Technical Report No. 19-08

# Aquatic Biomonitoring at Red Dog Mine, 2018

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

**by**

**Chelsea M. Clawson and Alvin G. Ott**

**May 2019**

**Alaska Department of Fish and Game** **Division of Habitat**

## Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Habitat, Sport Fish, and Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, Technical Reports and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

**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, $\chi^2$, etc.) |
| confidence interval | CI |
| correlation coefficient (multiple) | R |
| correlation coefficient (simple) | r |
| covariance | cov |
| degree (angular) | ° |
| degrees of freedom | df |
| expected value | *E* |
| fork length | FL |
| 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 |
| total length | TL |
| variance | |
| population | Var |
| sample | var |

*TECHNICAL REPORT NO. 19-08*

# AQUATIC BIOMONITORING AT RED DOG MINE, 2018

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

By

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May, 2019

Cover: Invertebrate drift nets on Ikalukrok Creek, July 2018. Photograph by Chelsea Clawson

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## Acknowledgements

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Chad Bear, Maria Wessel, and Audra Brase with the Alaska Department of Fish and Game (ADF&G) Division of Habitat and Brendan Scanlon with ADF&G Division of Sport Fish aided with field and laboratory work. Fred DeCicco (DeCicco-Alaska) conducted the fall aerial surveys for Dolly Varden and chum salmon, and collected the fall sample of adult Dolly Varden from the Wulik River.

Nora Foster (NRF Taxonomic Services) was responsible for sorting and identification of aquatic invertebrates. Robert Napier and Audra Brase provided constructive reviews of this report.

## Executive Summary

- In 2018, median metals concentrations (lead, zinc, aluminum, cadmium) in North Fork Red Dog Creek, Buddy Creek, and Bons Pond were consistent with past years' results, and were lower when compared with pre-mining data. Median concentrations of cadmium, lead, and zinc were consistently higher in Mainstem Red Dog Creek as compared with Buddy and North Fork Red Dog creeks and Bons Pond. The pH and total dissolved solids (TDS) in Mainstem Red Dog Creek were higher than pre-mining, but consistent with past years' data.

- Zinc increased sharply in Mainstem Red Dog Creek in 2018. The anomaly was traced upstream to Station 145/Upper Middle Fork Red Dog Creek, above the clean water bypass system. The source of the anomaly is currently unknown, but Teck is actively investigating the issue.

- Periphyton standing crop, as estimated by chlorophyll-a concentration, is determined each year in drainages near the Red Dog Mine. In 2018, chlorophyll-a concentrations were highest in Bons Creek below the pond and lowest in Middle Fork Red Dog Creek. Chlorophyll-a concentration in Ikalukrok Creek at Station 9 continues to track closely with zinc and cadmium in the water. The major source of cadmium and zinc at Station 9 is the Cub Creek natural seep.

- Aquatic invertebrate densities are used as an index of stream productivity and health. In 2018, ten sites were sampled, and the aquatic invertebrate density was highest in Bons Creek upstream of Buddy Creek (Station 220). In 2018 all sites sampled except for Ikalukrok Creek upstream of the confluence with Red Dog Creek (Station 9) contained a higher percentage of Chironomidae than Ephemeroptera, Plecoptera, and Trichoptera (EPT). Overall taxa richness was similar among the sites and ranged from 18 to 24 taxa.

- Juvenile Arctic grayling from Bons Pond have been analyzed for selected whole body elements in 2004, 2007, 2010, and 2014 – 2018. Average cadmium, lead, and zinc concentrations in Arctic grayling juveniles were lowest in 2017, and slightly increased in 2018, but were still within the range of values seen in previous years. Average selenium concentration in juvenile Arctic grayling slightly increased in 2018 but was still lower than the 2014 peak. Average mercury concentration was 0.06 mg/kg in 2018, a slight increase from the previous high value of 0.05 mg/kg seen in 2007, 2010, 2016, and 2017.

- Juvenile Dolly Varden from Mainstem Red Dog, Buddy, and Anxiety Ridge creeks have been analyzed for selected whole body elements from 2005 to 2011 and from 2014 to 2018. In all years, juvenile Dolly Varden median whole-body concentrations of cadmium, lead, and zinc are consistently highest in Mainstem Red Dog Creek. Median selenium concentrations were highest in Buddy Creek in 2018. Median mercury concentrations have consistently been highest in Anxiety Ridge Creek. Median whole-body cadmium and zinc concentrations seem to track somewhat with water quality - lead and selenium do not.

- Selenium concentrations were compared among Arctic grayling in Bons Pond, North Fork Red Dog Creek, and Fish Creek (Ft. Knox Mine). Selenium concentrations were highest in Arctic grayling ovaries from Bons Pond and lowest in Fish Creek. Selenium concentrations in ovaries from North Fork Red Dog Creek were intermediate between Bons Pond and Fish Creek. Higher selenium concentrations in 2018 samples could be due to the age and maturity of the fish sampled. Fish were all in non-spawning condition, and based on their ages, had likely never spawned before. Past years' samples were mature, ready to spawn females that had likely spawned before.

- In 2018 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. None of the analytes measured appear to concentrate in muscle. Various elements concentrate in specific tissues.

- Aerial surveys are used each fall to estimate the number of overwintering Dolly Varden in the Wulik River. The number of fish overwintering in the Wulik River decreased from 2006 to 2012, reaching a low of 21,084 fish. Numbers have rebounded since then, reaching 97,385 in 2018. Prior to mine development found, over 90% of overwintering Dolly Varden in the Wulik River were located below the mouth of Ikalukrok Creek. Surveys performed since development of the mine show the same distribution.

- Annual aerial surveys assessed the distribution of chum salmon in Ikalukrok Creek. The chum salmon return in 2018 was estimated at 1,229 fish.

- In spring 2018, resident Dolly Varden (n = 6) were collected with fyke nets in North Fork Red Dog Creek, averaging 166 mm FL. Juvenile Dolly Varden sampling with minnow traps was conducted in late summer 2018. The total number of juvenile Dolly Varden captured in early August was 194 fish with an average size of 103 mm FL. The highest catch was on Buddy Creek (109 fish).

- In spring 2018, the Arctic grayling spawning migration into North Fork Red Dog Creek was monitored. Spawning time in Mainstem Red Dog Creek could not be determined as spent females were never captured. Larval Arctic grayling were captured in drift nets in July in both Mainstem Red Dog and North Fork Red Dog creeks, indicating spawning was successful in both locations. The 2017 population of Arctic grayling in North Fork Red Dog Creek could not be estimated due to a lack of recaptures.

- The estimated Arctic grayling population in Bons Pond in 2017 was 1,572 fish $\geq$ 200 mm FL. The estimated population has gradually increased since 2014. Sampling in recent years (2014, 2015, and 2017) has included catches of juvenile fish (< 200 mm FL) suggesting that the population likely will continue to increase, although very few small fish were caught in 2018.

- Pre-mining slimy sculpin abundance is unknown. Baseline studies indicated that sculpin were numerous in the Ikalukrok Creek drainage but were uncommon in the Red Dog Creek drainage. Slimy sculpin continue to be captured in Mainstem Red Dog Creek, but the highest catches consistently occur in Ikalukrok Creek downstream of the mouth of Dudd Creek.

