Technical Report No. 23-03

Baseline Aquatic Biomonitoring for the Anarraaq and Aktigiruq Prospects near the Red Dog Mine, 2022

by

Olivia N. Edwards

August 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)

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. 23-03

BASELINE AQUATIC BIOMONITORING FOR THE ANARRAAQ AND AKTIGIRUQ PROSPECTS NEAR THE RED DOG MINE, 2022

By

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August 2023

Cover: Dolly Varden captured in upper Grayling Junior Creek watershed August 2022

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Acknowledgements

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Nora Foster (NRF Taxonomic Services) was responsible for sorting and identification of aquatic invertebrates.

Chelsea Clawson, Al Ott, Audra Brase, Heidi Tillquist, and Emily Hart provided constructive reviews of this report.

Executive Summary

This report summarizes results of 2022 biomonitoring work performed in streams in the vicinity of the Anarraaq and Aktigiruq prospects located northwest of the Red Dog Mine. Biomonitoring included surveys of periphyton (measured by chlorophyll-a), aquatic invertebrates, and fish; these data were collected annually from 2014 through 2022. Biomonitoring data from 2000 through 2002 and reported in Weber Scannell and Ott (2006) are included for comparison. The purpose of this report is to document the existing aquatic environment and to provide a basis for monitoring as exploration continues and/or development of the ore bodies occurs.

Water quality in streams near the Anarraaq and Aktigiruq prospects varies considerably. Creeks draining from the area where the orebody is located (West Fork Ikalukrok, Noa, Moil, Ikalukrok, and Competition creeks) exhibit naturally degraded water quality (e.g., high metals, low pH), low periphyton standing crop, low aquatic invertebrate density, and very few fish. Noa and Moil creeks are no longer sampled for fish. In 2022, no fish were captured in West Fork Ikalukrok Creek, Ikalukrok Creek upstream of Cub Creek Seep, and Competition Creek.

During 2000 through 2002 sampling, water quality in Sourdock, Competition, upper Ikalukrok, East Fork Ikalukrok, Grayling Junior, and Sled creeks was of a higher quality than in recent years (e.g., lower metals, neutral pH). Arctic grayling and juvenile Dolly Varden were present in Competition Creek and juvenile Dolly Varden were present in Sourdock Creek. Arctic grayling and juvenile Dolly Varden were found in East Fork Ikalukrok Creek and in Ikalukrok Creek downstream of its confluence with the East Fork. Grayling Junior Creek contained Arctic grayling, slimy sculpin, and juvenile Dolly Varden, and in some years large numbers (about 300) of Arctic grayling were found at the confluence of Grayling Junior and Ikalukrok creeks. Sourdock Creek, a tributary to Competition Creek, supported juvenile Dolly Varden. Sled Creek does not support fish, likely due to the stream going subsurface during the ice-free season before entering Ikalukrok Creek.

In 2022, additional sample sites for periphyton and invertebrates were added on Upper Grayling Junior 1, Upper Volcano Creek, and Upper North Fork Red Dog 1. An additional minnow trap site was added on Upper Volcano Creek.

Measurements of periphyton standing crop, aquatic invertebrates, and fish distribution vary among the sample sites. In 2022, periphyton as measured by chlorophyll-a was highest in Sled Creek (3.30 mg/m^2) as has been the case for the last four years. East Fork Ikalukrok, Volcano, and Warf creeks all had overlapping error bars with Sled Creek. Periphyton as measured by chlorophyll-a at all other sites was very low (<1.00 mg/m^2). Fish catch per unit effort (CPUE, number of fish caught/24 hrs) was highest at Grayling Junior Creek 2, the most upstream Grayling Junior sample site, for the second year in a row. The only other two sites where fish were captured in 2022 were Grayling Junior and Volcano creeks.

In 2022, sediment samples were collected for the first time in Upper Competition, Sourdock, Lower Competition, West Fork Ikalukrok, Upper Ikalukrok, Ikalukrok (downstream of Cub Creek seep), East Fork Ikalukrok, Grayling Junior, Noa, Moil, Sled, and Volcano creeks. Metal concentrations were variable among sites. Visual freshwater mussel surveys were also performed at several sites in 2022, but no evidence of mussels was found.

Introduction

Teck American has been conducting mineral exploration drilling around the Anarraaq Prospect since the mid-1990's and more recently at a second prospect (Aktigiruq) in the same general area. Both prospects are zinc (Zn) and lead (Pb) subsurface deposits collectively located in Sections 11, 14, and 23, T32N, R19W (De Long Mountains A-2). The deposits are located about 16 km northwest of the Red Dog Mine (Figure 1).

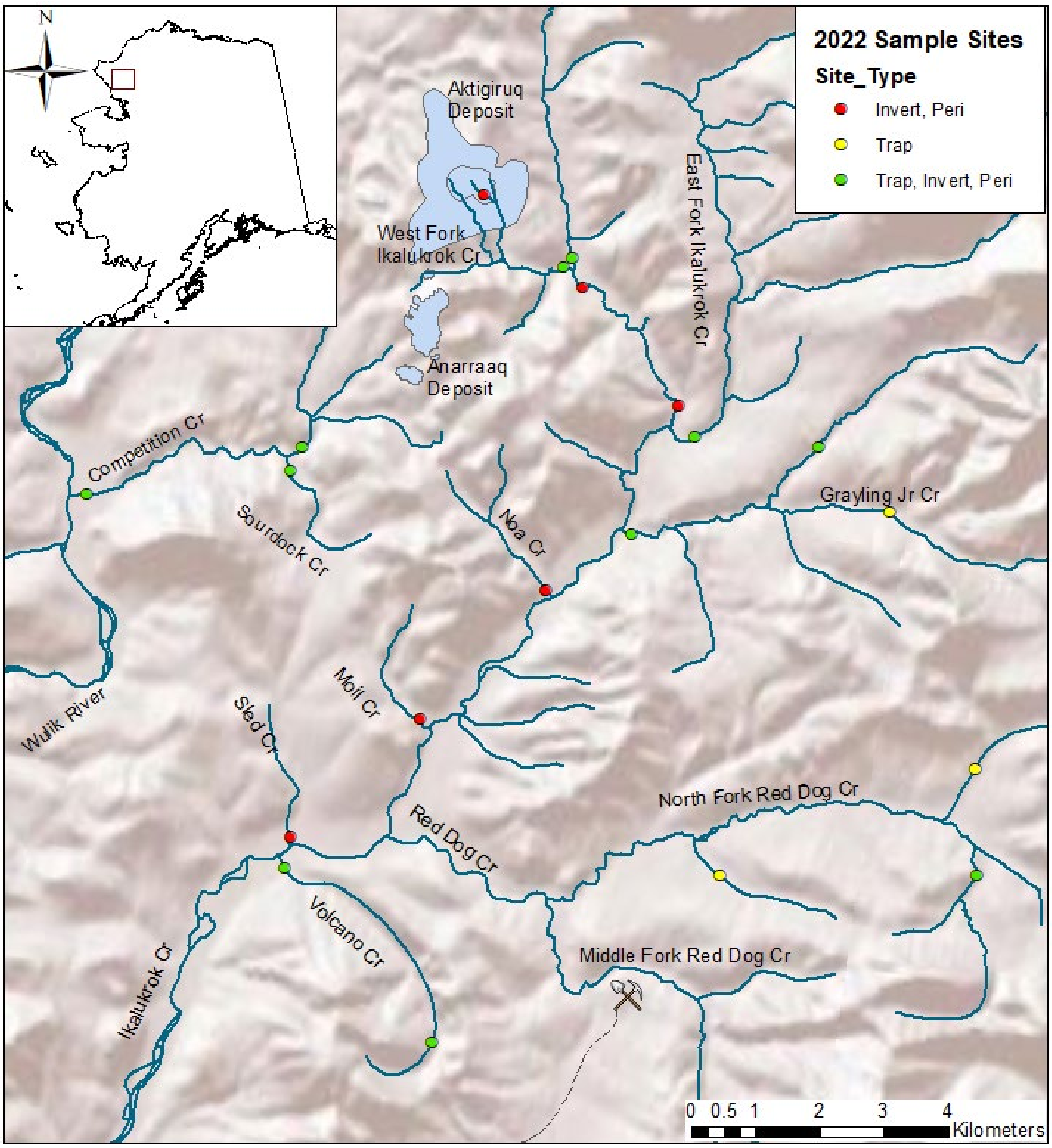

Figure 1. Map showing sampling points and general location of Anarraaq and Aktigiruq deposits (blue polygons).

Aquatic baseline data collection near the Anarraaq Prospect began in 2000 and continued through 2002 (Table 1). Alaska Department of Natural Resources (ADNR) technical reports summarize water quality, periphyton, aquatic invertebrate, and fish data collected in 2000, 2001, and 2002 (Weber Scannell and Ott 2006).

From 2014 through 2022, sampling work focused on streams which flow to the west and east from the Anarraaq and Aktigiruq ore bodies (Table 1). Volcano Creek, a tributary to Ikalukrok Creek, is a potential site for future mine facilities and an aquatic biomonitoring station was established in the creek in 2014. Periphyton (chlorophyll-a concentrations), aquatic invertebrates (taxonomic richness and abundance), and fish (presence and use) data were collected. Additional parameters of mussel presence and sediment analysis were added to some sites in 2022 (Table 1). Periphyton and aquatic invertebrates were collected in early July while fish sampling was conducted in early August. Mussel observations and sediment samples were also collected in July.

In 2013, the United States Environmental Protection Agency (EPA) published the updated Clean Water Act, which included ambient water quality criteria recommendations for ammonia for the protection of the aquatic community, including fish, mussels, and other mollusks. Mussels in the order Unionoida (freshwater mussels) are some of the most sensitive aquatic species to ammonia but are not present in all waters. Therefore, the EPA allows for site-specific criteria with higher ammonia concentrations if applicants demonstrate that mussels are absent. These site-specific criteria are still protective of aquatic life in the waterbody. The Alaska Department of Environmental Conservation has not yet implemented the more restrictive water quality criteria for ammonia but may do so in the future. To have the necessary documentation for future ammonia criteria recalculation, in 2020 the ADF&G Habitat Section added visual surveys for mussel presence/absence to the annual aquatic biomonitoring at a subset of sites.

Access for future underground exploration of the orebodies will be via an all-weather road following Mainstem Red Dog Creek, crossing North Fork Red Dog, Grayling Junior, and Ikalukrok creeks, and then following Ikalukrok Creek to access the deposit area. North Fork Red Dog, Grayling Junior, and Ikalukrok creeks are all anadromous waterbodies which support Dolly Varden, plus the resident fish species Arctic grayling and slimy sculpin.

The Anarraaq and/or Aktigiruq Prospects may ultimately be developed as an underground mine located about 600 m below the ground surface. Details on mine development, operations, and closure are not available at this time, but would be required prior to mining.

Methods

Details for most of the methods used for this aquatic biomonitoring study are described in ADF&G Technical Report 17-09 *Methods for Aquatic Life Monitoring at the Red Dog Mine Site* (Bradley 2017). Location of the sample sites described in this report and the years they were sampled are listed in Table 1.

Periphyton was sampled in July directly from cobble on the streambed. The periphyton was collected from a riffle area of submerged cobble, following the rapid bioassessment techniques of Barbour et al. 1997, but with ten replicates per site to increase sample precision. The concentrations of chlorophyll-a were determined to estimate periphyton standing crop. Periphyton attached microalgae biomass were collected in early July and are presented as mg/m^2 chlorophyll-a.

Prior to 2022, aquatic invertebrates were collected at each sample site using five drift nets installed in riffle habitat along a transect perpendicular to flow. Beginning in 2022, invertebrate sampling was conducted in early July solely with Hess samplers following a combination test season in 2021[1]. Hess samplers are more effective for identifying the in-situ benthic community than drift nets, which mostly capture invertebrates drifting downstream suspended in the water column. This new method provides a more accurate baseline for evaluating changes at each site, rather than changes occurring upstream. 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. Samples were preserved in 90% ethanol leading up to lab identification. Densities through 2021 are expressed as the average number of aquatic

[1] Both drift nets and Hess samplers were used for collecting samples in the 2021 field season. Results for each method were compared in the ADF&G annual technical report (Clawson 2022). Although differences were found in the results, invertebrate data is so variable there is not a way to convert data between Hess and drift net results to allow for continued chronological comparison. Given that the Hess sampling method better accomplishes the goal of documenting conditions at each site rather than those upstream, the decision was made to continue with the new (Hess) method despite the loss of the ability to compare to previous years' results.

invertebrates per cubic meter of water. Beginning in 2022, densities are reported as number of invertebrates per m^2 of substrate. Comparisons between the total percent of Ephemeroptera, Plecoptera and Tricoptera (EPT) vs. Chironomidae (CHIROS) were also made. In general, the higher the percentage of EPT at a site, the higher the water quality. Taxa richness, in this report, is defined as the total number of taxa found at a sample site.

Ten minnow traps were set at each site for fish sampling and baited with salmon roe for about 24 hours, in late July or early August each year. Visual observations were made when appropriate. All fish captured in the minnow traps were identified and measured (fork length, mm), and released. Densities are presented in Catch Per Unit Effort (CPUE), defined as the total number of fish caught at a site per 24-hour period. These results are rounded to the nearest whole number. At some sites, juvenile Dolly Varden (between 90 and 140 mm long) were retained for whole body analyses of selected elements[2]. Whole body element concentration results are presented with data from the ADF&G Red Dog Mine technical report to provide context and comparison with nearby drainages (Clawson 2023).

Visual surveys for freshwater mussel presence/absence were conducted in areas of low water velocity such as back eddies or pools at a subset of sample sites in early July. Biologists looked for trails in the substrate, live animals, and shells from dead animals. In areas of poor water visibility, an Aquascope was used to obtain a clearer view of the substrate.

In July 2022, in-stream sediment samples were collected at a subset of sample sites and analyzed for cadmium, copper, lead, mercury, selenium and zinc. Approximately 200 mL of sand or silt was collected from a sandbar or backwater pool near each invertebrate/periphyton sample site using a clean plastic bag. Samples were frozen until analysis was performed. Sediment element concentration analyses were conducted by ACZ Laboratories.

All 2022 water quality sampling was performed by Red Dog Mine personnel following their standard methodology. Water quality analysis was performed by laboratories and results provided to ADF&G for inclusion in this report. All water quality presented in this report are for "total

[2] Whole body element concentrations are not equivalent to human exposure. This methodology is used over specific tissue element concentrations to due to the chance of contamination and difficulty of removing the intestinal tract or performing gastric lavage in the field on juvenile fish.

recoverable" unless otherwise specified. The number of water quality samples taken each year varies, but samples are collected twice each month with a sample size of 9 to 13 per year per site.

Table 1. Location of sample sites, parameters collected, and years sampled. Parameters include periphyton (P), aquatic invertebrates (AI), fish (F), mussels (M), and instream sediment (S).

Station No.	Stream/Site Name	2022 Parameters	Years Sampled
202	Lower Competition	P, AI, F	2000-2002 and 2014-2022
203	Upper Competition	P, AI, F	2000-2002 and 2014-2022
204	Sourdock	P, AI, F	2000-2002 and 2014-2022
205	West Fork Ikalukrok	P, AI, F, M	2000-2002 and 2015-2022
206	Ikalukrok (above West Fork)	P, AI, F, M	2000-2002 and 2015-2022
207	Ikalukrok[2]	P, AI, M	1997-1998, 2000-2002, and 2016-2022
208	East Fork Ikalukrok	P, AI, F, M	1997-1998, 2000-2002, and 2016-2022
209	Grayling Junior	P, AI, F, M	2000-2002 and 2016-2022
210	Noa	P, AI	2000-2002 and 2016-2022
211	Moil	P, AI	2000-2002 and 2016-2022
212	Sled	P, AI	2000-2002 and 2015-2022
N/A	Volcano	P, AI, F	2014-2022
N/A	Warf Creek	P, AI	2021-2022
230	Ikalukrok (below West Fork)	P, AI	2021-2022
N/A	Grayling Junior 1	P, AI, F	2021-2022
N/A	Grayling Junior 2	F	2021-2022
N/A	Upper NFRD Trib	F	2021-2022
N/A	Upper NFRD 1	P, AI, F	2021-2022
N/A	Upper NFRD 2	F	2021-2022
N/A	Upper Volcano	P, AI, F	2016 and 2022

[1]Site was not sampled in 2020

[2]Sample site is downstream of Cub Creek Seep

Results and Discussion

This section presents the biomonitoring results for each site listed in Table 1. Comparisons are made to prior work performed in 2000 through 2002 and published in Weber Scannell and Ott (2006). Detailed data for fish catches can be found in Appendix 1. Additional detailed data (periphyton, aquatic invertebrates and fish whole body element concentrations) are available upon request[3].

Upper Competition Creek (Station 203)

Water Quality

Upper Competition Creek had moderately low pH and elevated concentrations of aluminum, cadmium, nickel, and zinc (Weber Scannell and Ott 2006). The substrate had a grayish-yellow precipitate in the early 2000s, but the precipitate in 2014 through 2022 varied from white to tan (Figure 2). Additionally, the water in Upper Competition Creek has varied from opaque white to orange in color.

Figure 2. Upper Competition Creek in 2018 (left) and 2022 (right). Note the color difference in both the precipitate and water between years.

Periphyton

Average chlorophyll-a concentration in 2022 was the highest observed since the early 2000's at 0.12 mg/m^2. This is still well below the highest observed value in 2002 of 0.42 mg/m^2. Average

[3] Submit detailed data requests to ADF&G Habitat Section - 1300 College Rd, Fairbanks, Alaska 99701 or dfg.hab.infofai@alaska.gov.

chlorophyll-a concentrations have been consistently lower in Upper Competition Creek during the recent sampling period (2014 through 2022) compared to the results in 2000 and 2002.

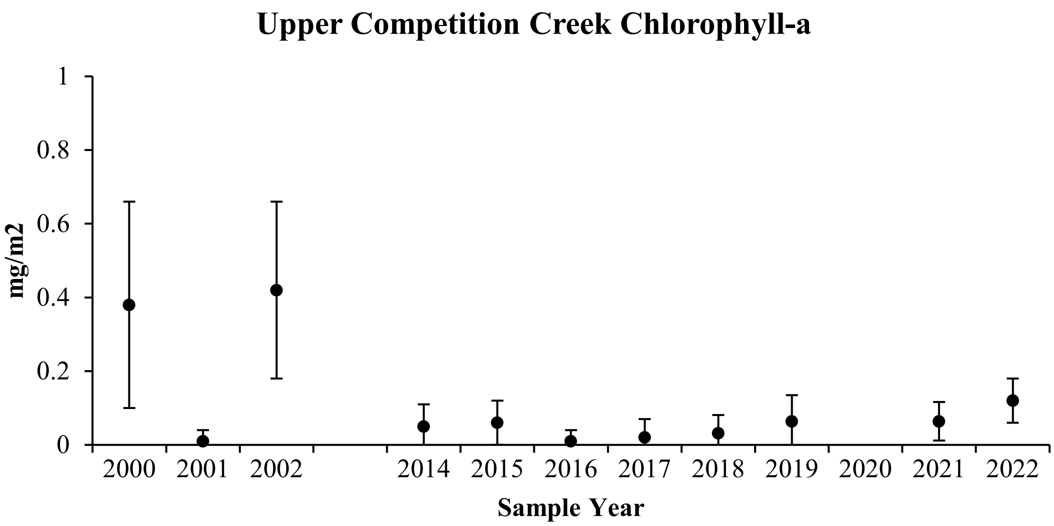

Figure 3. Average concentration of chlorophyll-a (± 1SD) in Upper Competition Creek.

Invertebrates

Aquatic invertebrate density in Upper Competition Creek in 2022 was 93.02/m^2. The percent Chironomidae is generally higher than percent EPT at this site, but in 2000 and 2016 the EPT was higher than Chironomidae (Figure 4). In past years the EPT was composed of mayflies and stoneflies with very few or no caddisflies, but there were no EPT in the 2021 or 2022 samples. Taxa richness in 2022 was the lowest on record at four taxa. Previously, taxa richness varied from 12 to 22 taxa per site over the sample years (Figure 5). The contrast with previous results in 2022 may be due to the change in sampling methods from drift nets to Hess samplers.

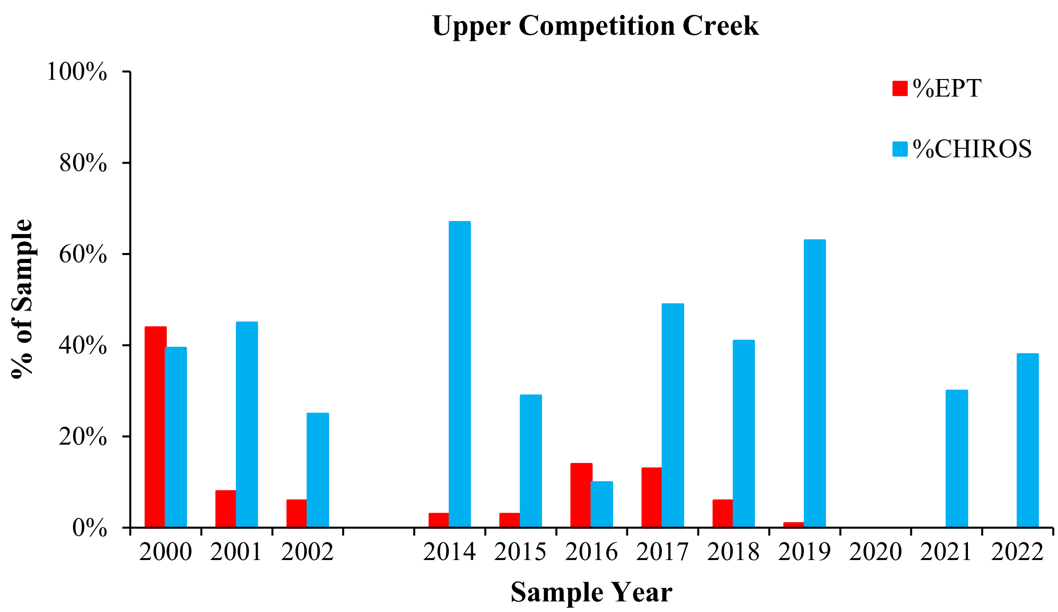

Figure 4. Percent Chironomidae and EPT in Upper Competition Creek. No sampling occurred at this site in 2020.

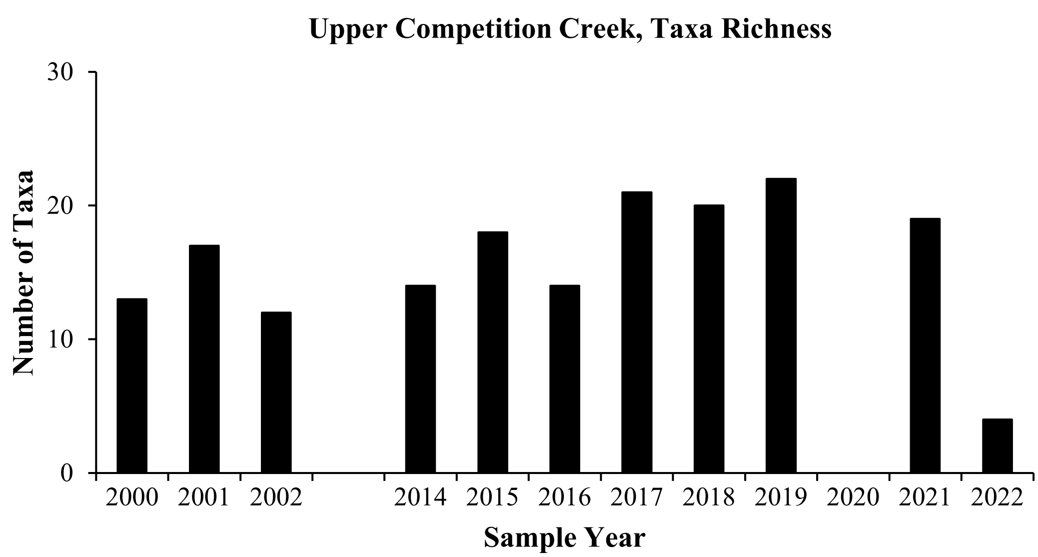

Figure 5. Aquatic invertebrate taxa richness at Upper Competition Creek. No sampling occurred at this site in 2020.

