Technical Report No. 25-08

Aquatic Biomonitoring at Red Dog Mine, 2024

A requirement under Alaska Pollution Discharge Elimination System Permit No. AK0038652

by

Chelsea M. Clawson

May 2025

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. 25-08

AQUATIC BIOMONITORING AT RED DOG MINE, 2024

A REQUIREMENT UNDER ALASKA POLLUTION DISCHARGE ELIMINATION SYSTEM PERMIT NO. AK0038652

By
Chelsea M. Clawson
Habitat Section, Fairbanks

Alaska Department of Fish and Game
Habitat Section
1300 College Rd, Fairbanks, Alaska, 99701

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Cover: Sampling at Station 10 on Red Dog Creek on July 6, 2024. Photo by Chelsea Clawson.

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Chelsea M. Clawson
Alaska Department of Fish and Game, Habitat Section
1300 College Rd., Fairbanks, AK 99701-1599, USA

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EXECUTIVE SUMMARY

● In 2024, median element concentrations of aluminum, cadmium, nickel, and zinc in water quality samples from Mainstem Red Dog Creek (Station 151) were comparable to 2023 concentrations. Since 2018, these element concentrations have remained higher than the values recorded during 1999–2017. Median levels of lead, selenium, pH, and total dissolved solids (TDS) in 2024 were consistent with past year.

● Median element concentrations (lead, zinc, selenium, cadmium) in water quality samples from Buddy Creek and Bons Pond were consistent with past years' results. In North Fork Red Dog Creek, cadmium and zinc increased in 2019, and have remained at levels higher than 2001–2018 values. Lead and selenium values were consistent with past years.

● Periphyton standing crop, as estimated by chlorophyll-a concentration, is determined each year in drainages near the Red Dog Mine. In 2024, the highest chlorophyll-a concentrations were in Bons Creek below the pond (Station 220) and the lowest concentrations were in upper Ikalukrok Creek (Station 9), Mainstem Red Dog Creek (Station 10), Middle Fork Red Dog Creek (Station 20), and lower Ikalukrok Creek (Station 160). Chlorophyll-a concentrations in Ikalukrok Creek at Station 9 continue to exhibit an inverse relationship with zinc and cadmium in the water. A major source of cadmium and zinc at Station 9 is the natural seep at Cub Creek.

● Benthic macroinvertebrate (BMI) densities are used as an index of stream productivity and health. In 2024, ten sites were sampled. The BMI density was highest at Bons Creek above the pond and Bons Creek below the pond (Station 220). Overall taxa richness varied from 3 to 25 taxa per site. Sampling method was changed from drift nets to Hess samplers in 2022 to better depict the in-situ aquatic community and evaluate potential changes.

● Juvenile Arctic grayling from Bons Pond have been analyzed for selected whole body elements in 2004, 2007, 2010, and 2014–2024. In 2024, the mean concentrations of cadmium, mercury, and selenium in Arctic grayling juveniles were consistent with previous years. In 2024, the mean lead concentration was the highest on record, although the wide standard deviation overlapped with previous years' values. After 3 consecutive years of increasing mean zinc concentrations, the mean zinc concentration decreased in 2024.

● In 2024, adult Dolly Varden captured in the Wulik River during spring and fall were analyzed for cadmium, copper, lead, selenium, zinc, and mercury in kidney, liver, ovary, testes, and muscle tissues. Various elements concentrate in specific tissues. None of the analytes measured appear to concentrate in muscle.

● Aerial surveys are used each fall to estimate the number of overwintering Dolly Varden in the Wulik River. In 2024, a total of 45,976 Dolly Varden were counted in the Wulik River, although this should be considered a minimum estimate due to reduced visibility from turbidity.

● During the September chum salmon aerial survey, high turbidity in Ikalukrok Creek obscured fish visibility and prevented the annual enumeration of spawning salmon.

● The estimated Arctic grayling population in Bons Pond in 2023 was 347 fish (95% CI, 237–457 fish) $\geq$ 200 mm FL. This is a slight decrease from the 2019–2022 population estimates.

INTRODUCTION

The Red Dog zinc and lead deposit is located in northwestern Alaska, about 130 km north of Kotzebue and 75 km inland from the Chukchi Sea coast (Figure 1). Mine operations, facilities, surrounding vegetation, and wildlife are described in the Alaska Department of Fish and Game (ADF&G) technical report: *Fisheries Resources and Water Quality, Red Dog Mine* (Weber-Scannell and Ott 1998). A chronology of development and operations at the Red Dog Mine for 2014 through 2024 is presented in Appendix 1. The summary of previous years of mine development and operations (1982–2013) can be found in Ott and Morris (2014). Aquatic resources in the Wulik River drainage are described in the ADF&G technical report: *Fish and Aquatic Taxa Report at Red Dog Mine, 1998–1999* (Weber-Scannell et al. 2000).

Aquatic biomonitoring has been conducted annually at the Red Dog Mine since 1995, focusing on periphyton, aquatic invertebrate, and fish sampling. Tissue and whole-body element analyses for Dolly Varden (*Salvelinus malma*) and spawning season monitoring for Arctic grayling (*Thymallus arcticus*) are performed annually. This long-term monitoring effort helps assess the ecological health of the drainages and track changes over time. This report presents data collected during summer 2024 and where applicable, these data are compared with previous years.

In 2017, the Alaska Department of Environmental Conservation (ADEC) issued Alaska Pollution Discharge Elimination System Permit (APDES) No. AK0038652 to Teck Alaska Incorporated (Teck) which allowed the discharge of up to 2.418 billion gallons of treated effluent per year into Middle Fork Red Dog Creek. The APDES Permit required the continuation of a bioassessment program that included periphyton, aquatic invertebrates, and fish in selected streams near the Red Dog Mine (Table 1). The current bioassessment program became fully effective and enforceable on September 1, 2017. To satisfy conditions in the ADEC permit the ADF&G submitted Technical Report #17-09: *Methods for Aquatic Life Monitoring at the Red Dog Mine Site: A requirement of the 2017 APDES Permit AK0038652* (Bradley 2017).

On September 23, 2021, the ADEC issued Waste Management Permit (WMP) No. 2021DB0001 for the Red Dog Mine that included a condition that Teck adhere to the requirements of the monitoring plan contained in the Integrated Waste Management Plan submitted by Teck in September 2021. Teck's Monitoring Plan includes sample sites, sampling frequency, and parameters for all aquatic sites, including those required by the APDES Permit (Table 1).

Under APDES Permit No. AK0038652, the Total Dissolved Solids (TDS) load discharged from Outfall 001 is limited from July 25 through the end of the discharge season to maintain total in-stream TDS concentrations at or below 500 mg/L at Station 160 on Ikalukrok Creek. This provision is included to properly protect chum salmon spawning in Ikalukrok Creek. In 2019 and 2020, discharge was paused for part of the discharge season due to background TDS levels at Station 160 approaching or exceeding the 500 mg/L threshold. Based on field measurements made by Teck, the elevated TDS concentrations were due to natural input from drainages in Ikalukrok Creek upstream of Mainstem Red Dog Creek. This inability of the Red Dog Mine to discharge at typical levels led to an increase in water elevation within the Tailings Storage Facility (TSF) and required Red Dog to take special actions throughout the winter of 2019–2020 to ensure the TSF water level remained within the criteria established in the State's (Department of Natural Resources) certificate to operate the dam. Background TDS levels at Station 160 have continued to exceed the 500 mg/L threshold, requiring a permit modification to continue discharging since 2021.

Red Dog Operations received a minor permit modification to APDES Permit No. AK0038652 on May 19, 2021, and it was then administratively extended on September 8, 2022. The permit modification allows continued discharge of high-quality treated wastewater when the TSF approaches within 15 feet of the freeboard limit, even though the natural TDS concentration of the receiving waterbody may exceed the 1,000 mg/L (prior to July 25) or 500 mg/L (July 25 and later) thresholds. The TDS concentration in treated water discharge remains the same; it is the naturally occurring background TDS in Ikalukrok Creek that has increased.

Teck's monitoring plan is incorporated by reference into the Alaska Department of Natural Resources (ADNR) Reclamation Plan Approval (F20219958) dated September 23, 2021. On March 10, 2010, the U.S. Department of the Army issued permit POA-1984-12-M45 to Teck which authorized development of the Aqqaluk Pit. This permit was extended in 2014 under POA-1984-0012-M46, with a new permit application currently in process under POA-2024-00116. Active mining in the Aqqaluk Pit began during 2012. In addition to mine drainage, certain waste rock from Aqqaluk and Qanaiyaq and treated water are placed in the mined out main pit.

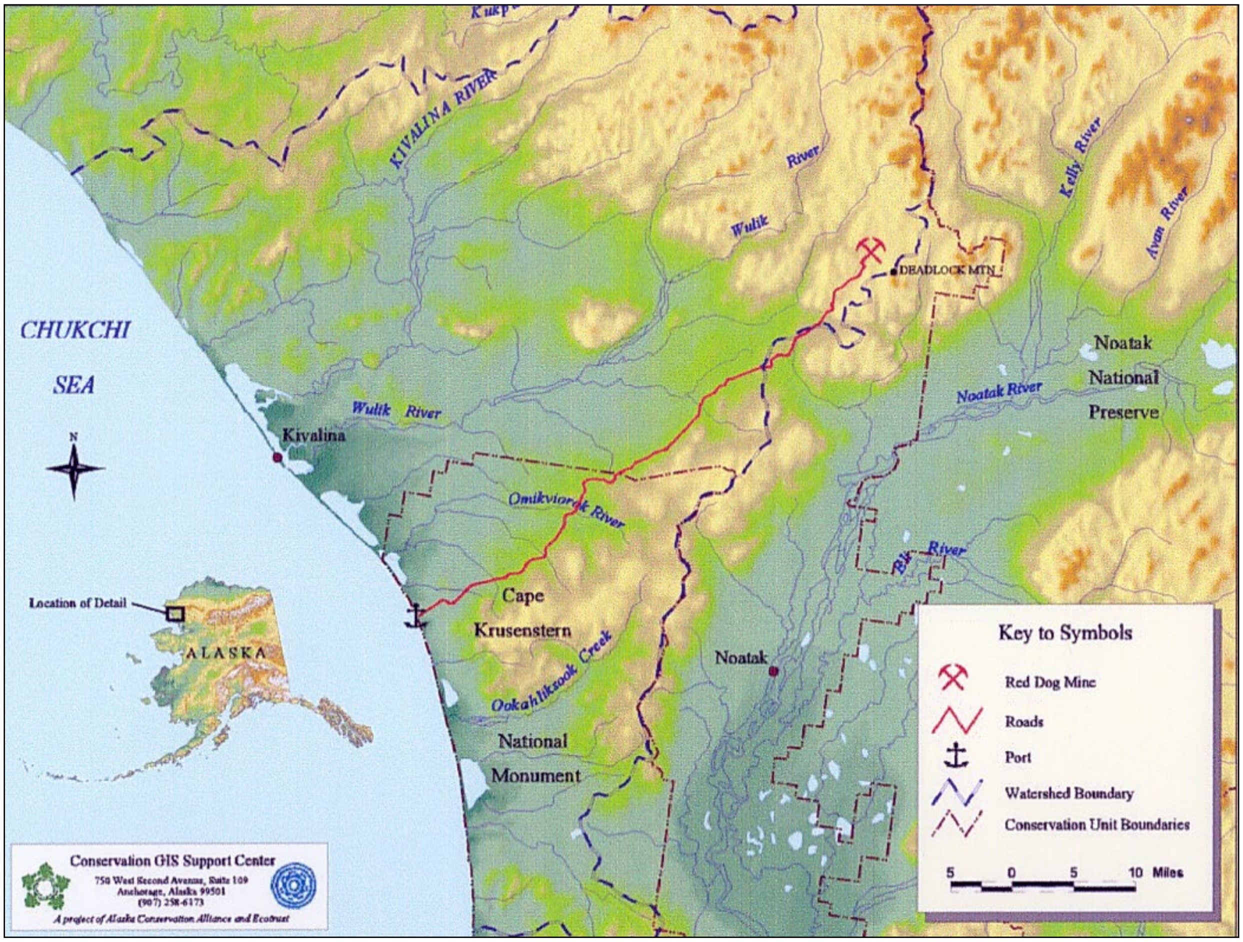

Figure 1.–Location of the Red Dog Mine in northwestern Alaska.[1]

[1] Map used with permission of Conservation GIS Support Center, Anchorage, Alaska.

Table 1.–Location of biological sample sites and factors measured at the Red Dog Mine, 2024[1].

Location	APDES/WMP	Location Description	Parameters
Wulik River	WMP	Kivalina Lagoon to 10 km past mouth of Ikalukrok Creek	Fall aerial surveys for overwintering Dolly Varden
Ikalukrok Cr	WMP	Lower Ikalukrok Creek to mouth of Dudd Creek	Fall aerial surveys for adult chum salmon
Ikalukrok Station 9	APDES/WMP	Ikalukrok Creek upstream of confluence with Red Dog Creek	Periphyton (as chlorophyll-a concentration) Benthic macroinvertebrates Fish presence and use
Ikalukrok Station 160	WMP	Lower Ikalukrok Creek	Periphyton (as chlorophyll-a concentration) Benthic macroinvertebrates Fish presence and use
Middle Fork Red Dog Station 20	WMP	Middle Fork Red Dog Creek above fish weir	Periphyton (as chlorophyll-a concentration) Benthic macroinvertebrates
Red Dog Station 10	APDES/WMP	Mouth of Red Dog Creek	Periphyton (as chlorophyll-a concentration) Benthic macroinvertebrates Fish presence and use Juvenile Dolly Varden elements in tissue
North Fork Red Dog Station 12	APDES/WMP	North Fork Red Dog Creek Above confluence with Mainstem Red Dog	Periphyton (as chlorophyll-a concentration) Benthic macroinvertebrates Fish presence and use Record of spawning activity Capture/mark Arctic grayling
Upper NFRD	APDES	Upper North Fork Red Dog Creek, above Aqqaluk	Periphyton (as chlorophyll-a concentration) Benthic macroinvertebrates Fish presence and use
Red Dog Station 151	APDES	Upper mainstem Red Dog Creek	Fish presence and use
Buddy Creek	WMP	Below falls, about 1.5 km downstream of haul road	Periphyton (as chlorophyll-a concentration) Benthic macroinvertebrates Fish presence and use Juvenile Dolly Varden elements in tissue
Buddy Station 221	WMP	Buddy Creek above haul road	Periphyton (as chlorophyll-a concentration) Benthic macroinvertebrates
Bons Station 220	WMP	Bons Creek below pond	Periphyton (as chlorophyll-a concentration) Benthic macroinvertebrates
Bons	WMP	Bons Creek above pond	Periphyton (as chlorophyll-a concentration) Benthic macroinvertebrates
Anxiety Ridge	WMP	Anxiety Ridge Creek below haul road	Fish presence and use Juvenile Dolly Varden elements in tissue
Evaingiknuk	WMP	Evaingiknuk Creek	Fish presence and use
Bons Pond	WMP	Above reservoir spillway	Juvenile Arctic grayling elements in tissue Arctic grayling population estimate

[1]Sampling for juvenile fish presence and use did not occur in 2024 due to high water conditions.

STRUCTURE OF REPORT

This report is presented in several sections as follows:

1) Overview of sampling sites and general methods;
2) Water quality;
3) Periphyton standing crop;
4) Benthic macroinvertebrates;
5) Element concentration data for juvenile Arctic grayling collected from Bons Pond, and adult Dolly Varden collected from the Wulik River;
6) Aerial survey estimates of overwintering Dolly Varden in the Wulik River and chum salmon (*Oncorhynchus keta*) spawners in Ikalukrok Creek; and
7) Biological monitoring data for Arctic grayling, and slimy sculpin (*Cottus cognatus*).

LOCATION AND DESCRIPTION OF SAMPLE SITES

Biomonitoring is conducted annually in streams near the Red Dog Mine as required under the APDES Permit No. AK0038652 and by the ADEC Waste Management Permit and the ADNR Reclamation Plan Approval (Table 1 and Figure 2). Water quality and fish data collected during four years of baseline studies (1979–1982) represent pre-mining conditions. Comparisons of existing conditions relative to baseline data should consider that there is a much longer time series of data since mining began (1990–2024) when compared to the pre-development baseline data. All streams in the study area including Red Dog, Ikalukrok, Bons and Buddy creeks are in the Wulik River drainage, except for Evaingiknuk Creek, which is in the Noatak River drainage. Station numbers correspond either to those used by Dames and Moore (1983) during baseline work or to the current water quality program being conducted by Teck.

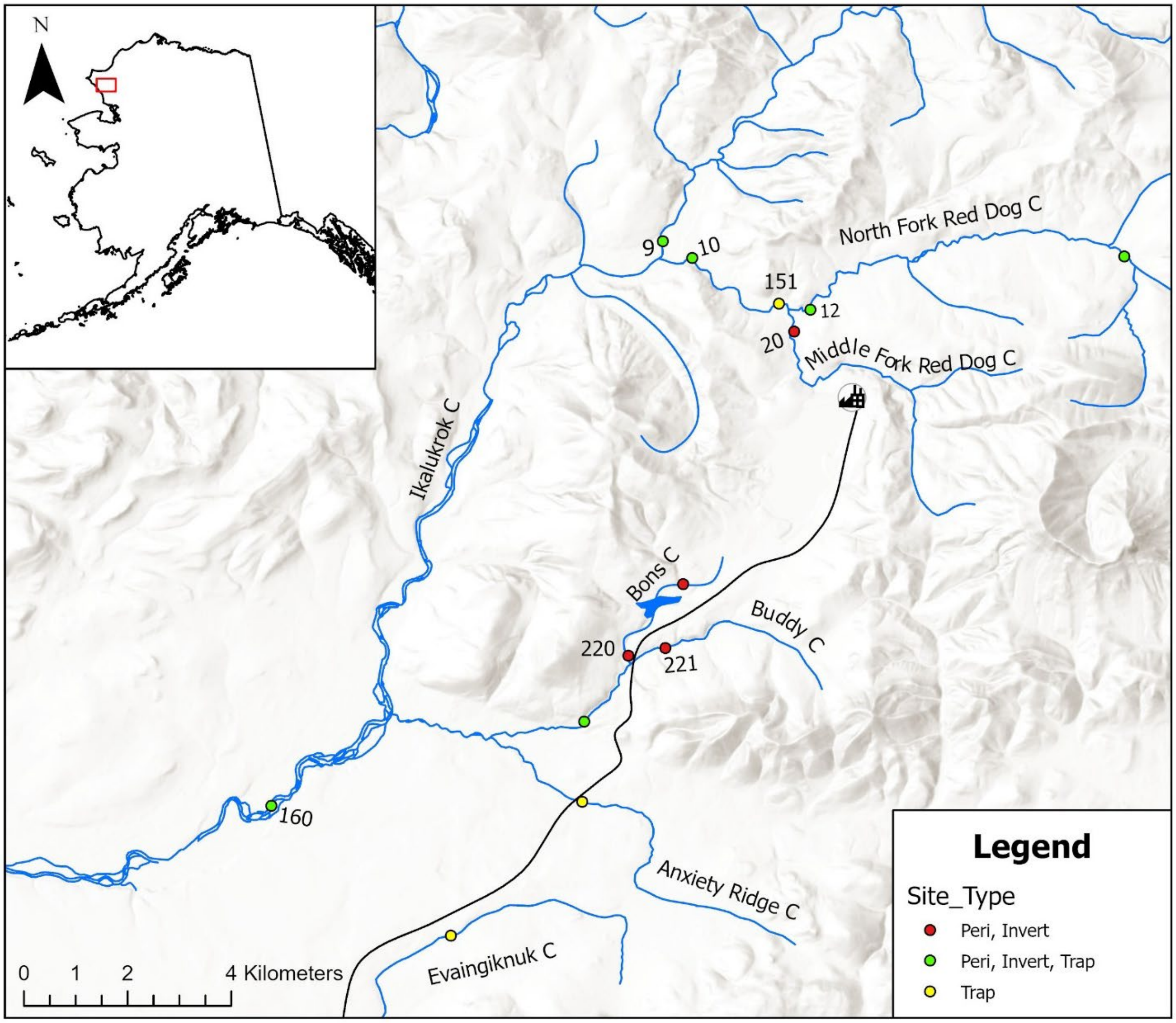

Figure 2.–Location of sample sites near Red Dog Mine.

There are 10 biomonitoring sites sampled for periphyton and aquatic macroinvertebrates. Six of those sites are also sampled for fish presence and use, and an additional three sites are sampled for fish presence and use (Table 1).

- **Ikalukrok Creek, Station 160, downstream of Dudd Creek:** This site is on lower Ikalukrok Creek, approximately 33 km upstream of the confluence with the Wulik River. Ikalukrok Creek is a major tributary of the Wulik River. Average channel width is 20-30 m in the vicinity of this sample site during moderate summer flows. There are large pools connected by riffles and runs. Substrate is primarily gravel and cobble. Riparian habitat consists of tundra, with willows, alders, and occasional cottonwoods along the stream bank. (Figure 3).

- **Ikalukrok Creek, Station 9:** This site is upstream of Red Dog Creek and the treated water discharge. Aquatic habitat consists of large pools and riffles connected by runs flowing over gravel and cobble, with intermittent boulders. Riparian habitat consists mostly of tundra, with willows lining the stream banks (Figure 3).
- **Middle Fork Red Dog Creek, Station 20:** Middle Fork Red Dog Creek originates above the active mining area and is routed around the existing pit via a series of lined ditches and pipes. The treated water discharge point (Outfall 001) is approximately 1.7 km upstream of this sample site. This stream was historically fishless, but after the mine commenced operation and began discharging treated water into Middle Fork Red Dog Creek, water quality improved and a fish weir was constructed near the mouth of Middle Fork Red Dog Creek to prevent fish passage up into the diversion system. Red precipitate is common on the channel bottom. Aquatic habitats are composed of riffles and runs with gravel and cobble substrate. Riparian vegetation is tundra with willows lining the stream banks (Figure 4).
- **Red Dog Creek, Station 10:** The sample site is located just upstream of the creek mouth on Ikalukrok Creek. Channel width is approximately 20 m during moderate summer flows. Riffles and runs are the majority of the aquatic habitat in the vicinity of the sample site, and riparian vegetation consists of tundra with willows lining the stream banks (Figure 4).
- **North Fork Red Dog Creek, Station 12:** North Fork Red Dog Creek joins with Middle Fork Red Dog Creek to form mainstem Red Dog Creek. The sample site is approximately 150 m above that confluence, above the influence of any mine discharge. The sample site is located on a gravel bar on an inside bend, where the channel is approximately 7 m wide, with a small cut bank on the outside bend. Riparian vegetation consists of tundra and willows (Figure 5).
- **Upper North Fork Red Dog Creek:** This sample site is located approximately 8 km upstream of Station 12, right below the confluence of two tributaries. Substrate consists of gravel and small cobbles, with riffles, runs, and small pools. Adult Arctic grayling are often observed at this site. Channel width is approximately 5 m, with mossy rocks and willows lining the banks. There is some overhanging riparian vegetation (Figure 5).
- **Bons Creek above the pond:** This sample site is located approximately 160 m upstream of the inlet on Bons Pond, the freshwater reservoir that provides potable water for various

mine uses. This section of Bons Creek is incised with streambanks vegetated with willows and sedges, and measures 1 to 2 m wide with depths from 0.3 to 1 m. The substrate consists of gravel in riffles, with fine sediments and organics in the pools. (Figure 6). In addition to invertebrate and chlorophyll sampling, a fyke net is also set here every spring to capture Arctic grayling.

- **Bons Creek, Station 220:** This sample site is below Bons Pond, and approximately 150 m above the confluence of Bons and Buddy creeks. Substrate is primarily cobble with some gravel, and the sample location is in the middle of a long stretch of riffle/run. There is typically green filamentous algae and moss on the substrate. Willows are taller here than other sample locations and overhang the edges of the creek. The only fish at this sample site are Arctic grayling that have left Bons Pond, as the falls on lower Buddy Creek are a barrier to upstream fish passage (Figure 6).
- **Buddy Creek, Station 221:** The sample site is located 45 m above the Haul Road. Substrate is gravel and cobble and the channel is approximately 5 m wide during moderate summer flows. There are shrubby willows along the banks (Figure 7).
- **Buddy Creek below falls:** The sample site is located approximately 0.5 km below a series of falls that form a barrier to upstream fish passage. The substrate is primarily cobble, with higher gradient riffles and runs. The creek is incised with overhanging willows on the banks and channel width is approximately 6 m during moderate summer flows. There is often filamentous green algae on the substrate (Figure 7).
- **Red Dog Creek, Station 151:** This location is only sampled for fish presence and use and is located 0.5 km downstream of the confluence of the Middle and North Forks of Red Dog Creek. The sample site is on a riffle-run sequence just downstream of a large pool at the base of a bluff, and the channel at the sample site is 12-14 m wide at moderate summer flows. Substrate is cobble with some gravel (Figure 8).
- **Anxiety Ridge Creek:** This site is only sampled for fish presence and use. Minnow traps are set above and below the Haul Road bridge over the creek. Substrate is gravel, cobble, and some small boulders, and channel width ranges from 4-8 m wide along the sampled segment during moderate summer flows. Aquatic habitat is mostly riffle-run sequences, with some pools. Riparian vegetation is tundra, with overhanging willows on the banks (Figure 8).

- **Evaingiknuk Creek:** This sample site is the Noatak River drainage and is on the east side of the Haul Road, and is crossed by a material site access road. This location is only sampled for fish presence and use. The creek is narrow and incised at the sample location, ranging from 2-4 m wide in the sample reach. Minnow traps are placed both upstream and downstream of the access road crossing. Substrate is gravel and cobble, with overhanging vegetation (Figure 9).

Figure 3.–Ikalukrok Station 160 below Dudd (left) and Ikalukrok Station 9 above Red Dog (right).

Figure 4.–Middle Fork Red Dog Station 20 (left) and mainstem Red Dog Creek Station 10 (right).

Figure 5.–North Fork Red Dog Creek Station 12 (left) and Upper North Fork Red Dog Creek (right).

Figure 6.–Bons upstream (left) and Bons downstream of the pond Station 220 (right).

Figure 7.–Buddy below falls (left) and Buddy above Haul Road Station 221 (right).

Figure 8.–Red Dog Creek Station 151 (left) and Anxiety Ridge Creek (right).

Figure 9.–Evangiknuk Creek upstream of the road (left) and downstream of the road (right).

METHODS

Four sampling events occurred in 2024 including spring Arctic grayling sampling and adult Dolly Varden sampling (June 10–17), mid-summer benthic macroinvertebrates and periphyton (July 1–9), fall aerial surveys of chum salmon in Ikalukrok Creek (September 5-9), and fall aerial surveys of Dolly Varden in the Wulik River (October 1–3). The late summer minnow trapping sampling was attempted August 12–15, but creek flows were too high to place gear in the water, so no sampling occurred.

Methods used for the 2024 Red Dog Mine aquatic biomonitoring study are fully described by ADF&G in Technical Report #17-09: *Methods for Aquatic Life Monitoring at the Red Dog Mine Site, a requirement of the 2017 APDES Permit AK0038652* (Bradley 2017).

Beginning in 2022, benthic macroinvertebrate (BMI) sampling at all sites was conducted with Hess samplers instead of drift nets. 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. However, since sampling methodology is different, previous years' results are not directly comparable to the results from 2022 onward.

The Hess stream bottom sampler has a 0.086 m^2 sample area and material is captured in a 200 mL cod end–both constructed with 300 µm mesh net. Rocks within the sample area were scoured by hand, and gravel, sand, and silt were disturbed to approximately 10 cm depth to dislodge invertebrates into the net. The cod end contents were then removed and placed in individual pre-labeled Nalgene bottles with denatured ethyl alcohol to preserve the macroinvertebrates. Samples were sorted and invertebrates identified by a private aquatic invertebrate lab in Fairbanks to the lowest practicable taxonomic level. BMI of the orders Ephemeroptera, Plecoptera, Trichoptera were identified to genus. Dipterans were identified to genus, except the nonbiting midges of the family Chironomidae. Copepoda, Collembola, and Coleoptera were identified to genus. Cladocera and Hydroida were identified to order. Oligochaeta, Ostracoda, Platyhelminthes, Nematoda, and Nematomorpha were identified to class level. Because invertebrates belonging to the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (EPT) are more sensitive to water quality, the total number of individual specimens of EPT was calculated and compared to groups of other invertebrates, which are less sensitive. The BMI density was calculated for each sample by dividing the number of BMI by 0.086 m^2, the Hess sampling area. Mean density was estimated for each site by calculating the mean density among the five samples. Taxa richness is reported as the number of taxonomic groups identified to the lowest practical level. Terrestrial organisms were excluded from all calculations.

All 2024 water quality sampling was performed by Red Dog Mine personnel following their standard methodology. Water quality analysis was performed by independent laboratories and results were provided to ADF&G for inclusion in this report. All water quality presented in this report are for "total recoverable" unless otherwise specified. The number of water quality samples taken each year varies depending upon duration of the open water season, but are collected according to Red Dog Mine's APDES permit and WMP. Baseline water quality pre-mining data presented in the report were collected from 1979 to 1982.

Additionally, ADF&G staff collected point measurements of water temperature (°C), dissolved oxygen (mg/L), specific conductance (µS/cm), conductivity (µS/cm), and pH using a handheld multiparameter YSI at each site concurrent with invertebrate and periphyton sampling. The probe was placed in flowing water, and measurements were allowed to equilibrate before being recorded. An Orion AQUAfast Turbidity meter was used to measure turbidity (NTU). At each site, the sample vial was rinsed with sample water three times, then filled with flowing water. Three turbidity readings of the sample were taken, and the average value of those readings was recorded.

In 2024, the abundance of Arctic grayling in Bons Pond was estimated using Chapman's modification of the Lincoln-Petersen two-sample mark-recapture model (Chapman 1951),

$$\widehat{N}_c = \left\{\frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)}\right\} - 1$$

where $\widehat{N}_c$ = estimated population, n_1 = fish marked in first capture event, n_2 = fish captured during recapture event, and m_2 = fish captured during recapture event that were marked in the capture event.

Variance was calculated as (Seber 1982):

$$\mathrm{var}(\widehat{N}_c) = \left\{\frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2(m_2 + 2)}\right\}$$

The 95% CI for the population estimate was calculated as:

$$95\%\ \mathrm{CI} = N_c \pm (1.960)\sqrt{\widehat{\mathrm{var}}(\widehat{N}_c)}$$

RESULTS AND DISCUSSION

WATER QUALITY

Water quality data collected in Mainstem Red Dog Creek prior to 2010 were from Station 10, located near the mouth of the creek. Data from 2010 to 2024 were collected at Station 151 located about 2 km upstream from Station 10. Station 151 is at the downstream end of the mixing zone in

Mainstem Red Dog Creek (Figure 8). There are no defined drainages entering Mainstem Red Dog Creek between these two water quality stations. Mainstem Red Dog Creek is directly affected by the treated mine wastewater effluent and by water from the clean water bypass. North Fork Red Dog Creek (Station 12) is a reference site with no direct effects from the mine.