# Introduction

The Red Dog zinc (Zn) and lead (Pb) 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, the 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 is presented in Appendix 1 and Ott et al. 2016. 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 occurred annually at the Red Dog Mine since 1995 and has included periphyton, aquatic invertebrate, and fish sampling. Tissue and whole-body element analyses for Dolly Varden (*Salvelinus malma*) and Arctic grayling (*Thymallus arcticus*) and spawning season monitoring for Arctic grayling are also performed. In 2017, the Alaska Department of Environmental Conservation (ADEC) issued Alaska Pollution Discharge Elimination System (APDES) Permit 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 effective September 1, 2017. The APDES Permit required a bioassessment program that included periphyton, aquatic invertebrates, and fish in selected streams near the Red Dog Mine (Tables 1 and 2). The current bioassessment program became fully effective and enforceable on September 1, 2017.

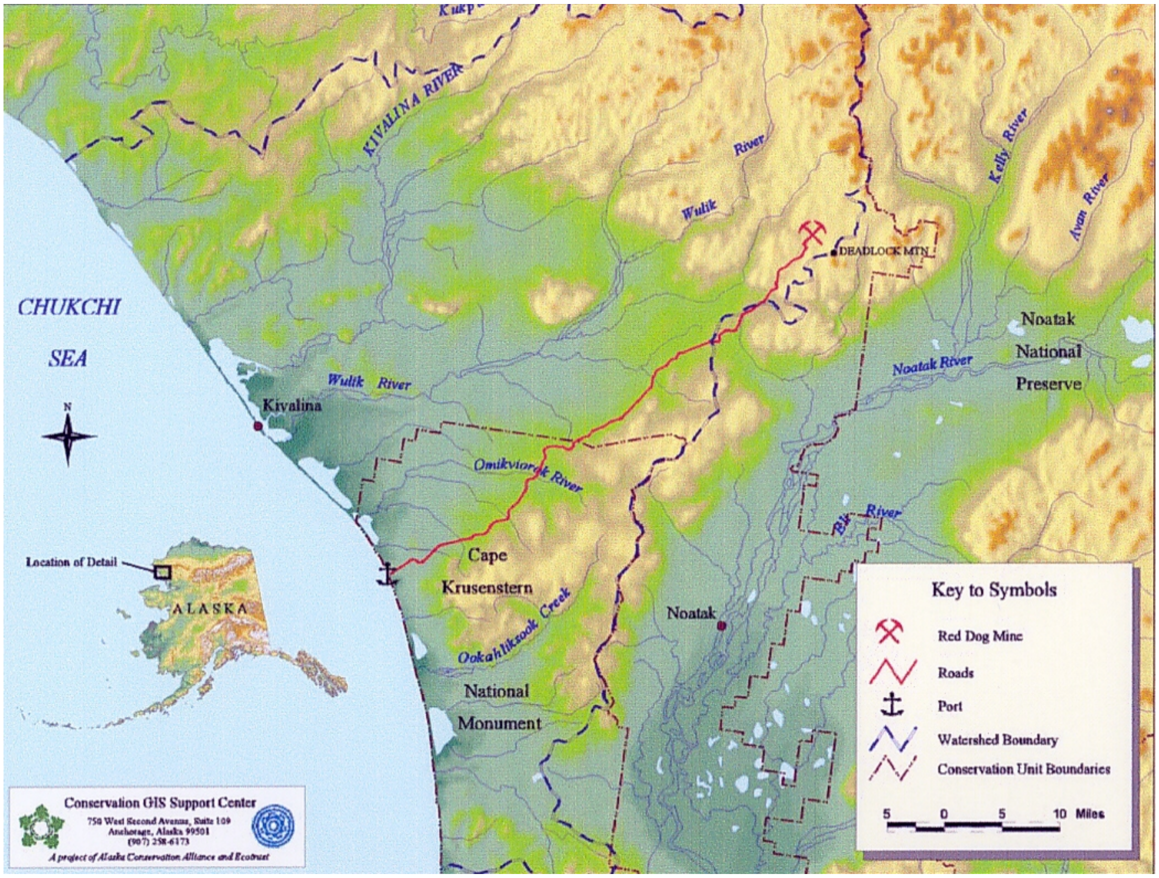



**Figure 1. Location of the Red Dog Mine in northwestern Alaska.**[1]

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, in October 2017.

On September 23, 2016, the ADEC issued Waste Management Permit No. 2016DB002 for the Red Dog Mine that included a condition that Teck adhere to the requirements of the monitoring plan submitted by Teck in November 2016. Teck's Monitoring Plan was revised in January 2018, and includes sample sites, sampling frequency, and parameters for all aquatic sites, including those required by the APDES Permit (Table 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, 2018.**

| Location | APDES[1]/WMP[2] | 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 |
| Station 9 | APDES/WMP | Ikalukrok Creek upstream of confluence with Red Dog Creek | Periphyton (as chlorophyll-a concentration)<br>Aquatic invertebrates<br>Fish presence and use |
| Station 160 | WMP | Lower Ikalukrok Creek | Periphyton (as chlorophyll-a concentration)<br>Aquatic invertebrates<br>Fish presence and use |
| Station 20 | WMP | Middle Fork Red Dog Creek | Periphyton (as chlorophyll-a concentration)<br>Aquatic invertebrates |
| Station 10 | APDES/WMP | Mouth of Red Dog Creek | Periphyton (as chlorophyll-a concentration)<br>Aquatic invertebrates<br>Fish presence and use<br>Juvenile Dolly Varden metals in tissue |
| Station 12 | APDES/WMP | North Fork Red Dog Creek | Periphyton (as chlorophyll-a concentration)<br>Aquatic invertebrates<br>Fish presence and use<br>Record of spawning activity<br>Capture/mark Arctic grayling |
| Upper NF | APDES | Upper North Fork Red Dog Creek, above Aqqaluk | Periphyton (as chlorophyll-a concentration)<br>Aquatic invertebrates<br>Fish presence and use |
| Station 151 | APDES | 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)<br>Aquatic invertebrates<br>Fish presence and use<br>Juvenile Dolly Varden metals in tissue |
| Buddy 221 | WMP | Buddy Creek above haul road | Periphyton (as chlorophyll-a concentration)<br>Aquatic invertebrates |
| Bons 220 | WMP | Bons Creek below pond | Periphyton (as chlorophyll-a concentration)<br>Aquatic invertebrates |
| Bons | WMP | Bons Creek above pond | Periphyton (as chlorophyll-a concentration)<br>Aquatic invertebrates |
| Anxiety Ridge | WMP | Anxiety Ridge Creek below haul road | Fish presence and use<br>Juvenile Dolly Varden metals in tissue |
| Evaingiknuk | WMP | Evaingiknuk Creek east of haul road | Fish presence and use |
| Bons Pond | WMP | Above reservoir spillway | Juvenile Arctic grayling metals in tissue<br>Arctic grayling population estimate |

[1]APDES – Alaska Permit Discharge Elimination System [2]WMP – Waste Management Plan

Teck’s monitoring plan is incorporated by reference into the Alaska Department of Natural Resources (ADNR) Reclamation Plan Approval (F20169958) dated September 28, 2016. On March 10, 2010, the U.S. Department of Army issued permit POA-1984-12-M45 to Teck which authorized development of the Aqqaluk Pit. Active mining in the Aqqaluk Pit began during 2012. In addition to mine drainage, certain waste rock from Aqqaluk and Qanaiyaq and treated water were placed in the mined out main pit. This report presents data collected during summer 2018 and where applicable, these data are compared with previous years.