Fish

The CPUE for Dolly Varden in minnow traps at Upper Competition Creek was five fish in 2000 and three fish in 2002. These catches coincided with the two years that had the highest periphyton concentrations (Figure 3). No fish were caught at the site from 2014 through 2022, which suggests that water quality has degraded to the point that fish are avoiding this stream reach. Upper Competition Creek appears to have changed over the time frame of our sampling effort with every indication that basic biological productivity has decreased.

Sediment

Sediment element concentrations in Upper Competition Creek are presented in Table 2. Cadmium and zinc concentrations were below the median among all sites. Copper and selenium concentrations were the highest recorded among all sites. Lead concentration was well above the median among all sites. Mercury concentration was slightly above the median among all sites.

Table 2. Sediment sample element concentrations in Upper Competition Creek, Alaska, 2022.

Element	Concentration (mg/kg dry weight)	Median Among All Sites (mg/kg dry weight)
Cadmium	1.93	2.59
Copper	250	131
Lead	79.7	22.5
Mercury	0.083	0.071
Selenium	5.50	2.48
Zinc	493	544

Sourdock Creek (Station 204)

Water Quality

Sourdock Creek (Figures 1 and 6) had moderate alkalinity (as $CaCO_3$), sulfate concentrations (2000 through 2002 median = 116 mg/L), and median hardness of 170 mg/L. The pH was neutral with slightly elevated concentrations of aluminum, cadmium, and zinc (Weber Scannell and Ott 2006). The large boulders were covered with a thick layer of moss from 2000 through 2002, but most of the moss has been absent during the 2014 through 2022 sample period. In 2021 and 2022, there was orange staining on the rocks and the water was more opaque than in past years (Figure 6).

Figure 6. Sourdock Creek in 2017 (left) and 2022 (right).

Periphyton

The average chlorophyll-a concentration in 2022 was 0.13 mg/m^2, the lowest on record for this site. The highest average chlorophyll-a concentration observed in Sourdock Creek was 12.44 mg/m^2 in 2002 (Figure 7). Chlorophyll-a has been considerably higher each sampling year in Sourdock Creek than in Upper Competition Creek up until 2022 when the two only differed by 0.01 mg/m^2. These two creeks merge just downstream of the sample sites to form Competition Creek.

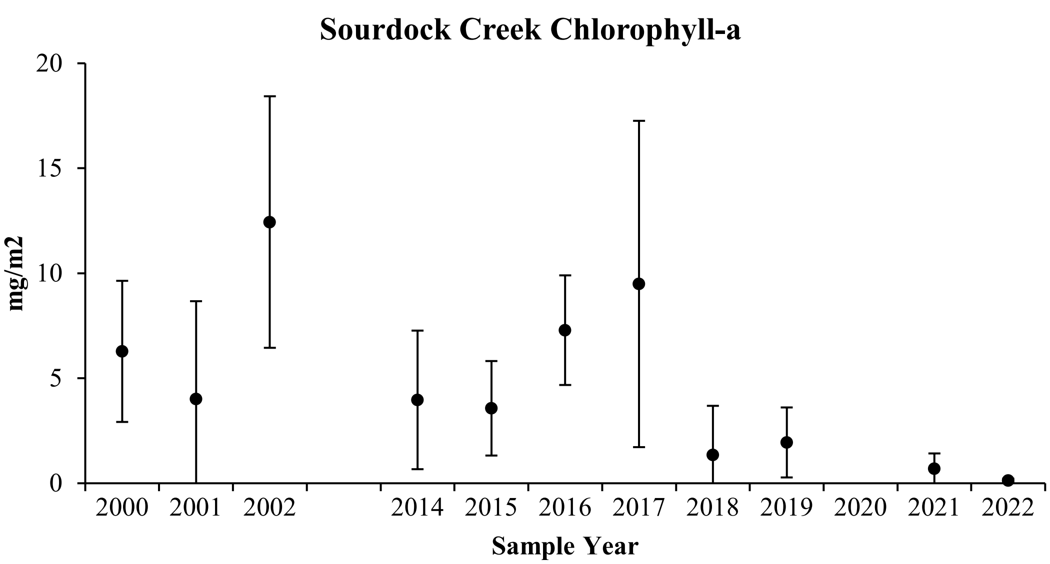

Figure 7. Average concentration of chlorophyll-a (± 1SD) in Sourdock Creek.

Invertebrates

Aquatic invertebrate density in Sourdock Creek was 46.51/m^2 in 2022. The percent Chironomidae in 2022 was greater than the previous two years of sampling and no EPT were found in the 2022 sample (Figure 8). Taxa richness prior to 2022 varied from 12 to 22 taxa but only two taxa were present in 2022 (Figure 9). The contrast with previous data in 2022 may be due to the change in sampling methods from drift nets to Hess samplers.

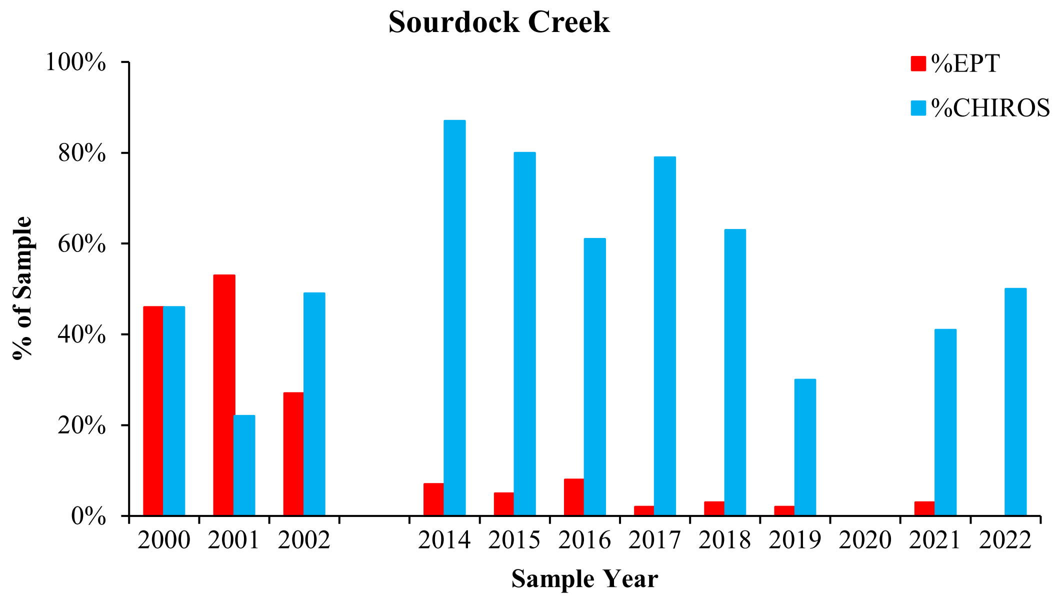

Figure 8. Percent Chironomidae and EPT in Sourdock Creek.

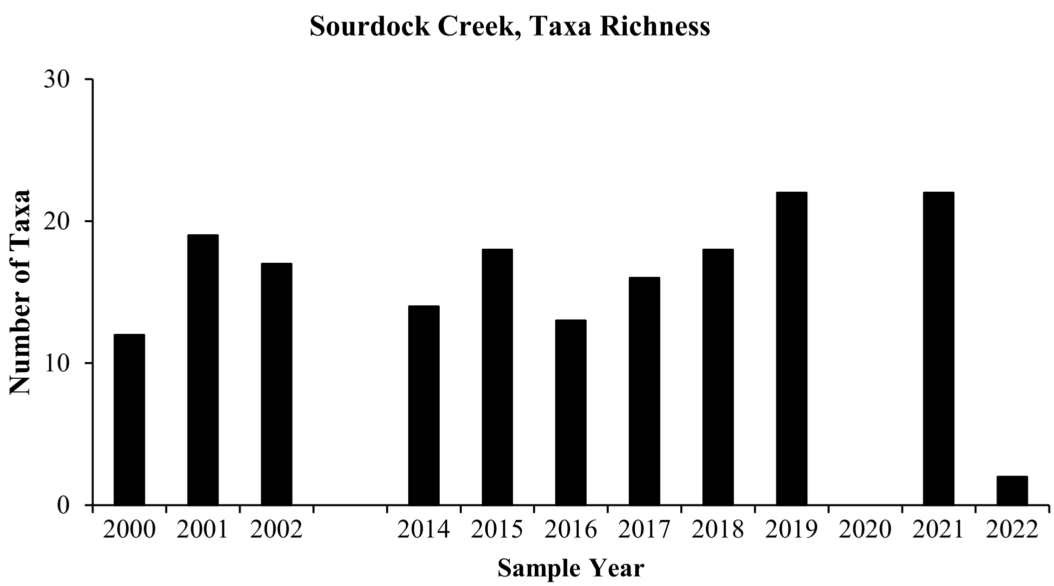

Figure 9. Aquatic invertebrate taxa richness in Sourdock Creek.

Fish

The CPUE for juvenile Dolly Varden at Sourdock Creek was highest in 2000 and has decreased over the sample period to zero fish caught in all years since 2014 except 2016, when 1 fish was caught (Figure 10). The element concentrations (e.g., metals) in Competition Creek may have increased, leading to a chemical barrier to the upstream movement of Dolly Varden juveniles from overwintering habitat in the Wulik River. Water quality in Sourdock Creek also appears to be degrading in recent years, as evidenced by the decrease in chlorophyll-a concentrations and the changed appearance of the creek.

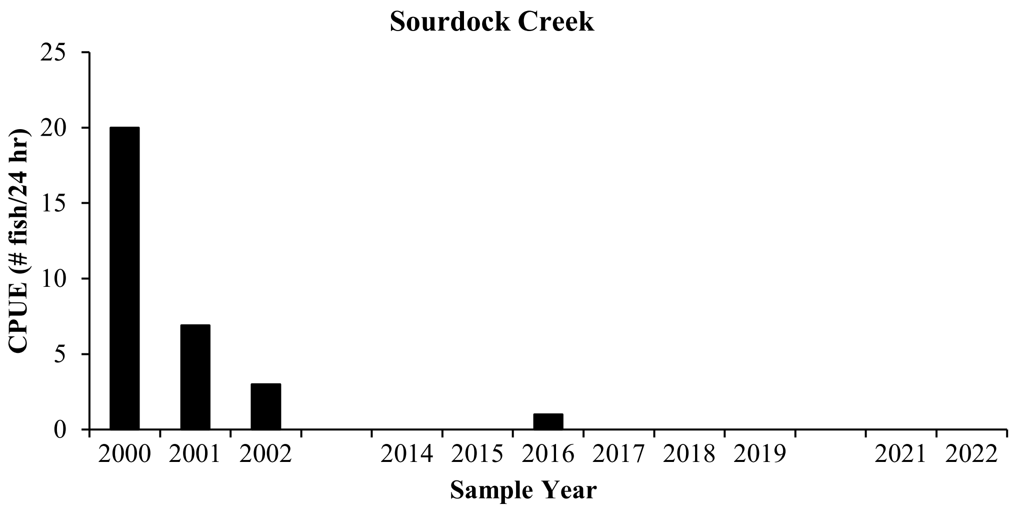

Figure 10. Catch per unit of effort for juvenile Dolly Varden in Sourdock Creek.

The length frequency distribution for all juvenile Dolly Varden caught in Sourdock Creek from 2000 through 2002 is presented in Figure 11. Only one fish has been captured since 2014, a 139 mm Dolly Varden that was captured in 2016. There appear to be at least two year-classes present in the 2000 through 2002 fish (most likely 1+ and 2+) which is consistent with data collected in other Red Dog Mine area streams.

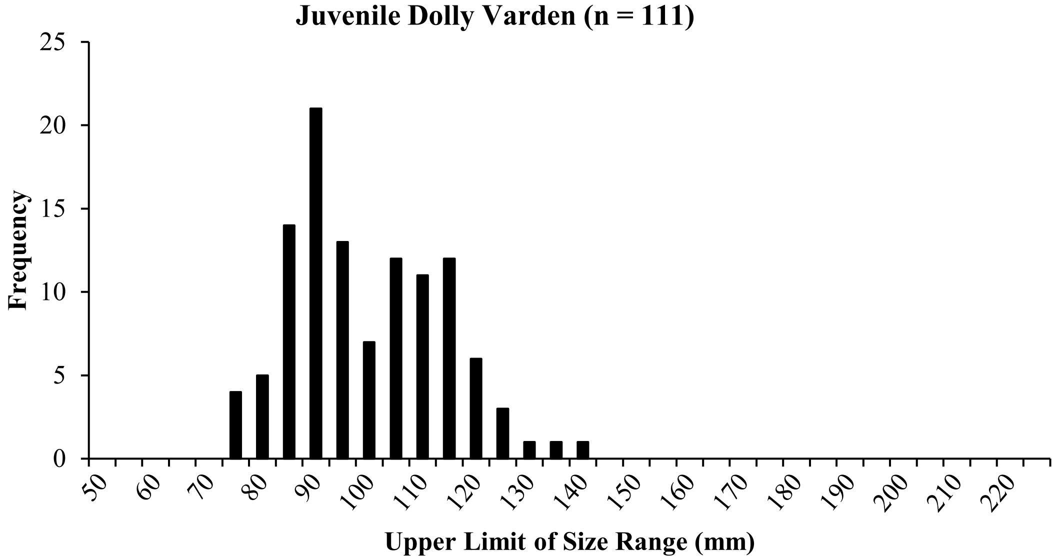

Figure 11. Length frequency distribution of Dolly Varden in Sourdock Creek, 2000-2002.

Sediment

Sediment element concentrations in Sourdock Creek are presented in Table 3. Cadmium and zinc concentrations were well above the median among all sites. Copper, lead, mercury, and selenium concentrations were on the low end of all site values.

Table 3. Sediment sample element concentrations in Sourdock Creek, 2022.

Element	Concentration (mg/kg dry weight)	Median Among All Sites (mg/kg dry weight)
Cadmium	5.85	2.59
Copper	72	131
Lead	15.1	22.5
Mercury	0.028	0.071
Selenium	2.09	2.48
Zinc	996	544

Lower Competition Creek (Station 202)

Water Quality

Historically, Lower Competition Creek (Figures 1 and 12) water quality appeared to be moderated by input from Sourdock Creek. Element concentrations (metals) at Lower Competition Creek were substantially lower than at the Upper Competition Creek sample site from 2000 through 2002

(Weber Scannell and Ott 2006). Unlike the Upper Competition Site, no samples from Lower Competition Creek contained concentrations of iron, nickel, or lead that exceeded the chronic criteria for aquatic life (Weber Scannell and Ott 2006). Although no quantitative data has been collected in recent years, it was visually apparent beginning in 2018 that water quality had changed from that observed from 2000 through 2002 (clear water) to red/orange staining and opaque water (Figure 12).

Figure 12. Lower Competition Creek in 2000 (left) and 2022 (right).

Periphyton

Average chlorophyll-a concentrations in Lower Competition Creek from 2014 through 2022 were substantially lower than those found from 2000 through 2002, an indication of degraded water quality (Figure 13). Chlorophyll-a concentration in 2022 was 0.04 mg/m^2. The highest ever observed was in 2002 at 4.42 mg/m^2.

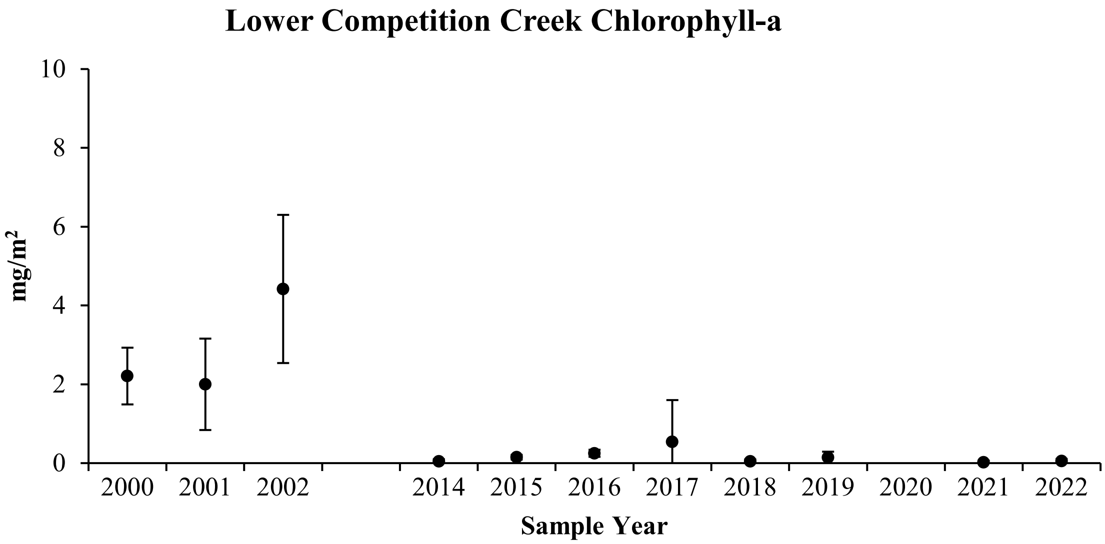

Figure 13. Average concentration of chlorophyll-a (± 1SD) in Lower Competition Creek.

Invertebrates

Aquatic invertebrate density in Lower Competition Creek was 209.3/m^2 in 2022. The percent EPT was higher than percent Chironomidae in 2022 for the first time since 2001 (Figure 14). From 2014 to 2021 percent Chironomidae was substantially greater than percent EPT (Figure 14). The EPT in 2022 was composed of stoneflies and caddisflies. Taxa richness was lowest on record in 2022 at seven taxa (Figure 15). Taxa richness previously ranged from 13 to 24 taxa. The contrast with previous results in 2022 may be due to the change in sampling methods from drift nets to Hess samplers.

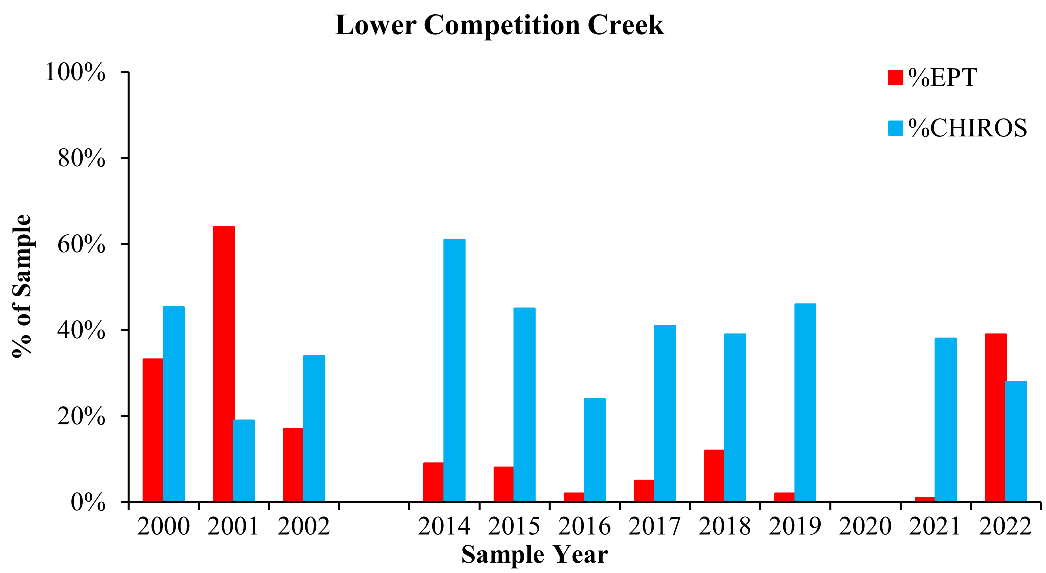

Figure 14. Percent Chironomidae and EPT in Lower Competition Creek.

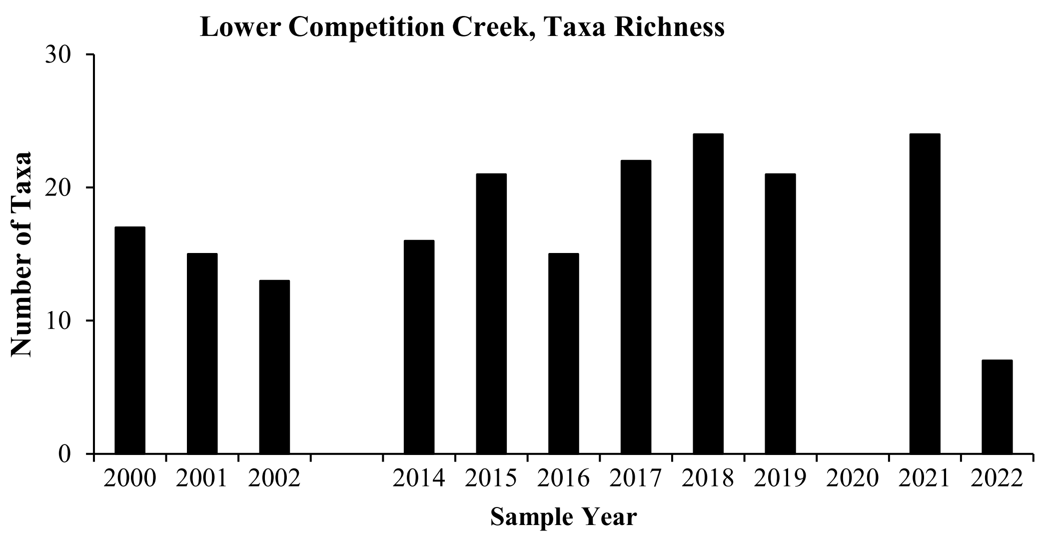

Figure 15. Aquatic invertebrate taxa richness in Lower Competition Creek.

Fish

Juvenile Dolly Varden historically used Lower Competition Creek as rearing habitat during the ice-free season (Bradley and Ott 2018). In 2000, fyke nets were used to catch fish moving either upstream or downstream in early July and late July. Catches yielded four juvenile Arctic grayling and 38 juvenile Dolly Varden (Weber Scannell and Ott 2006).

Minnow trap data collected from 2000 through 2002 and from 2014 to 2022 are presented in Figure 16. The CPUE has been variable since 2014 with a low of zero fish caught in 2021 and 2022, and a high of 47 fish in 2016 (Figure 16). Generally, the CPUE was higher from 2014 through 2019 than in 2000 through 2002. This may reflect a higher number of fish using this section of the creek due to degraded water quality conditions in the upper part of the drainage (e.g., Upper Competition Creek). However, water clarity was poorer in both 2021 and 2022, which may be why no fish were caught during the early August sampling events.

