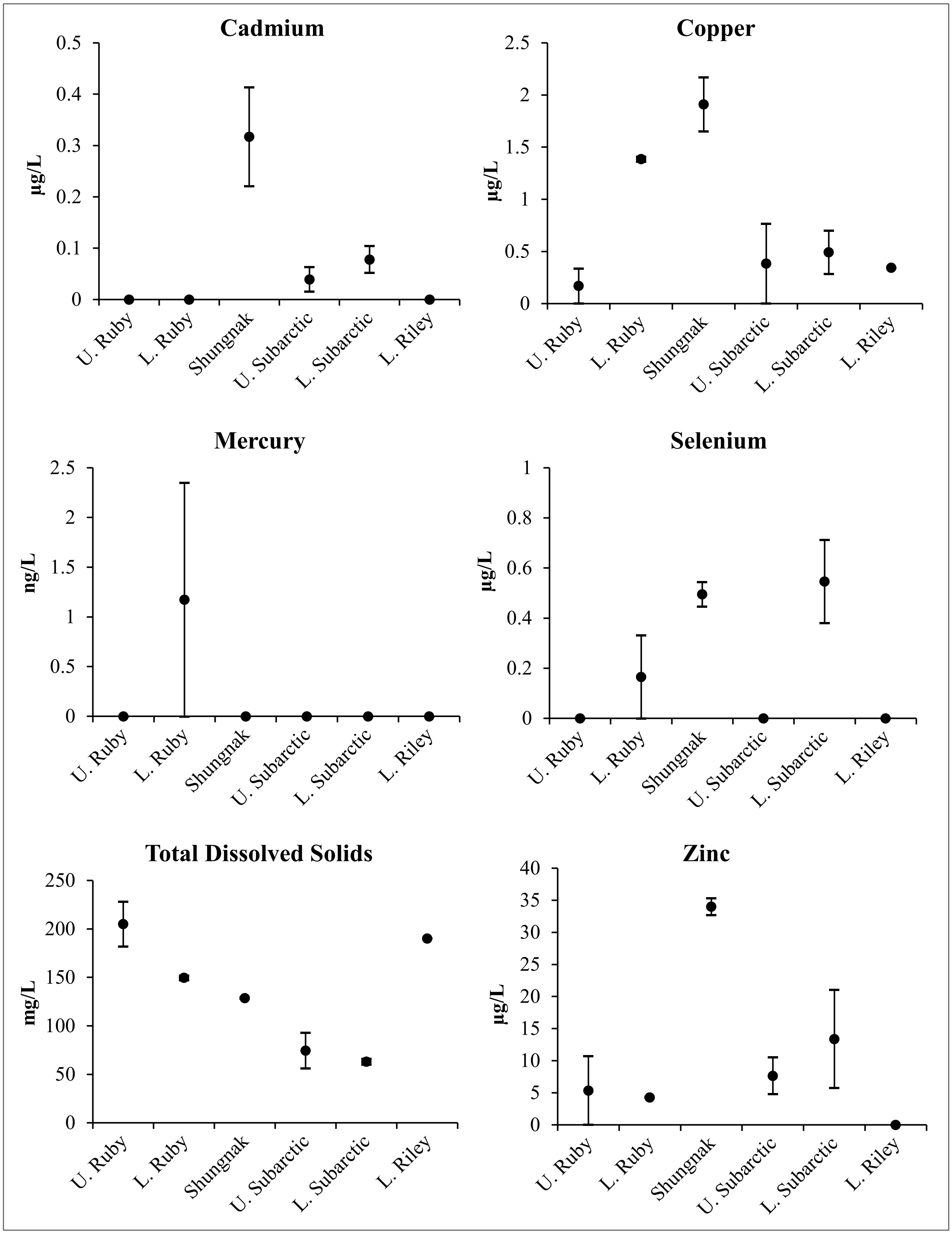

Figure 6. Mean, minimum, and maximum analyte concentrations at water quality sample sites, 2022. All results are total recoverable. Please note the difference in y-axis units and scale between analytes.

Periphyton

In 2022, mean chlorophyll-a concentrations were highest in Upper Ruby Creek (40.00 mg/m^2) and lowest in Lower Red Rock Creek (0.28 mg/m^2) (Figure 7). The mean chlorophyll-a concentrations at the remaining sites ranged from 0.83 mg/m^2 to 4.40 mg/m^2. Mean chlorophyll-a concentrations in 2022 were similar to previous years' values (Figures 7 and 8). Upper Ruby Creek has consistently had the highest chlorophyll-a concentration of all the sample sites since data collection began.

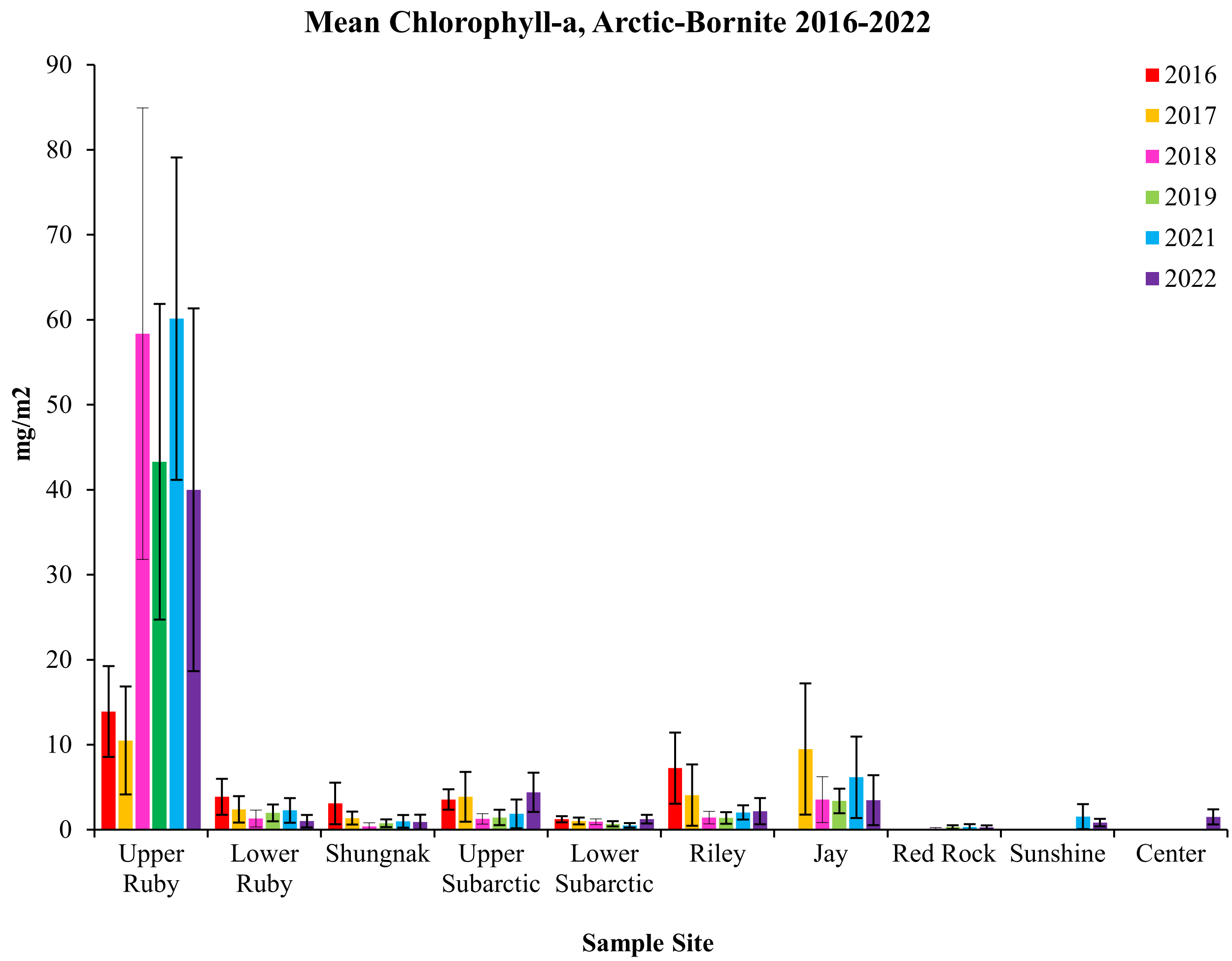

Figure 7. Mean chlorophyll-a concentrations ± 1 SD, 2016 – 2022. The Jay Creek site was added in 2017, the Red Rock Creek site was added in 2018, the Sunshine Creek site was added in 2021, and the Center of the Universe Creek site was added in 2022. No sampling was performed in 2020.

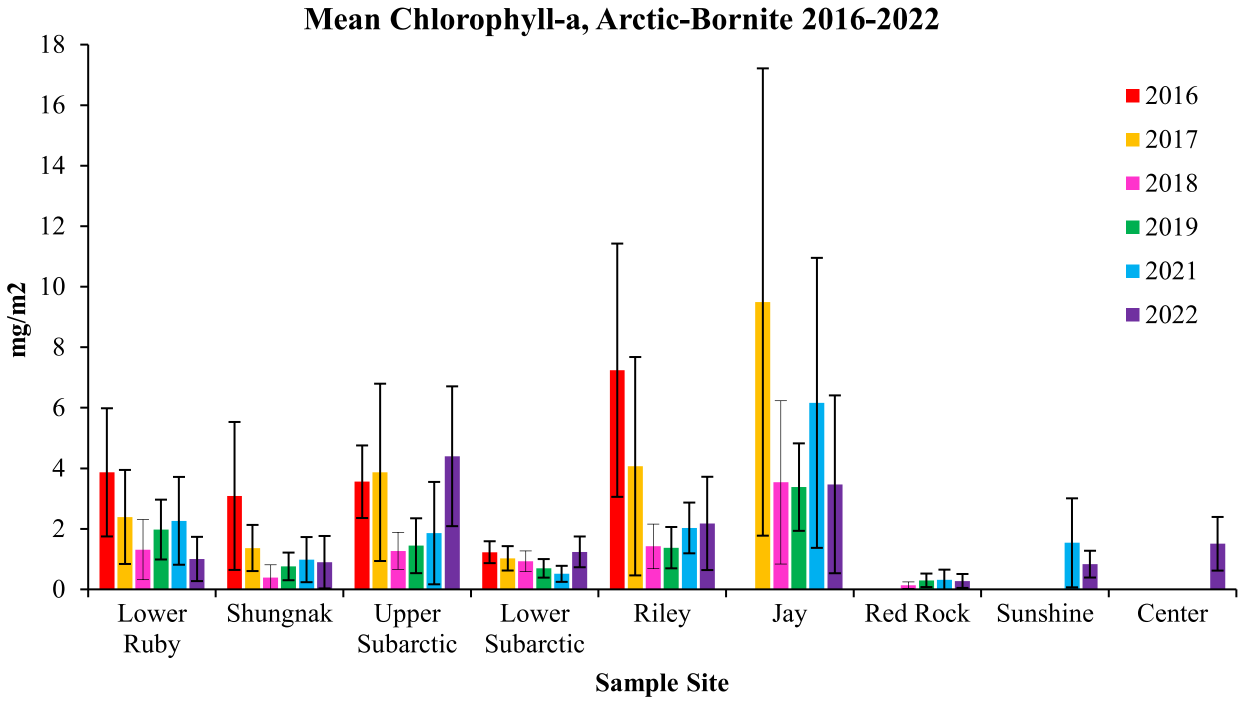

Figure 8. Mean chlorophyll-a concentrations ± 1 SD for all sites except Upper Ruby, 2016 – 2022.

Aquatic Invertebrates

Trends in aquatic invertebrate abundance in 2022 were similar to past years. The average aquatic invertebrate density at Upper Ruby Creek in 2022 was 72,733 aquatic invertebrates/m^2 of substrate, much higher than any other site (Figure 9). This has consistently been the case in all sample years. Red Rock Creek had the lowest density at 72 aquatic invertebrates/m^2 of substrate, also consistent with past years (Figure 9). Upper Ruby Creek samples are dominated by aquatic Diptera, primarily chironomids. The Subarctic Creek sample sites generally have a higher proportion of EPT species than the Ruby Creek sample sites, which was also the case in 2022. In 2022, Red Rock Creek had a higher proportion of EPT than Upper or Lower Subarctic Creek, but given that only 28 individual aquatic invertebrates were captured at Lower Red Rock Creek, caution should be used in interpreting those results (Figure 10). In comparison, 1,719 aquatic invertebrates were captured at Upper Subarctic Creek and 1,072 were captured at Lower Subarctic Creek (Figure 9). In 2022, 52% of the aquatic invertebrate sample at Upper Subarctic Creek was comprised of other species, primarily Ostrocods. Similarly, 38% of the community composition at Lower Subarctic Creek was other species, but at this site those were primarily Oligochaetes

(Figures 10 and 11). Taxa richness varied from a minimum of 8 species at Lower Red Rock Creek to a maximum of 23 species at Lower Ruby, Riley, and Jay creeks. The remaining sites ranged from 16 – 21 species.

