Technical Report No. 19-10

Baseline Aquatic Biomonitoring for the Anarraaq and Aktigiruq Prospects near the Red Dog Mine, 2018.

by

Chelsea M. Clawson and Alvin G. Ott

May 2019

Alaska Department of Fish and Game Habitat Section

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Weights and measures (metric)	
centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm
Weights and measures (English)	
cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd
Time and temperature	
day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s
Physics and chemistry	
all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General	
Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics	
all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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BASELINE AQUATIC BIOMONITORING FOR THE ANARRAAQ AND AKTIGIRUQ PROSPECTS NEAR THE RED DOG MINE, 2018

By

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May 2019

Cover: Grayling Junior Creek, July 2018, Photograph by Chelsea Clawson

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Acknowledgements

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

Robert Napier and Audra Brase 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 2018. 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, and Ikalukok creeks (upstream of its confluence with East Fork Ikalukrok Creek).

Water quality in Sourdock, upper Ikalukrok, East Fork Ikalukrok, Grayling Junior, and Sled creeks is of a higher quality (e.g., lower metals, neutral pH). Juvenile Dolly Varden and Arctic grayling were present in Competition Creek and juvenile Dolly Varden were present in Sourdock Creek. Arctic grayling, slimy sculpin, and Dolly Varden were found in East Fork Ikalukrok Creek and in Ikalukrok Creek downstream of its confluence with the East Fork. Grayling Junior Creek contains Arctic grayling, slimy sculpin, and juvenile Dolly Varden, and in some years large numbers (about 300) of Arctic grayling may be found at the confluence of Grayling Junior Creek and Ikalukrok Creek. Sourdock Creek, a tributary to Competition Creek, supports rearing Dolly Varden. Sled Creek does not support fish and the absence of fish in Sled Creek is likely due to the fact that the stream goes subsurface during the ice-free season before entering Ikalukrok Creek.

Measurements of periphyton standing crop, aquatic invertebrates, and fish distribution also vary among the sample sites. Periphyton as measured by chlorophyll-a was highest in Sled, Volcano, and East Fork Ikalukrok creeks ($\geq$ 1.5 mg/m^2), while aquatic invertebrate densities were highest in Sled and Volcano ($\geq$ 10 invertebrates/m^3). The highest fish use in 2018 was in Lower Competition Creek, although catches were lower than most previous sample years.

Introduction

Teck Alaska Inc. has been conducting geotechnical drilling in the area of the Anarraaq Prospect since the mid-1990's and recently announced that there is a second prospect (Aktigiruq) in the same general area. Both prospects are zinc (Zn) and lead (Pb) subsurface deposits located in Section 23, T32N, R19W (De Long Mountains A-2). The deposits are located about 16 km northwest of the Red Dog Mine (Figure 1).

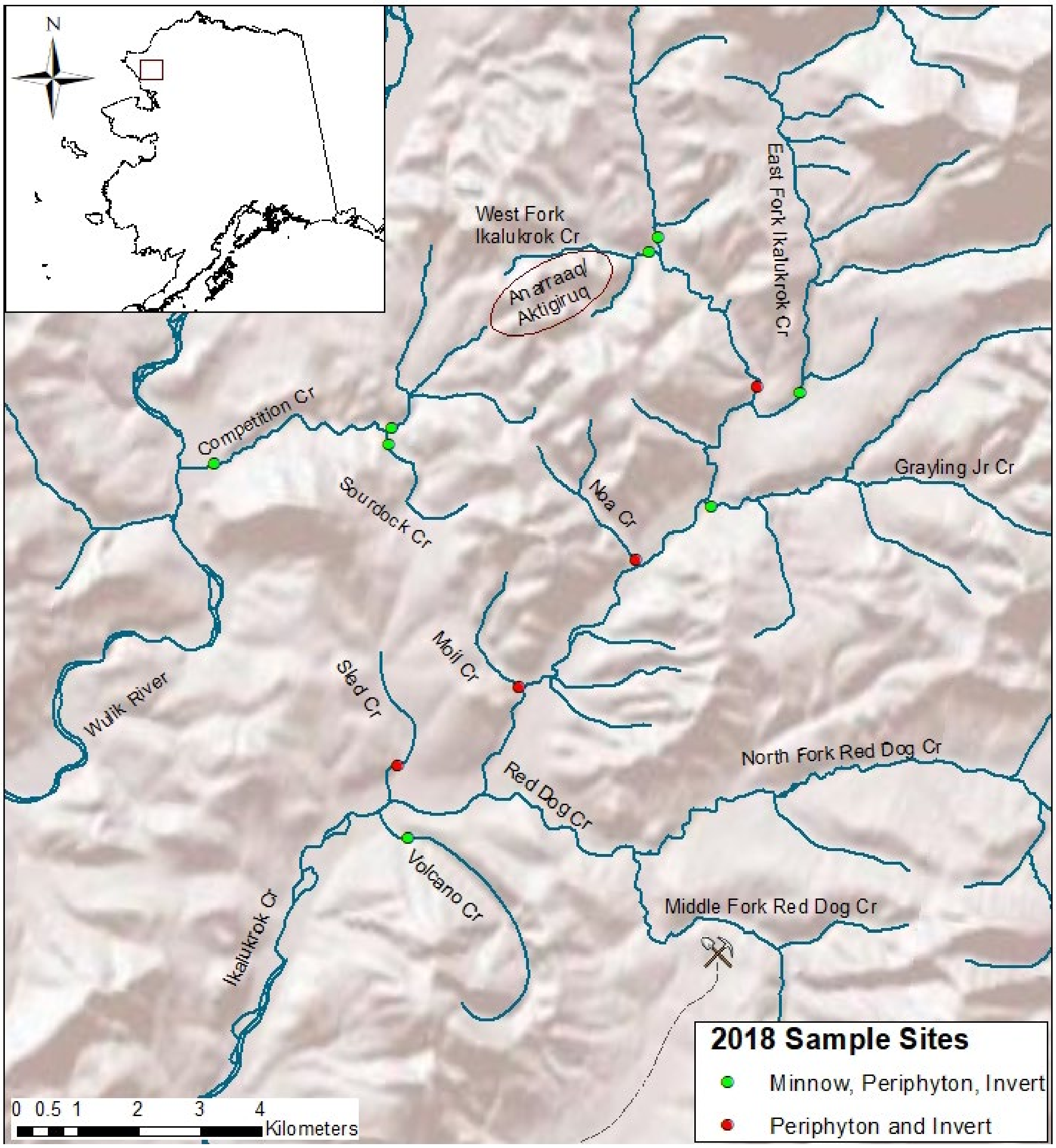

Figure 1. Map showing sampling points and general location of the Anarraaq/Aktigiruq Prospect.

Aquatic baseline data collection near the Anarraaq/Aktigiruq 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 2018, 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 a new tailings dam 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 late July to early August.

The Anarraaq and Aktigiruq Prospects ultimately may 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. Exploration access to the orebodies may be via an all-weather (exploration) road following Mainstem Red Dog Creek, crossing North Fork Red Dog, Grayling Junior, and Ikalukrok creeks, and then up Ikalukrok Creek to access the mine area. North Fork Red Dog, Grayling Junior, and Ikalukrok creeks are all anadromous waterbodies which support Arctic grayling, Dolly Varden, and slimy sculpin.

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 shown 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 more 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.

Fish sampling typically 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.

Table 1. Location of Sample Sites and Years Sampled.

Station No.	Stream/Site Name	Years Sampled
202	Lower Competition	2000-2002 and 2014-2018
203	Upper Competition	2000-2002 and 2014-2018
204	Sourdock	2000-2002 and 2014-2018
205	West Fork Ikalukrok	2000-2002 and 2015-2018
206	Ikalukrok (above West Fork)	2000-2002 and 2015-2018
207	Ikalukrok[1]	1997-1998, 2000-2002, and 2016-2018
208	East Fork Ikalukrok	1997-1998, 2000-2002, and 2016-2018
209	Grayling Junior	2000-2002 and 2016-2018
210	Noa	2000-2002 and 2016-2018
211	Moil	2000-2002 and 2016-2018
212	Sled	2000-2002 and 2015-2018
N/A	Volcano	2014-2018

[1] Sample site is located downstream of the Cub Creek seep.

Results and Discussion

This section presents the biomonitoring results for each creek listed in Table 1. Biomonitoring data were collected from 2014 to 2018 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 data (periphyton, aquatic invertebrates and fish whole body element concentrations) are available upon request[2].

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, and as a comparison of the total percent of Ephemeroptera, Plecoptera and Tricoptera (EPT) vs. Chironomidae (CHIROS). In general, the higher the percentage of EPT at a site, the higher the water quality. Taxa richness, in this report, was 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) 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 2018 varied from white to tan (Figure 2). Additionally, the water color in Upper Competition Creek has varied from an opaque white to orange.

[2] Submit detailed data requests to ADF&G Division of Habitat - 1300 College Rd, Fairbanks, Alaska 99708.

Figure 2. Upper Competition Creek July 11, 2018

Periphyton

Average chlorophyll-a concentrations were low in Upper Competition Creek and ranged from 0.01 mg/m^2 in 2001 and 2016 to 0.42 mg/m^2 in 2002 (Figure 3).

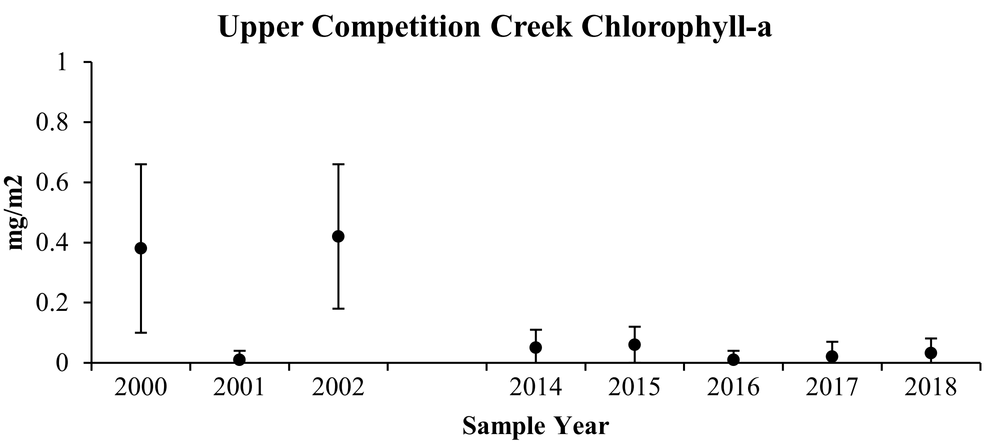

Figure 3. Average concentration of chlorophyll-a (± 1SD) in Upper Competition Creek.

Invertebrates

The average aquatic invertebrate density in Upper Competition Creek has varied from 1.2 invertebrates/m^3 in 2002 to 14.9 invertebrates/m^3 in 2001 (Figure 4). The percent Chironomidae was highest in 2014 and 2017, but in 2000 and 2016 the EPT was higher than Chironomidae (Figure 5). Taxa richness varied from 12 to 21 taxa per site over the sample years (Figure 6).

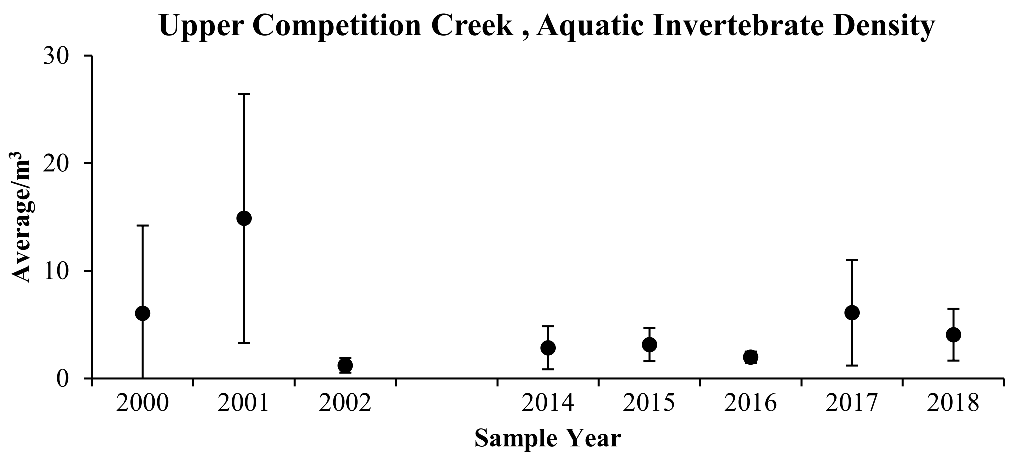

Figure 4. Average aquatic invertebrate density ±1 SD, in Upper Competition Creek.

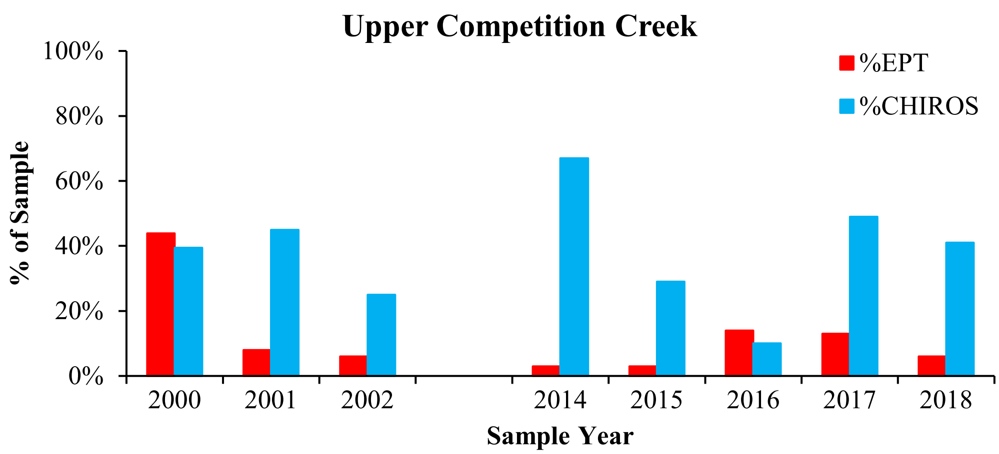

Figure 5. Percent Chironomidae and EPT, in Upper Competition Creek.

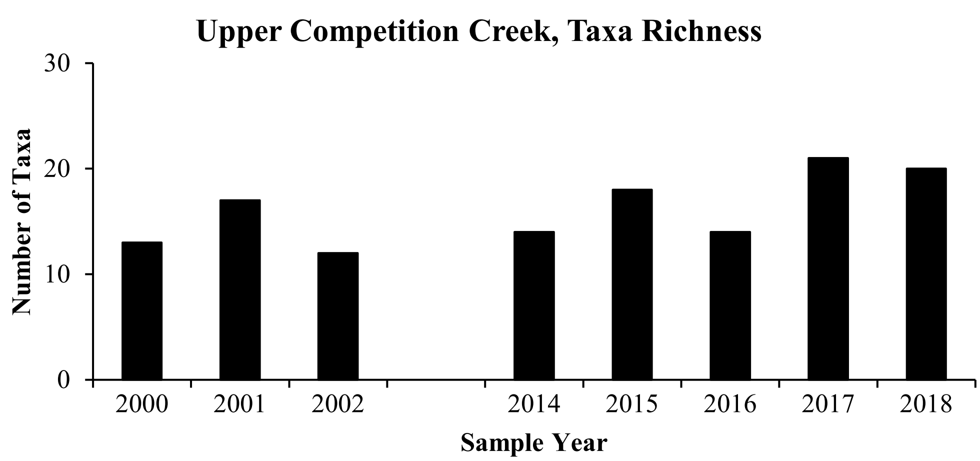

Figure 6. Aquatic invertebrate taxa richness at Upper Competition Creek.

Fish

The CPUE of Dolly Varden in minnow traps at Upper Competition Creek was five fish in 2000 and three fish in 2002. Catches of these fish coincided with the two years that had the highest periphyton concentrations (Figure 3). Catches were zero for all other sample years. No fish were caught at the site from 2014 to 2018, 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 was gone during the 2014 to 2018 sample period. In 2018, there was orange staining and precipitate on the substrate in Sourdock Creek (Figure 7).

Figure 7. Sourdock Creek (left photo 7/3/2017 and right photo 7/11/2018).

Periphyton

The average chlorophyll-a concentration in Sourdock Creek ranged from a high of 12.44 mg/m^2 in 2002 to a low of 1.36 mg/m^2 in 2018 (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.