## Structure of Report

This report is presented in several sections as follows:

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

## Location and Description of Sample Sites

Biomonitoring is conducted annually in streams in the vicinity of the Red Dog Mine as required under the APDES Permit No. AK0038652 (Table 1 and Figure 2) and by the ADEC Waste Management Permit and the ADNR Reclamation Plan Approval. 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. Water quality and fish data collected during four years of baseline studies (1979 to 1982) represent pre-mining conditions. Any comparison of existing conditions to baseline data should acknowledge the much longer time series of data generated since mining began (1990 to 2018) when compared to the pre-development baseline data.

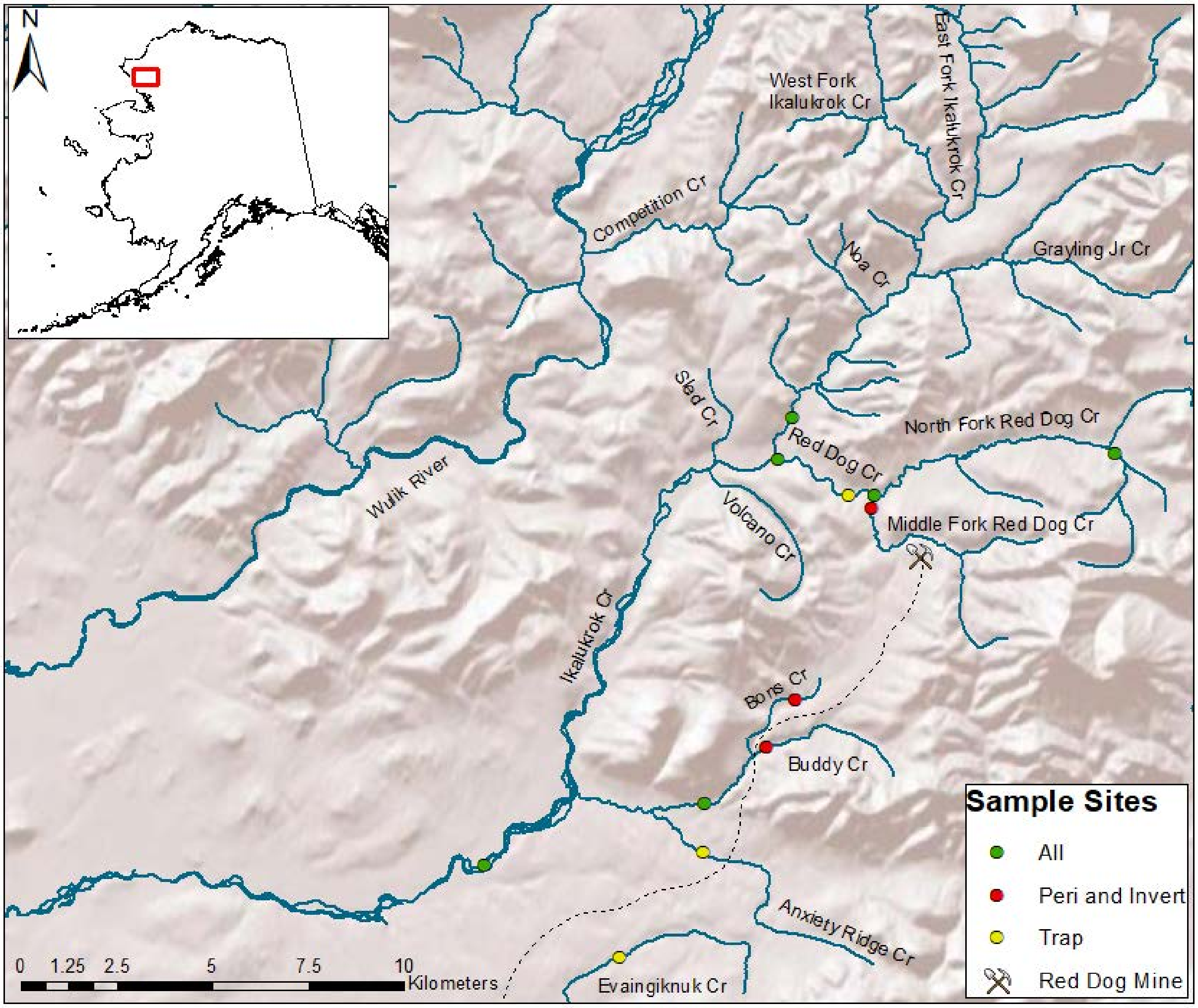



**Figure 2. Location of sample sites in the Ikalukrok Creek drainage (tributary of the Wulik River) and Evaingiknuk Creek (a tributary of the Noatak River) drainage.**

## Methods

Four sampling events occurred in the Red Dog vicinity in 2018 including spring Arctic grayling and adult Dolly Varden sampling (June 12 - 18), mid-summer aquatic invertebrates and periphyton (July 9 - 16), late-summer juvenile Dolly Varden sampling (August 2 - 6), and fall aerial surveys of Dolly Varden in Wulik River and fall chum salmon in Ikalukrok Creek (October 4 - 5).

All methods used for the 2018 Red Dog Mine aquatic biomonitoring study are fully described by ADF&G (2017) in Technical Report No. 17-09 Methods for Aquatic Life Monitoring at the Red Dog Mine Site, a requirement of the 2017 APDES Permit AK0038652.

All 2018 water quality sampling was performed by Red Dog Mine personnel following their standard methodology. Water quality analysis was performed by a laboratory and results provided to ADF&G for inclusion in this report. All water quality presented in this report are for "total recoverable." The number of water quality samples taken each year varies, but samples are collected twice each month with a sample size of 9 to 13 per year per site. Baseline water quality pre-mining data presented in the report were collected from 1979 to 1982.

In 2018, the abundance of Arctic grayling in Bon's Pond and North Fork Red Dog Creek was estimated using Chapman's modification of the Lincoln-Petersen two-sample mark-recapture model (Chapman 1951),

$$\widehat{\mathrm{N}}_{\mathrm{c}} = \left\{\frac{(\mathrm{n}_1 + 1)(\mathrm{n}_2 + 1)}{(\mathrm{m}_2 + 1)}\right\} - 1$$

where $\widehat{\mathrm{N}}_{\mathrm{c}}$ = estimated population, $\mathrm{n}_1$ = fish marked in first capture event, $\mathrm{n}_2$ = fish captured during recapture event, and $\mathrm{m}_2$ = fish captured during recapture event that were marked in the capture event. Variance was calculated as (Seber 1982):

$$\mathrm{var}(\widehat{\mathrm{N}}_{\mathrm{c}}) = \left\{\frac{(\mathrm{n}_1 + 1)(\mathrm{n}_2 + 1)(\mathrm{n}_1 - \mathrm{m}_2)(\mathrm{n}_2 - \mathrm{m}_2)}{(\mathrm{m}_2 + 1)^2(\mathrm{m}_2 + 2)}\right\}$$

The 95% C.I. for the population estimate was calculated as:

$$95\%\ \mathrm{C.I.} = \mathrm{N}_{\mathrm{c}} \pm (1.960)\sqrt{\widehat{\mathrm{var}}(\widehat{\mathrm{N}}_{\mathrm{c}})}$$

## 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 2018 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 3). 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 is a reference site with no direct effects from the mine.

**Figure 3. Downstream end of mixing zone in Mainstem Red Dog Creek in early August 2015 (Station 151).**

In 2018, 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 4). This water is moved through the mine pit area, including by the currently active Aqqaluk pit, to its original channel via a combination of culverts and lined open ditch. These bypass conveyance structures serve to isolate the non-contact water from areas disturbed by mining activities.