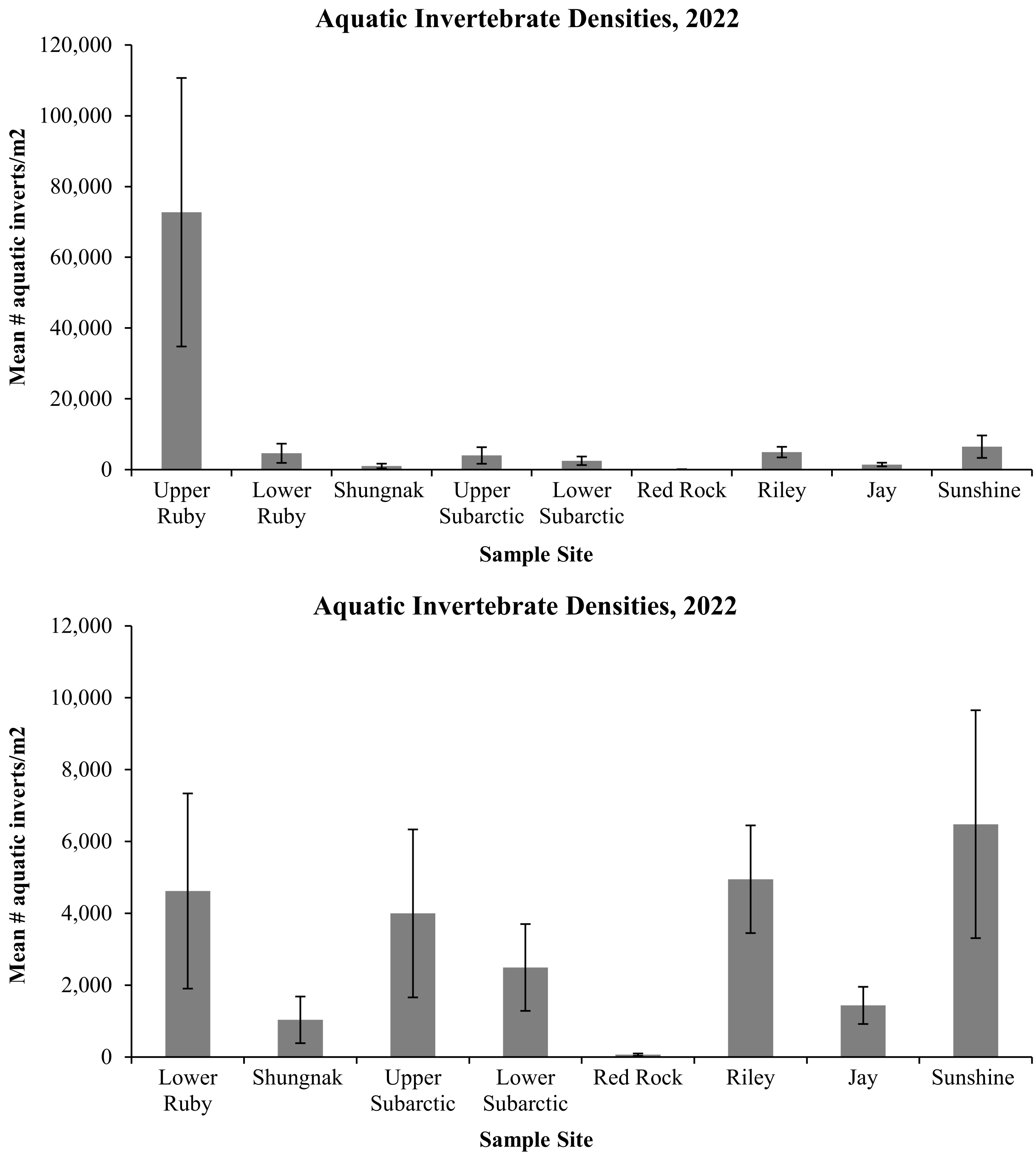

Figure 9. Mean number of aquatic invertebrates/m^2 substrate (± 1 SD) at each sample site, 2022. The bottom figure excludes the Upper Ruby Creek sample site and has a different scale on the y-axis.

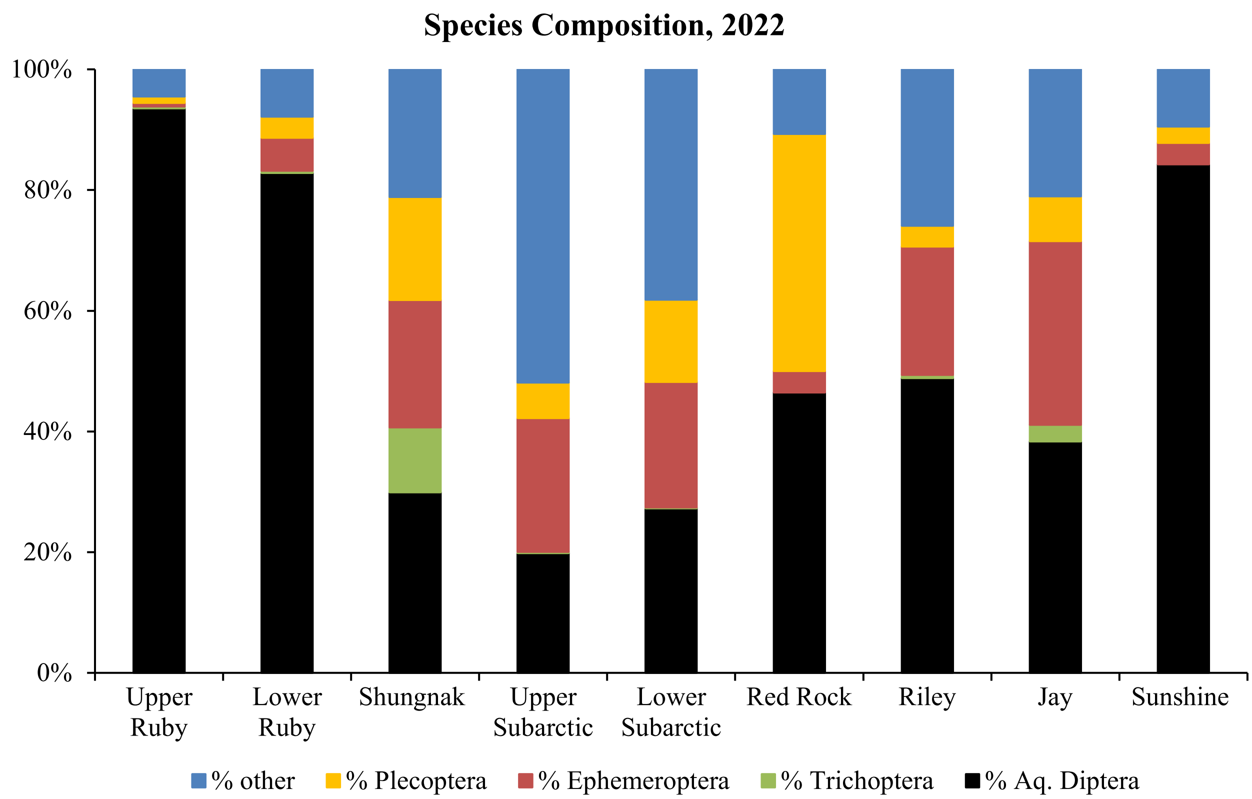

Figure 10. Mean percent EPT, aquatic diptera, and other species in the aquatic invertebrate samples, 2022.

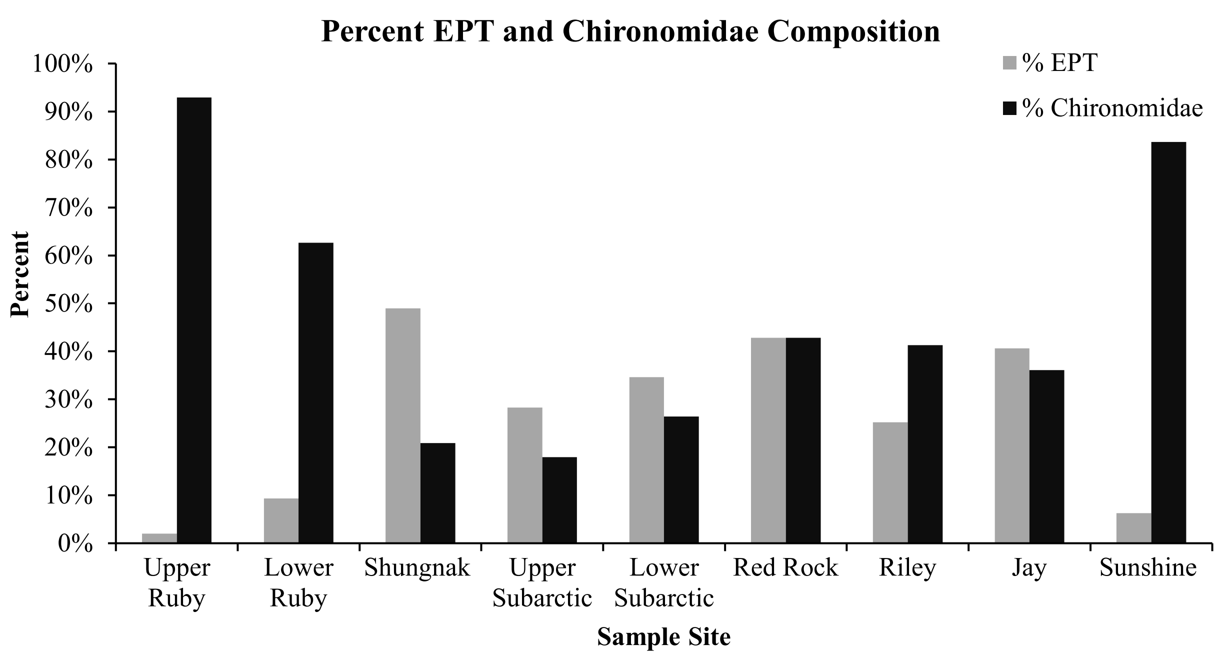

Figure 11. Percent EPT and Chironomidae in the aquatic invertebrate samples, 2022.

Fish Captures

April Minnow Traps

During the April sampling event, three Dolly Varden were caught in the minnow traps at Lower Center of the Universe Creek, and two Dolly Varden were caught at Middle Subarctic Creek (Figure 12). There was no surface water connection between the lower section of the creek and these upper sites, therefore these fish captures confirm that Dolly Varden overwinter in Center of the Universe Creek, and provide additional evidence that Dolly Varden overwinter in Subarctic Creek. One Dolly Varden was captured at Upper Subarctic Creek in March 2021 (Clawson 2022), so the capture of two fish in the middle section of Subarctic Creek indicates that there is overwintering habitat in multiple locations throughout the drainage. Water quality sampling throughout the Subarctic Creek drainage confirms that at least portions of this creek remain flowing all winter, likely due to the extensive groundwater inputs throughout Subarctic Valley. The fish captured in April 2022 ranged from 64 – 130 mm FL.

Figure 12. Fish capture location at Lower Center of the Universe Creek (left) and Middle Subarctic Creek (right) in April 2022.

July Minnow Traps

Throughout Ruby Creek, slimy sculpin dominated catches in 2022 (Table 2). No Dolly Varden were captured at Lower Ruby Creek, as is typical in most sample years. Lower Ruby Creek is the only location where Alaska blackfish and longnose suckers have been captured, although they are not captured every year. Three Dolly Varden were captured in Upper Ruby Creek. There are many beaver dams in this drainage which may impede passage of fish, but ponds created by beavers may also provide overwintering habitat for fish in Upper Ruby Creek by creating large, deep pools.

Dolly Varden dominated catches in Subarctic Creek, with only four slimy sculpin captured at the Lower Subarctic Creek sample site (Table 2). Typically, many more Dolly Varden are captured at the Upper Subarctic Creek site than at the Lower Subarctic Creek site. Three Dolly Varden from the lower sample site and eight from the upper sample site were retained for whole body element analysis.

A total of 10 slimy sculpin and one Dolly Varden were captured on Riley Creek in 2022 (Table 2). Six slimy sculpin were retained for whole body element analysis. Fish catches in Riley Creek are generally a mix of slimy sculpin and Dolly Varden, although typically more slimy sculpin are caught than Dolly Varden.

Two Dolly Varden were captured on Jay Creek (Table 2). Since we are unable to consistently catch enough fish for an adequate sample size in this creek, we did not retain any fish for element analysis.

Red Rock Creek was initially sampled in 2018 to ascertain if Red Rock Creek could provide viable fish habitat in case Subarctic Creek is altered by mine development. Three locations throughout the creek were sampled in 2018, and Dolly Varden were captured at all three sample sites, even above a series of small waterfalls between the middle and upper sample sites. After 2018, sampling was condensed to the lower site only. In 2022, 12 Dolly Varden and four slimy sculpin were captured and six Dolly Varden were retained for element analysis (Table 2).

Center of the Universe Creek had been previously sampled in September to document spawning Dolly Varden, but had not been minnow trapped in July prior to 2021 (Clawson 2020). In 2022, five Dolly Varden were captured during the July sampling event (Table 2).