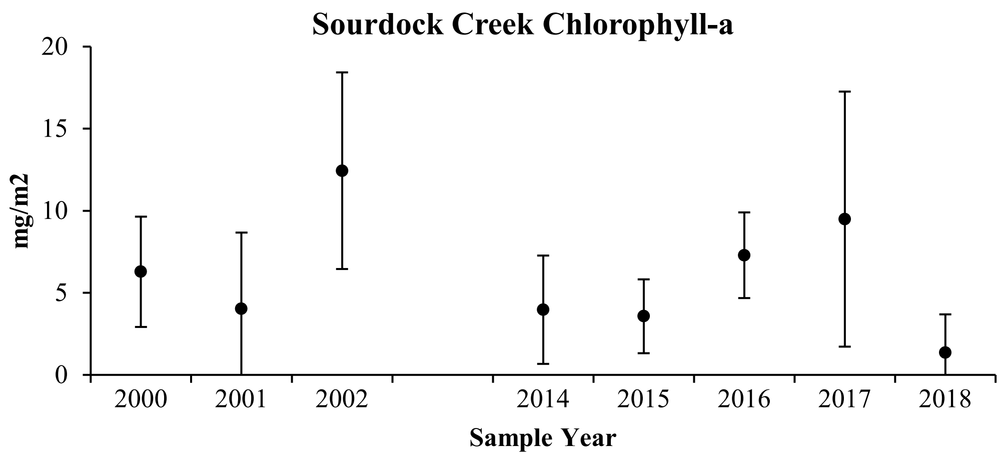

Figure 8. Average concentration of chlorophyll-a (± 1SD) in Sourdock Creek.

Invertebrates

The average aquatic invertebrate density in Sourdock Creek was highest in 2017 (Figure 9). Average density ranged from a low of 3.0 invertebrates/m^3 to a high of 15.4 invertebrates/m^3. The percent Chironomidae was much higher from 2014 to 2018 than from 2000 to 2002 (Figure 10). Taxa richness varied from 12 to 19 taxa per site over the sample years (Figure 11).

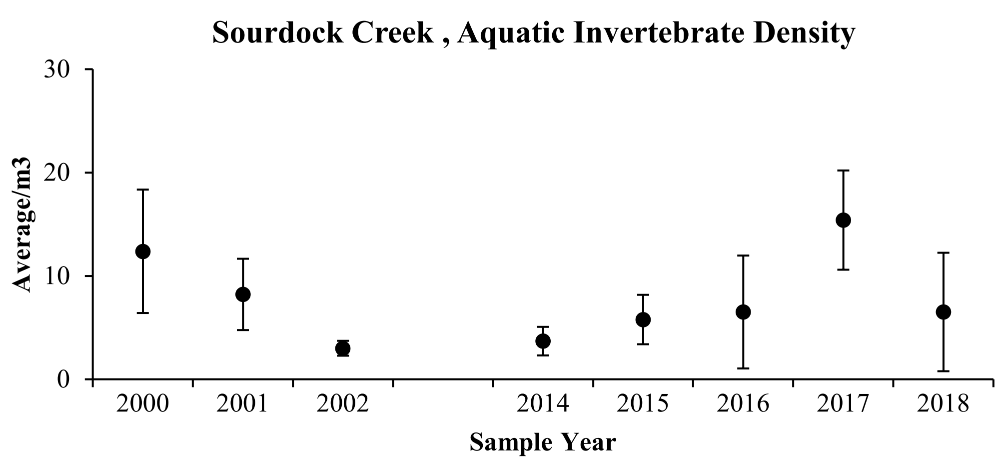

Figure 9. Average aquatic invertebrate densities ± 1SD, in Sourdock Creek.

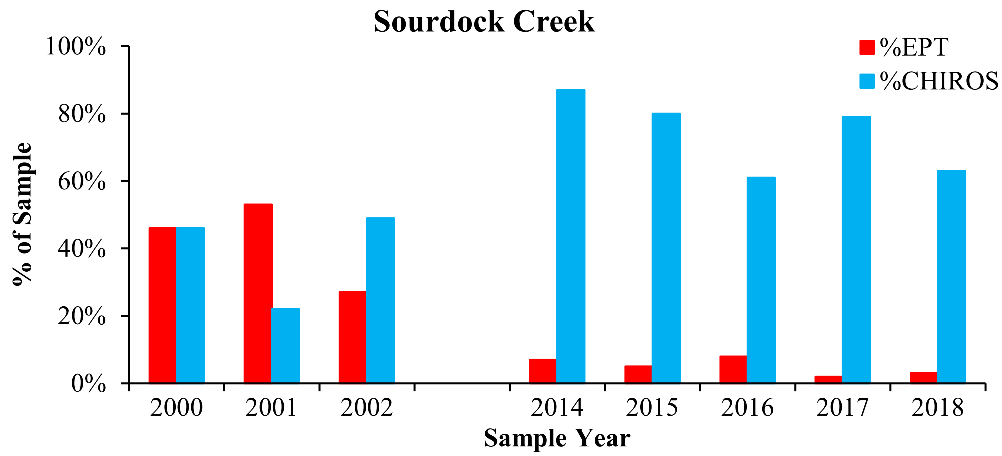

Figure 10. Percent Chironomidae and EPT, in Sourdock Creek.

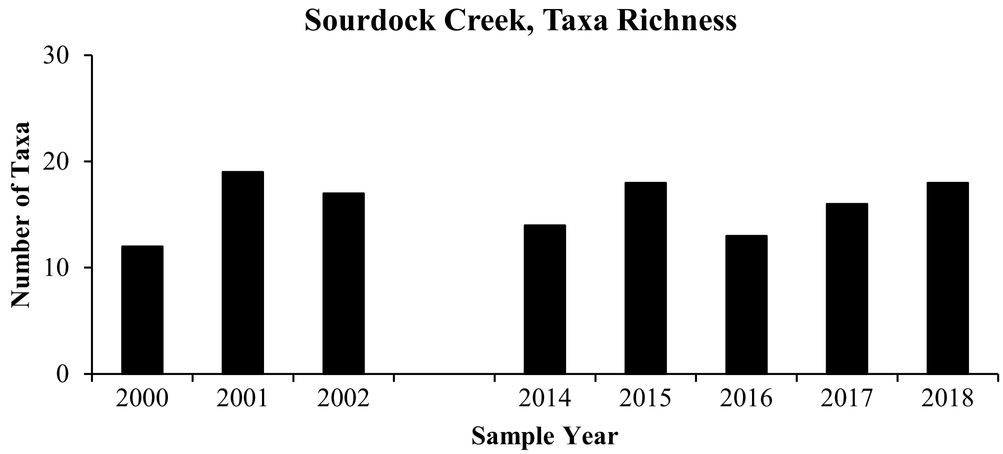

Figure 11. Aquatic invertebrate taxa richness, in Sourdock Creek.

Fish

The CPUE of juvenile Dolly Varden at Sourdock Creek was highest in 2000 and has decreased over the sample period to zero fish 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. Small streams around the Red Dog Mine area are typically used by rearing Dolly Varden during the ice-free season and the lower CPUE over the last five years in Sourdock Creek indicates that this movement has been curtailed.

The length frequency distribution for all juvenile Dolly Varden caught in Sourdock Creek is presented in Figure 13. There appear to be at least two year classes present (most likely 1+ and 2+) which is consistent with data collected in other Red Dog Mine area streams.

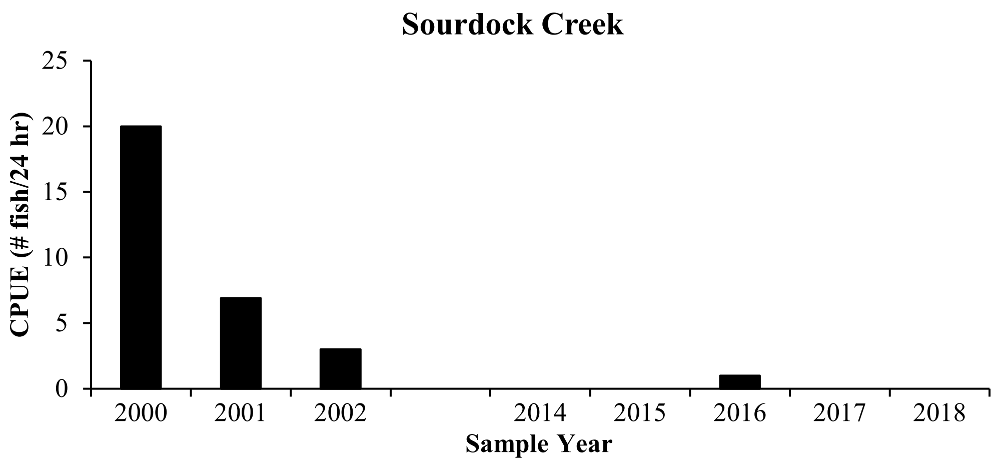

Figure 12. Catch per unit of effort for juvenile Dolly Varden in Sourdock Creek.

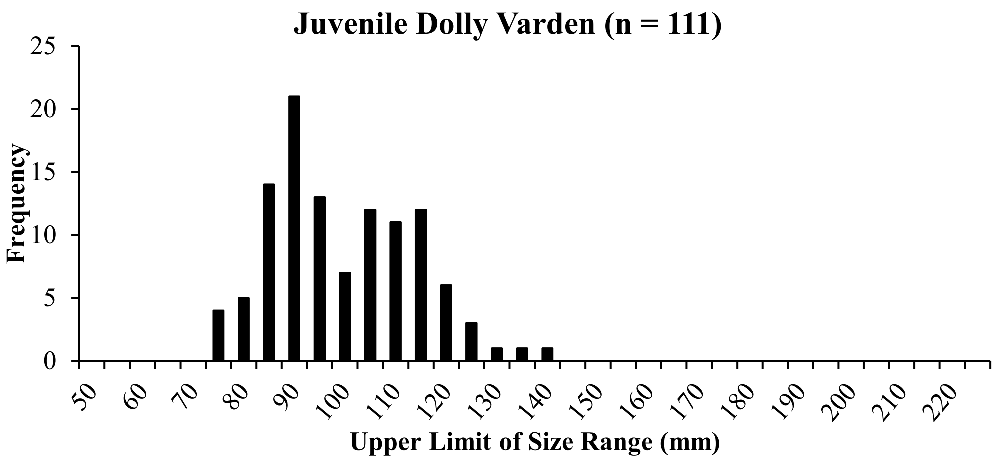

Figure 13. Length frequency distribution of Dolly Varden in Sourdock Creek.

Lower Competition Creek (Station 202)

Water Quality

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). It was apparent in the 2014 to 2018 sample period 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 (left photo 2000/2002 and right photo 7/11/2018).

Periphyton

Average chlorophyll-a concentrations in Lower Competition Creek from 2014 through 2018 were substantially lower than those found from 2000 to 2002, an indication of degraded water quality (Figure 15).

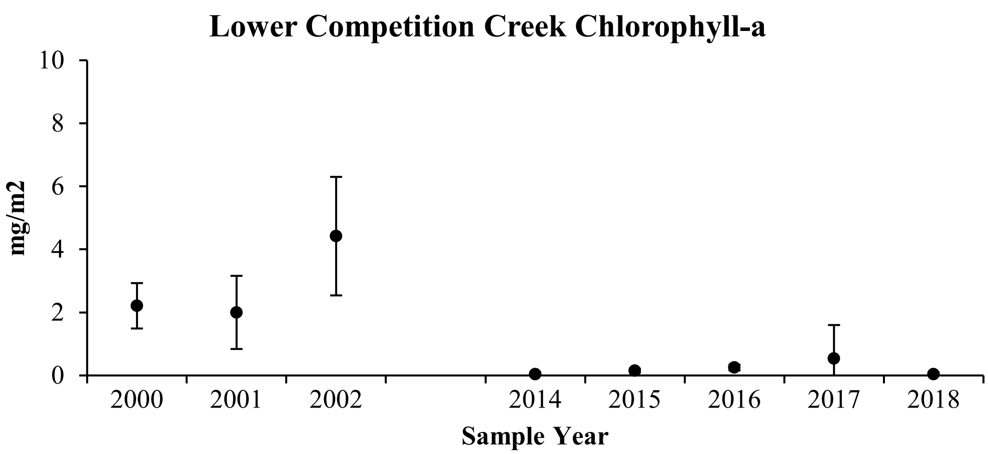

Figure 15. Average concentration of chlorophyll-a (± 1SD) in Lower Competition Creek.

Invertebrates

The average aquatic invertebrate density in Lower Competition Creek was highest in 2000 (Figure 16). Average density ranged from 1.3 in 2014 to 26.2 invertebrates/m^3 in 2000. Aquatic invertebrate densities from 2014 to 2018 were substantially lower than the previous sample period, another indication of degraded water quality. The percent Chironomidae was also higher from 2014 to 2018 than it was from 2000 to 2002 (Figure 17). Taxa richness varied from 13 to 24 taxa per site over the sample years and was generally higher during the 2014 to 2018 sample period (Figure 18).

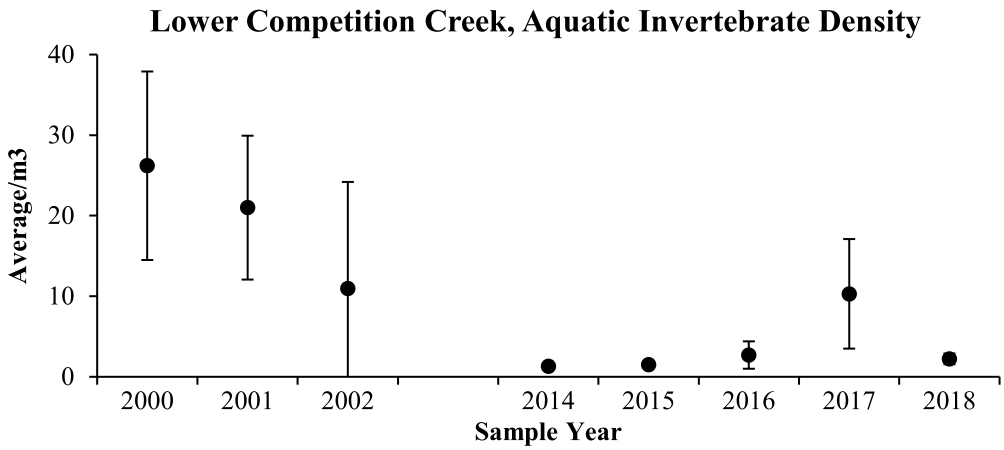

Figure 16. Average aquatic invertebrate densities ± 1SD in Lower Competition Creek.

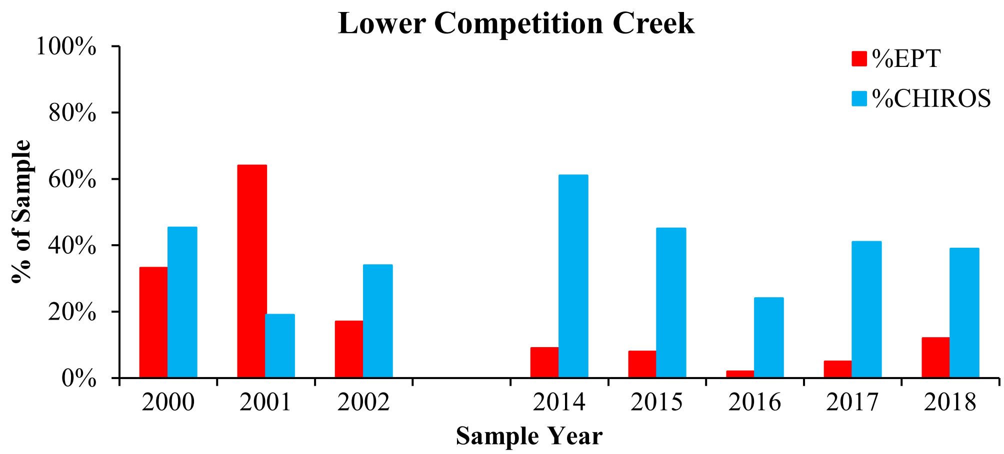

Figure 17. Percent Chironomidae and EPT in Lower Competition Creek.