In 2024, Teck continued to maintain the mine's clean water bypass system which picks up non-mining impacted water (non-contact water) from Sulfur, Shelly, Connie, Rachel, and Upper Middle Fork Red Dog creeks (Figure 10). This water is moved through the mine pit area, including the currently active Aqqaluk pit, to its original channel via a combination of culverts and lined open ditches. These bypass conveyance structures serve to isolate the non-contact water from areas disturbed by mining activities.

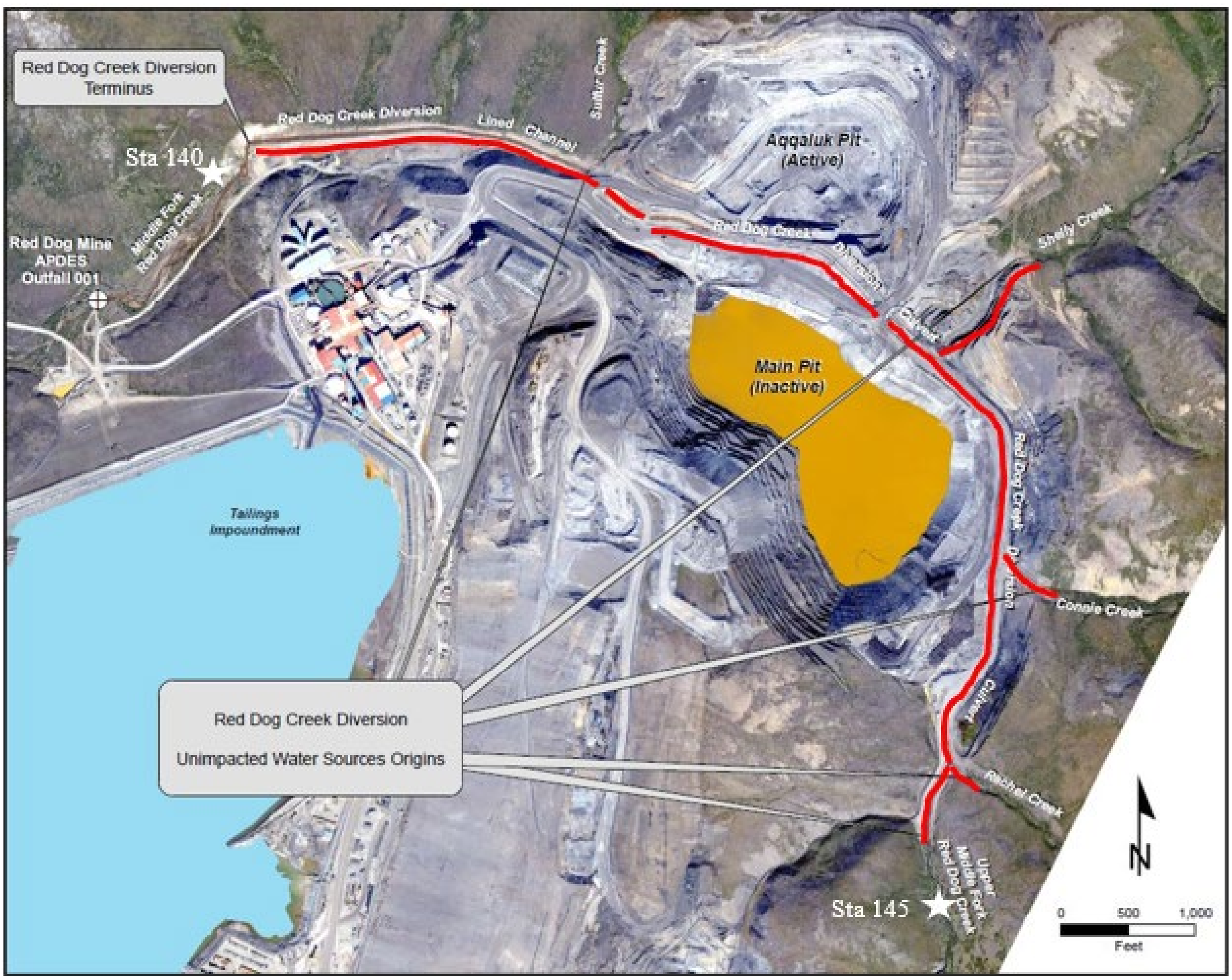

Figure 10.–Clean water bypass system at the Red Dog Mine. The Red Dog Creek diversion structure is shown in red.[2]

[2] Figure provided by Teck with modifications made by ADF&G.

In 2024, the median lead concentration in Mainstem Red Dog Creek (Station 151/10), downstream of the clean water bypass system, remained lower than the pre-mining (1979–1983) median concentration. However, in some years the maximum lead concentration has been higher than pre-mining (Figure 11). The maximum lead concentration in 2024 was 160.0 µg/L, the highest observed since 2013, although the median value remained steady at 6.0 µg/L.

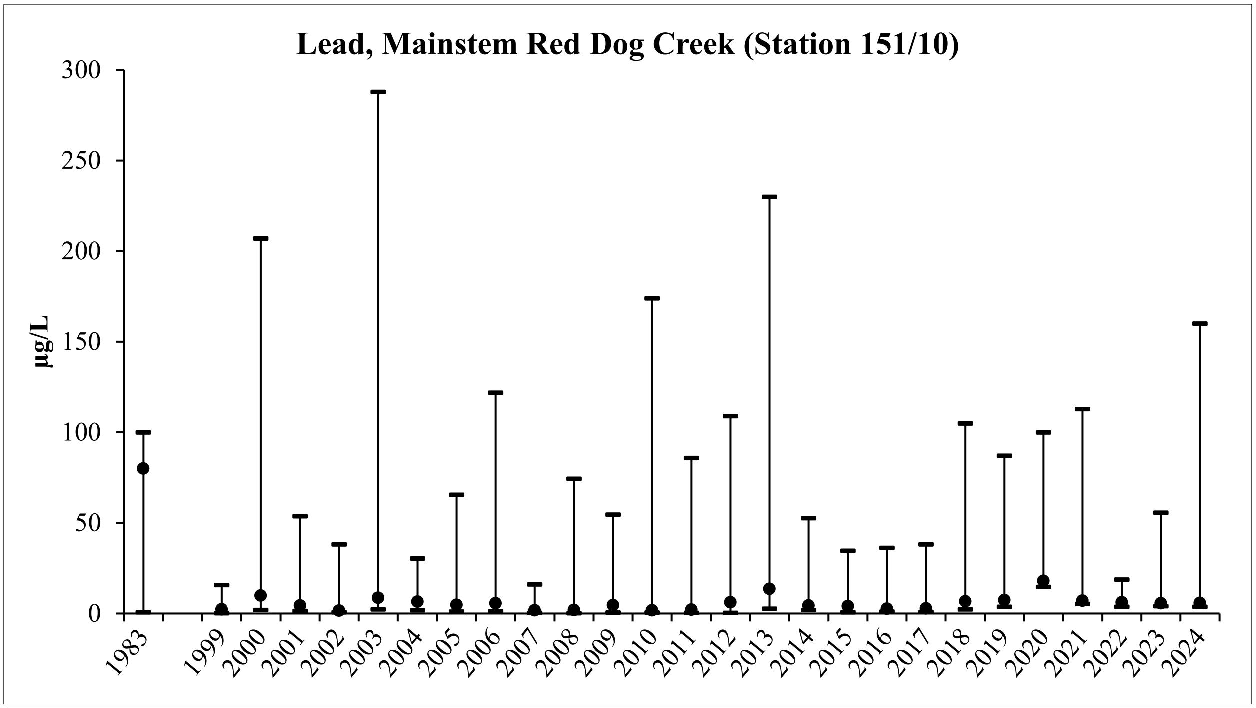

Figure 11.–Median, maximum, and minimum lead concentrations at Station 151/10.

In 2024, the component of the bypass system with the highest concentration of lead was Sulfur Creek, with a median lead concentration of 110.4 µg/L (Figure 12). In the last 10 years, median lead concentrations in Sulfur Creek have ranged from 71.9 to 1550.0 µg/L (Figure 13). Flows in Sulfur Creek are typically low, so although lead concentrations are often high in Sulfur Creek, it does not have much effect on overall lead concentrations in Mainstem Red Dog Creek. At Station 145, lead concentrations have decreased from a peak of 215.0 µg/L in 2020, following the diversion of Kaviqsaaq Seep in 2021. The seep is now redirected to the tailings pond for treatment. However, lead levels remain above pre-2020 levels, possibly due to additional mineralized seeps that have emerged above Station 145.

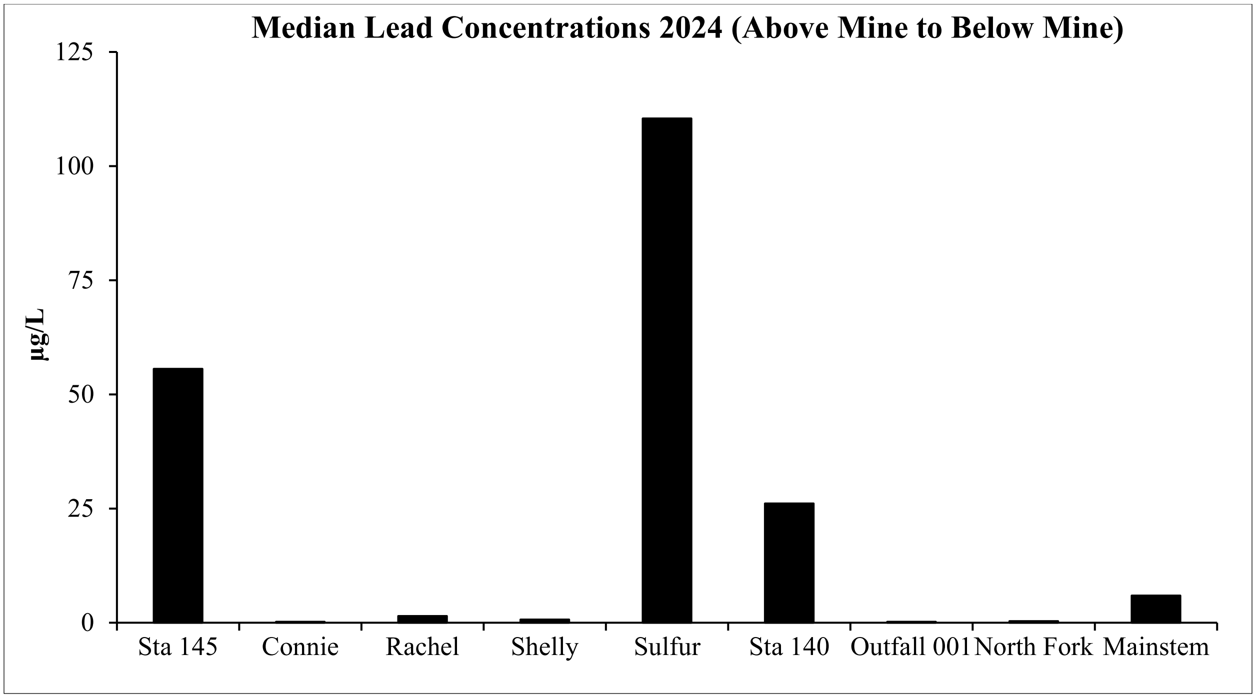

Figure 12.–Median lead concentrations in 2024 from upstream (Station 145) of the clean water bypass, including tributaries to the clean water bypass (Connie, Rachel, Shelly, and Sulfur creeks), Station 140 (above the Outfall 001), Outfall 001, and North Fork Red Dog and Mainstem Red Dog creeks.

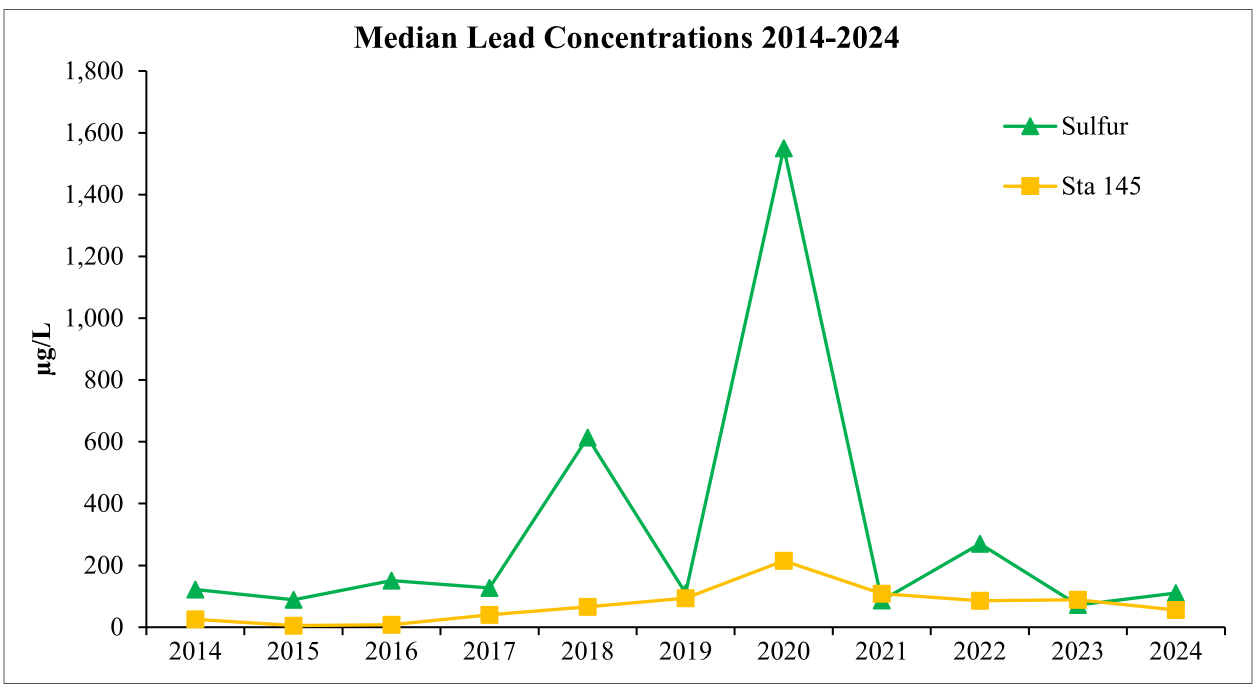

Figure 13.–Median lead concentrations from Sulfur Creek and Station 145 on Middle Fork Red Dog Creek.

The median zinc concentration in Mainstem Red Dog Creek (Station 151/10) decreased slightly in 2024 (Figure 14). Zinc levels from 2018–2024 have been higher than values observed from 1999–

2017. Station 140 on Middle Fork Red Dog Creek, upstream of the treated mine discharge Outfall 001 and downstream of the non-contact water diversion, increased slightly in 2024 to a median concentration of 18,100 µg/L (Figure 15). Zinc levels at Station 145, above the clean water bypass, continued to decrease in 2024, down to a median concentration of 31,800 µg/L. The sharp decrease in zinc levels from the spike in 2020 is due to the capture and diversion of Kaviqsaaq seep in 2021. The other component creeks of the clean water bypass (Connie, Rachel, Shelly, and Sulfur creeks) have lower zinc concentrations, and all decreased slightly in 2024 (Figure 16).

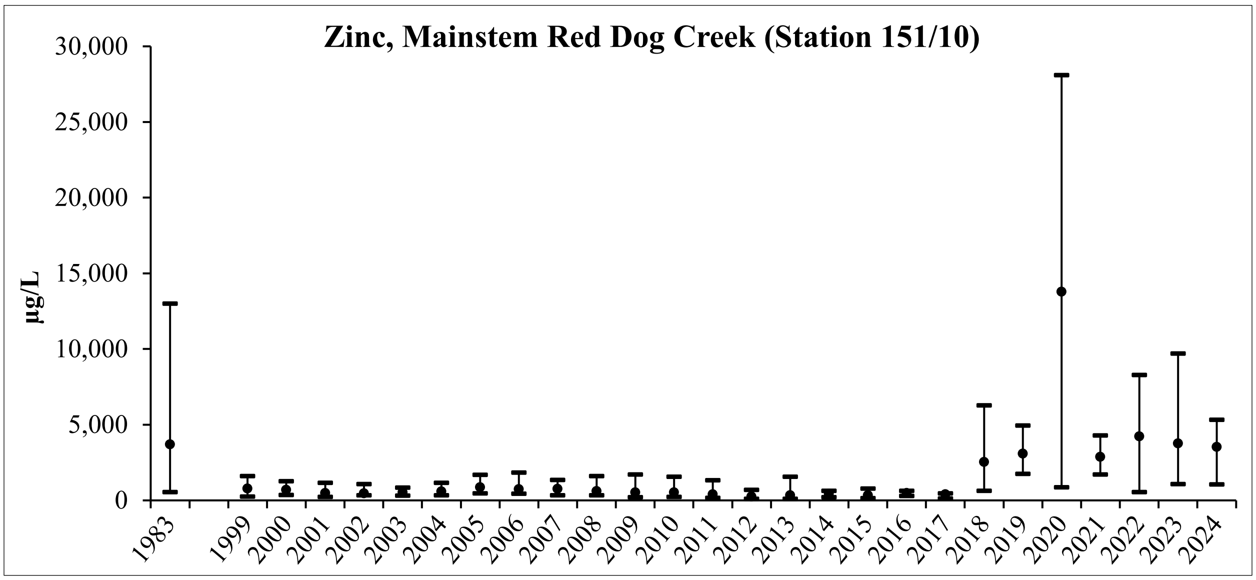

Figure 14.–Median, maximum, and minimum zinc concentrations at Station 151/10, 1983 and 1999–2024.

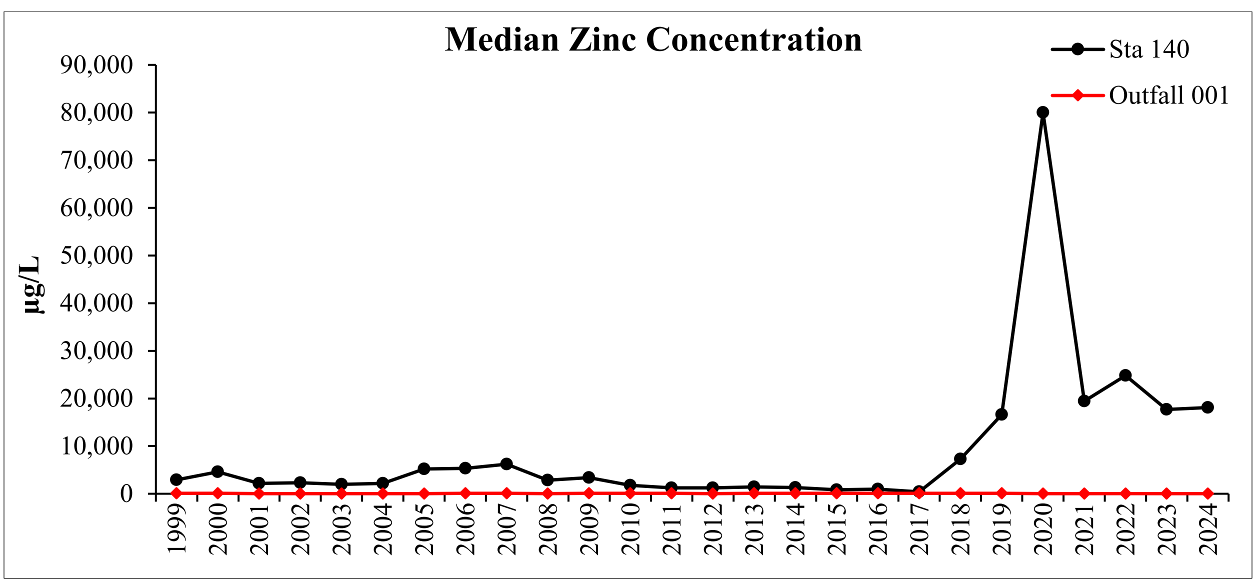

Figure 15.–Median zinc levels in water samples from Station 140 and Outfall 001, 1999–2024.

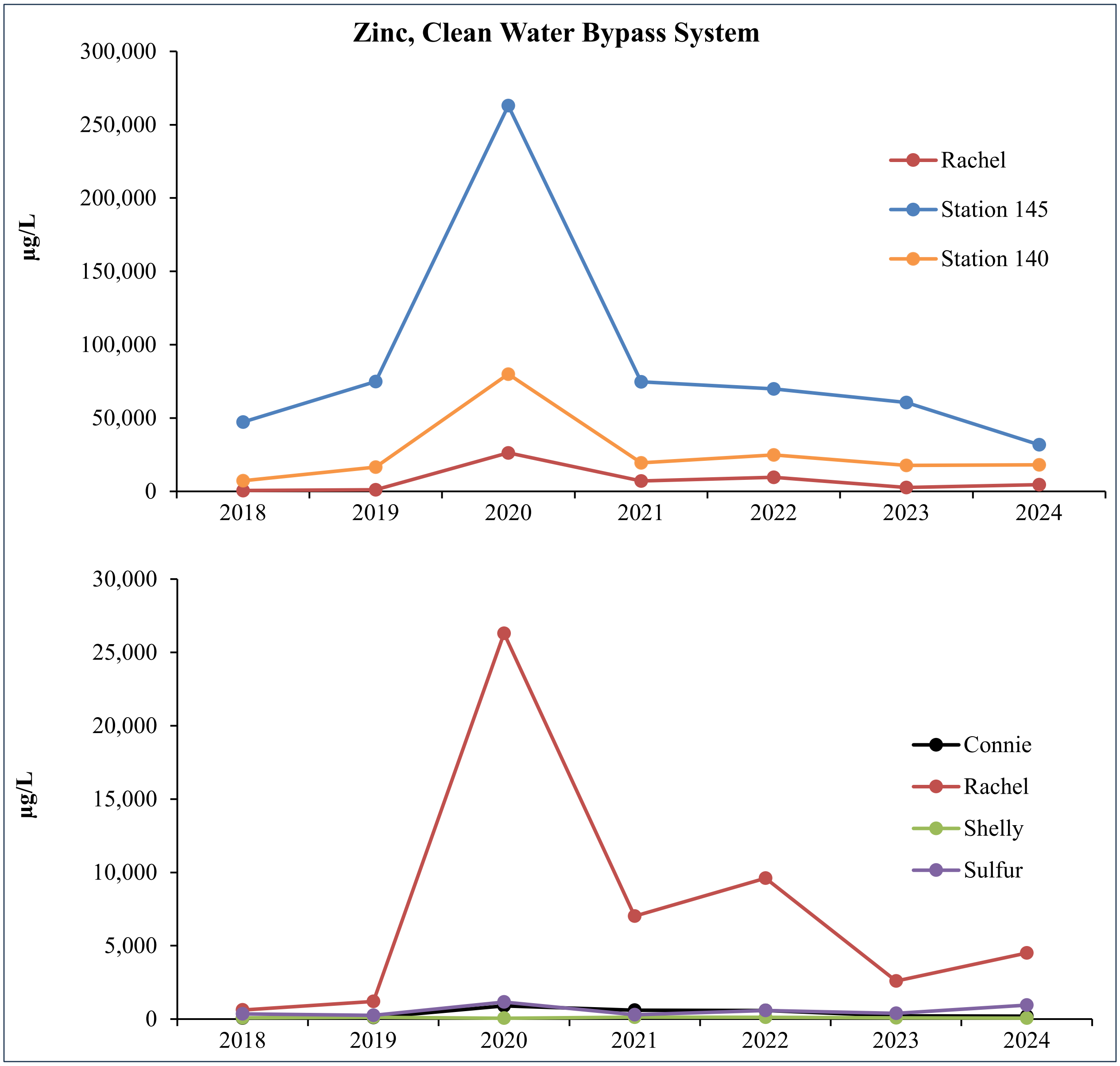

Figure 16.–Median zinc concentrations in water samples from Sulfur, Shelly, Connie, and Rachel creeks, and Stations 145 and 140 on Middle Fork Red Dog Creek, 2018–2024. Station 145 is on Middle Fork Red Dog Creek, downstream of the Kaviqsaaq Seep and before the clean water diversion system begins and Station 140 is below the clean water diversion but above Outfall 001. Please note the different y-axis scale on the bottom figure.

The median aluminum concentration in mainstem Red Dog Creek (Station 151/10) was 566 µg/L, very similar to the median concentrations in 2022 and 2023 (Figure 17). The median cadmium concentration of 14.2 µg/L in 2024 was consistent with levels seen since 2018, aside from the sharp spike in 2020 (Figure 18).

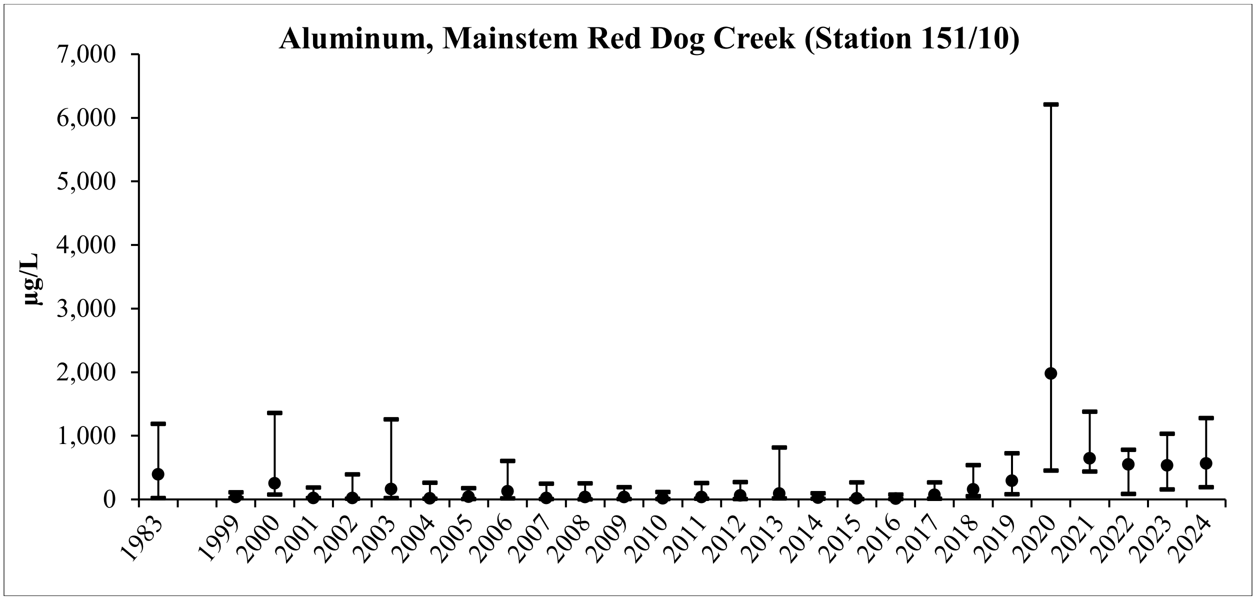

Figure 17.–Median, maximum, and minimum aluminum concentrations at Station 151/10.

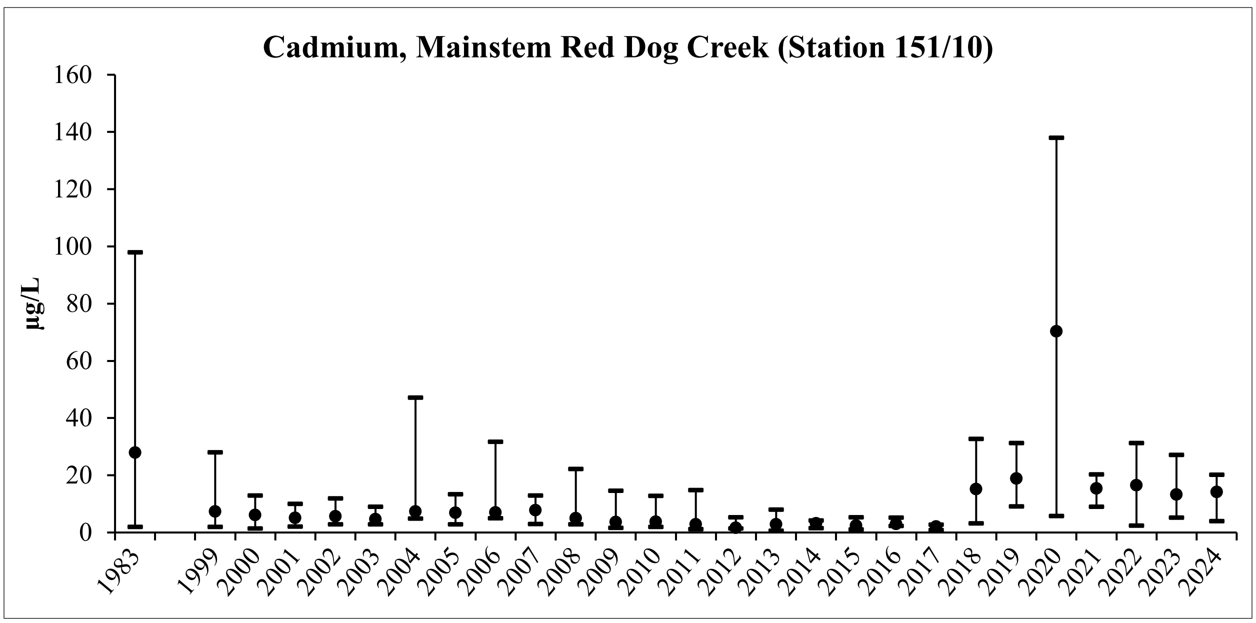

Figure 18.–Median, maximum, and minimum cadmium concentrations at Station 151/10.

Pre-mining data for selenium are not available. Median selenium concentrations in Mainstem Red Dog Creek (Station 151/10) remained similar from 2001–2007, but have generally increased since then. In 2012, discharge of treated water to Middle Fork Red Dog Creek was stopped on June 8 due to elevated selenium and was not resumed for the remainder of 2012. After selenium decreased in treated water and a mixing zone was authorized in Mainstem Red Dog Creek, discharge resumed in 2013. Selenium remained low from 2014–2017, then began to increase in 2018 to a median selenium concentration of 3.2 µg/L in 2020 and 3.1 µg/L in 2021 (Figure 19). Selenium has slightly decreased since then, and the median concentration in 2024 was 2.9 µg/L.