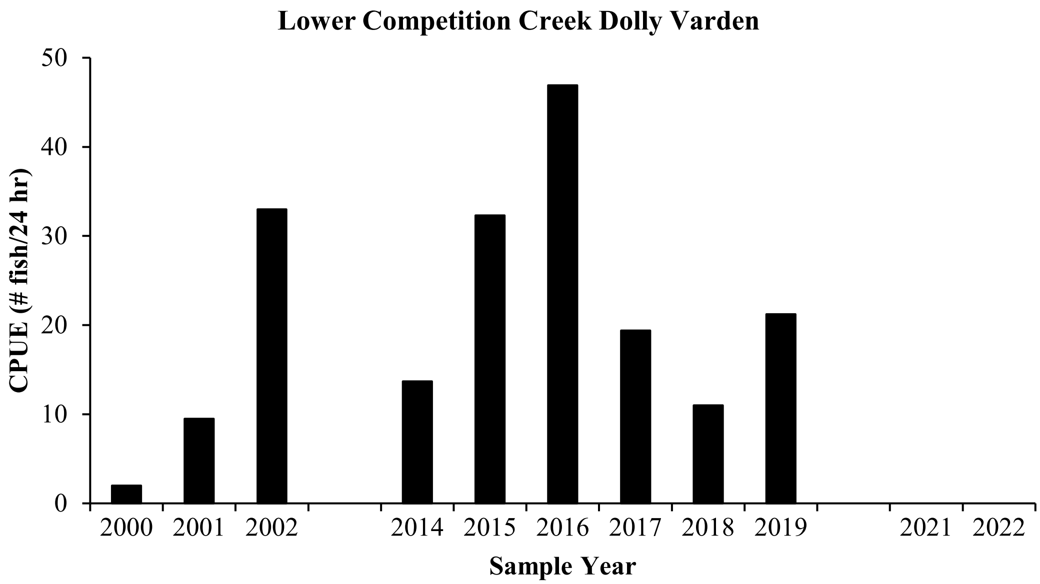

Figure 16. Catch per unit of effort for juvenile Dolly Varden in Lower Competition Creek. No sampling occurred in 2020.

The length frequency distribution of juvenile Dolly Varden in Lower Competition Creek from all sampling years using both fyke nets and minnow traps is presented in Figure 17. There appear to be at least two year-classes (most likely 1+ and 2+) which dominate the catch, and a small number of larger fish (multiple age classes). Length frequency distribution is similar between the two sample periods (2000 through 2002 and 2014 through 2021).

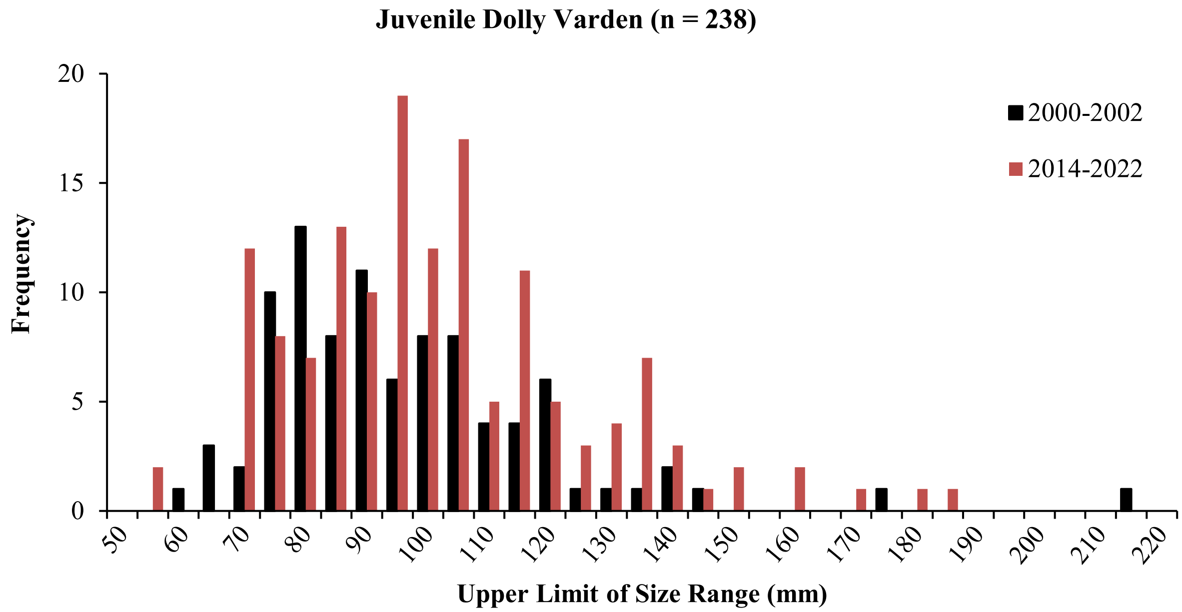

Figure 17. Length frequency distribution of Dolly Varden in Lower Competition Creek.

Juvenile Dolly Varden were retained from Lower Competition Creek from 2015 through 2019 for whole body element concentration (cadmium, lead, selenium, zinc, and mercury). These data were compared with Dolly Varden collected in Mainstem Red Dog (stations 151 and 10) and Anxiety Ridge creeks (Figures 18 through 22) during the same time frame. Cadmium, selenium, and zinc concentrations were similar in Competition and Anxiety Ridge creeks, and higher in Red Dog Creek. Lead was lowest in Competition Creek, highest in Red Dog Creek, and intermediate in Anxiety Ridge Creek (Figure 19). Mercury concentrations were similar in Competition and Red Dog creeks, and slightly higher in Anxiety Ridge Creek (Figure 22).

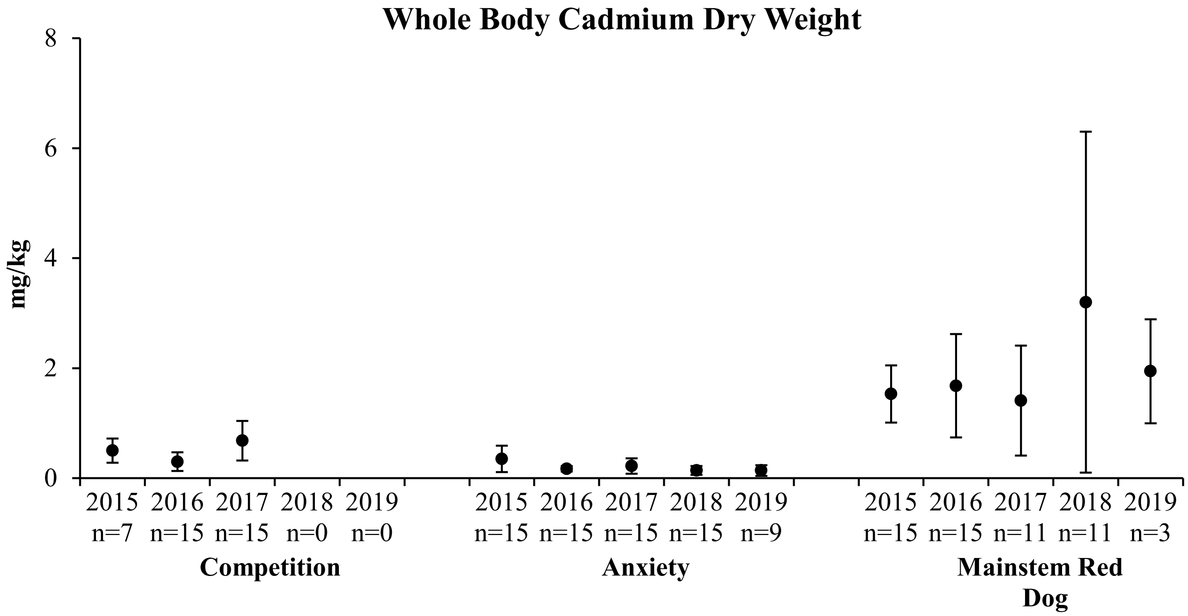

Figure 18. Mean cadmium concentrations (± 1SD) in juvenile Dolly Varden collected from Competition, Anxiety Ridge, and Mainstem Red Dog creeks, 2015–2019.

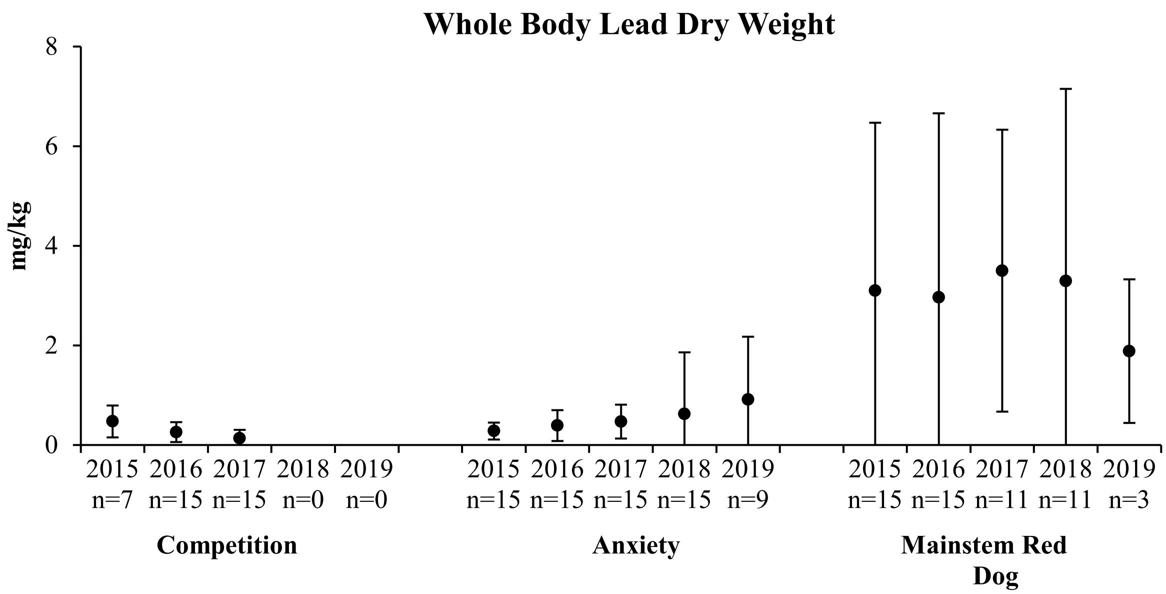

Figure 19. Mean lead concentrations (± 1SD) in juvenile Dolly Varden collected from Competition, Anxiety Ridge, and Mainstem Red Dog creeks, 2015–2019.

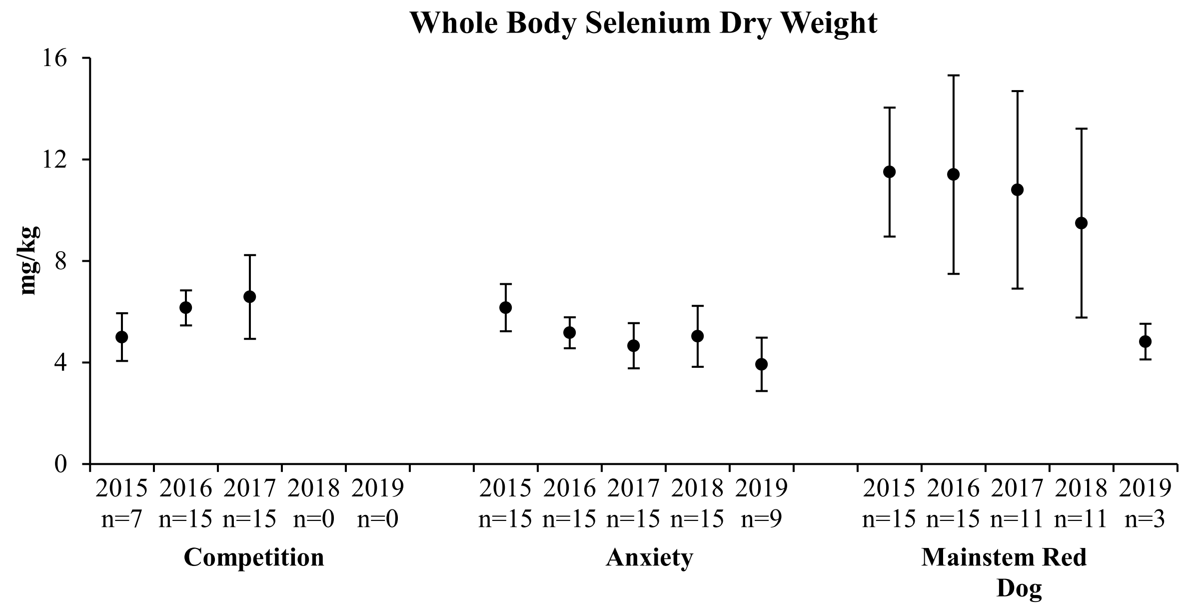

Figure 20. Mean selenium concentrations (± 1SD) in juvenile Dolly Varden collected from Competition, Anxiety Ridge, and Mainstem Red Dog creeks, 2015–2019.

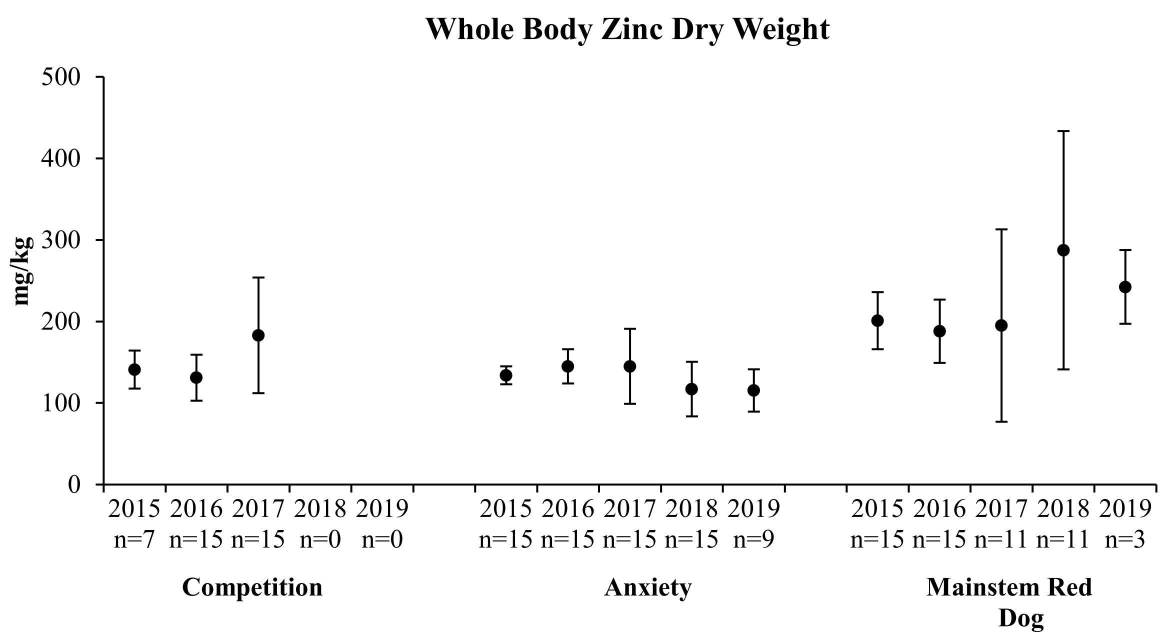

Figure 21. Mean zinc concentrations (± 1SD) in juvenile Dolly Varden collected from Competition, Anxiety Ridge, and Mainstem Red Dog creeks, 2015–2019.

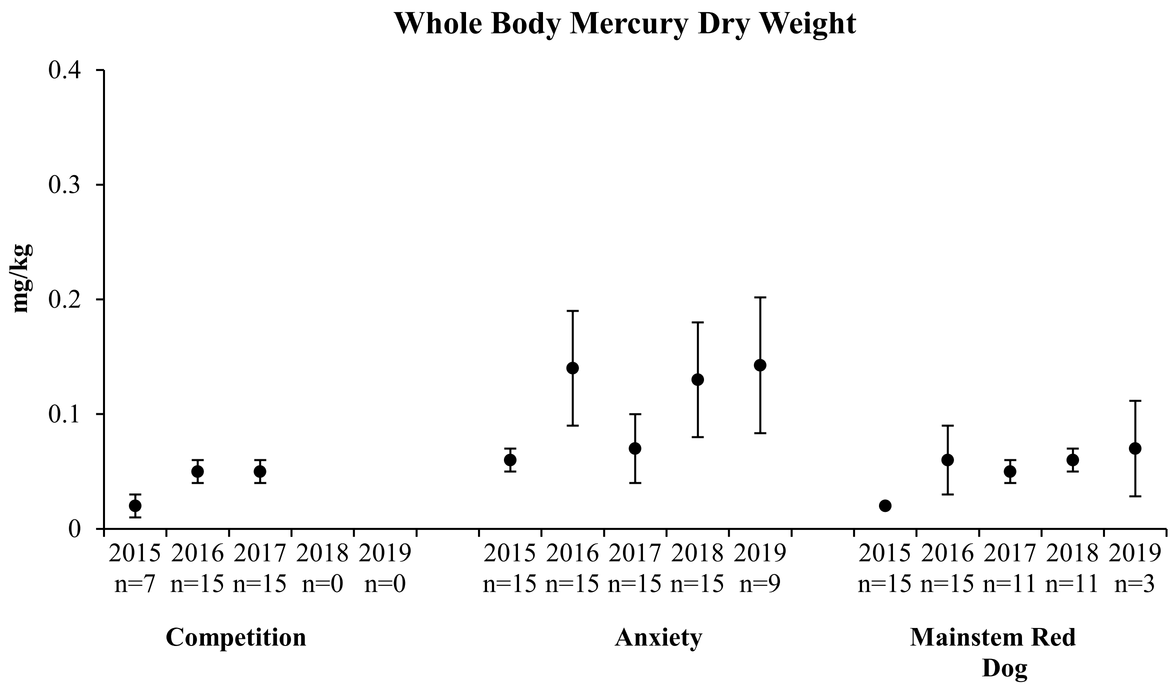

Figure 22. Mean mercury concentrations (± 1SD) in juvenile Dolly Varden collected from Competition, Anxiety Ridge, and Mainstem Red Dog creeks, 2015–2019.

Sediment

Sediment element concentrations in Lower Competition Creek are presented in Table 4.

Concentrations for all metals at this site were above the medians among all sites.

Table 4. Sediment sample element concentrations in Lower Competition Creek, 2022.

Element	Concentration (mg/kg dry weight)	Median Among All Sites (mg/kg dry weight)
Cadmium	3.59	2.59
Copper	222	131
Lead	42.3	22.5
Mercury	0.094	0.071
Selenium	6.00	2.48
Zinc	711	544

West Fork Ikalukrok Creek (Station 205)

Water Quality

From 2000 through 2002, water hardness in West Fork Ikalukrok Creek (Figures 1 and 23) was relatively high. Combined with low alkalinity and higher concentrations of sulfate, this indicated that the system was dominated by calcium sulfate rather than calcium bicarbonate (Weber Scannell and Ott 2006). From 2000 through 2002, the pH in this creek was low and ranged from 4.3 to 6.8. West Fork Ikalukrok Creek had high concentrations of most elements analyzed, especially aluminum, cadmium, copper, nickel, and zinc. Since sampling began in the area, a white precipitate (probably zinc and/or aluminum) has been observed at the mouth of the creek as the waters mix with Ikalukrok Creek (Figure 23). This precipitate was more pronounced since 2020 than in previous years (Figure 23). There was also red staining on the rocks in West Fork Ikalukrok Creek. Water quality data collected by Teck in 2022 is presented in Appendix 2.

Figure 23. West Fork Ikalukrok Creek at the confluence with main stem Ikalukrok Creek in 2015 (left) and 2020 (right). West Fork Ikalukrok enters on the left side of 2015 photo.

Periphyton

In West Fork Ikalukrok Creek, the mean chlorophyll-a concentrations from 2015 through 2022 were generally lower than those found from 2000 through 2002 (Figure 24). Mean chlorophyll-a concentration in 2022 was 0.15 mg/m^2 and varies from a low of 0.04 mg/m^2 in 2018 to a high of 3.45 mg/m^2 in 2002.

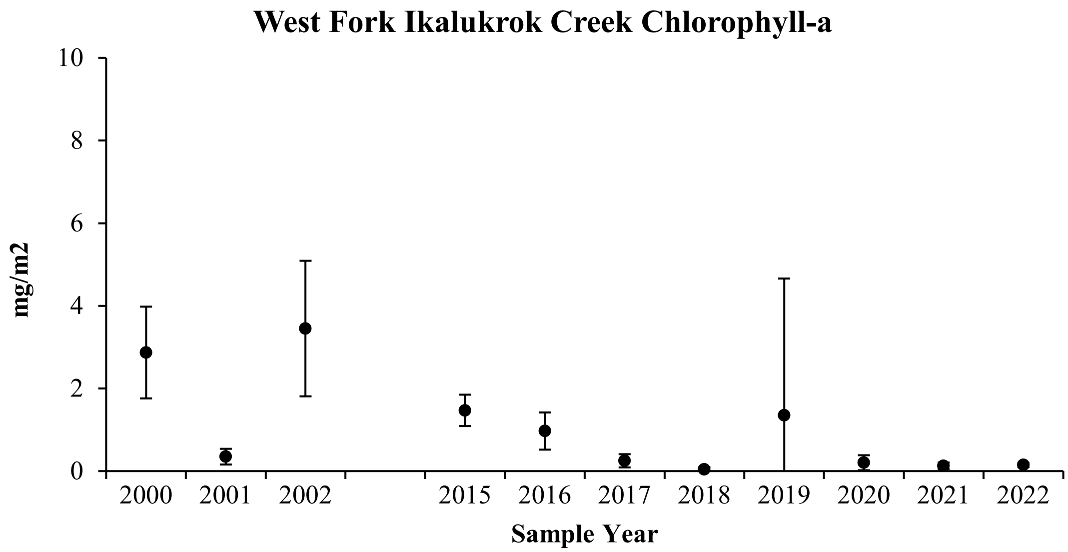

Figure 24. Average concentration of chlorophyll-a (± 1SD) in West Fork Ikalukrok Creek.

Invertebrates

Aquatic invertebrate density in West Fork Ikalukrok Creek was 93.02 aquatic invertebrates/m^2 in 2022. In 2015, the aquatic invertebrate density was very high (27.7 invertebrates/m^3) and was dominated by mayflies. The percent Chironomidae exceeded the EPT in eight of the ten years (Figure 25). Taxa richness previously varied from 15 to 25 taxa, but only four taxa were identified in 2022 (Figure 26).

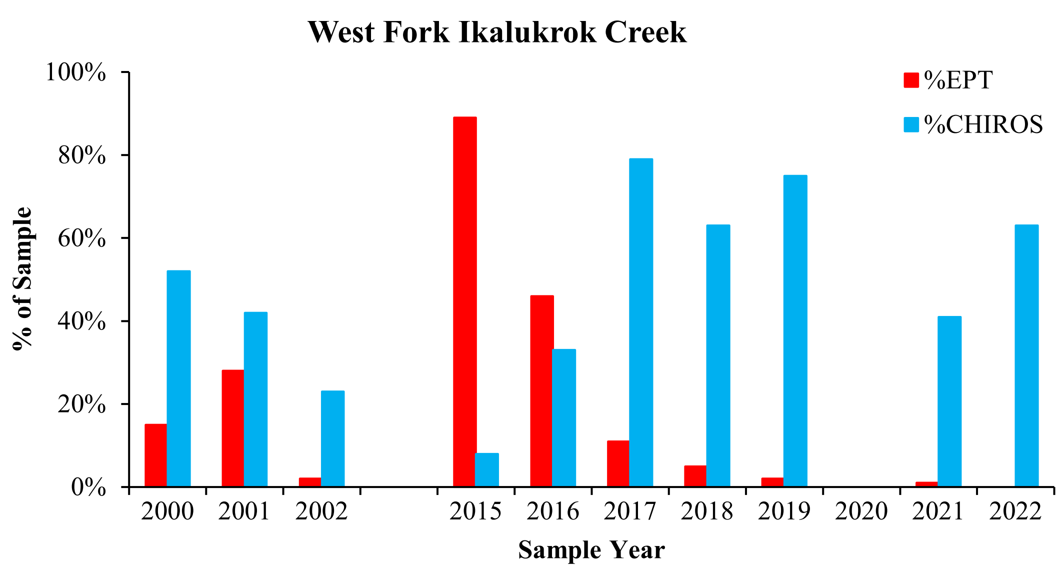

Figure 25. Percent Chironomidae and EPT in West Fork Ikalukrok Creek.