One Dolly Varden was captured at the Sunshine Creek site (Table 2; Figure 13). Flow patterns had changed somewhat in 2022, and there was limited habitat in the approximately 100 meters between the large beaver pond and the high gradient section of the creek.

Figure 13. Sunshine Creek sample site, looking downstream toward a beaver pond.

Table 2. Number, mean length, and length range of slimy sculpin and Dolly Varden captured in minnow traps, July 2022.

Sample Site	Slimy Sculpin			Dolly Varden		
	Number captured	Mean total length (mm)	Length range (mm)	Number captured	Mean fork length (mm)	Length range (mm)
Subarctic						
Upper	0	---	---	34	108	64-165
Lower	4	70	50-81	3	107	90-135
Ruby						
Upper	36	77	56-100	3	148	146-150
Lower	36	68	50-82	0	---	---
Red Rock						
Lower	4	66	64-70	12	128	69-160
Center of the Universe	0	---	---	5	129	94-152
Jay	0	---	---	2	121	117-124
Riley	10	68	52-90	1	130	130
Sunshine	0	---	---	1	80	80

July Fyke nets

On July 19, two fyke nets were set near the mouth of Ruby Creek, one to capture fish moving upstream, and the other set to capture fish moving downstream. The nets were checked on July 20 and the upstream net was pulled as it had been severely damaged by a beaver. The downstream net was clogged with beaver debris, so it was cleaned and reset further downstream. The downstream net was checked and pulled on July 21. All captured fish except slimy sculpin received a fin clip on the upper caudal fin to prevent double counting. A total of 34 round whitefish, 25 Arctic grayling, one longnose sucker, and three slimy sculpin were captured (Figure 14). The captured Arctic grayling ranged from 79 – 222 mm FL, with an average size of 146 mm (Figure 15). Captured round whitefish ranged from 40 – 412 mm FL, with an average size of 133 mm (Figures 15 and 16). Eight round whitefish between 90 – 140 mm FL were retained for whole body element analysis.

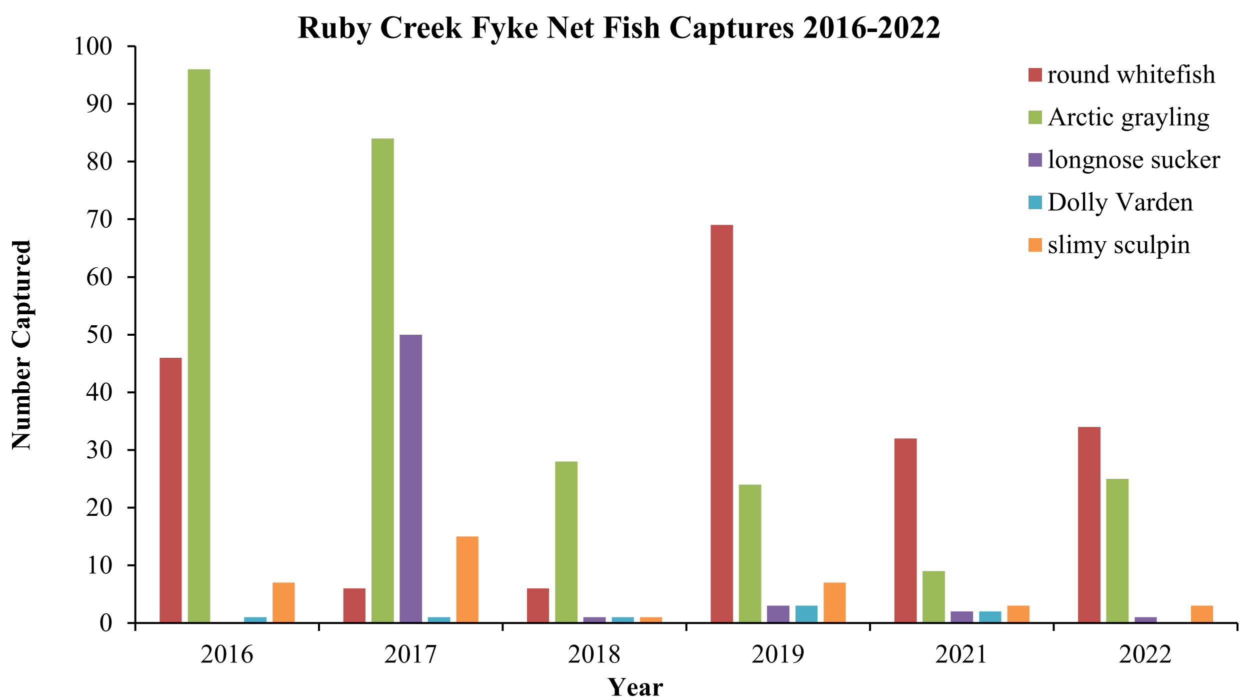

Figure 14. Ruby Creek fyke net fish captures by species for 2016 – 2022. No sampling occurred in 2020.

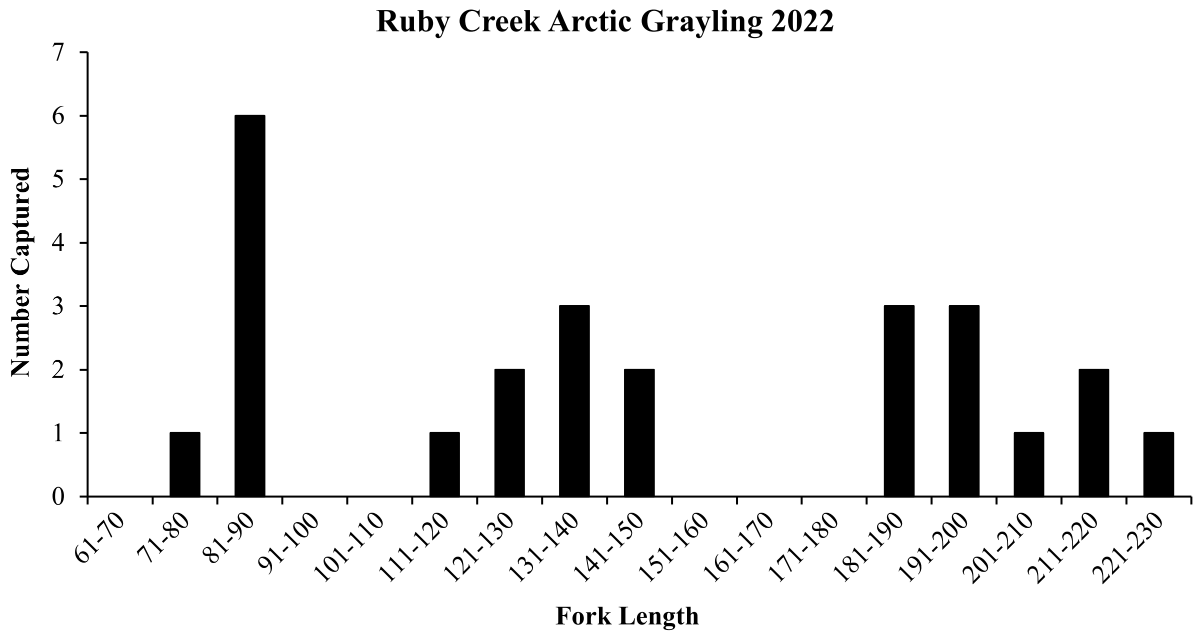

Figure 15. Length frequency distribution of Arctic grayling captured near the mouth of Ruby Creek in 2022.

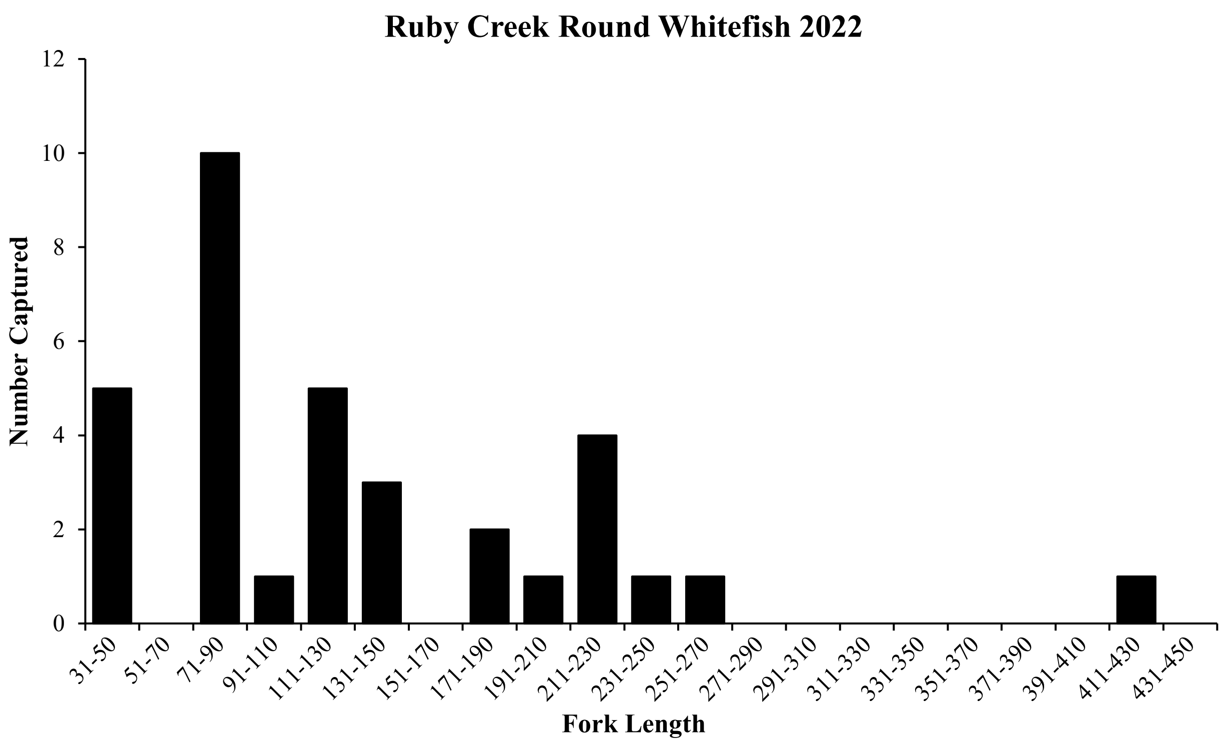

Figure 16. Length frequency distribution of round whitefish captured near the mouth of Ruby Creek in 2022.

Figure 17. Round whitefish captured in the fyke net near the mouth of Ruby Creek.

October Fish Sampling

During the October sampling event, 17 Dolly Varden were caught in the minnow traps at Upper Subarctic Creek and six Dolly Varden were caught at Lower Subarctic Creek. Six Dolly Varden were caught at Lower Center of the Universe Creek and eight at Upper Center of the Universe. Fish ranged from 74 to 166 mm FL and averaged 118 mm FL. Size range was similar to that observed in fish captured in July (Figure 18). Of the captured fish, 17 were in spawning condition and 20 of the captured fish were immature or unknown. Nine of the spawning condition fish were ripe males, and the remaining eight were likely female, although none were ripe enough to expel eggs when gently pressed. The smallest ripe male was 106 mm FL. Based on the reproductive condition of the captured fish, it is likely that spawning occurs in late October and early November.

An aerial survey of the Kogoluktuk River was conducted using a helicopter from the mouth of the Kogoluktuk on the Kobuk River upstream until sheet pan ice obscured the channel. Approximately 17 km of river were surveyed, and the survey terminated shortly downstream of the mouth of Riley Creek on the Kogoluktuk. No large anadromous fish, carcasses and/or redds were observed. Approximately 12 medium sized fish were seen that were likely Arctic grayling, but species identification was not confirmed with hook and line sampling due to time and weather constraints.