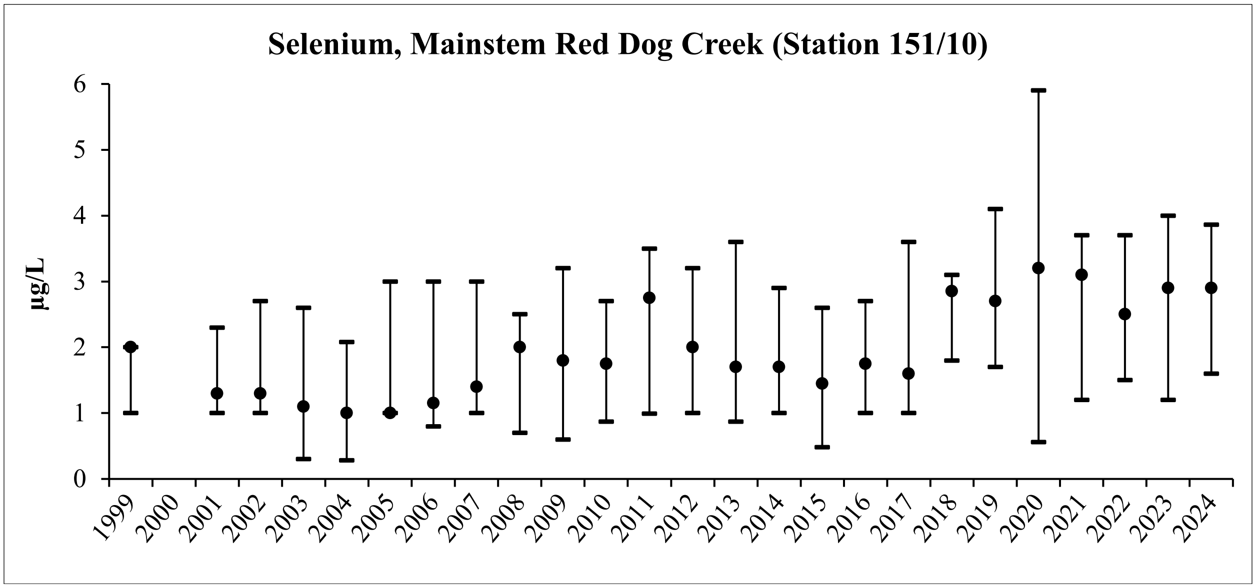

Figure 19.–Median, maximum, and minimum selenium concentrations at Station 151/10.

Pre-mining data for nickel are not available. Median nickel concentration in Mainstem Red Dog Creek (Station 151/10) increased sharply in 2020 to 394 µg/L, the highest median concentration since 1999, and an order of magnitude greater than any previously recorded value (Figure 20). Median nickel concentration has decreased since that peak but remains higher than pre-2020 values. The median concentration in 2024 was 76.6 µg/L. The component creeks of the clean water bypass system were not analyzed for nickel in recent years, so the source of the increased nickel concentration is unknown.

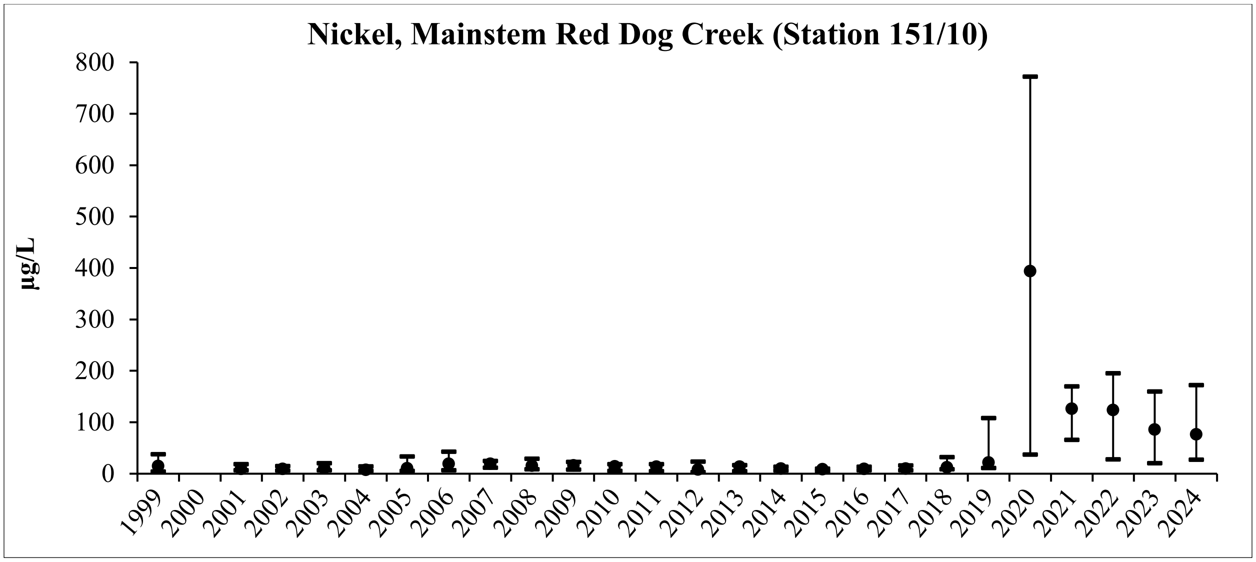

Figure 20.–Median, maximum, and minimum nickel concentrations at Station 151/10.

In 2024, the median pH in Mainstem Red Dog Creek (Station 151/10) was slightly higher (more basic) compared to pre-mining values, a trend consistently observed since 1999 (Figure 21). The median pH dropped in 2020 to 7.17, the lowest median value since mining began. Median pH increased the following year (2021) to 7.53, and the median value in 2024 was similar at 7.4. The clean water bypass system was built and operational prior to spring breakup in 1991, and since then the minimum pH value has only dropped below 6.0 once, in 2011. The 1990 data set is during mining, but prior to construction of the clean water bypass system.

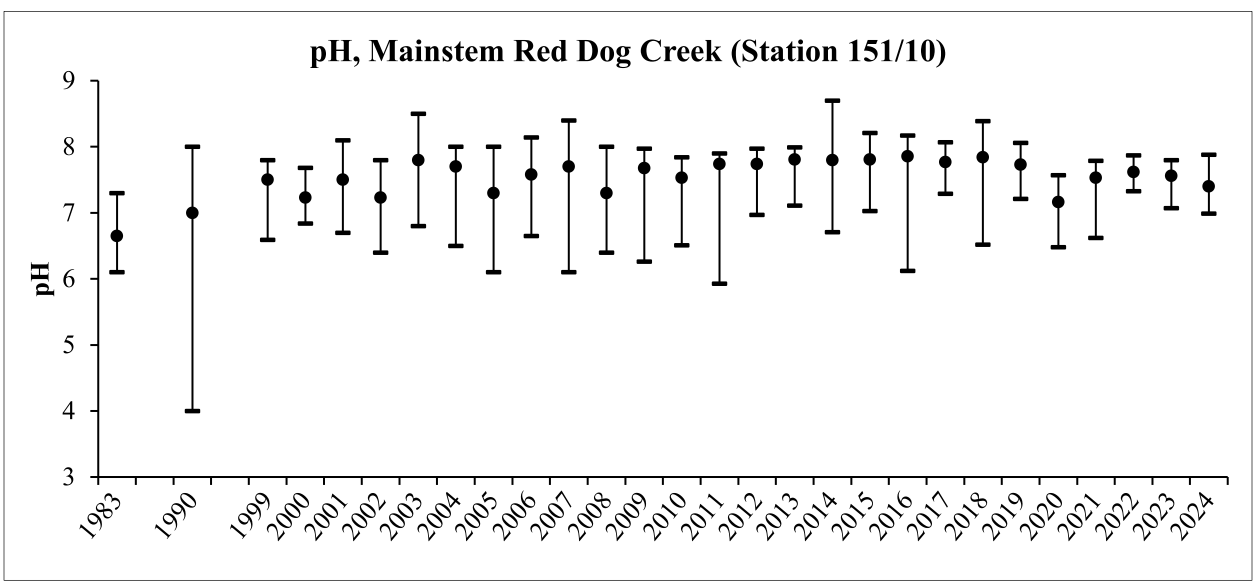

Figure 21.–Median, maximum, and minimum pH values at Station 151/10. The optimal pH range for aquatic life is 6.5 to 9.

Total dissolved solids (TDS) in Mainstem Red Dog Creek (Station 151/10) are higher than pre-mining levels (Figure 22). TDS are directly related to high concentrations of calcium and sulfates in the treated wastewater discharge at Outfall 001. Calcium hydroxide is added to precipitate and collect metals from the tailings water as metal hydroxides prior to discharge. Sulfates released in this process along with the calcium result in elevated TDS concentrations, however natural changes in water quality attributed to permafrost thaw are also increasing TDS levels throughout the Ikalukrok Creek drainage (Clawson 2023). The changes in water clarity that were initially observed throughout the Ikalukrok Creek drainage in 2019 have continued, with some seeps and tributaries changing from clear to very turbid and either milky-white or yellowish-orange (Clawson and Ott 2020). Median TDS was 775 mg/L in 2024, lower than the previous two years. Water levels were high in the Wulik River drainage throughout the 2024 open water season due to increased precipitation, which may have had a diluting effect on the TDS levels in Red Dog Creek (Figure 23).

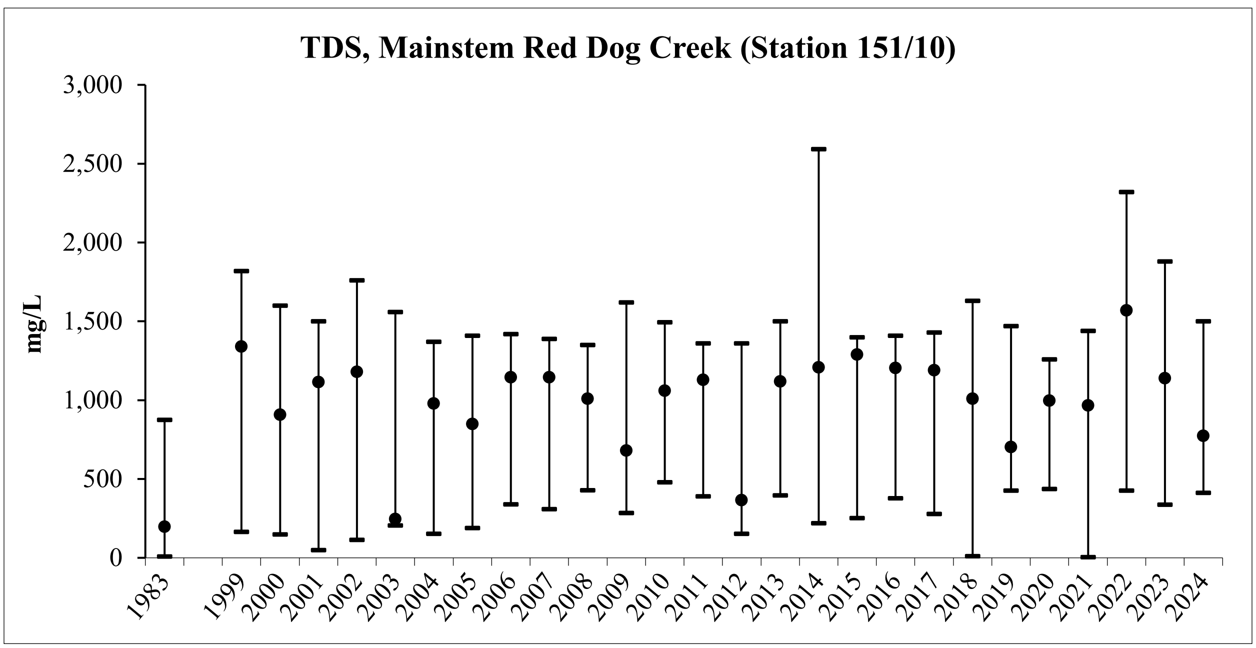

Figure 22.–Median, maximum, and minimum TDS concentrations at Station 151/10.

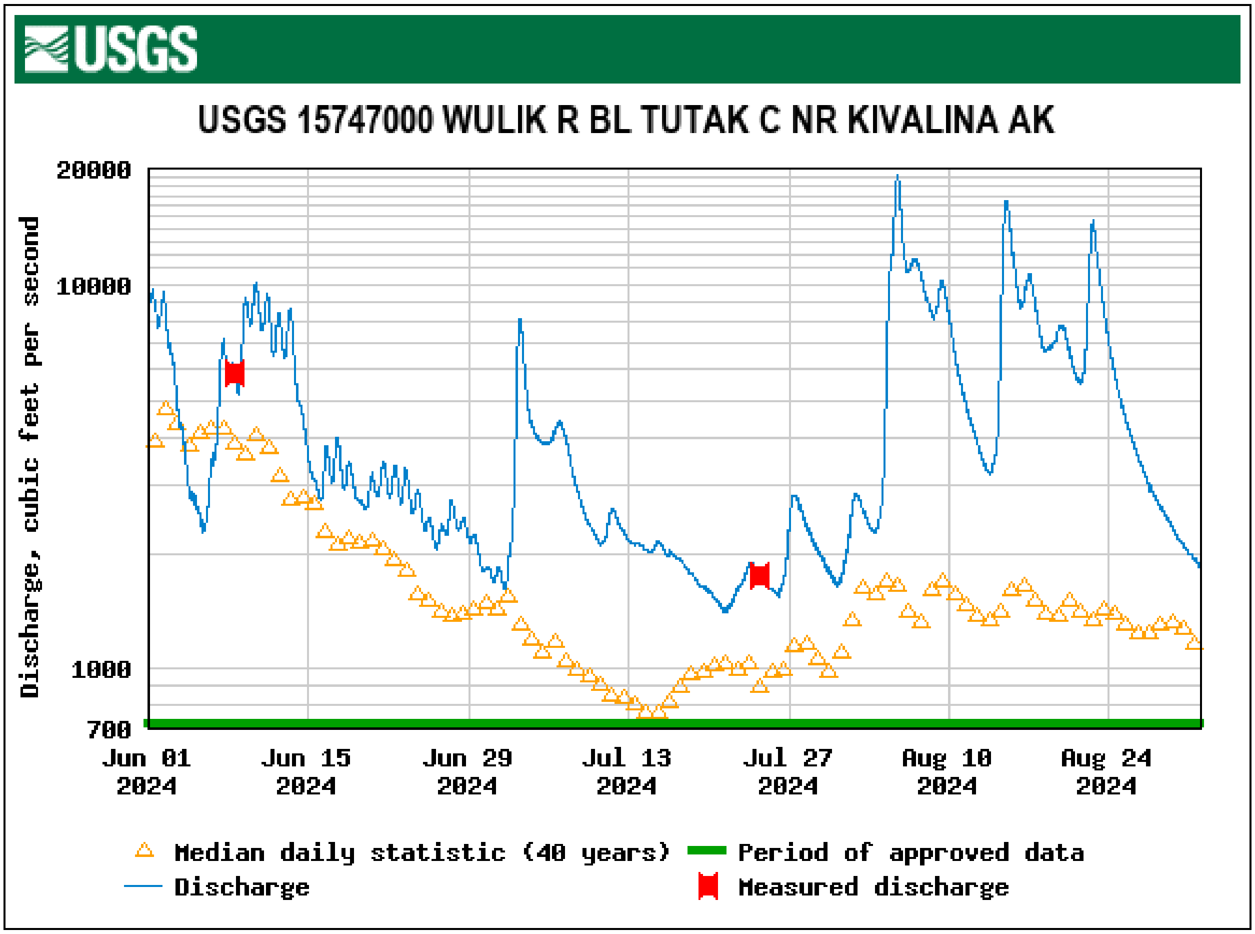

Figure 23.–Discharge on the Wulik River from June 1–August 31, 2024 and median discharge for the same time period.

Cadmium, lead, zinc, and selenium concentrations in Mainstem Red Dog Creek (Station 151/10) were compared with those found in North Fork Red Dog Creek, Buddy Creek (below the confluence of Bons and Buddy creeks), and Bons Pond. Sites in North Fork Red Dog and Buddy creeks and Bons Pond were selected because they are reference sites with no direct effects from the mine process or discharge. Mainstem Red Dog Creek (Station 151/10) is directly downstream of the mine clean water bypass and wastewater effluent discharge at Outfall 001. Buddy Creek and Bons Pond are reference sites but have the potential to be affected by the road, airport, overburden stockpile, and they are down gradient from the tailing impoundment backdam. Cadmium, lead, zinc, and selenium were selected for comparison because these elements are analyzed for whole body element concentrations in juvenile Arctic grayling from Bons Pond and juvenile Dolly Varden from Mainstem Red Dog, Anxiety Ridge, and Buddy creeks.

Cadmium, lead, and zinc median concentrations are highest in Mainstem Red Dog Creek. The mine discharge of treated water at Outfall 001 has very low concentrations of these elements, so the major sources of these elements are the clean water bypass and other locations in the Red Dog Creek drainage. Cadmium was low and stable in North Fork Red Dog Creek, Buddy Creek, and Bons Pond from 2001–2018. From 2019–2024, cadmium levels remained low in Buddy Creek and Bons Pond but increased in North Fork Red Dog Creek. Cadmium in Mainstem Red Dog Creek is higher than the other creeks, and has increased beginning in 2018, with a spike to 70.3 µg/L in 2020. Median concentrations have decreased since that peak, but remain higher than pre-2018 values. The median cadmium concentration in Mainstem Red Dog Creek was 14.2 µg/L in 2024 (Figure 24). Lead concentrations demonstrate more variability than cadmium but are consistently highest in Mainstem Red Dog Creek (Figure 25). Zinc concentrations have followed the same pattern as cadmium, where zinc levels are highest in Mainstem Red Dog Creek with a spike in 2020. Buddy Creek and Bons Pond have remained fairly stable but levels in North Fork Red Dog Creek have increased beginning in 2019 (Figure 26). Selenium concentrations among these sites are similar, and variable among years, although the general trend appears to be increasing (Figure 27). The median selenium concentrations in Mainstem Red Dog, North Fork Red Dog, and Buddy creeks and Bons Pond in summer 2024 were 2.9 µg/L, 2.0 µg/L, 2.5 µg/L, and 2.4 µg/L, respectively.

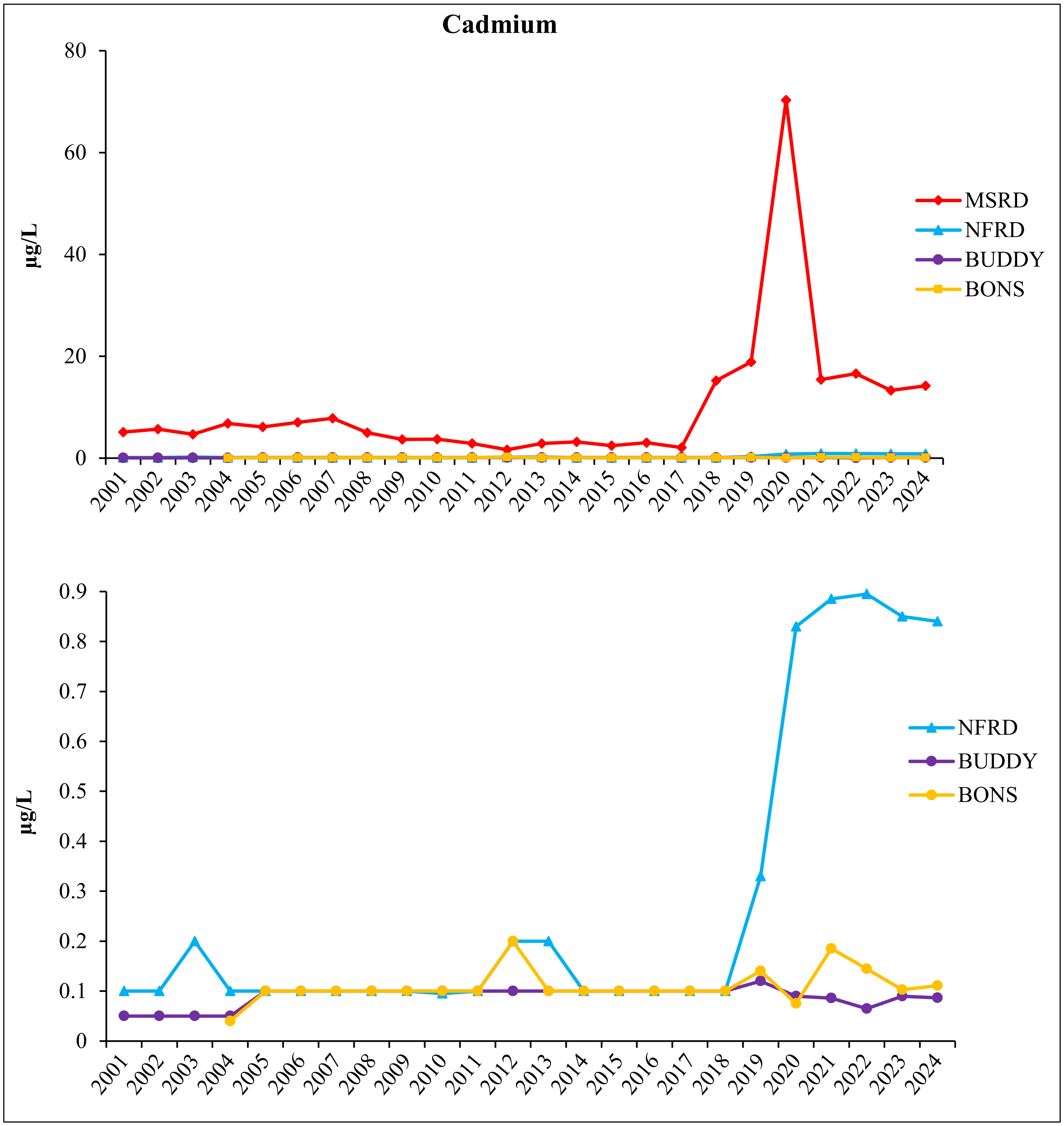

Figure 24.–Median cadmium concentrations in Mainstem Red Dog (MSRD), North Fork Red Dog (NFRD), and Buddy creeks and Bons Pond (2001–2024). Two graphs are presented, the bottom graph presents the same data but uses a different y-axis scale as it does not include Mainstem Red Dog Creek.

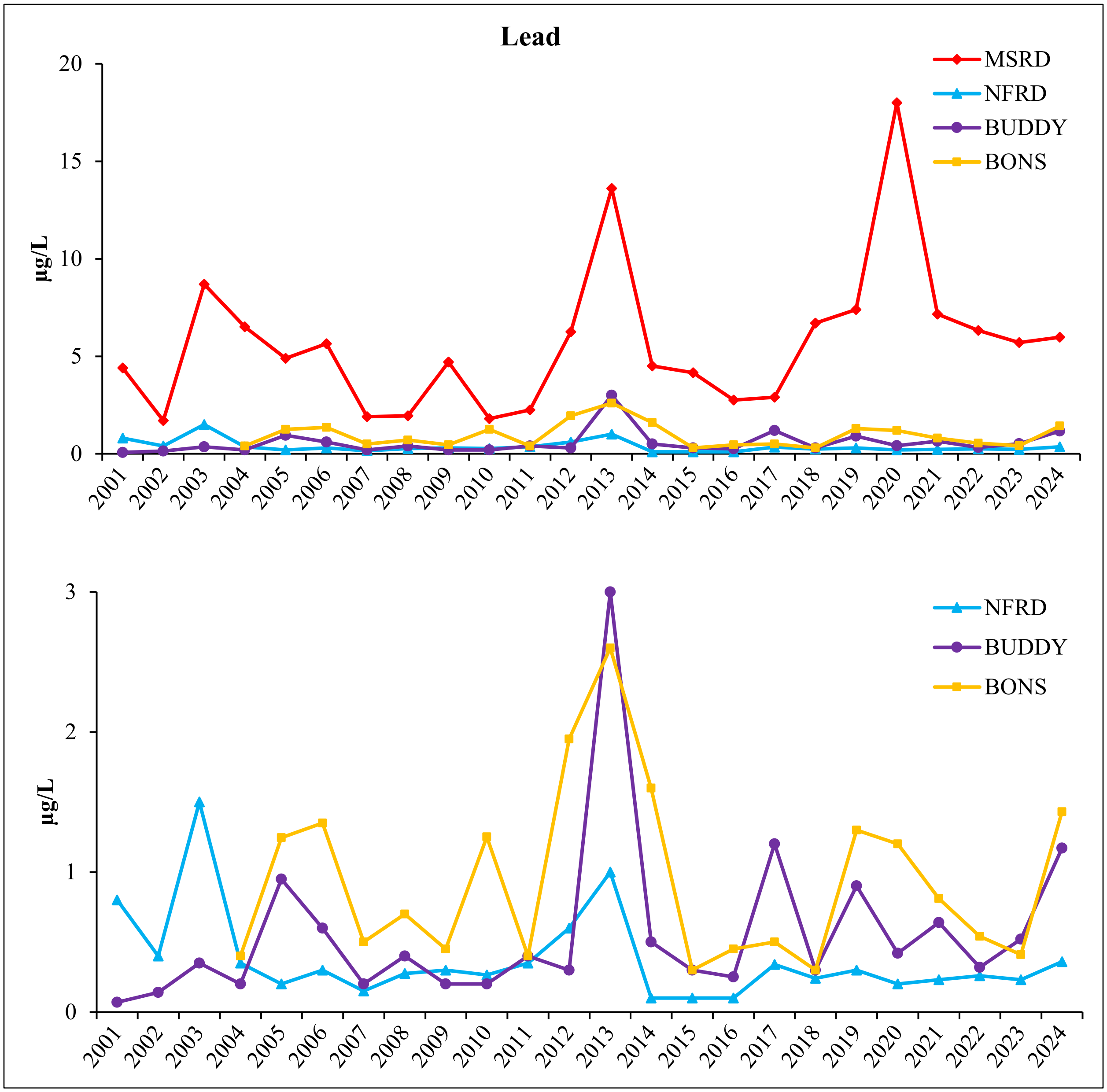

Figure 25.–Median lead concentrations in Mainstem Red Dog (MSRD), North Fork Red Dog (NFRD), and Buddy creeks and Bons Pond (2001–2024). Two graphs are presented, the bottom graph presents the same data but uses a different y-axis scale as it does not include Mainstem Red Dog Creek.

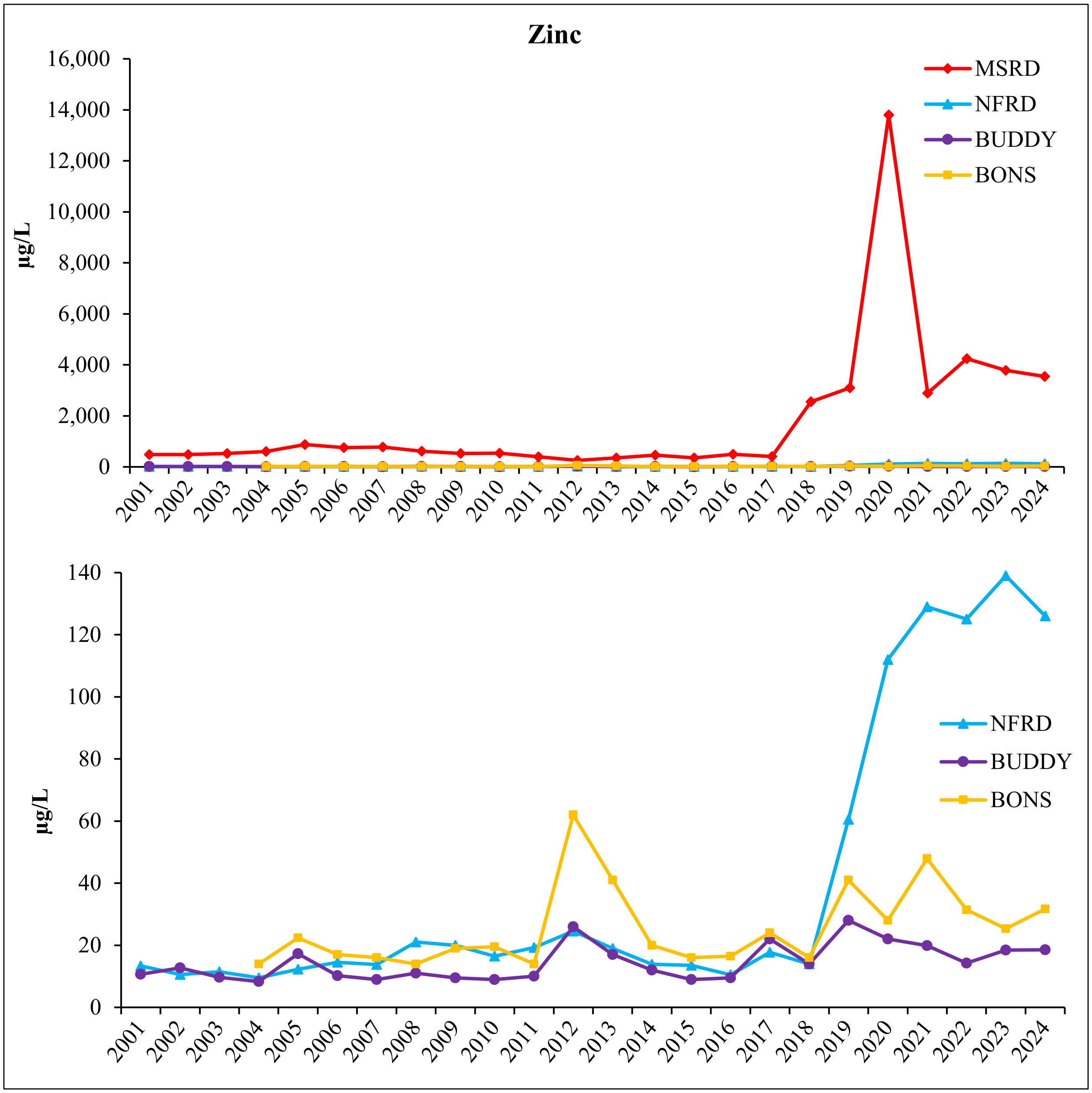

Figure 26.–Median zinc concentrations in Mainstem Red Dog (MSRD), North Fork Red Dog (NFRD), and Buddy creeks and Bons Pond (2001–2024). Two graphs are presented, the bottom graph presents the same data but uses a different y-axis scale as it does not include Mainstem Red Dog Creek.