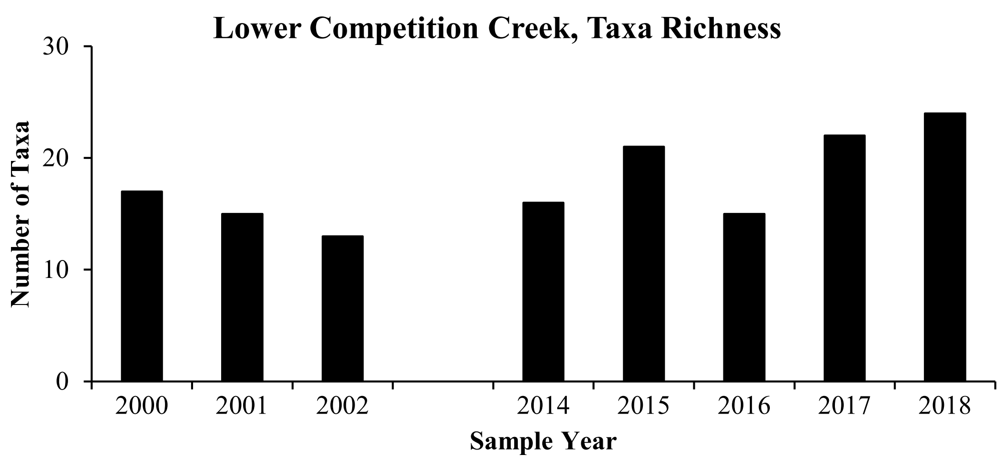

Figure 18. Aquatic invertebrate taxa richness in Lower Competition Creek.

Fish

Juvenile Dolly Varden use 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 2018 are presented in Figure 19. The CPUE has been highly variable with a low of two fish/day in 2000 and a high of 47 fish/day in 2016. Generally, the CPUE was higher from 2014 to 2018 and 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).

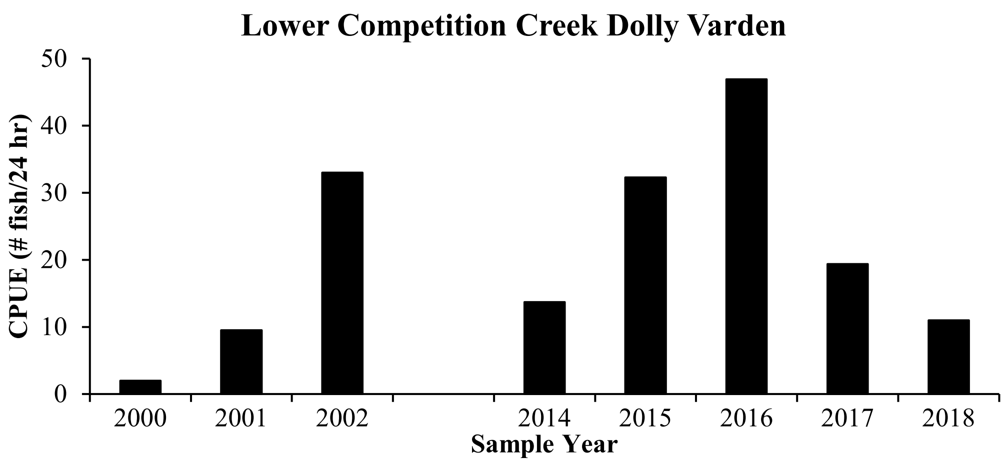

Figure 19. Catch per unit of effort for juvenile Dolly Varden in Lower Competition Creek.

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.

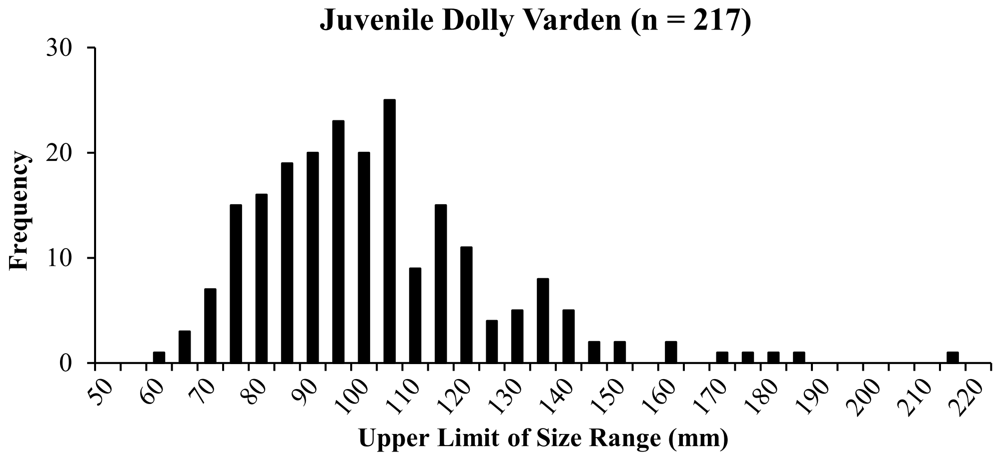

Figure 20. Length frequency distribution of Dolly Varden in Lower Competition Creek.

Juvenile Dolly Varden were retained from Lower Competition Creek from 2015-2017 for whole body element concentration (cadmium, lead, selenium, zinc, and mercury). No fish were retained in 2018. These data were compared with Dolly Varden collected in Mainstem Red Dog and Anxiety Ridge creeks (Figures 21 to 25) during the same time frames. The cadmium, lead, and selenium concentrations were higher in Mainstem Red Dog Creek and the zinc and mercury concentrations were similar (Figures 21 to 25).

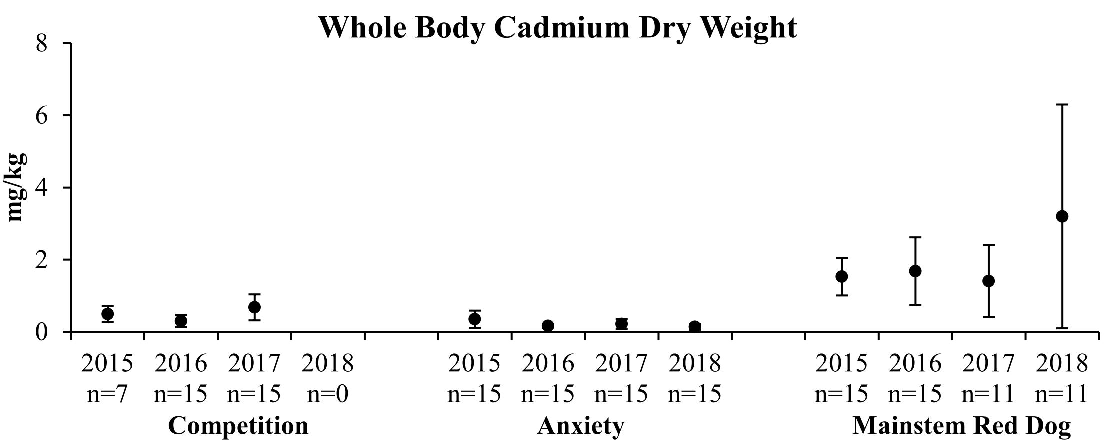

Figure 21. Average cadmium concentrations (± 1SD) in juvenile Dolly Varden collected from Competition, Anxiety Ridge, and Mainstem Red Dog creeks, 2015-18.

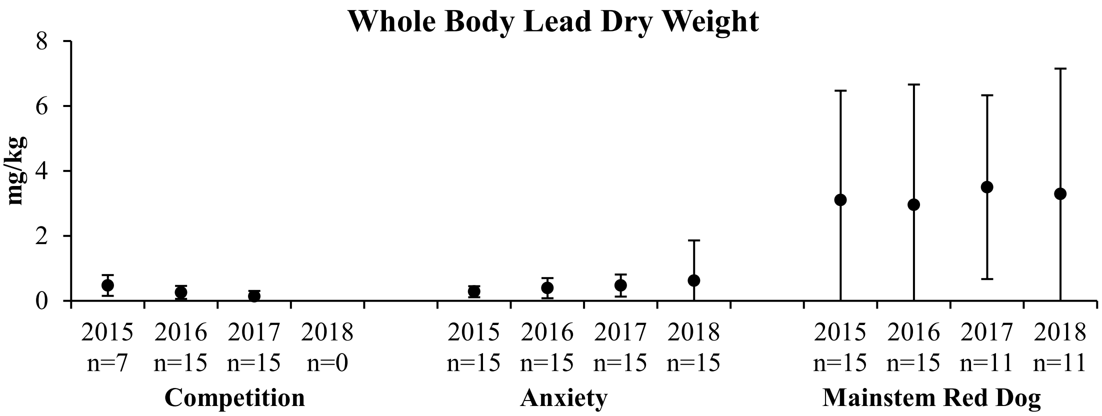

Figure 22. Average lead concentrations (± 1SD) in juvenile Dolly Varden collected from Competition, Anxiety Ridge, and Mainstem Red Dog creeks, 2015-18.

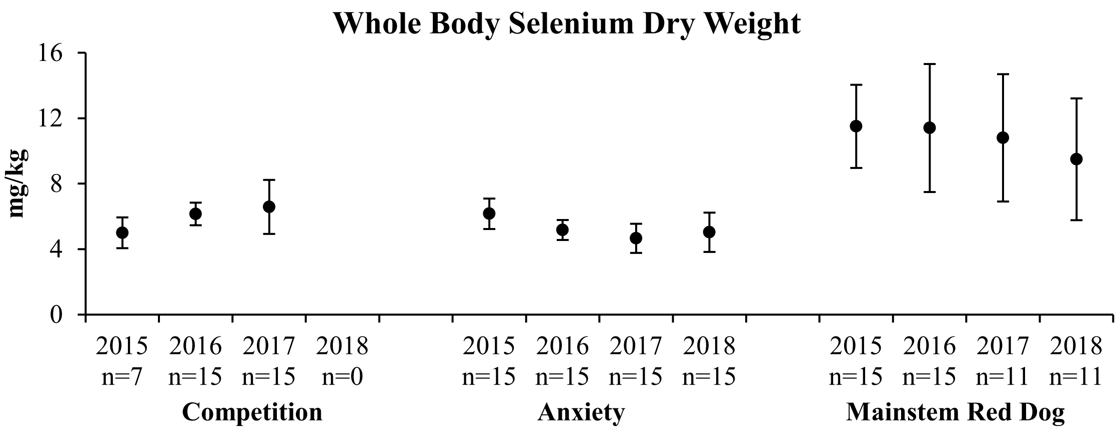

Figure 23. Average selenium concentrations (± 1SD) in juvenile Dolly Varden collected from Competition, Anxiety Ridge, and Mainstem Red Dog creeks, 2015-18.

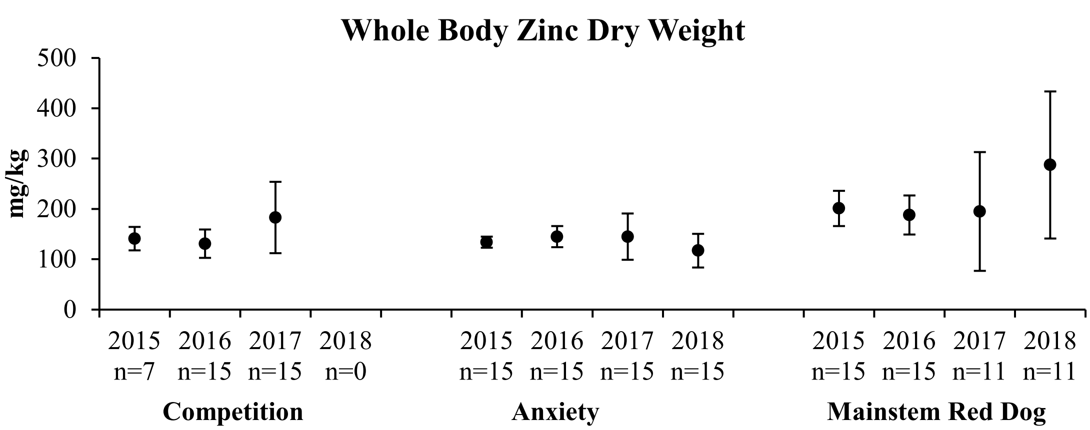

Figure 24. Average zinc concentrations (± 1SD) in juvenile Dolly Varden collected from Competition, Anxiety Ridge, and Mainstem Red Dog creeks, 2015-18.

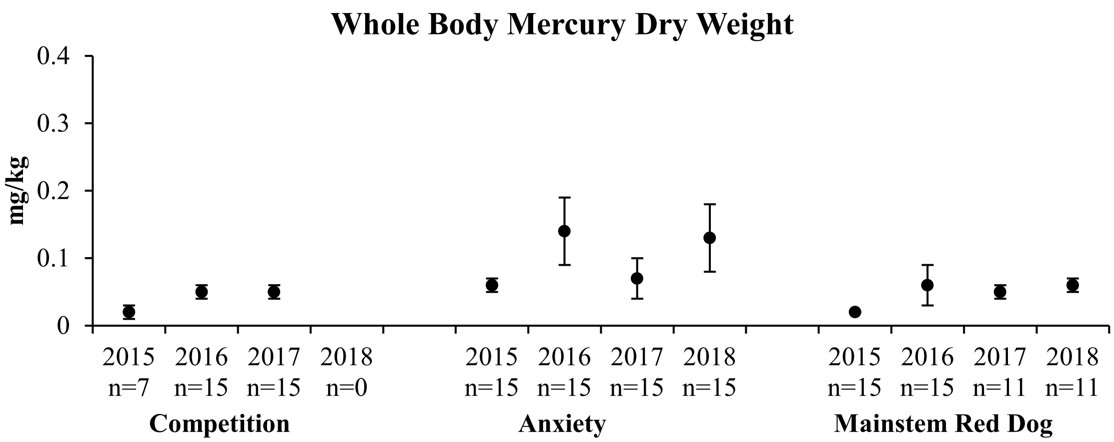

Figure 25. Average mercury concentrations (± 1SD) in juvenile Dolly Varden collected from Competition, Anxiety Ridge, and Mainstem Red Dog creeks, 2015-18.

West Fork Ikalukrok Creek (Station 205)

Water Quality

West Fork Ikalukrok Creek (Figures 1 and 26) had a relatively high 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).

Figure 26. West Fork Ikalukrok Creek, note white staining in left photo (7/12/2015) at the confluence of the West Fork and mainstem Ikalukrok.

Periphyton

In West Fork Ikalukrok Creek, the average chlorophyll-a concentrations from 2015 through 2018 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.

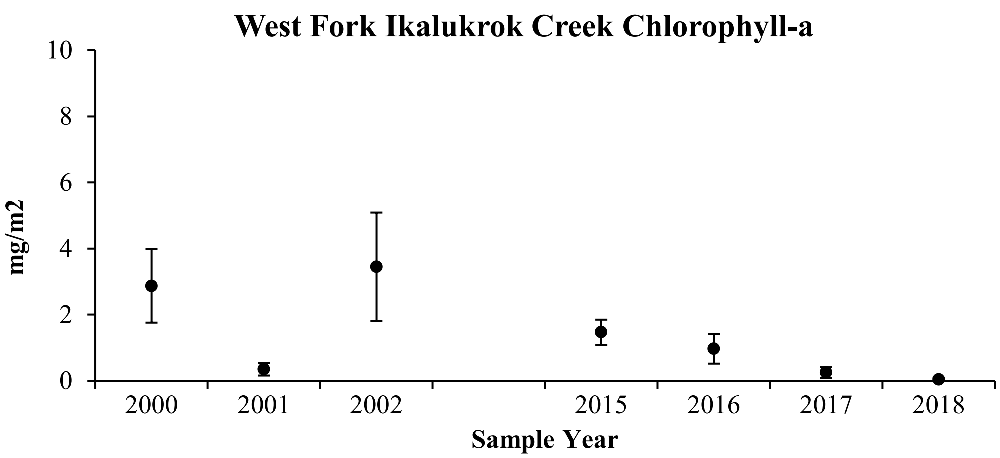

Figure 27. Average concentration of chlorophyll-a (± 1SD) in West Fork Ikalukrok Creek.

Invertebrates

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, but higher from 2015 to 2018 (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 five of the seven years (Figure 29). Taxa richness varied from 15 to 21 taxa per site over the sample years (Figure 30).