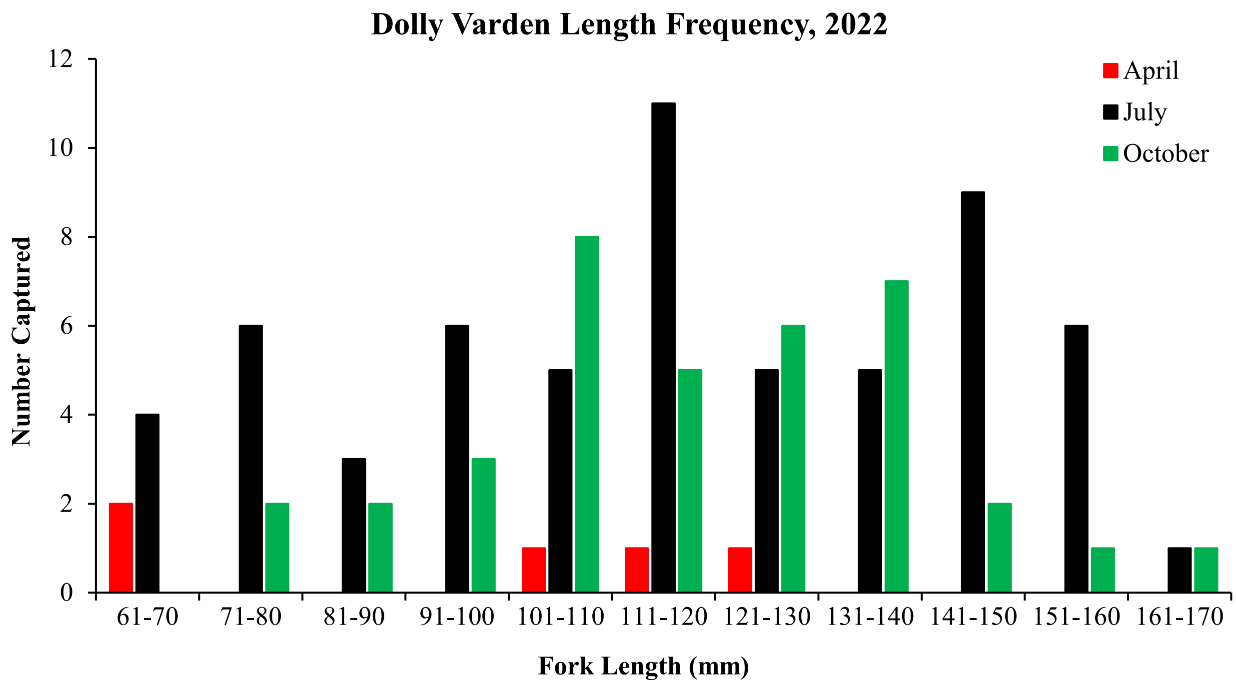

Figure 18. Length frequency for all Dolly Varden captured in minnow traps from various drainages in the vicinity of the Arctic Bornite prospects in 2022.

Fish Metals

Fish retained for element analysis are listed in Appendix 2 and results for each fish are listed in Appendix 3. Similar elements have been examined in whole body juvenile Dolly Varden around the state including Tulsequah Chief Mine, the Pebble prospect, Red Dog Mine, Greens Creek Mine, and Kensington Mine and provide a good data set for comparative purposes (Legere and Timothy 2016). Arctic grayling, slimy sculpin, Dolly Varden, and round whitefish have been captured in creeks around the Arctic-Bornite Prospect and analyzed for whole body element concentrations from 2016 to 2022. A component of developing the baseline biomonitoring program at Arctic-Bornite has been determining which fish species could reliably be captured in sufficient numbers for element analysis in each system. Dolly Varden are reliably captured and a subset are retained for element analysis in Subarctic Creek and Lower Red Rock Creek, but we discontinued retaining fish from Jay Creek in 2021 since we have been unable to capture an adequate sample size in recent years. Slimy sculpin are retained from Riley Creek, and round whitefish are reliably captured and a subset are retained in the fyke net on Ruby Creek.

In 2022, median cadmium concentrations were highest, but variable, in the Dolly Varden from Lower Red Rock Creek, with a mean cadmium concentration of 0.82 mg/kg (Figure 21). Slimy sculpin from Riley Creek had the lowest mean cadmium concentration of 0.30 mg/kg. Typically, Ruby Creek fish have had the lowest cadmium concentrations since sampling began in 2016, but this was not the case in 2022 (Figure 19). The annual median whole body cadmium concentration in Dolly Varden captured in Buddy Creek near the Red Dog Mine has ranged from 0.27 to 1.64 mg/kg (Clawson and Ott 2021). The cadmium concentrations in fish from the Arctic-Bornite area are generally within the lower range of concentrations seen in Buddy Creek Dolly Varden.

Mean copper concentration in 2022 was highest in Red Rock Creek Dolly Varden at 4.63 mg/kg, consistent with past years (Figures 19 and 20). Concentrations were lowest in Ruby Creek round whitefish (3.36 mg/kg) and slimy sculpin from Riley Creek (3.47 mg/kg). These copper concentrations in Dolly Varden at Arctic-Bornite are similar to other locations from across the state (Legere and Timothy 2016). For example, the annual median whole body copper concentration in Dolly Varden captured in Buddy Creek near Red Dog Mine was 3.2 mg/kg in 2014 and 3.9 mg/kg in 2015 (Ott et al. 2016).

Mean mercury concentration in 2022 was highest in slimy sculpin from Riley Creek (0.18 mg/kg) and lowest in Red Rock Creek DV (0.06 mg/kg) (Figure 19). Slimy sculpin from Riley Creek have consistently had the highest mercury concentrations (Figure 21). Median mercury concentrations in Dolly Varden from Buddy Creek (Red Dog Mine) have ranged from 0.02 to 0.06 mg/kg (Clawson and Ott 2021). Mercury concentrations in fish from the Arctic-Bornite creeks are generally higher those measured in fish from Buddy Creek.

The highest mean selenium concentration in 2022 was 6.16 mg/kg in slimy sculpin from Riley Creek (Figure 19). Riley Creek slimy sculpin typically have the highest mean selenium concentration (Figure 22). These values are slightly higher than those found at Tulsequah Chief Mine and the Pebble Prospect, and comparable to those found in juvenile Dolly Varden at Red Dog Mine, Greens Creek Mine, and Kensington Mine (Legere and Timothy 2016). Median selenium concentrations in Dolly Varden from Buddy Creek have ranged from 3.8 to 9.1 mg/kg (Clawson and Ott 2021).

In 2022, mean zinc concentration was highest in Dolly Varden from Subarctic Creek (156.95 mg/kg) and lowest in round whitefish from Ruby Creek (93.26 mg/kg) (Figure 19). Zinc concentrations have consistently been lowest in round whitefish from Ruby Creek since collection began (Figure 23). These zinc concentrations are slightly higher than those found in juvenile Dolly Varden from Buddy Creek near Red Dog Mine (116 – 227 mg/kg), but are within the range of concentrations found in Dolly Varden in other regions of the state (Legere and Timothy 2016).

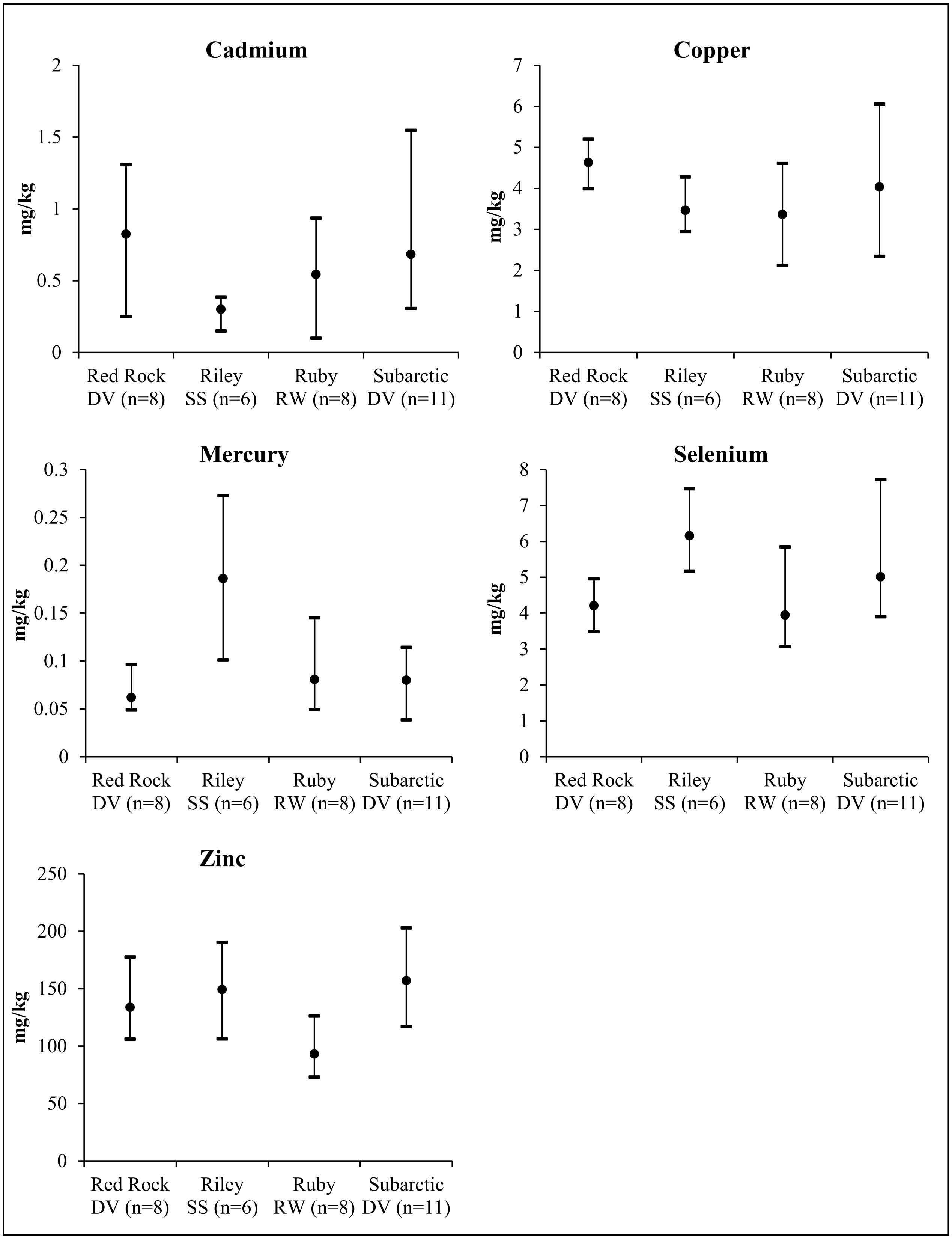

Figure 19. Minimum, mean, and maximum whole body dry weight concentrations of various elements in Dolly Varden, slimy sculpin, and round whitefish from various drainages in the vicinity of the Arctic Bornite prospects, 2022.

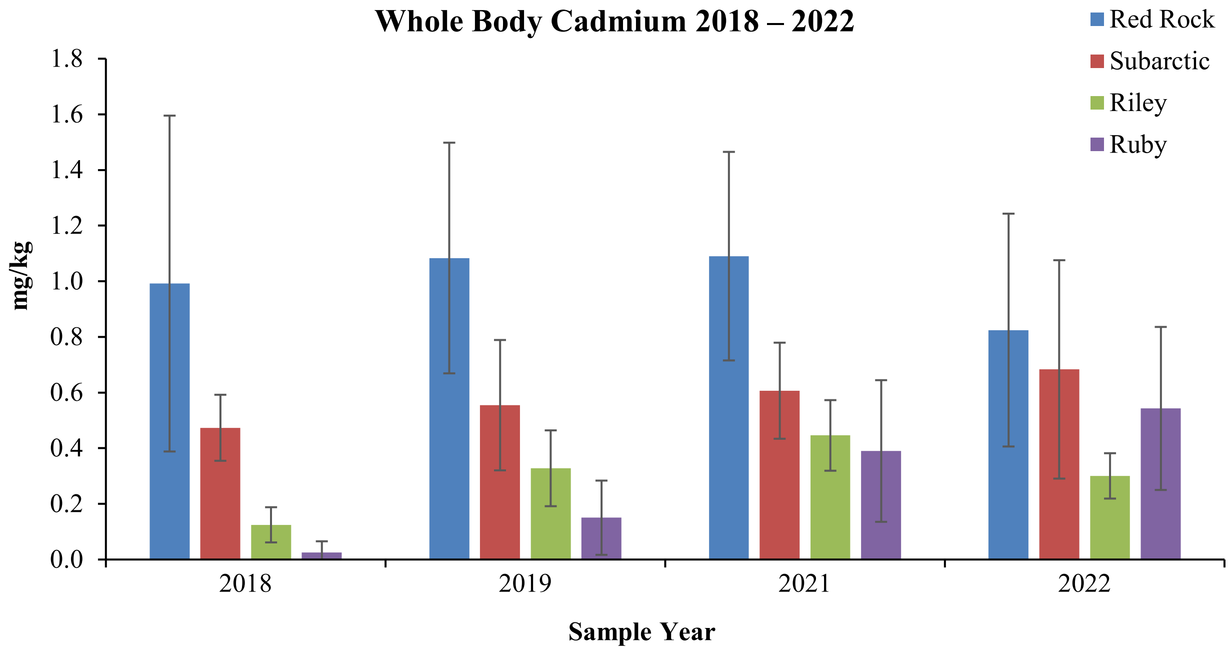

Figure 20. Mean (± 1 SD) whole body cadmium concentrations in Dolly Varden from Subarctic and Red Rock creeks, slimy sculpin from Riley Creek, slimy sculpin from Ruby Creek (2018 only), and round whitefish from Ruby Creek (2019 – 2022).