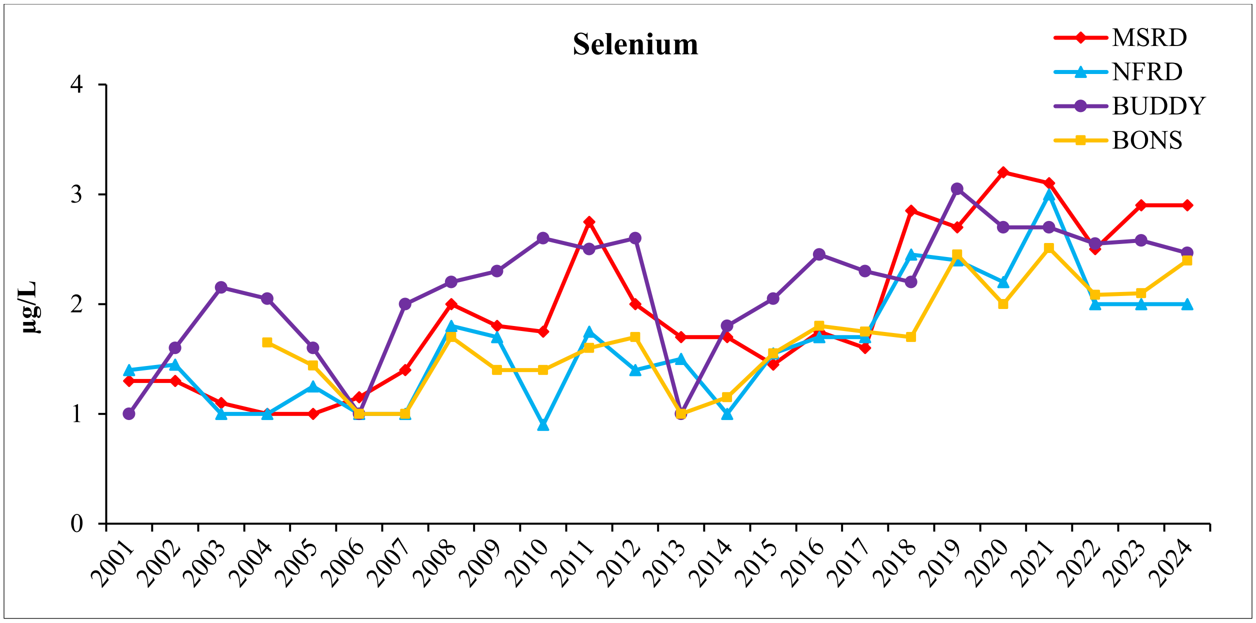

Figure 27.–Median selenium concentrations in Mainstem Red Dog (MSRD), North Fork Red Dog (NFRD), and Buddy creeks and Bons Pond (2001–2023).

Point measurements of in-situ water quality collected by ADF&G staff concurrent with periphyton and invertebrate sampling are presented in Table 2. Water temperature varied from a high of 11.9 °C at Bons Creek below Bons Pond (Station 220) to a low of 3.5 °C at Ikalukrok Creek below Dudd Creek (Station 160). The cooler water temperatures at sites sampled on July 6 and July 7 are due to the period of cool weather and precipitation that occurred July 2–5. Dissolved oxygen was lowest in Bons Creek below Bons Pond (Station 220), likely due to the lower oxygen content in lentic environments. The sample site is approximately 1.25 km below the outlet of Bons Pond. Dissolved oxygen was very similar for all sites besides the Bons Creek sites and Middle Fork Red Dog Creek (Station 20), ranging from 12.04 mg/L to 12.69 mg/L. Specific conductivity and conductivity were highest at Middle Fork Red Dog Creek (Station 20), which is to be expected as that site is downstream of the treated water discharge, which has high concentrations of calcium and sulfates. Calcium hydroxide is added to precipitate and collect metals from the tailings water as metal hydroxides prior to discharge, and sulfates are released as part of this process. The U.S. EPA standard for aquatic life in freshwater is 6.5 to 9, and all point measurements in 2024 fall within that range (U.S. EPA 1986). The Bons Creek drainage flows through ice-rich permafrost with thermal erosion and sediment/organic input that varies with seasonal conditions. The high turbidity value in Bons Creek above Bons Pond was likely a result of those erosion dynamics combined with rising stream levels due to precipitation during sampling.

Table 2.–In-situ measurements of water quality collected during July 2024.

Date	Site	Temp (°C)	DO (mg/L)	SPC (mS/cm)	Conductivity (mS/cm)	pH	Turbidity (NTU)
7/2/24	NFRD Sta 12	7.1	12.69	0.62	0.41	8.52	6.37
7/2/24	MFRD Sta 20	11.2	10.28	2.19	1.61	7.94	6.54
7/2/24	Bons Sta 220	11.9	10.08	0.38	0.29	7.73	0.87
7/2/24	Buddy Sta 221	5.4	12.04	0.25	0.16	8.16	0.80
7/2/24	Bons above pond	7.2	10.24	0.38	0.25	8.05	11.23
7/6/24	Red Dog Sta 10	5.6	12.50	1.20	0.78	8.26	8.92
7/6/24	Ikalukrok Sta 9	4.3	12.50	0.47	0.29	8.01	4.50
7/6/24	Upper NFRD	3.6	12.32	0.44	0.26	8.07	10.90
7/6/24	Buddy blw falls	6.3	12.05	0.33	0.21	8.51	1.11
7/7/24	Ikalukrok Sta 160	3.5	12.35	0.56	0.33	8.39	5.90

PERIPHYTON STANDING CROP

Periphyton (attached microalgae) biomass samples have been collected annually since 1999. Under the program initiated in 2010, sampling occurred at a minimum of nine sites (Table 1). In 2024, samples were collected at all nine standard sites, with the addition of Upper North Fork Red Dog Creek (Appendix 2). Periphyton samples were processed in the laboratory and standing crop was determined as mg/m^2 chlorophyll-a.

Mean chlorophyll-a concentration in 2024 was highest at Station 220 on Bons Creek (12.36 mg/m^2) and lowest at Station 9 on Ikalukrok Creek (0.06 mg/m^2) (Figure 28). Periphyton standing crop was also very low at Station 160 on Ikalukrok Creek (0.07 mg/m^2), Station 10 on Red Dog Creek (0.10 mg/m^2), and Middle Fork Red Dog Creek at Station 20 (0.11 mg/m^2) (Figure 28).

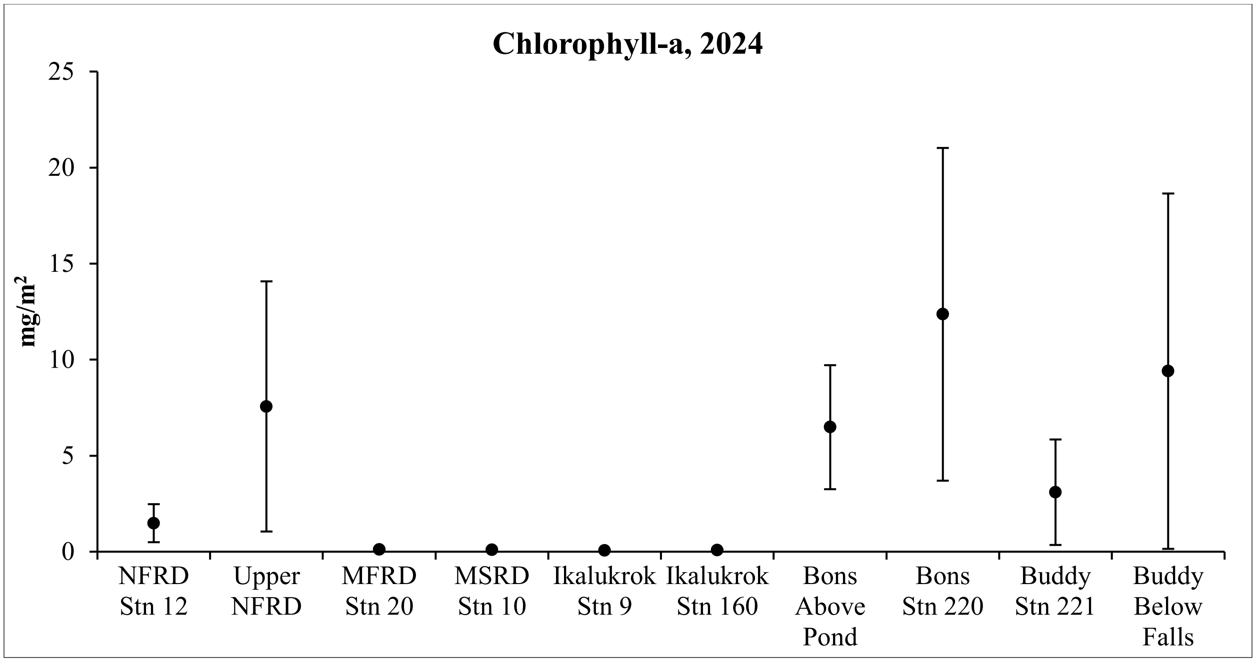

Figure 28.–Mean concentration of chlorophyll-a (± 1 SD) at Red Dog Mine sample sites, 2024. Sites in the Red Dog Creek drainage include Middle Fork Red Dog (MFRD), Upper North Fork Red Dog (Upper NFRD), North Fork Red Dog (NFRD), and Mainstem Red Dog (MSRD).

Historically, mean chlorophyll-a concentrations were higher in Mainstem Red Dog and North Fork Red Dog creeks as compared with Middle Fork Red Dog Creek, but since 2020 chlorophyll-a concentrations in Mainstem Red Dog Creek have also been very low (Figure 29). In 17 of 25 years, mean chlorophyll-a concentrations in North Fork Red Dog Creek were equal to or higher than Mainstem Red Dog Creek. Lower chlorophyll-a concentrations in Middle Fork Red Dog Creek are likely related to higher TDS and metals concentrations in the creek. Most of the metals in Middle Fork Red Dog Creek originate from the clean water bypass and its tributaries, as metals concentrations in the treated effluent discharge from Outfall 001 are very low. The treated effluent discharge at Outfall 001 on Middle Fork Red Dog Creek contributes TDS to the creek, but the naturally occurring background levels of TDS in Red Dog Creek and surrounding streams have increased since 2020. Similar to Middle Fork Red Dog Creek, low chlorophyll-a concentrations in Mainstem Red Dog Creek from 2019–2024 are likely related to the increased metals concentrations from the clean water bypass. These levels have been high enough that the diluting influence of the low metals water from North Fork Red Dog Creek is no longer sufficient to mitigate impacts to periphyton growth in Mainstem Red Dog Creek. Metals and TDS have also increased in Ikalukrok Creek, which could explain the low chlorophyll-a levels at Station 9 and Station 160.

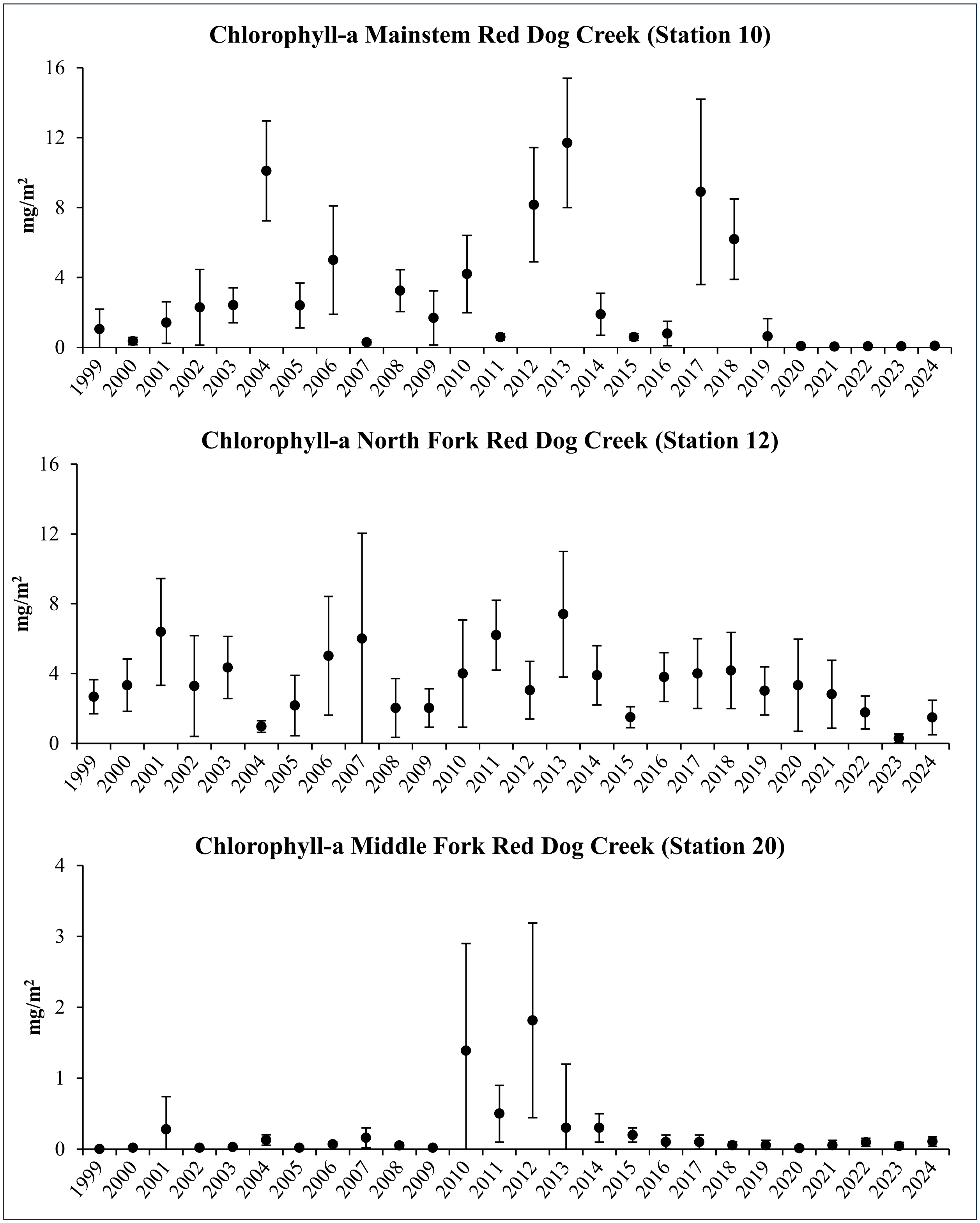

Figure 29.–Mean concentration (± 1 SD) of chlorophyll-a in Mainstem Red Dog Creek (Station 10/151), North Fork Red Dog Creek (Station 12), and Middle Fork Red Dog Creek (Station 20), 1999–2024. Note the different y-axis scale for Middle Fork Red Dog Creek.

Periphyton standing crop has an inverse relationship with zinc and cadmium in Ikalukrok Creek at Station 9, which is just upstream of the mouth of Mainstem Red Dog Creek. Water quality at this site is not affected by water from the Red Dog Mine but is affected by natural mineral seeps located upstream and along Ikalukrok Creek (Ott and Morris 2007). The concentration of chlorophyll-a is higher when the zinc and cadmium concentrations are lower (Figure 30 and Figure 31). Both zinc and cadmium increased beginning in 2019, with a notable spike in 2020, and chlorophyll-a concentrations dropped to below detection limits. The variability in chlorophyll-a concentrations from 2002–2017 is likely due to other biological factors such as water temperature and flow as both cadmium and zinc concentrations were consistently low during this period. Based on water quality sampling conducted by Red Dog Mine, the major source of zinc and cadmium to Ikalukrok Creek is the Cub Creek seep, although there are other seeps along Ikalukrok Creek which are potential sources (Figure 32).

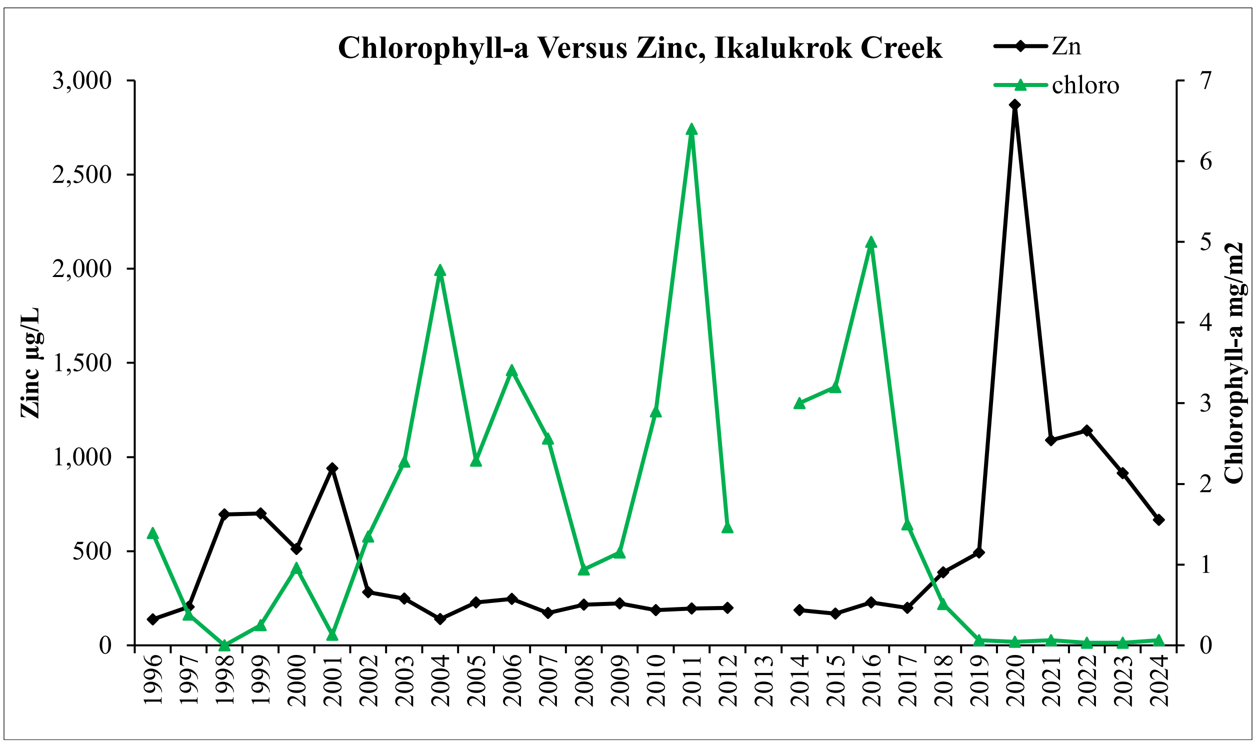

Figure 30.–Mean concentrations of chlorophyll-a and zinc in Ikalukrok Creek (Station 9), 1996–2024.

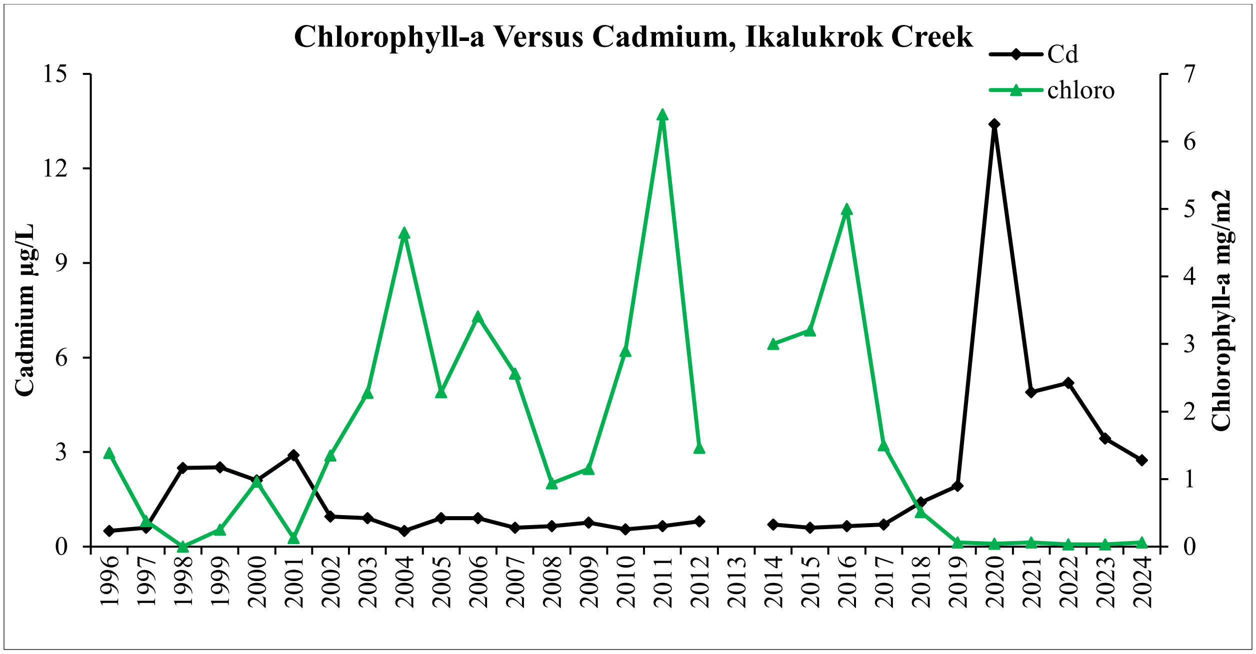

Figure 31.–Mean concentrations of chlorophyll-a and cadmium in Ikalukrok Creek (Station 9), 1996–2024.

Figure 32.–Ikalukrok Creek at the Cub Creek seep about 10 km upstream of Station 9, July 2017. The Cub Creek seep originates at the top of this image and enters Ikalukrok Creek, which flows from left to right.

BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrate (BMI) samples are collected annually using Hess samplers (Appendix 3). The purpose of this effort is to evaluate variations in BMI populations across sampling sites and to monitor changes between and among sample sites over time.

In 2024, mean BMI density was highest in Bons Creek above Bons Pond, with 15,395 BMI/m^2 (Figure 33). Bons Creek Station 220 also had high BMI density with 12,853 BMI/m^2, followed closely by Upper North Fork Red Dog with 12,834 BMI/m^2. Buddy below the falls was also high, with 11,398 BMI/m^2. In 2022, the sample method was changed from drift nets to Hess samplers, so any comparisons with past years' results should account for the change in collection method. With both drift net sampling and Hess samplers, the sample sites in Bons Creek and Buddy Creek typically have the highest densities of BMI. In the Red Dog Creek drainage, BMI densities are typically higher at the North Fork Red Dog Creek sample sites (Upper NFRD and Station 12) than in Mainstem Red Dog Creek (Figure 34). However, in 2024 BMI density at North Fork Red Dog Creek Station 12 was much lower than at Upper North Fork Red Dog, with 844 BMI/m^2.

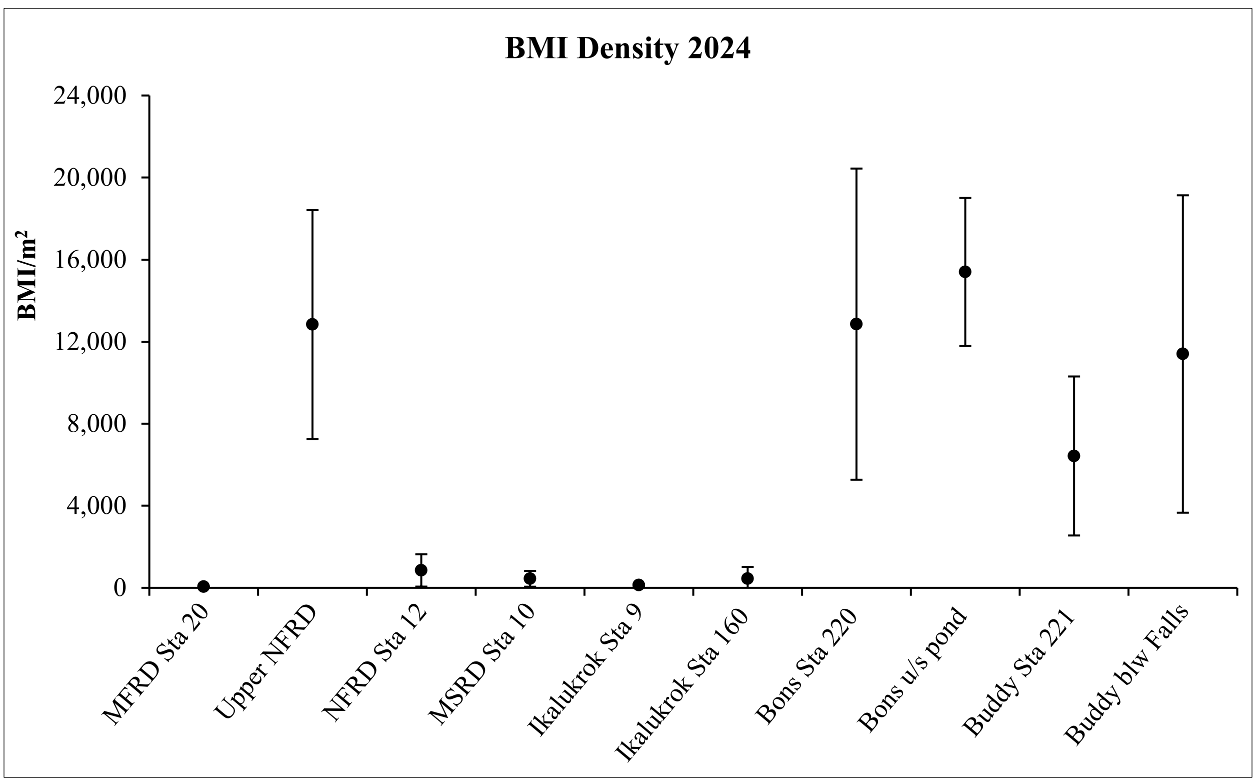

Figure 33.–Mean BMI densities (± 1 SD) in all sample sites near the Red Dog Mine, July 2024.

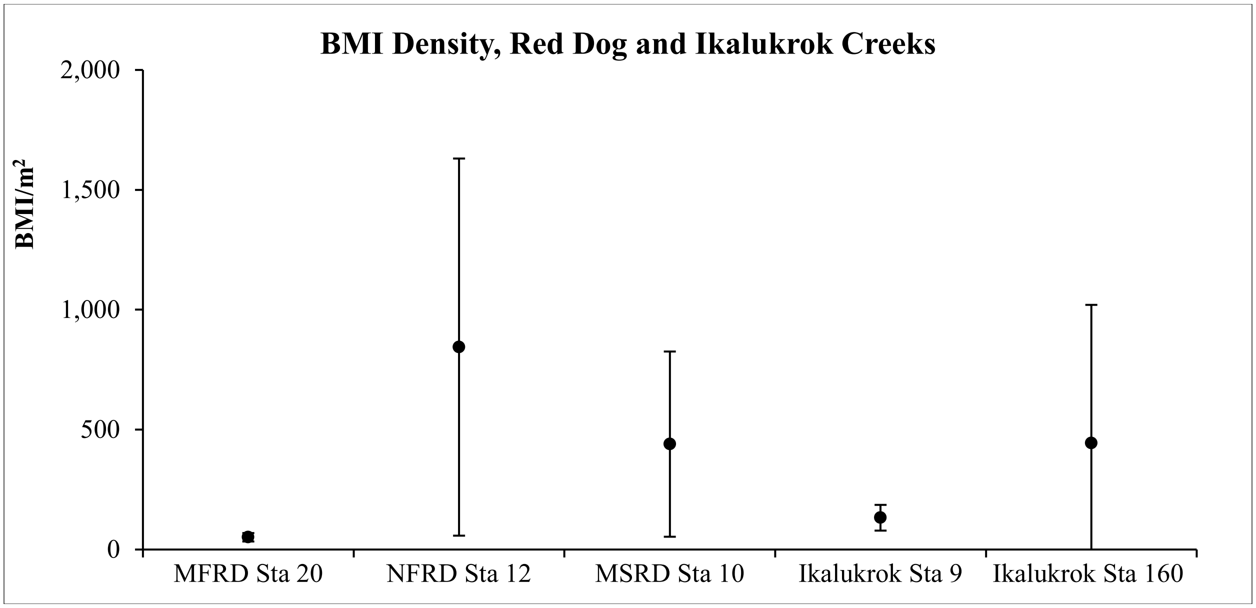

Figure 34.–The mean BMI density (± 1 SD) at sample sites in the Red Dog and Ikalukrok creek drainages in July 2024. This is the same data as Figure 32 but is presented at a different y-axis scale as it does not include the results from Upper North Fork Red Dog, Bons or Buddy creeks.

The percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) and the percent Chironomidae for sample sites in 2024 are presented in Figure 35. Trichoptera are not common in the samples and are not a substantial contributor to EPT. Typically, the percentage of Chironomidae is higher than EPT at most sample sites. In 2024 all sample sites had more Chironomidae than EPT.

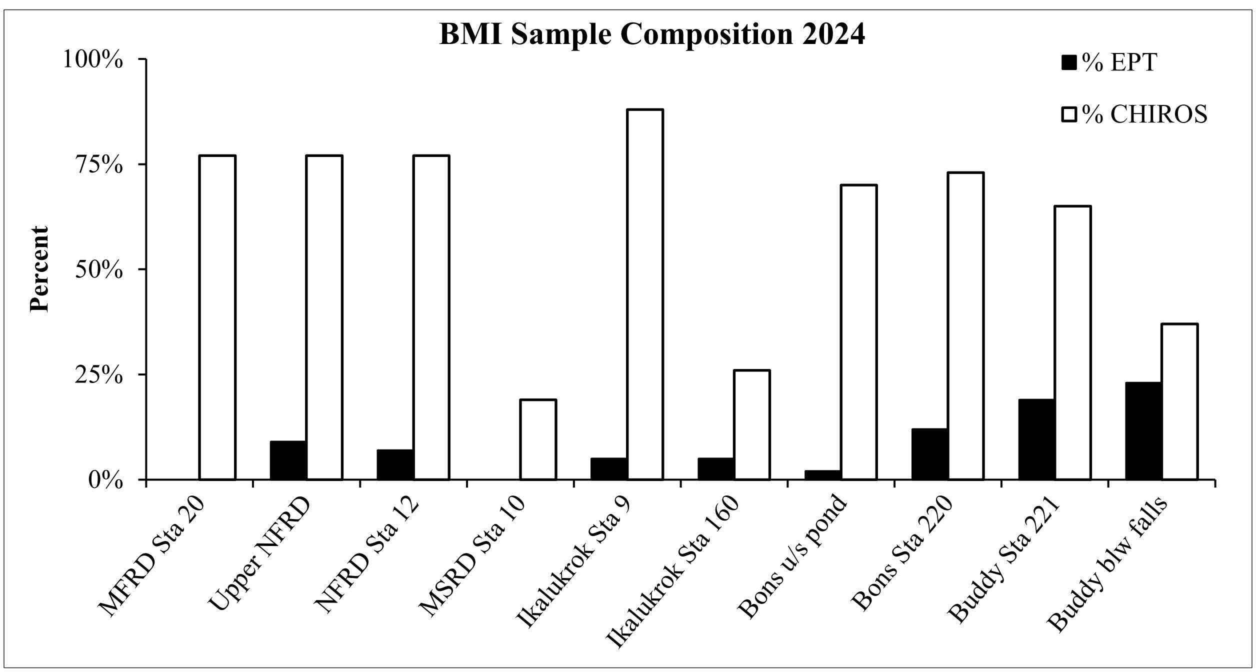

Figure 35.–Percent EPT and Chironomidae in the BMI samples at all sample sites Red Dog Mine, July 2024.