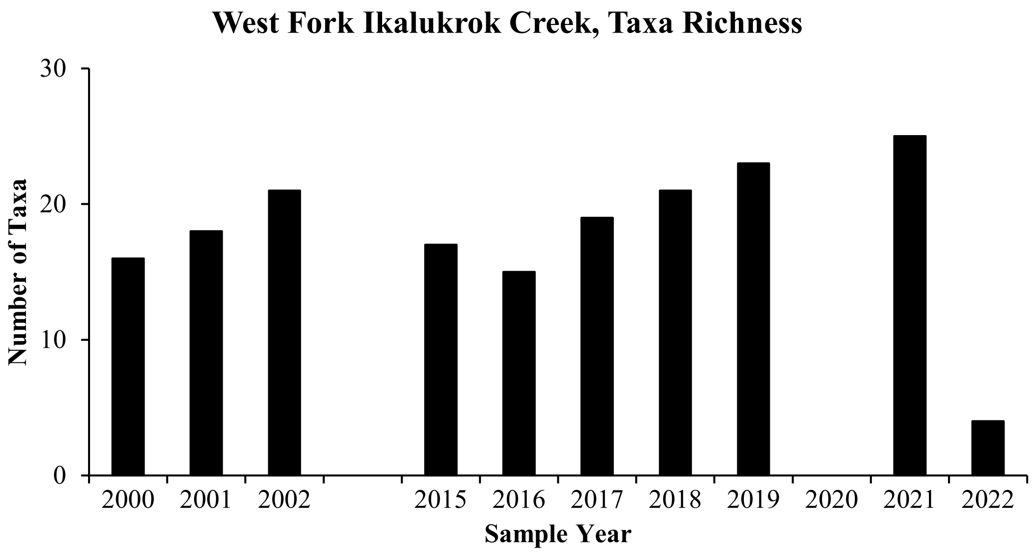

Figure 26. Aquatic invertebrate taxa richness in West Fork Ikalukrok Creek.

Fish

Fish sampling has occurred each sample year using minnow traps. Fish have not been caught or observed in West Fork Ikalukrok Creek. Absence of fish may be due to degraded water quality in Ikalukrok Creek from various seeps, including the Cub Creek seep (located approximately 2 km downriver). These mineral seeps likely form a chemical barrier to fish passage, preventing fish from moving into productive habitats from overwintering areas located downstream.

Mussels

No live mussels, mussel shells from dead animals, or mussel trails in the substrate have been observed to date.

Sediment

Sediment element concentrations in West Fork Ikalukrok Creek are presented in Table 5. Cadmium, lead, mercury, and zinc concentrations were on the low end among all sample sites. Copper concentration was near the median among all sites (median=131 mg/kg) as was selenium concentration (median=2.48 mg/kg).

Table 5. Sediment sample element concentrations in West Fork Ikalukrok Creek, 2022.

Element	Concentration (mg/kg dry weight)	Median Among All Sites (mg/kg dry weight)
Cadmium	0.62	2.59
Copper	159	131
Lead	18.0	22.5
Mercury	0.029	0.071
Selenium	2.45	2.48
Zinc	179	544

Upper Ikalukrok Creek (Station 206)

Water Quality

Upper Ikalukrok Creek (upstream of West Fork Ikalukrok Creek) is a clear water system with decent water quality (Weber Scannell and Ott 2006). From 2000 through 2002, the pH was near neutral and ranged from 6.5 to 8.1. Concentrations of all metals in Upper Ikalukrok Creek are substantially lower than in Ikalukrok Creek downstream of the Cub Creek seep. Typically, Ikalukrok Creek above the West Fork confluence is clear, but in 2020 the water was milky with white and orange staining and precipitate on the rocks (Figure 27). Water clarity was better in both 2021 and 2022, but the orange staining has persisted. Water quality data collected by Teck in 2022 is presented in Appendix 2.

Figure 27. Ikalukrok Creek immediately upstream of West Fork Ikalukrok Creek in 2020 (left) and 2022 (right).

Periphyton

In Upper Ikalukrok Creek average chlorophyll-a concentrations from 2019 through 2022 were very low. Concentrations from 2000 through 2002 and from 2015 through 2018 were higher but variable. Throughout the sample time frame, average chlorophyll-a concentration ranged from a low of 0.03 mg/m^2 in 2020 to a high of 3.48 mg/m^2 in 2002 (Figure 28).

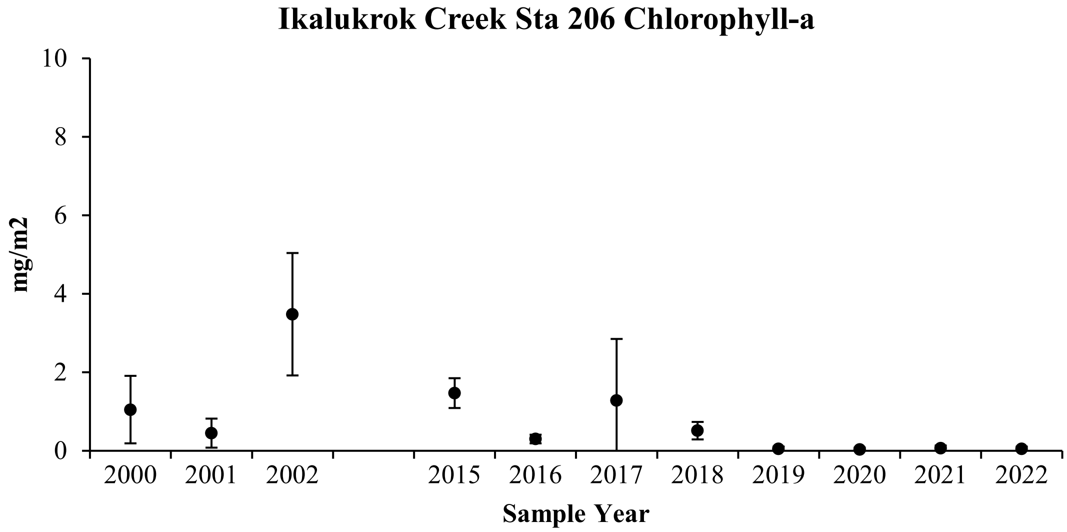

Figure 28. Average concentration of chlorophyll-a (± 1SD) in Upper Ikalukrok Creek.

Invertebrates

The aquatic invertebrate density in Upper Ikalukrok Creek was 1,174 aquatic invertebrates/m^2 in 2022. The percent EPT in two of the ten years of sampling greatly exceeded the chironomids (Figure 29), due to abundant mayflies. Percent Chironomidae exceeded percent EPT for the third year in a row in 2022. Taxa richness previously varied from 13 to 29 taxa but only six taxa were identified in 2022 (Figure 30).

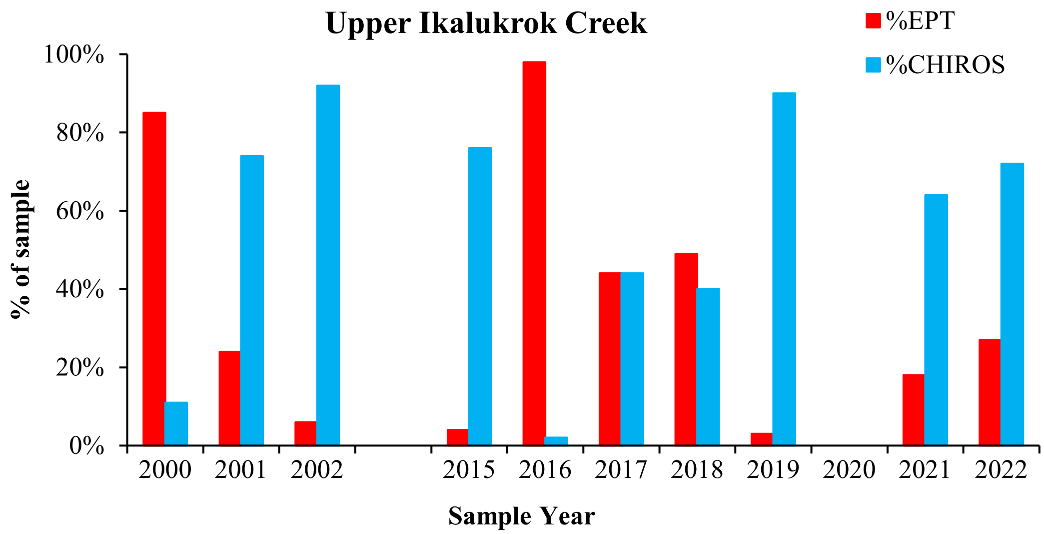

Figure 29. Percent Chironomidae and EPT in Upper Ikalukrok Creek.

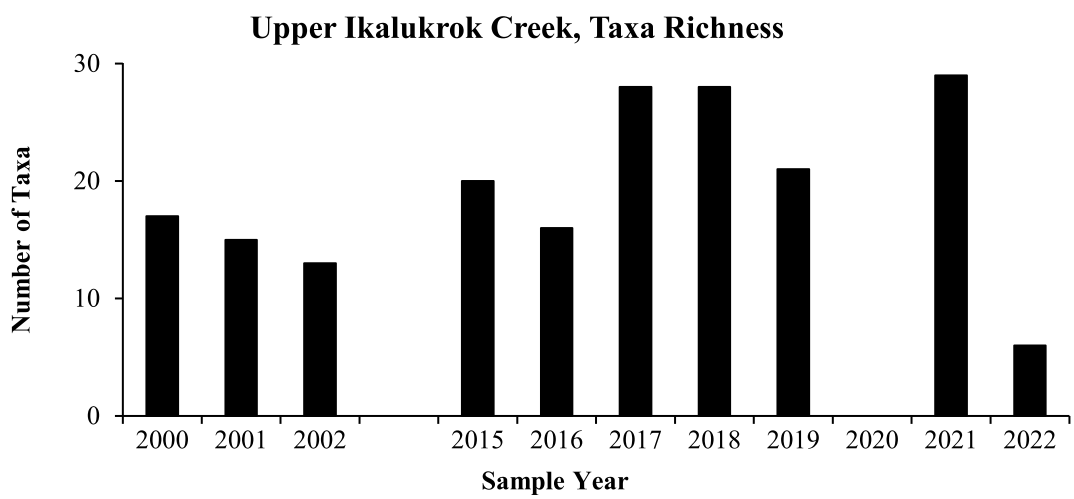

Figure 30. Aquatic invertebrate taxa richness in Upper Ikalukrok Creek.

Fish

Fish sampling has occurred each sample year using minnow traps. Similar to West Fork Ikalukrok Creek, fish have not been caught or observed in Upper Ikalukrok Creek, even though there appears to be high quality fish habitat in the creek. This lack of fish may be due to degraded water quality downstream that likely creates a chemical barrier to fish passage.

Mussels

No live mussels, mussel shells from dead animals, or mussel trails in the substrate have been observed to date.

Sediment

Sediment element concentrations in Upper Ikalukrok Creek are presented in Table 6. Cadmium and zinc concentrations were near the median among all sites. Copper concentration was the second highest value among all sites (201 mg/kg). Lead, mercury, and selenium concentrations were on the low end among all sample sites.

Table 6. Sediment sample element concentrations in Upper Ikalukrok Creek, 2022.

Element	Concentration (mg/kg dry weight)	Median Among All Sites (mg/kg dry weight)
Cadmium	3.25	2.59
Copper	201	131
Lead	13.4	22.5
Mercury	0.038	0.071
Selenium	1.50	2.48
Zinc	595	544

Ikalukrok Creek (Station 207)

Water Quality

Ikalukrok Creek, upstream of East Fork Ikalukrok Creek and downstream of West Fork Ikalukrok Creek, is directly impacted by natural mineral seeps – the most visible being Cub Creek seep, located upstream of this sample site (Weber Scannell and Ott 2006). The pH of water samples from 2005 through 2019 in Cub Creek has ranged from 2.5 to 7.3, with a median value of 3.4 (Napier, 2019 pers comm). Substrate in this section of Ikalukrok Creek is stained red with iron flocculent (Figure 31) and in some years the staining extends downstream for several kilometers. Specific element concentrations in Ikalukrok Creek were high (aluminum, cadmium, copper, iron, nickel, lead, and zinc) and often exceeded the US EPA chronic criteria for aquatic life (Weber Scannell and Ott 2006). The pH was below the range for aquatic life in most of the water samples collected by Teck Alaska from 2005 through 2019. Water quality data collected by Teck in 2022 is presented in Appendix 2.

Figure 31. The Cub Creek seep entering Ikalukrok Creek above the sample site in 2007 (left) and Ikalukrok Creek below Cub Creek seep in 2022 (right).

Periphyton

Chlorophyll-a concentrations have been consistently low since sampling began. Periphyton samples in 2021 had the highest average chlorophyll-a concentrations on record at 0.11 mg/m^2, which is still low (Figure 32). Chlorophyll-a concentration in 2022 was 0.05 mg/m^2 (Figure 32). Most of the samples collected from 1997 through 2002 were below the detection limit. Additional samples were collected in 1997 and 1998 as a part of a Teck Alaska supplemental environmental project (Ott 1997).

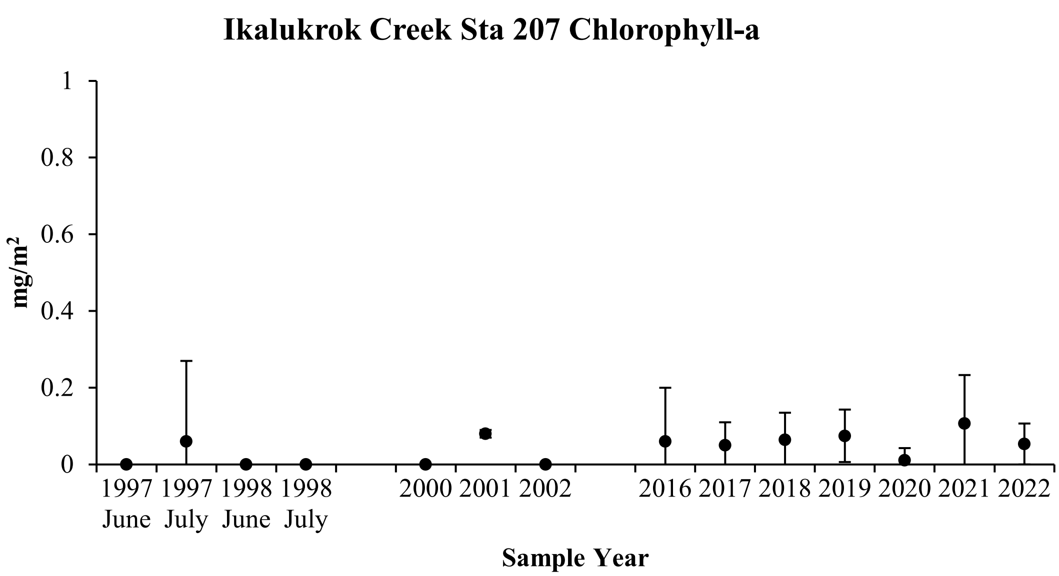

Figure 32. Average concentration of chlorophyll-a (± 1SD) in Ikalukrok Creek downstream of the Cub Creek seep.

Invertebrates

The aquatic invertebrate density Ikalukrok Creek below Cub Creek was 1,500 aquatic invertebrates/m^2 in 2022. During the first period of sampling, the percent chironomids generally exceeded the EPT, except for the July 1998 sample. In 2016 through 2018 percent EPT was higher than chironomids (Figure 33). Since 2019, chironomids have made up over 50% of the sample taxa. Taxa richness has varied from 10 to 29 taxa across all years of data (Figure 34).

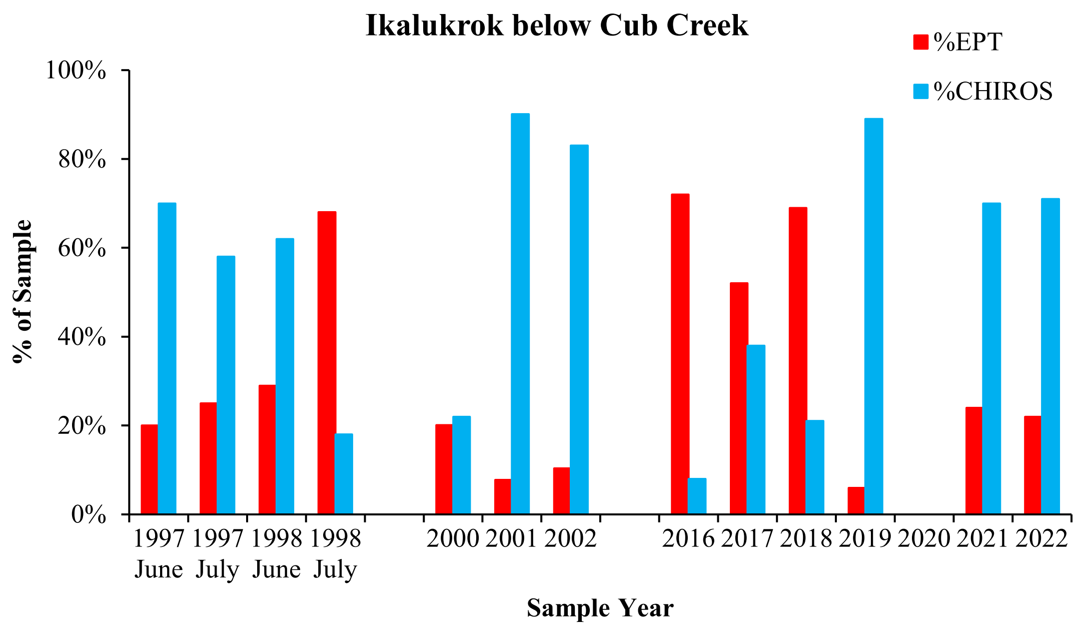

Figure 33. Percent Chironomidae and EPT in Ikalukrok Creek below Cub Creek.

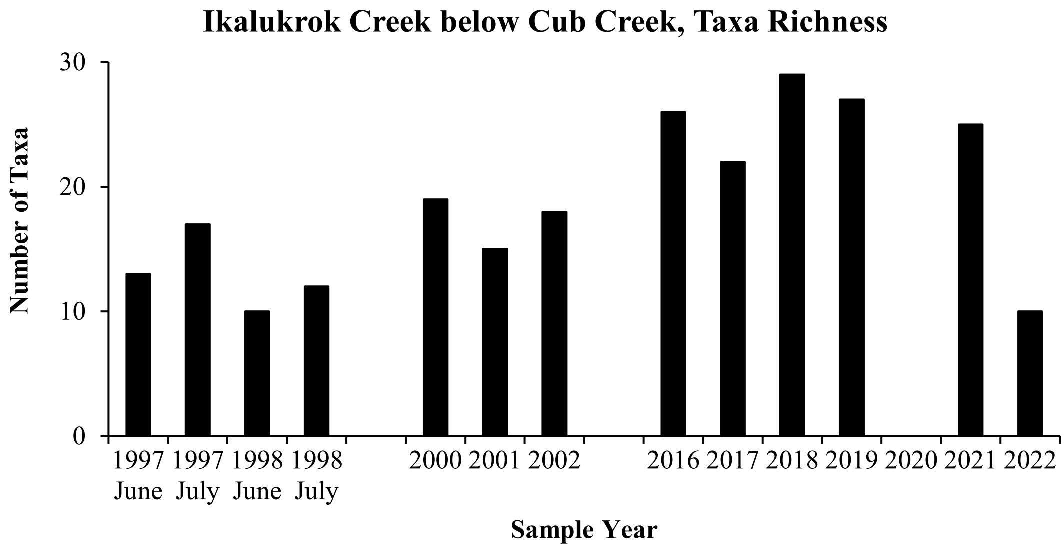

Figure 34. Aquatic invertebrate taxa richness in Ikalukrok Creek below Cub Creek.

Fish

During the 2000 sampling event, one lethargic adult Arctic grayling was observed in Ikalukrok Creek near Station 207 (Weber Scannell and Ott 2006). Since then, no fish have been caught or observed in this section of Ikalukrok Creek, although minnow trapping has not been performed since 2002. Similar to West Fork Ikalukrok and Upper Ikalukrok creeks, it is assumed that the degraded water quality from various seeps is limiting fish movement into high quality habitat particularly in Ikalukrok Creek upstream of West Fork Ikalukrok Creek.

Mussels

No live mussels, mussel shells from dead animals, or mussel trails in the substrate have been observed to date.

Sediment

Sediment element concentrations in Ikalukrok Creek below Cub Creek are presented in Table 7. Cadmium and zinc concentrations were near the median among all sites. Copper concentration was the second highest value among all sites (201 mg/kg). Lead, mercury, and selenium concentrations were on the low end among all sample sites.

Table 7. Sediment sample element concentrations in Ikalukrok Creek (Station 207), 2022.

Element	Concentration (mg/kg dry weight)	Median Among All Sites (mg/kg dry weight)
Cadmium	3.36	2.59
Copper	190	131
Lead	102	22.5
Mercury	0.049	0.071
Selenium	2.0	2.475
Zinc	754	544

East Fork Ikalukrok Creek (Station 208)

Water Quality

East Fork Ikalukrok Creek is a clear water system that joins with Ikalukrok Creek just downstream of the sample site (Figures 1 and 35). Only one spring water sample exceeded acute chronic criteria for cadmium, lead, and zinc (Weber Scannell and Ott 2006). The pH was near neutral and ranged from 6.6 to 8.5 with lower values in early spring during snowmelt. Water has moderately high hardness (median 130 mg/L) and alkalinity (median 117 mg/L), which is typical of a calcium-bicarbonate dominated system (Weber Scannell and Ott 2006). Water quality data collected by Teck in 2022 is presented in Appendix 2. Extensive aufeis occurs in the canyon-like area above the sample site.

Figure 35. Sample site on East Fork Ikalukrok Creek in 2021 (left) and in 2022 (right).

Periphyton

Average chlorophyll-a concentration in 2022 was the highest observed in East Fork Ikalukrok Creek since 2018 at 1.52 mg/ m^2. This is following the lowest concentrations on record in 2021 at 0.47 mg/m^2. East Fork Ikalukrok Creek is generally one of the more highly productive sites in the upper Ikalukrok drainage, although chlorophyll-a concentrations have remained relatively low in recent years compared to a high of 7.36 mg/ m^2 in 2002 (Figure 36).