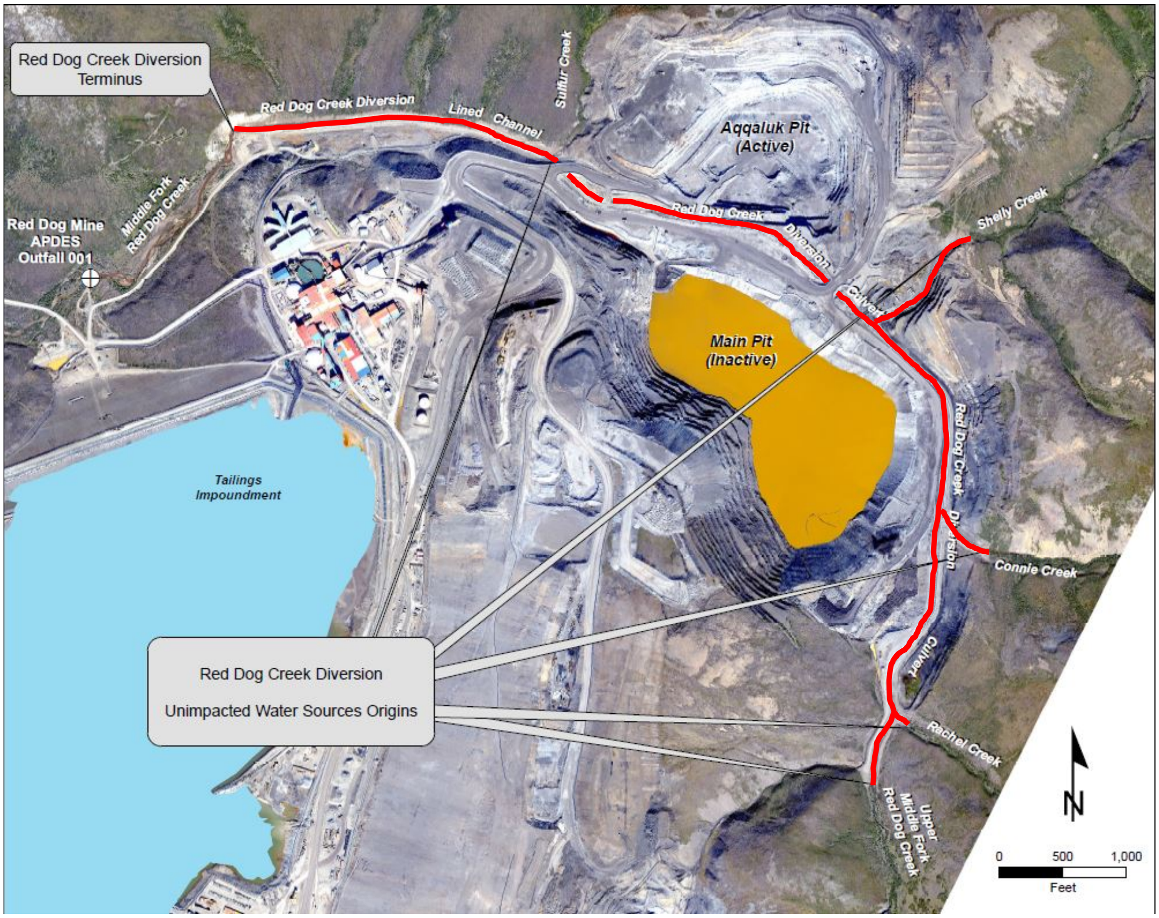



**Figure 4. Clean water bypass system at the Red Dog Mine. The Red Dog Creek diversion structure (delineated by labels in the photograph and shown in red) picks up non-mining impacted waters from upstream tributaries and moves them between the Aqqaluk pit and the main pit back to the original Middle Fork Red Dog Creek streambed (flow is from right to left).[2]**

In 2018, the median lead concentration at Station 151/10, downstream of the clean water bypass system, was lower than pre-mining (1979-82). However, in some years the maximum lead concentration has been higher than pre-mining (Figure 5). Median lead concentrations increased from 2011 to 2013 to a high of 13.6 µg/L, decreased from 2014 to 2017 to a low of 2.9, then rose again in 2018 to 6.7 µg/L.

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

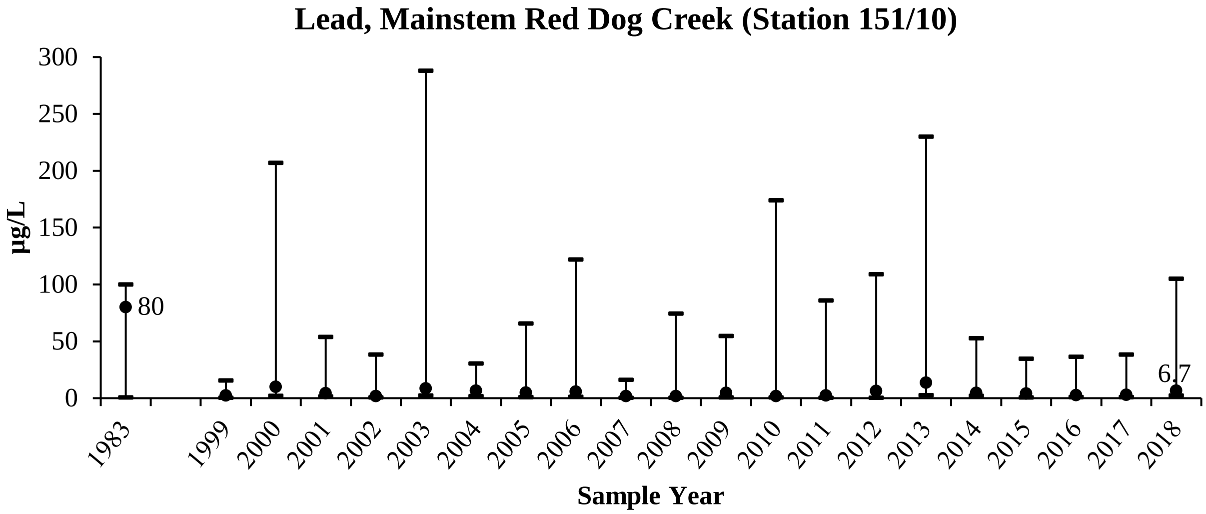



**Figure 5. Median, maximum, and minimum lead concentrations at Station 151/10 (selected median values shown).**

In 2018, the system with the highest concentration of lead was Sulfur Creek (a tributary to the clean water bypass), with a median lead concentration of 613.6 µg/L (Figure 6). Sulfur Creek has had the highest median lead concentration since 2013. The median lead concentration in Sulfur Creek was 362 µg/L in 2013, 122.4 µg/L in 2014, 88.4 µg/L in 2015, 150.6 µg/L in 2016, and 127 µg/L in 2017. Sulfur Creek may eventually be incorporated into the Aqqaluk Pit.

