Technical Report No. 22-02

Baseline Aquatic Biomonitoring for the Anarraaq and Aktigiruq Prospects near the Red Dog Mine, 2021

by

Chelsea M. Clawson

August 2022

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. 22-02

BASELINE AQUATIC BIOMONITORING FOR THE ANARRAAQ AND AKTIGIRUQ PROSPECTS NEAR THE RED DOG MINE, 2021

By

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August 2022

Cover: Dolly Varden captured in Grayling Junior Creek August 2021, Photograph by Chelsea Clawson

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Acknowledgements

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Olivia Edwards, Al Ott, Audra Brase, and Emily Hart provided constructive reviews of this report.

Executive Summary

This report summarizes results of 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 to 2021. Biomonitoring data from 2000 to 2002 and reported in Weber Scannell and Ott (2006) are included here 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. No fish were found in Noa, Moil, West Fork Ikalukrok Creek and Ikalukok Creek upstream of Cub Creek Seep.

During 2000-2002 baseline sampling, water quality in Sourdock, 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 and 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 2021, additional sample sites for periphyton and invertebrates were added on Warf Creek, a tributary to West Fork Ikalukrok Creek, and mainstem Ikalukrok Creek downstream of the West Fork (Sta 230). Additional minnow trapping sites were added in two locations in the upper Grayling Junior Creek drainage, and at three locations in the upper North Fork Red Dog Creek drainage. A second minnow trapping event was added at the end of August to check for changes in fish presence at different times of year.

Measurements of periphyton standing crop, aquatic invertebrates, and fish distribution vary among the sample sites. In 2021, periphyton as measured by chlorophyll-a was highest in Sled Creek (4.04 mg/m^2) and was very low (<1.00 mg/m^2) at all other sample sites. Fish catch per unit effort (CPUE, number of fish caught/24 hrs) during the early August sampling event was highest at Grayling Junior Creek 2, the most upstream Grayling Junior sample site. CPUE during the late August sampling event was highest at Volcano Creek.

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).

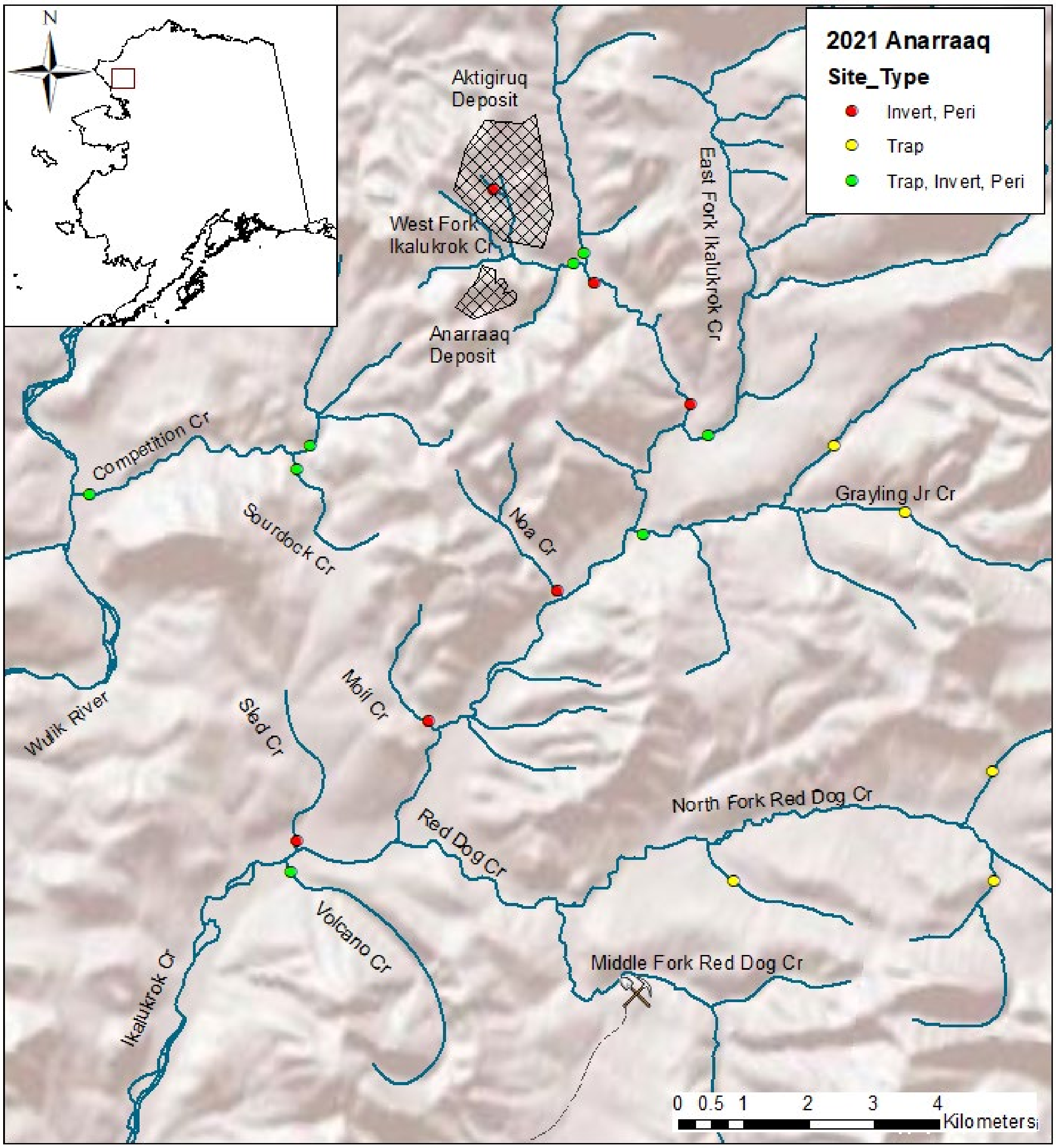

Figure 1. Map showing sampling points and general location of Anarraaq and Aktigiruq deposits.

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 to 2021, sampling work focused on streams which flow to the west and east from the Anarraaq/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 at each site. Periphyton and aquatic invertebrates were collected in early July while fish sampling was done in early August.

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. In order 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 may be via an all-weather road following Mainstem Red Dog Creek, crossing North Fork Red Dog, Grayling Junior, and Ikalukrok creeks, and then up 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 mine development.

Methods

Details of the methods used for the 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 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.

Aquatic invertebrates were collected at each sample site using five drift nets installed in riffle habitat along a transect perpendicular to flow. The drift nets were set for one hour and the water depth and average water velocity through each net were measured. After one hour, the drift nets were pulled, materials (debris and invertebrates) in the net were flushed to the cod end, transferred to a labeled sample container, preserved in denatured ethanol, and transported back to Fairbanks where they were sorted and identified.

In 2021 invertebrate sampling was conducted at East Fork Ikalukrok Creek (Sta 208) and Ikalukrok Creek downstream of Cub Seep (Sta 207) sites using Hess samplers in addition to drift nets. The Hess stream bottom sampler has a 0.086 m2 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. After samples were collected, methods for preservation and identification of invertebrates were identical to those used for drift net invertebrate samples. Hess samplers are potentially more accurate at identifying the in-situ benthic community, rather than the drifting invertebrate community. This provides a more accurate baseline for evaluating changes at each site, rather than changes occurring upstream.

Fish sampling consisted of setting ten minnow traps baited with salmon roe at each sample site for about 24 hours. Visual observations were made when appropriate. The minnow traps were pulled, the fish identified and measured (fork length, mm), and released. In some cases, juvenile Dolly Varden (between 90 and 140 mm long) were retained for whole body analyses of selected elements.

Visual surveys for freshwater mussel presence/absence were conducted in areas of slow moving water such as back eddies or pools at a subset of sample sites. 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.

Table 1. Location of sample sites and years sampled.

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

[1]Site was not sampled in 2020
[2]Sample site is downstream of Cub Creek Seep
*Mussel survey location

Results and Discussion

This section presents the biomonitoring results for each creek listed in Table 1. Biomonitoring data were collected from 2014 to 2021 and are summarized here. Comparisons are made to prior work performed in 2000 to 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[1].

Periphyton attached microalgae biomass were collected in early July of each sample year and are presented as mg/m^2 chlorophyll-a.

Aquatic invertebrates were also collected in early July of each sample year and the densities are expressed as the average number of aquatic invertebrates/m^3. 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.

Fish were sampled in late July or early August of each sample year and densities are presented in Catch Per Unit Effort (CPUE). CPUE is defined as the number of fish caught per 24 hour period for all ten minnow traps. Numbers of fish presented in the text are rounded to the nearest whole number.

Upper Competition Creek (Station 203)

Water Quality

Upper Competition Creek (Figures 1 and 2) 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 to 2021 varied from white to tan (Figure 2). Additionally, the water in Upper Competition Creek has varied from opaque white to orange in color.

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

Figure 2. Upper Competition Creek in 2018 (left) and 2021 (right). Note the color difference in both the precipitate and water between years.

Periphyton

Average chlorophyll-a concentration in 2021 was 0.06 mg/m^2. Average chlorophyll-a concentrations have been consistently lower in Upper Competition Creek during the recent sampling period (2014-2021) compared to the results in 2000 and 2002.

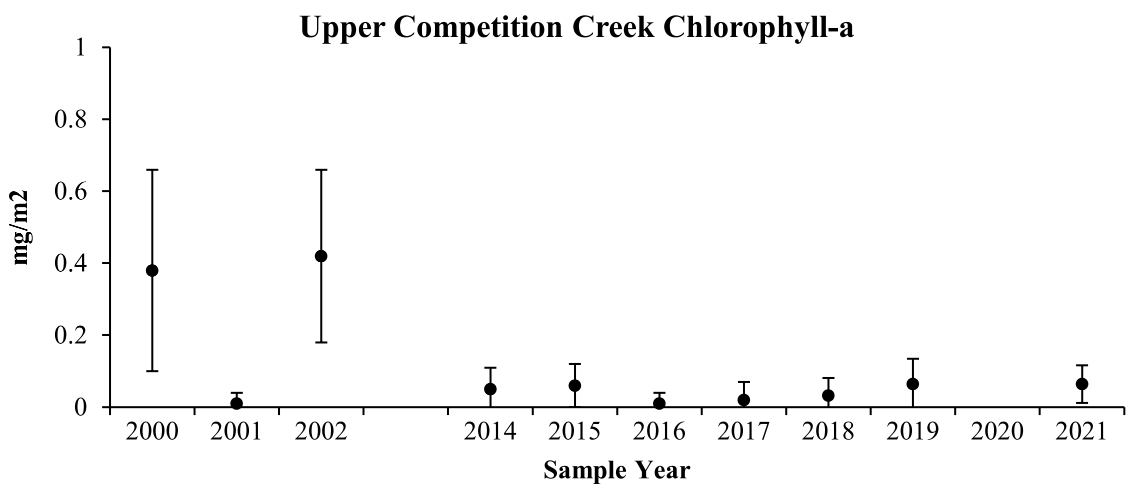

Figure 3. Average concentration of chlorophyll-a (± 1SD) in Upper Competition Creek.

Invertebrates

The average aquatic invertebrate density in Upper Competition Creek in 2021 was 1.81 invertebrates/m^3, and has ranged from 0.5 invertebrates/m^3 in 2019 to 14.9 invertebrates/m^3 in 2001 (Figure 4). The percent Chironomidae is generally higher than percent EPT, but in 2000 and 2016 the EPT was higher than Chironomidae (Figure 5). In past years the EPT was composed of mayflies and stoneflies with very few or no caddisflies, but there was no EPT in the 2021 samples. Taxa richness varied from 12 to 22 taxa per site over the sample years (Figure 6).

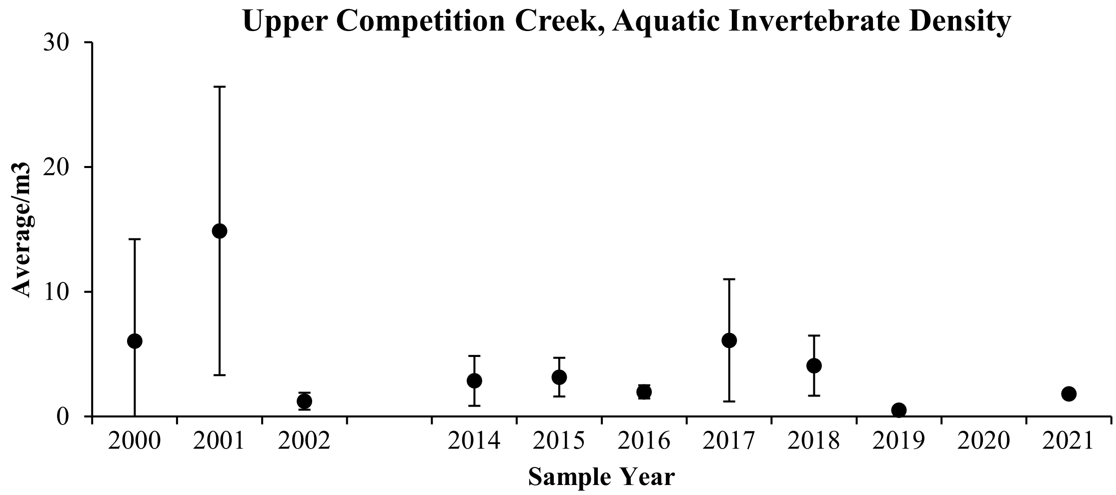

Figure 4. Average aquatic invertebrate density (±1 SD) in Upper Competition Creek.

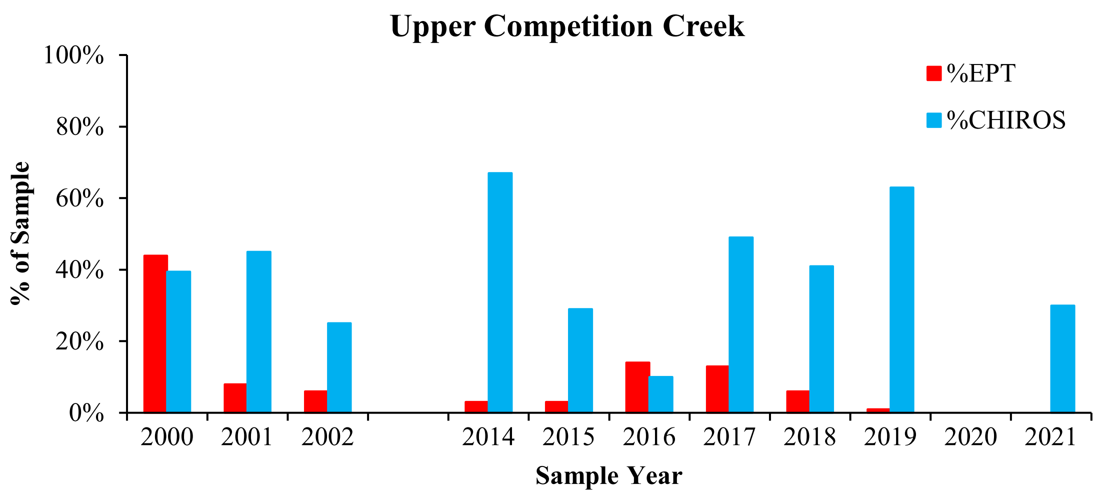

Figure 5. Percent Chironomidae and EPT in Upper Competition Creek.

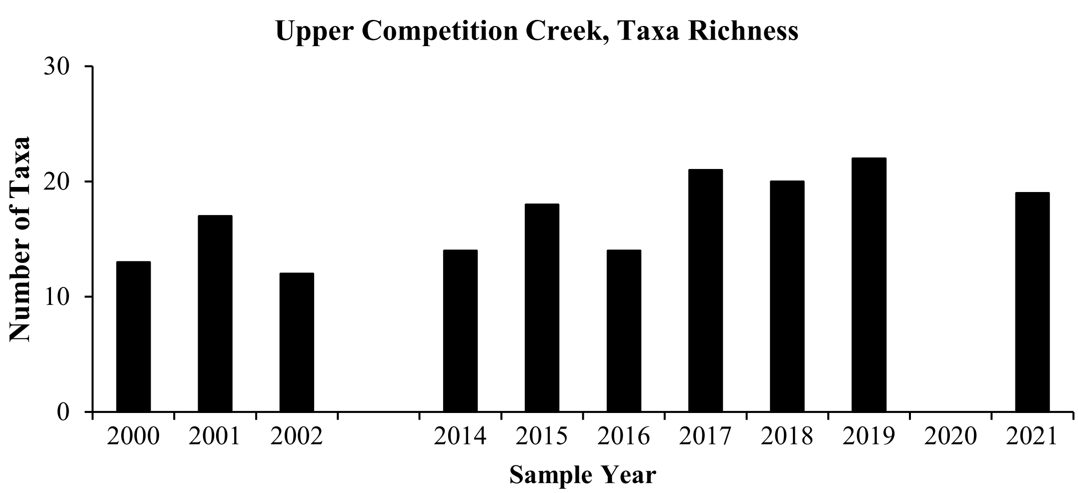

Figure 6. Aquatic invertebrate taxa richness at Upper Competition Creek.

Fish
The catch per unit of effort of 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 to 2021, 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.

Sourdock Creek (Station 204)

Water Quality
Sourdock Creek (Figures 1 and 7) had moderate alkalinity (as $CaCO_3$), sulfate concentrations (2000 to 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 to 2002, but most of the moss has been absent during the 2014 to 2021 sample period. In 2021, there was orange staining on the rocks and the water was milkier than in past years (Figure 7).

Figure 7. Sourdock Creek in 2017 (left) and 2021 (right).

Periphyton
The average chlorophyll-a concentration in 2021 was low of 0.69 mg/m^2, the lowest ever observed during sampling. The highest average chlorophyll-a concentration ever observed in Sourdock Creek was 12.44 mg/m^2 in 2002 (Figure 8). Chlorophyll-a has been considerably higher each sampling year in Sourdock Creek than in Upper Competition Creek. These two creeks merge just downstream of the sample sites to form Competition Creek.

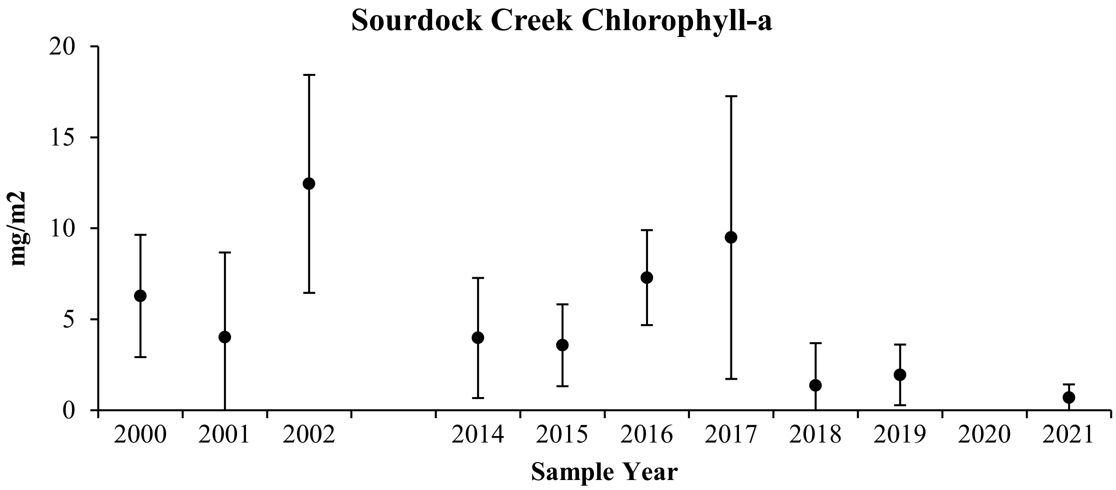

Figure 8. Average concentration of chlorophyll-a (± 1SD) in Sourdock Creek.

Invertebrates

The average aquatic invertebrate density in Sourdock Creek was 3.0 invertebrates/m^3 in 2021, and has ranged from 2.1 invertebrates/m^3 in 2019 to a high of 15.4 invertebrates/m^3 in 2017 (Figure 9). The percent Chironomidae was much higher from 2014 to 2018 than from 2000 to 2002, while in 2019 and 2021 other taxa, primarily Collembolans and Acarians, made up a higher proportion of the sample (Figure 10). The EPT was composed of mayflies and stoneflies with very few or no caddisflies. Taxa richness varied from 12 to 22 taxa per site over the sample years (Figure 11).