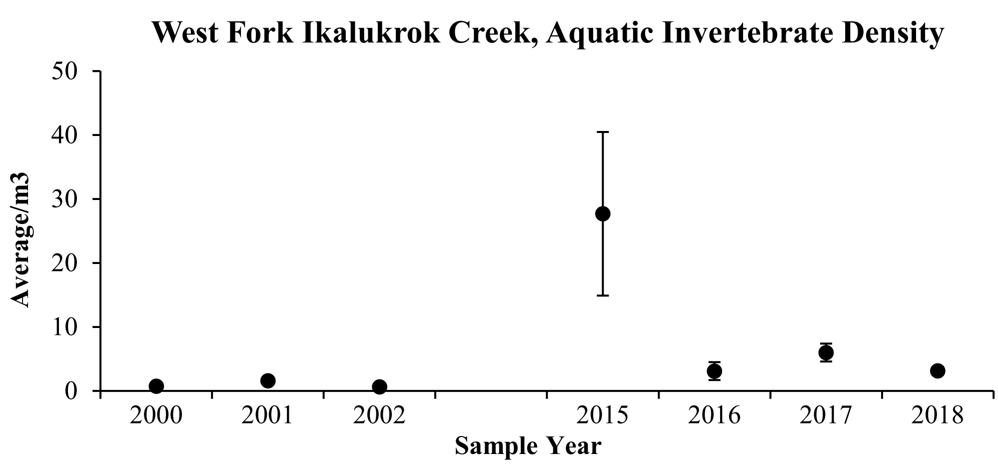

Figure 28. Average aquatic invertebrate densities ± 1SD in West Fork Ikalukrok Creek.

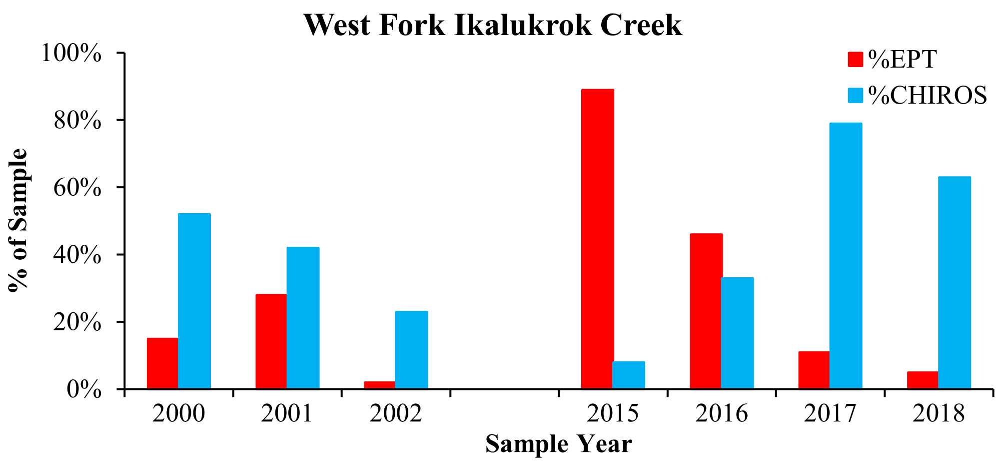

Figure 29. Percent Chironomidae and EPT in West Fork Ikalukrok Creek.

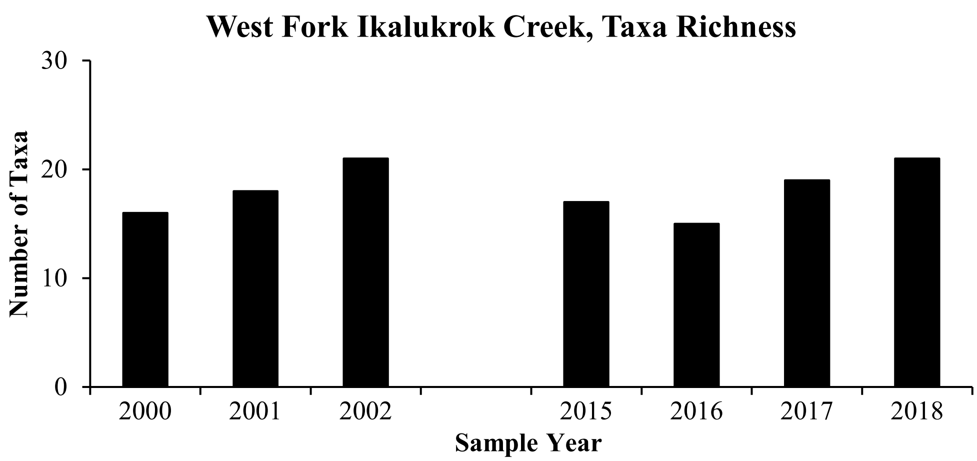

Figure 30. Aquatic invertebrate taxa richness in West Fork Ikalukrok Creek.

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 contribute to a chemical barrier to fish passage, preventing fish from moving into these productive habitats from overwintering areas located downstream.

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).

Figure 31. Ikalukrok Creek immediately upstream of West Fork Ikalukrok Creek, 2018.

Periphyton

In Upper Ikalukrok Creek average chlorophyll-a concentrations from 2000 to 2002 and from 2015 to 2018 were similar. Throughout the sample time frame, average chlorophyll-a concentration varied from a low of 0.3 mg/m^2 (2016) to a high of 3.48 mg/m^2 (2002) (Figure 32).

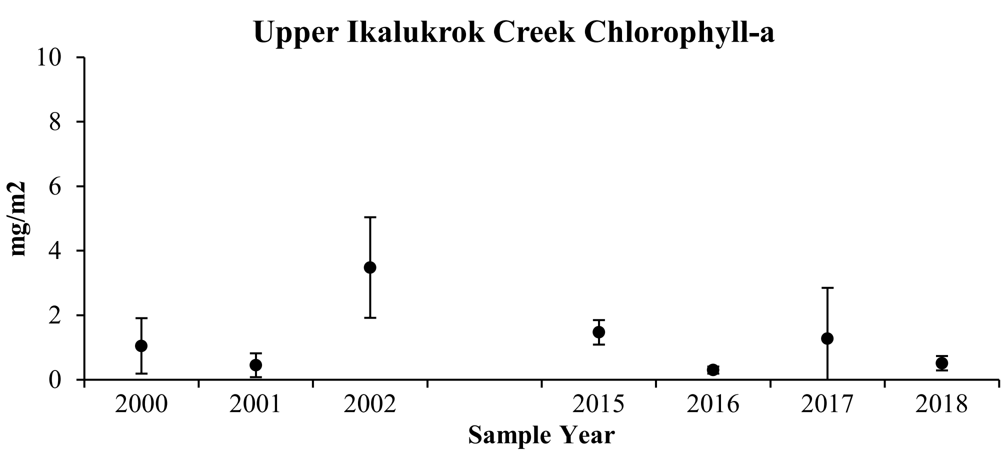

Figure 32. Average concentration of chlorophyll-a (± 1SD) in Upper Ikalukrok Creek.

Invertebrates

The average number of aquatic invertebrates 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 28 taxa in 2017 and 2018 (Figure 35).

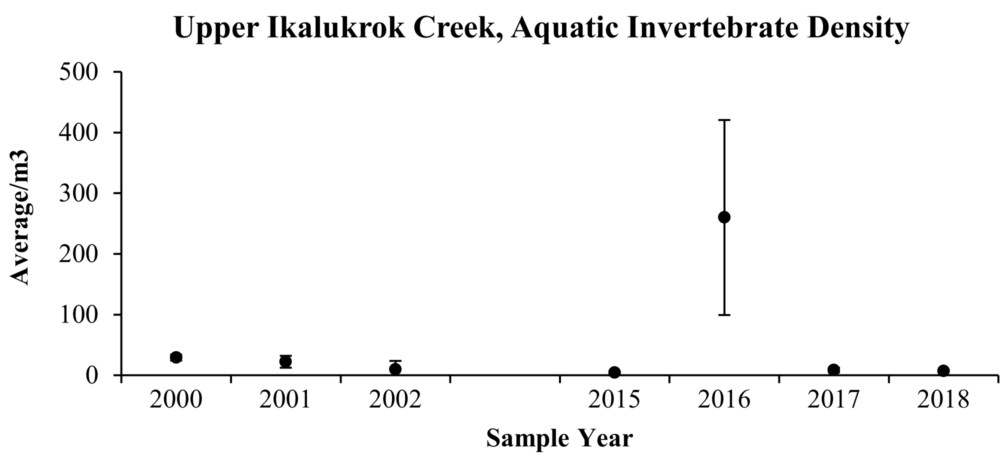

Figure 33. Average aquatic invertebrate densities ± 1SD in Upper Ikalukrok Creek.

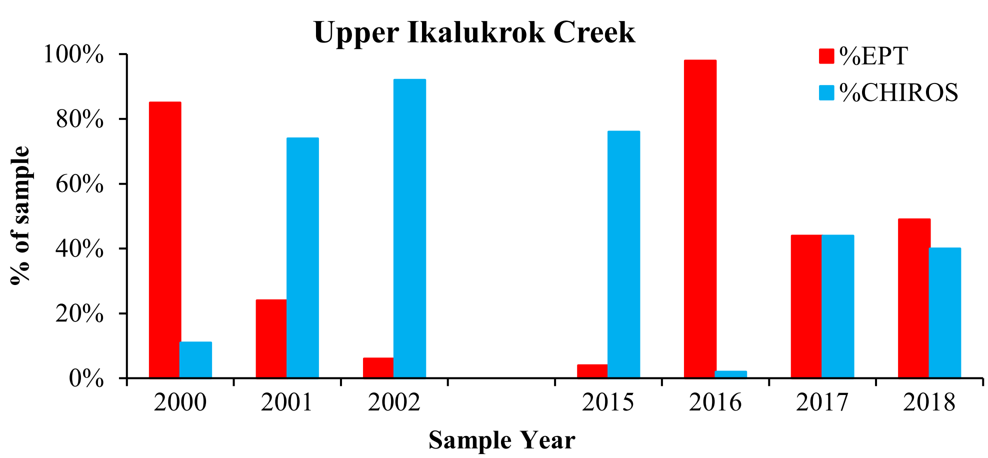

Figure 34. Percent Chironomidae and EPT in Upper Ikalukrok Creek.

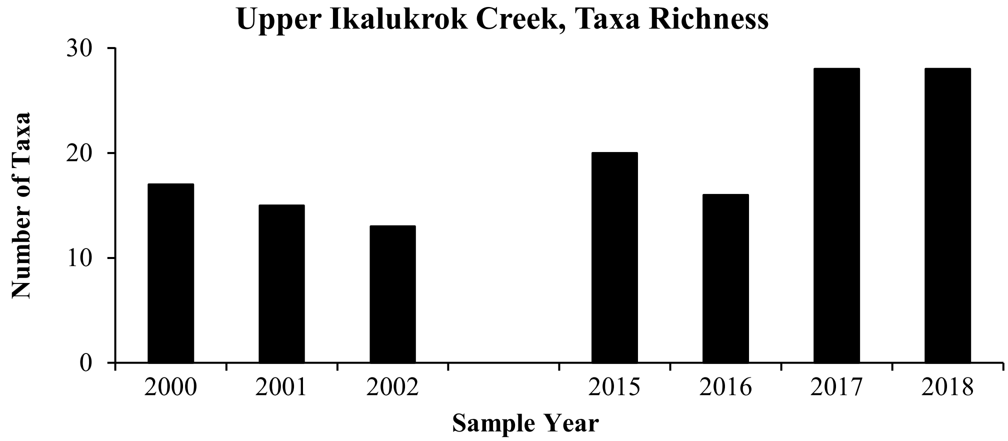

Figure 35. Aquatic invertebrate taxa richness in Upper Ikalukrok Creek.

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.

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 – 2018 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 (Weber Scannell and Anderson 2000).

Figure 36. Ikalukrok Creek below Cub Creek on 7/12/2018 (left), and the Cub Creek seep entering Ikalukrok Creek above the sample site in 2007 (right).

Periphyton

In Ikalukrok Creek, the average chlorophyll-a concentrations in all samples were low (Figure 37). Additional samples were collected in 1997 and 1998 as a part of a Teck supplemental environmental project (Ott 1997), and in most years, chlorophyll-a was below the detection limit. The highest average chlorophyll-a concentrations were in 2001 (0.08 mg/m^2), 2016 (0.06 mg/m^2), and 2017 (0.05 mg/m^2).

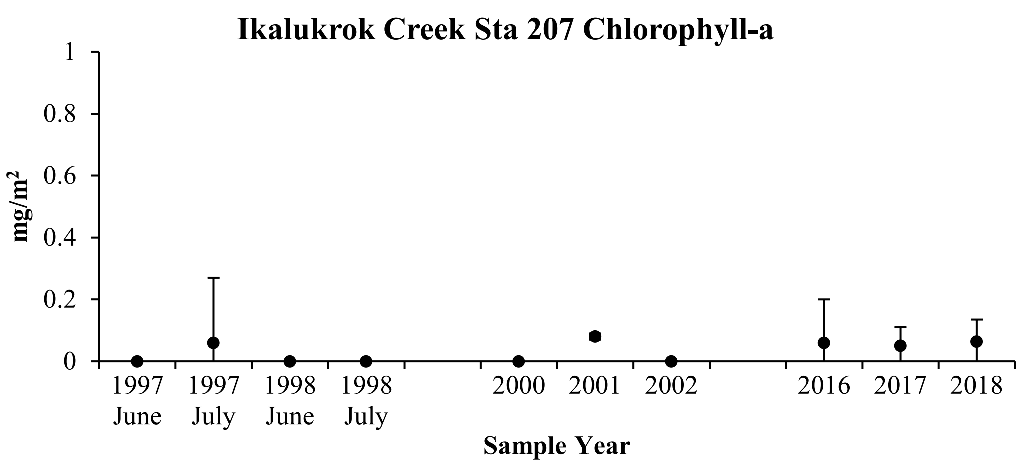

Figure 37. Average concentration of chlorophyll-a (± 1SD) in Ikalukrok Creek downstream of the Cub Creek seep.

Invertebrates

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

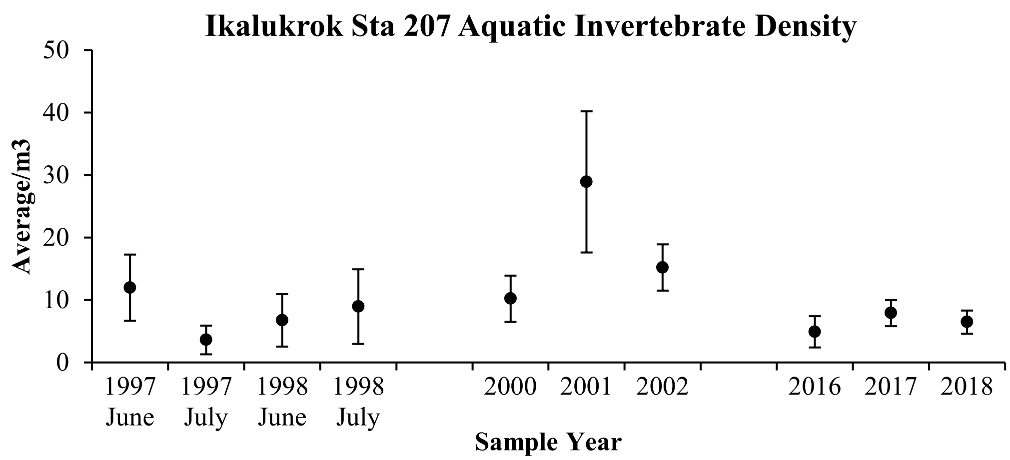

Figure 38. Average aquatic invertebrate densities ± 1SD in Ikalukrok Creek.

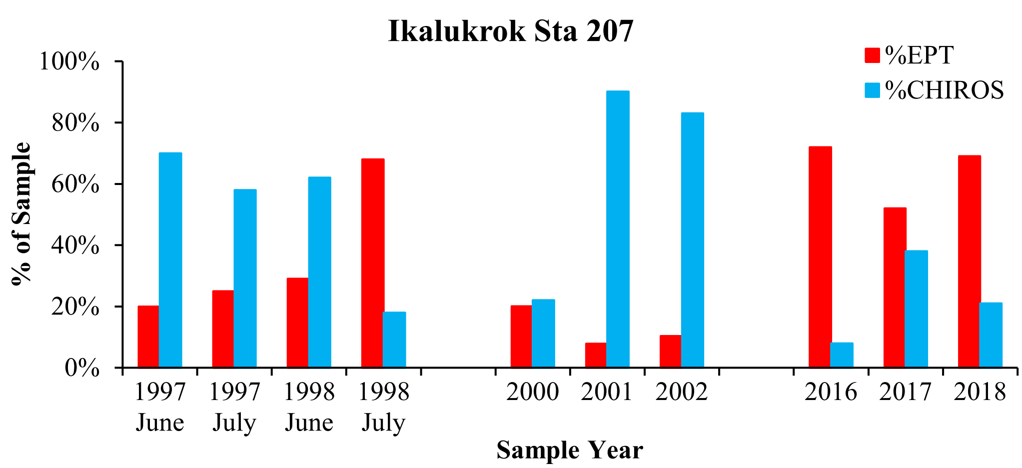

Figure 39. Percent Chironomidae and EPT in Ikalukrok Creek.