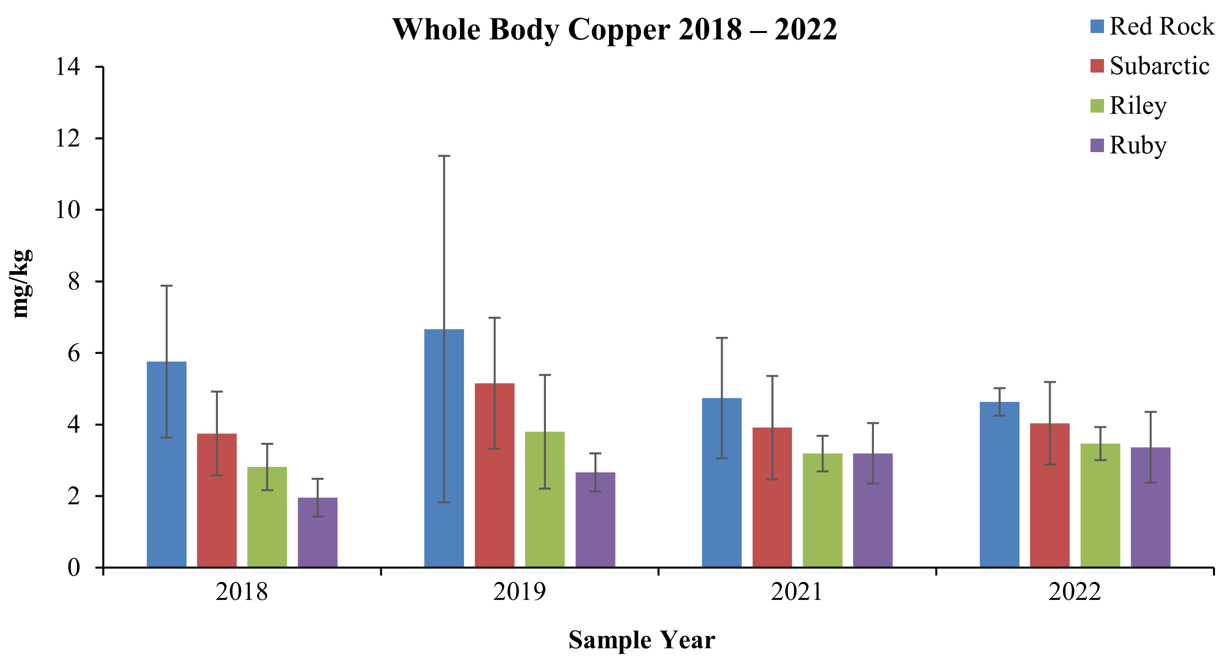

Figure 21. Mean (± 1 SD) whole body copper concentrations in Dolly Varden from Subarctic and Red Rock Creek, slimy sculpin from Riley Creek, slimy sculpin from Ruby Creek (2018 only), and round whitefish from Ruby Creek (2019 – 2022).

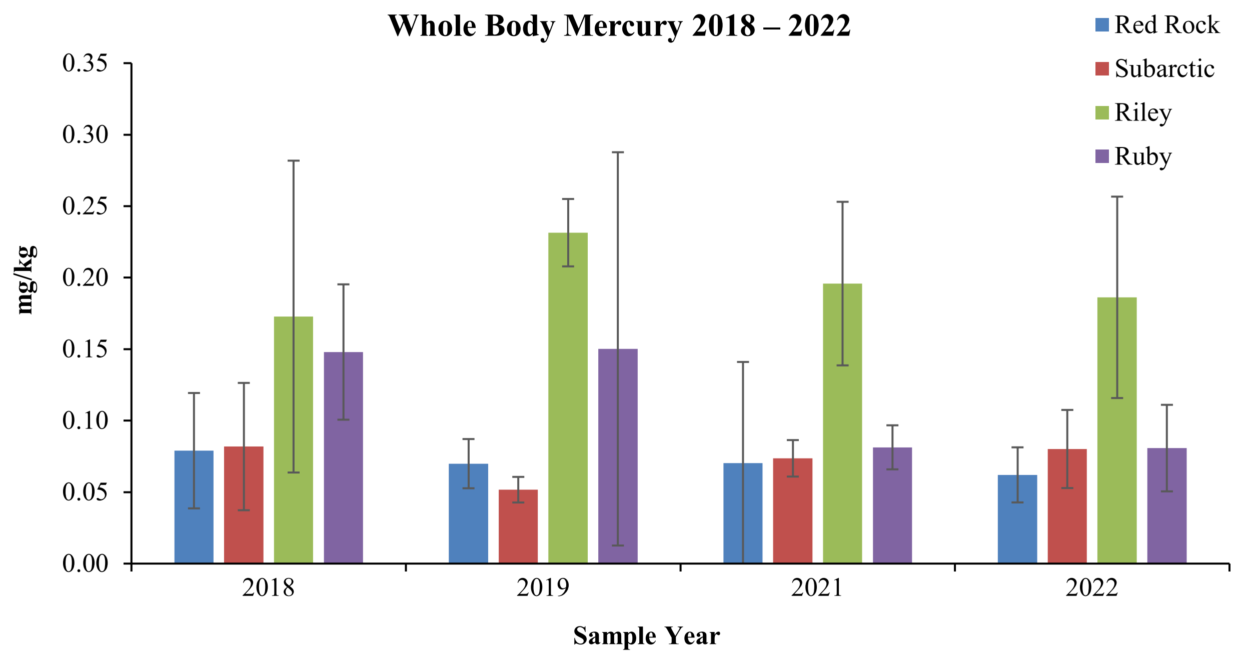

Figure 22. Mean (± 1 SD) whole body mercury concentrations in Dolly Varden from Subarctic and Red Rock Creek, slimy sculpin from Riley Creek, slimy sculpin from Ruby Creek (2018 only), and round whitefish from Ruby Creek (2019 – 2022).

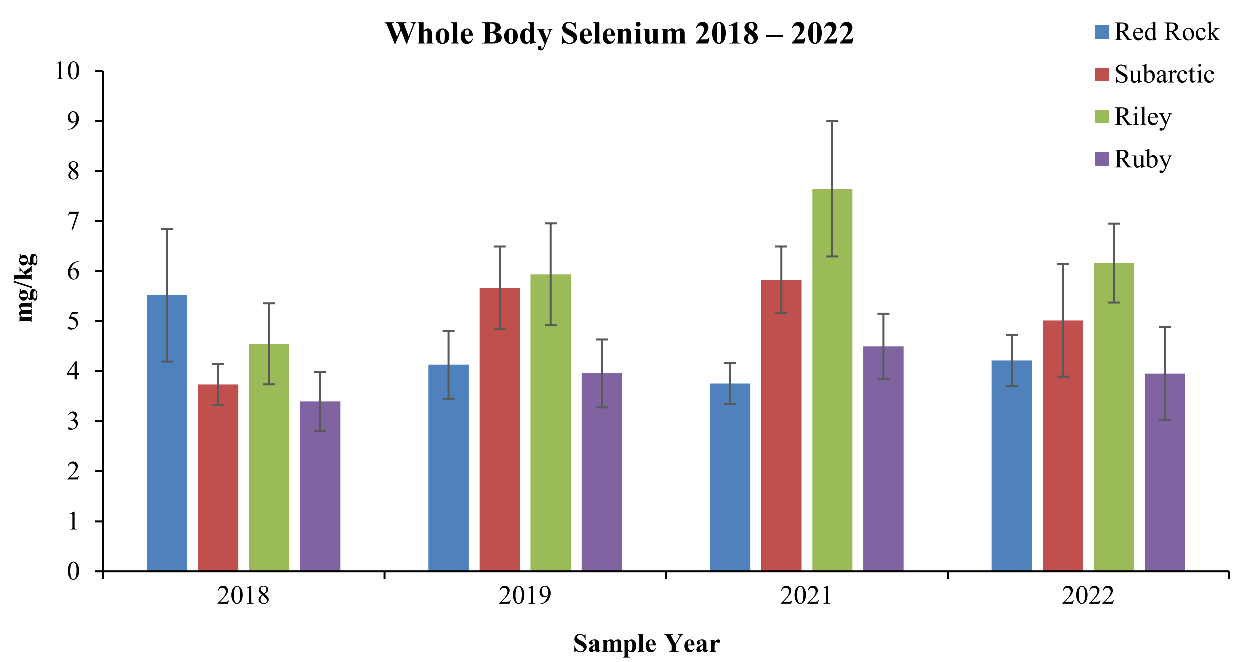

Figure 23. Mean (± 1 SD) whole body selenium concentrations in Dolly Varden from Subarctic and Red Rock Creek, slimy sculpin from Riley Creek, slimy sculpin from Ruby Creek (2018 only), and round whitefish from Ruby Creek (2019 – 2022).

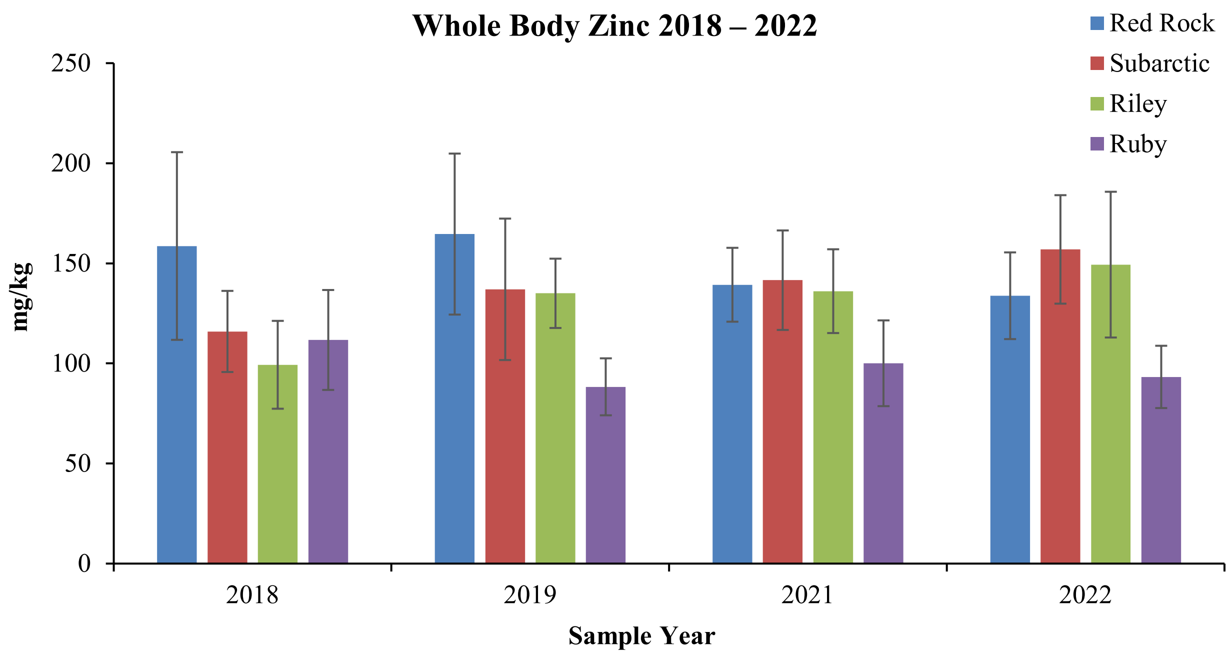

Figure 24. Mean (± 1 SD) whole body zinc concentrations in Dolly Varden from Subarctic and Red Rock Creek, slimy sculpin from Riley Creek, slimy sculpin from Ruby Creek (2018 only), and round whitefish from Ruby Creek (2019 – 2022).

CONCLUSION

Despite being isolated from the Kobuk River by a large waterfall, the Shungnak River drainage supports self-sustaining populations of Arctic grayling, Dolly Varden, round whitefish, slimy sculpin, longnose sucker, and Alaska blackfish.

Similar to previous years, catches in Subarctic Creek in 2022 were dominated by Dolly Varden. Dolly Varden have been captured at all sample sites throughout the 12 km long creek although catches are usually higher in the upper creek. Spawning is known to occur in the upper section of the creek since both male and female ripe fish have been captured there in late fall. Overwintering has been confirmed at the Upper and Middle Subarctic Creek sample sites after fish were captured in March 2021 and April 2022, and it is likely that overwintering occurs throughout the drainage. In other populations of dwarf resident Dolly Varden, males mature as early as age 2 and almost all are mature by age 3, while females mature at ages 3 or 4 (McCart and Craig 1973; McCart and Bain 1974; Armstrong and Morrow 1980). Based on the sizes of ripe fish captured in Subarctic Creek, it appears that males mature earlier than females, consistent with these studies. The oldest

Dolly Varden that has been aged from the sample sites was an age 7 fish from Subarctic Creek. Dolly Varden in other resident populations have attained age 10, but few fish survive beyond age 5 (Armstrong and Morrow 1980).

Catches in Red Rock and Center of the Universe creeks are also dominated by Dolly Varden. Generally, catches are higher in Center of the Universe Creek (an upper tributary of Red Rock Creek) than at Lower Red Rock Creek. Spawning is known to occur in Red Rock Creek and Center of the Universe Creek as a very small young of the year fish was captured in Red Rock Creek in July 2018 and ripe males and females have been captured in both creeks during fall sampling. Red Rock and Center of the Universe creeks provide similar habitat to the potentially mine affected stretch of Subarctic Creek. Genetic work conducted in 2018 showed that the breeding populations in Red Rock and Subarctic creeks are genetically distinct, indicating that the greater Shungnak River drainage supports more than one breeding population of Dolly Varden. It is likely that each tributary of the Shungnak River has its own breeding population, as this type of population structure in resident salmonids is not uncommon, even at small spatial scales with no physical barriers to gene flow (Koizumi et al. 2006).