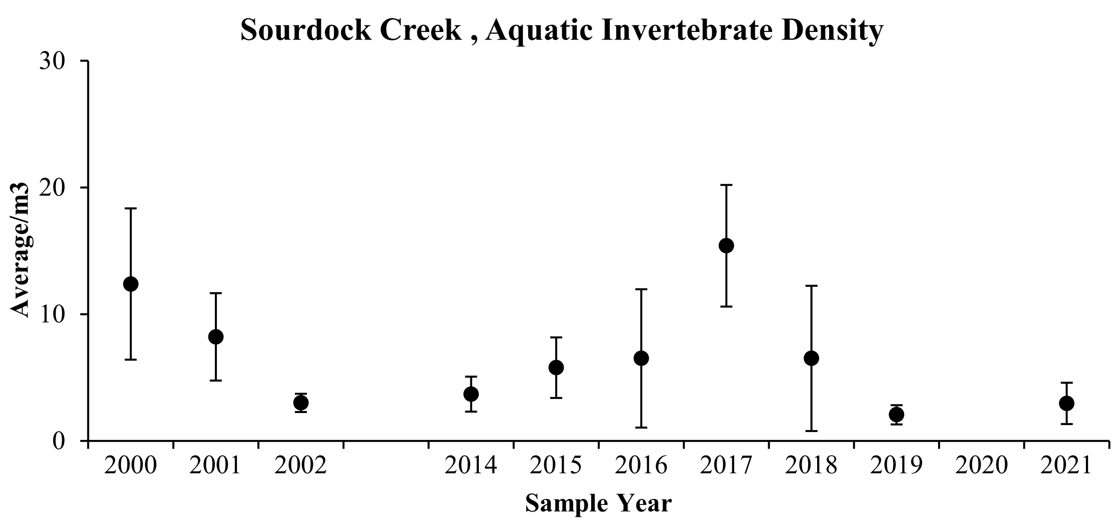

Figure 9. Average aquatic invertebrate densities (± 1SD) in Sourdock Creek.

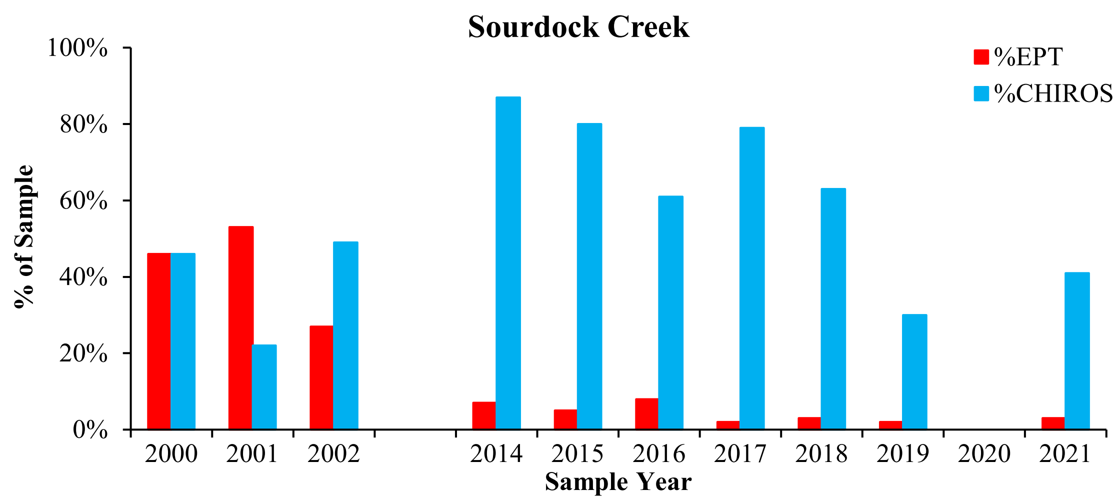

Figure 10. Percent Chironomidae and EPT in Sourdock Creek.

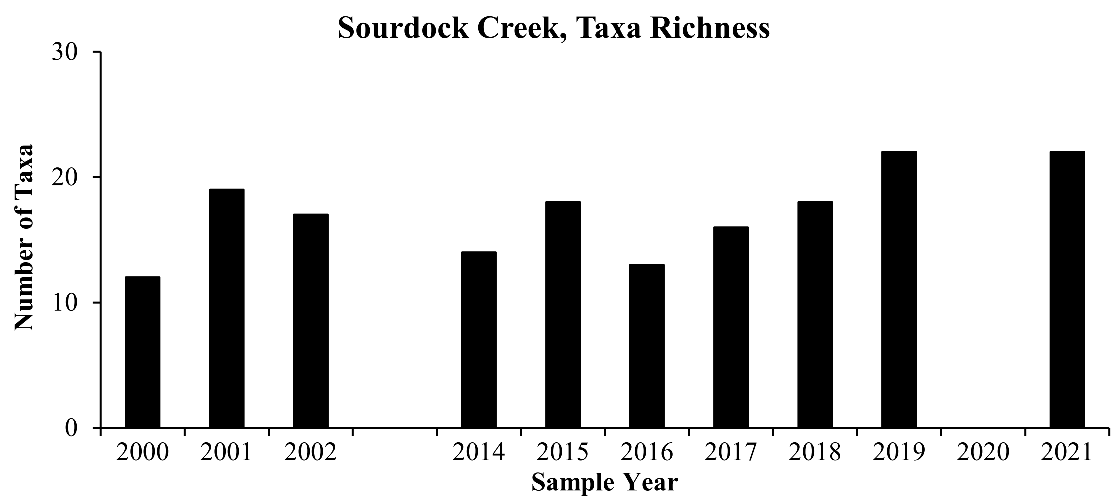

Figure 11. Aquatic invertebrate taxa richness, in Sourdock Creek.

Fish

The catch per unit of effort of 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 12). 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.

The length frequency distribution for all juvenile Dolly Varden caught in Sourdock Creek from 2000 to 2002 is presented in Figure 13. Only one fish has been captured since 2014, a 139 mm FL Dolly Varden that was captured in 2016. There appear to be at least two year classes present in the

2000-2002 fish (most likely 1+ and 2+) which is consistent with data collected in other Red Dog Mine area streams.

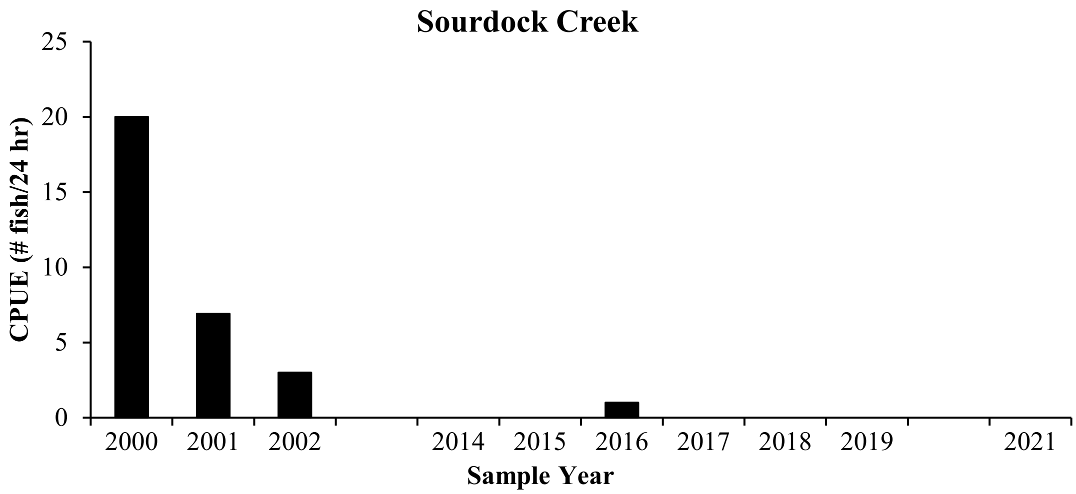

Figure 12. Catch per unit of effort for juvenile Dolly Varden in Sourdock Creek.

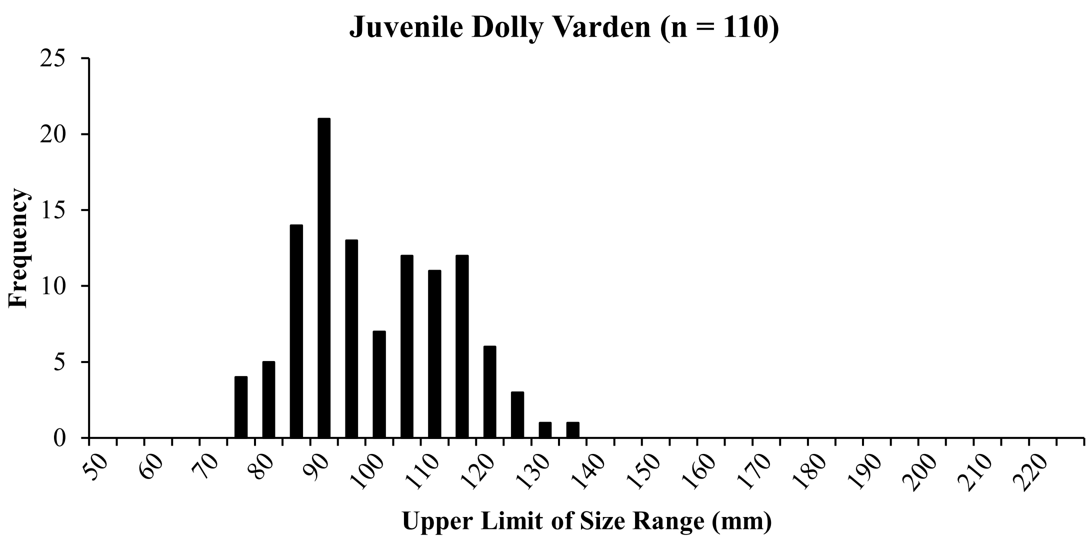

Figure 13. Length frequency distribution of Dolly Varden in Sourdock Creek captured in 2000 – 2002.

Lower Competition Creek (Station 202)

Water Quality

Historically, Lower Competition Creek (Figure 1 and 14) 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 to 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 to 2002 (clear water) to red/orange staining and opaque water (Figure 14).

Figure 14. Lower Competition Creek in 2000 (left) and 2021 (right).

Periphyton

Average chlorophyll-a concentrations in Lower Competition Creek from 2014 through 2021 were substantially lower than those found from 2000 to 2002, an indication of degraded water quality (Figure 15). Chlorophyll-a concentration in 2021 was the lowest ever observed at 0.02 mg/m^2.

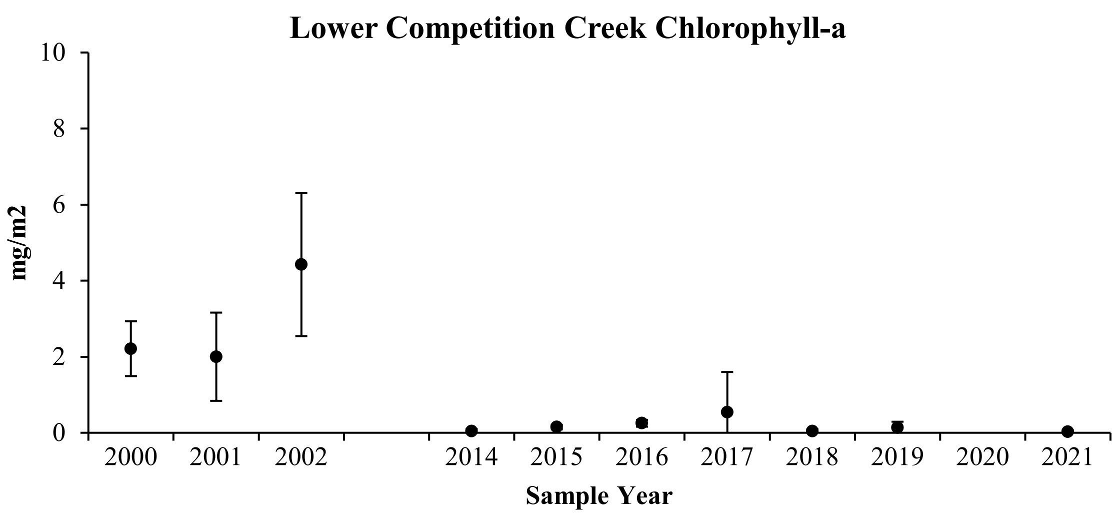

Figure 15. Average concentration of chlorophyll-a (± 1SD) in Lower Competition Creek.

Invertebrates

The average aquatic invertebrate density in Lower Competition Creek in 2021 invertebrates/m^3, and has ranged from a low of 1.05 invertebrates/m^3 in 2019 to 26.2 invertebrates/m^3 in 2000 (Figure 16). Aquatic invertebrate densities from 2014 to 2021 were substantially lower than the previous sample period, another indication of degraded water quality. The percent Chironomidae was also higher from 2014 to 2021 than it was from 2000 to 2002 (Figure 17). The EPT was generally composed of mayflies and stoneflies with very few or no caddisflies. Taxa richness varied from 13 to 24 taxa per site over the sample years and was generally higher during the 2014 to 2021 sample period (Figure 18).

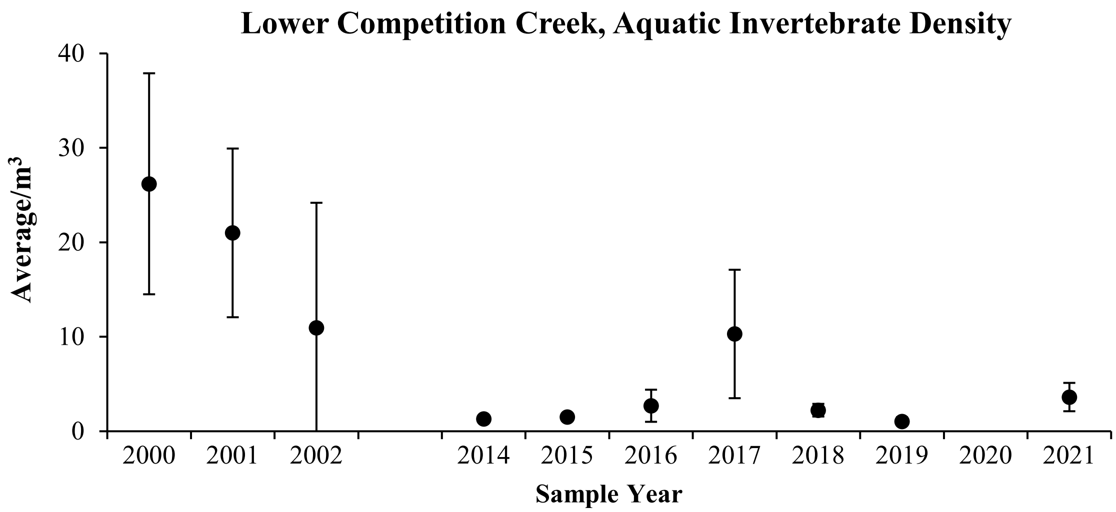

Figure 16. Average aquatic invertebrate densities (± 1SD) in Lower Competition Creek.

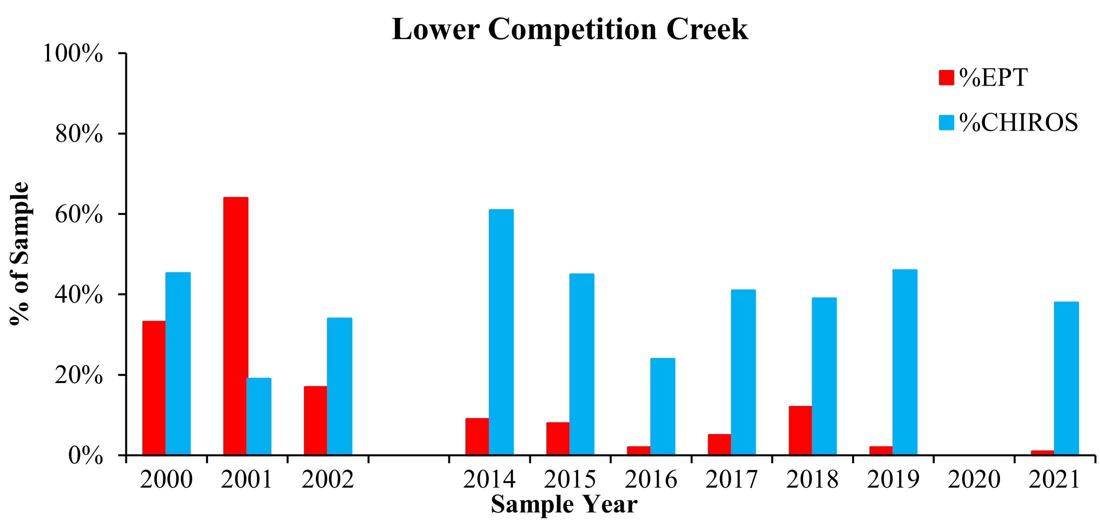

Figure 17. Percent Chironomidae and EPT in Lower Competition Creek.

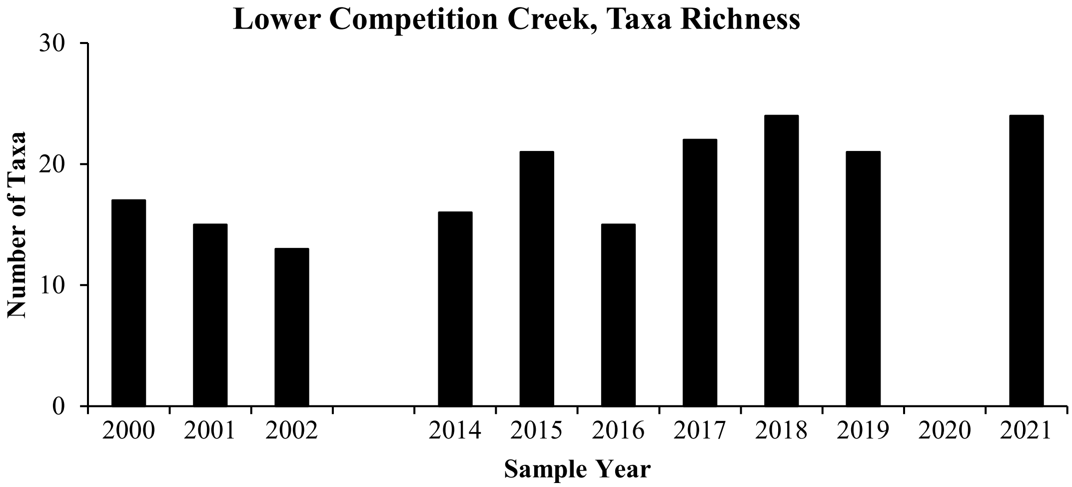

Figure 18. Aquatic invertebrate taxa richness in Lower Competition Creek.

Fish

Juvenile Dolly Varden have 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 to 2002 and from 2014 to 2021 are presented in Figure 19. The CPUE has been highly variable since 2014 with a low of zero fish caught in 2021 and a high of 47 fish in 2016. Generally, the CPUE was higher from 2014 to 2019 than in 2000-2002. 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 quality was visibly poorer in 2021, which may be why no fish were caught during the early August sampling event. Additional minnow trapping occurred in late August and no fish were caught.

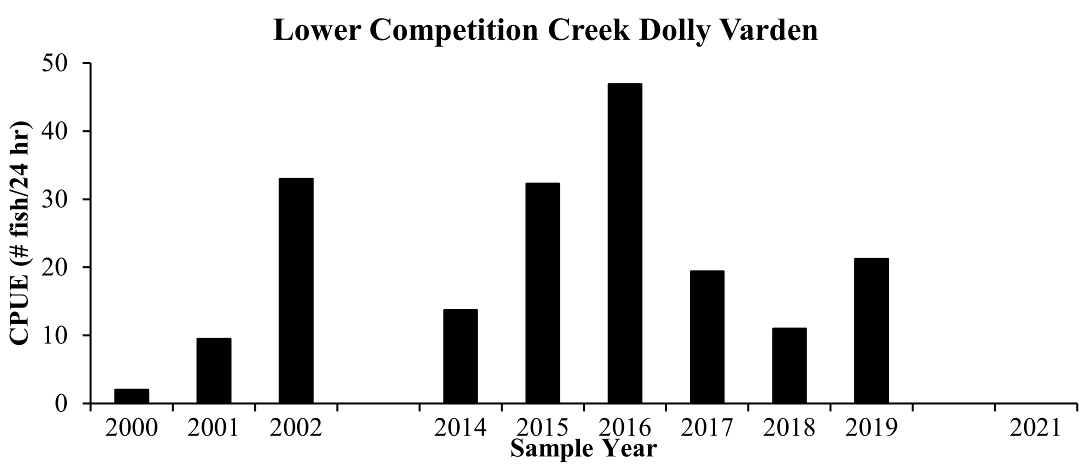

Figure 19. Catch per unit of effort for juvenile Dolly Varden in Lower Competition Creek. No sampling occurred in 2020.