The percent EPT in North Fork Red Dog Creek has been highly variable, ranging from 3% in 2010 and 2011 to 57% in 2002 (Figure 36). In 21 out of the last 26 years, percent Chironomidae has been higher than percent EPT in North Fork Red Dog Creek (Figure 37). Mainstem Red Dog Creek has also had highly variable percent EPT, ranging from 0% in 2024 to 55% in 2003 (Figure 36). Like North Fork Red Dog Creek, percent Chironomidae has been higher than percent EPT in 20 out of the last 26 years in Mainstem Red Dog Creek. Buddy Creek at Station 221 has had a much higher percentage of EPT than either North Fork Red Dog or Mainstem Red Dog creeks in certain years (2004, 2011, 2012, 2014–2016, and 2021–2023) (Figure 36). In Buddy Creek Station 221, percent Chironomidae has been higher than the percent EPT in 13 out of 21 years.

The very low percentage of both EPT and Chironomidae in the Mainstem Red Dog Creek samples since 2022 is likely due to the change in sampling method from drift nets to Hess samples, and the degraded water quality due to increased input from mineral-rich seeps. In 2024, the majority of BMI in the samples from Mainstem Red Dog Creek were Oligochaetes, accounting for 78% of the total. Oligochaetes, which are small slender worms that live in sediment, are unlikely to be captured in drift nets but are easily captured with Hess samplers as the stream bed is disturbed as part of sampling. Similar numbers of Oligochaetes were captured at Buddy Creek Station 221 and Mainstem Red Dog Creek in 2024, 142 and 145 Oligochaetes, respectively. But an additional 2,621 BMI were captured at Buddy Creek while only 44 additional BMI were captured at Red Dog Creek.

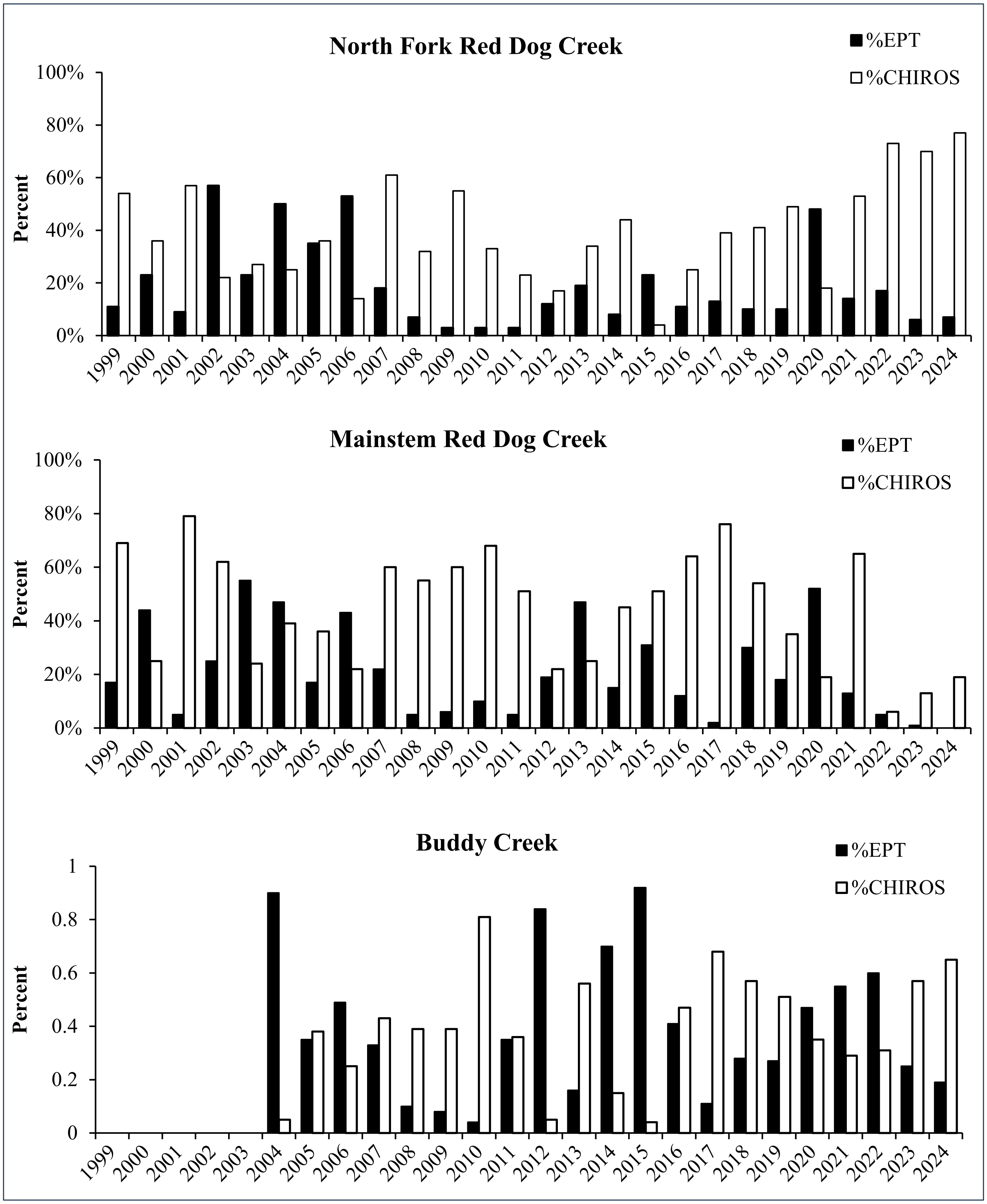

Figure 36.–Percent EPT and Chironomidae in North Fork Red Dog Creek (top), Mainstem Red Dog Creek (middle), and Buddy Creek (bottom) 1999–2024. Aquatic invertebrate sampling in Buddy Creek drainage began in 2004. Sampling method was changed from drift nets to Hess samplers in 2022.

Taxa richness was compared between North Fork Red Dog, Mainstem Red Dog, and Buddy creeks (Figure 37). In 2024, taxa richness was highest in Bons Creek Station 220 with 25 taxa identified. Buddy Creek Station 221 had 19 taxa, and Bons above Bons Pond had 18 taxa. Taxa richness in 2024 was generally similar to taxa richness in 2022 and 2023, after the sampling method was changed to Hess samplers. Since sampling method changed in 2022, comparisons to historical data at all sites should be evaluated with caution.

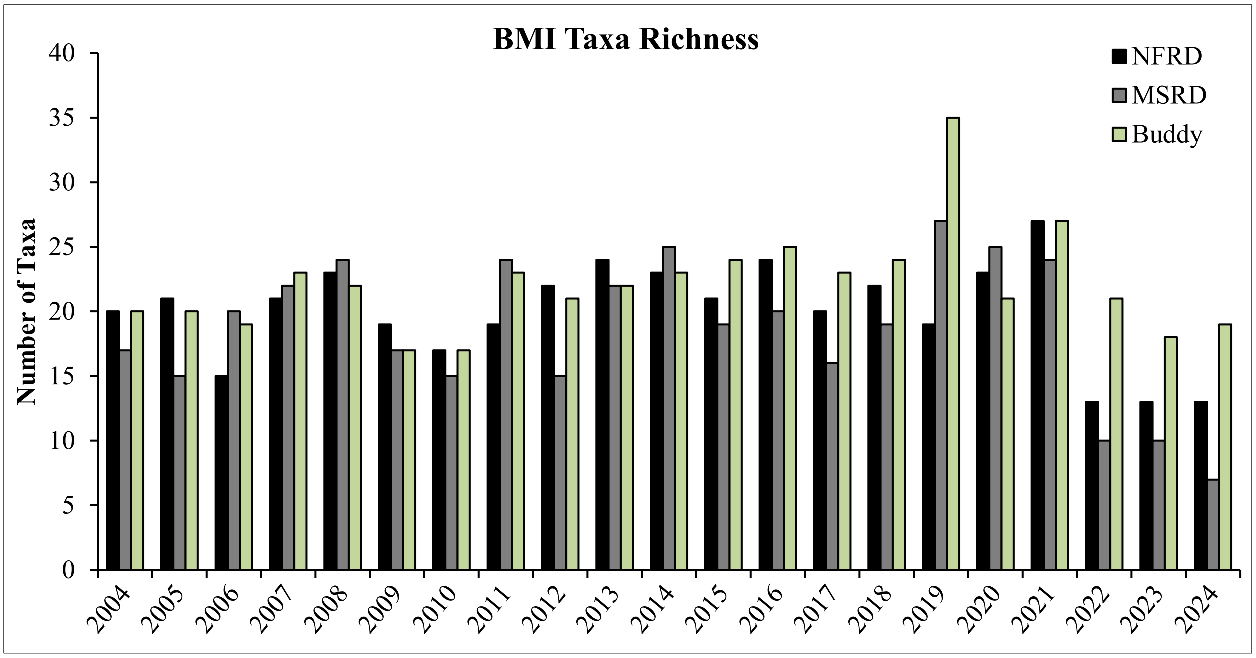

Figure 37.–BMI taxa richness in North Fork Red Dog (Station 12), Mainstem Red Dog (Station 10), and Buddy (Station 221) creeks 2004–2024. Sampling method was changed from drift nets to Hess samplers in 2022.

METAL CONCENTRATIONS IN JUVENILE ARCTIC GRAYLING

Juvenile Arctic grayling were sampled to determine whole body concentrations of selected elements. The purposes of this effort are to: (1) determine if differences exist in element concentrations in fish among sample sites that can be linked with background water quality; and (2) track changes over time.

Juvenile Arctic grayling were selected for long-term monitoring after a self-sustaining population became established in Bons Pond. Arctic grayling captured in Bons Pond have been in the pond system, including upstream tributaries for their entire life cycle. Arctic grayling that leave Bons Pond go over a waterfall that prohibits upstream/return movement of fish. Therefore, these Arctic grayling serve as an indicator of the varying conditions in Bons Pond over time. Fish samples are typically collected during the spring sampling event when fish are moving from Bons Pond into Bons Creek.

Juvenile Arctic Grayling

Fifteen juvenile Arctic grayling were captured in Bons Pond in mid-June, 2024 with a mean length of 168.0 mm FL ± 8.0 mm (Appendix 4). These fish were analyzed for whole-body concentrations of cadmium, lead, selenium, zinc and mercury in mg/kg dry weight. In 2024, 8 juvenile Arctic grayling with a mean length of 167.2 mm FL ± 7.9 mm were captured from the Water Storage Reservoir (WSR)/Fish Creek drainage at Fort Knox mine and analyzed for whole-body element concentrations of aluminum, arsenic, cadmium, lead, mercury, and selenium. Similar to Bons Pond Arctic grayling, fish captured upstream of the WSR spillway have spent the entirety of their life cycle within the Fort Knox wetlands complex. The element concentration results for cadmium, lead, mercury, and selenium from Fort Knox Arctic grayling are provided here for comparison. All results are for whole body in mg/kg dry weight.

In 2024, the mean cadmium concentration in Bons Pond juvenile Arctic grayling was 0.13 mg/kg (Figure 38). The highest mean cadmium concentration observed since sampling began was 0.27 mg/kg in 2014. Concentrations have been fairly stable since 2019. Cadmium concentrations in Fort Knox juvenile Arctic grayling were much lower, with a mean concentration of 0.04 mg/kg (Bear 2025).

In 2024, the mean lead concentration was 1.29 mg/kg in juvenile Arctic grayling from Bons Pond, the highest mean concentration since sampling began, however standard deviations from the 2024 mean overlap with values from past years (Figure 39). The median lead concentration in water quality samples from Bons Pond increased somewhat in 2024 compared to the previous 6 years of data, but the range of values still overlapped with recent years' values (Figure 25). The mean lead concentration in 2024 Fort Knox Arctic grayling was 0.08 mg/kg, much lower than the mean concentration in Bons Pond Arctic grayling (Bear 2025).

In 2024, the mean selenium concentration in juvenile Arctic grayling from Bons Pond was 16.68 mg/kg (Figure 40). Mean concentrations have been variable over the sample years, but with generally overlapping standard deviations. The mean selenium concentration in Fort Knox Arctic grayling was 2.45 mg/kg, much lower than any mean concentration observed in Bons Pond juvenile Arctic grayling since sampling began (Bear 2025). Past sampling of selenium concentrations in adult female Arctic grayling ovaries from Bons Pond, North Fork Red Dog Creek, and Fish Creek (Fort Knox) found that selenium was much lower in Fish Creek fish (Clawson and Ott 2020). Concentrations in Bons Pond Arctic grayling ovaries were often higher than the U.S. EPA final chronic aquatic life criterion for fresh water of 15.1 mg/kg dry weight of ovary (U.S. EPA 2016). The U.S. EPA criterion for whole body selenium is 8.5 mg/kg dry weight, which all 2024 Bons Pond juvenile Arctic grayling also exceeded. However, a study of the effects of selenium concentrations in 2017 found no statistically significant relationships between selenium concentrations in Arctic grayling from Bons Pond, Red Dog Creek, and Fish Creek and embryo/fry survival, development, and growth (Windward 2018 and Owl Ridge 2018). While selenium concentrations are naturally high in Arctic grayling from Bons Pond, there does not appear to be any negative effects on survival and reproduction.

In 2024, mean zinc concentration in juvenile Arctic grayling from Bons Pond was 86.16 mg/kg, a decrease from the high mean value of 124.76 in 2023 (Figure 41).

Mean mercury concentrations in juvenile Arctic grayling from Bons Pond have been variable and ranged from a high of 0.06 mg/kg in 2018 and 2019 to a low of the detection limit of 0.02 mg/kg in 2004 and 2014 (Figure 42). The mean mercury concentration in 2024 was 0.05 mg/kg. In Fort Knox juvenile Arctic grayling, the mean mercury concentration in 2024 was 0.19 mg/kg, higher than any value seen in Bons Pond juvenile Arctic grayling over all sample years (Bear 2025).

The differing element concentrations in Bons Pond and Fish Creek juvenile Arctic grayling are a reflection of the various elements that naturally occur in the water as a result of the underlying geology. Streams around Red Dog tend to have higher concentrations of cadmium, lead, and zinc in the water, since there are high concentrations in the underlying deposits. The geology surrounding Fort Knox, a gold mine, is quite different and therefore the element concentrations in water and fish reflect those differences.

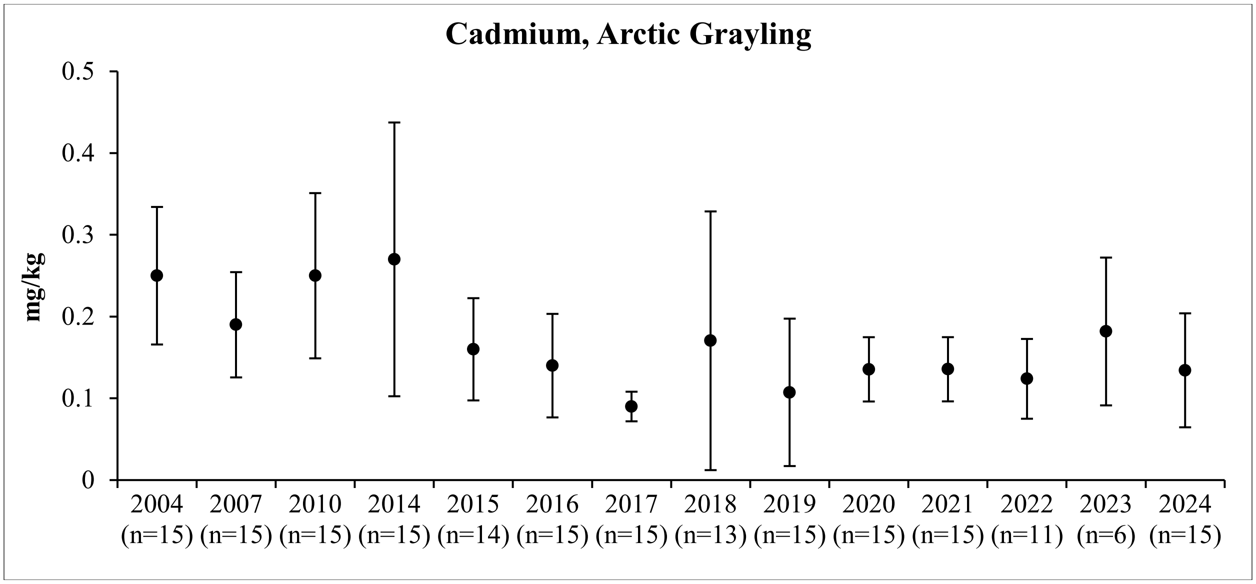

Figure 38.–Mean cadmium concentrations (± 1 SD) in juvenile Arctic grayling collected from Bons Pond drainage (whole body dry weight).

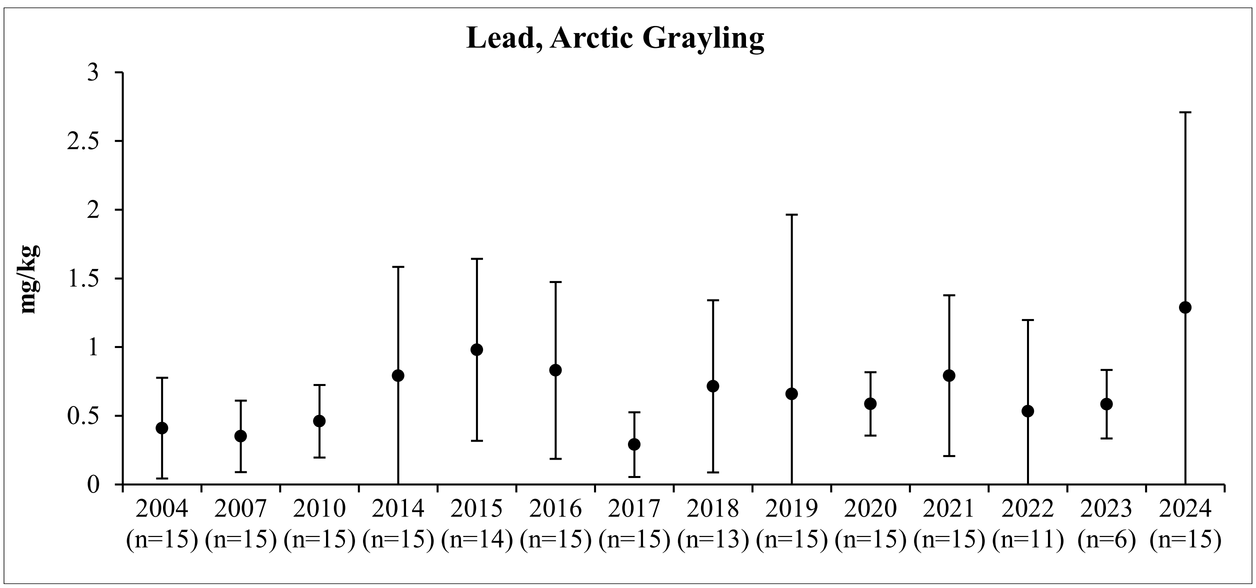

Figure 39.–Mean lead concentrations (± 1 SD) in juvenile Arctic grayling collected from Bons Pond drainage (whole body dry weight).

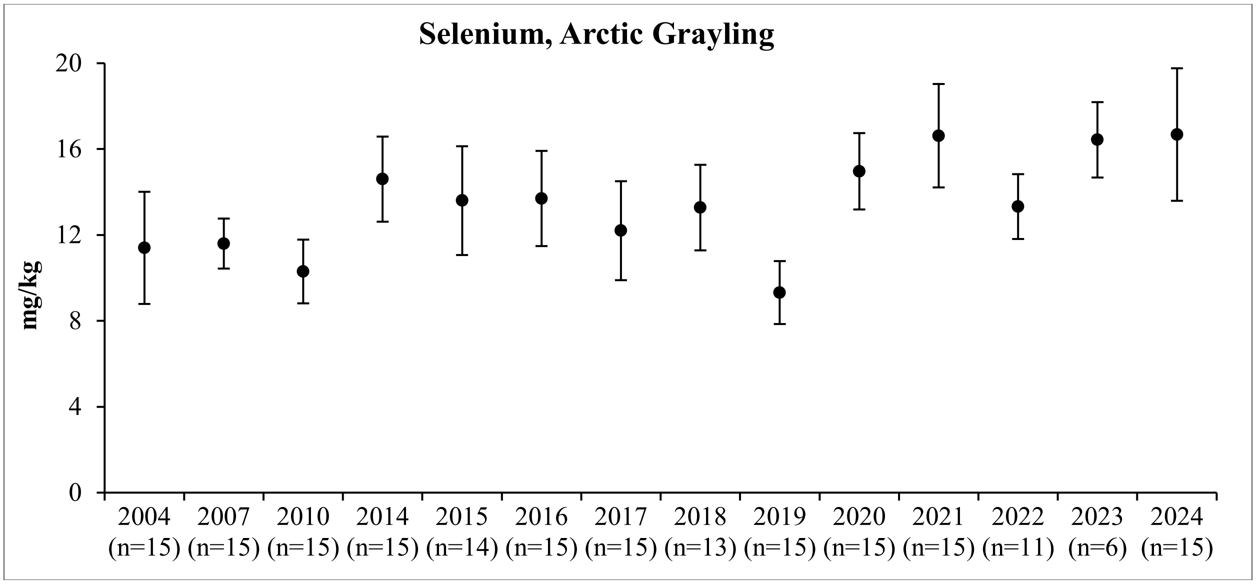

Figure 40.–Mean selenium concentrations (± 1 SD) in juvenile Arctic grayling collected from Bons Pond drainage (whole body dry weight).

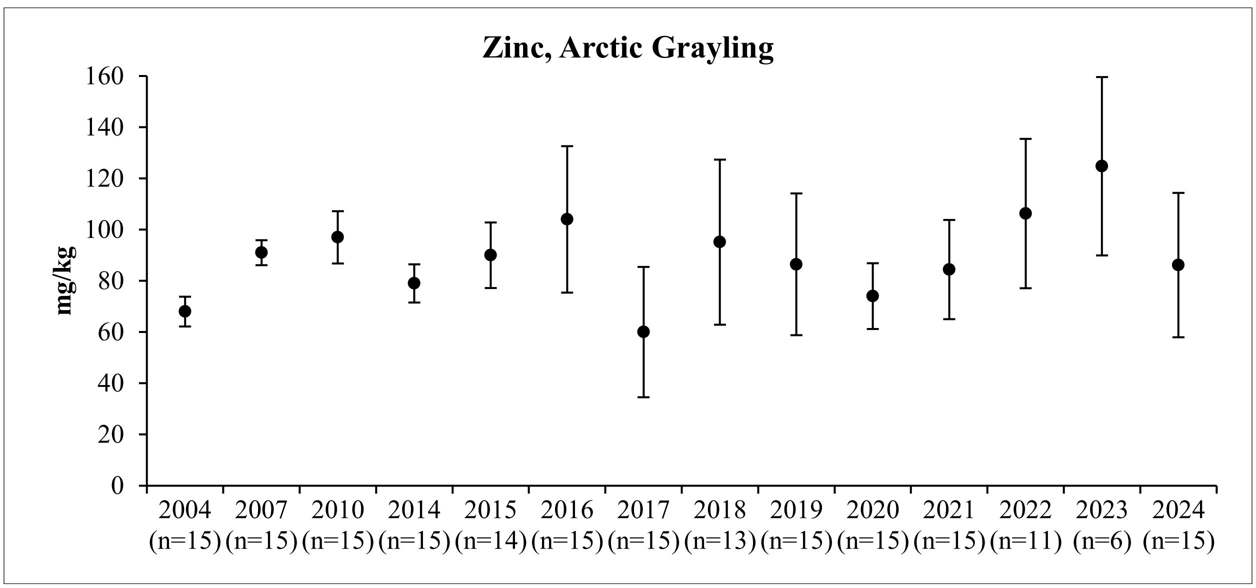

Figure 41.–Mean zinc concentrations (± 1 SD) in juvenile Arctic grayling collected from Bons Pond drainage (whole body dry weight).

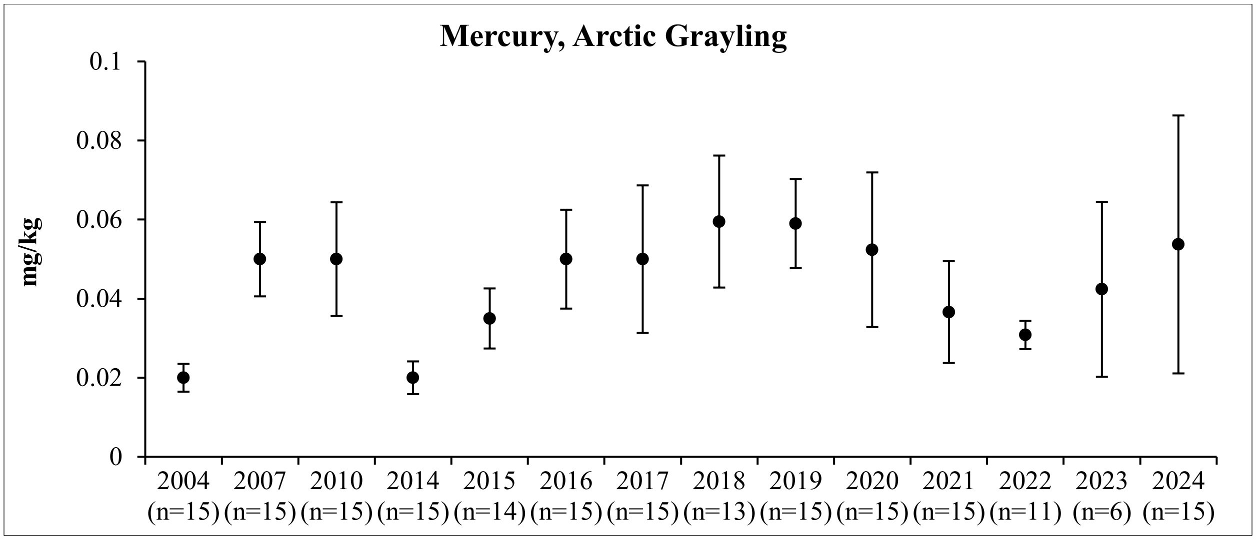

Figure 42.–Mean mercury concentrations (± 1 SD) in juvenile Arctic grayling collected from Bons Pond drainage (whole body dry weight).

ELEMENT CONCENTRATIONS IN ADULT DOLLY VARDEN

In 2024, adult Dolly Varden were collected from the Wulik River about 2 km downstream from the mouth of Ikalukrok Creek, near Tutak Creek, to be sampled for selected element concentrations in kidney, liver, muscle, and reproductive tissue. Fourteen fish were sampled in 2024, 7 in the spring and 7 in the fall.

The purpose of sampling adult Dolly Varden for element concentration is to monitor tissue concentrations over time and to provide a database for use by other professionals. It is unlikely that tissue element concentrations in adult fish could be related to events at the Red Dog Mine since most Dolly Varden growth occurs in the marine environment. All laboratory work was done with Level III Quality Assurance. Data for 2024 fish are presented in Appendices 5 and 6.

Certain elements are known to concentrate preferentially in certain organs; however, the relationship of organ concentration to ambient environmental concentrations is unknown. Concentrations of selected elements vary with season, age, size, weight, and feeding habits of fish (Jenkins 1980) and in the case of anadromous Dolly Varden, the element concentrations vary with exposure to freshwater and marine environments. None of the analytes measured appear to concentrate in muscle tissue (Figure 43). In Wulik River Dolly Varden sampled from 1999–2024, cadmium was highest in kidney samples, copper was highest in liver samples, lead was highest in testes tissue, zinc was highest in reproductive tissues, selenium was highest in ovaries and kidneys, and mercury was highest in kidneys.

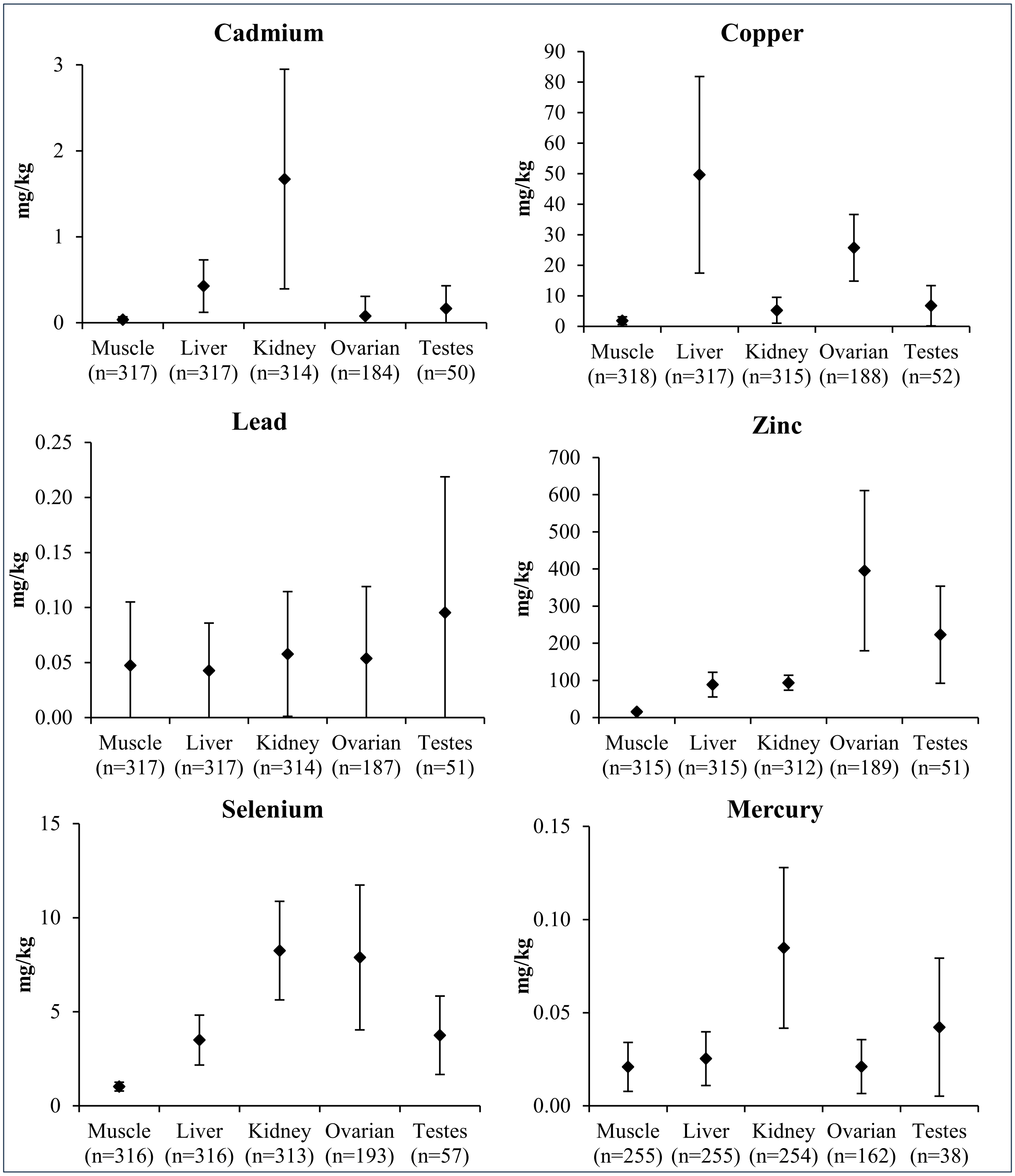

Figure 43.–Mean element concentration (±1 SD; dry weight) in adult Dolly Varden tissues, Wulik River (1999–2024[3]).