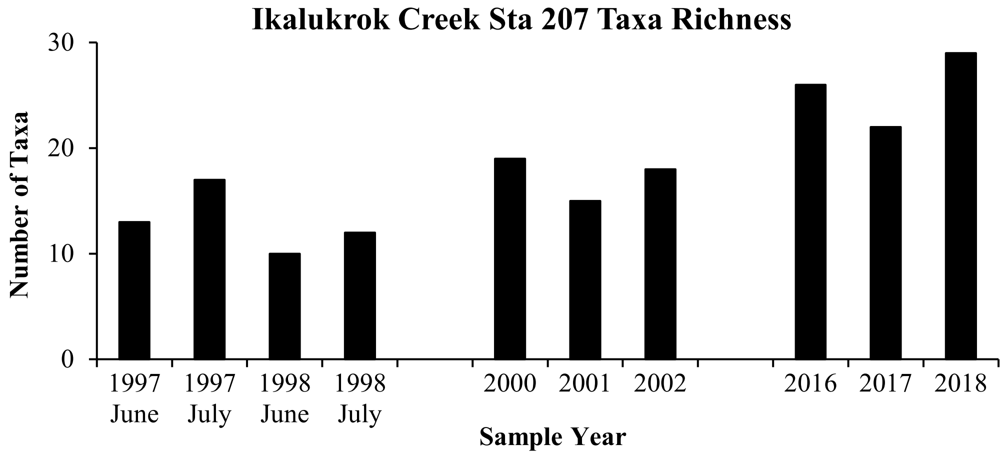

Figure 40. Aquatic invertebrate taxa richness in Ikalukrok Creek.

Fish

During the 2000 sampling event, one lethargic adult Arctic grayling was observed in Ikalukrok Creek (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.

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. A waterfall exists at the upper end of the canyon that is a barrier to upstream fish movement.

Figure 41. Drift nets in East Fork Ikalukrok Creek, 2018.

Periphyton

Chlorophyll-a concentrations were high in East Fork Ikalukrok Creek in most years, ranging from 1.21 mg/m^2 in 2016 to 7.36 mg/m^2 in 2002 (Figure 41). As measured by chlorophyll-a concentration, East Fork Ikalukrok Creek is generally one of the more highly productive sites.

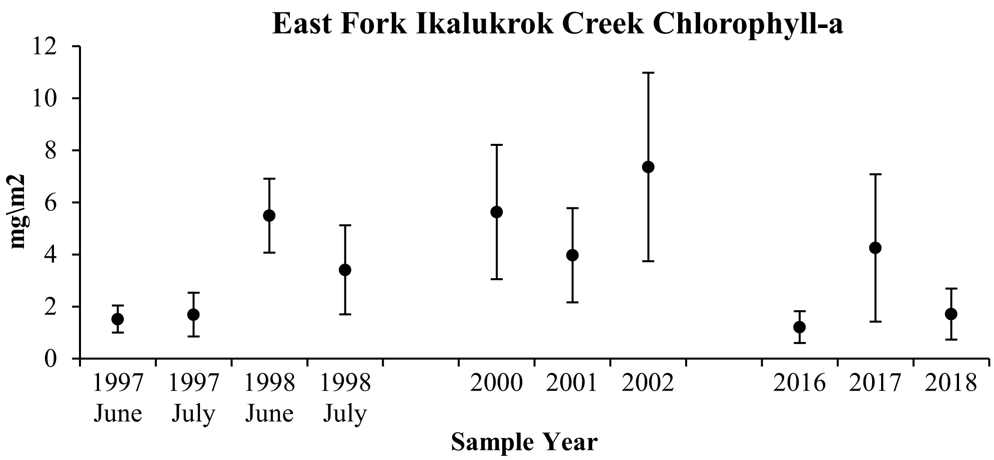

Figure 42. Average concentration of chlorophyll-a (± 1SD) in East Fork Ikalukrok Creek.

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 26.0 invertebrates/m^3 in 2001 (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, but EPT (both mayflies and stoneflies) was well represented in 1997 and 1998 (Figure 44). EPT and Chironomid sample percentages were similar in the 2016 to 2018 samples. Taxa richness varied from a low of 13 taxa per site in 2000 to a high of 26 taxa per site in 2018 (Figure 45).

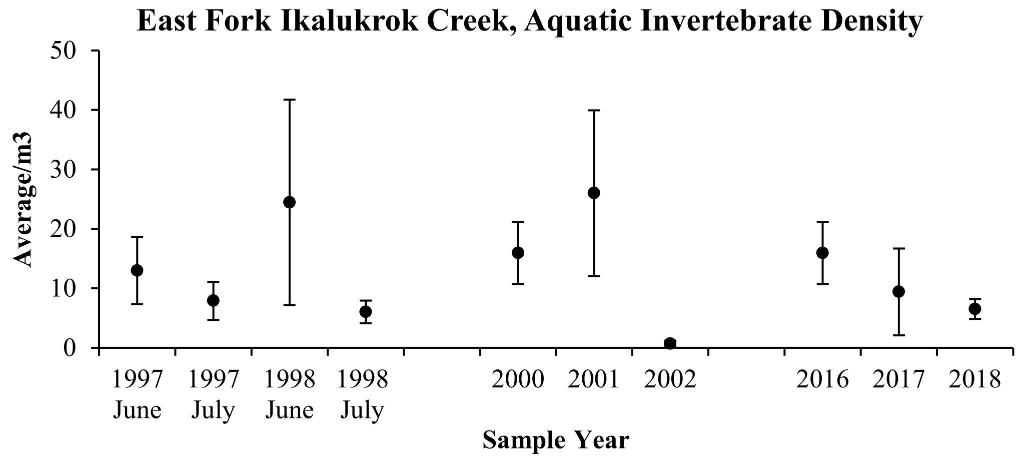

Figure 43. Average aquatic invertebrate densities ± 1SD in East Fork Ikalukrok Creek.

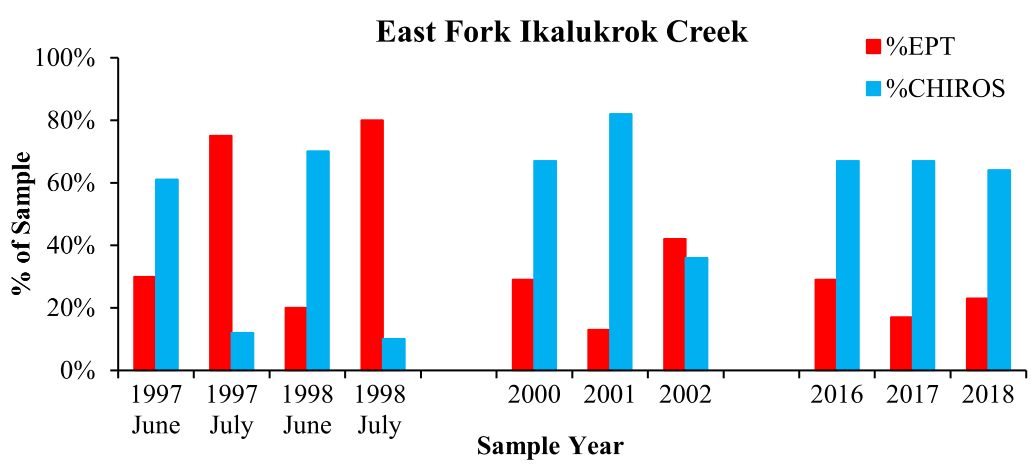

Figure 44. Percent Chironomidae and EPT in East Fork Ikalukrok Creek.

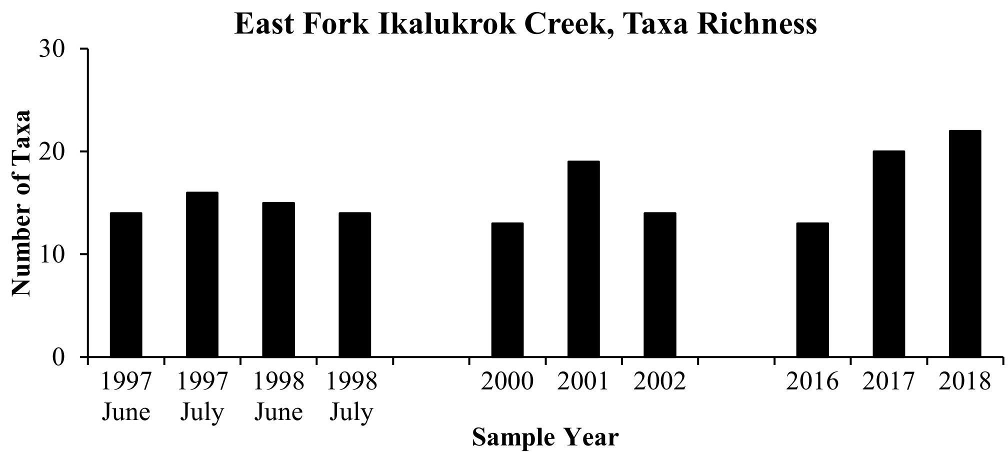

Figure 45. Aquatic invertebrate taxa richness in East Fork Ikalukrok Creek.

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 2018 (Figure 46). The majority of catches were juvenile Dolly Varden, but two slimy sculpin (81 and 108 mm) were also caught in 2017.

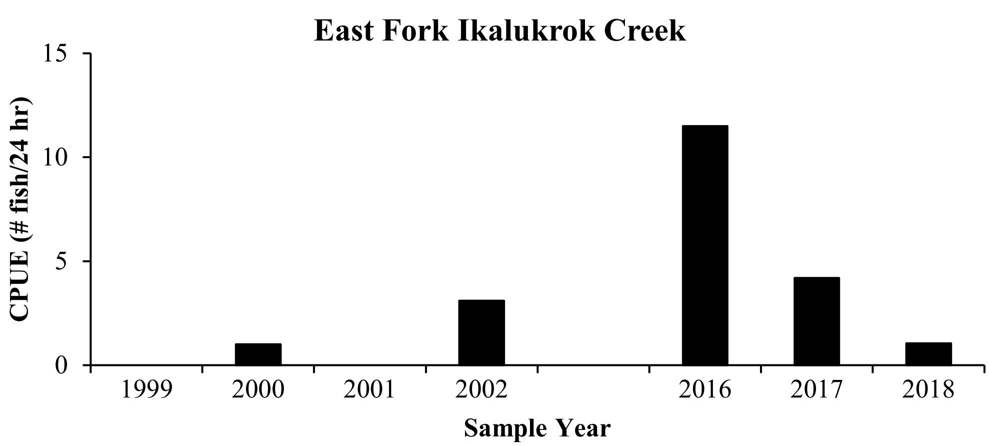

Figure 46. Catch per unit of effort for juvenile Dolly Varden in East Fork Ikalukrok Creek.

Aerial surveys (helicopter) were conducted opportunistically and Arctic grayling were sampled by angling (Weber Scannell and Ott 2006). In some years (1999, 2000, and 2002) from 1997 to 2005, 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 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.

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.

Figure 47. Grayling Junior Creek drift net sampling, 2018.

Periphyton

Chlorophyll-a concentrations in Grayling Junior Creek varied from a low of 0.98 mg/m^2 in 2018 to a high of 4.63 mg/m^2 in 2002 (Figure 48). As measured by chlorophyll-a concentration, Grayling Junior Creek is generally a moderately productive site.

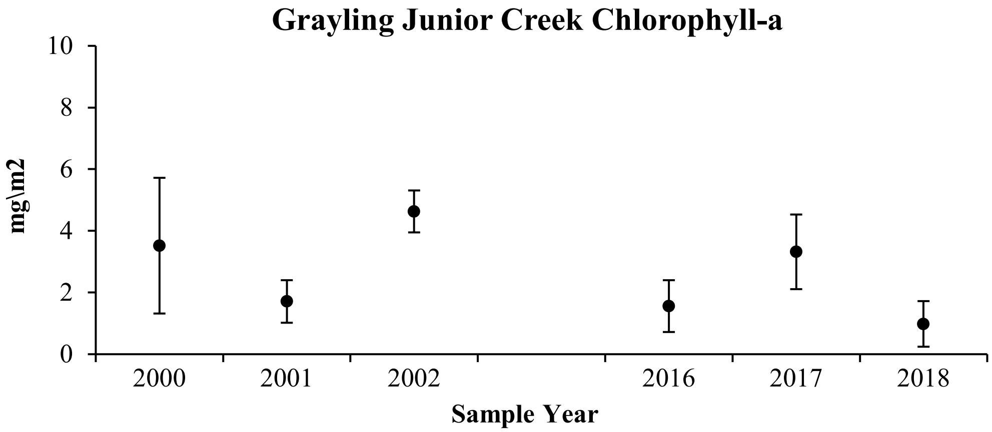

Figure 48. Average concentration of chlorophyll-a (± 1SD) in Grayling Junior Creek.

Invertebrates

Aquatic invertebrate density in Grayling Junior Creek varied from a low of 3.3 invertebrates/m^3 to a high of 11.6 invertebrates/m^3 (Figure 49). The EPT was composed of mayflies and stoneflies with very few 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 26 taxa in 2018 (Figure 51).

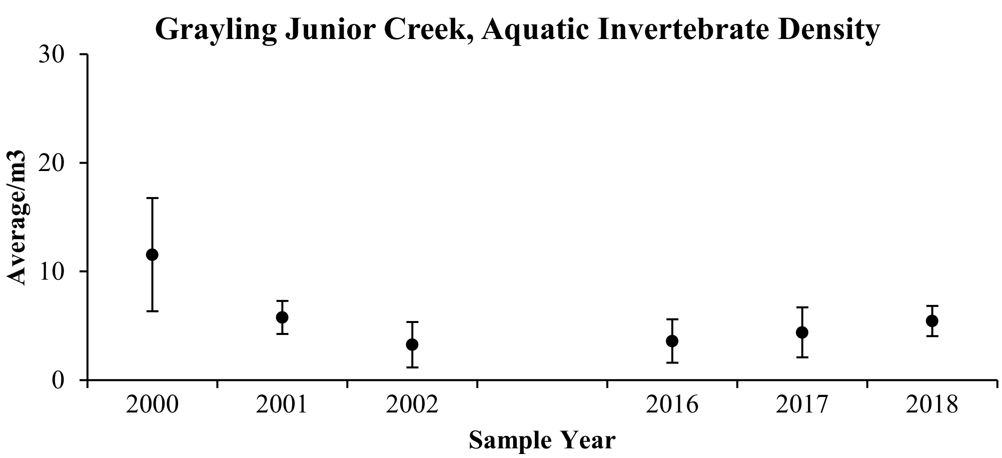

Figure 49. Average aquatic invertebrate densities ± 1SD in Grayling Junior Creek.

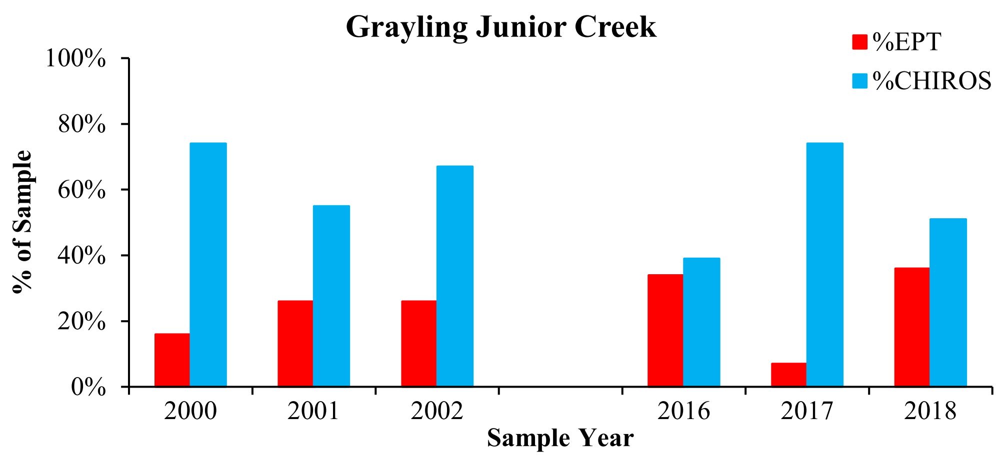

Figure 50. Percent Chironomidae and EPT in Grayling Junior Creek.