The length frequency distribution of juvenile Dolly Varden in Lower Competition Creek is presented in Figure 20. 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). Data presented in Figure 20 include the minnow trap and the fyke net catches. Length frequency distribution is similar between the two sample periods (2000-2002 and 2014-2021).

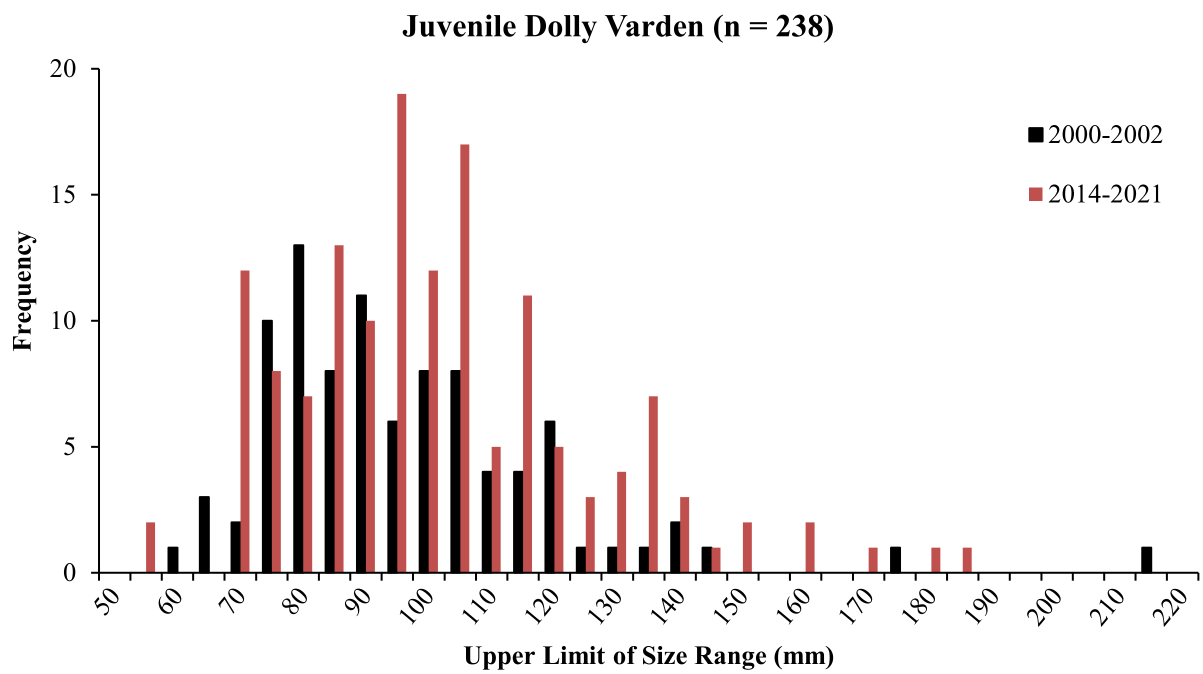

Figure 20. Length frequency distribution of Dolly Varden in Lower Competition Creek.

Juvenile Dolly Varden were retained from Lower Competition Creek from 2015-2017 for whole body element concentration (cadmium, lead, selenium, zinc, and mercury). These data were compared with Dolly Varden collected in Mainstem Red Dog and Anxiety Ridge creeks (Figures 21 to 25) 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. Mercury concentrations were similar in Competition and Red Dog creeks, and slightly higher in Anxiety Ridge Creek (Figures 21 to 25).

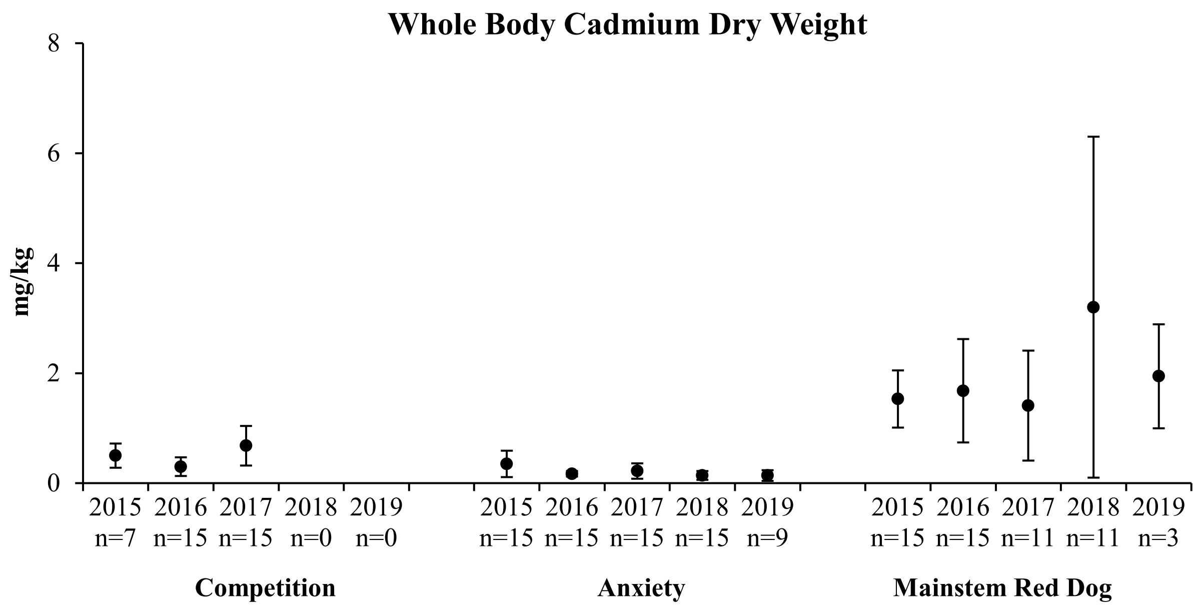

Figure 21. Average cadmium concentrations (± 1SD) in juvenile Dolly Varden collected from Competition, Anxiety Ridge, and Mainstem Red Dog creeks, 2015 - 2019.

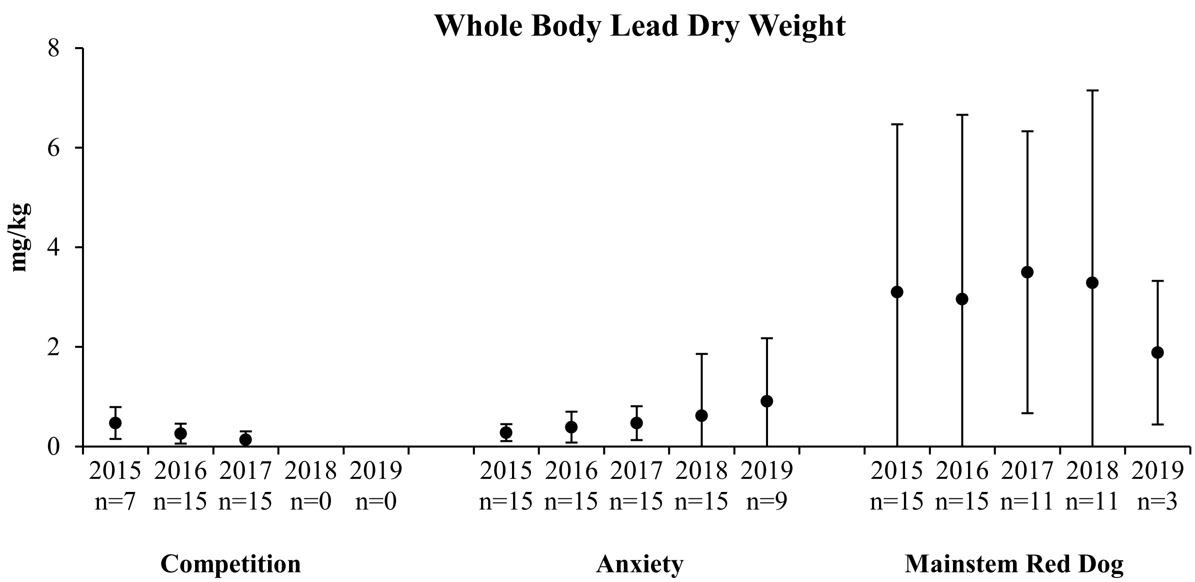

Figure 22. Average lead concentrations (± 1SD) in juvenile Dolly Varden collected from Competition, Anxiety Ridge, and Mainstem Red Dog creeks, 2015 - 2019.

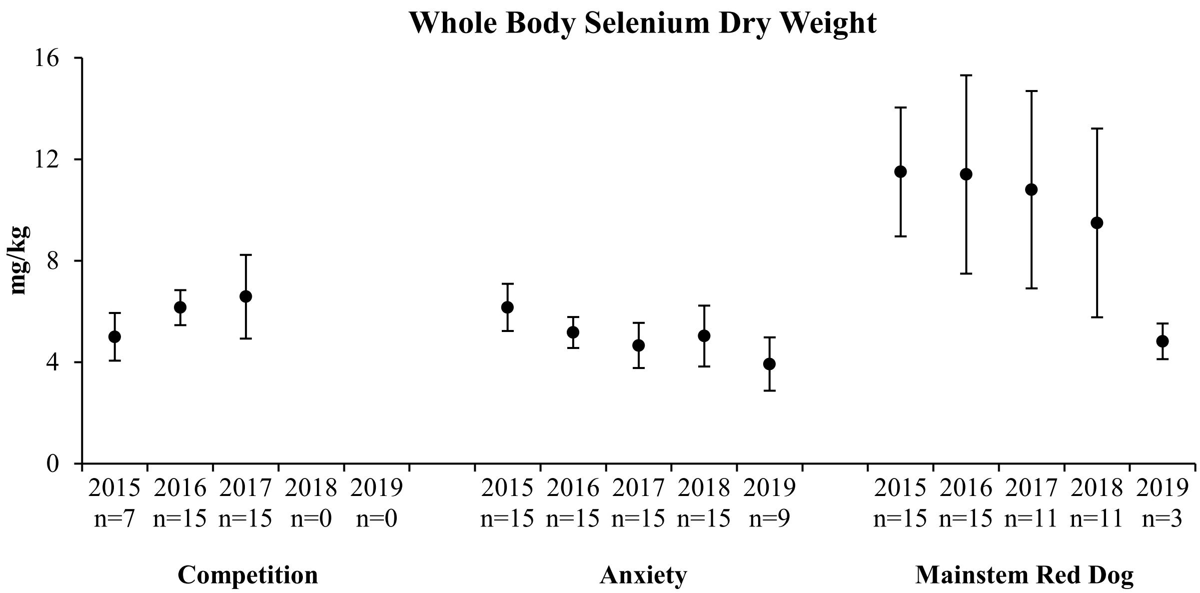

Figure 23. Average selenium concentrations (± 1SD) in juvenile Dolly Varden collected from Competition, Anxiety Ridge, and Mainstem Red Dog creeks, 2015 - 2019.

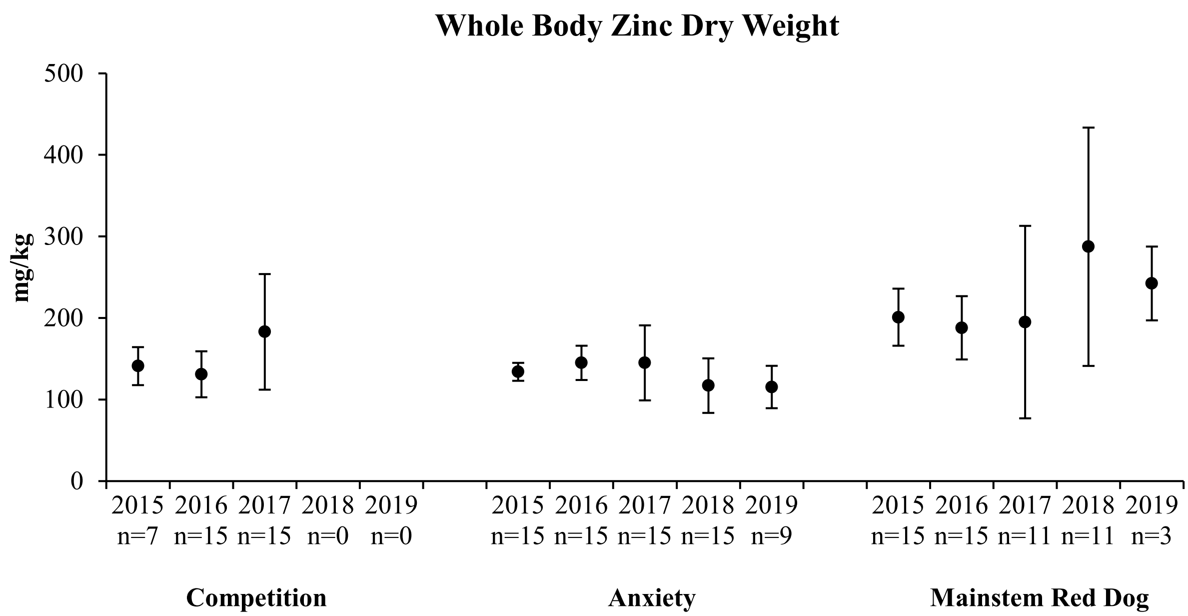

Figure 24. Average zinc concentrations (± 1SD) in juvenile Dolly Varden collected from Competition, Anxiety Ridge, and Mainstem Red Dog creeks, 2015 - 2019.

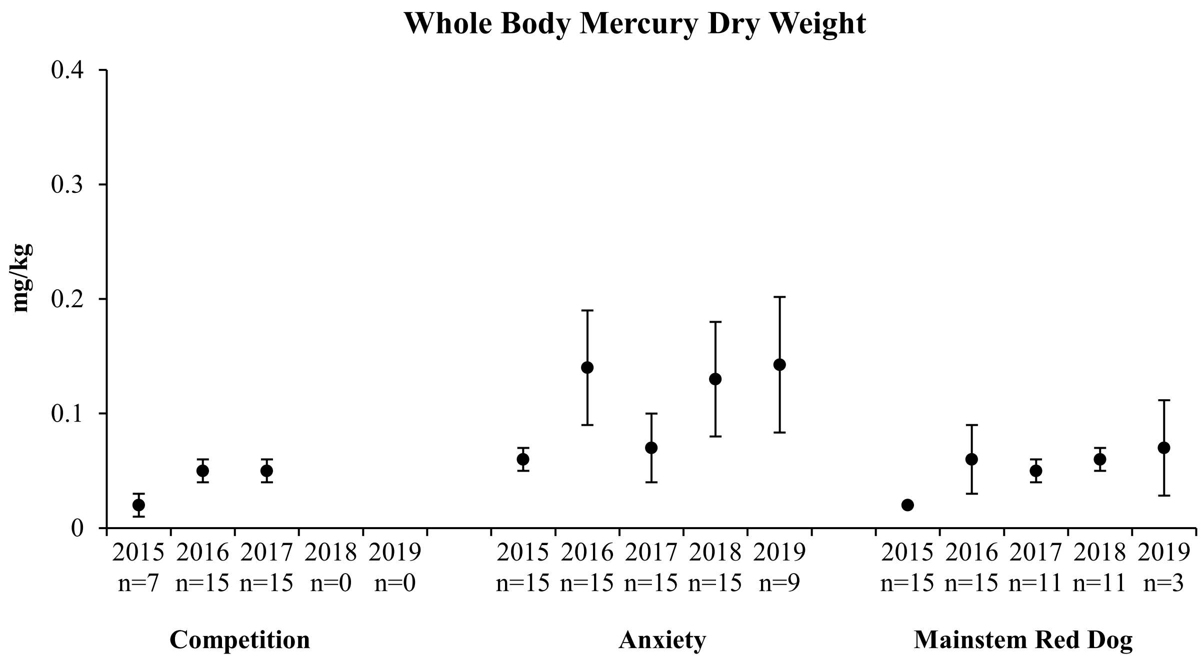

Figure 25. Average mercury concentrations (± 1SD) in juvenile Dolly Varden collected from Competition, Anxiety Ridge, and Mainstem Red Dog creeks, 2015 - 2019.

West Fork Ikalukrok Creek (Station 205)

Water Quality

From 2000-2002, West Fork Ikalukrok Creek (Figures 1 and 26) had a relatively high water hardness combined with low alkalinity and higher concentrations of sulfate, which indicated that this system was dominated by calcium sulfate rather than calcium bicarbonate (Weber Scannell and Ott 2006). From 2000 to 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 26). This precipitate was more pronounced in 2020 than in previous years (Figure 26). There was also red staining on the rocks in West Fork Ikalukrok Creek.

Figure 26. 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 the photos.

Periphyton

In West Fork Ikalukrok Creek, the average chlorophyll-a concentrations from 2015 through 2021 were generally lower than those found from 2000 to 2002 (Figure 27). Average chlorophyll-a concentration varied from a low of 0.04 mg/m^2 in 2018 to a high of 3.45 mg/m^2 in 2002.

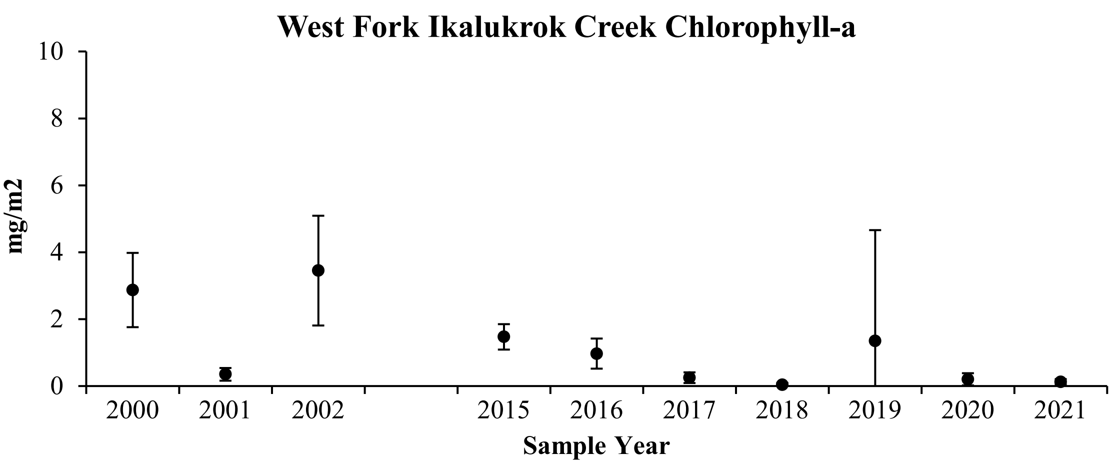

Figure 27. Average concentration of chlorophyll-a (± 1SD) in West Fork Ikalukrok Creek.

Invertebrates

Average aquatic invertebrate density was very low in 2021 at 0.5 invertebrates/m^3 of water. The average number of aquatic invertebrates per m^3 of water in West Fork Ikalukrok Creek was low (<2 invertebrates/m^3) from 2000 to 2002, higher from 2015 to 2019, and low again in 2021 (Figure 28). 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 seven of the nine years (Figure 29). Taxa richness varied from 15 to 25 taxa per site over the sample years (Figure 30).