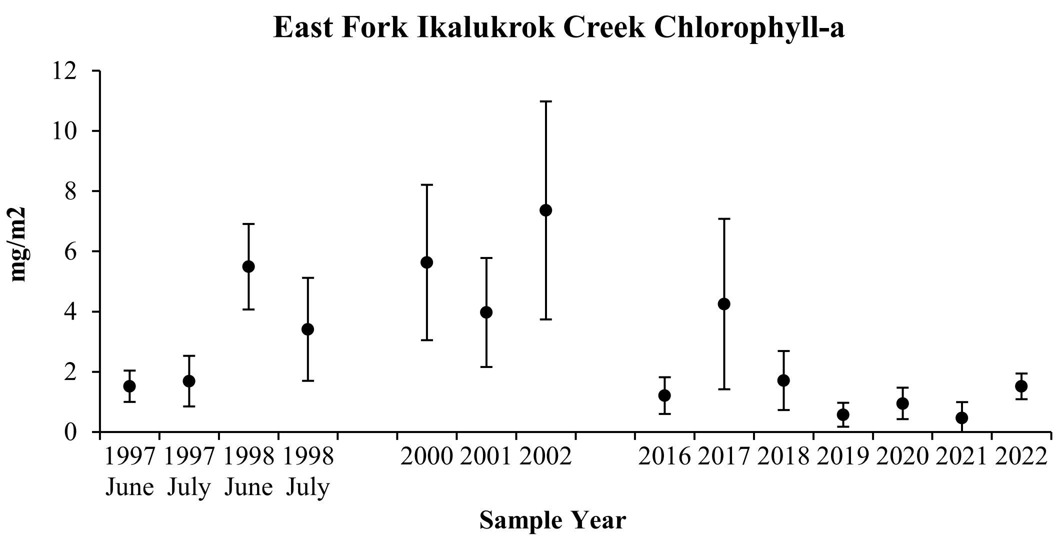

Figure 36. Average concentration of chlorophyll-a (± 1SD) in East Fork Ikalukrok Creek.

Invertebrates

The aquatic invertebrate density in East Fork Ikalukrok Creek was 26,314 aquatic invertebrates/m^2 in 2022. The percent EPT was greater than the percent Chironomidae in 2022 for the first time since 2002 (Figure 37). Taxa richness varied from a low of 13 taxa per site in 2000 to a high of 26 taxa per site in 2019 and 2021 (Figure 38). Taxa richness was 17 in 2022 (Figure 38).

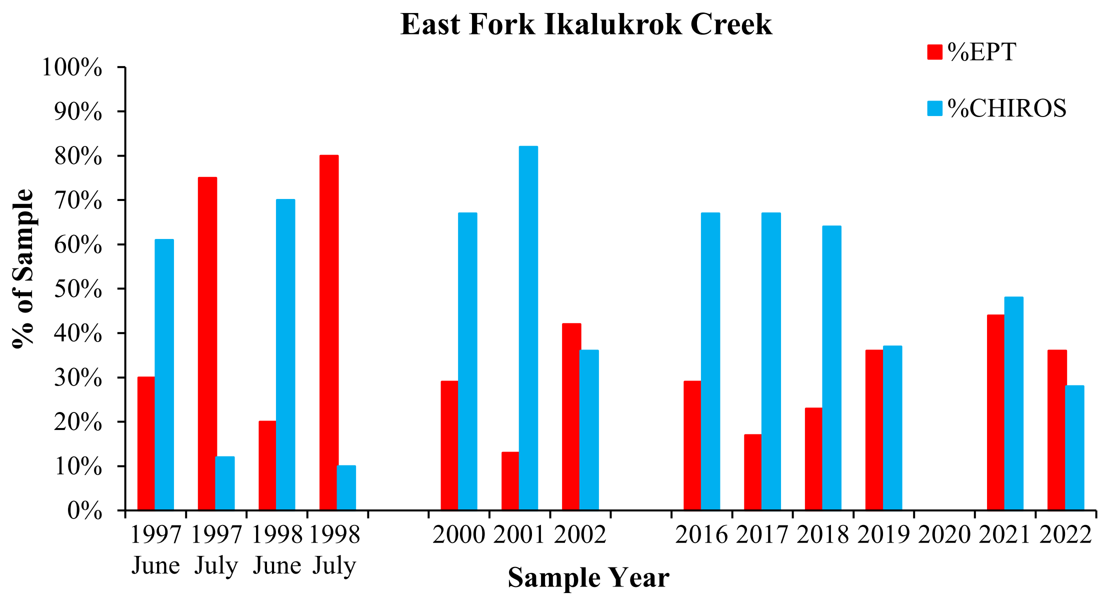

Figure 37. Percent Chironomidae and EPT in East Fork Ikalukrok Creek.

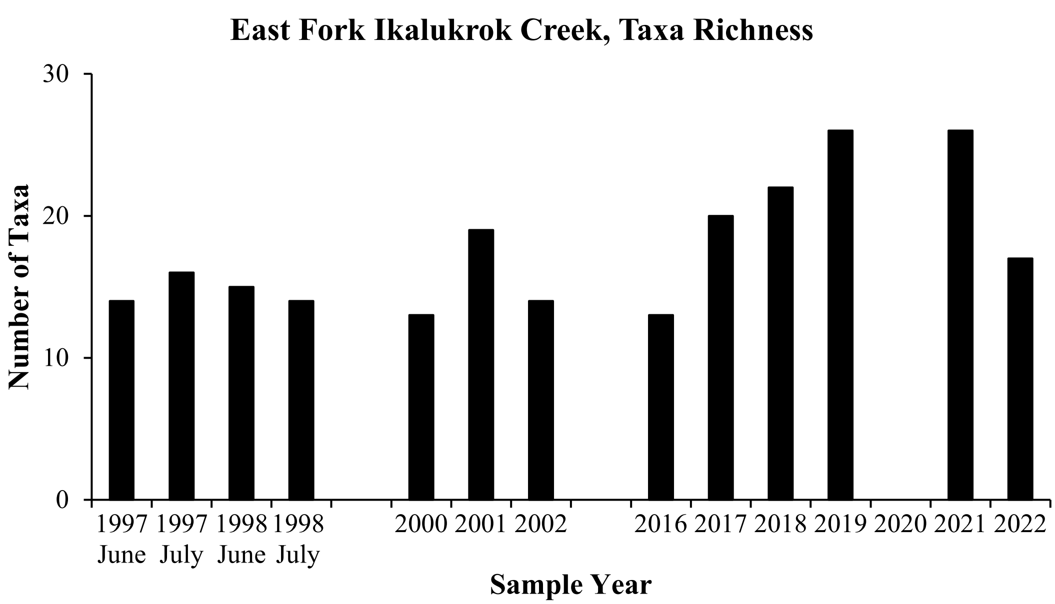

Figure 38. Aquatic invertebrate taxa richness in East Fork Ikalukrok Creek.

Fish

Fish sampling with minnow traps and angling, including visual observations and aerial surveys, has been conducted in East Fork Ikalukrok Creek. Fish sampling with minnow traps was done in East Fork Ikalukrok Creek in 1999, 2000 through 2002 (two sampling events per year), and 2016 through 2022 (Figure 39). There appear to be at least two year-classes (most likely 1+ and 2+)

which dominate the catch, and a small number of larger fish likely made up of multiple age classes (Figure 40). Juvenile Dolly Varden were captured most frequently, but two slimy sculpin (81 and 108 mm) were also caught in 2016. No fish were caught from 2020 through 2022.

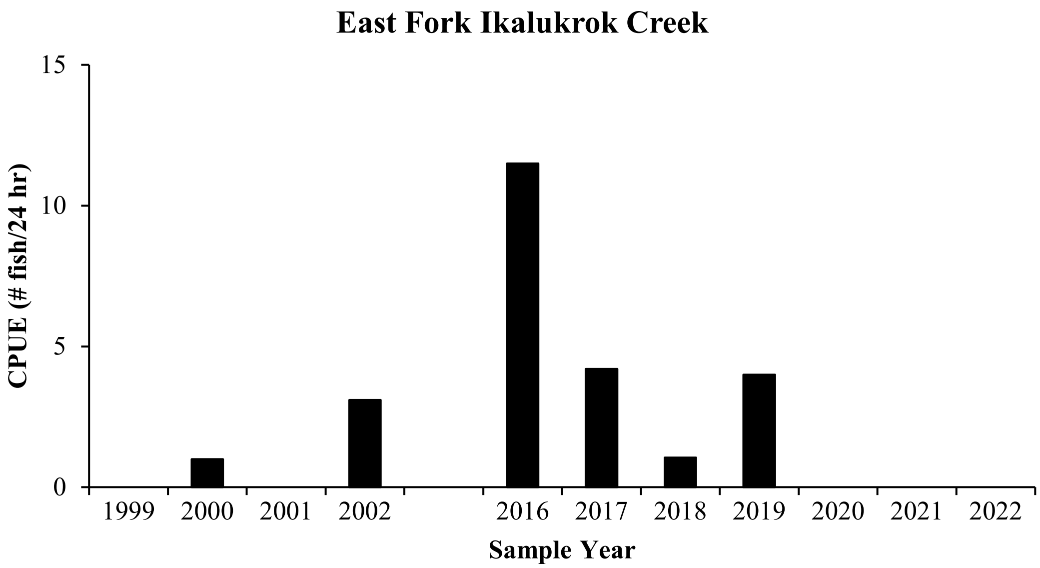

Figure 39. Catch per unit of effort for juvenile Dolly Varden in East Fork Ikalukrok Creek.

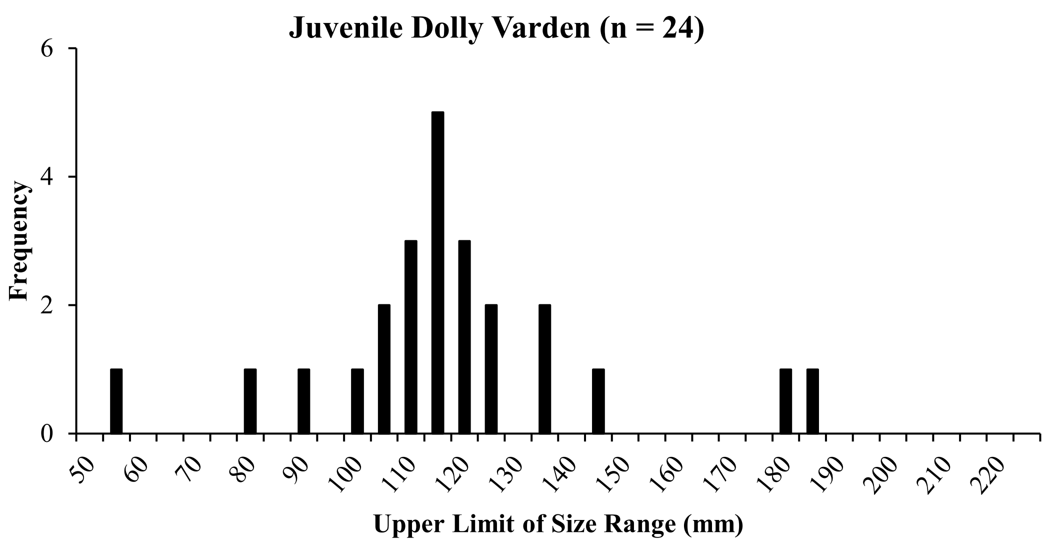

Figure 40. Length frequency distribution of Dolly Varden in East Fork Ikalukrok Creek, all years.

Aerial surveys (helicopter) were conducted opportunistically, and Arctic grayling were sampled by angling (Weber Scannell and Ott 2006). In 1999, 2000, and 2002 several hundred Arctic grayling were observed during aerial surveys in East Fork Ikalukrok Creek. Several Arctic grayling collected by angling in East Fork Ikalukrok Creek during these aerial surveys had been previously tagged in Mainstem Red Dog or North Fork Red Dog creeks.

In spring 2011, 14 adult Arctic grayling in North Fork Red Dog Creek were radio-tagged and tracked for one year. One of the adult Arctic grayling spent part of the summer in East Fork Ikalukrok Creek before moving to overwintering habitat in the Wulik River immediately downstream of Ikalukrok Creek (Ott and Morris 2012 and 2013). Five of the radio-tagged Arctic grayling returned to Mainstem Red Dog and North Fork Red Dog creeks in spring 2012 for spawning.

Mussels

No live mussels, mussel shells from dead animals, or mussel trails in the substrate have been observed to date.

Sediment

Sediment element concentrations in East Fork Ikalukrok Creek are presented in Table 8. Cadmium, copper, and zinc concentrations were on the low end among all sites. Lead, mercury, and selenium concentrations were near the median among all sites.

Table 8. Sediment sample element concentrations in East Fork Ikalukrok Creek, 2022.

Element	**Concentration (mg/kg dry weight)**	**Median Among All Sites (mg/kg dry weight)**
Cadmium	1.19	2.59
Copper	52	131
Lead	35.8	22.5
Mercury	0.089	0.071
Selenium	2.02	2.48
Zinc	211	544

Grayling Junior Creek (Station 209)

Water Quality

Grayling Junior Creek is a clear water system that joins with Ikalukrok Creek just downstream of the sample site (Figures 1 and 41). It is the first major tributary entering Ikalukrok Creek from the east after the East Fork Ikalukrok and Ikalukrok creeks merge. Overall water quality was considered excellent with only a few samples exceeding the US EPA aquatic life criteria for aluminum and iron (Weber Scannell and Ott 2006). The pH was neutral to slightly basic and concentrations of zinc were slightly elevated and ranged from the detection limit to 106 µg/L. In 2020, Grayling Junior Creek was milky throughout the open water season, in marked contrast to the clear waters observed previously. The water was clearer in 2022 than it has been since 2019 (Figure 41). Water quality data collected by Teck in 2022 is presented in Appendix 2.

Figure 41. Grayling Junior Creek in 2020 (left) and 2022 (right).

Periphyton

Chlorophyll-a concentrations in Grayling Junior Creek varied from a low of 0.02 mg/m^2 in 2020 to a high of 4.63 mg/m^2 in 2002 (Figure 42). Chlorophyll-a concentration in 2022 was similar to 2019 concentration and slightly higher than both 2020 and 2021 at 0.17 mg/m^2. Grayling Junior Creek is generally a moderately productive site, although chlorophyll-a has decreased since 2018. The decrease in productivity could be related to the changes in water quality.

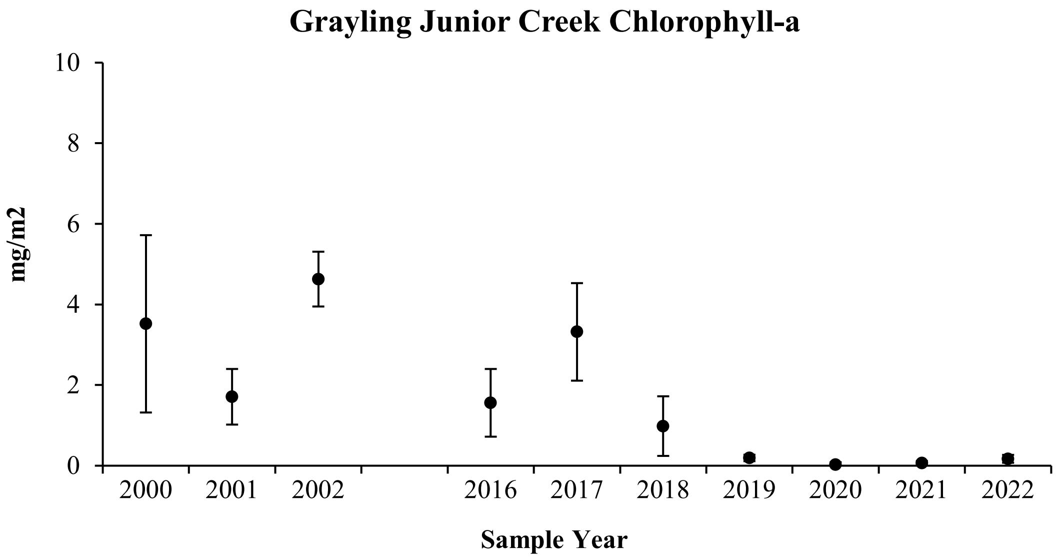

Figure 42. Average concentration of chlorophyll-a (± 1SD) in Grayling Junior Creek.

Invertebrates

The aquatic invertebrate density in Grayling Junior Creek was 47 aquatic invertebrates/m^2 in 2022. In all sample years, the percent chironomids exceeded the percent EPT (Figure 43). Zero EPT were captured in 2022 (Figure 43). Taxa richness previously varied from 10 to 29 taxa but only two taxa were identified in 2022 (Figure 44).

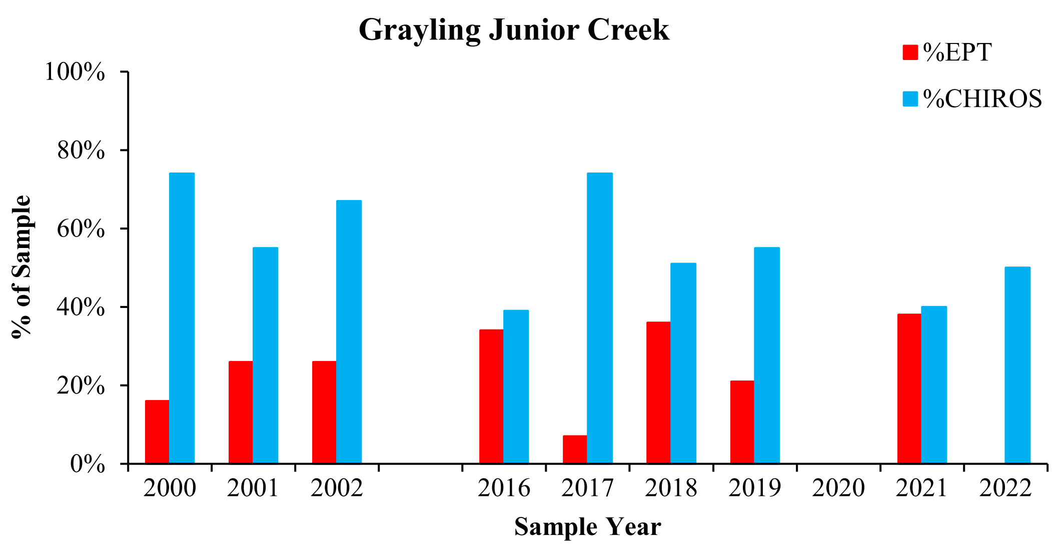

Figure 43. Percent Chironomidae and EPT in Grayling Junior Creek.

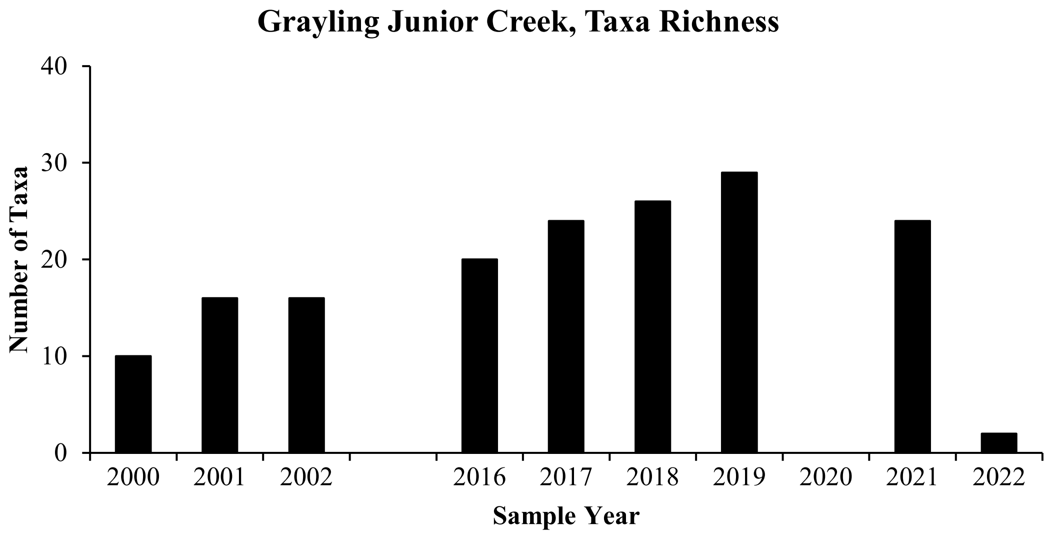

Figure 44. Aquatic invertebrate taxa richness in Grayling Junior Creek.

Fish

Aerial surveys (helicopter) were conducted opportunistically, Arctic grayling were sampled by angling (fish were tagged and recaptures recorded), and juvenile Dolly Varden were sampled with minnow traps (Weber Scannell and Ott 2006). In July 1999, we estimated there were about 300 adult Arctic grayling in Ikalukrok Creek near the mouth of Grayling Junior Creek, but this large aggregation of Arctic grayling has not been observed there since (Figure 45). Mark-recapture sampling indicated that Arctic grayling moved between the Red Dog Creek drainage and Ikalukrok Creek drainage including Grayling Junior Creek.


Figure 45. Arctic grayling at the confluence of Grayling Junior and Ikalukrok creeks, 1999.

Fish were sampled with minnow traps in Grayling Junior Creek from 2000 through 2002, 2004, and 2016 through 2022 (Appendix 3). Dolly Varden juveniles, slimy sculpin, and age-0 Arctic grayling were captured in minnow traps. Age-0 Arctic grayling were captured in late August 2004 indicating that spawning occurred there in spring 2004 (n = 5, 65 to 79 mm long, average 71.2 mm).

The CPUE for Dolly Varden in the minnow traps varied from a low of zero in 2018 to a high of 44 in 2002 (Figure 46). Four Dolly Varden were captured in 2022. Slimy sculpin were also captured periodically in the minnow traps. Length frequency distribution of Dolly Varden is shown in Figure 47. Most of these fish are likely age 1 and 2 with multiple age classes for the larger fish (≥ 120 mm).

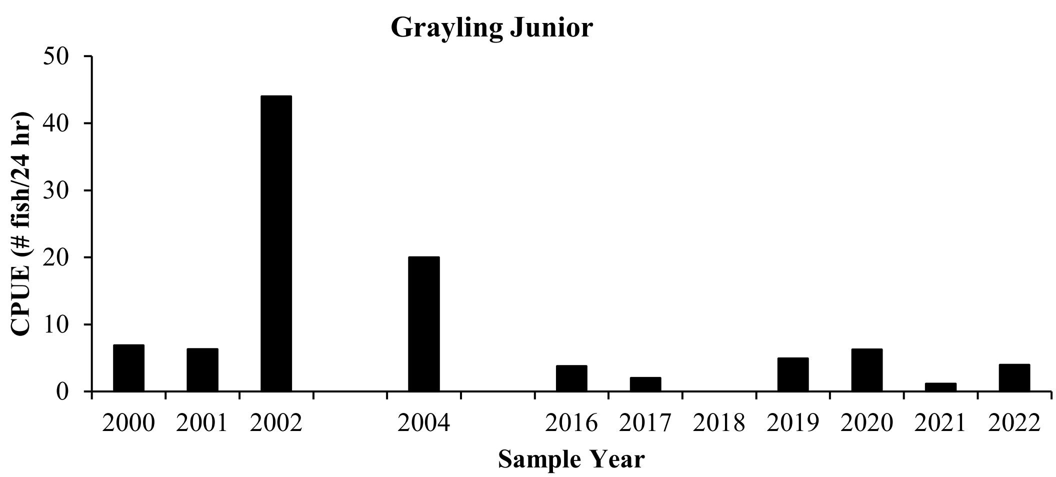

Figure 46. Catch per unit of effort for juvenile Dolly Varden in Grayling Junior Creek.