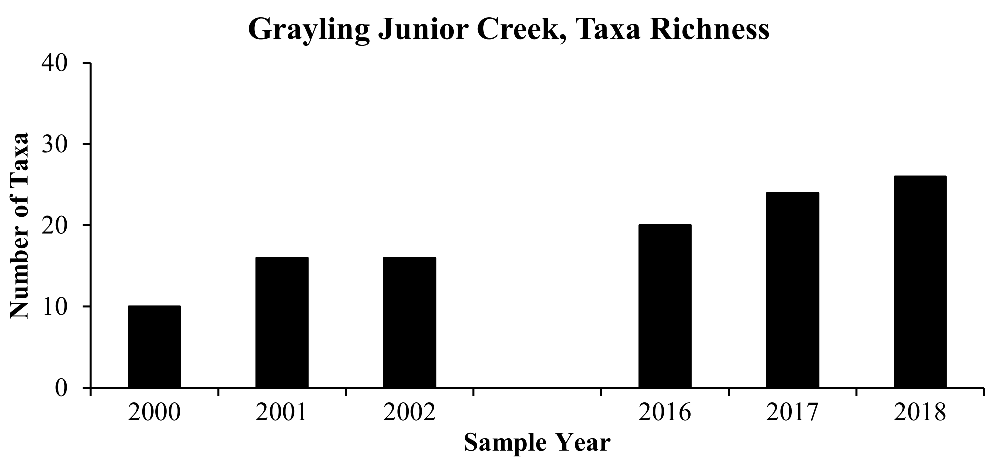

Figure 51. Aquatic invertebrate taxa richness in Grayling Junior Creek.

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 about 300 adult Arctic grayling in Ikalukrok Creek at the mouth of Grayling Junior Creek (Figure 52). Mark-recapture sampling indicated that Arctic grayling moved between the Red Dog Creek drainage and Ikalukrok Creek drainage including Grayling Junior Creek. The very high numbers of fish seen at the mouth of Grayling Junior Creek was only documented in 1999.

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

Fish sampling with minnow traps was done in Grayling Junior Creek from 2000 to 2002 (two sampling events per year), 2004 (one sampling event), and in 2016 to 2018 (one sampling event) (Appendix 3). Dolly Varden juveniles, slimy sculpin, and age-0 Arctic grayling were captured in minnow traps. Arctic grayling age-0 fish 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). Slimy sculpin are 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.

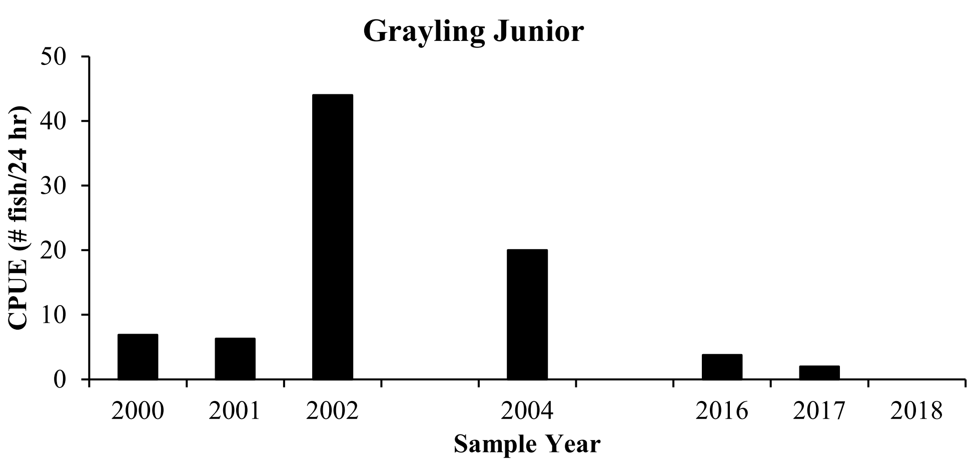

Figure 53. Catch per unit of effort for juvenile Dolly Varden in Grayling Junior Creek.

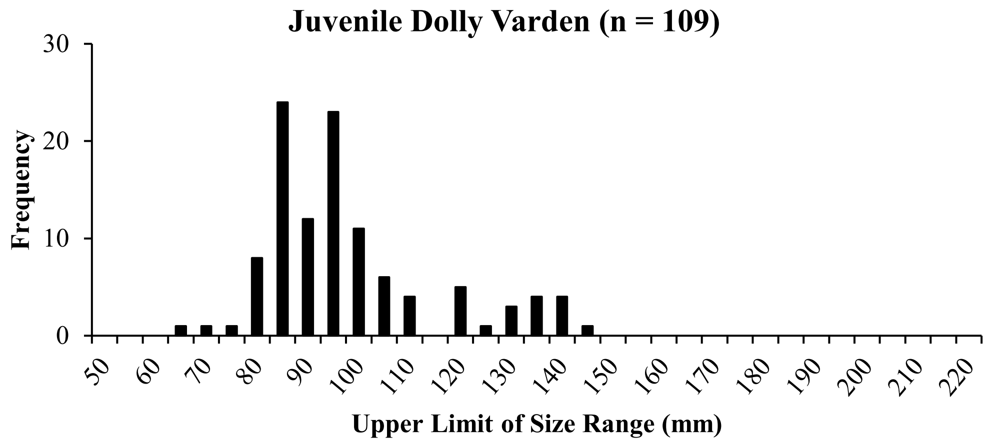

Figure 54. Length frequency distribution of Dolly Varden in Grayling Junior Creek.

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 (Figure 55).

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 (Figure 55). Zinc concentrations were highest in fish from Grayling Junior Creek in 2001, but similar among fish from the three creeks for the remaining samples (Figure 55). Mercury concentrations were similar from all three creeks with concentrations near the detection limit (Figure 55).

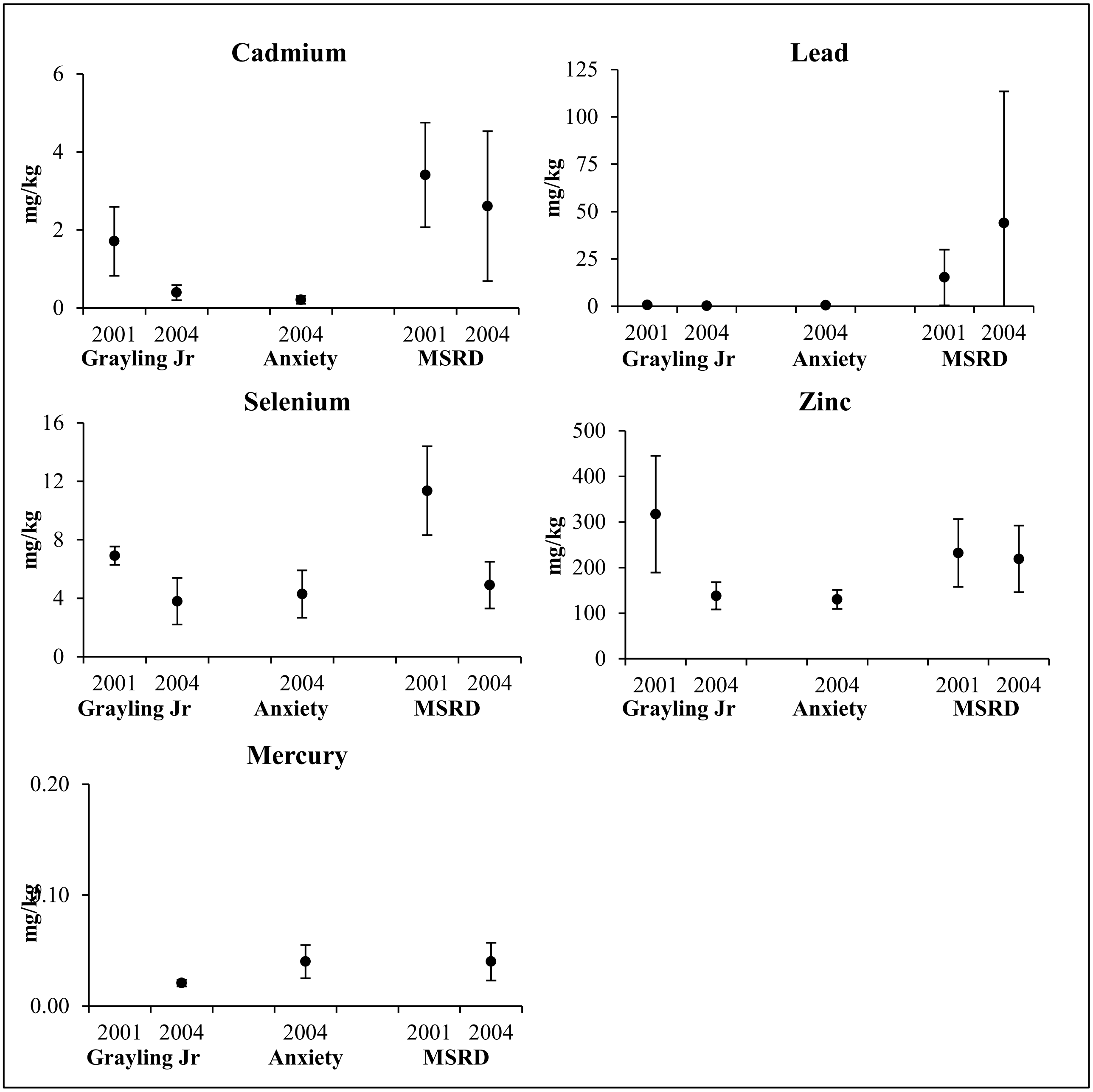

Figure 55. Average dry weight whole body element concentrations (± 1SD) in juvenile Dolly Varden collected from Grayling Junior, Anxiety Ridge, and Mainstem Red Dog (MSRD) creeks, note that samples were not tested for mercury in 2001.

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).

Figure 56. The mouth of Noa Creek on Ikalukrok Creek (left) and the sample site on Noa Creek just upstream of the mouth (right), July 12, 2018.

Periphyton

Average chlorophyll-a concentrations in Noa Creek have been low, ranging from 0.14 mg/m^2 in 2008 to 0.32 mg/m^2 in 2000 (Figure 57).

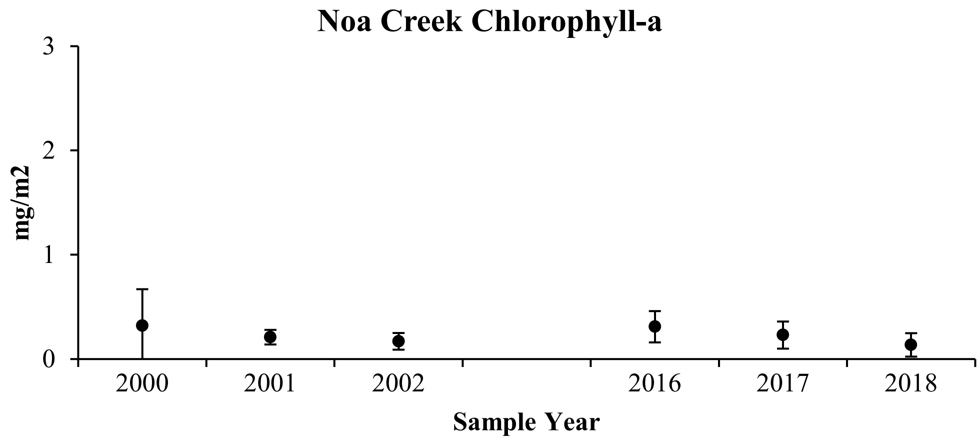

Figure 57. Average concentration of chlorophyll-a (± 1SD) in Noa Creek.

Invertebrates

Aquatic invertebrate density has varied from a low of 3.9 invertebrates/m^3 in 2000 to a high of 38.1 invertebrates/m^3 in 2002, and was generally dominated by aquatic diptera (Figure 58). EPT was virtually absent from the samples (Figure 59). Taxa richness varied from 15 to 21 taxa per site over the sample years (Figure 60).

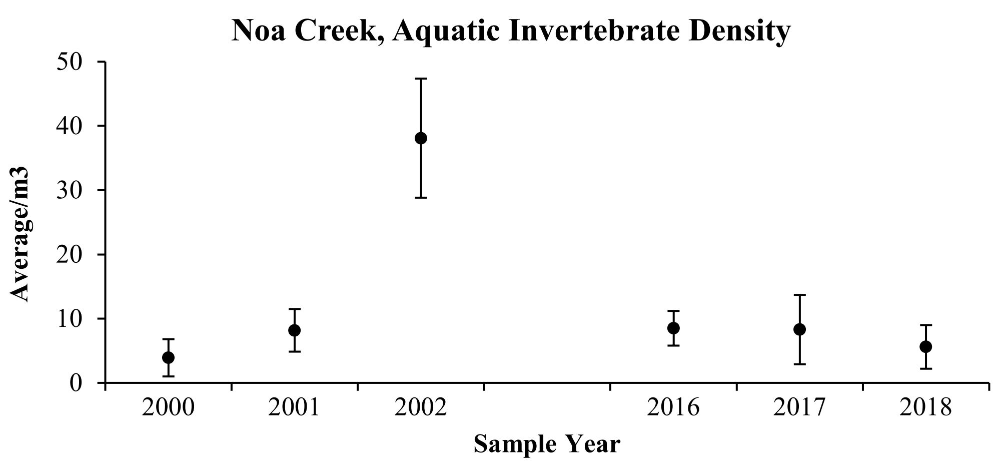

Figure 58. Average aquatic invertebrate densities ± 1SD in Noa Creek.

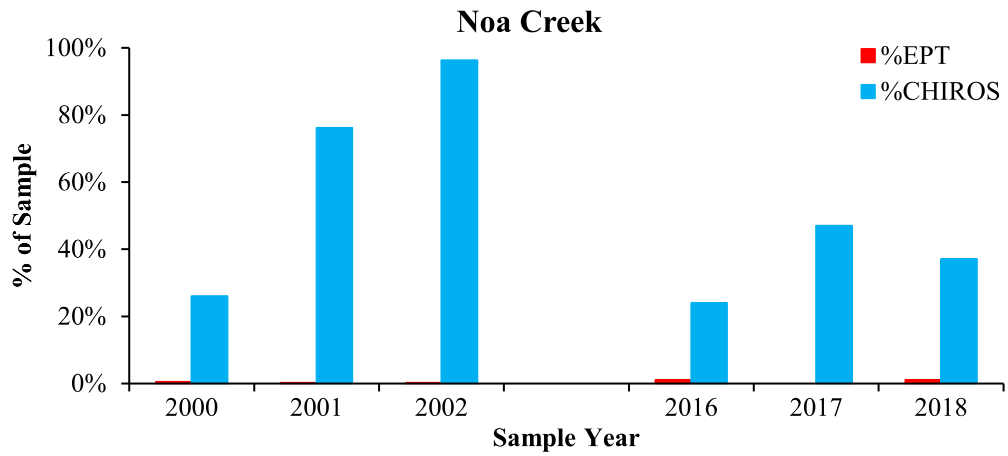

Figure 59. Percent Chironomidae and EPT in Noa Creek.

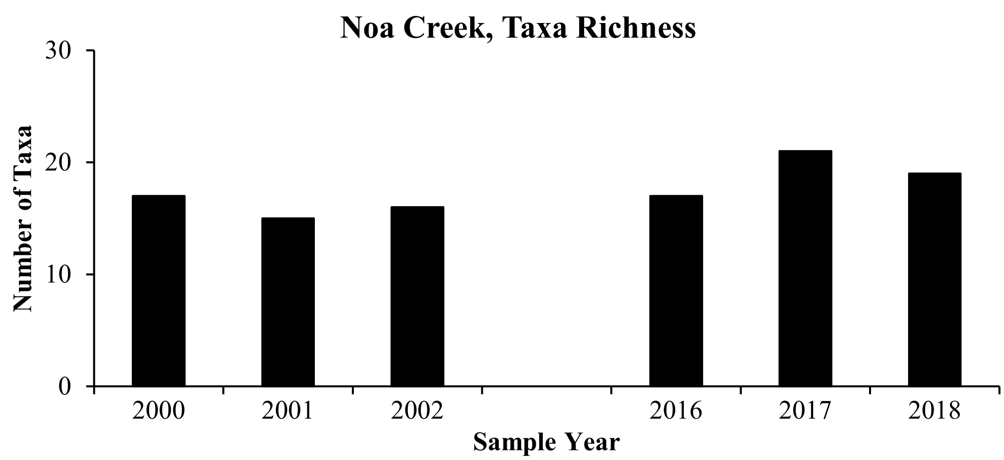

Figure 60. Aquatic invertebrate taxa richness in Noa Creek.