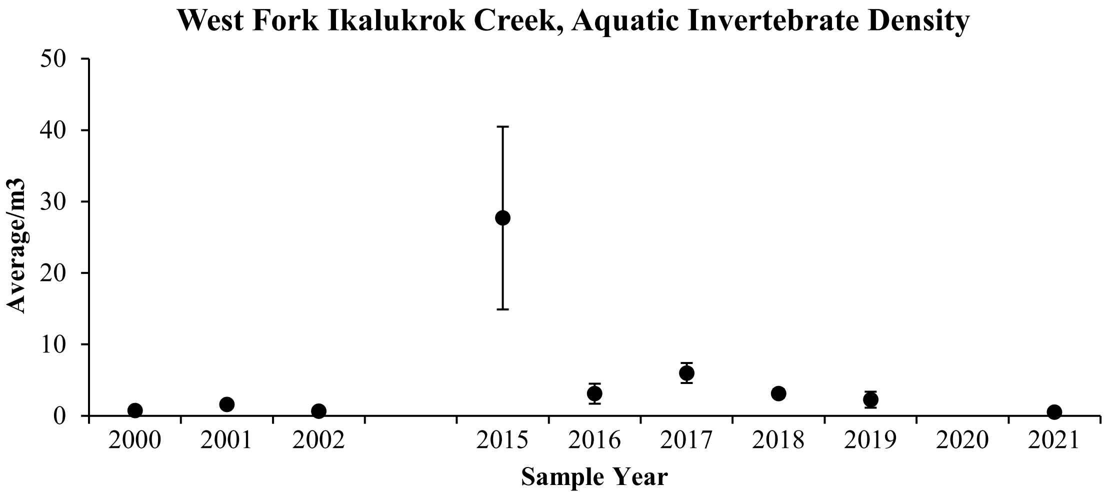

Figure 28. Average aquatic invertebrate densities (± 1SD) in West Fork Ikalukrok Creek.

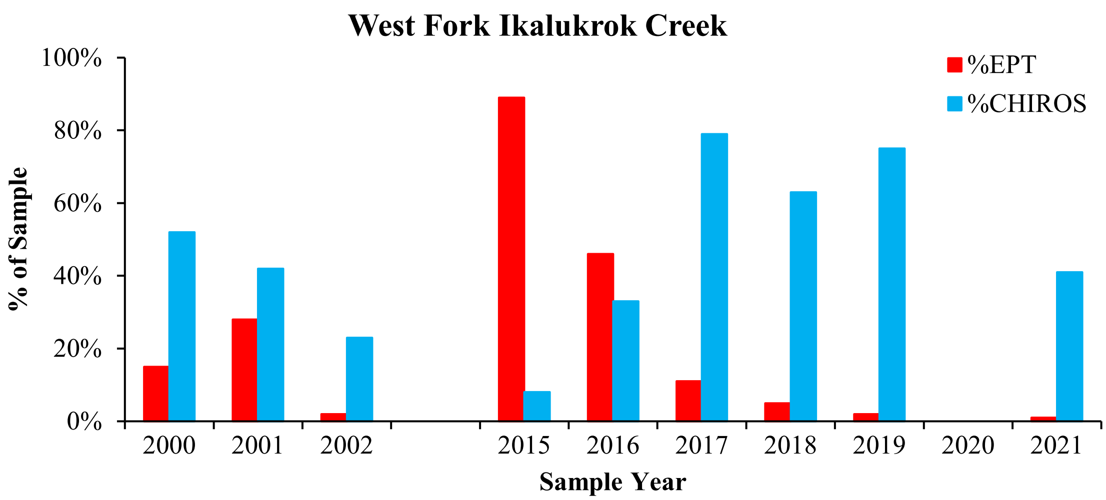

Figure 29. Percent Chironomidae and EPT in West Fork Ikalukrok Creek.

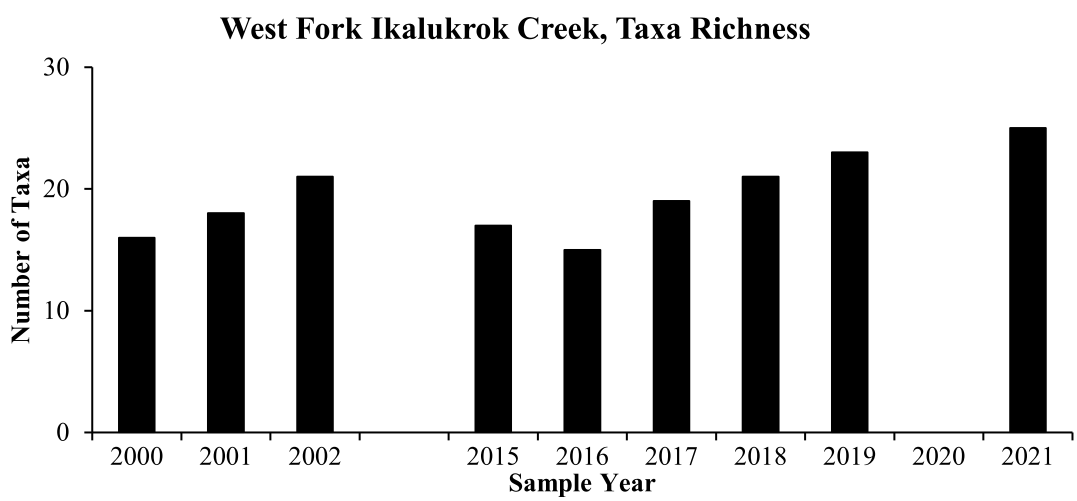

Figure 30. Aquatic invertebrate taxa richness in West Fork Ikalukrok Creek.

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 were observed.

Upper Ikalukrok Creek (Station 206)

Water Quality

Upper Ikalukrok Creek (upstream of West Fork Ikalukrok Creek) is a clear water system with fairly good water quality (Weber Scannell and Ott 2006). From 2000 to 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 (Figure 31). 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 31). Water clarity was better in 2021, although heavy precipitation and increased flows may have diluted existing turbidity.

Figure 31. Ikalukrok Creek immediately upstream of West Fork Ikalukrok Creek in 2020 (left) and 2021 (right).

Periphyton

In Upper Ikalukrok Creek average chlorophyll-a concentrations 2019 - 2021 were very low. Concentrations from 2000 to 2002 and from 2015 to 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 32).

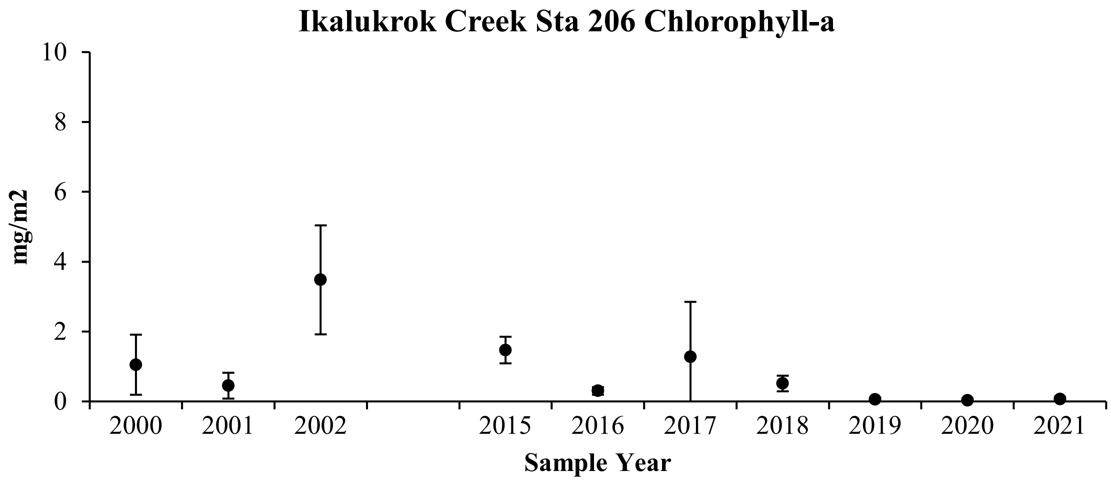

Figure 32. Average concentration of chlorophyll-a (± 1SD) in Upper Ikalukrok Creek.

Invertebrates

In 2021 the aquatic invertebrate density was 13.8 invertebrates/m^3 water. The average number of aquatic invertebrates per m^3 of water in Upper Ikalukrok Creek was moderately high for all years except 2016 when it was extremely high (Figure 33). In 2016, the aquatic invertebrate density was 259.9/m^3 and was primarily composed of mayflies. The percent EPT in two of the six years of sampling greatly exceeded the chironomids (Figure 34), again due to abundant mayflies. The taxa richness varied from a low of 13 taxa in 2002 to a high of 29 taxa in 2021 (Figure 35).

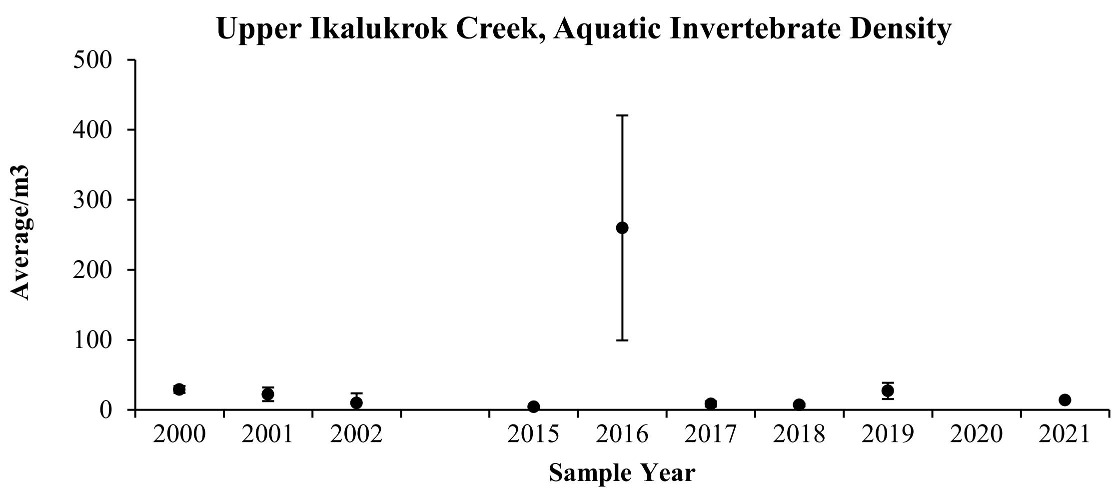

Figure 33. Average aquatic invertebrate densities (± 1SD) in Upper Ikalukrok Creek.

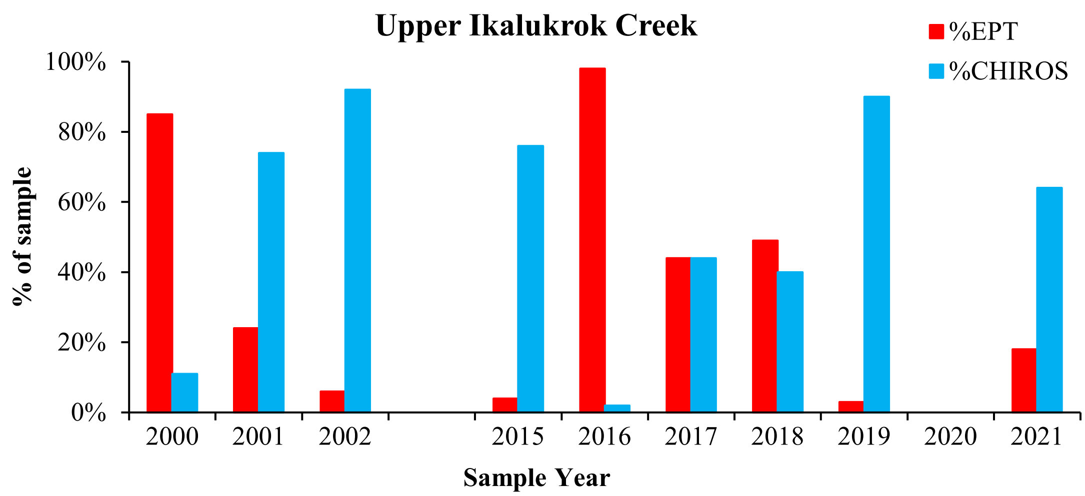

Figure 34. Percent Chironomidae and EPT in Upper Ikalukrok Creek.

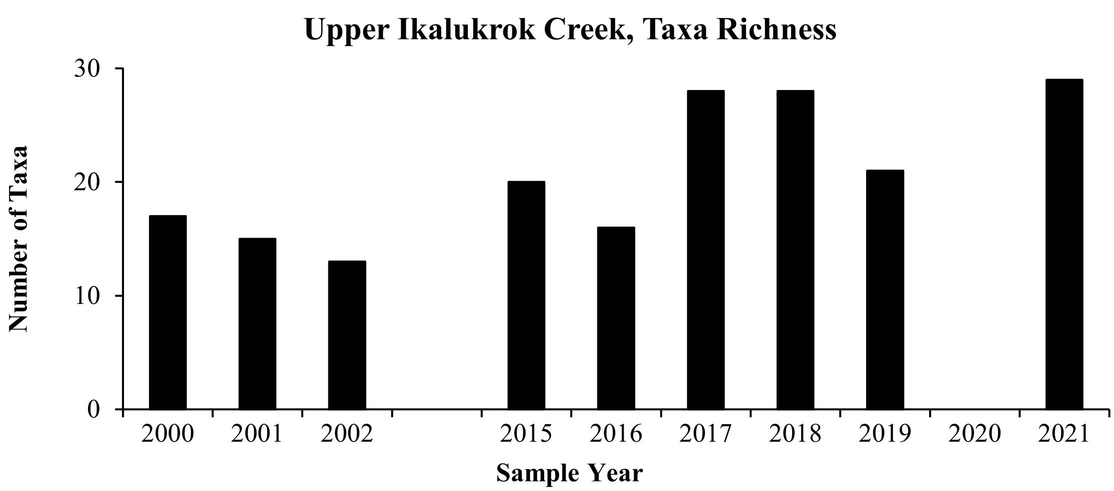

Figure 35. Aquatic invertebrate taxa richness in Upper Ikalukrok Creek.

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 were observed.

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 section of Ikalukrok Creek (Weber Scannell and Ott 2006). The pH of water samples from 2005 – 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 36) 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 to 2019.

Figure 36. Ikalukrok Creek below Cub Creek in 2020 (left), and the Cub Creek seep entering Ikulukrok Creek above the sample site in 2007 (right).

Periphyton

Periphyton samples in 2021 had the highest average chlorophyll-a concentrations since sampling began at 0.11 mg/m^2, which is still extremely low (Figure 37). Samples collected from 1997 to 2002 were mostly below the detection limit. Additional samples were collected in 1997 and 1998 as a part of a Teck Alaska supplemental environmental project (Ott 1997).

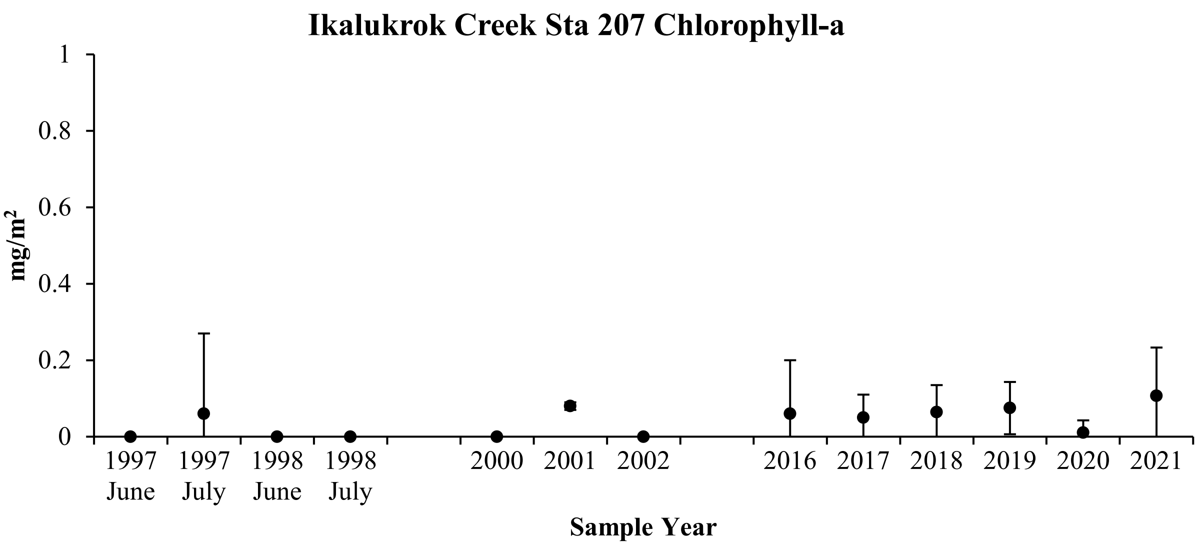

Figure 37. Average concentration of chlorophyll-a (± 1SD) in Ikalukrok Creek downstream of the Cub Creek seep.

Invertebrates

In Ikalukrok Creek aquatic invertebrate density varied from a low of 3.6 invertebrates/m^3 in July 1997 to a high of 28.9 invertebrates/m^3 in 2001 (Figure 38). The percent chironomids generally exceeded the EPT in the earlier sample years, except for the July 1998 sample. In 2016 to 2018 percent EPT was higher than chironomids (Figure 39). The high numbers of mayflies and stoneflies in those years were likely drifting from higher quality habitat in the upper reaches of the system. Taxa richness has been variable, from a low of 10 taxa in 1998 to a high of 29 taxa in 2018 (Figure 40).

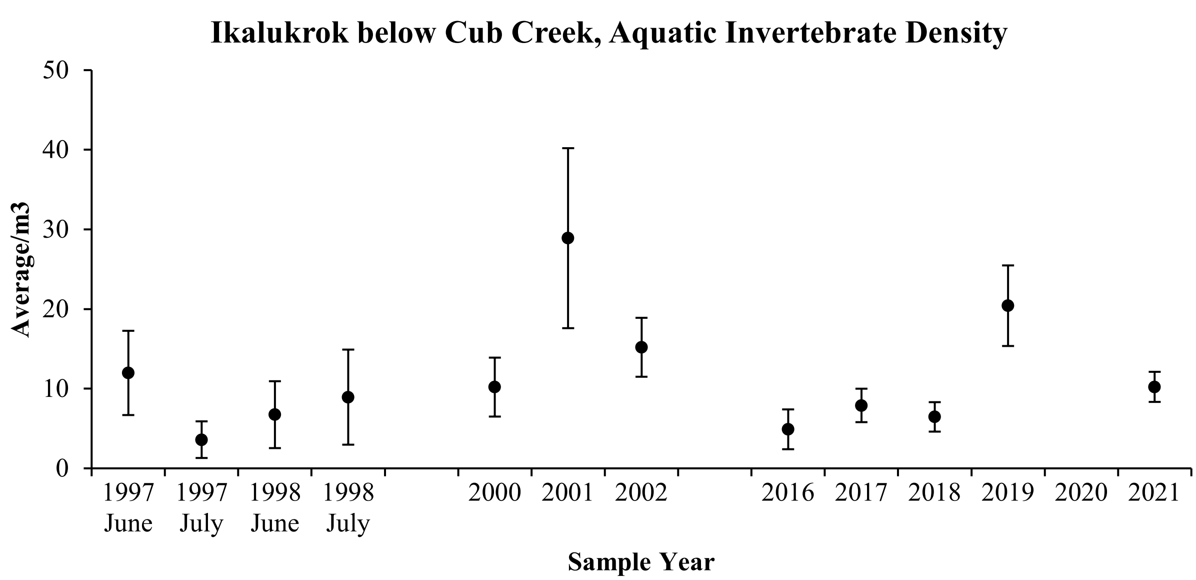

Figure 38. Average aquatic invertebrate densities (± 1SD) in Ikalukrok Creek.