The Dolly Varden captured in Riley Creek in July have the potential to be anadromous as no permanent physical barrier exists downstream. A series of rapids on the Kogoluktuk River could impede upstream passage but are not known to definitively prevent upstream movement. If some of these fish are anadromous, Riley Creek may serve as spawning habitat for resident Dolly Varden and rearing habitat for anadromous juveniles. However, the presence of small, sexually mature males found in previous years does not prove there is a self-sustaining resident population of Dolly Varden in Riley Creek. Many anadromous populations of Dolly Varden contain "residual" males that never migrate to the ocean, but instead spend their entire life cycle in freshwater. These males act as sneaker males and spawn with anadromous females (Armstrong and Morrow 1980). If the Riley Creek area remains in consideration as a tailings storage facility location, future fish sampling in Riley Creek will potentially involve genetic sampling to compare to Subarctic resident Dolly Varden and Kobuk drainage anadromous Dolly Varden. With the baseline genetic information on the resident Dolly Varden in Subarctic and Red Rock creeks showing reproductive isolation and less genetic variation than anadromous Dolly Varden from the Kobuk River, genetics from Riley Creek could provide insight into potential anadromy. The continuation of fall aerial surveys in the Kogoluktuk River to look for anadromous Dolly Varden would help confirm the presence or absence of anadromous fish.

In 2016, fyke net catches in Ruby Creek were dominated by age 0 Arctic grayling and round whitefish. In 2017 and 2018 most Arctic grayling were age 1+ and very few round whitefish were captured. From 2019 – 2022 the fyke nets in Ruby Creek were fished for longer periods of time to better capture the range of fish species and movement in this tributary to the Shungnak River. The increased fishing time resulted in higher numbers of fish captures, including a wider range of age classes of Arctic grayling and round whitefish. Based on catches from 2016 – 2022, it is likely that Arctic grayling, round whitefish, and longnose suckers spawn upstream of Ruby Creek in the Shungnak River drainage.

If future aquatic sampling is planned, we recommend continuation of periphyton and aquatic invertebrate sampling. Future fish work should be focused on expanding our understanding of how and when fish utilize target areas around the Arctic and Bornite deposits. Additional recommendations include obtaining greater sample sizes for fish whole body element analysis and continuing fall aerial surveys.

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APPENDIX 1. WATER QUALITY DATA

Only metals data used in fish whole body element analyses are shown. Acute and chronic water quality standards for aquatic life are shown for cadmium, copper, and zinc, which are dependent on water hardness. The cadmium samples highlighted in yellow were the only samples that exceeded the more stringent chronic aquatic life exposure limit.

2022

Site Location	Collection Date	Cadmium (ug/L)	Cadmium Acute Limit (ug/L)	Cadmium Chronic Limit (ug/L)	Copper (ug/L)	Copper Acute Limit (ug/L)	Copper Chronic Limit (ug/L)	Mercury (ng/L)	Selenium (ug/L)	TDS (mg/L)	Zinc (ug/L)	Zinc Acute Limit (ug/L)	Zinc Chronic Limit (ug/L)	Hardness CaCO3 (mg/L)
Upper	4/18/2022	0.000	3.834	0.390	0.34	25.092	15.777	0.000	0.000	228	0.000	205.452	207.132	194
Ruby	8/14/2022	0.000	2.773	0.309	0.00	18.328	11.866	0.000	0.000	182	10.700	154.893	156.160	139
Lower	8/19/2022	0.000	2.443	0.282	1.410	16.208	10.614	0.000	0.000	147	4.350	138.684	139.819	122
Ruby	10/18/2022	0.000	3.025	0.329	1.360	19.939	12.808	2.350	0.332	152	4.180	167.083	168.449	152
Shungnak	4/18/2022	0.221	1.967	0.242	1.650	13.135	8.772	0.000	0.544	129	35.300	114.793	115.732	98
	8/13/2022	0.413	1.943	0.240	2.170	12.983	8.680	0.000	0.447	128	32.700	113.596	114.525	96
Upper	4/22/2022	0.063	1.074	0.157	0.766	7.310	5.155	0.000	0.000	93	4.750	67.771	68.325	52
Subarctic	8/12/2022	0.015	1.016	0.151	0.000	6.928	4.911	0.000	0.000	56	10.500	64.579	65.108	50
Lower	4/19/2022	0.052	1.136	0.163	0.286	7.717	5.415	0.000	0.713	60.000	5.750	71.153	71.735	56
Subarctic	8/12/2022	0.104	0.978	0.147	0.699	6.677	4.749	0.000	0.380	66.000	21.000	62.473	62.984	48
Riley	4/18/2022	0.000	3.237	0.345	0.345	21.296	13.596	0.000	0.000	190	0.000	177.273	178.723	163

2021

Site Location	Collection Date	Dissolved Cadmium (ug/L)	Cadmium Acute Limit (ug/L)	Cadmium Chronic Limit (ug/L)	Dissolved Copper (ug/L)	Copper Acute Limit (ug/L)	Copper Chronic Limit (ug/L)	Mercury (ng/L)	Dissolved Selenium (ug/L)	TDS (mg/L)	Dissolved Zinc (ug/L)	Zinc Acute Limit (ug/L)	Zinc Chronic Limit (ug/L)	Hardness CaCO3 (mg/L)
Upper	6/8/2021	0.000	2.287	0.269		15.205	10.017	1.440	0.500	155		130.939	132.011	114
Ruby	8/29/2021	0.000	2.502	0.287	0.38	16.584	10.837	0.000	0.452	186	0.000	141.569	142.727	125
Lower	1/28/2021	0.000	3.160	0.339		20.803	13.311	0.709	0.569	188		173.580	175.000	159
Ruby	6/9/2021	0.000	2.229	0.264		14.828	9.791	1.630	0.421	141		128.014	129.061	111
	8/31/2021	0.000	2.131	0.256	1.120	14.198	9.413	1.280	0.000	144	0.000	123.111	124.118	106
	9/30/2021	0.000	2.676	0.301	0.512	17.706	11.500	0.000	0.420	176	0.000	150.159	151.387	134
Shungnak	6/20/2021	0.321	1.532	0.202		10.313	7.044		0.468	115		92.351	93.106	76
	8/20/2021	0.365	1.647	0.213	1.230	11.058	7.504	0.000	0.335	112	26.700	98.327	99.132	81
	9/29/2021	0.365	1.928	0.238	0.959	12.881	8.618	0.000	0.680	121	28.800	112.797	113.720	96
Upper	1/26/2021	0.018	1.253	0.175		8.488	5.903	0.518	0.310	64		77.512	78.146	61
Subarctic	3/11/2021	0.123	0.972	0.146		6.638	4.724	0.610	0.000	77		62.139	62.647	47
	6/20/2021	0.000	0.789	0.126		5.427	3.935		0.000	32		51.849	52.273	38
	8/22/2021	0.016	0.922	0.141	0.000	6.307	4.509	0.000	0.000	72	0.000	59.345	59.830	45
	9/29/2021	0.017	0.952	0.144	0.000	6.506	4.638	0.000	0.398	62	3.640	61.024	61.523	46
Lower	6/20/2021	0.058	0.846	0.132		5.801	4.180		0.368	36.000		55.051	55.502	41
Subarctic	8/22/2021	0.109	0.807	0.128	0.933	5.548	4.014	0.000	0.588	73.000	11.400	52.882	53.314	39
	9/29/2021	0.103	0.904	0.139	0.672	6.187	4.432	0.000	0.800	71.000	12.400	58.333	58.810	44
Lower	6/9/2021	0.000	2.012	0.246		13.426	8.948	0.793	0.691	125		117.081	118.039	100
Riley	8/21/2021	0.000	2.151	0.258	0.577	14.324	9.489	0.000	0.649	132	0.000	124.094	125.109	107
	9/30/2021	0.000	2.560	0.292	0.432	16.958	11.059	0.000	0.872	167	0.000	144.442	145.624	128

2019

Site Location	Collection Date	Cadmium (ug/L)	Cadmium Acute Limit (ug/L)	Cadmium Chronic Limit (ug/L)	Copper (ug/L)	Copper Acute Limit (ug/L)	Copper Chronic Limit (ug/L)	Mercury (ng/L)	Selenium (ug/L)	TDS (mg/L)	Zinc (ug/L)	Zinc Acute Limit (ug/L)	Zinc Chronic Limit (ug/L)	Hardness CaCO3 (mg/L)
Upper	3/30/2019	0.025	3.120	0.340	0.273	20.556	13.167	0.831	0.382	198	5.000	171.728	173.133	157
Ruby	6/6/2019	0.025	2.346	0.274	0.527	15.582	10.242	0.677	0.596	147	5.000	133.853	134.948	117
	8/29/2019	0.025	2.676	0.301	0.287	17.706	11.500	0.736	0.391	165	5.000	150.159	151.387	134
	12/5/2019	0.025	3.160	0.339	0.370	20.803	13.311	2.190	0.536	198	5.000	173.580	175.000	159
Lower	3/30/2019	0.025	2.793	0.311	0.536	18.452	11.939	0.500	0.574	180	5.000	155.837	157.111	140
Ruby	6/22/2019	0.025	2.735	0.306	1.750	18.080	11.720	1.780	0.500	153	5.000	153.002	154.254	137
	9/2/2019	0.025	2.948	0.323	1.380	19.444	12.520	1.480	0.500	165	5.000	163.350	164.686	148
	12/9/2019	0.025	4.083	0.408	1.120	26.673	16.676	1.130	0.808	294	3.790	217.059	218.834	207
Shungnak	6/27/2019	0.239	1.562	0.205	1.440	10.506	7.163	0.671	0.341	124	19.300	93.903	94.671	77
	8/24/2019	0.369	1.778	0.225	2.160	11.914	8.029	0.544	0.393	75	29.000	105.151	106.012	88
Upper	4/1/2019	0.047	1.006	0.150	0.305	6.862	4.868	0.707	0.409	63	5.000	64.026	64.550	49
Subarctic	6/7/2019	0.018	0.543	0.096	0.250	3.777	2.833	1.940	0.500	23	5.000	37.425	37.731	26
	8/23/2019	0.018	0.946	0.143	0.247	6.466	4.612	0.500	0.500	51	5.000	60.689	61.185	46
	12/8/2019	0.025	1.086	0.158	0.203	7.389	5.206	0.733	0.500	67	5.000	68.428	68.988	53
Lower	6/7/2019	0.085	0.563	0.099	2.230	3.914	2.926	1.210	0.420	34	11.300	38.641	38.957	27
Subarctic	12/11/2019	0.063	1.026	0.152	0.655	6.994	4.953	2.020	0.620	65	7.830	65.132	65.664	50
Lower	6/11/2019	0.025	1.896	0.236	0.618	12.678	8.495	0.500	0.700	151	5.000	111.195	112.105	94
Riley	8/21/2019	0.025	2.307	0.271	0.602	15.331	10.092	1.440	0.593	143	5.000	131.912	132.991	115

2018

Site Location	Collection Date	Cadmium (ug/L)	Cadmium Acute Limit (ug/L)	Cadmium Chronic Limit (ug/L)	Copper (ug/L)	Copper Acute Limit (ug/L)	Copper Chronic Limit (ug/L)	Mercury (ng/L)	Selenium (ug/L)	TDS (mg/L)	Zinc (ug/L)	Zinc Chronic/ Acute Limit (ug/L)	Hardness CaCO3 (mg/L)
Upper	6/29/2018	0.025	2.980	0.350	0.341	19.090	12.360	0.939	0.500	156	3.10	158.380	139
Ruby	8/26/2018	0.025	3.070	0.350	0.392	19.610	12.660	2.030	0.435	179	5.00	162.230	143
	12/10/2018	0.025	3.130	0.360	0.500	20.000	12.890	0.606	0.459	176	5.00	165.110	146
	12/10/2018	0.025	3.290	0.370	0.500	20.900	13.420	*0.500	0.532	158	5.00	171.790	153
Lower	3/22/2018	0.025	3.110	0.360	0.699	19.870	12.820	0.562	1.000	178	3.10	164.150	145
Ruby	6/28/2018	0.025	2.720	0.320	0.896	17.530	11.440	1.140	0.500	148	3.98	146.710	127
	8/24/2018	0.025	2.480	0.300	1.080	16.100	10.590	1.280	0.500	152	5.00	135.870	116
	12/10/2018	0.025	3.090	0.350	0.542	19.740	12.740	0.871	0.592	187	5.00	163.190	144
Upper	6/27/2018	0.219	1.530	0.210	1.820	10.270	7.050	1.040	0.521	86	18.00	90.710	72
Shungnak	8/26/2018	0.227	1.810	0.240	1.420	12.010	8.120	0.513	0.595	104	17.20	104.400	85
Upper	3/25/2018	*0.015			0.250	7.700	5.420	*0.500	1.000	72	3.10	69.970	53
Subarctic	6/24/2018	0.025	0.710	0.120	0.323	5.070	3.710	0.889	0.500	38	3.10	48.030	34
	8/26/2018	0.025	0.950	0.150	0.249	6.600	4.720	0.773	0.450	56	5.00	60.910	45
	12/7/2018	0.017	1.050	0.160	0.250	7.290	5.160	0.601	0.500	56	5.00	66.600	50
Lower	3/24/2018	0.042	1.050	0.160	0.303	7.290	5.160	*0.500	1.000	73	4.49	66.600	50
Subarctic	6/27/2018	0.102	0.630	0.110	1.610	4.500	3.330	0.859	0.337	47	16.40	43.200	30
	6/27/2018	0.103	0.690	0.120	1.580	4.930	3.620	0.965	0.500	44	14.20	46.830	33
	8/26/2018	0.078	0.840	0.140	0.705	5.900	4.260	0.672	0.711	59	9.61	55.120	40
Lower	7/1/2018	0.025	2.110	0.270	0.513	13.870	9.250	0.890	0.825	106	3.10	118.800	99
Riley	7/1/2018	0.034	2.290	0.280	0.863	14.920	9.880	0.976	0.685	111	3.10	126.890	107
	8/28/2018	0.025	2.420	0.300	0.714	15.710	10.360	1.420	0.473	121	5.00	132.890	113