[3] Mercury results from 2018 samples are not included in the running mean. Lab equipment was being repaired and samples were analyzed past holding time, producing unreliable results.

Cadmium concentrations in adult Dolly Varden kidney tissue have been variable since 1999 (Figure 44). Concentrations of cadmium slightly increased from 1999–2002, then abruptly decreased and remained around 1 mg/kg through spring of 2009. Mean cadmium concentrations doubled in fall of 2009 to 1.99 mg/kg, increased to 2.96 mg/kg in spring 2011, then have generally remained intermediate and variable since 2013. The mean cadmium concentration in fish from the spring 2023 sample was higher than any seen previously, but fall 2023 concentrations were within the range of historical values, and the mean in spring 2024 decreased back within the range previously observed.

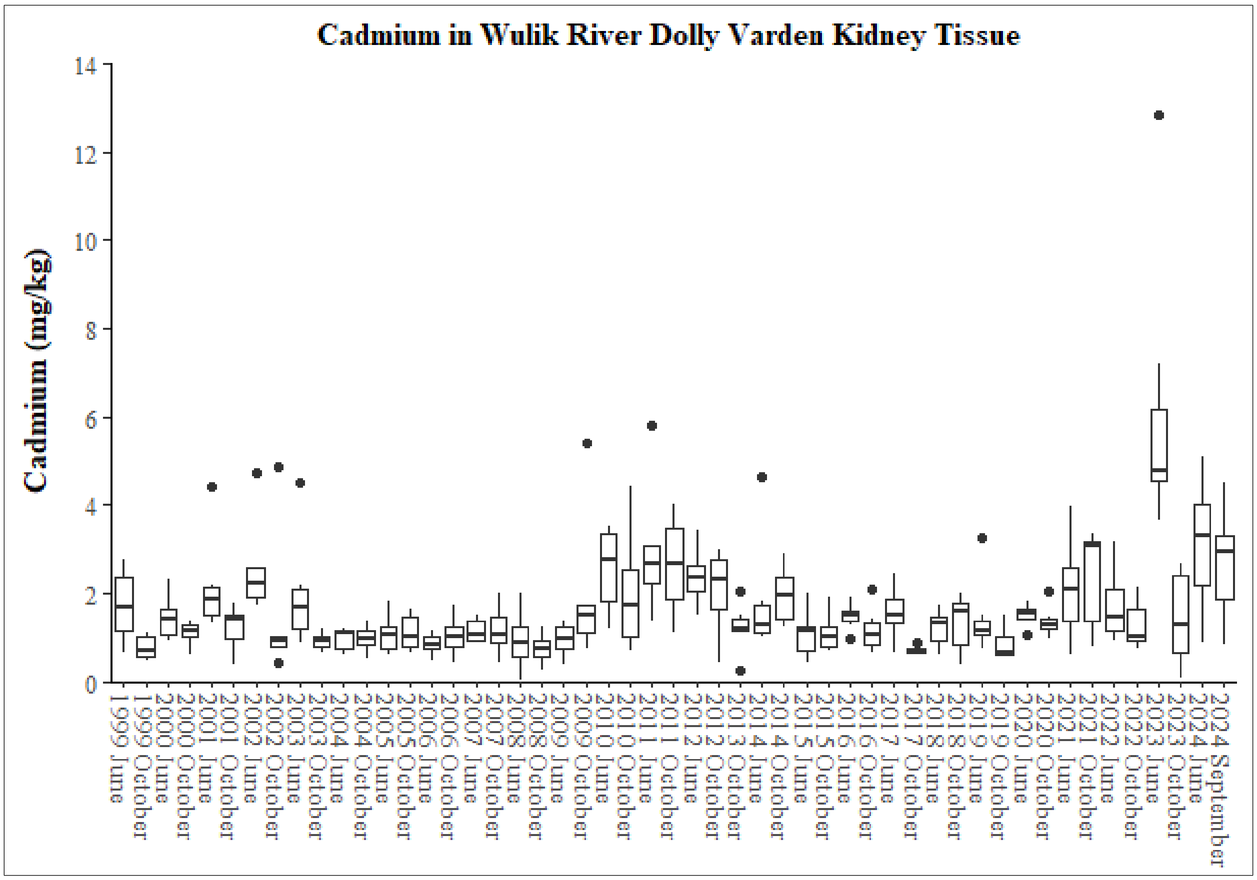

Figure 44.–Boxplot of cadmium concentrations in adult Dolly Varden kidney tissues from 1999–2024. No fish were collected in spring 2013.

The mean selenium concentration in adult Dolly Varden ovaries is higher for fish sampled in the fall (9.74 mg/kg) than for fish sampled in the spring (5.62 mg/kg) (Figure 45). Using an unpaired two-sample Wilcoxon test for data with a non-normal distribution to compare the fall and spring ovary sample means returned a p-value of 2.2×10^{-16}, which is less than the significance level alpha = 0.05. The spring and fall selenium concentrations in Dolly Varden ovaries are significantly different. The cause of this difference is unknown but likely has to do with the environment the fish inhabited in the months prior to being caught. The spring fish would have overwintered in freshwater in the Wulik River since the previous fall, while the Dolly Varden sampled in the fall would have recently returned from the marine environment, which is likely where they acquired the selenium.

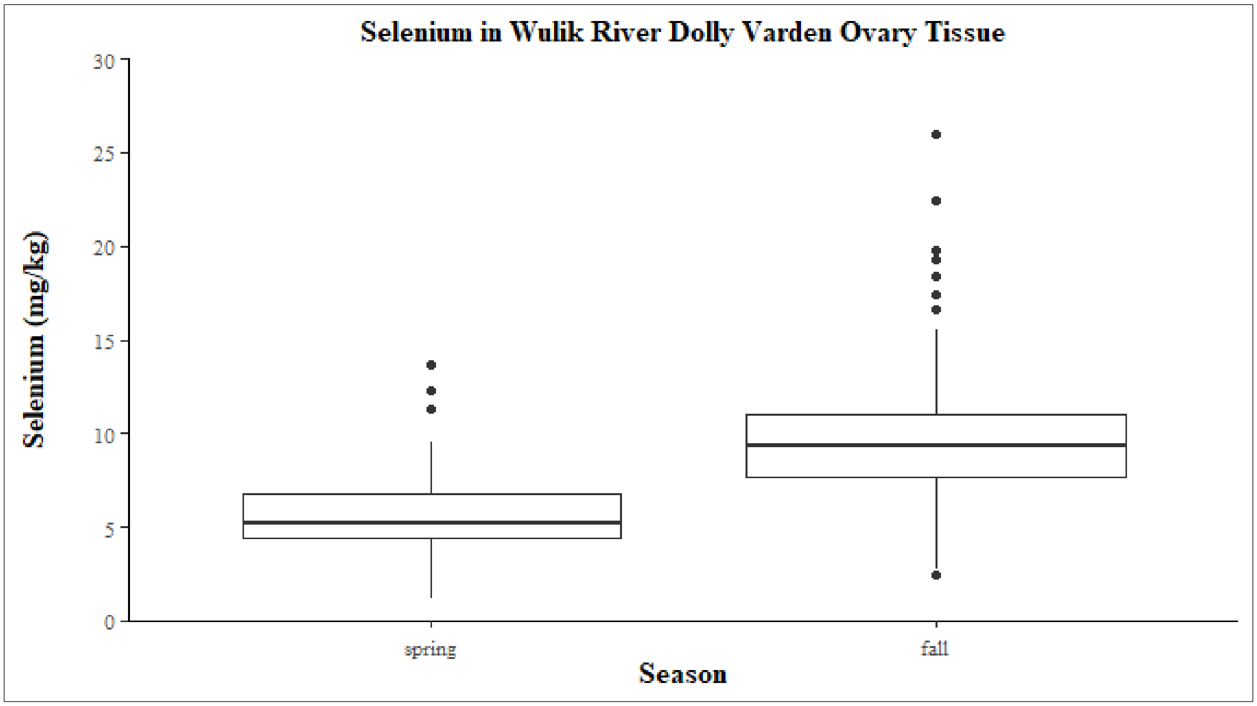

Figure 45.–Selenium concentrations (dry weight) in Dolly Varden ovaries from 1999–2024. Spring n=86 and Fall n=107.

DOLLY VARDEN, OVERWINTERING

An aerial survey was conducted using a helicopter on October 2–3, 2024, to estimate the number of overwintering Dolly Varden in the Wulik River (Figure 46). Lower Ikalukrok Creek was also surveyed, but Dolly Varden observed here are considered fall spawning fish and are not included in the count of overwintering fish. Mineral seeps in Ikalukrok Creek and the Wulik River coated the riverbed with dark red and black precipitates in places, making it difficult to discern fish. Turbidity from these seeps also impacted visibility in the deep-water sections downstream of the mouth of Ikalukrok Creek. A total of 45,976 Dolly Varden were counted in the Wulik River, although this should be considered a minimum estimate due to reduced visibility (Figure 47). The 2023 aerial survey estimate was 12,898 fish, the second lowest on record. However, similar to 1986, when only 5,590 fish were counted, anecdotal reports from Kivalina residents suggest that many Dolly Varden moved into overwintering areas under the ice in November, after the October survey was completed (Bernard and DeCicco 1987; K. Moselle, Teck American, Anchorage, personal communication).

On average, 95% of Dolly Varden observed have been downstream of the mouth of Ikalukrok Creek (39 surveys 1979–2024; Table 3). However, in 2019–2021 and 2023–2024 a higher percentage of fish were counted upstream of the mouth of Ikalukrok Creek. In 2024, 13% (5,762 fish) of the counted fish were above the mouth. This shift in fish distribution could be related to water quality, as the increased mineral seeps in Ikalukrok Creek have impacted the water quality on the Wulik River downstream of the mouth of Ikalukrok Creek. However, these seeps have also impacted water visibility, making it challenging to accurately enumerate fish in the Wulik River downstream of Ikalukrok Creek.

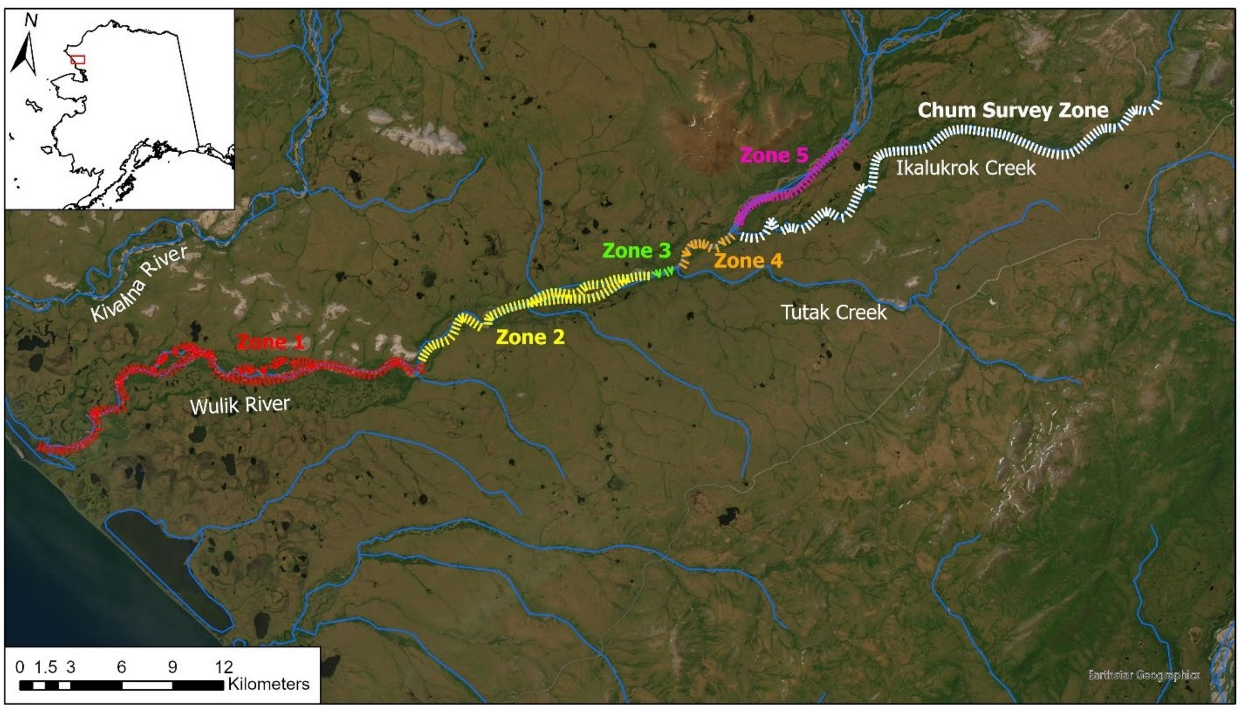

Figure 46.–Dolly Varden and chum salmon aerial survey area.

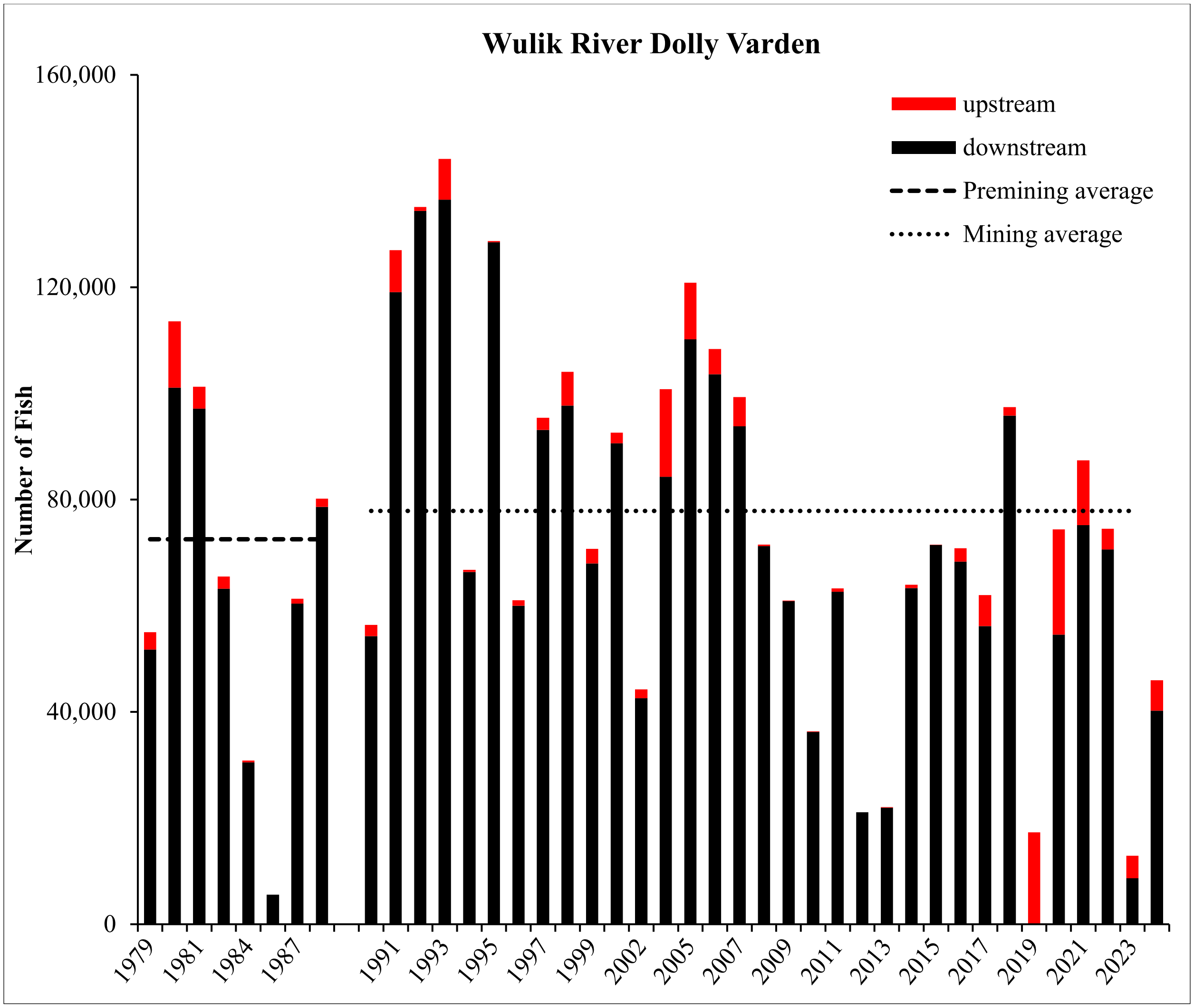

Figure 47.–Aerial survey estimates of the number of Dolly Varden in the Wulik River just prior to freeze up, 1979–2024. "Upstream" fish are those counted upstream of the mouth of Ikalukrok Creek on the Wulik River.

Table 3.–Estimated number of Dolly Varden in the Wulik River.

Year	Wulik River u/s Ikalukrok Creek	Wulik River d/s of Ikalukrok Creek	Total Fish	% of fish d/s of Ikalukrok Creek
Before Mining 1979	3,305	51,725	55,030	94
1980	12,486	101,067	113,553	89
1981	4,125	97,136	101,261	96
1982	2,300	63,197	65,497	97
1984	370	30,483	30,853	99
1986			5,590	unknown
1987	893	60,397	61,290	99
1988[1]	1,500	78,644	80,144	98
During Mining 1989	2,110	54,274	56,384	96
1991	7,930	119,055	126,985	94
1992	750	134,385	135,135	99
1993	7,650	136,488	144,138	95
1994[2]	415	66,337	66,752	99
1995	240	128,465	128,705	99
1996	1,010	59,995	61,005	98
1997	2,295	93,117	95,412	98
1998	6,350	97,693	104,043	94
1999	2,750	67,954	70,704	96
2000[3]				
2001	2,020	90,594	92,614	98
2002	1,675	42,582	44,257	96
2003[3]				
2004	16,486	84,320	100,806	84
2005	10,645	110,203	120,848	91
2006	4,758	103,594	108,352	96
2007	5,503	93,808	99,311	94
2008	271	71,222	71,493	99
2009	122	60,876	60,998	99
2010	70	36,248	36,318	99
2011	637	62,612	63,249	99
2012	0	21,084	21,084	100
2013	114	21,945	22,059	99
2014	610	63,341	63,951	99
2015	10	71,474	71,484	100
2016	2,490	68,312	70,802	96
2017	5,856	56,173	62,029	91
2018	1,590	95,795	97,385	98
2019	17,308	too turbid	incomplete	unknown
2020	19,860	54,546	74,406	73
2021	12,201	75,160	87,361	86
2022	3,887	70,595	74,482	95
2023	4,245	8,653	12,898	67
2024	5,762	40,214	45,976	87

[1]The population estimate (mark/recapture) for winter 1988/1989 for fish > 400 mm was 76,892 (DeCicco 1990).
[2]The population estimate (mark/recapture) for winter 1994/1995 for fish > 400 mm was 361,599 (DeCicco 1996).
[3]Fall 2000 and 2003 aerial surveys did not occur due to weather.

CHUM SALMON, SPAWNING

Spawning chum salmon are counted annually in Ikalukrok Creek from its confluence with the Wulik River upstream to Dudd Creek. In 2024 the survey was flown on September 8, but as in recent years, turbidity was high in Ikalukrok Creek, preventing fish counts in the mainstem. Chum salmon carcasses were observed on two gravel bars in the lower section of the creek (Figure 48).

Figure 48.–Turbid water in Ikalukrok Creek on September 8, 2024.

ARCTIC GRAYLING, BONS POND

Bons Pond is an impoundment created by construction of an earthen dam placed on Bons Creek. Dam construction was completed in 1988 to provide potable and make-up water for operational activities. Prior to construction of the dam, there were no fish present in Bons Creek due to a series of impassable waterfalls and chutes in bedrock about 1 km downstream of the dam (Figure 49). Bons Creek flows into Buddy Creek and eventually into Ikalukrok Creek.

A diversion ditch was constructed in 1997 to carry surface water around the overburden stockpile. Thermal and hydraulic erosion in the diversion ditch contributes seasonally to the sediment and organic load in Bons Creek. Generally, there is a high input of sediments and organics to Bons Creek, particularly during rainfall events.

Figure 49.–The outlet of Bons Pond. Arctic grayling leaving Bons Pond go over the falls and into Bons Creek.

The Arctic grayling population in Bons Pond is the result of fish transplant events conducted in 1994 and 1995 (Ott and Townsend 2003). In 1994, 102 Arctic grayling from North Fork Red Dog Creek that ranged in size from 158 to 325 mm FL and five Arctic grayling from Ikalukrok Creek (350 to 425 mm FL) were transplanted to Bons Pond. In 1995, about 200 Arctic grayling fry were caught in North Fork Red Dog Creek and moved to Bons Pond.

In 1996 and 1997 visual observations and fyke net sampling in Bons Pond were conducted and no fish were caught or observed. From 1995 to 1997, 12 of the marked Arctic grayling transplanted to Bons Pond were recaptured in North Fork Red Dog Creek. Initially, it was believed that the fish transplant was unsuccessful since no fish were observed in Bons Pond. However, in 2001 and 2002 Arctic grayling juveniles were observed in Bons Creek immediately downstream of the blast road (upstream from Bons Pond). In summer 2003, fish sampling was conducted in Bons Pond to determine fish use and the estimated Arctic grayling population was 6,773 fish ≥ 200 mm FL (Ott and Townsend 2003).

Since 2003, Bons Pond and Bons Creek have been sampled in the spring with additional sampling later in the ice-free season to increase the number of marked fish and catch juveniles for element analysis, as needed. Spawning has been observed in Bons Creek and in the outlet of Bons Pond. The current program in Bons Pond includes a mark/recapture study to estimate the population size and the collection of juvenile Arctic grayling for whole body element analysis.

Three fyke nets were set in the pond and creek from June 11–June 17, 2024: 1 in Bons Creek, 1 in the outlet of Bons Pond, and 1 in Bons Pond by the pumphouse. A total of 75 Arctic grayling of taggable size, plus 1,466 fish too small to tag (< 200 mm FL), were captured in the 3 nets. Of the 75 fish total that were ≥ 200 mm FL, 38 were recaptures.

The CPUE for all fish in the Bons Creek fyke net in 2024 was 167 fish/day (Figure 50). The CPUE for Arctic grayling < 200 mm FL in the Bons Creek fyke net in 2024 was 165 fish/day, the highest CPUE for small fish since sampling began (Figure 51).

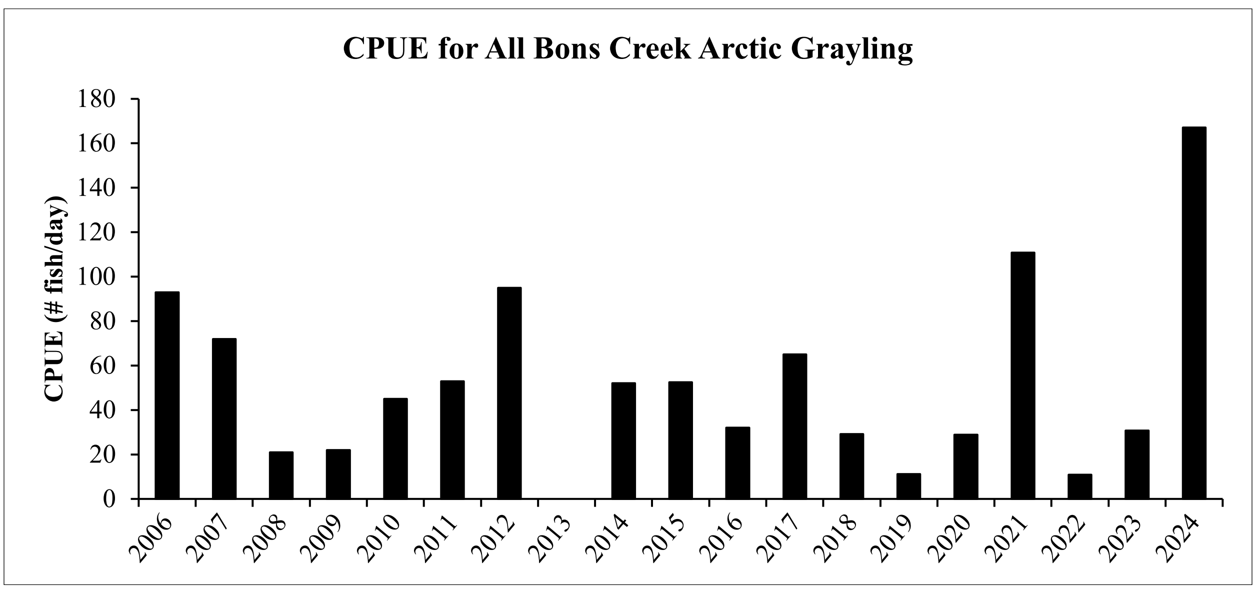

Figure 50.–CPUE for all Arctic grayling in Bons Creek 2006–2024. Sampling was not done in 2013 due to high water.

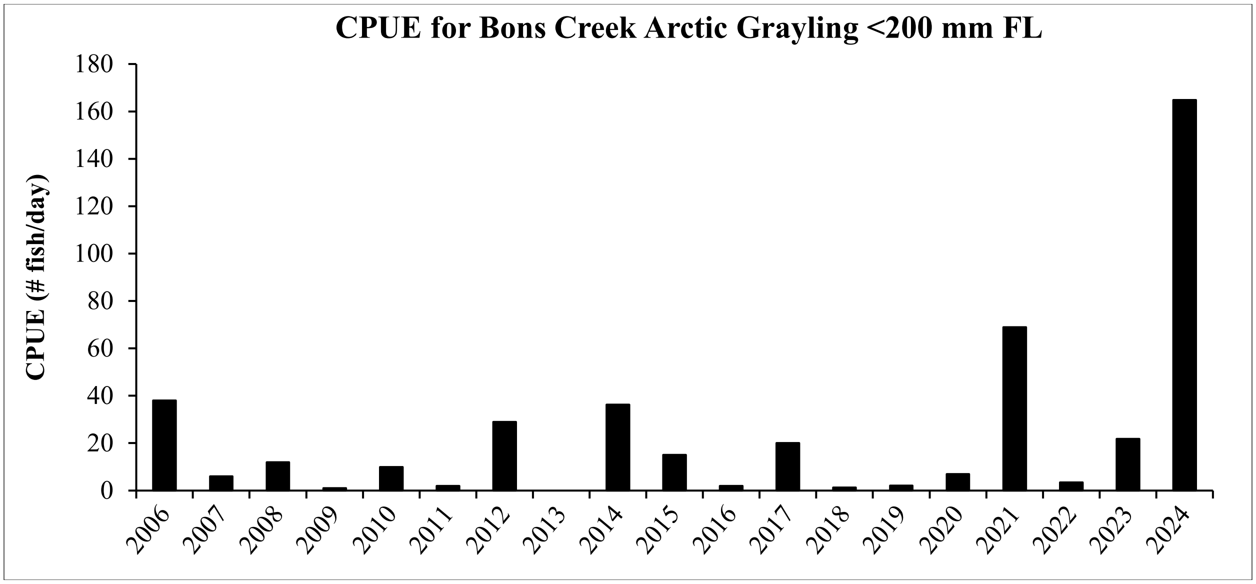

Figure 51.–CPUE for Arctic grayling < 200 mm FL in Bons Creek 2006–2024. Sampling was not done in 2013 due to high water.

The length frequency distribution for Arctic grayling caught in all three fyke nets in spring 2024 is presented in Figure 52 and Figure 53. The length frequency distribution in Bons Pond fish has been relatively consistent over the past several years, with a stable population of mature fish 300–420 mm FL. Since 2019, many small fish 50–150 mm FL have been captured each year. In some years (2019 and 2023) most of these small fish were under 100 mm FL. In 2020, 2021, 2022, and 2024, the large numbers of small fish were 100–150 mm FL. These large numbers of age-1 and age-2 fish have not carried over into captures of subadult fish 200–250 mm FL in subsequent years. Studies of other Arctic fish populations in lakes have documented similar bimodal length frequency distributions, with many small, few intermediate, and many large fish (Power 1978). In these studies, in which fish populations have an initial high mortality rate that declines rapidly to a low rate for most of the life span, the length frequency distribution of the resulting population has this bimodal distribution (Power 1978). It is also possible that intermediate fish are leaving Bons Pond due to competition for food or other factors, since numerous Arctic grayling in this intermediate size range were observed in Bons Creek downstream of the waterfall during July 2022 periphyton and BMI sampling.

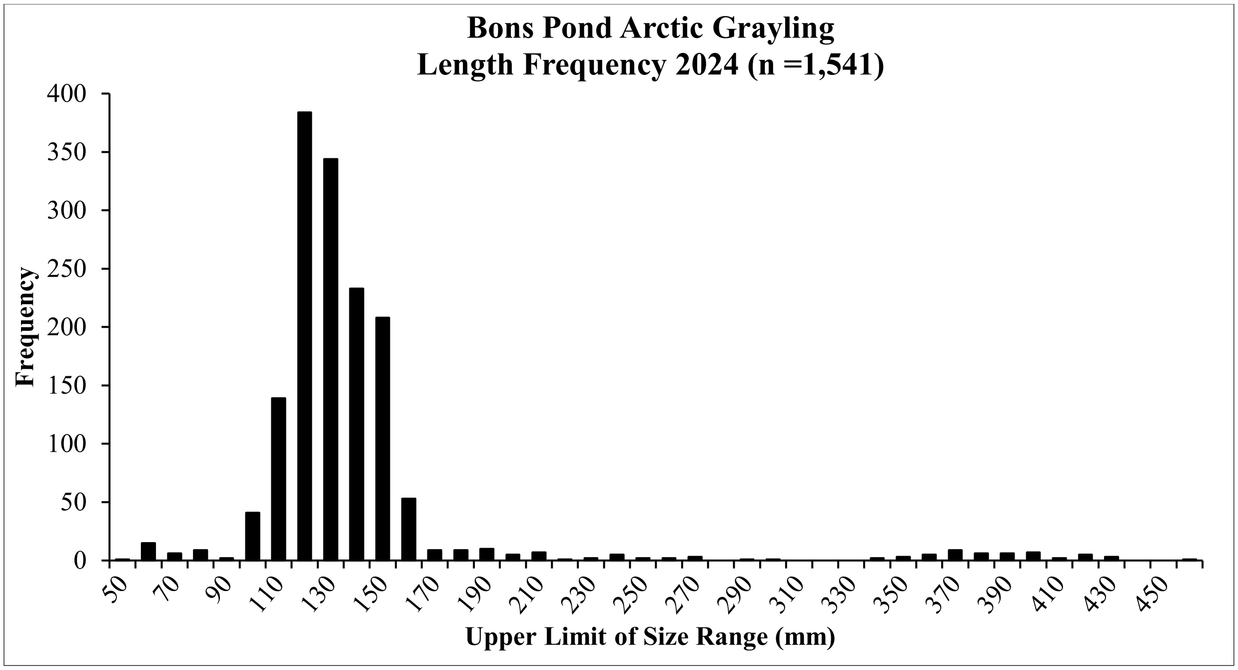

Figure 52.–Length frequency distribution of all captured Arctic grayling from Bons Pond and Bons Creek in spring 2024.