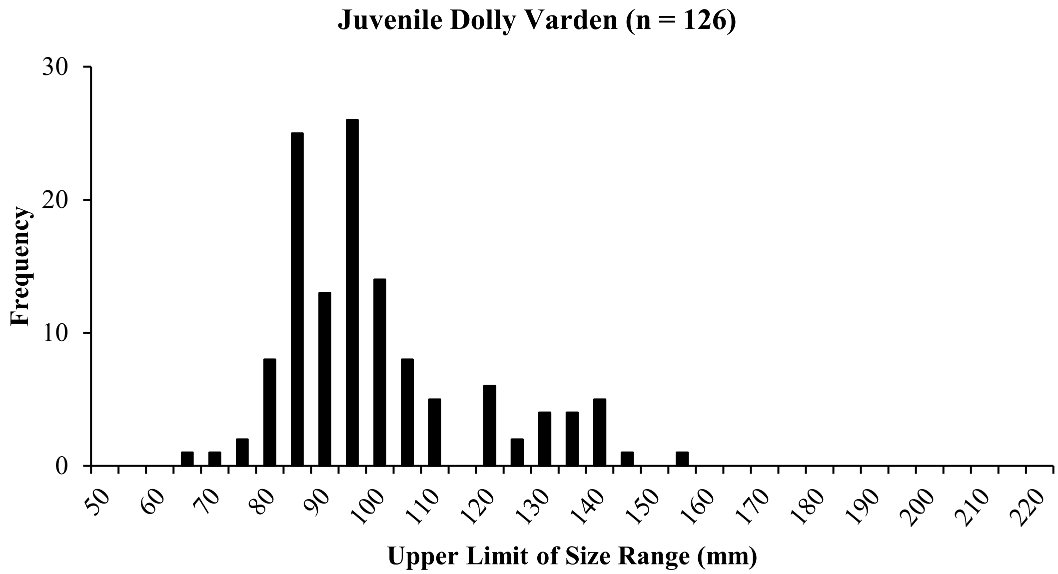

Figure 47. Length frequency distribution of Dolly Varden in Grayling Junior Creek, all years.

In spring 2011, 14 adult Arctic grayling in North Fork Red Dog Creek were radio-tagged and tracked for one year. Two of the adult Arctic grayling spent part of the summer in Grayling Junior Creek. One of the radio-tagged fish in Grayling Junior was still present late in the fall and presumed to be dead (Ott and Morris 2012 and 2013). Five of the radio-tagged Arctic grayling returned to Mainstem Red Dog and North Fork Red Dog creeks in spring 2012 for spawning.

Juvenile Dolly Varden were retained in 2001 and 2004 for whole body element concentration (cadmium, lead, selenium, zinc, and mercury). These data were compared graphically with Dolly Varden collected in Mainstem Red Dog and Anxiety Ridge creeks during the same time frame (Figure 56). The cadmium and lead concentrations were higher in Mainstem Red Dog Creek. The selenium concentrations in whole body Dolly Varden were similar, with the exception of fish from Mainstem Red Dog Creek in 2001, which had higher concentrations. Zinc concentrations were highest in fish from Grayling Junior Creek in 2001, but similar among fish from the three creeks for the remaining samples. Mercury concentrations were similar from all three creeks with concentrations near the detection limit.

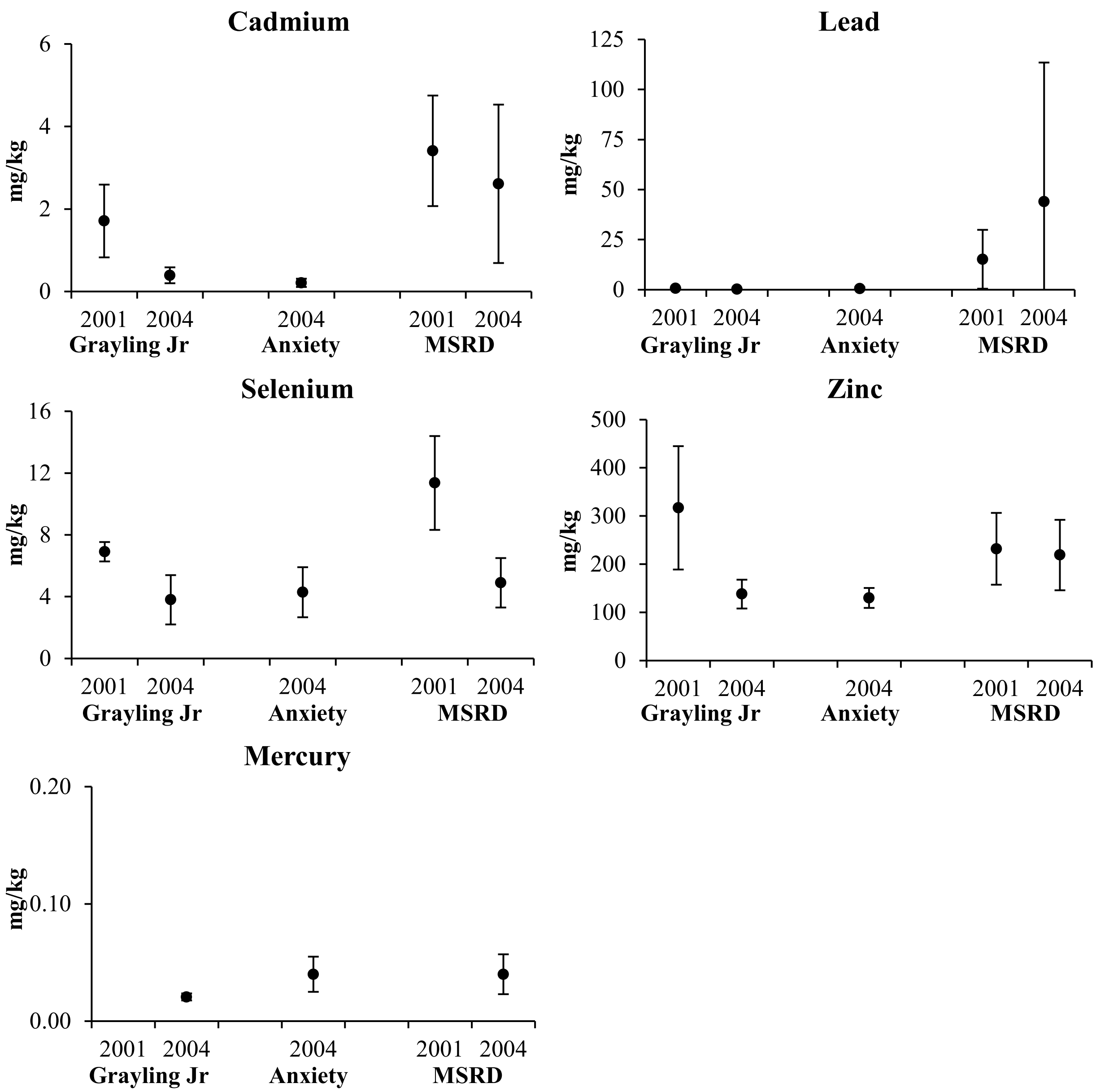

Figure 48. Average dry weight whole body element concentrations (± 1SD) in juvenile Dolly Varden collected from Grayling Junior, Anxiety Ridge, and Mainstem Red Dog (MSRD) creeks, note that samples were not tested for mercury in 2001. Fish catches in 2001 in Anxiety Ridge Creek were very low, and no fish in the appropriate size range for element analysis were captured.

Mussels

No live mussels, mussel shells from dead animals, or mussel trails in the substrate have been observed to date.

Sediment

Sediment element concentrations in Grayling Junior Creek are presented in Table 9. Cadmium and zinc concentrations were the second highest recorded among all sites. Copper and lead concentrations were below the median among all sites, while mercury and selenium concentrations were above the median among all sites.

Table 9. Sediment sample element concentrations in Grayling Junior Creek, 2022.

Element	Concentration (mg/kg dry weight)	Median Among All Sites (mg/kg dry weight)
Cadmium	9.74	2.59
Copper	116	131
Lead	17.1	22.5
Mercury	0.083	0.071
Selenium	3.60	2.48
Zinc	1640	544

Noa Creek (Station 210)

Water Quality

Noa Creek, a tributary to Ikalukrok Creek, has degraded water quality with 95% of water samples exceeding the chronic aquatic life criteria for aluminum and cadmium, 90% exceeding the nickel and zinc criteria, and 76% have a pH below the water quality criteria for aquatic life (Weber Scannell and Ott, 2006). Noa Creek is small, incised, and has dense riparian vegetation (Figure 49). This site was not sampled in 2020.

Figure 49. The sample site on Noa Creek just upstream of the mouth in 2021 (left) and the confluence Noa Creek and Ikalukrok Creek in 2022 (right).

Periphyton

Prior to 2020, the average chlorophyll-a concentrations in Noa Creek were consistently low, ranging from 0.075 mg/m^2 in 2019 to 0.32 mg/m^2 in 2000 (Figure 50). However, 2021 and 2022 were the two highest concentrations on record for this creek.

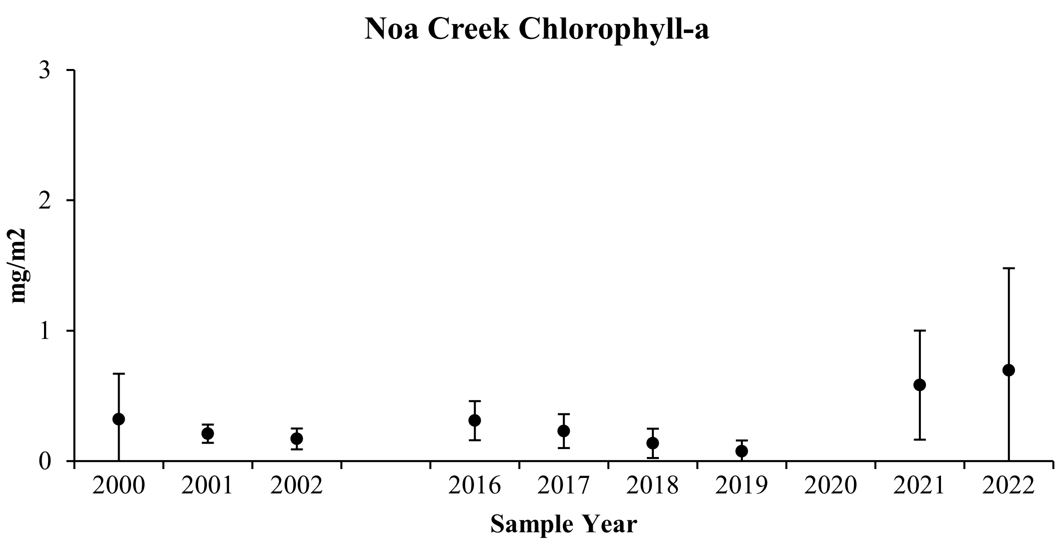

Figure 50. Average concentration of chlorophyll-a (± 1SD) in Noa Creek.

Invertebrates

The aquatic invertebrate density in Noa Creek was 70 aquatic invertebrates/m^2 in 2022. EPT were virtually absent from the samples until 2022 when Chironomidae and EPT each made up 17% of the sample (Figure 51). Taxa richness previously varied from 15 to 23 taxa but only four taxa were identified in 2022 (Figure 52).

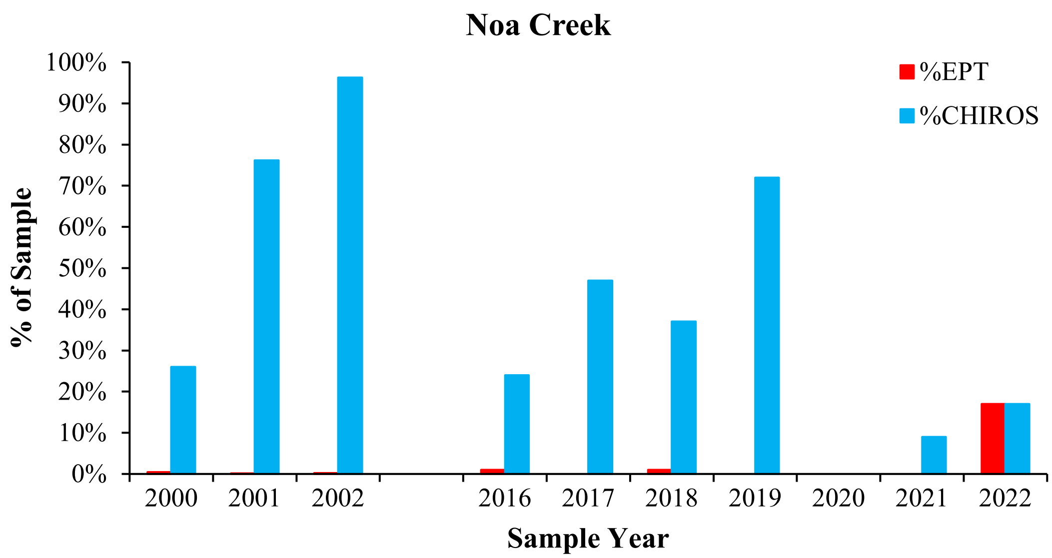

Figure 51. Percent Chironomidae and EPT in Noa Creek.

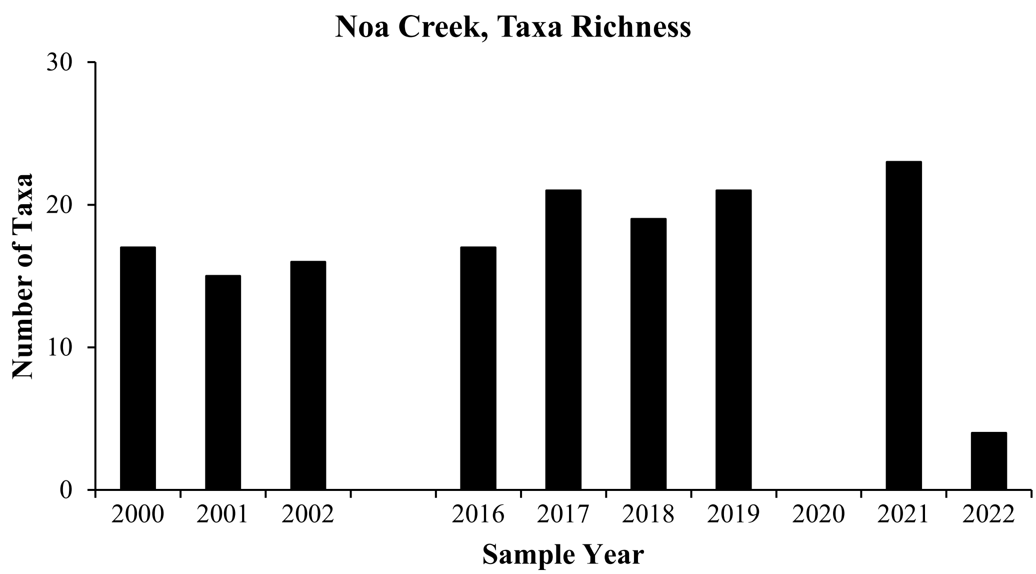

Figure 52. Aquatic invertebrate taxa richness in Noa Creek.

Fish

Fish sampling with minnow traps and visual observations was conducted in Noa Creek from 2000 through 2002 (two sampling days in 2000 and 2001 and one in 2002). Zero fish were caught and none were seen. Fish sampling has not occurred since the early 2000's. Noa Creek is connected by surface flow to Ikalukrok Creek, so fish do have access to the creek during the ice-free months.

Sediment

Sediment element concentrations in Noa Creek are presented in Table 10. Concentrations of all metals at this site were below the median among all sites. Cadmium and lead concentrations were the lowest recorded of all sites. Selenium concentration was also the lowest among all sites but the same value as Ikalukrok Creek upstream of West Fork Ikalukrok Creek (1.5 mg/kg).

Table 10. Sediment sample element concentrations in Noa Creek, 2022.

Element	Concentration (mg/kg dry weight)	Median Among All Sites (mg/kg dry weight)
Cadmium	0.45	2.59
Copper	112	131
Lead	13.2	22.5
Mercury	0.036	0.071
Selenium	1.50	2.48
Zinc	316	544

Moil Creek (Station 211)

Water Quality

Moil Creek, a tributary to Ikalukrok Creek, has degraded water quality with 95% of water samples exceeding the chronic aquatic life criteria for cadmium, copper, nickel, and zinc and 65% have a pH below the chronic criteria. Metals concentrations are high, especially copper, iron, aluminum, and zinc (Weber Scannell and Ott, 2006). Moil Creek is small with summer discharges typically ranging from three to five cfs (Figure 53). This site was not sampled in 2020. Water quality data collected by Teck in 2022 are presented in Appendix 2.

Figure 53. The mouth of Moil Creek on Ikalukrok Creek in 2021 (left) and the sample site in July 2022 (right).

Periphyton

Average chlorophyll-a concentrations in Moil Creek were low across all years, ranging from 0 mg/m^2 in 2002 to a high of 0.14 mg/m^2 in 2017 (Figure 54). Chlorophyll-a concentration was 0.06 mg/m^2 in 2022.

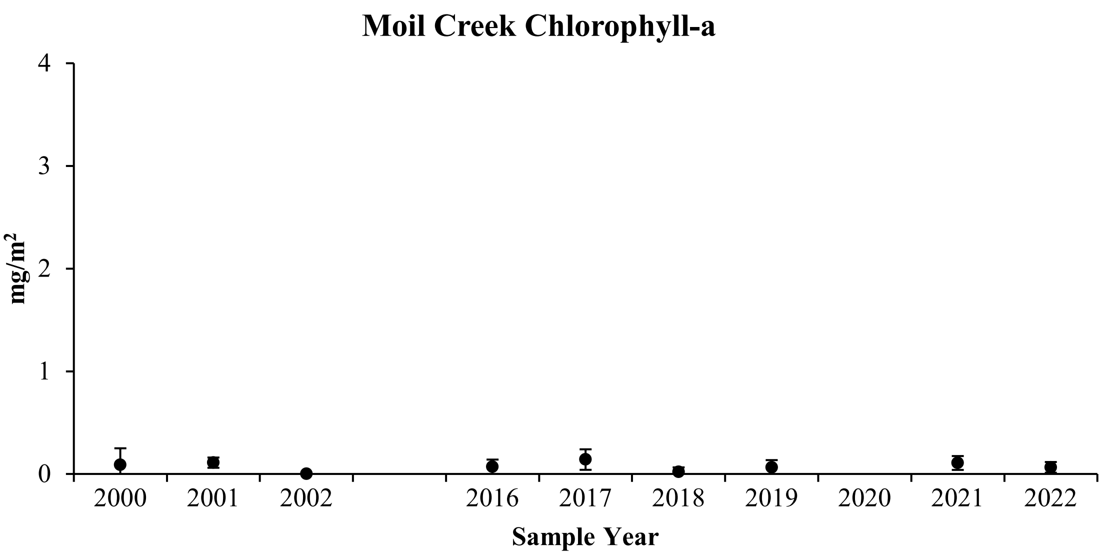

Figure 54. Average concentration of chlorophyll-a (± 1SD) in Moil Creek.

Invertebrates

The aquatic invertebrate density in Moil Creek was 12 aquatic invertebrates/m^2 in 2022. EPT were absent or made up a small percentage of the samples in all years (Figure 55). Only one individual aquatic invertebrate was in the sample in 2022. Taxa richness previously varied from 13 to 24 taxa but only one taxon (Collembola) was identified in 2022 (Figure 56).

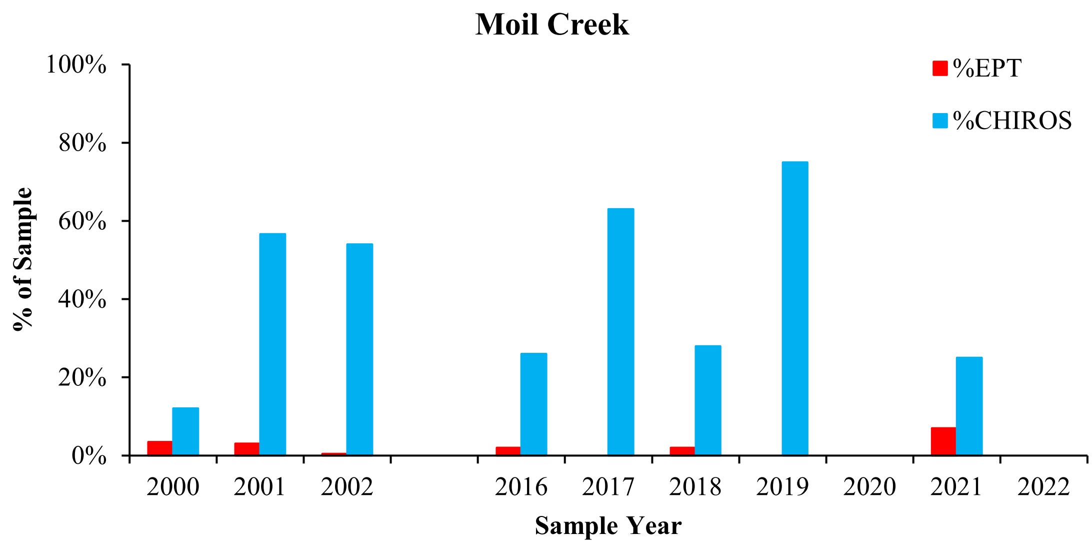

Figure 55. Percent Chironomidae and EPT in Moil Creek.

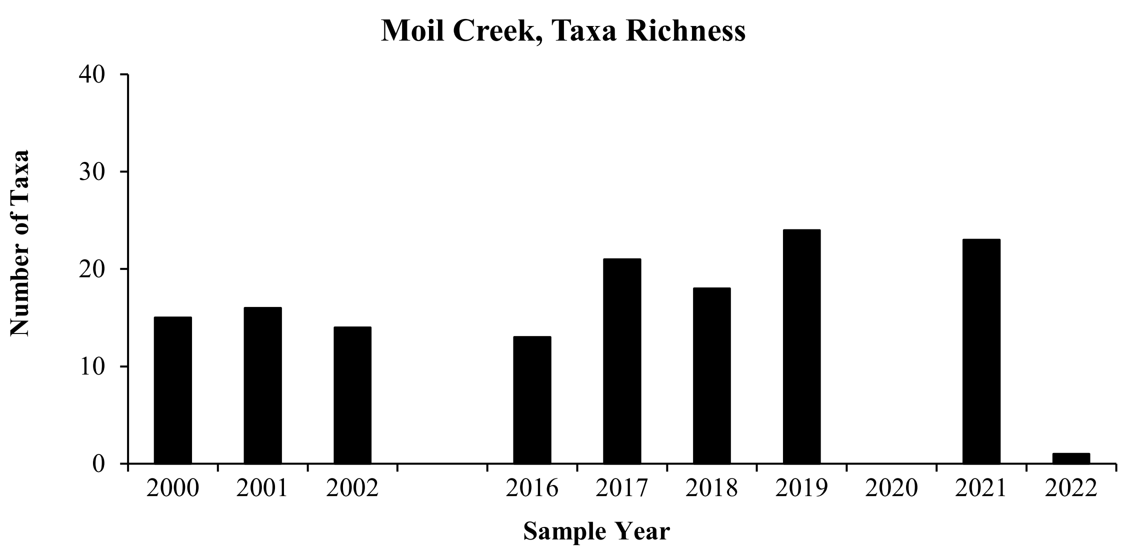

Figure 56. Aquatic invertebrate taxa richness in Moil Creek.

Fish

Fish sampling with minnow traps, including visual observations, was conducted in Moil Creek from 2000 through 2002 (two sampling days in 2000 and 2001 and one in 2002). No fish were caught and none were seen. Fish sampling has not occurred since the early 2000's. Moil Creek is connected by surface flow to Ikalukrok Creek, so fish have access to the creek during the ice-free months. In some years, large adult Arctic grayling have been seen in Ikalukrok Creek near the mouth of Moil Creek but have not been observed entering Moil Creek.

Sediment

Sediment element concentrations in Moil Creek are presented in Table 11. Cadmium, copper, lead, and zinc concentrations were below the median among all sites. Copper concentration was the lowest recorded of all sites. Mercury concentration was near the median while selenium concentration was well above the median and the highest recorded of all sites.