2017

Location	Date Collected	Cadmium µg/L	Cadmium Acute Limit µg/L	Copper Chronic Limit µg/L	Copper µg/L	Copper Acute Limit µg/L	Copper Chronic Limit µg/L	Mercury ng/L	Selenium µg/L	Zinc µg/L	Zinc Acute Limit µg/L	Zinc Chronic Limit µg/L	Hardness $CaCO_3$ mg/L	TDS mg/L
Upper Ruby	4/27/2017	*0.015			0.33	20.38	13.12	*0.5	*0.31	1.56	167.98	167.98	149	169
Upper Ruby	7/18/2017	*0.015			0.47	18.96	12.28	0.605	0.329	1.25	157.41	157.41	138	163
Upper Ruby	8/23/2017	*0.015			0.41	17.14	11.21	*0.5	0.547	1.43	143.77	143.77	124	136
Upper Ruby	9/18/2017	*0.015			0.53	15.18	10.04	0.876	0.385	1.66	128.89	128.89	109	132
Upper Ruby	12/2/2017	0.015	2.98	0.35	0.82	19.09	12.36	*0.5	0.588	4.36	158.38	158.38	139	166
Lower Ruby	4/27/2017	*0.015			0.46	20.25	13.04	*0.5	0.345	0.81	167.02	167.02	148	173
Lower Ruby	7/24/2017	0.0298	1.90	0.25	3.00	12.58	8.47	2.25	*0.31	4.24	108.86	108.86	89.3	119
Lower Ruby	8/26/2017	0.0165	2.52	0.31	1.17	16.36	10.75	0.612	0.409	2.12	137.85	137.85	118	149
Lower Ruby	9/22/2017	*0.015			0.95	16.10	10.59	0.744	*0.31	11.90	135.87	135.87	116	113
Lower Ruby	11/30/2017	*0.015			0.57	19.35	12.51	0.749	0.622	1.32	160.31	160.31	141	160
Upper Shungnak	4/27/2017	0.097	1.77	0.24	0.67	11.80	7.99	*0.5	0.334	8.39	102.74	102.74	83.4	108
Upper Shungnak	7/22/2017	0.130	1.78	0.24	0.88	11.81	8.00	*0.5	0.369	7.45	102.84	102.84	83.5	116
Upper Shungnak	8/24/2017	0.219	1.68	0.23	1.45	11.20	7.62	*0.5	0.563	17.10	98.02	98.02	78.9	97
Upper Shungnak	9/20/2017	0.217	1.57	0.22	1.53	10.54	7.21	0.701	*0.31	16.70	92.84	92.84	74	92
Upper Subarctic	7/21/2017	0.0165	0.89	0.14	0.22	6.21	4.46	*0.5	*0.31	0.96	57.68	57.68	42.2	55
Upper Subarctic	8/21/2017	0.0963	1.05	0.16	0.69	7.29	5.16	*0.5	0.426	3.29	66.60	66.60	50	58
Upper Subarctic	9/20/2017	0.0166	0.86	0.14	0.26	6.06	4.36	0.695	*0.31	1.35	56.41	56.41	41.1	48
Lower Subarctic	4/27/2017	0.0415	1.08	0.16	0.31	7.42	5.25	*0.5	0.704	4.32	67.72	67.72	51	68
Lower Subarctic	7/19/2017	0.1610	0.98	0.15	3.22	6.82	4.86	0.95	0.315	16.10	62.74	62.74	46.6	62
Lower Subarctic	8/24/2017	0.0829	0.81	0.13	1.02	5.71	4.14	*0.5	0.402	11.50	53.48	53.48	38.6	44
Lower Subarctic	9/20/2017	0.1020	0.77	0.13	1.33	5.42	3.94	0.746	0.398	15.30	51.01	51.01	36.5	41
Lower Riley	7/19/2017	*0.015			0.45	14.92	9.88	0.645	0.546	1.15	126.89	126.89	107	129
Lower Riley	8/22/2017	*0.015			0.65	15.58	10.28	*0.5	0.781	1.29	131.89	131.89	112	123
Lower Riley	9/20/2017	0.015	2.10	0.27	0.81	13.77	9.19	0.783	0.464	1.12	118.09	118.09	98.3	115

APPENDIX 2. FISH RETAINED FOR ELEMENT ANALYSIS

Sample ID	Stream	Site	Date Collected	Fish Spp[1]	Length (mm)	Weight (g)	Metals to be analyzed				
							Cu	Hg	Se	Cd	Zn
072022RUBRWJ01	Ruby	Fyke Mouth	7/20/2022	RW	86	4.6	x	x	x	x	x
072022RUBRWJ02	Ruby	Fyke Mouth	7/20/2022	RW	134	16.2	x	x	x	x	x
072022RUBRWJ03	Ruby	Fyke Mouth	7/20/2022	RW	143	29.0	x	x	x	x	x
072022RUBRWJ04	Ruby	Fyke Mouth	7/20/2022	RW	126	14.7	x	x	x	x	x
072022RUBRWJ05	Ruby	Fyke Mouth	7/20/2022	RW	120	12.6	x	x	x	x	x
072022RUBRWJ06	Ruby	Fyke Mouth	7/20/2022	RW	142	23.7	x	x	x	x	x
072022RUBRWJ07	Ruby	Fyke Mouth	7/20/2022	RW	90	6.2	x	x	x	x	x
072022RUBRWJ08	Ruby	Fyke Mouth	7/20/2022	RW	90	5.7	x	x	x	x	x
072022LLLDV01	Red Rock	Lower	7/20/2022	DV	96	7.7	x	x	x	x	x
072022LRRDV02	Red Rock	Lower	7/20/2022	DV	111	12.3	x	x	x	x	x
072022LRRDV03	Red Rock	Lower	7/20/2022	DV	135	22.1	x	x	x	x	x
072022LRRDV04	Red Rock	Lower	7/20/2022	DV	98	8.2	x	x	x	x	x
072022LRRDV05	Red Rock	Lower	7/20/2022	DV	123	16.6	x	x	x	x	x
072122UCNDV06	Red Rock	Upper	7/21/2022	DV	112	10.9	x	x	x	x	x
072122UCNDV07	Red Rock	Upper	7/21/2022	DV	139	25.2	x	x	x	x	x
072122UCNDV08	Red Rock	Upper	7/21/2022	DV	94	7.4	x	x	x	x	x
072022LSADV01	Subarctic	Lower	7/20/2022	DV	135	20.6	x	x	x	x	x
072022LSADV02	Subarctic	Lower	7/20/2022	DV	95	7.1	x	x	x	x	x
072022LSADV03	Subarctic	Lower	7/20/2022	DV	90	6.2	x	x	x	x	x
072022LSADV04	Subarctic	Lower	7/20/2022	DV	90	6.3	x	x	x	x	x
072122USADV05	Subarctic	Upper	7/21/2022	DV	93	7.1	x	x	x	x	x
072122USADV06	Subarctic	Upper	7/21/2022	DV	108	10.5	x	x	x	x	x
072122USADV07	Subarctic	Upper	7/21/2022	DV	102	8.9	x	x	x	x	x
072122USADV08	Subarctic	Upper	7/21/2022	DV	90	5.6	x	x	x	x	x
072122USADV09	Subarctic	Upper	7/21/2022	DV	75	3.8	x	x	x	x	x
072122USADV10	Subarctic	Upper	7/21/2022	DV	119	16.8	x	x	x	x	x
072122USADV11	Subarctic	Upper	7/21/2022	DV	103	9.8	x	x	x	x	x
072322RILSS01	Riley		7/23/2022	SS	86	6.7	x	x	x	x	x
072322RILSS02	Riley		7/23/2022	SS	90	6.5	x	x	x	x	x
072322RILSS03	Riley		7/23/2022	SS	81	4.8	x	x	x	x	x
072322RILSS04	Riley		7/23/2022	SS	74	4.0	x	x	x	x	x
072322RILSS05	Riley		7/23/2022	SS	66	3.3	x	x	x	x	x
072322RILSS06	Riley		7/23/2022	SS	65	3.3	x	x	x	x	x

[1] Dolly Varden (DV), slimy sculpin (SS), and round whitefish (RW)

APPENDIX 3. RESULTS FOR WHOLE BODY ELEMENT ANALYSIS

Round Whitefish

Sample ID	Site	Collection Date	Analyte	Dry Wt Result (mg/Kg)	Dry Wt MDL (mg/kg)	% Solid
072022RUBRWJ01	Ruby	7/20/2022	Cadmium	0.49	0.04	22.1
072022RUBRWJ02	Ruby	7/20/2022	Cadmium	0.41	0.05	21.1
072022RUBRWJ03	Ruby	7/20/2022	Cadmium	0.29	0.04	21.6
072022RUBRWJ04	Ruby	7/20/2022	Cadmium	0.47	0.05	20.1
072022RUBRWJ05	Ruby	7/20/2022	Cadmium	0.94	0.04	20.5
072022RUBRWJ06	Ruby	7/20/2022	Cadmium	0.87	0.03	21.5
072022RUBRWJ07	Ruby	7/20/2022	Cadmium	0.10	0.07	18.4
072022RUBRWJ08	Ruby	7/20/2022	Cadmium	0.78	0.05	21.6
072022RUBRWJ01	Ruby	7/20/2022	Copper	3.93	0.71	22.1
072022RUBRWJ02	Ruby	7/20/2022	Copper	4.61	0.72	21.1
072022RUBRWJ03	Ruby	7/20/2022	Copper	3.08	0.69	21.6
072022RUBRWJ04	Ruby	7/20/2022	Copper	2.12	0.74	20.1
072022RUBRWJ05	Ruby	7/20/2022	Copper	2.19	0.62	20.5
072022RUBRWJ06	Ruby	7/20/2022	Copper	4.00	0.54	21.5
072022RUBRWJ07	Ruby	7/20/2022	Copper	2.60	1.07	18.4
072022RUBRWJ08	Ruby	7/20/2022	Copper	4.37	0.85	21.6
072022RUBRWJ01	Ruby	7/20/2022	Mercury	0.06	0.01	22.1
072022RUBRWJ02	Ruby	7/20/2022	Mercury	0.09	0.01	21.1
072022RUBRWJ03	Ruby	7/20/2022	Mercury	0.09	0.01	21.6
072022RUBRWJ04	Ruby	7/20/2022	Mercury	0.07	0.01	20.1
072022RUBRWJ05	Ruby	7/20/2022	Mercury	0.07	0.01	20.5
072022RUBRWJ06	Ruby	7/20/2022	Mercury	0.15	0.01	21.5
072022RUBRWJ07	Ruby	7/20/2022	Mercury	0.07	0.01	18.4
072022RUBRWJ08	Ruby	7/20/2022	Mercury	0.05	0.01	21.6
072022RUBRWJ01	Ruby	7/20/2022	Selenium	3.60	0.09	22.1
072022RUBRWJ02	Ruby	7/20/2022	Selenium	3.38	0.09	21.1
072022RUBRWJ03	Ruby	7/20/2022	Selenium	3.07	0.09	21.6
072022RUBRWJ04	Ruby	7/20/2022	Selenium	3.71	0.09	20.1
072022RUBRWJ05	Ruby	7/20/2022	Selenium	5.85	0.08	20.5
072022RUBRWJ06	Ruby	7/20/2022	Selenium	4.84	0.07	21.5
072022RUBRWJ07	Ruby	7/20/2022	Selenium	3.39	0.13	18.4
072022RUBRWJ08	Ruby	7/20/2022	Selenium	3.77	0.11	21.6
072022RUBRWJ01	Ruby	7/20/2022	Zinc	126.24	5.29	22.1
072022RUBRWJ02	Ruby	7/20/2022	Zinc	90.05	5.40	21.1
072022RUBRWJ03	Ruby	7/20/2022	Zinc	97.69	5.14	21.6
072022RUBRWJ04	Ruby	7/20/2022	Zinc	73.13	5.52	20.1
072022RUBRWJ05	Ruby	7/20/2022	Zinc	97.56	4.68	20.5
072022RUBRWJ06	Ruby	7/20/2022	Zinc	89.77	4.05	21.5
072022RUBRWJ07	Ruby	7/20/2022	Zinc	89.67	7.99	18.4
072022RUBRWJ08	Ruby	7/20/2022	Zinc	81.94	6.39	21.6