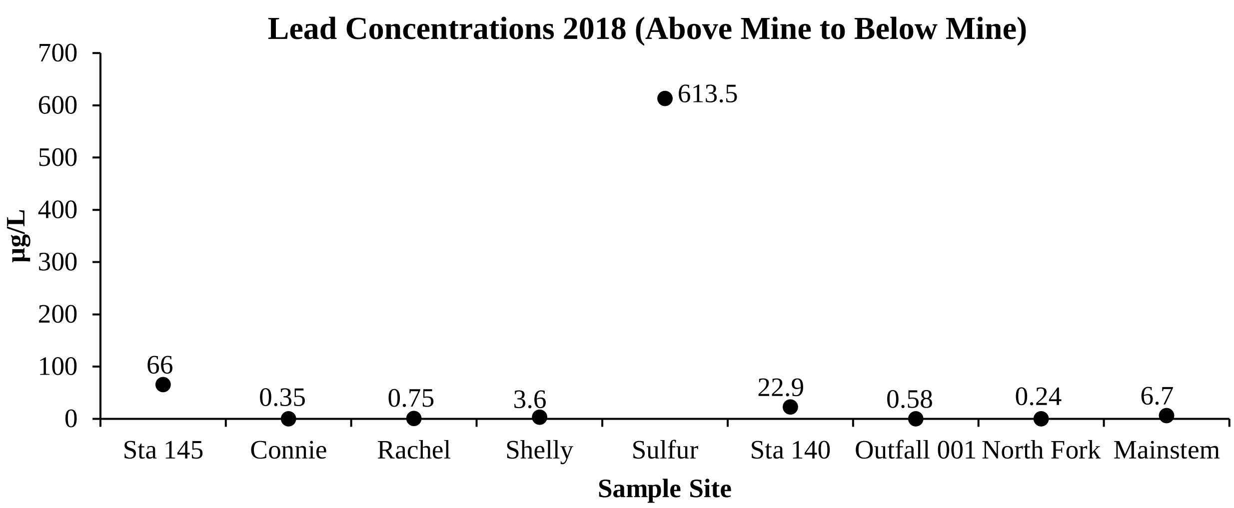



**Figure 6. Median lead concentrations in 2018 from upstream (Station 145) of the clean water bypass, including tributaries to the clean water bypass (Connie, Rachel, Shelly, and Sulfur), and Station 140 (above the Outfall 001), Outfall 001, and North Fork Red Dog and Mainstem Red Dog creeks.**

Median zinc concentration at Station 151 rose sharply to 2,550 µg/L in 2018, higher than any median zinc concentration seen since 1999 (Figure 7). Station 140, which is on Middle Fork Red Dog Creek, upstream of the treated mine discharge Outfall 001 and downstream of the non-contact water diversion, also exhibited a sharp increase in zinc levels to 7,250 µg/L, the highest median level since monitoring began in 1999 (Figure 8). The zinc levels of the creeks in the clean water bypass system provided further information about the source of the elevated zinc levels. Sulfur, Shelly, Connie, and Rachel creeks all had low zinc levels, but Station 145 on Upper Middle Fork Red Dog Creek had extremely high zinc (Figure 9). The source of the elevated zinc detected at Station 145 is unknown. There is mining occurring on the Hilltop/Qanaiyaq deposit upslope from Station 145/Upper Middle Fork Red Dog Creek. The source of the zinc could also be a new seep, or natural erosion into a near surface ore body. Environmental staff at Red Dog are investigating the cause of the zinc concentration anomaly.