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).

Figure 61. The mouth of Moil Creek on Ikalukrok Creek (left) and the sample site upstream on Moil Creek (right), July 12, 2018.

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).

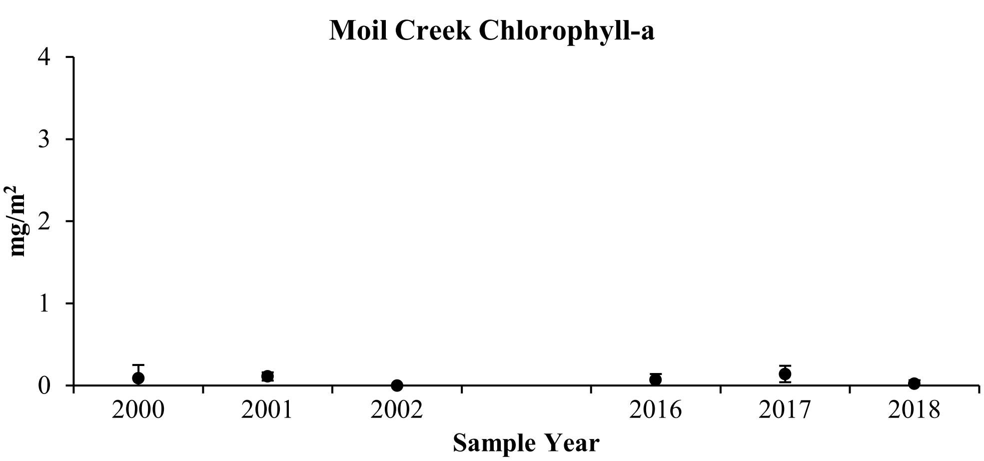

Figure 62. Average concentration of chlorophyll-a (± 1SD) in Moil Creek.

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 21 taxa per site over the sample years (Figure 65).

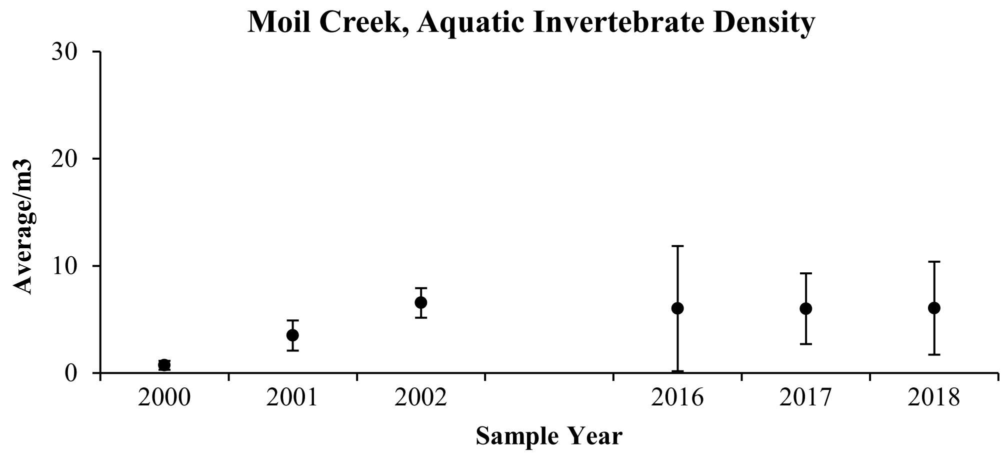

Figure 63. Average aquatic invertebrate densities ± 1SD in Moil Creek.

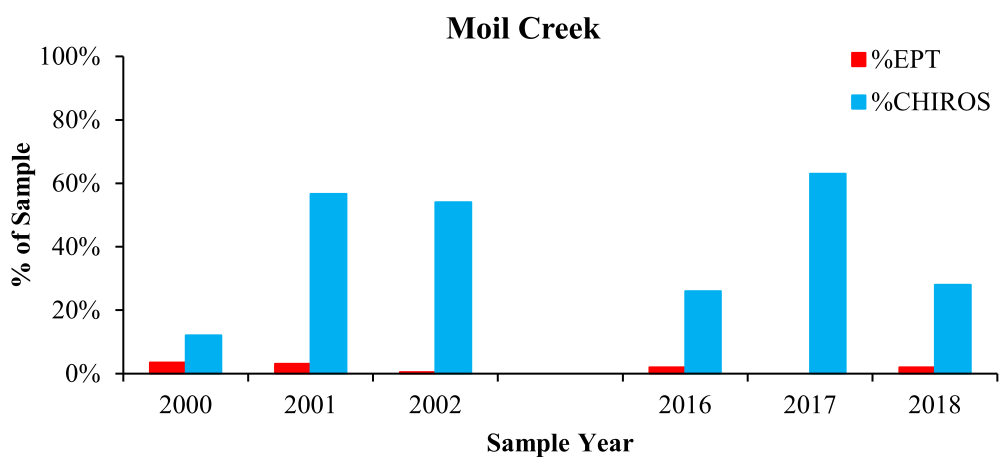

Figure 64. Percent Chironomidae and EPT in Moil Creek.

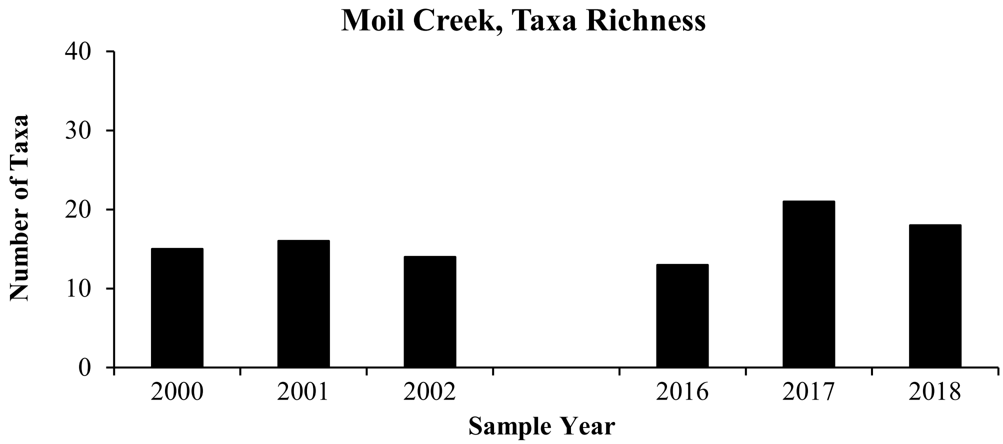

Figure 65. Aquatic invertebrate taxa richness in Moil Creek.

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 (left photo 7/5/2016 and right photo 7/12/2018).

Periphyton

Average chlorophyll-a concentrations in Sled Creek were relatively high ranging from 1.85 mg/m^2 in 2002 to 6.2 mg/m^2 in 2000 (Figure 67).

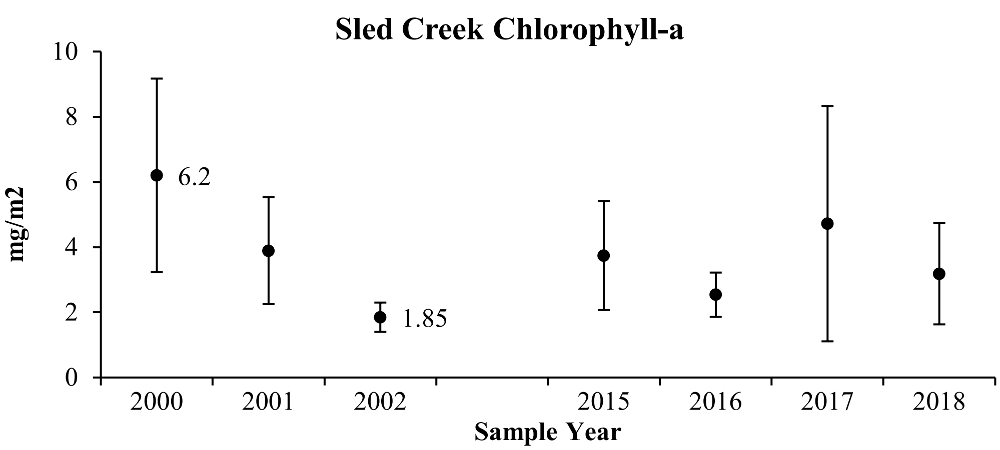

Figure 67. Average concentration of chlorophyll-a (± 1SD) in Sled Creek.

Invertebrates

Aquatic invertebrate density in Sled Creek varied from a low of 8.5 invertebrates/m^3 in 2002 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). 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 14 to a high of 23 over the sample years (Figure 70).

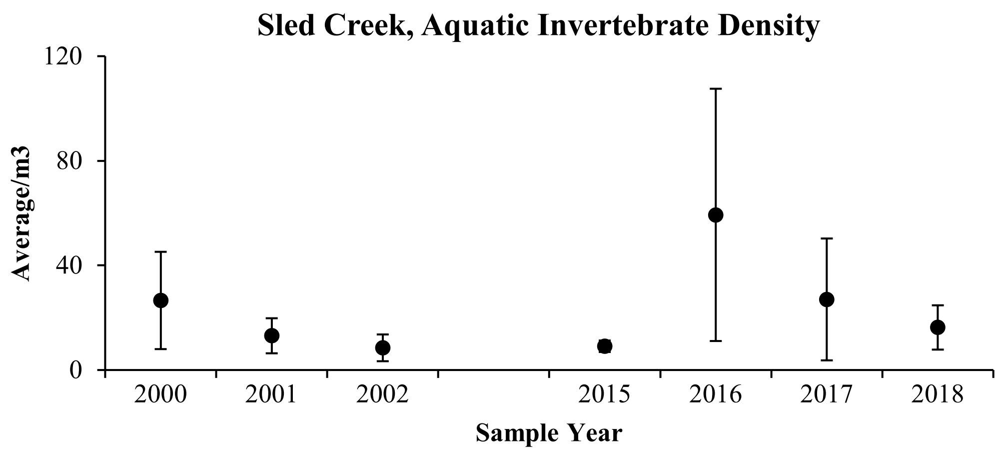

Figure 68. Average aquatic invertebrate densities ± 1SD in Sled Creek.

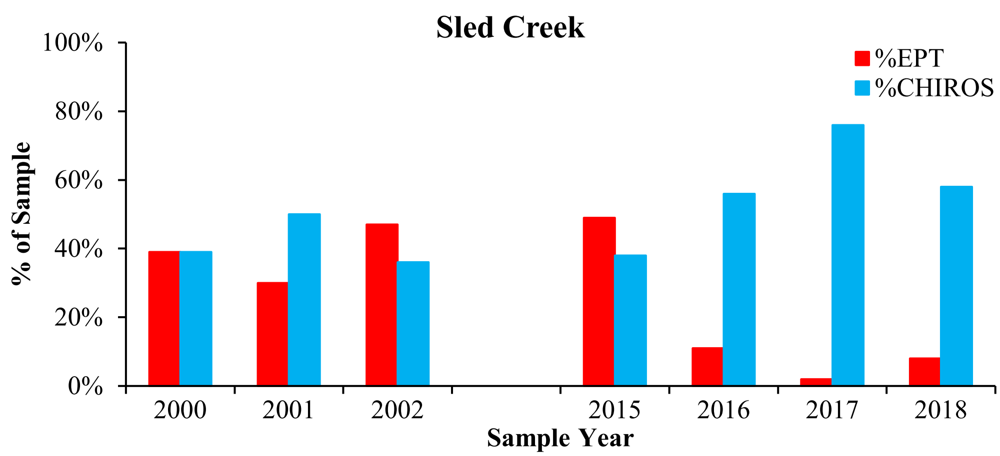

Figure 69. Percent Chironomidae and EPT in Sled Creek.

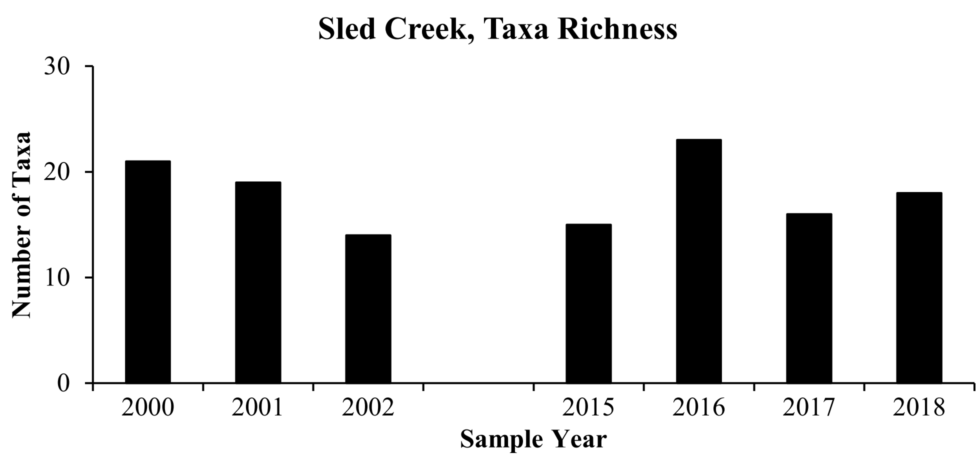

Figure 70. Aquatic invertebrate taxa richness in Sled Creek.

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 2018. Visual observations and biological data collected indicate that Volcano Creek is a productive aquatic system (Figure 71).

Figure 71. Volcano Creek (left photo 7/9/2015 and right photo 7/5/2017).

Periphyton

Average chlorophyll-a concentrations were high in Volcano Creek ranging from a low of 1.78 mg/m^2 in 2018 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 in 2018.

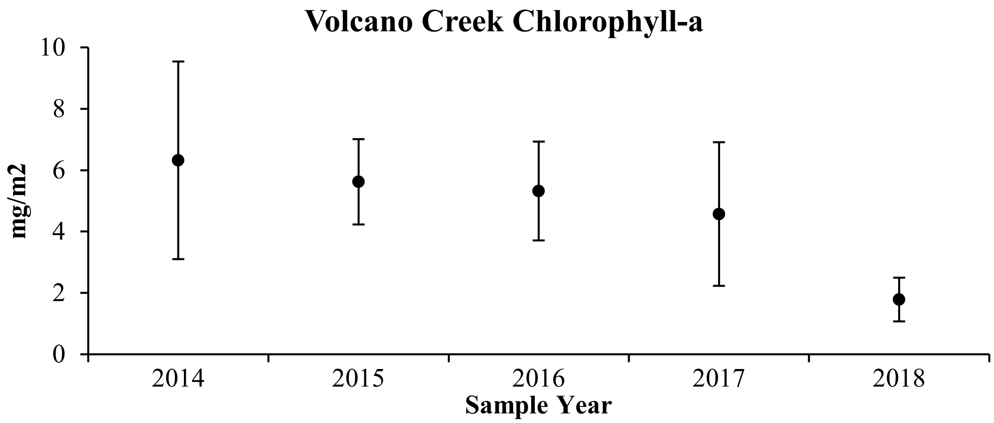

Figure 72. Average concentration of chlorophyll-a (± 1SD) in Volcano Creek.

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 (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).

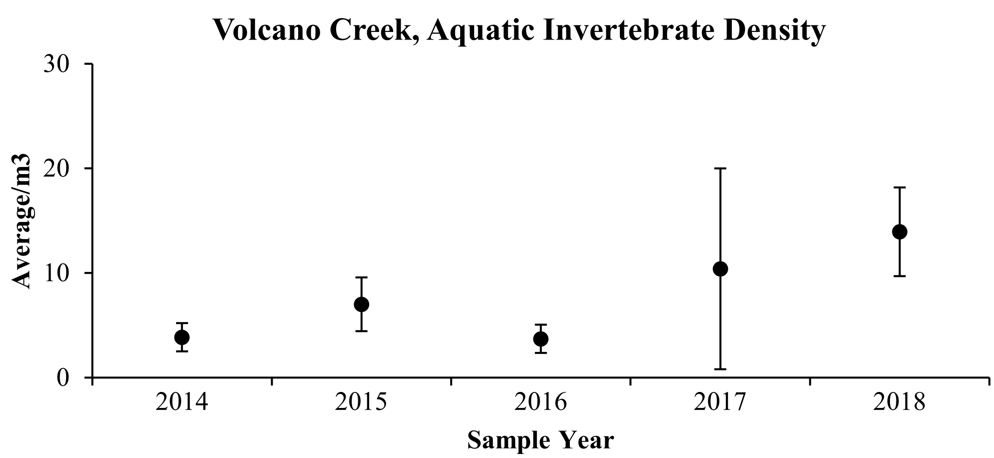

Figure 73. Average aquatic invertebrate densities ± 1SD in Volcano Creek.