*MDL = Method Detection Limit

Dolly Varden

Sample ID	Site	Collection Date	Analyte	Dry Wt Result (mg/Kg)	Dry Wt MDL (mg/kg)	% Solid
072022LRRDV01	Red Rock	7/20/2022	Cadmium	0.56	0.05	21
072022LRRDV02	Red Rock	7/20/2022	Cadmium	1.14	0.04	23.5
072022LRRDV03	Red Rock	7/20/2022	Cadmium	1.22	0.04	20.6
072022LRRDV04	Red Rock	7/20/2022	Cadmium	1.31	0.07	18.4
072022LRRDV05	Red Rock	7/20/2022	Cadmium	1.14	0.05	24.4
072122UCNDV06	Red Rock	7/21/2022	Cadmium	0.42	0.04	22.9
072122UCNDV07	Red Rock	7/21/2022	Cadmium	0.25	0.05	22.4
072122UCNDV08	Red Rock	7/21/2022	Cadmium	0.56	0.04	26.2
072022LRRDV01	Red Rock	7/20/2022	Copper	4.70	0.84	21
072022LRRDV02	Red Rock	7/20/2022	Copper	4.72	0.61	23.5
072022LRRDV03	Red Rock	7/20/2022	Copper	3.99	0.56	20.6
072022LRRDV04	Red Rock	7/20/2022	Copper	5.20	1.04	18.4
072022LRRDV05	Red Rock	7/20/2022	Copper	4.88	0.79	24.4
072122UCNDV06	Red Rock	7/21/2022	Copper	4.20	0.70	22.9
072122UCNDV07	Red Rock	7/21/2022	Copper	4.55	0.75	22.4
072122UCNDV08	Red Rock	7/21/2022	Copper	4.81	0.66	26.2
072022LRRDV01	Red Rock	7/20/2022	Mercury	0.10	0.01	21
072022LRRDV02	Red Rock	7/20/2022	Mercury	0.05	0.01	23.5
072022LRRDV03	Red Rock	7/20/2022	Mercury	0.05	0.01	20.6
072022LRRDV04	Red Rock	7/20/2022	Mercury	0.05	0.01	18.4
072022LRRDV05	Red Rock	7/20/2022	Mercury	0.05	0.01	24.4
072122UCNDV06	Red Rock	7/21/2022	Mercury	0.05	0.01	22.9
072122UCNDV07	Red Rock	7/21/2022	Mercury	0.09	0.01	22.4
072122UCNDV08	Red Rock	7/21/2022	Mercury	0.05	0.01	26.2
072022LRRDV01	Red Rock	7/20/2022	Selenium	4.37	0.10	21
072022LRRDV02	Red Rock	7/20/2022	Selenium	3.74	0.08	23.5
072022LRRDV03	Red Rock	7/20/2022	Selenium	3.49	0.07	20.6
072022LRRDV04	Red Rock	7/20/2022	Selenium	3.82	0.13	18.4
072022LRRDV05	Red Rock	7/20/2022	Selenium	4.14	0.10	24.4
072122UCNDV06	Red Rock	7/21/2022	Selenium	4.41	0.09	22.9
072122UCNDV07	Red Rock	7/21/2022	Selenium	4.78	0.09	22.4
072122UCNDV08	Red Rock	7/21/2022	Selenium	4.96	0.08	26.2
072022LRRDV01	Red Rock	7/20/2022	Zinc	143.81	6.29	21
072022LRRDV02	Red Rock	7/20/2022	Zinc	129.36	4.60	23.5
072022LRRDV03	Red Rock	7/20/2022	Zinc	142.72	4.22	20.6
072022LRRDV04	Red Rock	7/20/2022	Zinc	126.09	7.83	18.4
072022LRRDV05	Red Rock	7/20/2022	Zinc	128.28	5.90	24.4
072122UCNDV06	Red Rock	7/21/2022	Zinc	106.11	5.24	22.9
072122UCNDV07	Red Rock	7/21/2022	Zinc	177.68	5.63	22.4
072122UCNDV08	Red Rock	7/21/2022	Zinc	116.41	4.92	26.2

*MDL = Method Detection Limit

Dolly Varden, continued

Sample ID	Site	Collection Date	Analyte	Dry Wt Result (mg/Kg)	Dry Wt MDL (mg/kg)	% Solid
072022LSADV01	Subarctic	7/20/2022	Cadmium	0.74	0.05	23.3
072022LSADV02	Subarctic	7/20/2022	Cadmium	0.40	0.05	17.8
072022LSADV03	Subarctic	7/20/2022	Cadmium	0.48	0.04	23
072022USADV04	Subarctic	7/21/2022	Cadmium	0.64	0.04	20.5
072122USADV05	Subarctic	7/21/2022	Cadmium	0.82	0.03	21.8
072122USADV06	Subarctic	7/21/2022	Cadmium	0.56	0.04	23.5
072122USADV07	Subarctic	7/21/2022	Cadmium	1.55	0.04	21.4
072122USADV08	Subarctic	7/21/2022	Cadmium	0.33	0.04	24.4
072122USADV09	Subarctic	7/21/2022	Cadmium	1.24	0.04	18
072122USADV10	Subarctic	7/21/2022	Cadmium	0.31	0.06	21
072122USADV11	Subarctic	7/21/2022	Cadmium	0.45	0.04	22.7
072022LSADV01	Subarctic	7/20/2022	Copper	6.05	0.86	23.3
072022LSADV02	Subarctic	7/20/2022	Copper	4.72	0.85	17.8
072022LSADV03	Subarctic	7/20/2022	Copper	4.00	0.71	23
072022USADV04	Subarctic	7/21/2022	Copper	3.36	0.64	20.5
072122USADV05	Subarctic	7/21/2022	Copper	4.77	0.51	21.8
072122USADV06	Subarctic	7/21/2022	Copper	2.86	0.56	23.5
072122USADV07	Subarctic	7/21/2022	Copper	5.37	0.67	21.4
072122USADV08	Subarctic	7/21/2022	Copper	2.34	0.69	24.4
072122USADV09	Subarctic	7/21/2022	Copper	3.90	0.71	18
072122USADV10	Subarctic	7/21/2022	Copper	4.25	0.93	21
072122USADV11	Subarctic	7/21/2022	Copper	2.73	0.67	22.7
072022LSADV01	Subarctic	7/20/2022	Mercury	0.05	0.01	23.3
072022LSADV02	Subarctic	7/20/2022	Mercury	0.05	0.01	17.8
072022LSADV03	Subarctic	7/20/2022	Mercury	0.04	0.01	23
072022USADV04	Subarctic	7/21/2022	Mercury	0.11	0.01	20.5
072122USADV05	Subarctic	7/21/2022	Mercury	0.10	0.01	21.8
072122USADV06	Subarctic	7/21/2022	Mercury	0.11	0.01	23.5
072122USADV07	Subarctic	7/21/2022	Mercury	0.07	0.01	21.4
072122USADV08	Subarctic	7/21/2022	Mercury	0.08	0.01	24.4
072122USADV09	Subarctic	7/21/2022	Mercury	0.08	0.01	18
072122USADV10	Subarctic	7/21/2022	Mercury	0.07	0.01	21
072122USADV11	Subarctic	7/21/2022	Mercury	0.11	0.01	22.7

*MDL = Method Detection Limit

Dolly Varden, continued

Sample ID	Site	Collection Date	Analyte	Dry Wt Result (mg/Kg)	Dry Wt MDL (mg/kg)	% Solid
072022LSADV01	Subarctic	7/20/2022	Selenium	7.73	0.11	23.3
072022LSADV02	Subarctic	7/20/2022	Selenium	6.18	0.11	17.8
072022LSADV03	Subarctic	7/20/2022	Selenium	5.00	0.09	23
072022USADV04	Subarctic	7/21/2022	Selenium	5.22	0.08	20.5
072122USADV05	Subarctic	7/21/2022	Selenium	5.23	0.06	21.8
072122USADV06	Subarctic	7/21/2022	Selenium	4.08	0.07	23.5
072122USADV07	Subarctic	7/21/2022	Selenium	3.90	0.08	21.4
072122USADV08	Subarctic	7/21/2022	Selenium	5.00	0.09	24.4
072122USADV09	Subarctic	7/21/2022	Selenium	4.29	0.09	18
072122USADV10	Subarctic	7/21/2022	Selenium	4.43	0.12	21
072122USADV11	Subarctic	7/21/2022	Selenium	4.10	0.08	22.7
072022LSADV01	Subarctic	7/20/2022	Zinc	129.61	6.44	23.3
072022LSADV02	Subarctic	7/20/2022	Zinc	175.28	6.40	17.8
072022LSADV03	Subarctic	7/20/2022	Zinc	116.96	5.35	23
072022USADV04	Subarctic	7/21/2022	Zinc	202.93	4.83	20.5
072122USADV05	Subarctic	7/21/2022	Zinc	186.70	3.85	21.8
072122USADV06	Subarctic	7/21/2022	Zinc	162.98	4.21	23.5
072122USADV07	Subarctic	7/21/2022	Zinc	167.29	5.05	21.4
072122USADV08	Subarctic	7/21/2022	Zinc	127.87	5.16	24.4
072122USADV09	Subarctic	7/21/2022	Zinc	162.78	5.33	18
072122USADV10	Subarctic	7/21/2022	Zinc	161.90	7.00	21
072122USADV11	Subarctic	7/21/2022	Zinc	132.16	5.02	22.7

*MDL = Method Detection Limit

Slimy Sculpin

Sample ID	Site	Collection Date	Analyte	Dry Wt Result (mg/Kg)	Dry Wt MDL (mg/kg)	% Solid
072322RILSS01	Riley	7/23/2022	Cadmium	0.31	0.04	24.1
072322RILSS02	Riley	7/23/2022	Cadmium	0.33	0.05	19.7
072322RILSS03	Riley	7/23/2022	Cadmium	0.28	0.03	22.3
072322RILSS04	Riley	7/23/2022	Cadmium	0.38	0.05	23.3
072322RILSS05	Riley	7/23/2022	Cadmium	0.15	0.05	25.5
072322RILSS06	Riley	7/23/2022	Cadmium	0.35	0.04	25.7
072322RILSS01	Riley	7/23/2022	Copper	3.12	0.66	24.1
072322RILSS02	Riley	7/23/2022	Copper	3.58	0.75	19.7
072322RILSS03	Riley	7/23/2022	Copper	2.95	0.56	22.3
072322RILSS04	Riley	7/23/2022	Copper	3.41	0.74	23.3
072322RILSS05	Riley	7/23/2022	Copper	3.46	0.74	25.5
072322RILSS06	Riley	7/23/2022	Copper	4.28	0.67	25.7
072322RILSS01	Riley	7/23/2022	Mercury	0.24	0.01	24.1
072322RILSS02	Riley	7/23/2022	Mercury	0.10	0.01	19.7
072322RILSS03	Riley	7/23/2022	Mercury	0.13	0.01	22.3
072322RILSS04	Riley	7/23/2022	Mercury	0.27	0.01	23.3
072322RILSS05	Riley	7/23/2022	Mercury	0.24	0.01	25.5
072322RILSS06	Riley	7/23/2022	Mercury	0.14	0.01	25.7
072322RILSS01	Riley	7/23/2022	Selenium	6.31	0.08	24.1
072322RILSS02	Riley	7/23/2022	Selenium	6.09	0.09	19.7
072322RILSS03	Riley	7/23/2022	Selenium	5.56	0.07	22.3
072322RILSS04	Riley	7/23/2022	Selenium	6.35	0.09	23.3
072322RILSS05	Riley	7/23/2022	Selenium	5.18	0.09	25.5
072322RILSS06	Riley	7/23/2022	Selenium	7.47	0.08	25.7
072322RILSS01	Riley	7/23/2022	Zinc	187.14	4.98	24.1
072322RILSS02	Riley	7/23/2022	Zinc	150.25	5.63	19.7
072322RILSS03	Riley	7/23/2022	Zinc	152.91	4.17	22.3
072322RILSS04	Riley	7/23/2022	Zinc	190.56	5.54	23.3
072322RILSS05	Riley	7/23/2022	Zinc	106.27	5.53	25.5
072322RILSS06	Riley	7/23/2022	Zinc	108.95	5.02	25.7

*MDL = Method Detection Limit