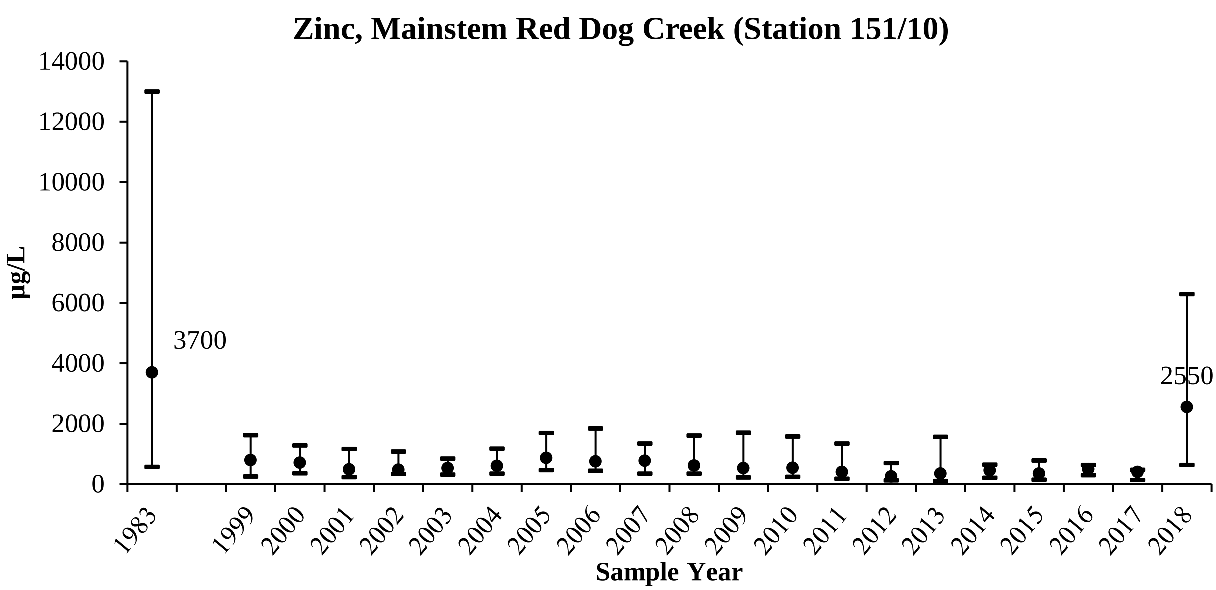



**Figure 7. Median, maximum, and minimum zinc concentrations at Station 151/10 (selected median values shown).**

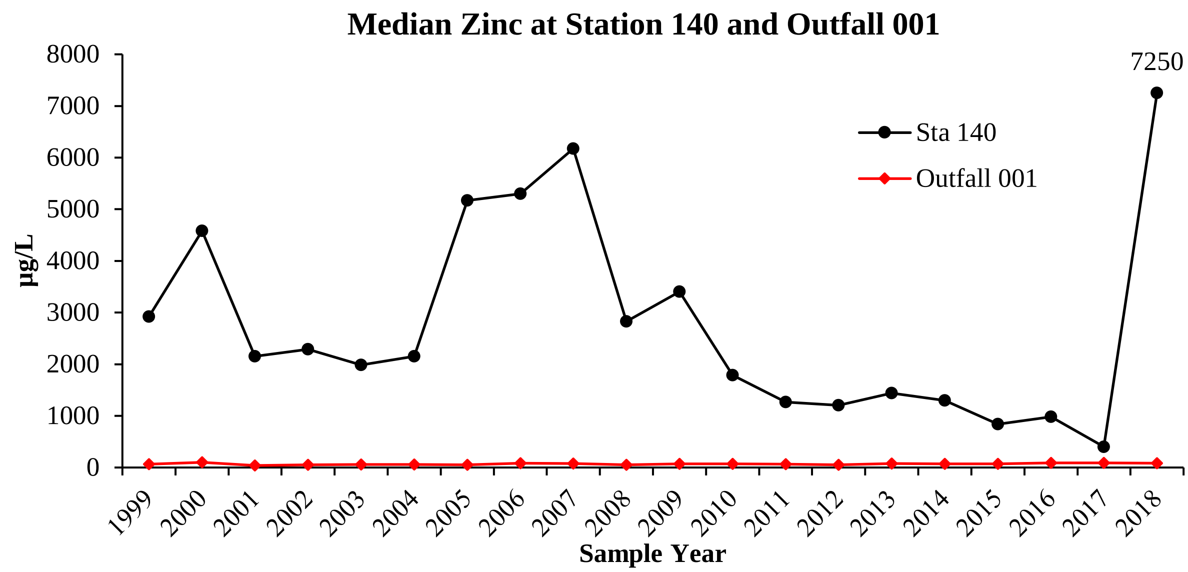



**Figure 8. Median zinc levels in water samples from Station 140 and Outfall 001, 1999 - 2018.**

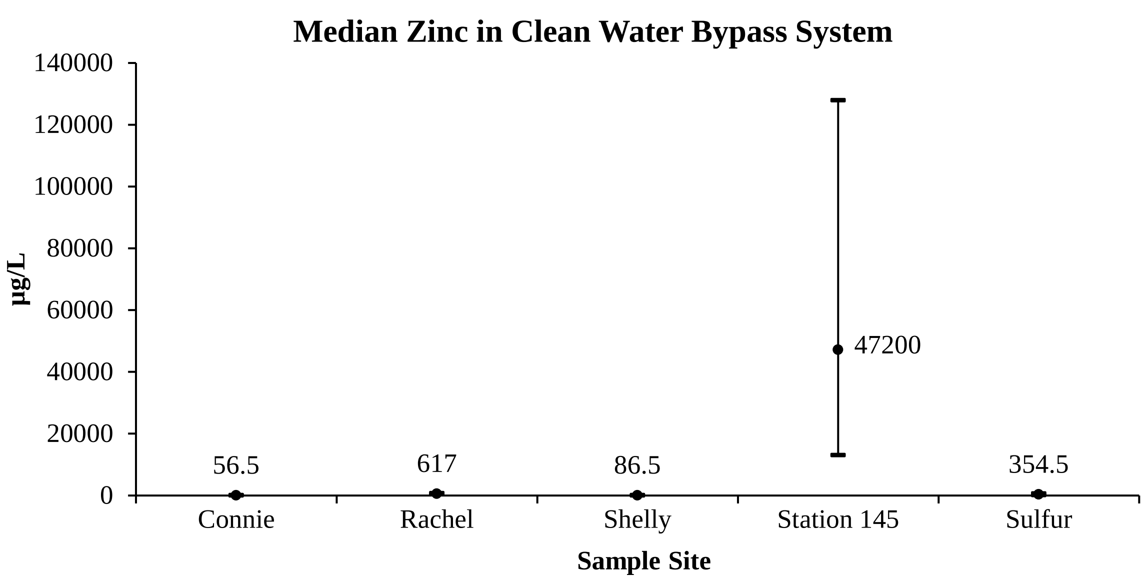



**Figure 9. Median zinc levels in water samples from Sulfur, Shelly, Connie, and Rachel creeks, and Station 145, 2018.**

Median aluminum concentrations at Station 10/151 continue to be lower than pre-mining (Figure 10). Cadmium concentrations were lower than pre-mining conditions (Figure 11), but the median concentration in 2018 of 15.2 µg/L was much higher than previous years of sampling after the mine was in operation.

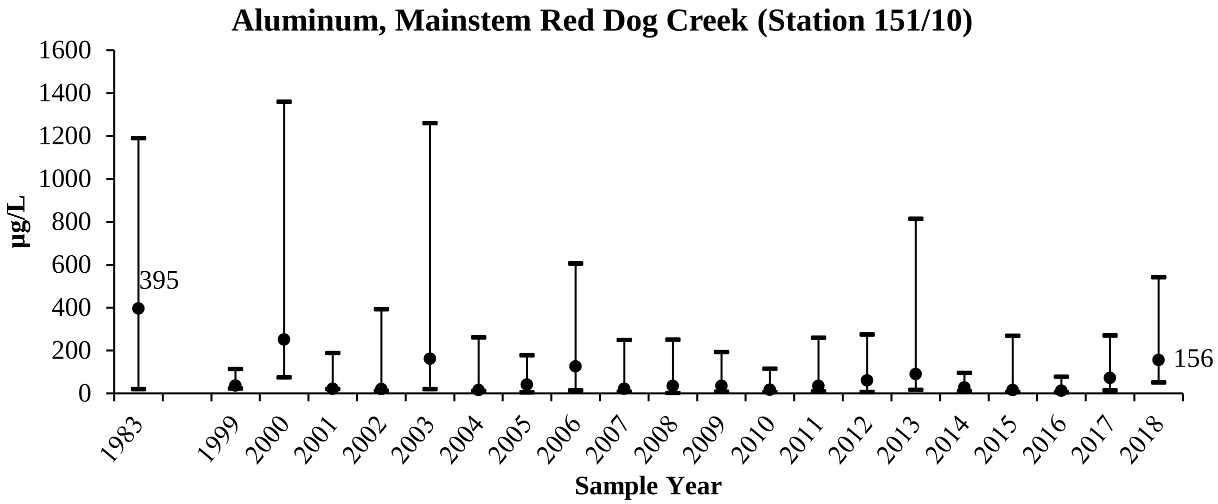



**Figure 10. Median, maximum, and minimum aluminum concentrations at Station 151/10 (selected median values shown).**

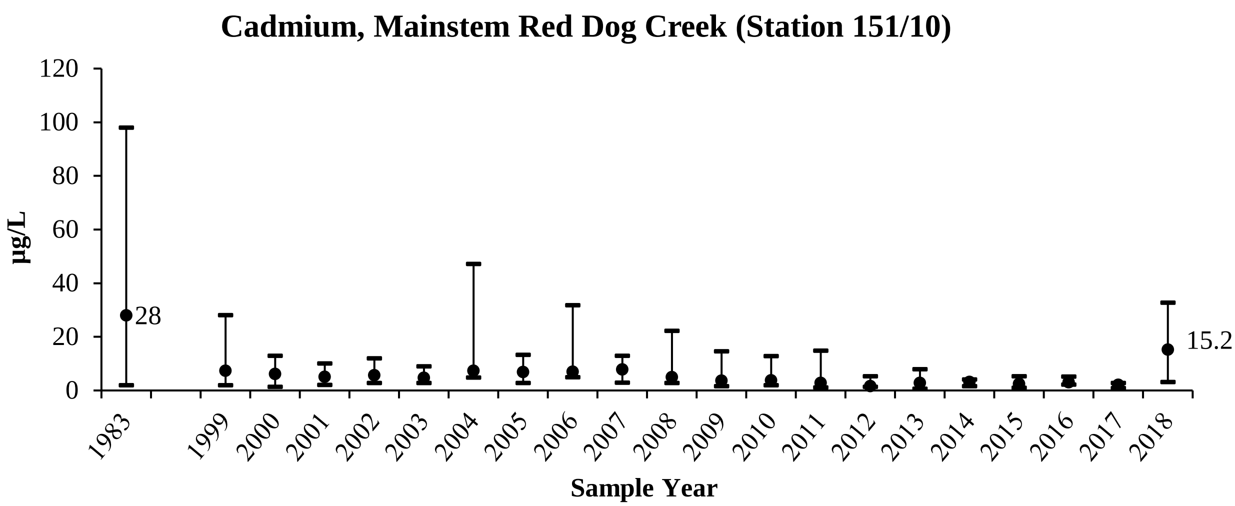



**Figure 11. Median, maximum, and minimum cadmium concentrations at Station 151/10 (selected median values shown).**

Pre-mining data for selenium are not available. Median selenium concentrations in Mainstem Red Dog Creek remained similar from 2001 to 2007, but then increased reaching a high of 2.75 µg/L in 2011 (Figure 12). In 2012, discharge of treated water to Middle Fork Red Dog Creek was stopped on June 8 and was not resumed for the remainder of the 2012 open water period. After selenium decreased in treated water and a mixing zone was authorized in Mainstem Red Dog Creek, discharge resumed in 2013 and by summer 2014, the median selenium concentration in Mainstem Red Dog Creek was 1.7 µg/L. Selenium remained low from 2014 to 2017, then increased in 2018 to a median selenium concentration of 2.85 µg/L.