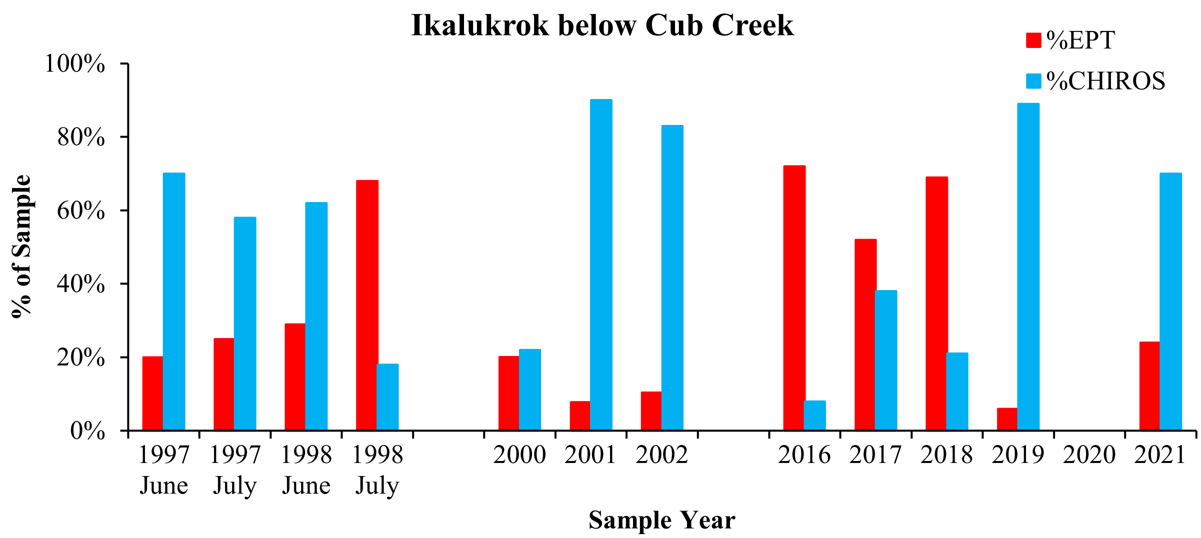

Figure 39. Percent Chironomidae and EPT in Ikalukrok Creek.

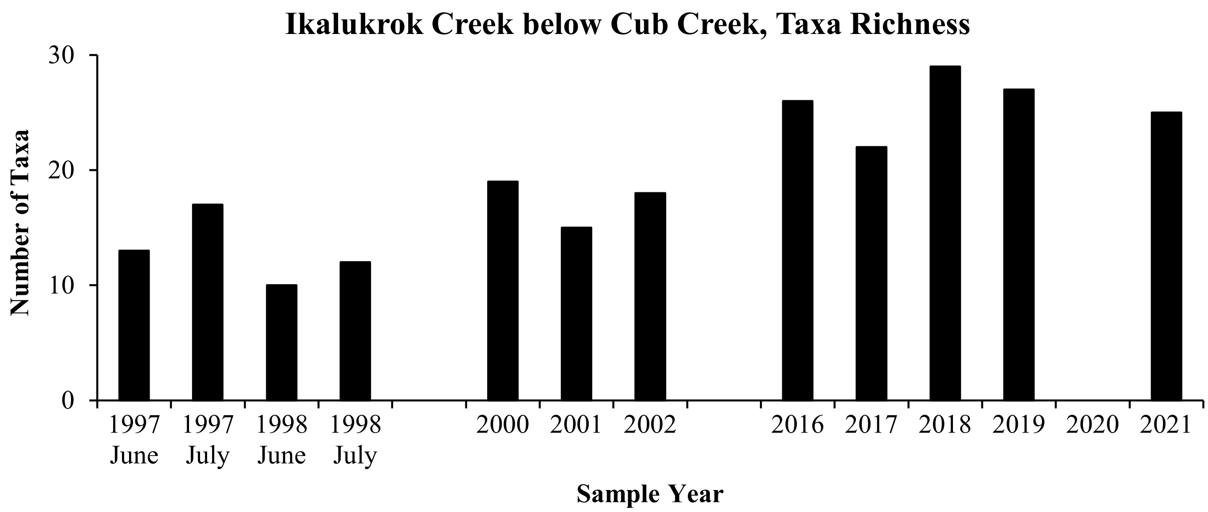

Figure 40. Aquatic invertebrate taxa richness in Ikalukrok Creek.

In addition to the drift net samples, aquatic invertebrates were collected with Hess samplers at Ikalukrok Creek below Cub Creek Seep. The total number of aquatic taxa collected with the Hess sampler was 7, while 25 taxa were found in the drift net samples. Notably, the average number of EPT in each sample decreased from 852 in the drift samples to 2 in the Hess samples. The proportion of EPT in the samples decreased from 24% to 14%, while the percent Chironomidae remained the same at 70 % (Table 2).

Table 2. Aquatic invertebrates collected with drift nets versus Hess sampler at Ikalukrok Creek downstream of Cub Creek Seep, Sta 207.

	Ik u/s Cub Sta 207 Drift	Ik u/s Cub Sta 207 Hess
Total aquatic taxa/site	25	19
Avg #/sample Ephemeroptera	823	1
Avg #/sample Plecoptera	26	1
Avg #/sample Trichop.	3	0
Avg #/sample Aq. Diptera	2663	10
Avg #/sample Misc.Aq.sp	95	2
% other	3%	13%
% Ephemeroptera	23%	10%
% Plecoptera	1%	4%
% Trichoptera	0%	0%
% Aq. Diptera	74%	73%
% EPT	24%	14%
% Chironomidae	70%	70%
% Dominant Taxon	65%	68%
Total aquatic inverts	18048	71
Total terrestrial inverts	5651	15
Total invertebrates	23699	86
% Sample aquatic	76%	83%
% Sample terrestrial	24%	17%

Fish

During the 2000 sampling event, one lethargic adult Arctic grayling was observed in Ikalukrok Creek near Station 207 (Weber Scannell and Ott 2006). However since then no fish have been caught or observed in this section of Ikalukrok Creek. 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 were observed.

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 41). 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). Extensive aufeis occurs in the canyon-like area above the sample site.

Figure 41. Sample site on East Fork Ikalukrok Creek (2021).

Periphyton

Average chlorophyll-a concentration in 2021 was the lowest ever observed in East Fork Ikalukrok Creek 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 were lower in 2019 – 2021 than in previous years (Figure 41).

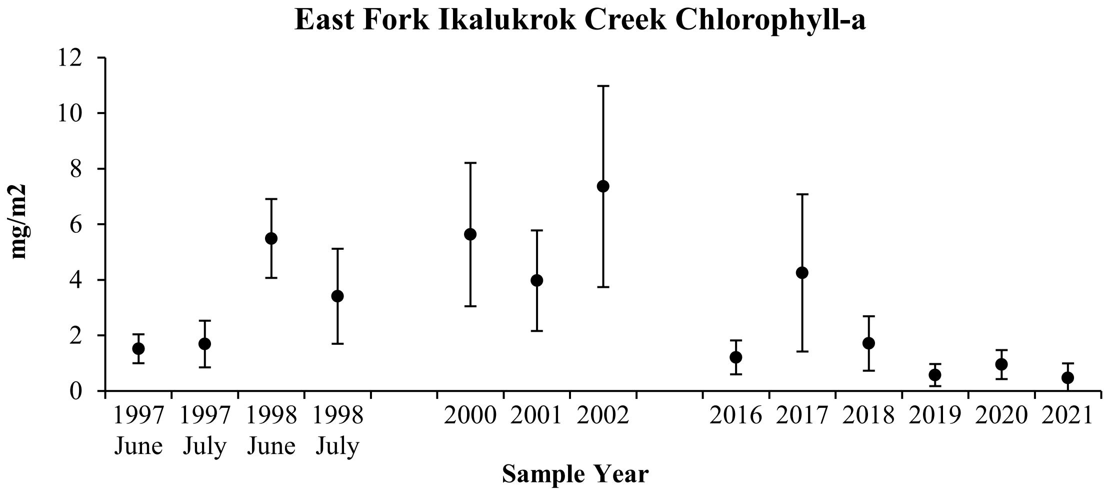

Figure 42. Average concentration of chlorophyll-a (± 1SD) in East Fork Ikalukrok Creek.

Invertebrates

Aquatic invertebrate density in East Fork Ikalukrok Creek varied from a low of 0.7 invertebrates/m^3 in 2002 to a high of 43.68 invertebrates/m^3 in 2021 (Figure 43). Generally, the average aquatic invertebrate density was high during all sample events except July 2002. The percent chironomids exceeded the EPT in most of the samples except July 1997 and July 1998 (Figure 44). 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 45).

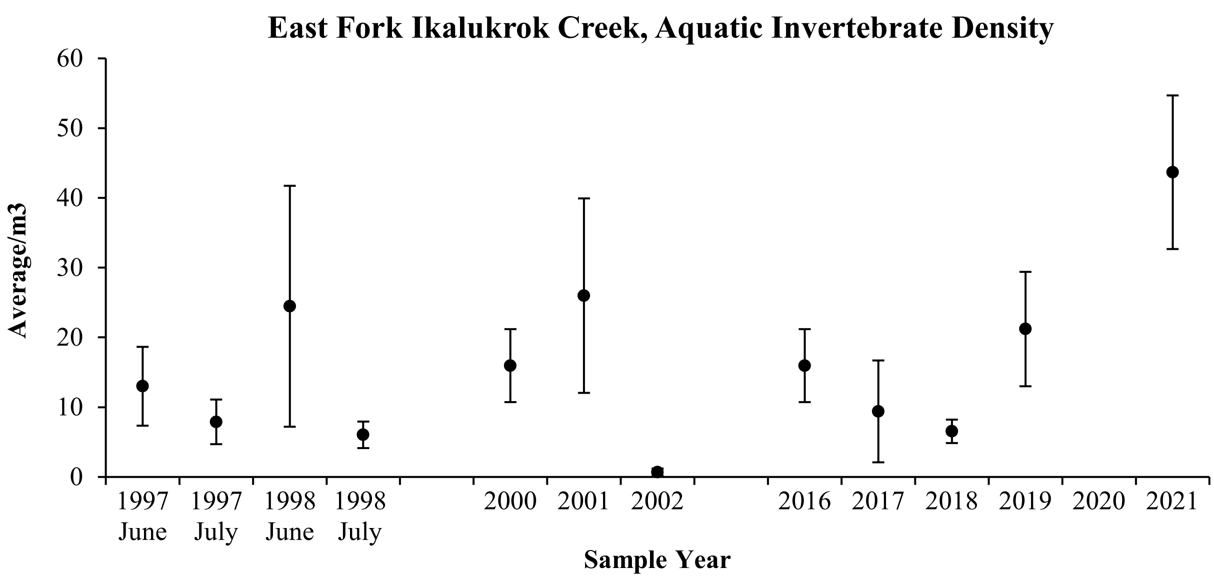

Figure 43. Average aquatic invertebrate densities (± 1SD) in East Fork Ikalukrok Creek.

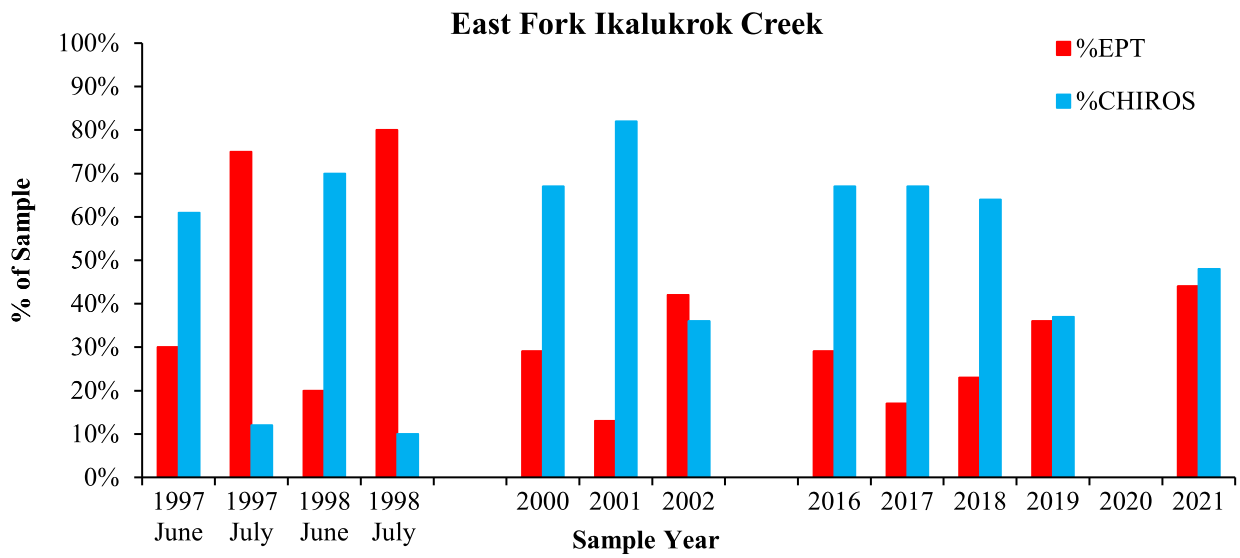

Figure 44. Percent Chironomidae and EPT in East Fork Ikalukrok Creek.

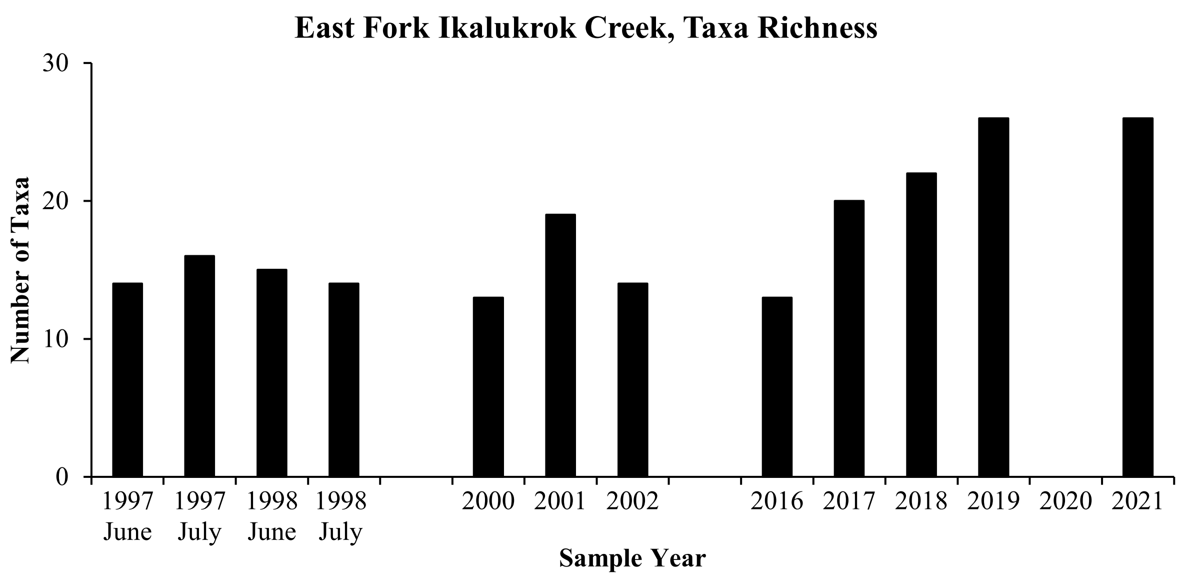

Figure 45. Aquatic invertebrate taxa richness in East Fork Ikalukrok Creek.

In addition to the drift net samples, aquatic invertebrates were collected with Hess samplers at Ikalukrok Creek below Cub Creek Seep. The total number of aquatic taxa collected with the Hess sampler was 16, while 26 taxa were found in the drift net samples. The overall proportion of EPT increased from 44% to 64% with the Hess sampler, while Chironomidae decreased from 48% to 9% (Table 3). The differences between the drift net and Hess results were not as pronounced at the East Fork Ikalukrok sample site as compared to the Ikalukrok downstream of Cub Creek sample site. This could be because the in situ conditions at Sta 208 are similar to the conditions upstream of the sample site, while the conditions at Sta 207 are markedly different than the waters upstream of Cub Creek Seep.

Table 3. Aquatic invertebrates collected with drift nets versus Hess sampler at East Fork Ikalukrok Creek, Sta 208.

	EF Ik Sta 208 Drift	EF Ik Sta 208 Hess
Total aquatic taxa/site	26	16
Avg #/sample Ephemeroptera	1023	112
Avg #/sample Plecoptera	170	27
Avg #/sample Trichop.	0	0
Avg #/sample Aq. Diptera	1419	30
Avg #/sample Misc.Aq.sp	113	49
% other	4%	23%
% Ephemeroptera	38%	51%
% Plecoptera	6%	13%
% Trichoptera	0%	0%
% Aq. Diptera	52%	14%
% EPT	44%	64%
% Chironomidae	48%	9%
% Dominant Taxon	36%	36%
Total aquatic inverts	13644	1089
Total terrestrial inverts	921	8
Total invertebrates	14565	1097
% Sample aquatic	94%	99%
% Sample terrestrial	6%	1%

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, from 2000 to 2002 (two sampling events per year), and in 2016 to 2021 (Figure 46). Juvenile Dolly Varden were captured most frequently, but two slimy sculpin (81 and 108 mm) were also caught in 2016. No fish were caught in 2020 or 2021. Additional minnow trapping occurred in late August 2021, but again, no fish were captured.

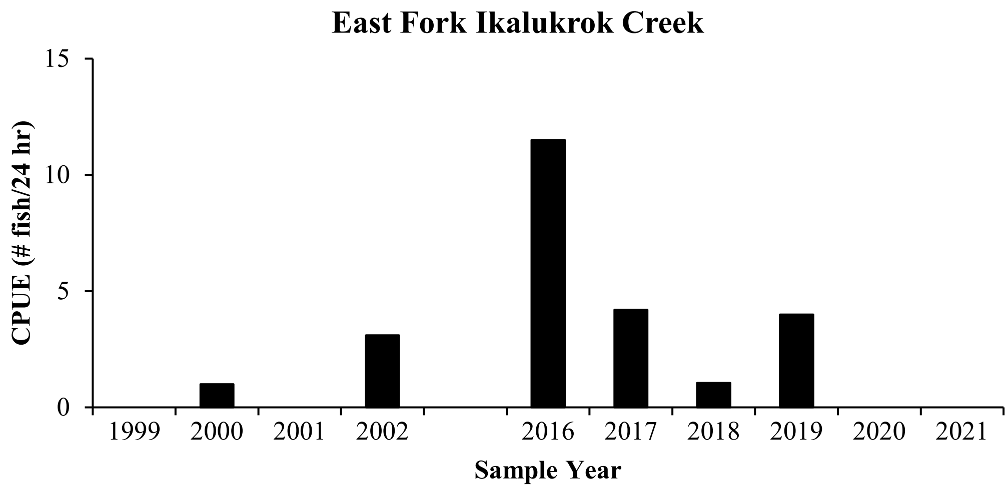

Figure 46. Catch per unit of effort for juvenile Dolly Varden in East Fork Ikalukrok Creek.

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 were observed.

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. It is the first major tributary entering Ikalukrok Creek from the east after the East Fork Ikalukrok and Ikalukrok creeks merge (Figures 1 and 47). 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. Water clarity improved in 2021, although not to the same clarity prior to 2020.

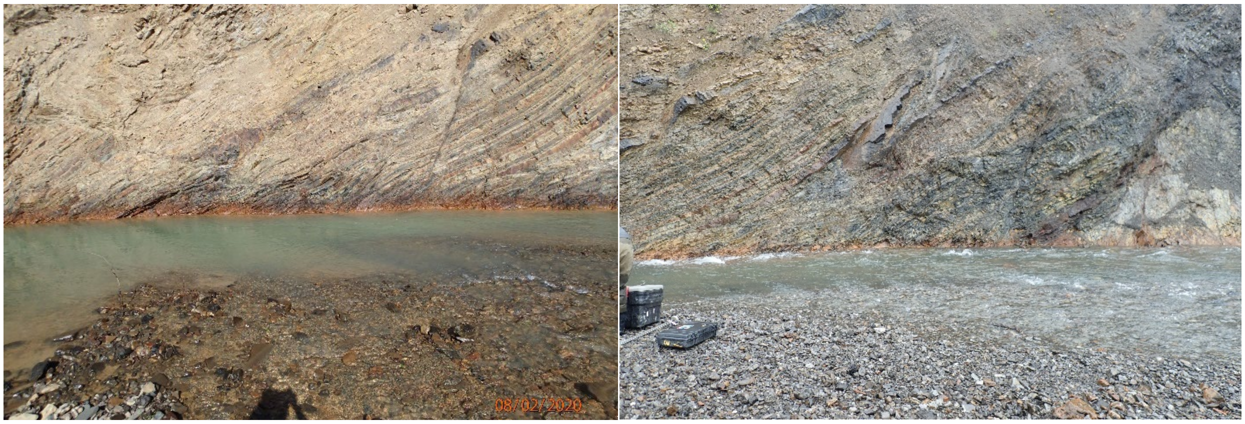

Figure 47. Grayling Junior Creek in 2020 (left) and 2021 (right).