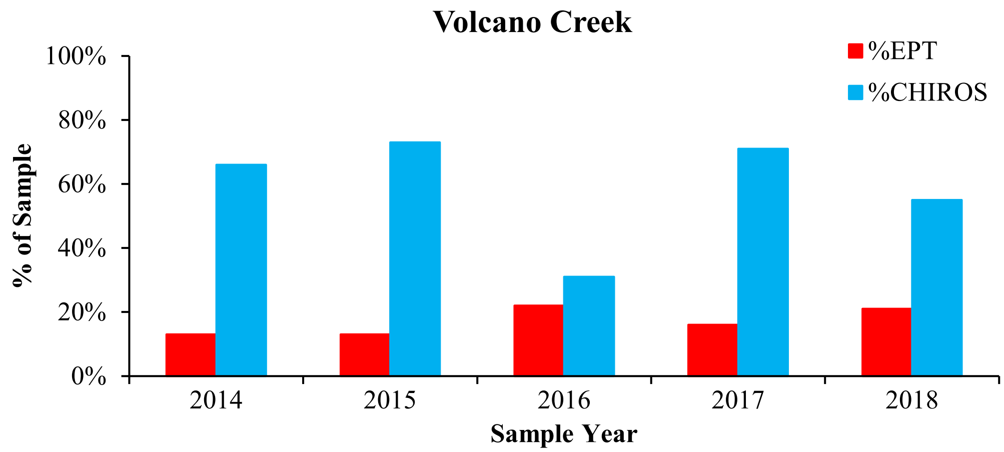

Figure 74. Percent Chironomidae and EPT in Volcano Creek.

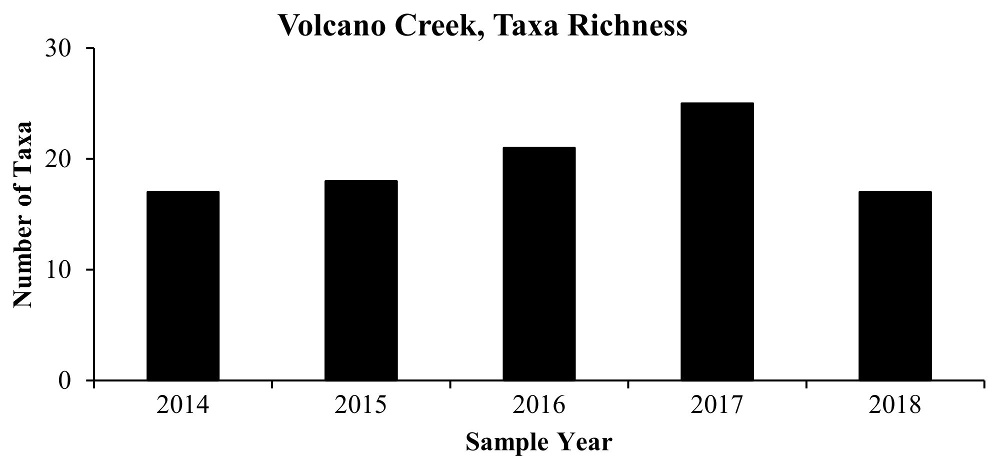

Figure 75. Aquatic invertebrate taxa richness in Volcano Creek.

Fish

Fish sampling with minnow traps and visual observations was conducted in Volcano Creek from 2014 to 2018 (Appendix 1). In 2016 a second site (about 2 km further upstream) was also sampled. No fish were caught in 2014, but Dolly Varden were found in 2015 to 2018 (Figure 76) and slimy sculpin were caught in 2017 and 2018. Length frequency distribution of all Dolly Varden caught is presented in Figure 77. Age 1 and 2 fish dominated the catch with some larger, older fish present.

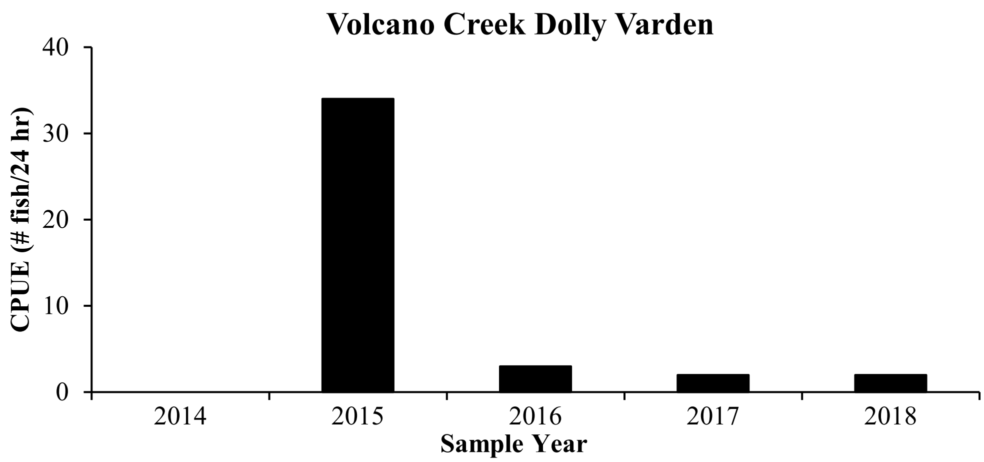

Figure 76. Catch per unit of effort for juvenile Dolly Varden in Volcano Creek.

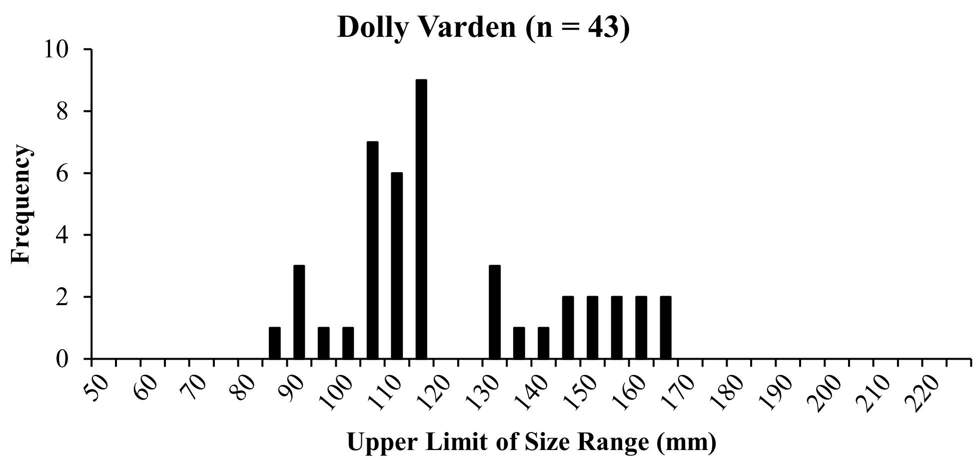

Figure 77. Length frequency distribution of Dolly Varden in Volcano Creek.

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). No Dolly Varden in the correct size range for retention were captured in 2018. These data were compared graphically with Dolly Varden collected in Mainstem Red Dog and Anxiety Ridge creeks (Figures 78 through 82) during the same time frame. The cadmium concentrations in Volcano Creek were similar to those found in Mainstem Red Dog Creek (Figure 78).

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 (Figures 79 and 80). Zinc concentrations in juvenile Dolly Varden were slightly higher in Mainstem Red Dog Creek as compared to Anxiety Ridge Creek (Figure 81) and mercury concentrations were slightly higher in Anxiety Ridge Creek (Figure 82). All mercury concentrations were low.

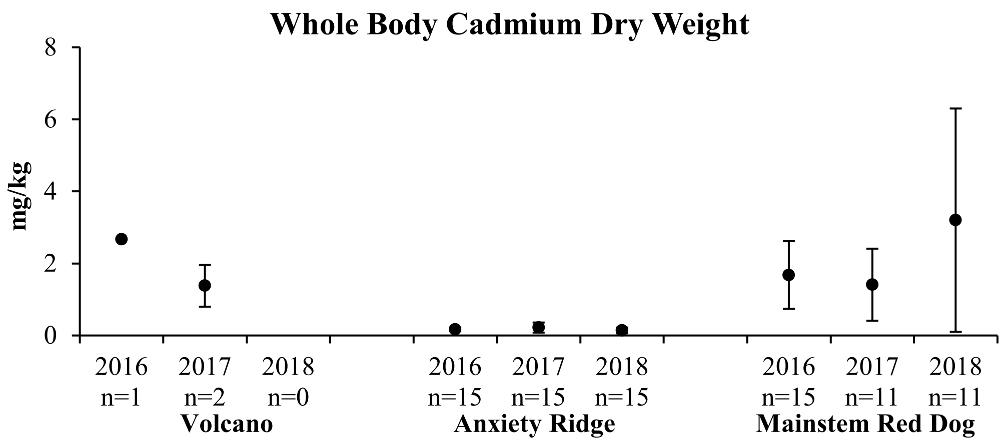

Figure 78. Average cadmium concentrations (± 1SD) in juvenile Dolly Varden collected from Volcano, Anxiety Ridge, and Mainstem Red Dog creeks.

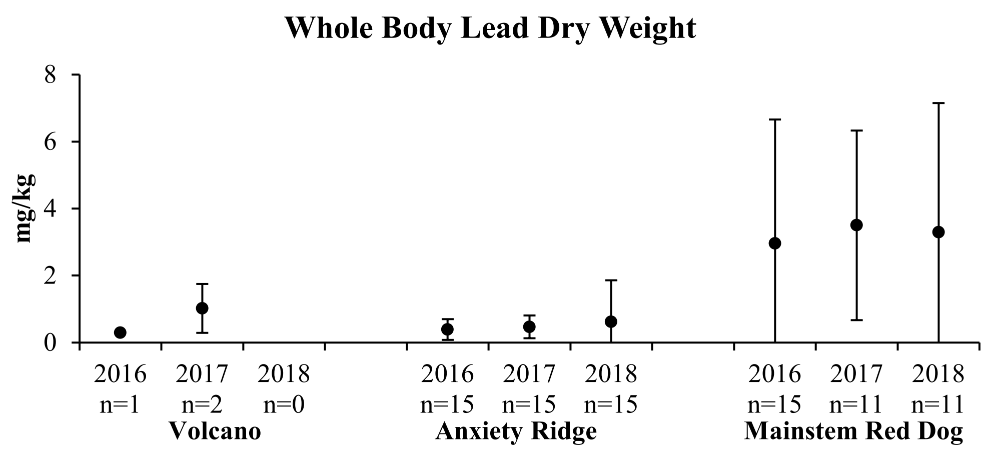

Figure 79. Average lead concentrations (± 1SD) in juvenile Dolly Varden collected from Volcano, Anxiety Ridge, and Mainstem Red Dog creeks.

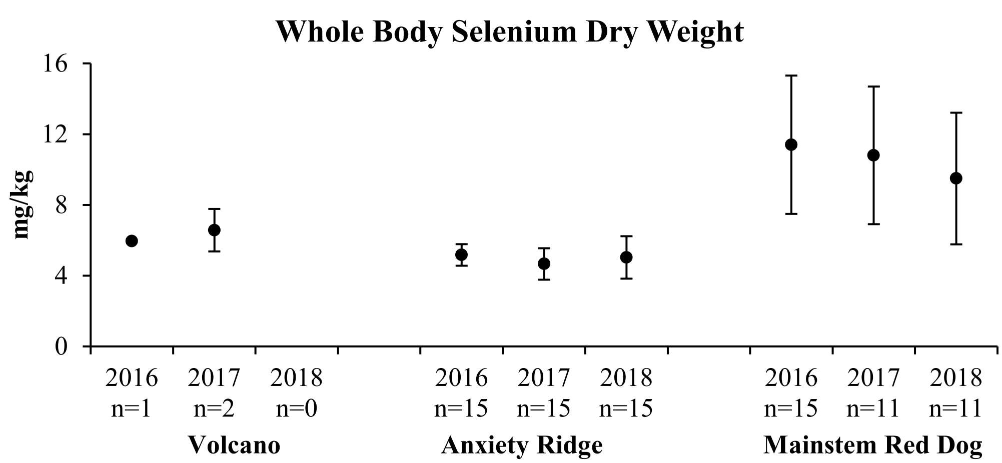

Figure 80. Average selenium concentrations (± 1SD) in juvenile Dolly Varden collected from Volcano, Anxiety Ridge, and Mainstem Red Dog creeks.

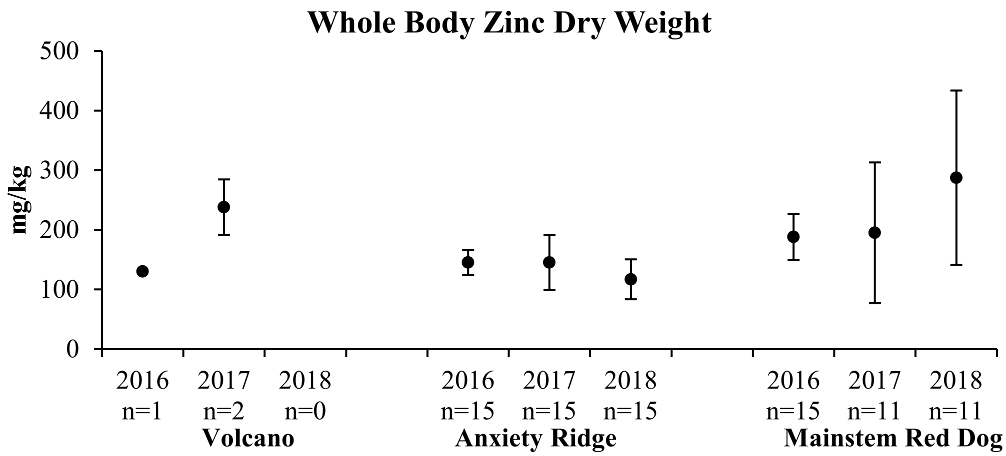

Figure 81. Average zinc concentrations (± 1SD) in juvenile Dolly Varden collected from Volcano, Anxiety Ridge, and Mainstem Red Dog creeks.

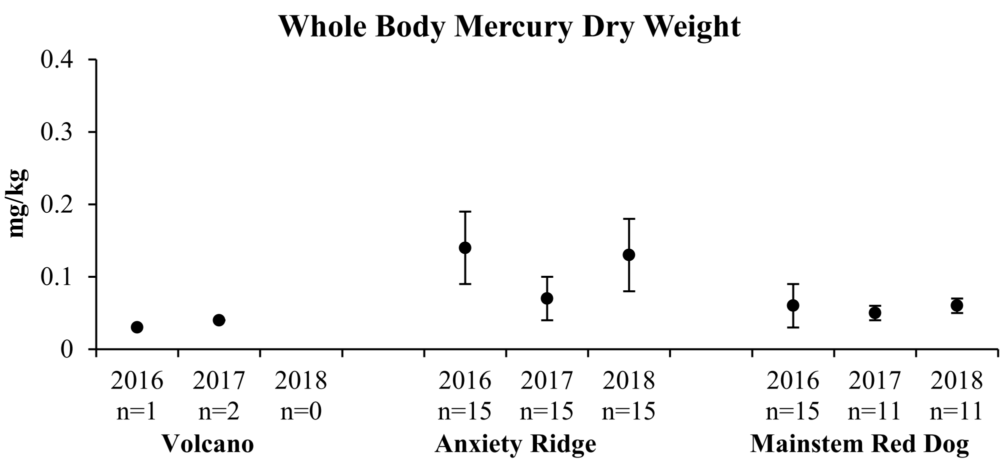

Figure 82. Average mercury concentrations (± 1SD) in juvenile Dolly Varden collected from Volcano, Anxiety Ridge, and Mainstem Red Dog creeks.

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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	
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	
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	

Appendix 1 continued.

Sample Location (Station)	Date Sampled	Hours Fished	Total Catch	CPUE	Other Fish
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	
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	
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	

Appendix 1 concluded.

Sample Location (Station)	Date Sampled	Hours Fished	Total Catch	CPUE	Other Fish
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
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