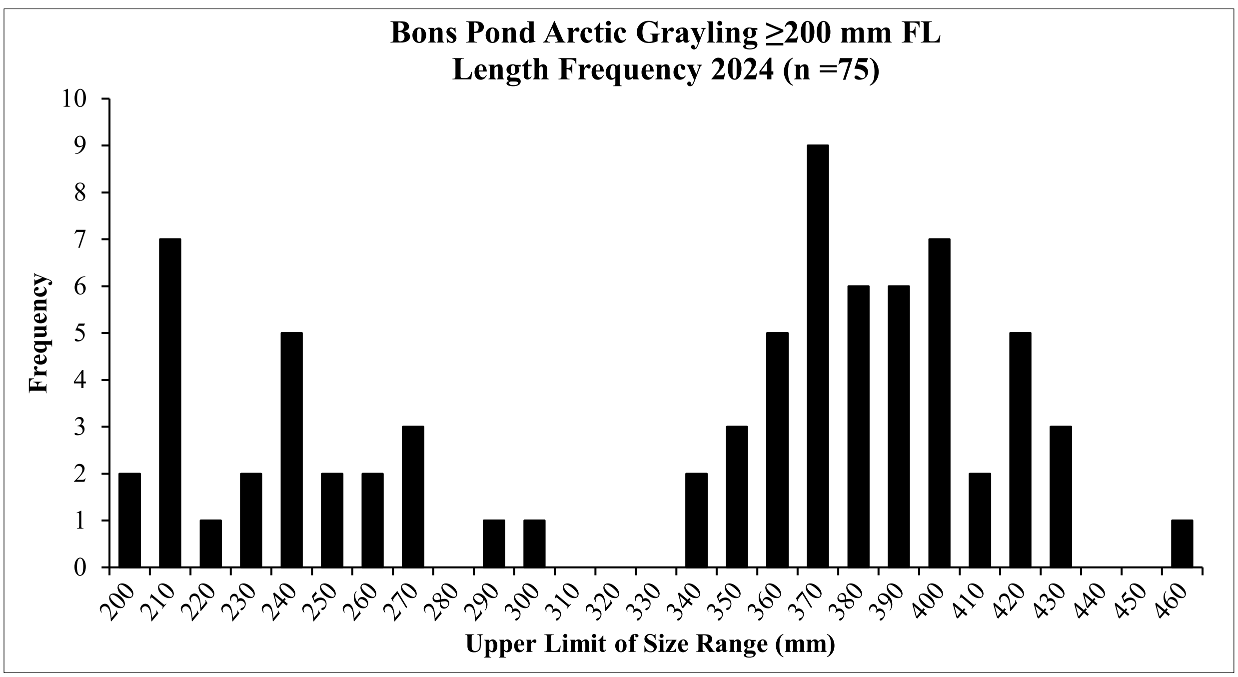

Figure 53.–Length frequency distribution of Arctic grayling ≥200 mm FL captured in Bons Pond and Bons Creek in spring 2024.

Growth rates for Bons Pond Arctic grayling have generally been higher after 2011 than for the time period immediately following colonization (2003–2010). Only growth data for fish ≥ 250 mm FL (at the time of marking) are presented as there are very few recaptures of marked fish from 200 to 249 mm FL (Figure 54). The average annual growth rate was 11 mm in 2023, a decrease from the high of 35 mm seen in 2021. This lower growth rate could be related to the late arrival of spring in 2023, with ice persisting on Bons Pond into the middle of June. However, growth rates are still higher than those observed in 2003–2010, when the population was high is Bons Pond. Higher growth rates in most years since 2011 could be related to the population decline which has resulted in decreased competition and increased food availability (Figure 55).

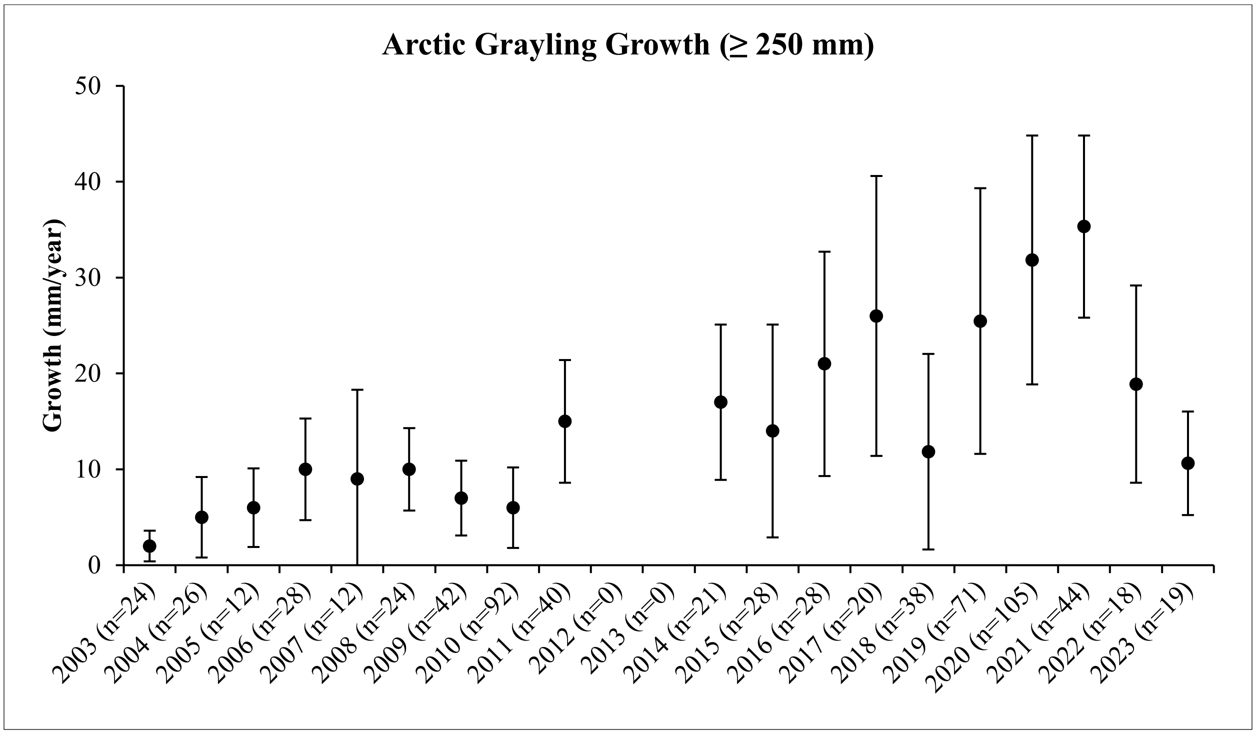

Figure 54.–Average annual growth (±1 SD) of Arctic grayling ≥ 250 mm FL at time of marking.

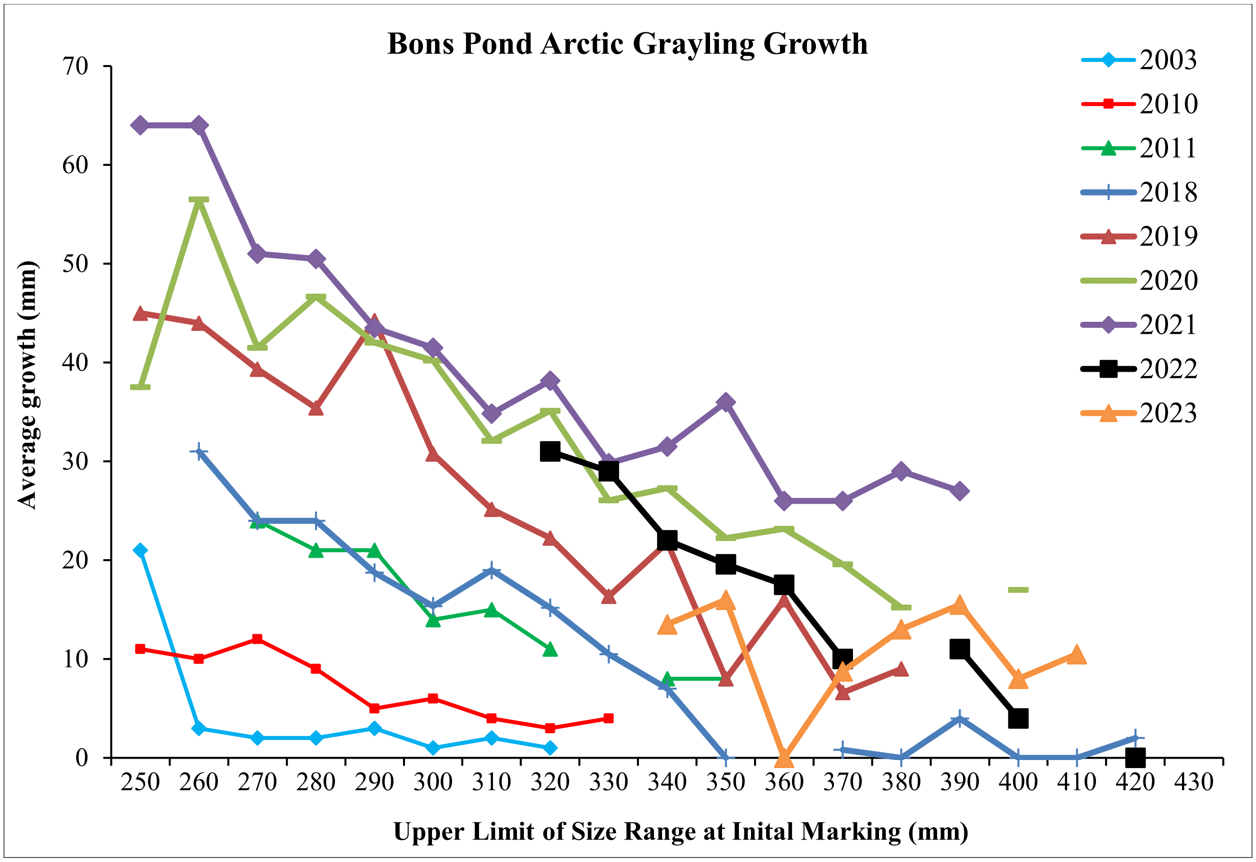

Figure 55.–Bons Pond Arctic grayling annual growth rates by size class for select years from 2003–2023.

The 2023 Arctic grayling population in Bons Pond was estimated by using spring 2023 as the mark event (n =119) and spring 2024 as the recapture event (n=57). The 2024 recapture number does not include fish less than 250 mm FL, as they were likely too small to tag in 2023. In spring 2024, 19 of the captured fish were seen during the spring 2023 mark event. Based on these numbers, the estimated Arctic grayling population for 2023 was 347 fish (95% CI, 237–457 fish) $\geq$ 200 mm FL. This is a decrease from the 2022 population estimate of 573 fish, and the lowest population estimate since sampling began in 2003 (Figure 56). The cause of this population decline is unknown, and future sampling will document if that population trend continues.

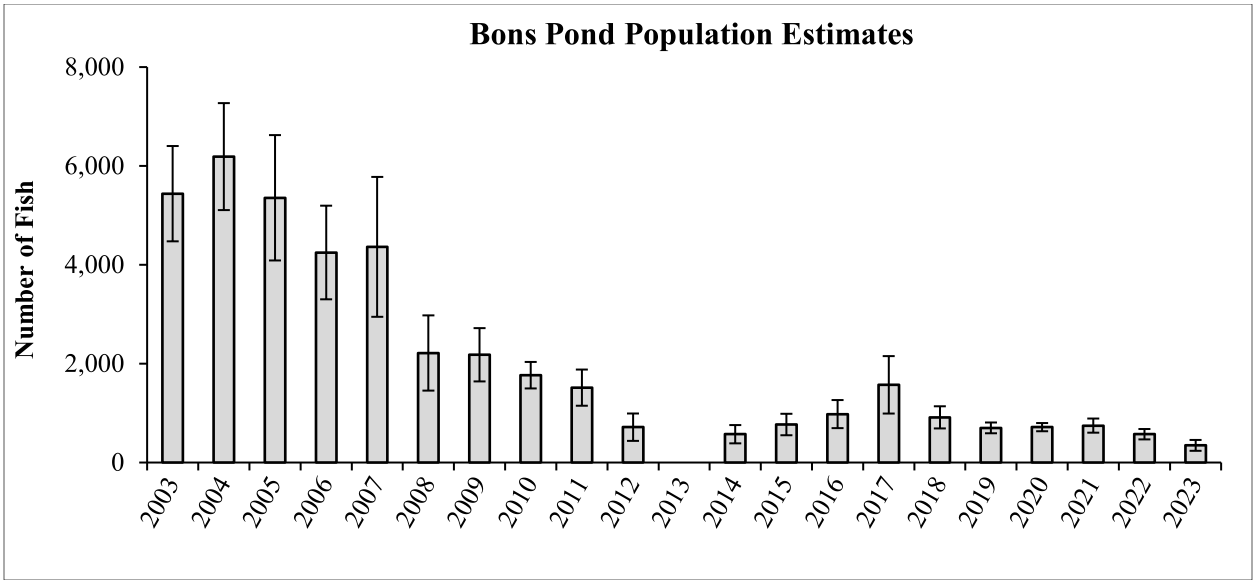

Figure 56.–Estimated Arctic grayling population (95% CI) in Bons Pond for fish ≥ 200 mm FL.

CONCLUSION

In the area surrounding Red Dog Mine there are generally several highly productive creeks characterized by high levels of chlorophyll-a, high density of aquatic invertebrates, and relatively high minnow trap catches. The sample sites on Buddy Creek and Bons Creek typically have the highest chlorophyll-a levels and aquatic invertebrate densities, and this historical trend held steady in 2024. Buddy Creek below the falls and Anxiety Ridge Creek typically have the highest minnow trap catches, but sampling did not occur in 2024 due to high water levels during the sampling period. While the sample sites in mainstem Red Dog Creek at Station 10 and Ikalukrok Creek at Station 9 have historically had lower chlorophyll-a concentrations and aquatic invertebrate densities than Buddy and Bons creeks, the difference between the low productivity and high productivity sites has become more pronounced in recent years. This decrease in productivity is likely linked to an increase of mineral seeps resulting from permafrost thaw, leading to observable and measurable changes in water quality in Ikalukrok and Red Dog creeks. These changes in water quality, and corresponding decreases in stream productivity, are occurring in streams both upstream and downstream of any mine influence and have also been documented in other drainages throughout Northern Alaska (O'Donnell et al 2024).

The diminished water quality in Ikalukrok Creek has prevented enumeration of spawning chum salmon since 2019, but spawned out adults have been observed on gravel bars, indicating that some amount of chum salmon spawning is still occurring in Ikalukrok Creek. The turbidity from Ikalukrok Creek has also impeded enumeration of overwintering Dolly Varden in the Wulik River, but counts of overwintering Dolly Varden in the Wulik River since 2019 have been within the range of counts seen in previous years (1979–2018). The concentrations of various analytes in adult Dolly Varden tissues have fluctuated over time, though none of the tested elements appear to concentrate in muscle tissue. Since Dolly Varden are anadromous and generally spend summers in the marine environment and overwinter in freshwater, they are exposed to different element concentrations in different locations.

The Arctic grayling population in Bons Pond has been slightly decreasing in recent years, although many age-1 and/or age-2 fish are captured each year. Growth rates of adult fish indicate that food availability is not a limiting factor, at least for larger fish. Future sampling efforts will continue to assess the population size and recruitment dynamics.

The ongoing natural water quality changes in the Ikalukrok Creek drainage, coupled with the range of natural variability across years of sampling, emphasize the importance of long term, ongoing aquatic biomonitoring.

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APPENDIX 1. SUMMARY OF RED DOG MINE DEVELOPMENT AND OPERATIONS, 2020–2024.[a]

2020

- January 8, Golder Associates Inc. issued "Summary Report of Zinc Concentrations, Red Dog Creek and Tributaries."
- February 14, DNR Amendment 3 to Reclamation Plan F20169958 to amend the closure design of the Main Waste Stockpile from an engineered compacted soil cover to a geosynthetic liner and cover design.
- February 19, DEC-Water issued addendum 2 to APDES Permit AK0038652 after determining that commissioning of a Reverse Osmosis Water Treatment Facility would have no or de minimis impacts to wastewater discharge.
- February 28, Teck submitted the Stage XIA Interim Dam Raise Design Report to DNR-Dam Safety.
- April 27, insulating cover rock placed over the regraded Qanaiyaq 1500' level to help address Kaviqsaaq Seep drainage.
- May 8, DNR issued Entry Authorization ADL 725670, authorizing tailings placement in the Millsite Lease Area.
- May 10, discharge through Outfall 001 to Red Dog Creek initiated under APDES Permit Number AK0038652.
- May 19, DNR-Dam Safety issued Certificate of Approval to Modify a Dam FY2020-23-AK00201 authorizing Teck to raise the nominal crest elevation of the Tailings Main Dam to 991 feet.
- May 19, Reverse Flow Pumping System shut down. Between December 2019 and May 19, 2020, 397 million gallons of reclaim water were removed from the Tailings Storage Facility with the Reverse Flow Pumping System and temporary winter water storage (TWUA F2019-134).
- May 28, DNR DMLW signed and executed Millsite Lease ADL 233521 for tailings placement.
- May 28, DNR-Mining issued Plan of Operations Approval F20209958POOA.
- June 1–9, the spring spawning migration of Arctic grayling in Bons Pond/Bons Creek and North Fork Red Dog Creek was sampled. Adult Dolly Varden were collected for tissue element analyses and juvenile Arctic grayling were retained from Bons Pond for whole body element analysis.
- June 21–28, treated water discharge temporarily halted due to increased background total dissolved solids (TDS) and decreased stream flow.
- July 6–11, periphyton and aquatic invertebrate sampling was done at all ten sites in accordance with permit requirements. In addition, aquatic biomonitoring (periphyton and aquatic invertebrates) was conducted at 9 sites near the Anarraaq Prospect.
- July 6, treated water discharge halted due to increased background total dissolved solids (TDS) and decreased stream flow.
- July 10, DEC-Water issued minor modification to APDES Permit No. AK0038652, adding end of pipe TDS limits to Outfall 001 when naturally occurring in-stream TDS encroaches on the permitted in-stream TDS limit at Stations 151 and 160.
- August 1–6, juvenile Dolly Varden sampling performed at all the APDES sample sites and sites located in the vicinity of the Anarraaq/Aktigiruq prospect.

- August 7, DEC-Water issued Installation Approval for the Reverse Osmosis wastewater treatment plant.
- August 26, discharge initialized from the Reverse Osmosis water treatment system.
- September 13, DeCicco and ADF&G conducted aerial surveys for Dolly Varden in the Wulik River and chum salmon in Ikalukrok Creek. Seven adult Dolly Varden were collected from the Wulik River for tissue analyses.
- September 22, DNR-Dam Safety issued Temporary Certificate of Approval to Operate a Dam FY2021-3-AK00201 for the Tailings Main Dam, and Temporary Certificate of Approval to Operate a Dam FY2020-4-AK00303 for the Tailings Back Dam.
- September 26, discharge halted for the season. Approximately 870 million gallons were discharged into Red Dog Creek from Outfall 001 under APDES Permit No. AK0038652.
- October 5–8, ADF&G conducted aerial surveys for Dolly Varden in Wulik and Kivalina rivers.

2021

- February 26, ADEC issued minor amendment to Red Dog Operations Oil Discharge Prevention and Contingency Plan #17-CP-3050.
- April 4, ADF&G Habitat issued Fish Habitat Permit #FH21-III-0078 for the low water vehicle and equipment crossing on the spillway of Bons Pond.
- April 9, ADNR Water issued Temporary Water Use Authorization F2020-090, authorizing the capture and diversion of the Kaviqsaaq Seep.
- April 30, DNR-Dam Safety issued Certificate of Approval to Operate a Dam FY2021-27-AK00200 for the Water Supply Dam on Bons Creek.
- May 19, discharge through Outfall 001 to Red Dog Creek initiated under APDES Permit Number AK0038652.
- May 19, ADEC issued minor modification to APDES Permit No. AK0038652, adding a TDS Compliance Schedule and Action Items. Specifically, when water in the TSF approaches within 15 feet of the freeboard limit, discharge of high quality treated wastewater is allowed as in the past even though the natural TDS concentration of the receiving water is increasing.
- May 27–June 3, the spring spawning migration of Arctic grayling in Bons Pond/Bons Creek and North Fork Red Dog Creek was sampled. Adult Dolly Varden were collected for tissue element analyses and juvenile Arctic grayling were retained from Bons Pond for whole body element analysis.
- June 10, diversion of the Kaviqsaaq Seep to the TSF was completed.
- June 22, ADNR issued a 5-year Land Use Permit (LAS 33736) for installation of a radio tower on top of Volcano Mountain.
- July 1–10, periphyton and aquatic invertebrate sampling was done at all eleven sites in accordance with permit requirements. In addition, aquatic biomonitoring (periphyton and aquatic invertebrates) was conducted at 13 sites near the Anarraaq Prospect.
- August 5–12, juvenile Dolly Varden sampling performed at all the APDES sample sites and sites located in the vicinity of the Anarraaq/Aktigiruq prospect.
- August 23–September 2, additional juvenile fish sampling and gamete collection for chum salmon and Dolly Varden fertilization tests. Adult Dolly Varden were collected for tissue element analyses.

- September 5–6 and 10, Owl Ridge Natural Resource Consultants conducted aerial surveys for chum salmon and Dolly Varden in the Wulik and Kivalina rivers and Ikalukrok Creek.
- September 23, ADNR issued Reclamation Plan Approval No. F20219958RPA, Plan of Operations Approval No. F20219958POOA, and Waste Management Permit No. 2021DB0001.
- September 25, discharge into Red Dog Creek from Outfall 001 was halted for the season. Approximately 1.719 billion gallons were discharged under APDES Permit No. AK0038652**.** 173 million gallons of the discharge was from the RO plant.
- October 6–9, ADF&G conducted aerial surveys for Dolly Varden in Wulik and Kivalina rivers.
- November 18, ADNR issued an amendment to Reclamation Plan Approval No. F20219958.01RPA to delay covering a small section of the Main Waste Dump.
- November 29, DNR-Dam Safety issued Certificate of Approval to Operate a Dam FY2022-12-AK00201 for the Tailings Main Dam, and Certificate of Approval to Operate a Dam FY2021-13AK00200 for the Tailings Back Dam.

2022

- January 25, Red Dog Mine 2021 Environmental Audit finalized and published.
- April 1, ADEC approved the routine update for the Red Dog Operations Contingency Plan #17-CP-3050.
- May 9, discharge through Outfall 001 to Red Dog Creek initiated under APDES Permit Number AK0038652.
- May 16, ADNR Dam Safety issued a Certificate of Approval to Modify a Dam for Stage XII of the Red Dog Tailings Main Dam. This approved the construction of the Main Dam to the final elevation of 1,007.4 feet.
- May 17, ADNR Dam Safety issued a Certificate of Approval to Modify a Dam for the Red Dog Tailings Back Dam Stage V Raise.
- June 2–9, ADF&G sampled the spring spawning migration of Arctic grayling in Bons Pond/Bons Creek and North Fork Red Dog Creek. Adult Dolly Varden were collected for tissue element analyses and juvenile Arctic grayling were retained from Bons Pond for whole body element analysis. ADF&G assisted Owl Ridge Natural Resource Consultants with Arctic grayling gamete collection for fertilization studies.
- July 7–14, ADF&G conducted periphyton and aquatic invertebrate sampling at all 10 sites in accordance with permit requirements. In addition, aquatic biomonitoring (periphyton and aquatic invertebrates) was conducted at 17 sites near the Anarraaq Prospect.
- August 1–6, ADF&G performed juvenile Dolly Varden sampling at all the APDES sample sites and sites located in the vicinity of the Anarraaq/Aktigiruq prospect.
- September 23, discharge into Red Dog Creek from Outfall 001 was halted for the season. Approximately 1.725 billion gallons were discharged under APDES Permit No. AK0038652**.**
- September 28, ADF&G issued Fish Habitat Permit FH22-III-0209 for water withdrawal from Bons Reservoir and Bons Creek under Water Right LAS 1453.
- October 1–3, ADF&G conducted aerial surveys for Dolly Varden in the Wulik and Kivalina rivers.
- December 29, ADNR Water issued water rights for five gravel pit ponds, Middle Fork Red Dog Creek, the Tailings Back Dam, South Fork Red Dog Creek Tailings Storage Facility, Middle Fork Red Dog Creek Bypass, and South Fork Red Dog Creek Bypass.

2023

- January 2, 700 gallons of zinc final concentrate was released on the ground under the mill building due to equipment failure.
- January 17, 2,000 pounds of copper sulfate was released to the ground outside the Reagents Building when a container broke during delivery.
- January 20, Minor Amendment to Red Dog Oil Discharge Prevention and Contingency Plan (ADEC Plan # 17-CP-3050) was approved.
- March 1, ADNR Water issued Temporary Water Use Authorization F2022-050A1 for the diversion of Willy Nilly, Sulfur, Shelly, Connie, and Rachel Creeks. The amendment also included water withdrawals from Sulfur Creek for drilling.
- March 31, a rabid fox attacked and bit a person outside the Personnel Accommodations Complex double doors and was subsequently dispatched by the Environmental Department. The carcass was shipped to ADF&G for necropsy and was confirmed to be rabid.
- May 1, ADF&G by email transmitted Technical Report No. 23-02 "Aquatic Biomonitoring at Red Dog Mine, 2022" to ADEC.
- May 22, discharge through Outfall 001 to Red Dog Creek initiated under APDES Permit Number AK0038652.
- June 15–21, the spring spawning migration of Arctic grayling in Bons Pond/Bons Creek was sampled by ADF&G. Adult Dolly Varden were collected for tissue element analyses and juvenile Arctic grayling were retained from Bons Pond for whole body element analysis. Water was too high to sample North Fork Red Dog Creek.
- July 6–13 periphyton and aquatic invertebrate sampling was done at all eleven sites in accordance with permit requirements as well as at 13 sites near the Aktigirug/Anarraaq Exploration Project (AAEP).
- July 11, ADNR Water issued Temporary Water Use Authorization F2023-037 for water withdrawal from the Mill Pad Area Dewatering Well 1.
- August 3–8, juvenile Dolly Varden sampling performed at all the APDES sample sites and AAEP sites.
- September 19, discharge into Red Dog Creek from Outfall 001 was halted for the season. Approximately 1.776 billion gallons were discharged under APDES Permit No. AK0038652**.**
- October 3–5, ADF&G conducted aerial surveys for Dolly Varden in the Wulik and Kivalina rivers.
- October 18, a zinc concentrate truck rolled over at MP 14.5 on the DeLong Mountain Transportation System (Port Road). Approximately 1 ton of zinc concentrate was released onto the snow-covered tundra.
- November 27, ADNR Water issued water rights for the Main Waste Acid Rock Drainage Collection system, Dewatering Wells, Bons Creek, Red Dog Port, South Fork Red Dog Creek and Tailings, and Diversion Ditches #1, #2, and #4.
- December 7, three caribou were struck and killed on the DMTS at MP 36 and MP 37.
- December 8, ADEC approved Red Dog Operations Oil Discharge Prevention and Contingency Plan #23-CP-2050.

2024

- February 14, 10 tons of zinc concentrate was spilled onto the tundra when a haul truck went off the DeLong Mountain Transportation System road at MP 29. Concentrate was vacuumed up on 2/24 and 2/25, with final clean up completed on 4/26.
- February 26, ADNR Dam Safety issued a Certificate of Approval to Operate a Dam FY2024-13-AK00200r for the Red Dog Water Supply Dam on Bons Creek.
- May 3, additional clean up of the MP 14.5 zinc concentrate spill from 10/18/23 occurred.
- May 8, Teck Alaska requested an amendment to the Reclamation Plan Approval F20219958RPAfor construction of exploration roads and pads north of the existing Aqqaluk Pit, which would include extending the existing Sulfur Creek diversion and construction of a Sulfur Creek bypass west of the Aqqaluk pit.
- May 20, Red Dog initiated discharge from Outfall 001.
- May 24, Ailuuraq Creek breached the DMTS road just north of the bridge due to aufeis buildup underneath the bridge.
- May 28, the Red Dog clean water diversion at Shelly Creek developed a leak at a pipe section joint. The pipe section was within a lined ditch and water flowed into the Main Pit Water Reservoir.
- June 10–17, the spring spawning migration of Arctic grayling in Bons Pond/Bons Creek was sampled by ADF&G. Adult Dolly Varden were collected for tissue element analyses and juvenile Arctic grayling were retained from Bons Pond for whole body element analysis.
- July 1–9, periphyton and aquatic invertebrate sampling was done at all 11 sites in accordance with permit requirements as well as sites near the Aktigirug/Anarraaq Extension Project (AAEP).
- July 5, ADEC issued an approval letter under ADEC ODPCP #23-CP-2050 for a construction project to replace pipelines and pipe runs near mine tanks M3 and M4.
- July 24, ADNR Large Mine Permitting Team and SOA Department of Law conducted a field inspection to ensure compliance with the Plan of Operations Approval F20219958POA and Reclamation Plan Approval F20219958RPA.2.
- July 24, additional clean up of the zinc concentrate spill at MP 14.5 on 10/18/23 occurred.
- August 12–15, juvenile Dolly Varden sampling was attempted but weather and water conditions did not allow for sampling.
- September 5–9, the chum salmon aerial survey, adult Dolly Varden collection, and water sample collection occurred.
- September 8, ADF&G assisted with euthanizing a moose that was injured in a collision with a haul truck on the DMTS.
- September 21, treated water discharge into Red Dog Creek from Outfall 001 was halted for the season. Approximately 1.735 billion gallons were discharged under APDES Permit No. AK0038652**.**
- September 25, final clean up of the zinc concentrate spill at MP 14.5 on 10/18/23 occurred.
- October 1–4, ADF&G conducted aerial surveys for Dolly Varden in the Wulik River.
- October 16, ADNR issued LAS 35236 for temporary installation of a 60-m meteorological tower adjacent to Material Site 12 at MP 43 on the DMTS road.
- November 15, a zinc concentrate truck rolled over at MP 2 on the DMTS road. Approximately 120,000 lbs of zinc concentrate was released onto the tundra.