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 48). Chlorphyll-a concentration in 2021 was slightly higher than 202 at 0.06 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.

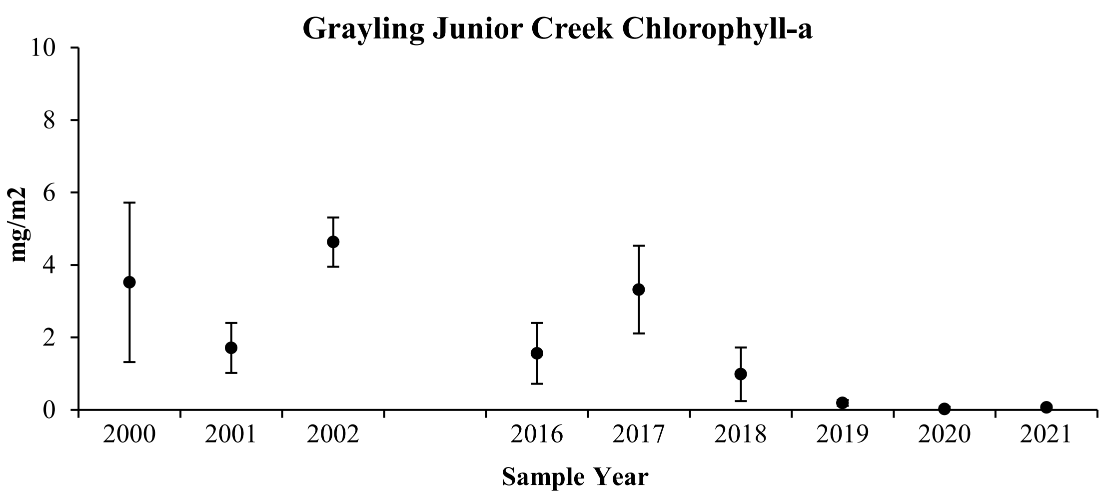

Figure 48. Average concentration of chlorophyll-a (± 1SD) in Grayling Junior Creek.

Invertebrates

Aquatic invertebrate density in Grayling Junior Creek varied from a low of 2.8 invertebrates/m^3 in 2019 to a high of 11.6 invertebrates/m^3 in 2000 (Figure 49). The EPT was composed of mayflies and stoneflies with no caddisflies. In all sample years, the percent chironomids exceeded the percent EPT (Figure 50). Taxa richness was variable among sample events, varying from a low of 10 taxa in 2000 to a high of 29 taxa in 2019 (Figure 51).

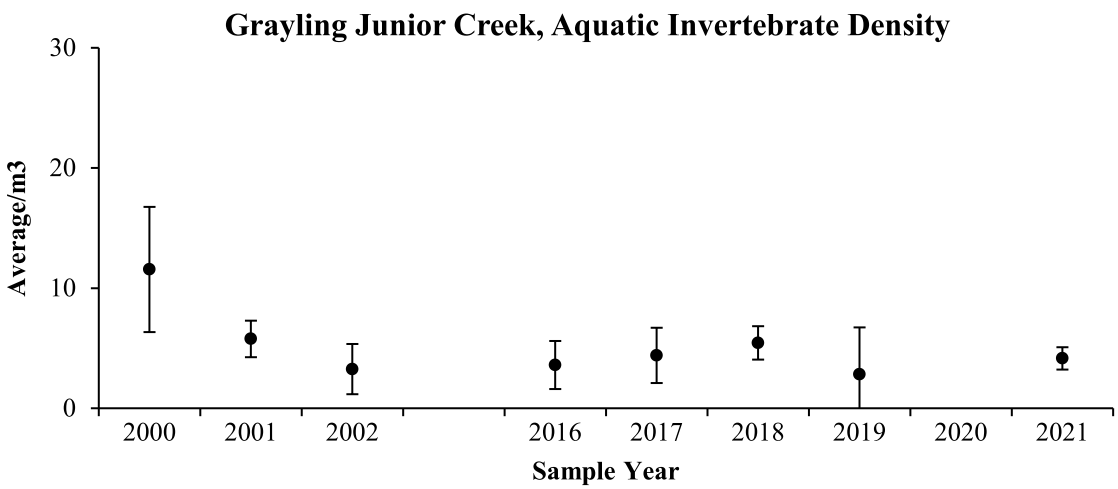

Figure 49. Average aquatic invertebrate densities (± 1SD) in Grayling Junior Creek.

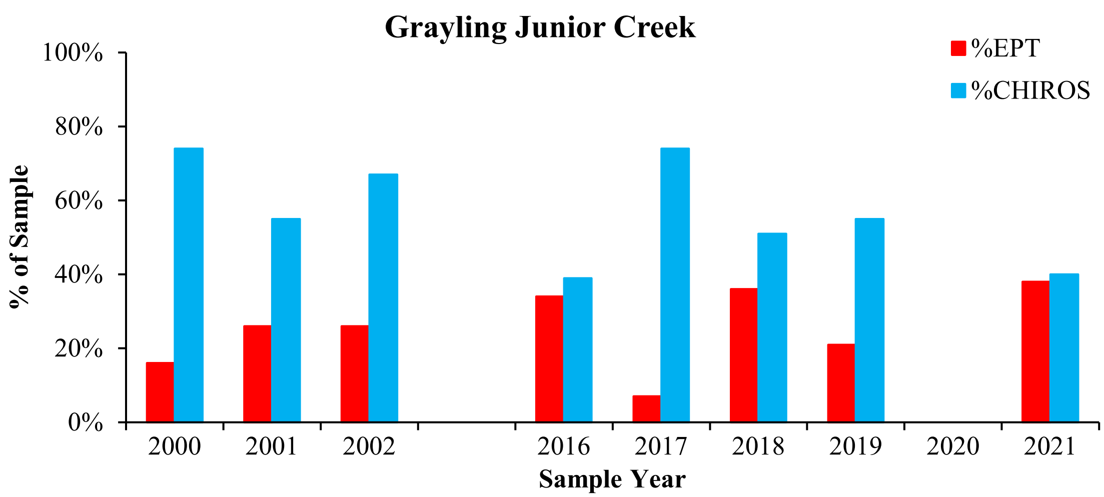

Figure 50. Percent Chironomidae and EPT in Grayling Junior Creek.

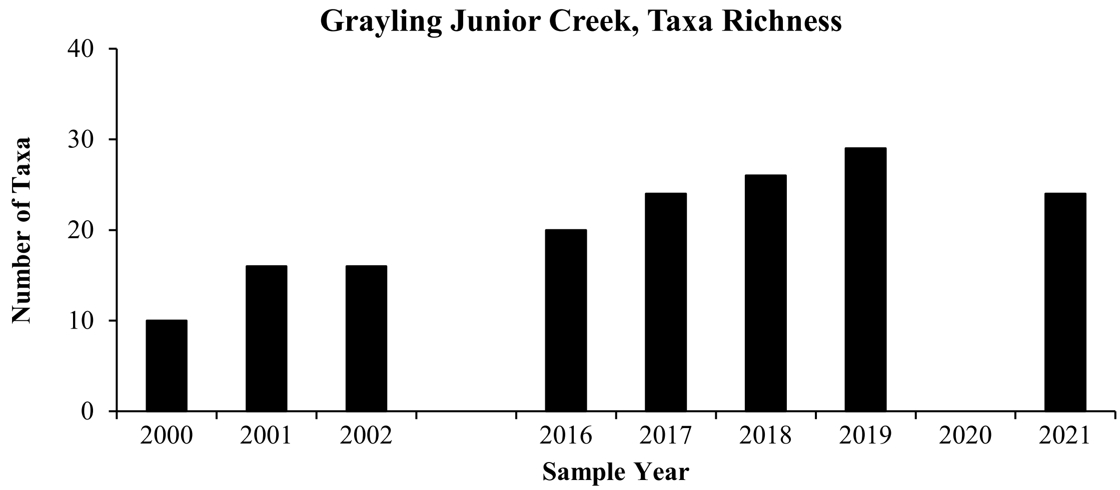

Figure 51. Aquatic invertebrate taxa richness in Grayling Junior Creek.

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 52). Mark-recapture sampling indicated that Arctic grayling moved between the Red Dog Creek drainage and Ikalukrok Creek drainage including Grayling Junior Creek.

Figure 52. Arctic grayling at the confluence of Grayling Junior and Ikalukrok creeks, 1999.

Fish were sampled with minnow traps in Grayling Junior Creek from 2000 to 2002, 2004, and 2016 to 2021 (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 53). One Dolly Varden was captured in the early August 2021 sampling event, and one Dolly Varden was captured in the late August 2021 sampling. Slimy sculpin were also captured periodically in the minnow traps. Length frequency distribution of Dolly Varden is shown in Figure 54. Based on length, the majority of these fish are likely age 1 and 2 with multiple age classes for the larger fish (≥ 120 mm).

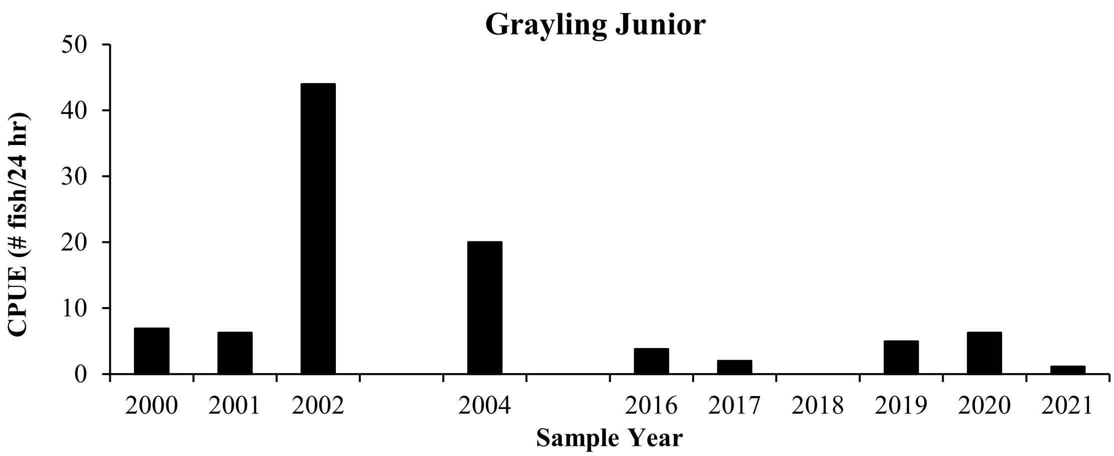

Figure 53. Catch per unit of effort for juvenile Dolly Varden in Grayling Junior Creek.

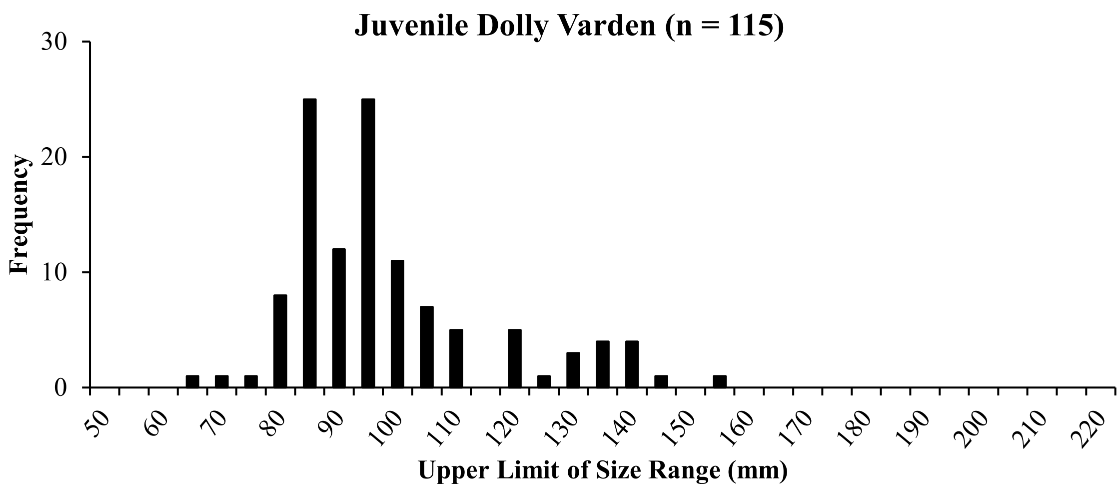

Figure 54. Length frequency distribution of Dolly Varden in Grayling Junior Creek.

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 55). 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.

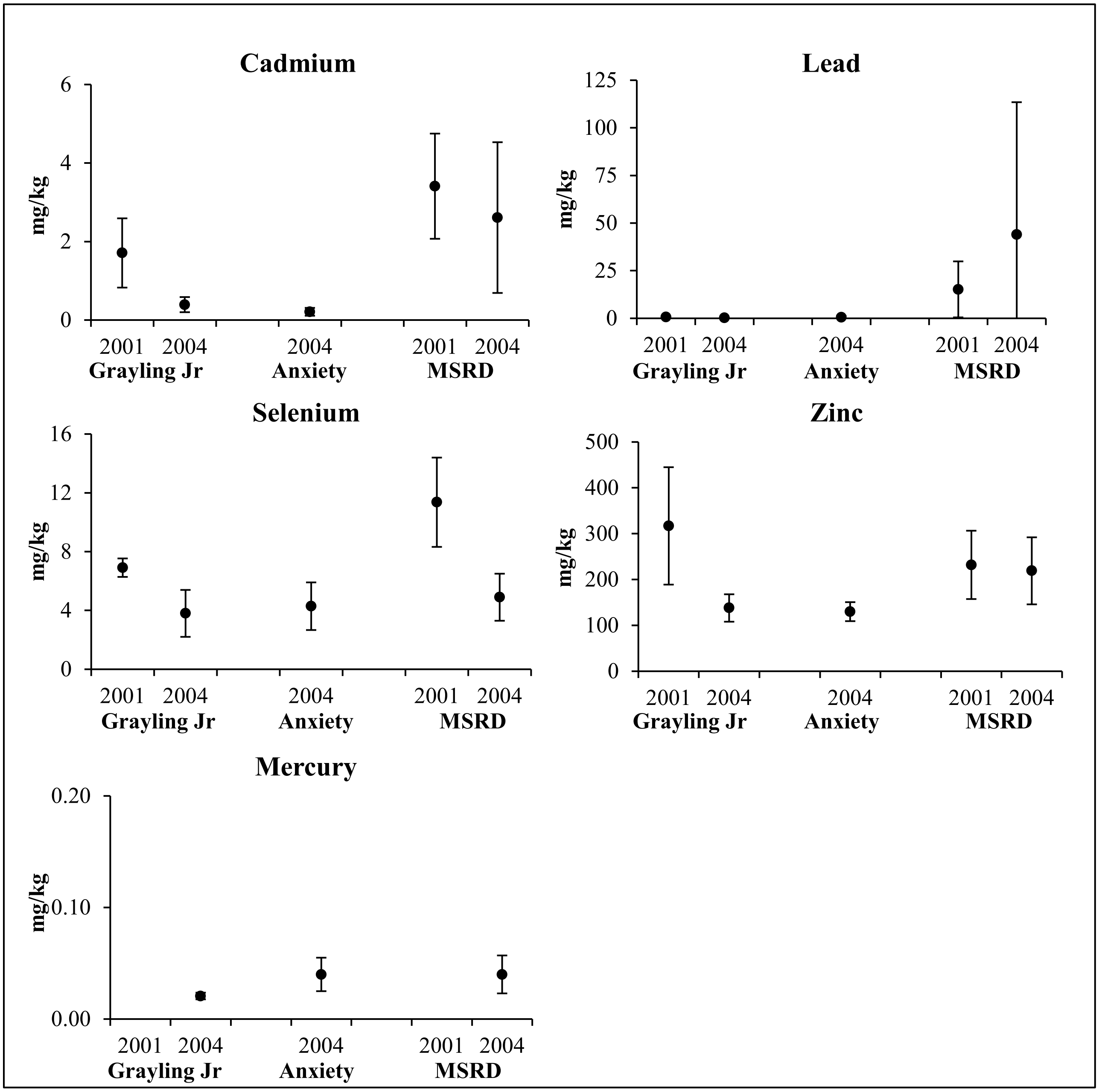

Figure 55. Average dry weight whole body element concentrations (± 1SD) in juvenile Dolly Varden collected from Grayling Junior, Anxiety Ridge, and Mainstem Red Dog (MSRD) creeks, note that samples were not tested for mercury in 2001. Fish catches in 2001 in Anxiety Ridge Creek were very low, and no 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 were observed.

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 and incised with breakup flows of about 20 cfs and has dense riparian vegetation (Figure 56). This site was not sampled in 2020.

Figure 56. The mouth of Noa Creek on Ikalukrok Creek in 2018 (left) and the sample site on Noa Creek just upstream of the mouth in 2021 (right).

Periphyton

Average chlorophyll-a concentrations in Noa Creek have been low, ranging from 0.075 mg/m^2 in 2019 to 0.58 mg/m^2 in 2021 (Figure 57).

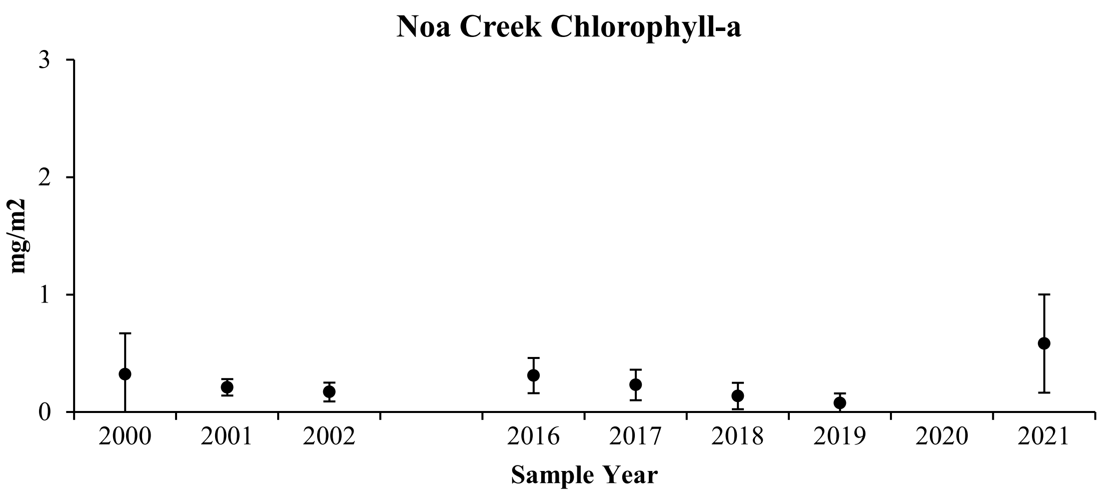

Figure 57. Average concentration of chlorophyll-a (± 1SD) in Noa Creek.

Invertebrates

Aquatic invertebrate density has varied from a low of 0.78 invertebrates/m^3 in 2019 to a high of 38.1 invertebrates/m^3 in 2002. Samples were generally dominated by aquatic diptera (Figure 58). EPT was virtually absent from the samples (Figure 59). Taxa richness varied from 15 to 23 taxa per site over the sample years (Figure 60).