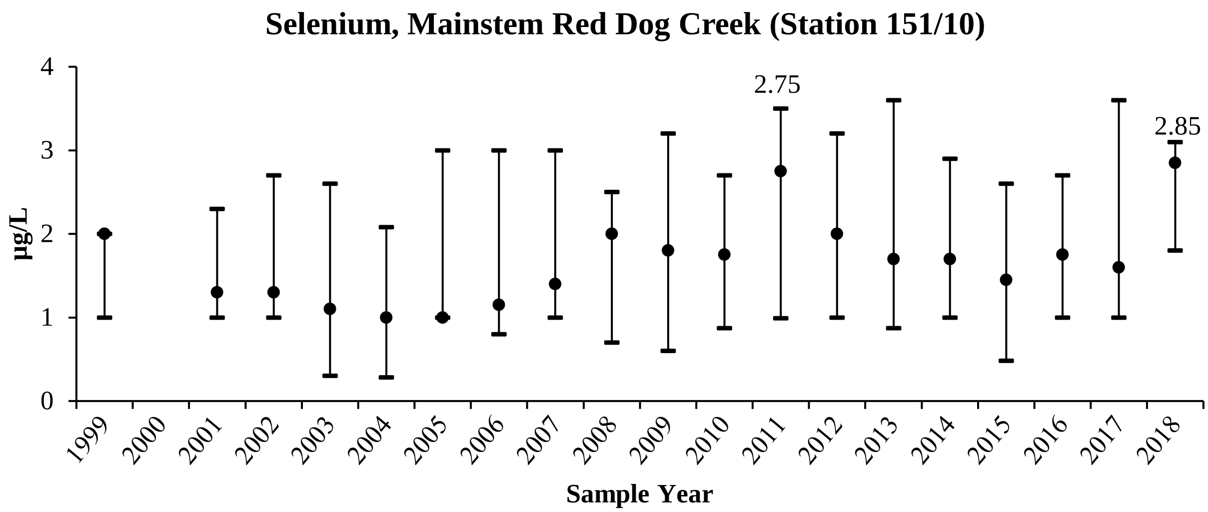



**Figure 12. Median, maximum, and minimum selenium concentrations at Station 151/10 (selected median values shown).**

Pre-mining data for nickel are not available. Median nickel concentrations at Station 151/10 were highest in 2006 and 2007 (Figure 13). The primary source of nickel to the clean water bypass system has been Rachel Creek (Ott and Morris 2010). Median nickel concentration in Mainstem Red Dog Creek was 12.5 µg/L in 2018.

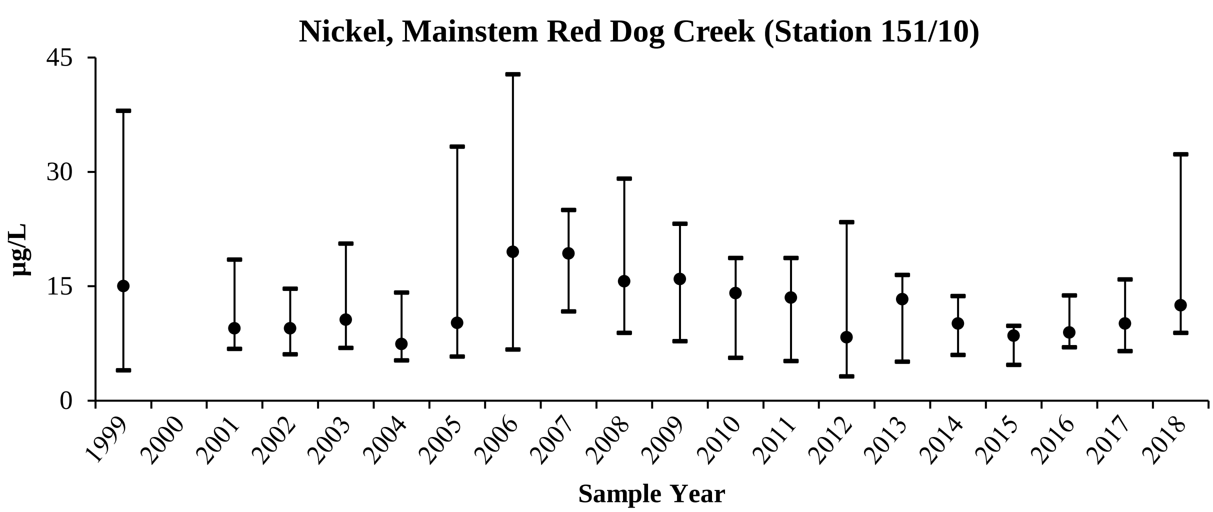



**Figure 13. Median, maximum, and minimum nickel concentrations at Station 151/10 (selected median values shown).**

In 2018, the pH at Station 151/10 was higher (more basic) than pre-mining (Figure 14). 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 six once, in 2011. The 1990 data set is during mining, but prior to construction of the clean water bypass system.