- December 13, ADNR Dam Safety issued a Certificate of Approval to Operate a Dam FY2025-07-AK00302 for the Tailings Main Dam and Certificate of Approval to Operate a Dam FY2025-08-AK00303 for the Tailings Back Dam.
- December 20, ADNR Dam Safety issued a Certificate of Approval to Operate a Dam FY2025-10-AK00260 for the Red Dog Mine Water Diversion Dam.

APPENDIX 2. PERIPHYTON STANDING CROP, RED DOG MINE MONITORING SITES 2024

Results below the detection limit are shaded in gray.

2024 Chloro Results - Red Dog					Linear Check Maximum = 69.02 mg/m2				
IDL = 0.14 mg/m2									
EDL = 0.51 mg/m2						Phaeo Corrected			
Daily Vial #	Site	Station	Date Analyzed	Vial Chl a	Chl a mg/m2	**Chl a mg/m2**	**664/665 ratio**	Chl b mg/m2	Chl c mg/m2
2	Bons Crk us pond	400	11/25/2024	3.21	12.83	**11.96**	1.66	0.49	0.44
3	Bons Crk us pond	400	11/25/2024	1.78	7.13	**6.73**	1.68	0.00	0.53
5	Bons Crk us pond	400	11/25/2024	0.58	2.32	**2.14**	1.65	0.13	0.15
4	Bons Crk us pond	400	11/25/2024	0.92	3.69	**3.42**	1.65	0.03	0.13
6	Bons Crk us pond	400	11/25/2024	0.77	3.08	**2.14**	1.42	0.29	0.42
7	Bons Crk us pond	400	11/25/2024	2.61	10.42	**9.61**	1.65	0.31	0.42
8	Bons Crk us pond	400	11/25/2024	2.64	10.57	**9.61**	1.63	0.15	0.53
9	Bons Crk us pond	400	11/25/2024	1.72	6.89	**6.41**	1.66	0.00	0.26
10	Bons Crk us pond	400	11/25/2024	1.21	4.83	**4.49**	1.66	0.02	0.24
11	Bons Crk us pond	400	11/25/2024	2.20	8.81	**8.33**	1.68	0.00	0.43
12	NFRD Crk	12	11/25/2024	0.27	1.09	**0.96**	1.60	0.01	0.12
13	NFRD Crk	12	11/25/2024	0.22	0.86	**0.85**	1.73	0.05	0.08
14	NFRD Crk	12	11/25/2024	0.23	0.90	**0.96**	1.82	0.10	0.14
15	NFRD Crk	12	11/25/2024	0.15	0.59	**0.53**	1.63	0.02	0.09
16	NFRD Crk	12	11/25/2024	0.25	1.00	**0.96**	1.69	0.00	0.06
17	NFRD Crk	12	11/25/2024	0.33	1.32	**1.39**	1.81	0.06	0.12
18	NFRD Crk	12	11/25/2024	0.33	1.32	**1.17**	1.61	0.06	0.12
19	NFRD Crk	12	11/25/2024	0.75	3.01	**2.88**	1.69	0.04	0.16
20	NFRD Crk	12	11/25/2024	1.00	4.02	**3.84**	1.69	0.00	0.15
21	NFRD Crk	12	11/25/2024	0.34	1.36	**1.28**	1.67	0.04	0.11
22	Red Dog Crk	10	11/25/2024	0.01	0.05	**0.11**		0.00	0.09
23	Red Dog Crk	10	11/25/2024	0.01	0.04	**0.11**		0.05	0.06
24	Red Dog Crk	10	11/25/2024	0.02	0.08	**0.21**		0.10	0.12
25	Red Dog Crk	10	11/25/2024	0.01	0.04	**0.11**		0.05	0.06
26	Red Dog Crk	10	11/25/2024	0.02	0.09	**0.11**	2.00	0.03	0.05
27	Red Dog Crk	10	11/25/2024	0.01	0.04	**0.11**		0.05	0.06
28	Red Dog Crk	10	11/25/2024	0.01	0.05	**0.11**		0.00	0.09
29	Red Dog Crk	10	11/25/2024	0.00	0.00	**0.00**		0.00	0.00
30	Red Dog Crk	10	11/25/2024	0.00	0.00	**0.00**		0.00	0.00
31	Red Dog Crk	10	11/25/2024	0.01	0.04	**0.11**		0.05	0.06

2024 Chloro Results - Red Dog					Linear Check Maximum = 69.02 mg/m2				
IDL = 0.14 mg/m2									
EDL = 0.51 mg/m2						**Phaeo Corrected**			
Daily Vial #	Site	Station	Date Analyzed	Vial Chl a	Chl a mg/m2	**Chl a mg/m2**	**664/665 ratio**	Chl b mg/m2	Chl c mg/m2
32	Buddy Crk blw falls	401	11/25/2024	7.12	28.49	**27.77**	1.69	6.06	1.96
32	Buddy Crk blw falls duplicate	401	11/25/2024	7.10	28.39	**27.55**	1.69	6.11	1.98
33	Buddy Crk blw falls	401	11/25/2024	0.85	3.38	**3.10**	1.63	0.47	0.25
34	Buddy Crk blw falls	401	11/25/2024	2.31	9.26	**8.54**	1.65	0.00	0.83
35	Buddy Crk blw falls	401	11/25/2024	0.41	1.64	**1.50**	1.64	0.00	0.14
36	Buddy Crk blw falls	401	11/25/2024	0.45	1.82	**1.50**	1.54	0.04	0.25
37	Buddy Crk blw falls	401	11/25/2024	3.65	14.59	**13.88**	1.68	0.00	1.21
37	Buddy Crk blw falls duplicate	401	11/25/2024	3.65	14.59	**14.10**	1.70	0.04	1.18
38	Buddy Crk blw falls	401	11/25/2024	0.52	2.08	**2.03**	1.70	0.15	0.32
39	Buddy Crk blw falls	401	11/25/2024	1.95	7.82	**7.48**	1.69	0.00	0.73
40	Buddy Crk blw falls	401	11/25/2024	0.31	1.23	**1.28**	1.80	0.02	0.16
41	Buddy Crk blw falls	401	11/25/2024	1.05	4.21	**4.06**	1.70	0.00	0.52
42	Buddy above rd	221	11/25/2024	1.03	4.11	**3.95**	1.70	0.00	0.34
43	Buddy above rd	221	11/25/2024	0.18	0.73	**0.64**	1.60	0.03	0.13
44	Buddy above rd	221	11/25/2024	0.02	0.09	**0.11**	2.00	0.03	0.05
45	Buddy above rd	221	11/25/2024	1.10	4.38	**4.17**	1.68	0.00	0.43
46	Buddy above rd	221	11/25/2024	1.82	7.27	**6.62**	1.64	0.00	0.60
47	Buddy above rd	221	11/25/2024	1.51	6.03	**5.55**	1.65	0.00	0.57
48	Buddy above rd	221	11/25/2024	1.99	7.96	**7.69**	1.71	0.00	0.61
49	Buddy above rd	221	11/25/2024	0.06	0.23	**0.11**	1.25	0.00	0.03
50	Buddy above rd	221	11/25/2024	0.51	2.06	**2.03**	1.73	0.00	0.22
51	Buddy above rd	221	11/25/2024	0.03	0.14	**0.11**	1.50	0.01	0.05
52	Ik above RD	9	11/25/2024	0.01	0.04	**0.11**		0.05	0.06
53	Ik above RD	9	11/25/2024	0.01	0.04	**0.11**		0.05	0.06
54	Ik above RD	9	11/25/2024	0.01	0.05	**0.11**		0.00	0.09
55	Ik above RD	9	11/25/2024	0.01	0.04	**0.11**		0.05	0.06
56	Ik above RD	9	11/25/2024	0.00	0.00	**0.00**		0.00	0.10
57	Ik above RD	9	11/25/2024	0.01	0.04	**0.11**		0.05	0.06
58	Ik above RD	9	11/25/2024	0.00	0.00	**0.00**		0.00	0.00
59	Ik above RD	9	11/25/2024	0.00	0.00	**0.00**		0.00	0.10
60	Ik above RD	9	11/25/2024	0.01	0.04	**0.11**		0.05	0.06
61	Ik above RD	9	11/25/2024	0.00	0.00	**0.00**		0.00	0.00
2	Upper NFRD	402	11/27/2024	0.45	1.81	**1.82**	1.74	0.22	0.09
3	Upper NFRD	402	11/27/2024	0.39	1.58	**1.50**	1.67	0.25	0.16
5	Upper NFRD	402	11/27/2024	2.22	8.90	**8.33**	1.65	1.76	0.16
4	Upper NFRD	402	11/27/2024	0.38	1.51	**1.39**	1.65	0.00	0.09
6	Upper NFRD	402	11/27/2024	2.43	9.70	**8.86**	1.61	3.17	0.21
7	Upper NFRD	402	11/27/2024	3.43	13.71	**13.03**	1.66	3.83	0.28
8	Upper NFRD	402	11/27/2024	1.78	7.13	**6.62**	1.65	1.04	0.15
9	Upper NFRD	402	11/27/2024	0.68	2.74	**2.56**	1.67	0.01	0.16
10	Upper NFRD	402	11/27/2024	6.43	25.74	**24.88**	1.68	7.03	0.78
11	Upper NFRD	402	11/27/2024	1.93	7.73	**6.94**	1.61	0.98	0.27
11	Upper NFRD duplicate	402	11/27/2024	1.95	7.81	**7.26**	1.65	1.01	0.32

2024 Chloro Results - Red Dog					Linear Check Maximum = 69.02 mg/m2				
IDL = 0.14 mg/m2									
EDL = 0.51 mg/m2						Phaeo Corrected			
Daily Vial #	Site	Station	Date Analyzed	Vial Chl a	Chl a mg/m2	Chl a mg/m2	664/665 ratio	Chl b mg/m2	Chl c mg/m2
2	Middle Fork Red Dog	20	12/3/2024	0.01	0.04	**0.11**		0.05	0.06
3	Middle Fork Red Dog	20	12/3/2024	0.01	0.04	**0.11**		0.04	0.16
4	Middle Fork Red Dog	20	12/3/2024	0.01	0.04	**0.11**		0.05	0.06
5	Middle Fork Red Dog	20	12/3/2024	0.01	0.04	**0.00**	1.00	0.04	0.16
6	Middle Fork Red Dog	20	12/3/2024	0.00	0.00	**0.00**		0.00	0.00
7	Middle Fork Red Dog	20	12/3/2024	0.02	0.08	**0.21**		0.10	0.12
8	Middle Fork Red Dog	20	12/3/2024	0.02	0.08	**0.11**	2.00	0.10	0.12
9	Middle Fork Red Dog	20	12/3/2024	0.02	0.08	**0.21**		0.09	0.22
10	Middle Fork Red Dog	20	12/3/2024	0.02	0.08	**0.11**	2.00	0.10	0.12
11	Middle Fork Red Dog	20	12/3/2024	0.01	0.03	**0.11**		0.13	0.13
12	Ik ds Dudd	160	12/3/2024	0.02	0.09	**0.11**	2.00	0.03	0.05
13	Ik ds Dudd	160	12/3/2024	0.01	0.04	**0.11**		0.05	0.06
14	Ik ds Dudd	160	12/3/2024	0.01	0.04	**0.11**		0.05	0.06
15	Ik ds Dudd	160	12/3/2024	0.01	0.04	**0.00**	1.00	0.05	0.06
16	Ik ds Dudd	160	12/3/2024	0.02	0.08	**0.00**	1.00	0.09	0.22
17	Ik ds Dudd	160	12/3/2024	0.01	0.04	**0.11**		0.05	0.06
18	Ik ds Dudd	160	12/3/2024	0.01	0.05	**0.11**		0.00	0.09
19	Ik ds Dudd	160	12/3/2024	0.01	0.05	**0.11**		0.00	0.00
20	Ik ds Dudd	160	12/3/2024	0.01	0.04	**0.00**	1.00	0.05	0.06
21	Ik ds Dudd	160	12/3/2024	0.01	0.04	**0.11**		0.05	0.06
22	Bons Crk us Buddy	220	12/3/2024	4.11	16.44	**15.70**	1.68	2.12	0.54
23	Bons Crk us Buddy	220	12/3/2024	0.84	3.35	**3.20**	1.68	0.34	0.22
24	Bons Crk us Buddy	220	12/3/2024	8.00	32.02	**31.08**	1.70	3.07	1.25
25	Bons Crk us Buddy	220	12/3/2024	1.87	7.47	**7.16**	1.67	1.96	0.26
26	Bons Crk us Buddy	220	12/3/2024	4.72	18.87	**17.62**	1.65	3.21	0.67
27	Bons Crk us Buddy	220	12/3/2024	0.34	1.36	**1.28**	1.67	0.12	0.18
28	Bons Crk us Buddy	220	12/3/2024	0.95	3.78	**3.52**	1.65	0.59	0.26
29	Bons Crk us Buddy	220	12/3/2024	4.99	19.96	**19.44**	1.70	2.53	1.43
29	Bons Crk us Buddy duplicate	220	12/3/2024	4.98	19.91	**19.33**	1.70	2.55	1.43
30	Bons Crk us Buddy	220	12/3/2024	2.12	8.48	**8.33**	1.70	1.78	0.38
31	Bons Crk us Buddy	220	12/3/2024	2.44	9.77	**9.29**	1.68	0.46	0.48

APPENDIX 3. BENTHIC MACROINVERTEBRATES, 2024.

Order	Family	Genus	Bons u/s Bons Pond	Bons u/s Buddy Sta 220	Buddy u/s road Sta 221	Buddy below falls	Ikalukrok u/s Red Dog Sta 9	Ikalukrok d/s Dudd Sta 160	Mainstem Red Dog Sta 10	Middle Fork Red Dog Sta 20	North Fork Red Dog Sta 12	Upper North Fork Red Dog
Acari	Acarina	spp	7	10	8	1	0	0	0	0	13	32
Cladocera	spp	spp	0	0	0	388	0	0	0	0	0	0
Coleoptera	spp	spp	1	0	0	0	0	0	0	0	0	0
Coleoptera	Staphylinidae	spp	0	0	0	0	0	1	0	0	0	0
Collembola	Entomobryidae	spp	1	0	0	2	0	0	0	0	0	0
Collembola	Poduridae	spp	3	0	0	0	0	0	0	0	2	1
Collembola	spp	spp	1	0	1	1	0	0	0	1	0	0
Collembola	Sminthuridae	Sminthurus	0	1	0	0	0	0	0	0	0	0
Collembola	Neanuridae	spp	0	0	1	0	0	0	0	0	0	0
Collembola	Isotomidae	spp	0	0	0	1	1	0	0	0	0	0
Collembola	Neanuridae	spp	0	0	0	0	0	0	0	1	0	0
Copepoda	Cyclopoida	spp	11	8	0	30	0	0	2	0	6	1
Copepoda	Harpacticoida	spp	24	2	1	1	0	0	0	0	0	2
Diptera	Chironomidae	spp	4625	4058	1789	1820	50	49	36	14	281	2709
Diptera	Simuliidae	Simulium	93	0	0	0	0	0	0	0	0	0
Diptera	Simuliidae	spp	798	266	252	873	0	123	0	0	0	124
Diptera	spp	spp	6	0	0	5	1	0	1	0	2	0
Diptera	Empididae	Chelifera	0	1	0	0	0	1	0	0	0	1
Diptera	Tipulidae	Dicranota	0	2	12	2	0	0	0	0	0	5
Diptera	Tipulidae	Tipula	0	4	14	23	0	0	0	0	0	6
Diptera	Ceratopogonidae	spp	0	0	0	0	1	2	1	0	1	0
Diptera	Empididae	spp	0	0	0	0	0	1	0	0	0	0
Diptera	Ephydridae	spp	0	0	0	0	0	1	0	0	0	0
Diptera	Tipulidae	Rhabdomastix	0	0	0	0	0	0	1	0	0	0
Diptera	Chironomidae	spp	0	0	0	0	0	0	0	3	0	0

Order	Family	Genus	Bons u/s Bons Pond	Bons u/s Buddy Sta 220	Buddy u/s road Sta 221	Buddy below falls	Ikalukrok u/s Red Dog Sta 9	Ikalukrok d/s Dudd Sta 160	Mainstem Red Dog Sta 10	Middle Fork Red Dog Sta 20	North Fork Red Dog Sta 12	Upper North Fork Red Dog
Ephemeroptera	Baetidae	Baetis	3	104	70	40	0	1	0	0	0	0
Ephemeroptera	Baetidae	spp	3	40	28	129	0	0	0	0	0	23
Ephemeroptera	Heptageniidae	Epeorus	3	267	102	521	0	5	0	0	1	50
Ephemeroptera	spp	spp	7	2	0	3	0	0	0	0	0	8
Ephemeroptera	Ameletidae	Ameletus	0	46	33	24	0	0	0	0	0	3
Ephemeroptera	Baetidae	Acentrella	0	46	0	0	0	0	0	0	1	0
Ephemeroptera	Ephemerellidae	spp	0	6	0	2	0	0	0	0	0	0
Ephemeroptera	Heptageniidae	Cinygmula	0	99	157	239	3	3	0	0	0	49
Ephemeroptera	Heptageniidae	spp	0	0	0	0	0	0	0	0	0	2
Lepidoptera	Pyralidae	spp	9	0	0	0	0	0	0	2	0	0
Lepidoptera	spp	spp	3	0	0	0	0	0	0	0	0	0
Lepidoptera	Pyralidae	spp	0	0	0	0	0	0	0	1	0	0
Nematoda	spp	spp	27	1	0	0	0	0	2	0	0	8
Oligochaeta	spp	spp	168	15	142	79	1	3	145	0	11	301
Ostracoda	spp	spp	695	467	8	189	0	0	1	0	19	95
Platyhelminthes	spp	spp	44	5	15	19	0	0	0	0	3	10
Plecoptera	Capniidae	spp	12	1	23	36	0	1	0	0	3	90
Plecoptera	Nemouridae	Zapada	64	41	3	31	0	0	0	0	0	0
Plecoptera	spp	spp	10	16	30	63	0	0	0	0	16	39
Plecoptera	Chloroperlidae	Suwallia	0	2	4	1	0	0	0	0	0	0
Plecoptera	Chloroperlidae	Sweltsa	0	4	0	3	0	0	0	0	0	0
Plecoptera	Chloroperlidae	spp	0	2	11	0	0	0	0	0	2	0
Plecoptera	Perlodidae	spp	0	6	9	0	0	0	0	0	0	0
Plecoptera	Nemouridae	Podmosta	0	0	47	0	0	0	0	0	2	66
Plecoptera	Nemouridae	spp	0	0	2	2	0	0	0	0	0	7
Plecoptera	Perlodidae	Haploperla	0	0	1	0	0	0	0	0	0	0
Plecoptera	Capniidae	Capnia	0	0	0	11	0	0	0	0	0	41
Plecoptera	Nemouridae	Ostrocerca	0	0	0	10	0	0	0	0	0	0
Plecoptera	Perlodidae	Isoperla	0	0	0	2	0	0	0	0	0	0
Plecoptera	Capniidae	Eucapnopsis	0	0	0	0	0	0	0	0	0	28
Trichoptera	Limnephilidae	spp	2	0	0	0	0	0	0	0	0	0
Trichoptera	Brachycentridae	Brachycentrus	0	5	0	0	0	0	0	0	0	0

APPENDIX 4. JUVENILE ARCTIC GRAYLING FROM BONS CREEK, WHOLE BODY ELEMENT CONCENTRATIONS, 2024.

Shaded cells indicate value was at or below method detection limit (MDL), so detection limit for that sample is reported. Detection limits for identified elements were based on % solids which varied for each fish.

Sample Number	Date Collected	Length (mm)	Weight (g)	Cadmium (mg/kg)	Lead (mg/kg)	Mercury (mg/kg)	Selenium (mg/kg)	Zinc (mg/kg)	% Solids
061224BPAGJ01	6/12/2024	180	59.0	0.05	0.27	0.03	20.84	66.00	25.0
061224BPAGJ02	6/12/2024	170	47.9	0.11	1.38	0.04	18.41	59.26	27.0
061224BPAGJ03	6/12/2024	160	43.5	0.07	0.16	0.08	14.04	61.42	26.7
061224BPAGJ04	6/12/2024	160	37.3	0.08	0.27	0.04	17.15	95.44	26.3
071023BPAGJ05	6/12/2024	180	50.7	0.09	0.55	0.04	19.43	142.68	24.6
061224BPAGJ06	6/12/2024	175	47.3	0.18	0.69	0.05	17.44	93.80	24.2
061224BPAGJ07	6/12/2024	165	46.8	0.21	4.98	0.04	17.17	116.73	26.9
061224BPAGJ08	6/12/2024	165	47.4	0.06	0.09	0.03	14.72	62.06	28.2
061224BPAGJ09	6/12/2024	165	44.7	0.28	2.99	0.03	20.07	65.71	28.0
061224BPAGJ10	6/12/2024	175	48.9	0.23	2.23	0.13	12.11	120.68	23.7
061224BPAGJ11	6/12/2024	160	39.8	0.18	1.00	0.03	15.68	84.21	26.6
061224BPAGJ12	6/12/2024	160	41.4	0.09	0.46	0.05	20.57	119.01	26.3
061224BPAGJ13	6/12/2024	165	41.9	0.17	0.20	0.13	10.82	48.64	25.7
061224BPAGJ14	6/12/2024	180	56.1	0.11	3.07	0.04	13.69	90.76	24.9
061224BPAGJ15	6/12/2024	160	40.4	0.11	0.96	0.04	18.04	66.04	26.5

APPENDIX 5. ELEMENT CONCENTRATIONS IN ADULT DOLLY VARDEN FROM THE WULIK RIVER, JUNE 2024.

Red numbers indicate value was at or below method detection limit (MDL), so detection limit for that sample is reported. Detection limits for identified elements were based on % solids which varied for each fish.

Tissue	Sample Identification	Fish Species	Sex	Length (mm)	Weight (grams)	Cadmium mg/kg	Copper mg/kg	Lead mg/kg	Selenium mg/kg	Zinc mg/kg	Mercury mg/kg	% Solids
Kidney	061524WUDVA01K	DV	F	565	2400	4.17	7.27	0.43	13.97	93.30	0.14	20.9
Kidney	061524WUDVA02K	DV	F	560	2480	5.10	8.52	0.48	12.95	130.48	0.21	21.0
Kidney	061524WUDVA03K	DV	M	575	2500	3.80	5.85	0.41	10.53	108.21	0.19	20.7
Kidney	061524WUDVA04K	DV	F	498	1580	3.96	7.11	0.51	8.89	103.89	0.08	18.0
Kidney	061524WUDVA05K	DV	F	550	2060	2.81	7.30	0.34	8.36	93.36	0.14	22.6
Kidney	061524WUDVA06K	DV	F	540	1820	2.32	6.27	0.34	7.63	86.40	0.10	22.8
Kidney	061524WUDVA07K	DV	M	630	3360	1.74	4.88	0.55	14.79	92.49	0.07	21.3
Kidney	061524WUDVA07K2	DV	M	630	3360	0.89	3.85	0.43	16.38	86.67	0.13	21.0
Liver	061524WUDVA01L	DV	F	565	2400	0.48	97.28	0.20	3.94	85.89	0.02	40.4
Liver	061524WUDVA02L	DV	F	560	2480	0.82	63.44	0.27	3.80	129.75	0.03	27.9
Liver	061524WUDVA03L	DV	M	575	2500	0.69	102.11	0.13	4.20	93.66	0.02	42.6
Liver	061524WUDVA04L	DV	F	498	1580	0.69	76.00	0.37	3.85	140.00	0.02	27.5
Liver	061524WUDVA05L	DV	F	550	2060	0.53	97.28	0.37	3.28	113.27	0.02	29.4
Liver	061524WUDVA06L	DV	F	540	1820	0.43	89.01	0.43	3.12	117.22	0.02	27.3
Liver	061524WUDVA07L	DV	M	630	3360	0.42	135.21	0.27	6.58	115.85	0.02	28.4
Liver	061524WUDVA07L2	DV	M	630	3360	0.34	108.05	0.25	5.53	97.40	0.02	38.5
Muscle	061524WUDVA01M	DV	F	565	2400	0.15	1.64	0.31	0.90	15.58	0.02	29.2
Muscle	061524WUDVA02M	DV	F	560	2480	0.18	1.26	0.36	0.87	14.78	0.02	27.8
Muscle	061524WUDVA03M	DV	M	575	2500	0.16	1.96	0.32	0.76	15.11	0.05	30.9
Muscle	061524WUDVA04M	DV	F	498	1580	0.18	1.48	0.36	0.81	14.96	0.02	26.2
Muscle	061524WUDVA05M	DV	F	550	2060	0.16	0.95	0.32	0.72	13.14	0.05	34.4
Muscle	061524WUDVA06M	DV	F	540	1820	0.20	1.36	0.41	1.12	17.24	0.07	25.7
Muscle	061524WUDVA07M	DV	M	630	3360	0.18	1.19	0.36	0.81	12.82	0.05	30.1
Muscle	061524WUDVA07M2	DV	M	630	3360	0.15	1.54	0.30	0.90	13.33	0.06	29.1
Reproductive	061524WUDVA01R	DV	F	565	2400	0.30	1.38	0.61	2.49	98.34	0.11	18.1
Reproductive	061524WUDVA02R	DV	F	560	2480	0.17	18.38	0.35	4.95	121.62	0.05	33.3
Reproductive	061524WUDVA03R	DV	M	575	2500	0.35	1.96	0.70	2.22	123.08	0.10	16.9
Reproductive	061524WUDVA04R	DV	F	498	1580	0.17	23.65	0.34	4.21	326.32	0.04	30.4
Reproductive	061524WUDVA05R	DV	F	550	2060	0.19	12.92	0.38	4.78	182.39	0.04	31.8
Reproductive	061524WUDVA06R	DV	F	540	1820	0.18	15.33	0.36	4.14	149.84	0.06	32.1
Reproductive	061524WUDVA07R	DV	M	630	3360	0.33	1.90	0.66	3.08	125.64	0.09	15.6
Reproductive	061524WUDVA07R2	DV	M	630	3360	0.38	1.43	0.76	3.88	136.23	0.11	13.8

APPENDIX 6. ELEMENT CONCENTRATIONS IN ADULT DOLLY VARDEN FROM THE WULIK RIVER, SEPTEMBER 2024.

Red numbers indicate value was at or below method detection limit (MDL), so detection limit for that sample is reported. Detection limits for identified metals were based on % solids which varied for each fish.

Tissue	Sample Identification	Fish Species	Sex	Length (mm)	Weight (grams)	Cadmium mg/kg	Copper mg/kg	Lead mg/kg	Selenium mg/kg	Zinc mg/kg	Mercury mg/kg	% Solids
Kidney	090724WUDVA01K	DV	M	555	2000	3.05	5.11	0.50	9.41	109.13	0.12	21.9
Kidney	090724WUDVA02K	DV	M	415	940	0.84	5.16	0.47	9.30	103.76	0.08	21.3
Kidney	090724WUDVA03K	DV	F	475	1360	1.98	7.72	0.52	8.02	134.65	0.11	20.2
Kidney	090724WUDVA04K	DV	M	605	3000	2.79	4.50	0.33	8.65	113.49	0.12	21.5
Kidney	090724WUDVA05K	DV	F	530	1600	4.50	7.58	0.54	12.28	114.61	0.22	21.9
Kidney	090724WUDVA06K	DV	M	507	1700	3.23	5.39	0.11	8.20	103.07	0.16	22.8
Kidney	090724WUDVA07K	DV	M	620	3340	3.56	7.54	0.21	12.41	158.29	0.22	18.7
Kidney	090724WUDVA07K2	DV	M	620	3340	1.46	5.21	0.42	15.82	158.73	0.21	18.9
Liver	090724WUDVA01L	DV	M	555	2000	0.45	91.51	0.22	5.09	100.27	0.03	37.7
Liver	090724WUDVA02L	DV	M	415	940	0.15	59.91	0.20	4.06	81.13	0.02	42.4
Liver	090724WUDVA03L	DV	F	475	1360	0.42	108.75	0.34	5.74	163.56	0.02	34.3
Liver	090724WUDVA04L	DV	M	605	3000	0.75	212.47	0.30	5.60	139.89	0.02	36.1
Liver	090724WUDVA05L	DV	F	530	1600	0.53	129.79	0.32	6.14	162.92	0.06	32.9
Liver	090724WUDVA06L	DV	M	507	1700	0.58	72.21	0.05	5.33	113.47	0.03	34.9
Liver	090724WUDVA07L	DV	M	620	3340	0.68	159.57	0.35	8.64	153.40	0.06	32.4
Liver	090724WUDVA07L2	DV	M	620	3340	0.80	175.32	0.35	10.98	157.59	0.06	31.6
Muscle	090724WUDVA01M	DV	M	555	2000	0.13	1.04	0.25	1.02	15.13	0.01	26.7
Muscle	090724WUDVA02M	DV	M	415	940	0.20	1.02	0.40	1.01	14.98	0.01	26.5
Muscle	090724WUDVA03M	DV	F	475	1360	0.15	1.30	0.31	1.08	15.92	0.06	26.0
Muscle	090724WUDVA04M	DV	M	605	3000	0.14	1.13	0.29	0.95	15.68	0.05	28.7
Muscle	090724WUDVA05M	DV	F	530	1600	0.18	1.24	0.36	0.92	18.16	0.02	25.6
Muscle	090724WUDVA06M	DV	M	507	1700	0.16	1.27	0.32	1.01	15.14	0.01	28.2
Muscle	090724WUDVA07M	DV	M	620	3340	0.18	1.34	0.37	0.96	15.63	0.06	28.6
Muscle	090724WUDVA07M2	DV	M	620	3340	0.14	1.85	0.29	1.19	19.45	0.07	25.4
Reproductive	090724WUDVA01R	DV	M	555	2000	0.57	3.46	1.14	5.05	372.06	0.09	20.4
Reproductive	090724WUDVA02R	DV	M	415	940	0.85	6.78	1.69	2.64	166.95	0.08	23.9
Reproductive	090724WUDVA03R	DV	F	475	1360	0.35	18.99	0.47	4.45	188.24	0.06	23.8
Reproductive	090724WUDVA04R	DV	M	605	3000	0.30	7.61	0.42	4.16	258.26	0.13	21.8
Reproductive	090724WUDVA05R	DV	F	530	1600	0.15	45.62	0.69	8.71	679.78	0.08	17.8
Reproductive	090724WUDVA06R	DV	M	507	1700	0.11	5.27	0.54	4.05	130.53	0.02	22.6
Reproductive	090724WUDVA07R	DV	M	620	3340	0.57	4.55	0.13	5.16	221.14	0.09	17.5
Reproductive	090724WUDVA07R2	DV	M	620	3340	0.23	3.42	0.45	4.50	187.05	0.08	19.3