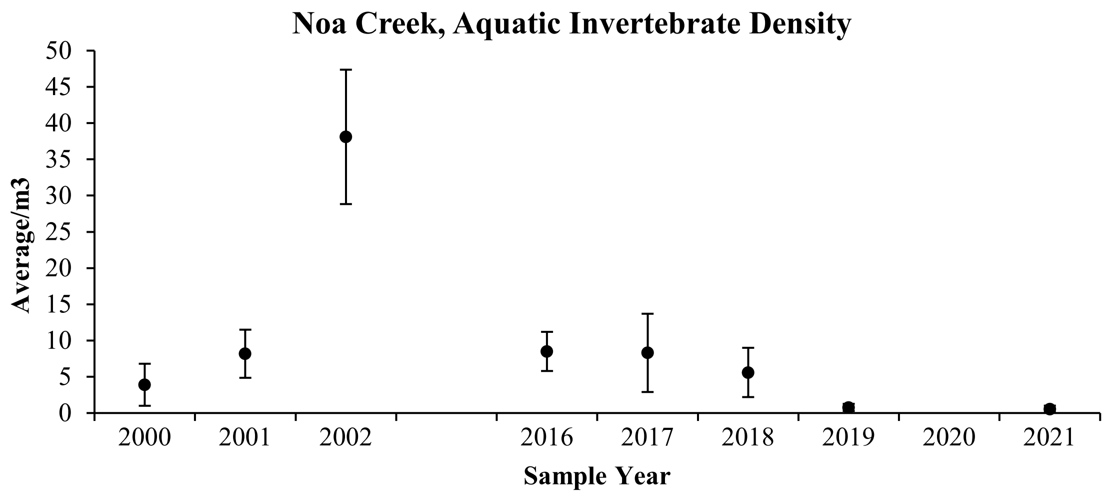

Figure 58. Average aquatic invertebrate densities (± 1SD) in Noa Creek.

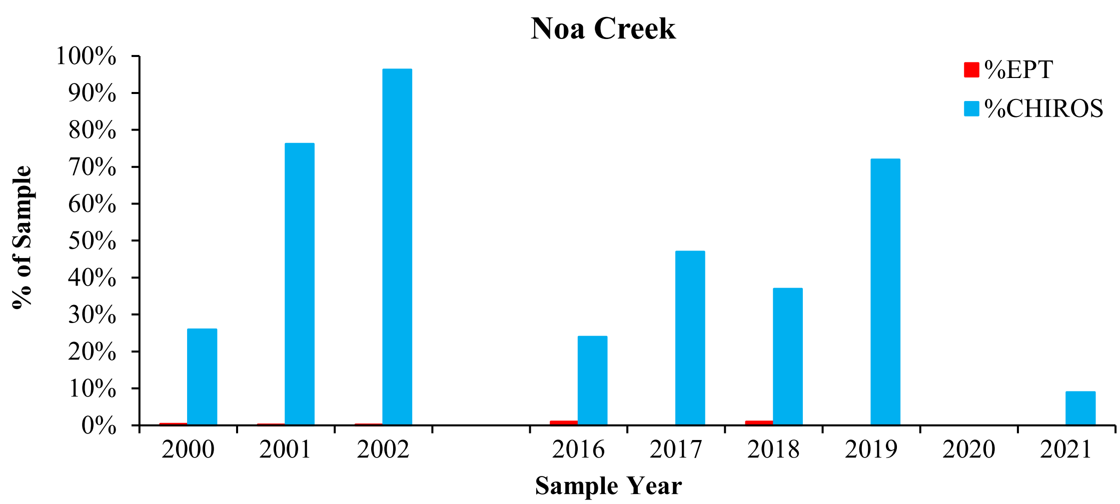

Figure 59. Percent Chironomidae and EPT in Noa Creek.

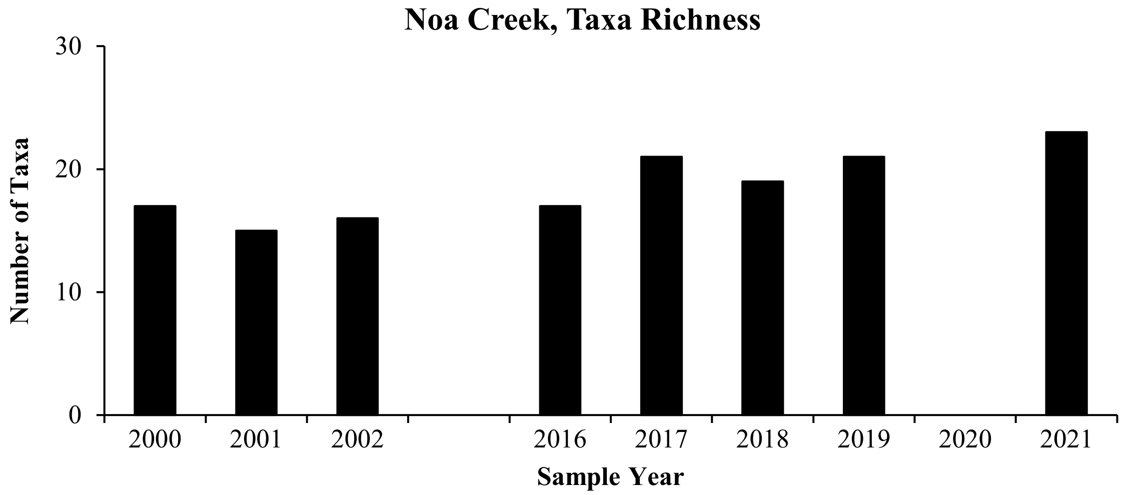

Figure 60. Aquatic invertebrate taxa richness in Noa Creek.

Fish

Fish sampling with minnow traps and visual observations was conducted in Noa Creek from 2000 to 2002 (two sampling days in 2000 and 2001 and one in 2002). Zero fish were caught and none were seen. Noa Creek is connected by surface flow to Ikalukrok Creek, so fish have access to the creek during the ice-free months.

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 61). This site was not sampled in 2020.

Figure 61. The mouth of Moil Creek on Ikalukrok Creek (left) and the sample site upstream on Moil Creek (right), 2021.

Periphyton

Average chlorophyll-a concentrations in Moil Creek were low, ranging from 0 mg/m^2 in 2002 to a high of 0.14 mg/m^2 in 2017 (Figure 62).

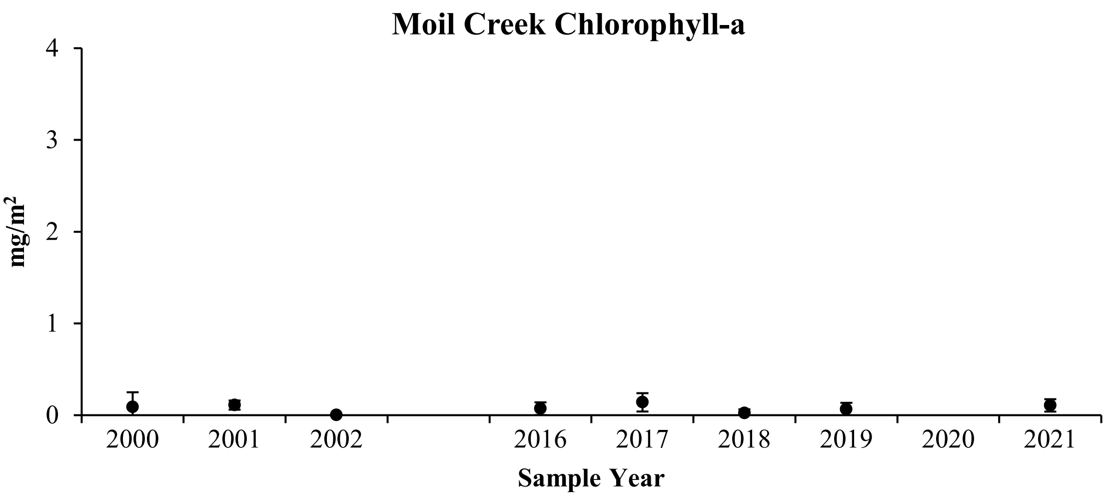

Figure 62. Average concentration of chlorophyll-a (± 1SD) in Moil Creek.

Invertebrates

Aquatic invertebrate density in Moil Creek varied from a low of 0.7 invertebrates/m^3 in 2000 to a high of 6.5 invertebrates/m^3 in 2002 and was dominated by aquatic diptera and miscellaneous aquatic species (Figure 63). EPT was virtually absent from the samples (Figure 64). Taxa richness varied from 13 to 24 taxa per site over the sample years (Figure 65).

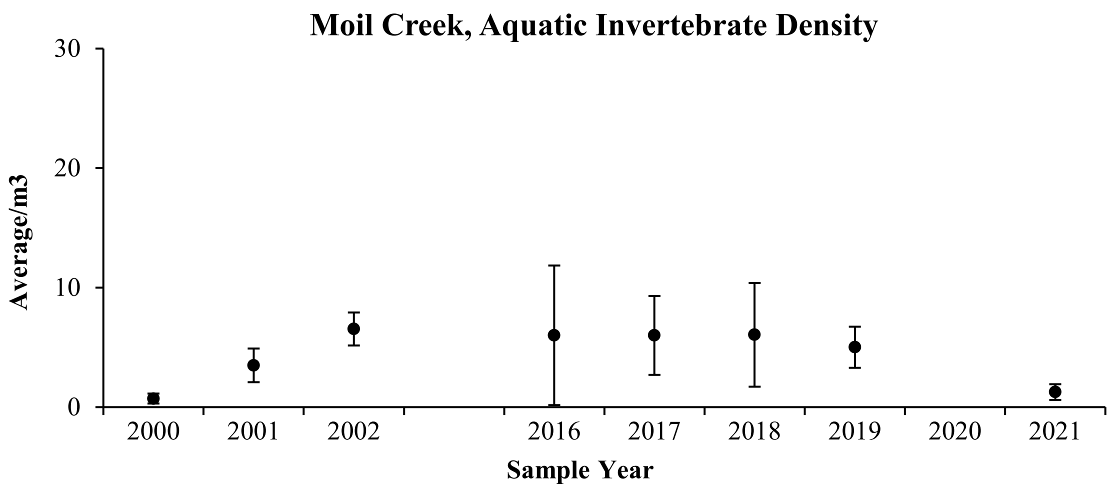

Figure 63. Average aquatic invertebrate densities (± 1SD) in Moil Creek.

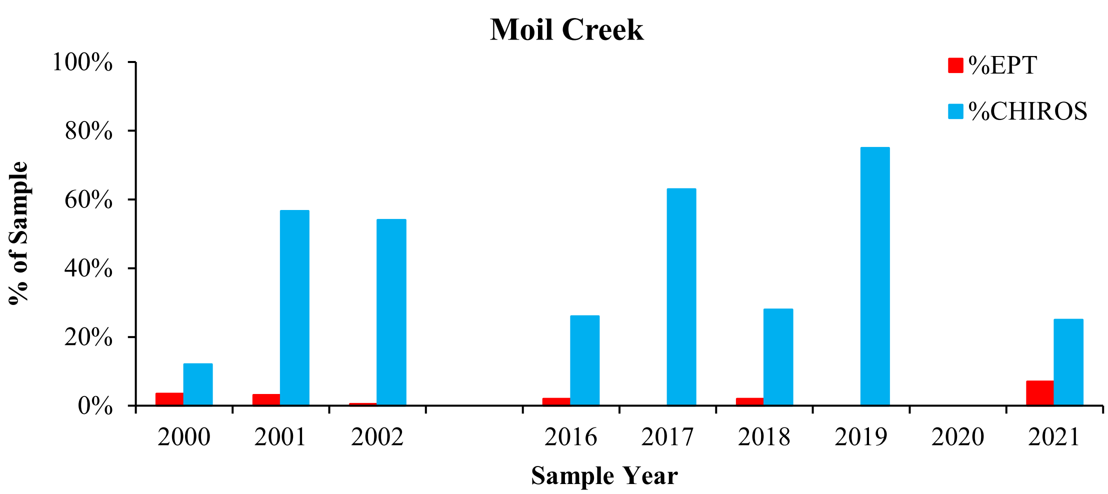

Figure 64. Percent Chironomidae and EPT in Moil Creek.

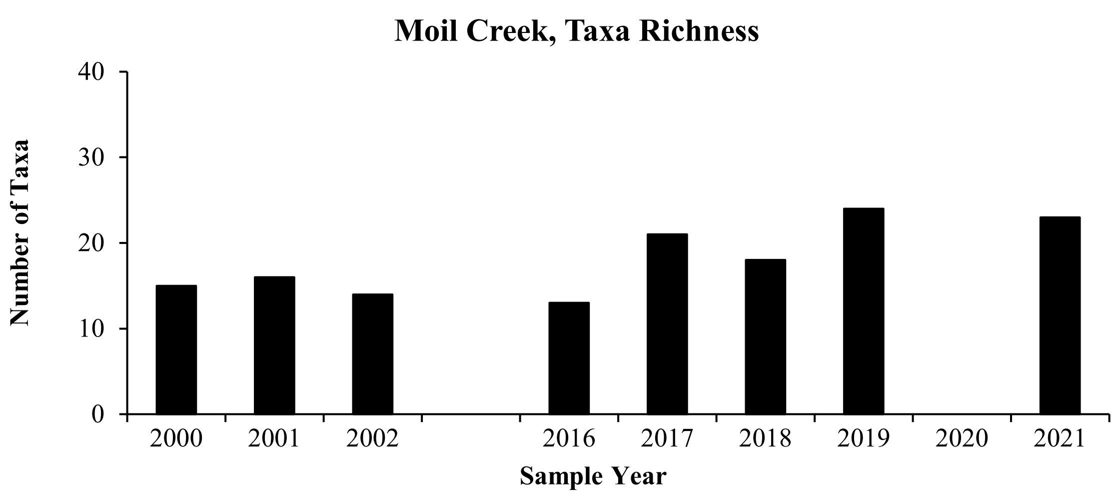

Figure 65. Aquatic invertebrate taxa richness in Moil Creek.

Fish

Fish sampling with minnow traps, including visual observations, was conducted in Moil Creek from 2000 to 2002 (two sampling days in 2000 and 2001 and one in 2002). No fish were caught and none were seen. 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.

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 66).

Figure 66. Sled Creek on 7/9/21.

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 67).

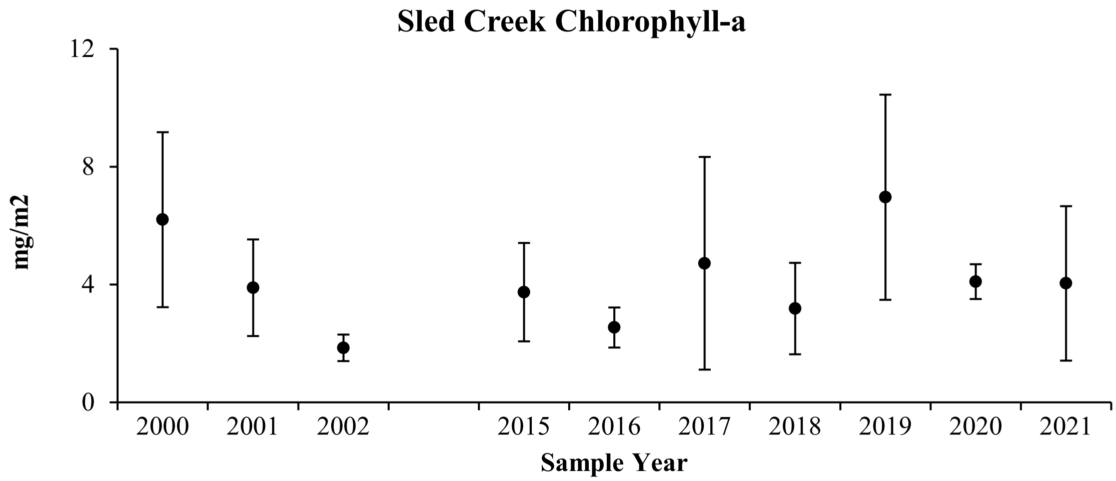

Figure 67. Average concentration of chlorophyll-a (± 1SD) in Sled Creek.

Invertebrates

Aquatic invertebrate density in Sled Creek varied from a low of 8.2 invertebrates/m^3 in 2021 to a high of 59.3 invertebrates/m^3 in 2016 (Figure 68). EPT were present in all sample years and twice exceeded the percentage of chironomids (Figure 69). The EPT was composed of mayflies and stoneflies with very few or no caddisflies. In sample years where EPT was low there was a high number of aquatic diptera. Taxa richness was variable and ranged from a low of 10 to a high of 25 over the sample years (Figure 70).

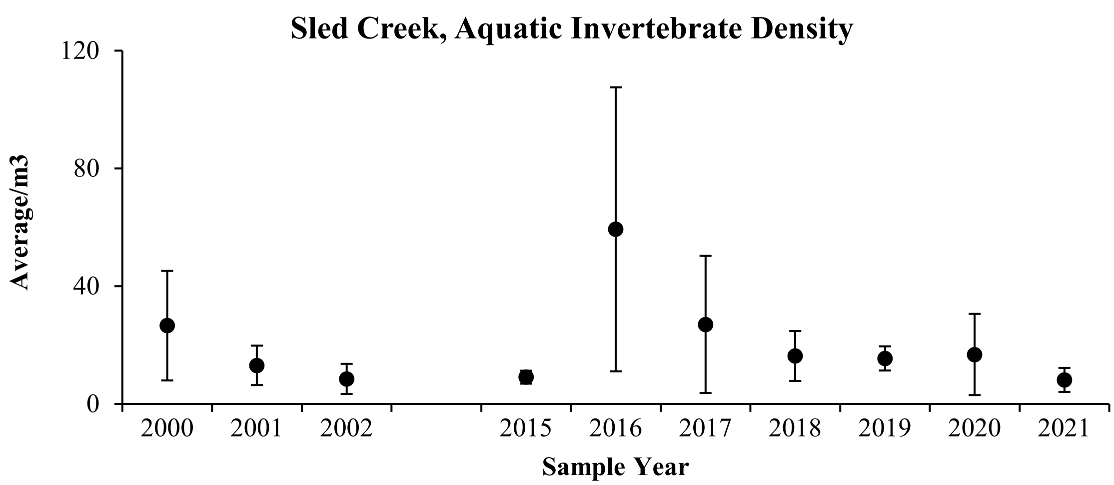

Figure 68. Average aquatic invertebrate densities (± 1SD) in Sled Creek.

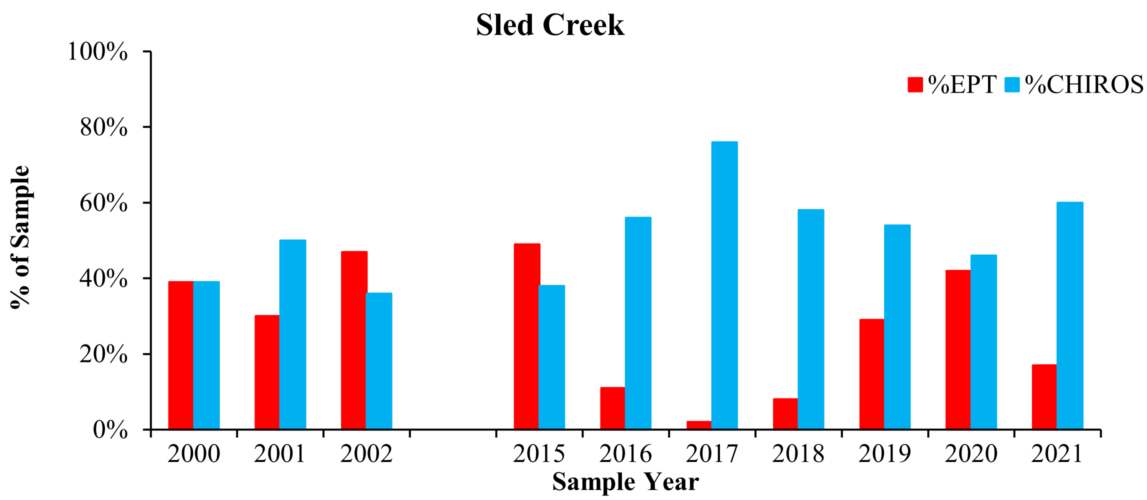

Figure 69. Percent Chironomidae and EPT in Sled Creek.