Table 11. Sediment sample element concentrations in Moil Creek, 2022.

Element	Mean Concentration (mg/kg dry weight)	Median Among All Sites (mg/kg dry weight)
Cadmium	0.63	2.59
Copper	51	131
Lead	19.5	22.5
Mercury	0.077	0.071
Selenium	9.70	2.48
Zinc	164	544

Sled Creek (Station 212)

Water Quality

Sled Creek, a tributary to Ikalukrok Creek, does not have a surface flow connection with Ikalukrok Creek. Overall, there was excellent water quality with only two samples exceeding the aquatic life criterion for aluminum and one sample exceeding the criteria for cadmium, copper, and zinc (Weber Scannell and Ott, 2006). Dense riparian vegetation is found throughout the sample reach (Figure 57).

 

Figure 57. Sled Creek in July 2021 (left) and upstream in July 2022 (right).

Periphyton

Average chlorophyll-a concentrations in Sled Creek were relatively high ranging from 1.85 mg/m^2 in 2002 to 6.96 mg/m^2 in 2019 (Figure 58). Chlorophyll-a concentration was 3.30 mg/m^2 in 2022.

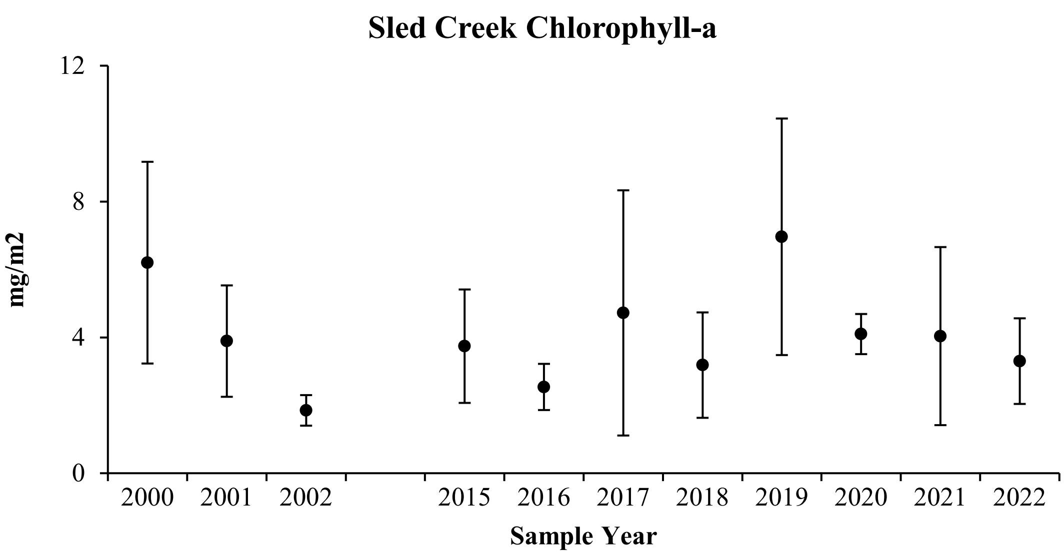

Figure 58. Average concentration of chlorophyll-a (± 1SD) in Sled Creek.

Invertebrates

The aquatic invertebrate density in Sled Creek was 37,779 aquatic invertebrates/m^2 in 2022. EPT were present in all sample years and thrice exceeded the percent Chironomidae, including in 2022 (Figure 59). In 2022, the percent EPT was greater than percent Chironomidae for the first time since 2015. The EPT in all years was composed of mayflies and stoneflies. Taxa richness varied from 10 to 29 over the sample years (Figure 60).

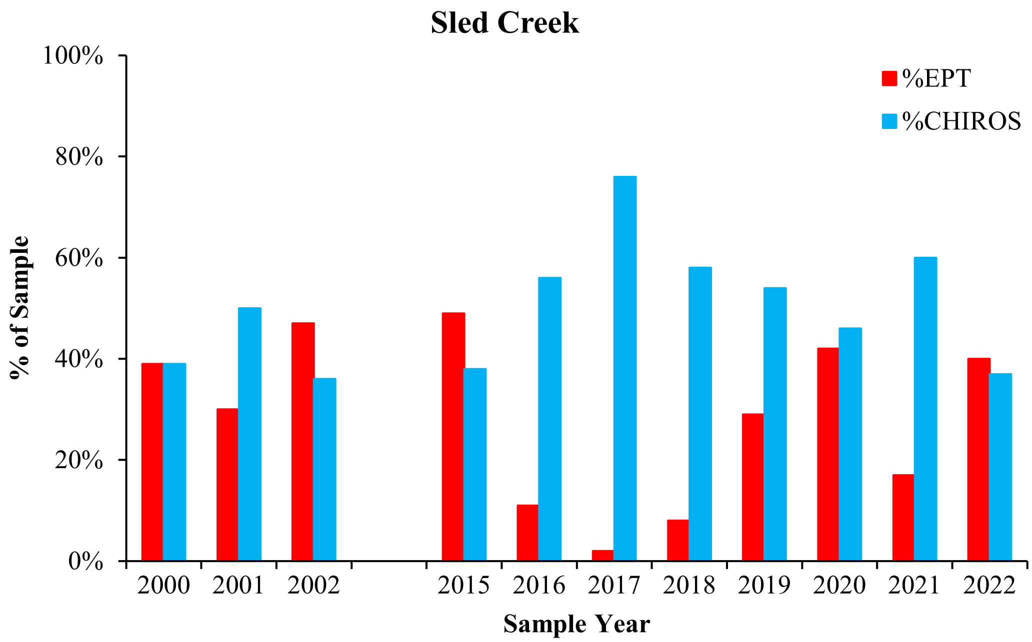

Figure 59. Percent Chironomidae and EPT in Sled Creek.

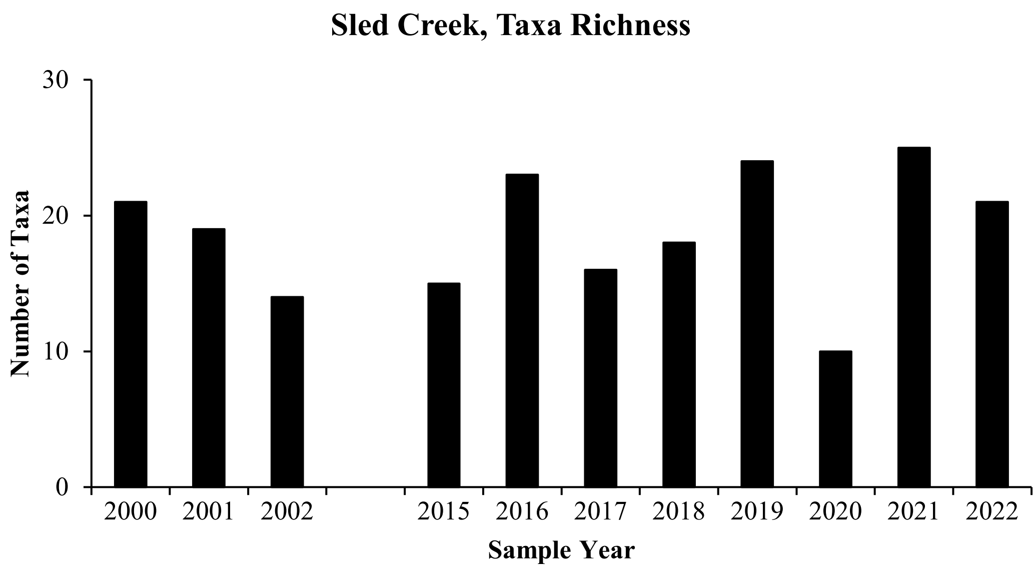

Figure 60. Aquatic invertebrate taxa richness in Sled Creek.

Fish

Fish sampling with minnow traps and visual observations was conducted in Sled Creek from 2000 through 2002 (two sampling days in 2000 and 2001 and one in 2002) and again in 2015. No fish were caught, and none were seen. Fish sampling has not occurred since. Fish do not have access to the creek because it is not connected by surface flow to Ikalukrok Creek during the ice-free season.

Sediment

Sediment element concentrations in Sled Creek are presented in Table 12. Cadmium, copper, mercury, and zinc concentrations were below the median among all sites. Mercury concentration was the lowest recorded of all sites. Lead concentration was above the median while selenium concentration was very near the median.

Table 12. Sediment sample element concentrations in Sled Creek, 2022.

Element	Concentration (mg/kg dry weight)	Median Among All Sites (mg/kg dry weight)
Cadmium	1.03	2.59
Copper	51	131
Lead	25.5	22.5
Mercury	0.065	0.071
Selenium	2.50	2.48
Zinc	249	544

Volcano Creek

Water Quality

Volcano Creek was not sampled from 2000 through 2002 but was sampled from 2014 through 2022. Visual observations and biological data collected indicate that Volcano Creek is a productive aquatic system (Figure 71).

Figure 61. Volcano Creek downstream in July 2021 (left) and lateral view in August 2022 (right).

Periphyton

Average chlorophyll-a concentrations were high in Volcano Creek ranging from a low of 0.32 mg/m^2 in 2021 to a high of 6.32 mg/m^2 in 2014 (Figure 62). Chlorophyll-a concentrations in Volcano Creek were consistent from 2014 to 2017, then decreased from 2018 to 2021. In 2022 chlorophyll-a concentration was greater than the previous two years at 1.40 mg/m^2.

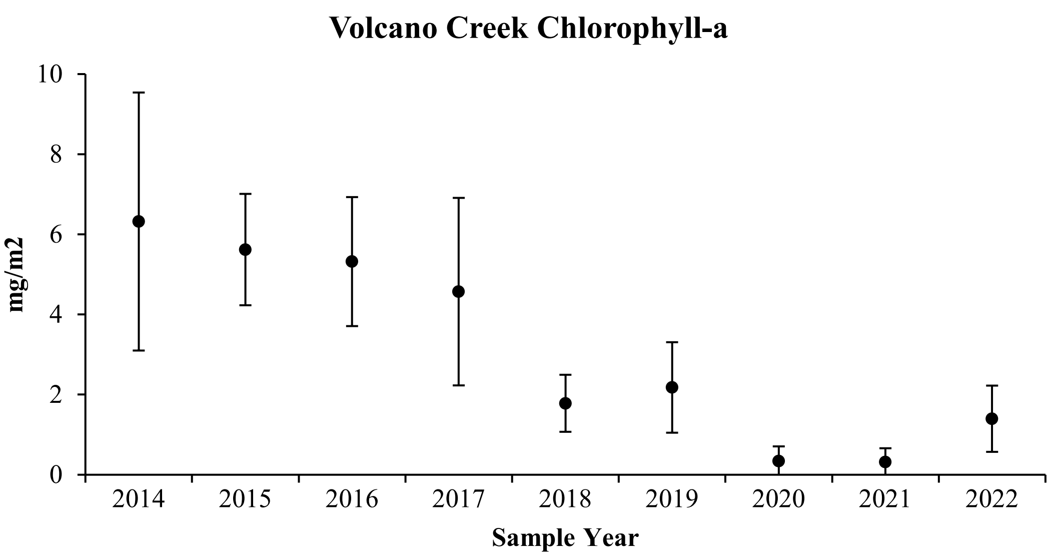

Figure 62. Average concentration of chlorophyll-a (± 1SD) in Volcano Creek.

Invertebrates

The aquatic invertebrate density in Volcano Creek was 12,046 aquatic invertebrates/m^2 in 2022. The percent EPT was the highest on record in 2022 at 40%, but Chironomidae did make up 55% of the sample (Figure 63). EPT were present in all sample years with mayflies and stoneflies represented, but percent Chironomidae exceeded percent EPT in all years (Figure 63). Taxa richness varied from a low of 11 in 2022 to a high of 25 in 2017 (Figure 64).

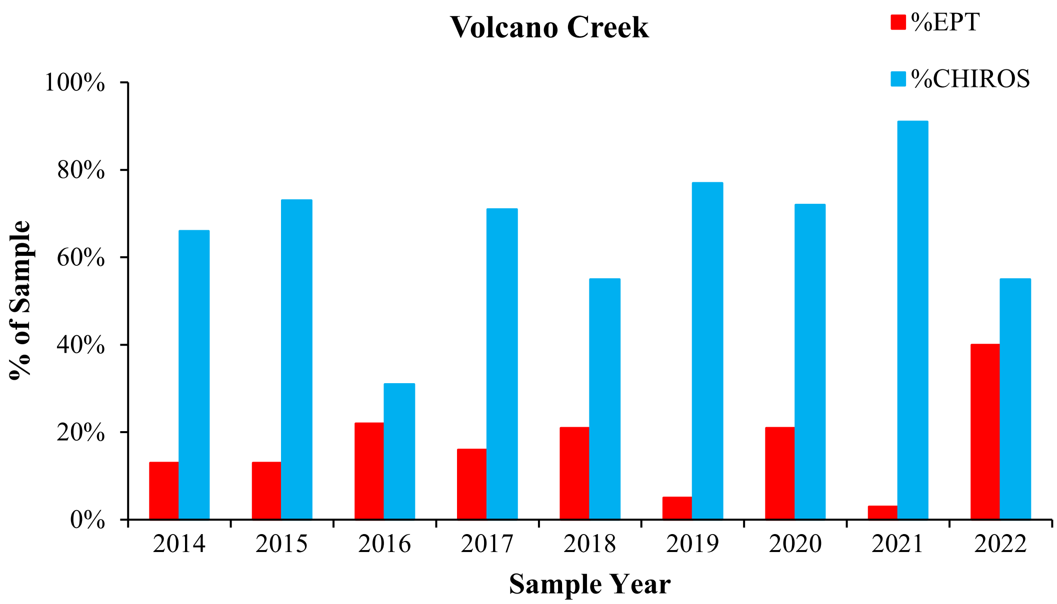

Figure 63. Percent Chironomidae and EPT in Volcano Creek.

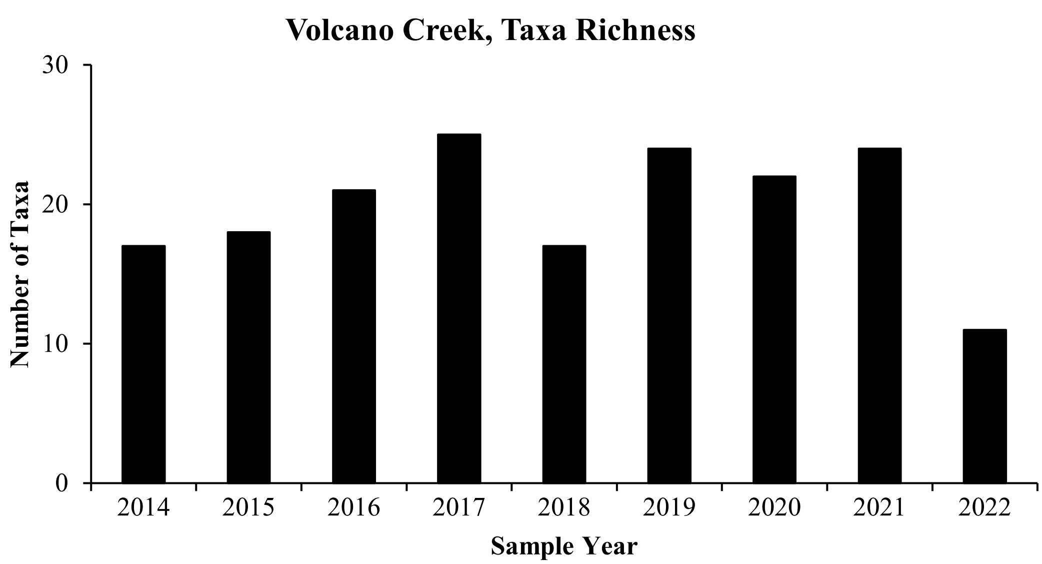

Figure 64. Aquatic invertebrate taxa richness in Volcano Creek.

Fish

Fish sampling with minnow traps and visual observations was conducted in Volcano Creek from 2014 through 2022 (Appendix 1). Dolly Varden were captured in most years and slimy sculpin were caught in 2017, 2018, and 2019. CPUE was the second highest on record in 2022 and the highest it's been since 2015 (Figure 65). Length frequency distribution of all Dolly Varden caught is presented in Figure 66. Age 1 and 2 fish dominated the catch, although some larger, older fish were also captured.

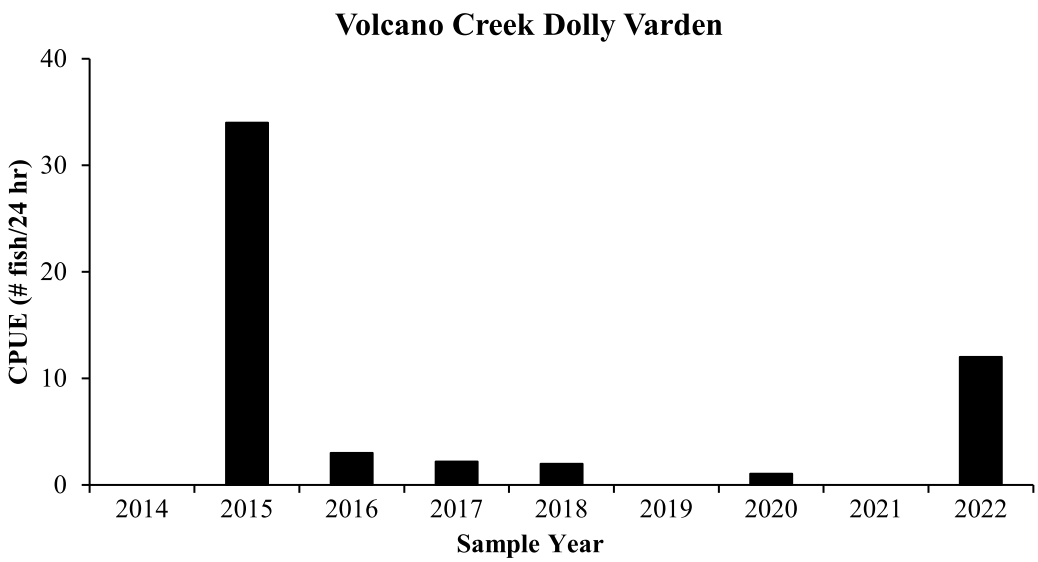

Figure 65. Catch per unit of effort for juvenile Dolly Varden in Volcano Creek.

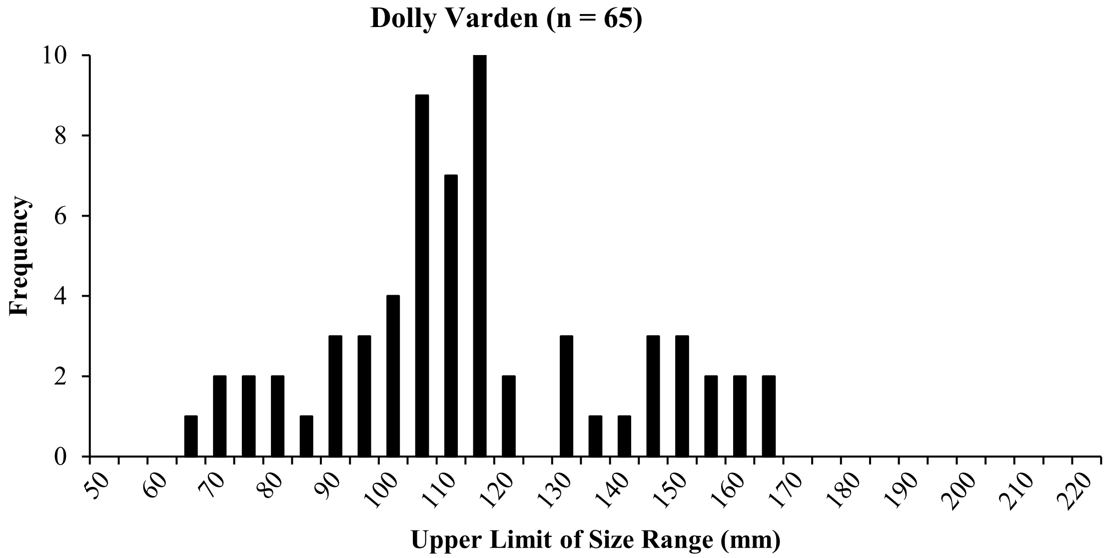

Figure 66. Length frequency distribution of Dolly Varden in Volcano Creek, all years.

A limited number of fish were retained in 2016 (n = 1) and 2017 (n = 2 juvenile Dolly Varden for whole body element concentration analysis (cadmium, lead, selenium, zinc, and mercury). These data were compared graphically with Dolly Varden collected in Mainstem Red Dog (stations 151 and 10) and Anxiety Ridge creeks during the same time frame (Figure 67). The cadmium concentrations in Volcano Creek were similar to those found in Mainstem Red Dog Creek, but higher than those found in Anxiety Ridge Creek. Whole body lead and selenium concentrations in fish from Volcano Creek were similar to those found in Anxiety Ridge Creek but lower than fish collected in Mainstem Red Dog Creek. Zinc concentrations in juvenile Dolly Varden were slightly higher in Mainstem Red Dog Creek as compared to Anxiety Ridge Creek and mercury concentrations were slightly higher in Anxiety Ridge Creek. All mercury concentrations were low (Figure 67).

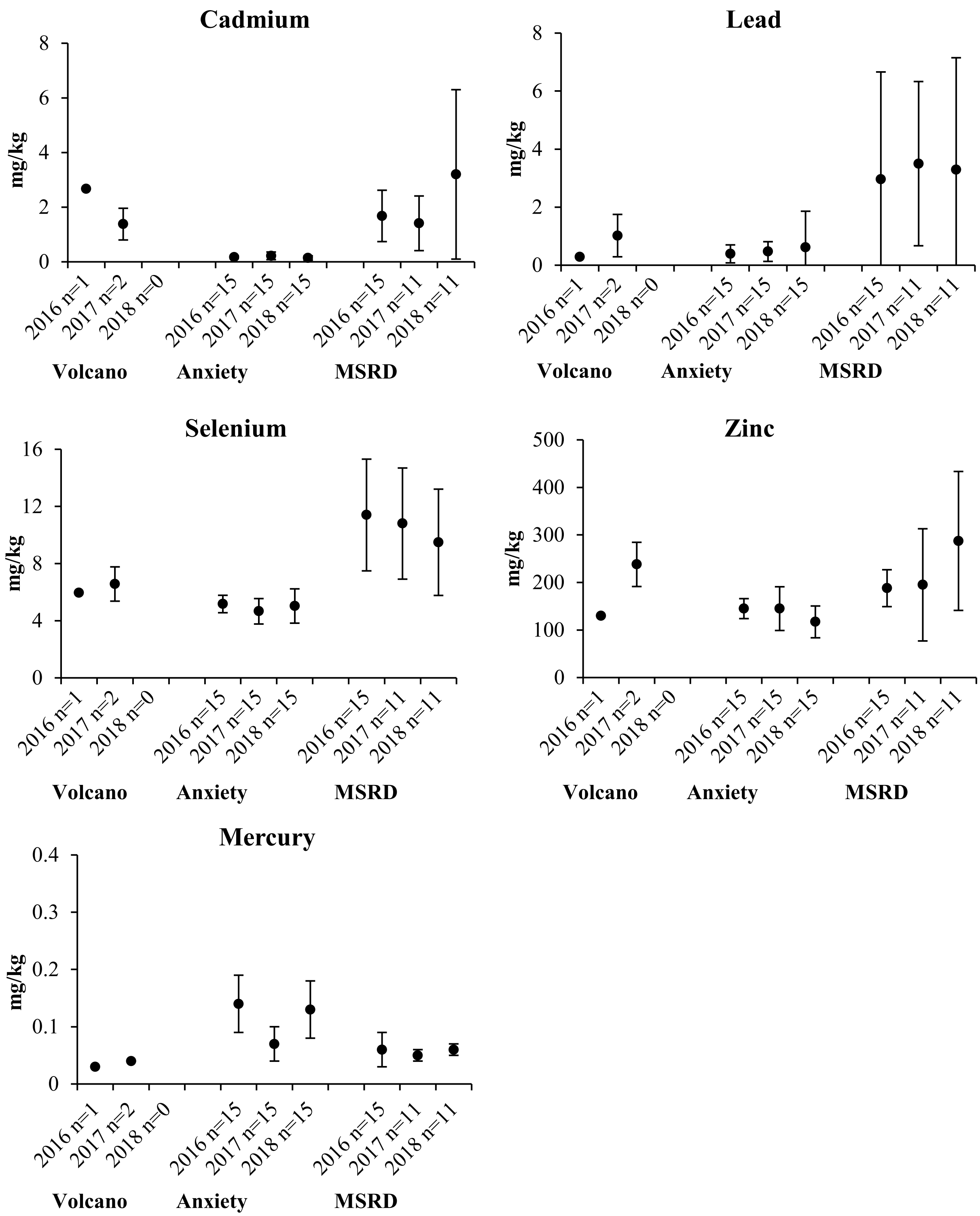

Figure 67. Average dry weight whole body element concentrations (± 1SD) in juvenile Dolly Varden collected from Volcano, Anxiety Ridge, and Mainstem Red Dog creeks.

Sediment

Sediment element concentrations in Volcano Creek are presented in Table 13. Cadmium, lead, and zinc concentrations were the highest recorded among all sites. Copper, mercury, and selenium concentrations were slightly above the median among all sites.

Table 13. Sediment sample element concentrations in Volcano Creek, 2022.

Element	Concentration (mg/kg dry weight)	Median Among All Sites (mg/kg dry weight)
Cadmium	36.10	2.59
Copper	146	131
Lead	126.0	22.5
Mercury	0.116	0.071
Selenium	3.00	2.48
Zinc	2990	544

Upper Volcano Creek

Water Quality

Upper Volcano Creek was not sampled from 2000 through 2002 but was sampled in 2016 for fish and again in 2022 for periphyton, aquatic invertebrates, and fish. Visual observations and biological data collected indicate that Upper Volcano Creek is a productive aquatic system (Figure 68).

Figure 68. Upper Volcano Creek downstream (left) and lateral view (right), July 2022.

Periphyton

Mean chlorophyll-a concentration in Upper Volcano Creek in 2022 was 8.84 mg/m^2.

Invertebrates

The aquatic invertebrate density in Upper Volcano Creek was 23,419 aquatic invertebrates/m^2 in 2022. The percent EPT was 68% and a total of 14 taxa were present in the samples.

Fish

No fish were captured in minnow traps in 2022 at Upper Volcano Creek. Four Dolly Varden were captured in 2016.

Warf Creek (Station 233)

Water Quality

Warf Creek is a clear water tributary to West Fork Ikalukrok Creek. There is some red staining on the substrate and a steep bank of loose shale along the sample site (Figure 69).

Figure 69. Warf Creek upstream in July 2021 (left) and July 2022 (right).

Periphyton

Mean chlorophyll-a concentration in Warf Creek was 2.18 mg/m^2 in 2022 and 0.14 mg/m^2 in 2021.

Invertebrates

The aquatic invertebrate density in Warf Creek was 360 aquatic invertebrates/m^2 in 2022. The percent EPT was 7% and a total of 8 taxa were present in the samples.

Ikalukrok Creek (below West Fork Ikalukrok; Station 230)

Water Quality

At this site, Ikalukrok Creek had clear water but some white staining was observed in shallow areas (Figure 70). Water quality data collected by Teck in 2022 is presented in Appendix 2.

Figure 70. Ikalukrok Creek upstream in 2022 (left) and white staining in a shallow area (right).

Periphyton

Mean chlorophyll-a concentration in Ikalukrok Creek below the West Fork Ikalukrok Creek in 2022 was 0.05 mg/m^2.

Invertebrates

The aquatic invertebrate density in Ikalukrok Creek below the West Fork Ikalukrok Creek was 3,186 aquatic invertebrates/m^2 in 2022. The percent EPT was 20% and a total of seven taxa were present in the samples.

East Fork Grayling Junior Creek

Water Quality

Sampling occurred in two different areas of this creek due to location miscommunications between years. The location for 2021 fish sampling and 2022 periphyton and invertebrate sampling had clear water with some residual red staining on larger rocks (Figure 71). The location for 2022 fish sampling had murkier water with strong red staining on all substrate material (Figure 71).

Figure 71. East Fork Grayling Junior Creek upstream in August 2021 (left) and at a different sampling location in August 2022 (right).

Periphyton

Mean chlorophyll-a concentration in East Fork Grayling Junior Creek in 2022 was 1.02 mg/m^2.

Invertebrates

The aquatic invertebrate density in East Fork Grayling Junior Creek was 6,791 aquatic invertebrates/m^2 in 2022. The percent EPT was 40% and a total of 13 taxa were present in the samples.

Fish

No fish were captured in minnow traps in 2022 at East Fork Grayling Junior Creek. One Dolly Varden was captured in August 2021. This may due to the discrepancy in minnow trapping locations between the two years where minnow traps were set in the channel with red staining and murkier water in 2022.

North Fork Grayling Junior Creek

Water Quality

North Fork Grayling Junior Creek is a clear water tributary that joins with East Fork Grayling Junior Creek to form Grayling Junior Creek. There are no visual indicators to suggest that water quality is impaired (Figure 72).

Figure 72. North Fork Grayling Junior Creek upstream in 2021 (left) and in 2022 (right).

Fish

A total of 18 Dolly Varden were captured in North Fork Grayling Junior Creek in 2022. In 2021, seven Dolly Varden were captured. Length frequency distribution of all Dolly Varden caught is presented in Figure 73. Age 1 and 2 fish dominated the catch, although one larger, likely older fish was captured in 2022.

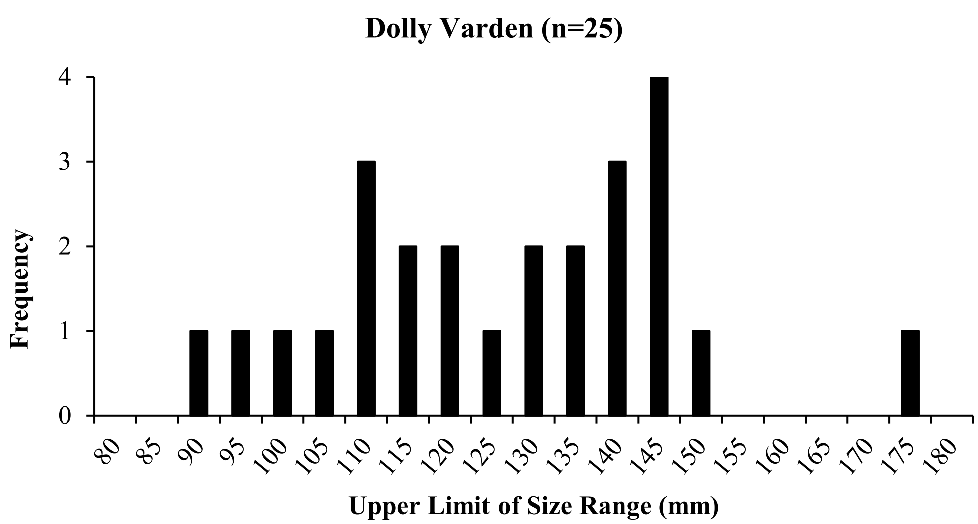

Figure 73. Length frequency distribution of Dolly Varden in Grayling Junior, all years.

Upper North Fork Red Dog Creek Tributary

Water Quality

Upper North Fork Red Dog Creek Tributary is a small slightly incised clearwater tributary to Red Dog Creek. There are no visual indicators to suggest that water quality is impaired (Figure 74).

Figure 74. Upper North Fork Red Dog Creek Tributary in August 2021 (left) and August 2022 (right).

Fish

No fish were captured in minnow traps in 2022 at Upper North Fork Red Dog Creek Tributary. One Dolly Varden was captured in August 2021.

Upper North Fork Red Dog Creek 1

Water Quality

Upper North Fork Red Dog Creek 1 is a small slightly incised clearwater tributary to Red Dog Creek. There are no visual indicators to suggest that water quality is impaired (Figure 75).

Figure 75. Upper North Fork Red Dog Creek 1 downstream in August 2021 (left) and upstream in August 2022 (right).

Periphyton

Mean chlorophyll-a concentration in Upper North Fork Red Dog Creek 1 in 2022 was 2.08 mg/m^2.

Invertebrates

The aquatic invertebrate density in Upper North Fork Red Dog Creek 1 was 19,605 aquatic invertebrates/m^2 in 2022. The percent EPT was 24% and a total of 18 taxa were present in the samples.

Fish

No fish were captured in minnow traps in 2022 at Upper North Fork Red Dog Creek 1, but one larger likely adult Arctic grayling was visually observed. Two Dolly Varden were captured in August 2021.

Upper North Fork Red Dog Creek 2

Water Quality

Upper North Fork Red Dog Creek 2 is a small clearwater tributary to Red Dog Creek. There are no visual indicators to suggest that water quality is impaired (Figure 76).

Figure 76. Upper North Fork Red Dog Creek 2 downstream in August 2021 (left) and upstream in August 2022 (right).

Fish

No fish were captured in minnow traps in 2021 or 2022 at Upper North Fork Red Dog Creek 2, but one larger likely adult Arctic grayling was visually observed in 2022.

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Appendix 1. Total numbers and CPUE of Dolly Varden juveniles captured in minnow traps at various streams near the Red Dog Mine site.

Sample Location (Station)	Date Sampled	Hours Fished	Total Catch	CPUE	Other Fish
Upper Competition Creek (203)	7/28/2000	23	5	5.2	
Upper Competition Creek (203)	7/7/2001	47	0	N/A	
Upper Competition Creek (203)	8/4/2001	28	0	N/A	
Upper Competition Creek (203)	8/3/2002	24	3	3	
Upper Competition Creek (203)	7/31/2014	19	0	N/A	
Upper Competition Creek (203)	7/31/2015	19.5	0	N/A	
Upper Competition Creek (203)	8/5/2016	23	0	N/A	
Upper Competition Creek (203)	8/6/2017	25.5	0	N/A	
Upper Competition Creek (203)	8/3/2018	22.66	0	N/A	
Upper Competition Creek (203)	8/8/2021	24.5	0	N/A	
Upper Competition Creek (203)	8/4/2022	22.25	0	N/A	
Sourdock Creek (204)	7/9/2000	30	52	41.6	
Sourdock Creek (204)	7/28/2000	24	20	20	
Sourdock Creek (204)	7/7/2001	48	26	13	
Sourdock Creek (204)	8/4/2001	28	8	6.9	
Sourdock Creek (204)	7/9/2002	28.5	1	0.8	
Sourdock Creek (204)	8/3/2002	24	3	3	
Sourdock Creek (204)	7/31/2014	21	0	N/A	
Sourdock Creek (204)	7/31/2015	20	0	N/A	
Sourdock Creek (204)	8/5/2016	23.5	1	0.1	
Sourdock Creek (204)	8/6/2017	25	0	N/A	
Sourdock Creek (204)	8/3/2018	24	0	N/A	
Sourdock Creek (204)	8/8/2021	24.5	0	N/A	
Sourdock Creek (204)	8/4/2022	22.25	0	N/A	
Lower Competition Creek (202)	7/9/2000	32	4	3	
Lower Competition Creek (202)	7/29/2000	24	2	2	
Lower Competition Creek (202)	7/30/2000	24	2	2	
Lower Competition Creek (202)	7/6/2001	24	1	1	
Lower Competition Creek (202)	8/4/2001	28	11	9.5	
Lower Competition Creek (202)	7/9/2002	27	1	0.9	
Lower Competition Creek (202)	8/3/2002	24	33	33	
Lower Competition Creek (202)	7/31/2014	23	13	13.7	
Lower Competition Creek (202)	8/1/2015	26	35	32.3	
Lower Competition Creek (202)	8/5/2016	22.5	44	46.9	
Lower Competition Creek (202)	8/6/2017	27.3	22	19.4	
Lower Competition Creek (202)	8/3/2018	24.1	11	11	
Lower Competition Creek (202)	8/5/2019	23.75	21	21.22	

Lower Competition Creek (202)	8/8/2021	25.83	0	N/A
Lower Competition Creek (202)	8/25/2021	26.33	0	N/A
Lower Competition Creek (202)	8/4/2022	22.5	0	N/A
West Fork Ikalukrok Creek (205)	7/8/2000	24	0	N/A
West Fork Ikalukrok Creek (205)	7/28/2000	28	0	N/A
West Fork Ikalukrok Creek (205)	7/7/2001	25	0	N/A
West Fork Ikalukrok Creek (205)	8/3/2001	54	0	N/A
West Fork Ikalukrok Creek (205)	7/11/2002	27	0	N/A
West Fork Ikalukrok Creek (205)	8/2/2002	26	0	N/A
West Fork Ikalukrok Creek (205)	8/1/2015	27	0	N/A
West Fork Ikalukrok Creek (205)	8/5/2016	23	0	N/A
West Fork Ikalukrok Creek (205)	8/7/2017	27	0	N/A
West Fork Ikalukrok Creek (205)	8/3/2018	21.1	0	N/A
West Fork Ikalukrok Creek (205)	8/5/2019	24	0	N/A
West Fork Ikalukrok Creek (205)	8/3/2020	20.5	0	N/A
West Fork Ikalukrok Creek (205)	8/8/2021	24.25	0	N/A
West Fork Ikalukrok Creek (205)	8/5/2022	23.25	0	N/A
Upper Ikalukrok Creek (206)	7/28/2000	28	0	N/A
Upper Ikalukrok Creek (206)	7/7/2001	24	0	N/A
Upper Ikalukrok Creek (206)	8/3/2001	54	0	N/A
Upper Ikalukrok Creek (206)	7/11/2002	26.5	0	N/A
Upper Ikalukrok Creek (206)	8/2/2002	26	0	N/A
Upper Ikalukrok Creek (206)	8/1/2015	26.5	0	N/A
Upper Ikalukrok Creek (206)	8/5/2016	23	0	N/A
Upper Ikalukrok Creek (206)	8/7/2017	27	0	N/A
Upper Ikalukrok Creek (206)	8/3/2018	21.3	0	N/A
Upper Ikalukrok Creek (206)	8/5/2019	23.8	0	N/A
Upper Ikalukrok Creek (206)	8/3/2020	20.5	0	N/A
Upper Ikalukrok Creek (206)	8/8/2021	24	0	N/A
Upper Ikalukrok Creek (206)	8/5/2022	23.5	0	N/A
Ikalukrok Creek (207)	July of 1999	24	0	N/A
Ikalukrok Creek (207)	7/8/2000	24.5	0	N/A
Ikalukrok Creek (207)	7/29/2000	23	0	N/A
Ikalukrok Creek (207)	7/7/2001	23.5	0	N/A
Ikalukrok Creek (207)	8/3/2001	53.5	0	N/A
Ikalukrok Creek (207)	7/12/2002	46.5	0	N/A
Ikalukrok Creek (207)	8/2/2002	25	0	N/A
East Fork Ikalukrok Creek (208)	July of 1999	24	0	N/A
East Fork Ikalukrok Creek (208)	7/8/2000	27	0	N/A
East Fork Ikalukrok Creek (208)	7/29/2000	23	1	1
East Fork Ikalukrok Creek (208)	7/8/2001	46	0	N/A

East Fork Ikalukrok Creek (208)	8/3/2001	54	0	N/A	
East Fork Ikalukrok Creek (208)	7/12/2002	27	0	N/A	
East Fork Ikalukrok Creek (208)	8/1/2002	23	3	3.1	
East Fork Ikalukrok Creek (208)	8/5/2016	22.9	11	11.5	2 SS
East Fork Ikalukrok Creek (208)	8/7/2017	23.8	4	4.2	
East Fork Ikalukrok Creek (208)	8/3/2018	22.8	1	1.1	
East Fork Ikalukrok Creek (208)	8/5/2019	24	4	4	
East Fork Ikalukrok Creek (208)	8/3/2021	22.5	0	N/A	
East Fork Ikalukrok Creek (208)	8/7/2021	20.5	0	N/A	
East Fork Ikalukrok Creek (208)	8/25/2021	25.25	0	N/A	
East Fork Ikalukrok Creek (208)	8/5/2022	23	0	N/A	
Grayling Junior Creek (209)	7/11/2000	23	14	14.6	
Grayling Junior Creek (209)	7/29/2000	28	8	6.9	
Grayling Junior Creek (209)	7/10/2001	42	5	2.9	
Grayling Junior Creek (209)	8/1/2001	46	12	6.3	
Grayling Junior Creek (209)	7/12/2002	26	0	N/A	
Grayling Junior Creek (209)	8/1/2002	24	44	44	
Grayling Junior Creek (209)	8/27/2004	24.02	20	20	5 AG, 2 SS
Grayling Junior Creek (209)	8/5/2016	27.75	4	3.8	3 SS
Grayling Junior Creek (209)	8/7/2017	24	2	2	1 SS
Grayling Junior Creek (209)	8/3/2018	23	0	N/A	6 SS
Grayling Junior Creek (209)	8/5/2019	24.25	5	4.95	2 SS
Grayling Junior Creek (209)	8/3/2020	23	6	6.26	
Grayling Junior Creek (209)	8/7/2021	20.75	1	1.16	
Grayling Junior Creek (209)	8/25/2021	23.83	1	1	
Grayling Junior Creek (209)	8/5/2022	24.25	4	3.96	
Grayling Junior upstream 1	8/6/2021	20.75	1	1.1	
Grayling Junior upstream 1	8/25/2021	24	0	N/A	
Grayling Junior upstream 1	8/6/2022	22.25	0	N/A	
Grayling Junior upstream 2	8/7/2021	20.58	7	8.16	
Grayling Junior upstream 2	8/5/2022	22.25	18	19.42	
Noa Creek (210)	7/10/2000	28	0	N/A	
Noa Creek (210)	7/30/2000	23	0	N/A	
Noa Creek (210)	7/10/2001	22	0	N/A	
Noa Creek (210)	8/1/2001	46	0	N/A	
Noa Creek (210)	8/1/2002	22.5	0	N/A	
Moil Creek (211)	7/10/2000	27	0	N/A	
Moil Creek (211)	7/30/2000	23	0	N/A	
Moil Creek (211)	7/10/2001	22	0	N/A	
Moil Creek (211)	8/5/2001	24	0	N/A	
Moil Creek (211)	8/1/2002	24	0	N/A	

Sled Creek (212)	7/9/2000	26	0	N/A	
Sled Creek (212)	7/29/2000	25	0	N/A	
Sled Creek (212)	7/10/2001	24	0	N/A	
Sled Creek (212)	8/5/2001	24	0	N/A	
Sled Creek (212)	7/31/2002	23.5	0	N/A	
Sled Creek (212)	7/31/2015	22	0	N/A	
Volcano Creek (lower)	7/30/2014	26	0	N/A	
Volcano Creek (lower)	8/1/2015	22.5	32	34	
Volcano Creek (lower)	8/6/2016	22	3	3.3	
Volcano Creek (upper)	8/6/2016	22	4	4.4	
Volcano Creek (lower)	8/6/2017	21.75	2	2.2	2 SS
Volcano Creek (lower)	8/3/2018	24.3	2	2	1 SS
Volcano Creek (lower)	8/2/2019	31	0	N/A	2 SS
Volcano Creek (lower)	8/5/2020	22.7	1	1.06	
Volcano Creek (lower)	8/9/2021	24.17	0	N/A	
Volcano Creek (lower)	8/27/2021	15.25	8	12.6	
Volcano Creek (lower)	8/3/2022	26	13	12	
Volcano Creek (upper)	8/3/2022	26.17	0	N/A	
North Fork Red Dog Creek tributary	8/11/2021	25.42	1	0.94	
North Fork Red Dog Creek tributary	8/5/2022	22.25	0	N/A	
Upper North Fork Red Dog 1	8/11/2021	25.42	2	1.89	
Upper North Fork Red Dog 1	8/5/2022	22.25			
Upper North Fork Red Dog 2	8/11/2021	24.8	0	N/A	
Upper North Fork Red Dog 2	8/5/2022	22.5	0	N/A	

Appendix 2. Water quality and metal concentration data at various streams around the Red Dog Mine site, 2022. Data collected by Teck. Season means are presented in shaded rows.

	EF Ikalukrok (208)	Grayling Jr (209)	Upper Ikalukrok (206)	Ikalukrok (207)	Lower Ikalukrok (230)	Moil (211)	WF Ikalukrok (205)
pH	7.95 (n=12)	7.59 (n=12)	6.48 (n=16)	6.51 (n=12)	6.34 (n=4)	3.84 (n=12)	4.03 (n=12)
Min	6.85	5.95	5.63	5.30	6.01	3.26	3.76
Max	8.49	8.21	7.03	7.30	6.62	4.43	4.30
Temperature (°C)	5.81 (n=12)	5.86 (n=12)	5.26 (n=16)	5.66 (n=12)	2.95 (n=3)	3.65 (n=12)	4.02 (n=12)
Min	0.00	0.00	0.00	0.00	0.00	-0.10	0.00
Max	10.50	11.70	11.40	10.60	6.40	7.40	7.10
Conductivity (uS/cm)	235.86 (n=12)	583.32 (n=12)	465.16 9 (n=16)	611.83 (n=12)	442.18 (n=4)	1088.92 (n=12)	939.17 (n=12)
Min	109.10	218.80	108.50	203.70	126.60	521.00	271.30
Max	317.20	786.00	754.00	914.00	805.00	1465.00	1468.00
TDS (mg/L)	228.55 (n=11)	630.27 (n=11)	446.36 (n=14)	732.18 (n=11)	545.33 (n=3)	1550.10 (n=10)	1154.55 (n=11)
Min	78.00	89.00	43.00	264.00	148.00	201.00	168.00
Max	314.00	952.00	844.00	1084.00	1060.00	2200.00	1948.00
Zinc (mg/L)	0.016 (n=12)	0.136 (n=12)	0.541 (n=15)	3.21 (n=12)	0.890 (n=3)	5.56 (n=12)	2.98 (n=12)
Min	0.007	0.075	0.172	1.200	0.241	2.640	0.818
Max	0.029	0.209	0.838	4.800	1.790	7.850	5.200
Lead (mg/L)	0.0002 (n=12)	0.0002 (n=12)	0.0002 (n=15)	0.0061 (n=12)	0.0002 (n=3)	0.0013 (n=12)	0.0002 (n=12)
Min	0.0001	0.0001	0.0001	0.0036	0.0001	0.0002	0.0001
Max	0.0007	0.0015	0.0013	0.0144	0.0005	0.0113	0.0006
Aluminum (mg/L)			0.405 (n=3)		1.038 (n=3)		
Min			0.284		0.419		
Max			0.615		1.980		
Cadmium (mg/L)			0.002 (n=3)		0.004 (n=3)		
Min			0.001		0.001		
Max			0.004		0.008		
Nickel (mg/L)			0.346 (n=3)		0.576 (n=3)		
Min			0.124		0.164		
Max			0.671		1.160		
Turbidity (NTU)			3.67 (n=4)		4.05 (n=4)		
Min			1.54		2.75		
Max			5.21		6.02		