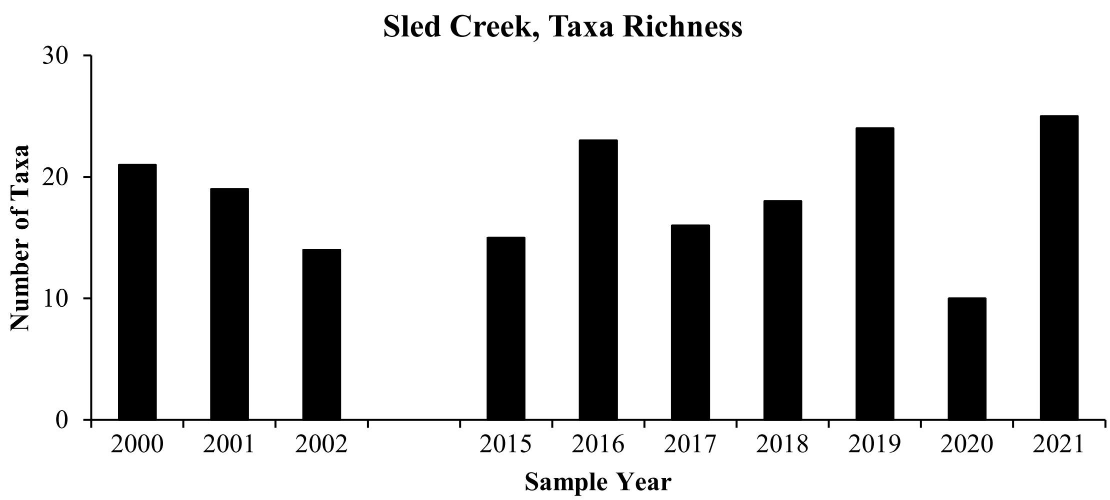

Figure 70. Aquatic invertebrate taxa richness in Sled Creek.

Fish

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

Volcano Creek

Water Quality

Volcano Creek was not sampled during the time frame from 2000 to 2002, but was sampled from 2014 to 2021. Visual observations and biological data collected indicate that Volcano Creek is a productive aquatic system (Figure 71).

Figure 71. Volcano Creek on 7/3/21.

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 72). Chlorophyll-a concentrations in Volcano Creek were consistent from 2014 to 2017, then decreased from 2018 to 2021.

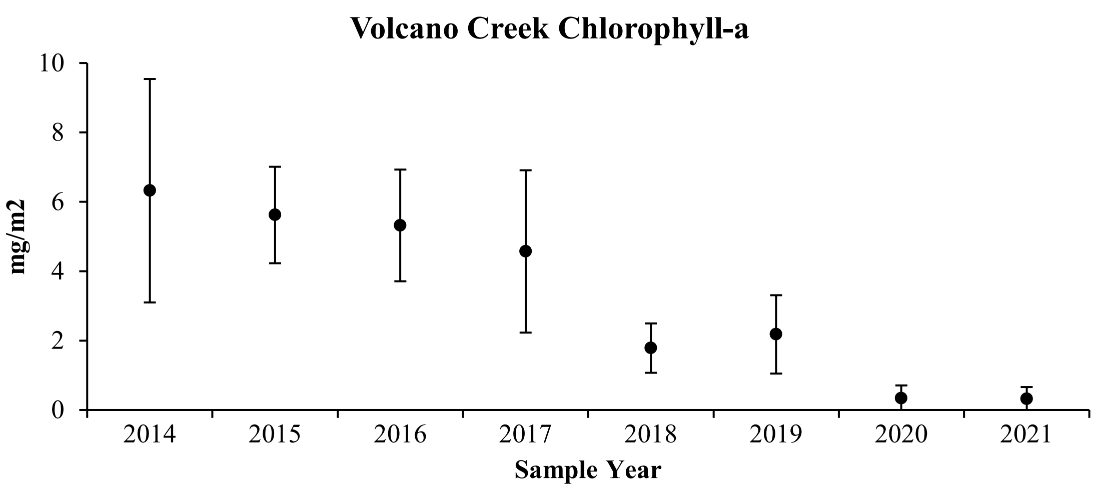

Figure 72. Average concentration of chlorophyll-a (± 1SD) in Volcano Creek.

Invertebrates

Aquatic invertebrate density at Volcano Creek varied from a low of 3.7 invertebrates/m^3 in 2016 to a high of 13.9 invertebrates/m^3 in 2018 (Figure 73). EPT were present in all sample years with both mayflies and stoneflies represented, but very few caddisflies (Figure 74). Samples were dominated by aquatic diptera, primarily chironomids. Taxa richness was variable and ranged from a low of 17 to a high of 25 over the sample years (Figure 75).

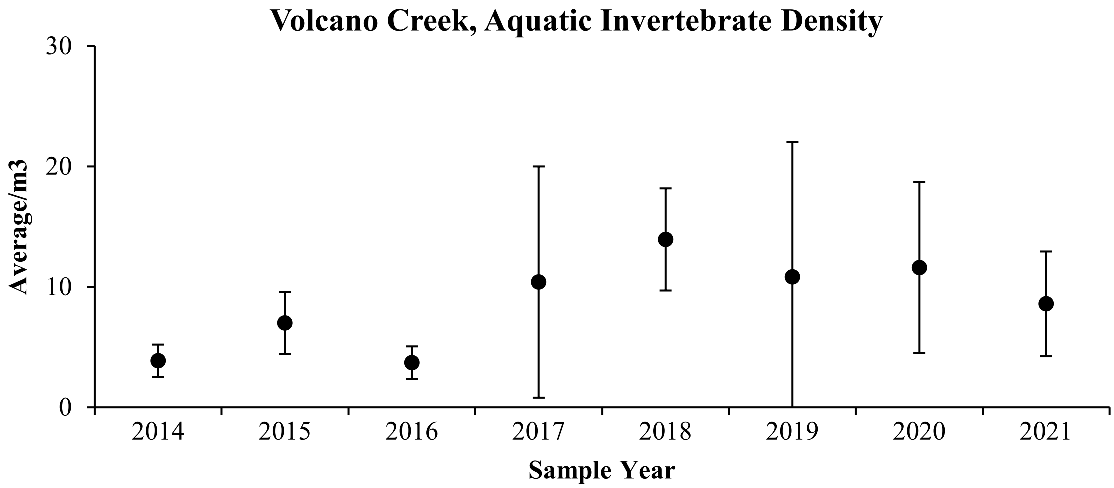

Figure 73. Average aquatic invertebrate densities (± 1SD) in Volcano Creek.

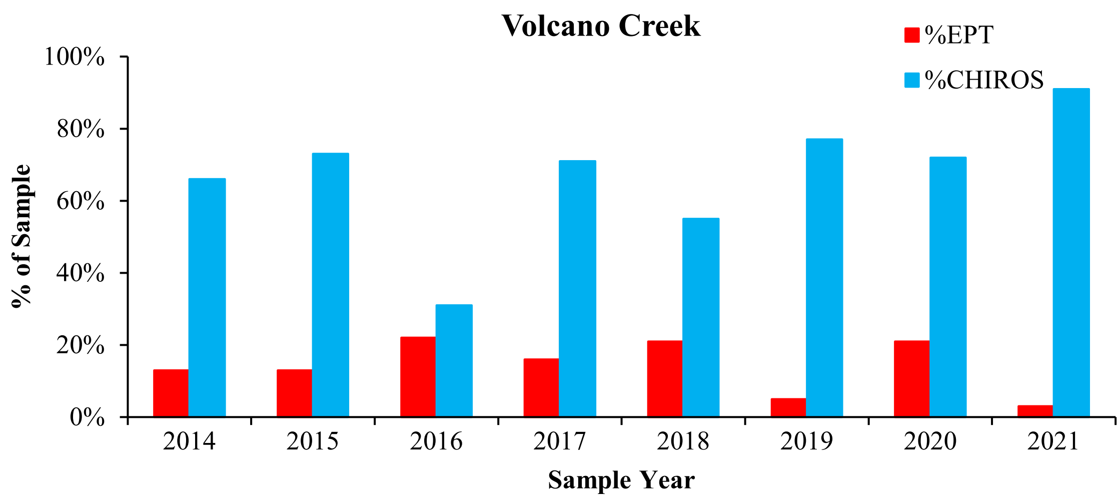

Figure 74. Percent Chironomidae and EPT in Volcano Creek.

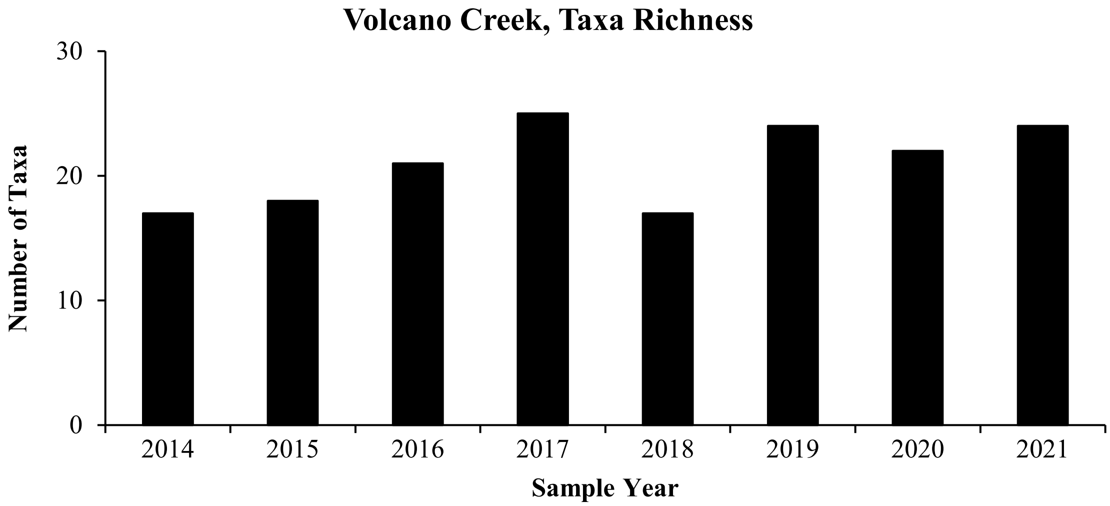

Figure 75. Aquatic invertebrate taxa richness in Volcano Creek.

Fish

Fish sampling with minnow traps and visual observations was conducted in Volcano Creek from 2014 to 2021 (Appendix 1). In 2016 a second site (about 2 km further upstream) was also sampled. Dolly Varden were captured in most years (Figure 76) and slimy sculpin were caught in 2017, 2018, and 2019. Length frequency distribution of all Dolly Varden caught is presented in Figure 77. Age 1 and 2 fish dominated the catch, although some larger, older fish were also captured.

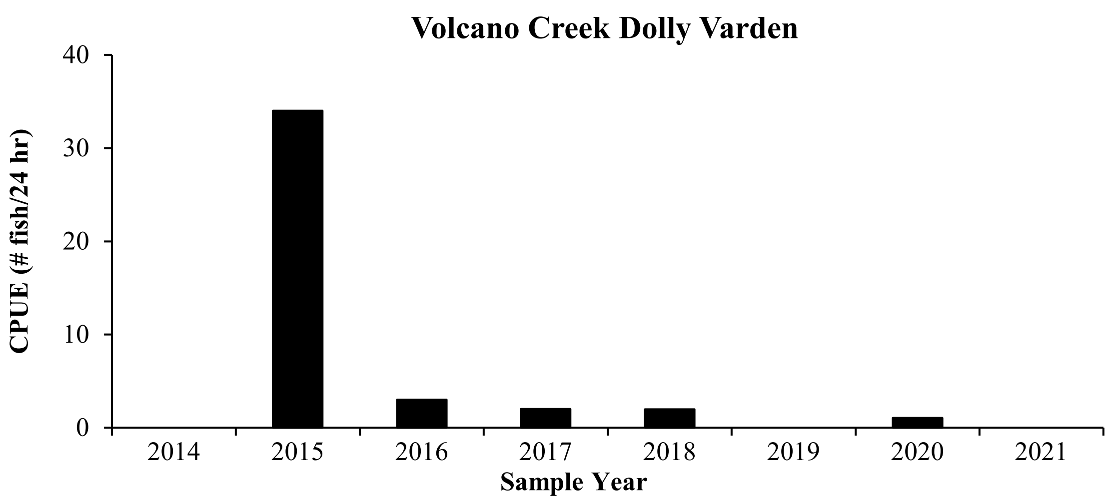

Figure 76. Catch per unit of effort for juvenile Dolly Varden in Volcano Creek.

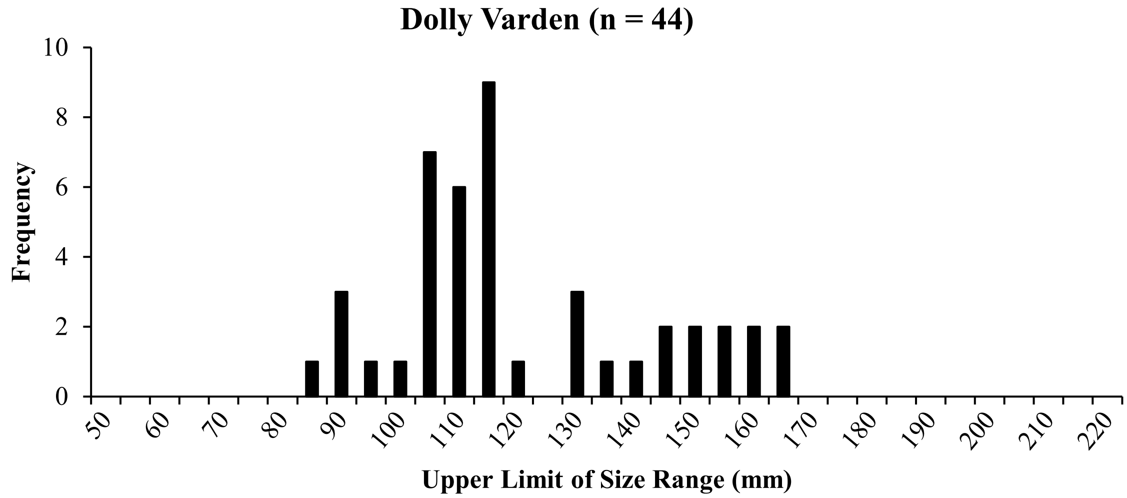

Figure 77. Length frequency distribution of Dolly Varden in Volcano Creek.

Juvenile Dolly Varden were retained in 2016 and 2017 for whole body element concentration analysis (cadmium, lead, selenium, zinc, and mercury). A limited number of fish were retained in 2016 (n = 1) and 2017 (n = 2). These data were compared graphically with Dolly Varden collected in Mainstem Red Dog and Anxiety Ridge creeks (Figure 78) during the same time frame. The cadmium concentrations in Volcano Creek were similar to those found in Mainstem Red Dog Creek, but higher than those founds 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 78).

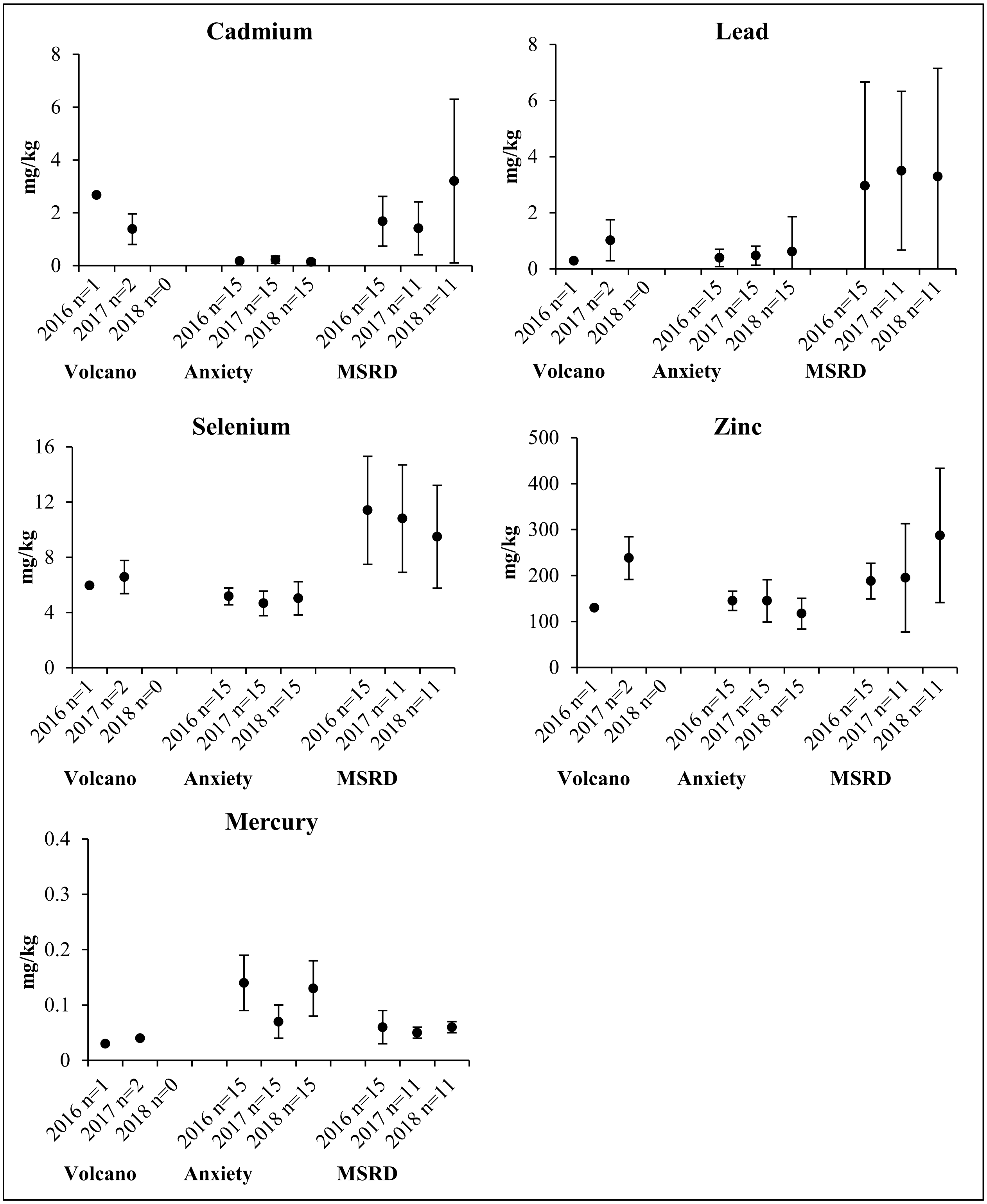

Figure 78. Average dry weight whole body element concentrations (± 1SD) in juvenile Dolly Varden collected from Volcano, Anxiety Ridge, and Mainstem Red Dog creeks.

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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	3.0	
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	
Sourdock Creek (204)	7/9/2000	30	52	41.6	
Sourdock Creek (204)	7/28/2000	24	20	20.0	
Sourdock Creek (204)	7/7/2001	48	26	13.0	
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	3.0	
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	
Lower Competition Creek (202)	7/9/2000	32	4	3.0	
Lower Competition Creek (202)	7/29/2000	24	2	2.0	
Lower Competition Creek (202)	7/30/2000	24	2	2.0	
Lower Competition Creek (202)	7/6/2001	24	1	1.0	
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	33.0	
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	11.0	
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	
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	
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	
Ikalukrok Creek (207) (DS of Cub Creek)	7/1999	24	0	N/A	
Ikalukrok Creek (207) (DS of Cub Creek)	7/8/2000	24.5	0	N/A	
Ikalukrok Creek (207) (DS of Cub Creek)	7/29/2000	23	0	N/A	
Ikalukrok Creek (207) (DS of Cub Creek)	7/7/2001	23.5	0	N/A	
Ikalukrok Creek (207) (DS of Cub Creek)	8/3/2001	53.5	0	N/A	
Ikalukrok Creek (207) (DS of Cub Creek)	7/12/2002	46.5	0	N/A	
Ikalukrok Creek (207) (DS of Cub Creek)	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	1.0	
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	
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	44.0	
Grayling Junior Creek (209)	8/27/2004	24.02	20	20.0	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	2.0	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)	8/25/21	23.83	1	1	
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 2	8/7/2021	20.58	7	8.16	
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	34.0	
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	8/3/2018	24.3	2	2	1 SS
Volcano Creek	8/2/2019	31	0	N/A	2 SS
Volcano Creek	8/5/2020	22.7	1	1.06	
Volcano Creek	8/9/2021	24.17	0	N/A	
Volcano Creek	8/27/2021	15.25	8	12.6	
North Fork Red Dog Creek tributary	8/11/2021	25.42	1	0.94	
Upper North Fork Red Dog 1	8/11/2021	25.42	2	1.89	
Upper North Fork Red Dog 2	8/11/2021	24.8	0	N/A	