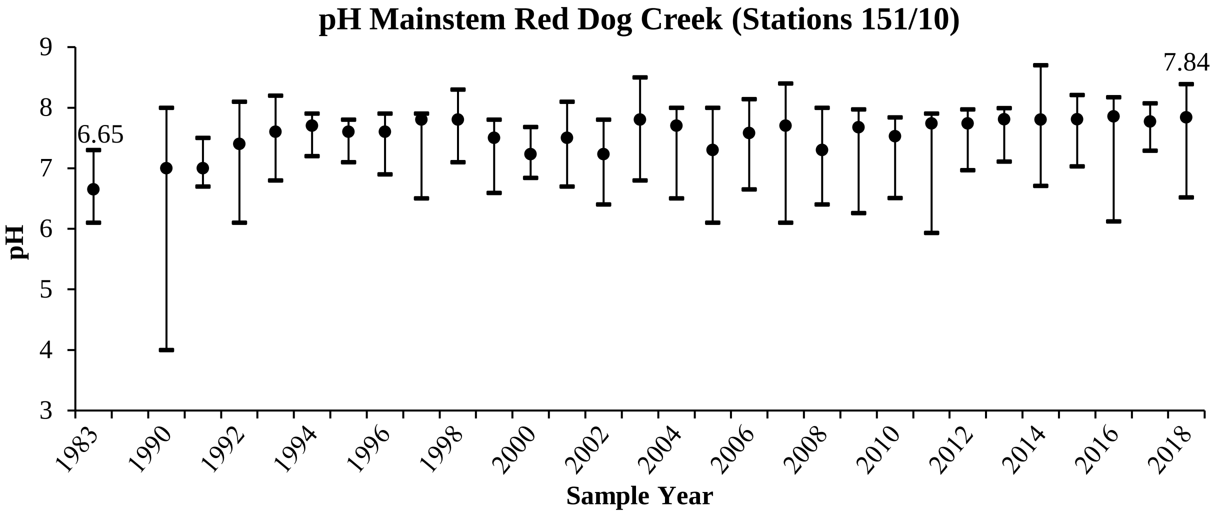



**Figure 14. Median, maximum, and minimum pH values at Station 151/10 (selected median values shown).**

Total dissolved solids (TDS) in Mainstem Red Dog Creek are higher than pre-mining (Figure 15). TDS are directly related to high concentrations of calcium hydroxide 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 the elevated TDS concentrations. TDS concentrations in Mainstem Red Dog Creek in summer 2018 exceeded the 1,500 mg/L standard (as specified in the APDES permit for Station 151) once, on July 16, 2018 with a measured value of 1,630 mg/L. Teck notified the Alaska Department of Environmental Conservation of the exceedance and conducted a full investigation into the cause of the incident. The exceedance was the result of an improper calibration of in-stream instruments on July 15, 2018. During the July 16 sample event, the discrepancy was recognized and corrected. Upon correction, in-stream readings increased from approximately 1,380 mg/L to 1,580 mg/L. Water treatment operations immediately reduced the Outfall 001 discharge rate. The duration of the inaccurate TDS readings was approximately 20 hours, and TDS at Station 151 may have exceeded 1,500 mg/L for up to 12 hours.

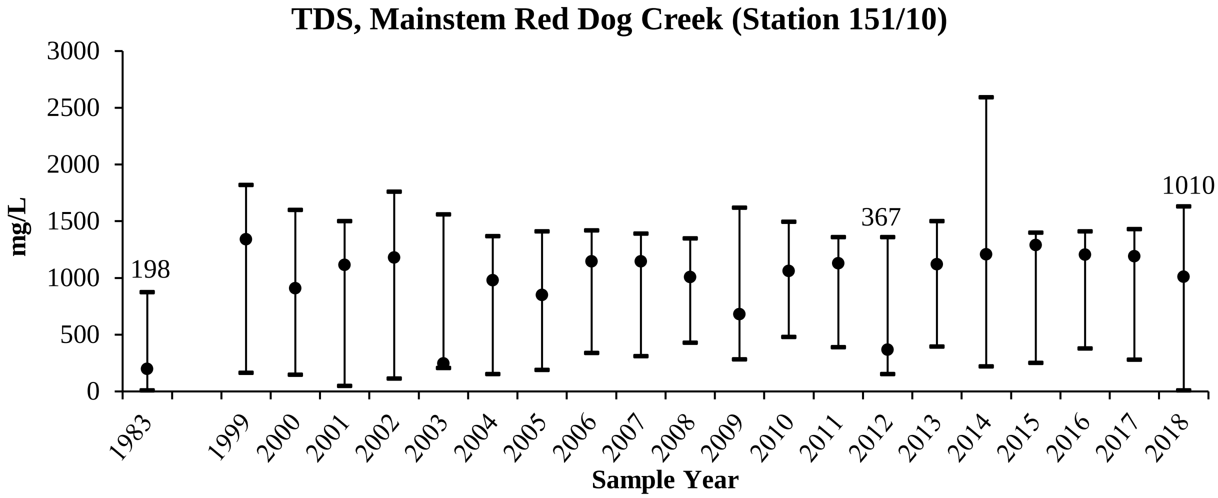


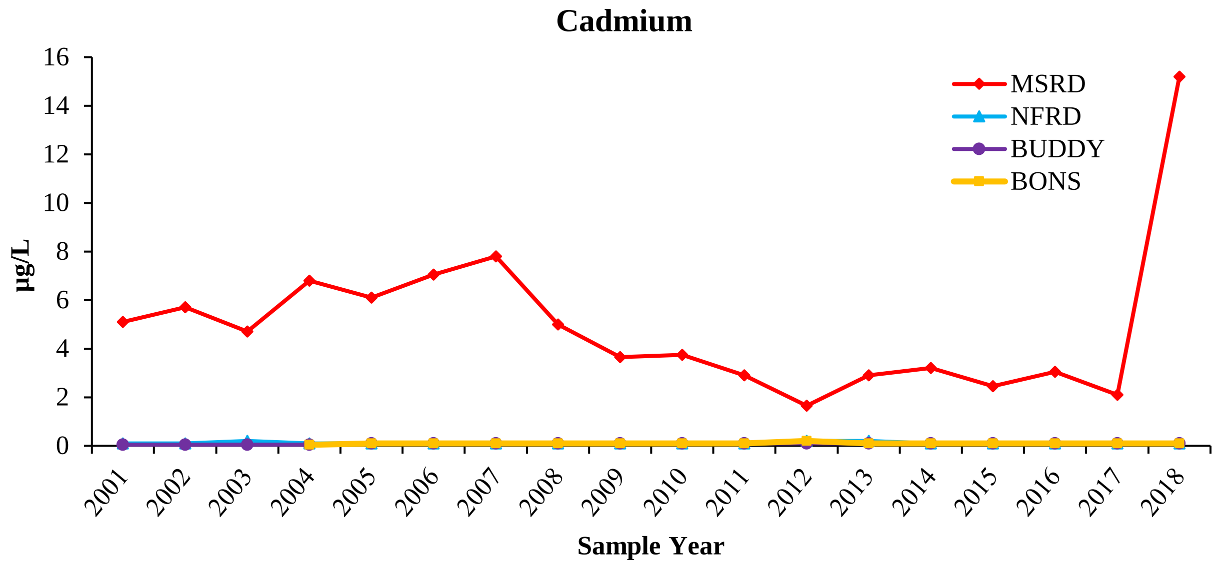

**Figure 15. Median, maximum, and minimum TDS concentrations at Station 151/10 (selected median values shown).**

On August 1, 2018, an unusual amount of orange precipitate was observed in Red Dog Creek by Red Dog employees. Red Dog environmental staff traced the apparent cause of the precipitate to one or both of two natural seeps above the diversion system. One is in the Middle Fork Red Dog Creek drainage basin approximately 300 m upstream of the diversion structure entrance on the west hill slope, and the other is in Connie Creek, approximately 100 m upstream of the diversion structure entrance on the north slope of the hill. Both of these seeps have been documented by Red Dog staff in past studies and were observed prior to mining activity. In 2018, the seeps were active, and the seepage was high in iron and began to precipitate on the rocks when exposed to air. The treated discharge water from Outfall 001 accelerated the precipitation due to the presence of calcium hydroxide. The mixing of the natural metals in the creek with the discharge water resulted in the formation of insoluble metal hydroxides. It is likely the combination of low creek flows and high natural metals concentrations resulted in the accumulation of precipitate in the summer of 2018.

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 (Figures 16 to 18). 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 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 with the potential to be affected by the road, airport, overburden stockpile, and they are down gradient from the tailings back dam. 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 were highest in Mainstem Red Dog Creek. The major source of these elements is from the clean water bypass and not from the mine discharge of treated water at Outfall 001. Cadmium has been low and stable in North Fork Red Dog Creek, Buddy Creek, and Bons Pond from 2001 to 2018. Cadmium in Mainstem Red Dog Creek is higher and much more variable and rose sharply in 2018 to 6.7 µg/L (Figure 16). Lead concentrations demonstrate more variability but are still consistently lower in North Fork Red Dog and Buddy creeks and Bons Pond than in Mainstem Red Dog Creek (Figure 17). After remaining fairly stable from 2001 to 2017, zinc levels in Mainstem Red Dog Creek sharply increased in 2018, as discussed earlier. Zinc levels in North Fork Red Dog Creek, Buddy Creek, and Bons Pond remained stable (Figure 18).



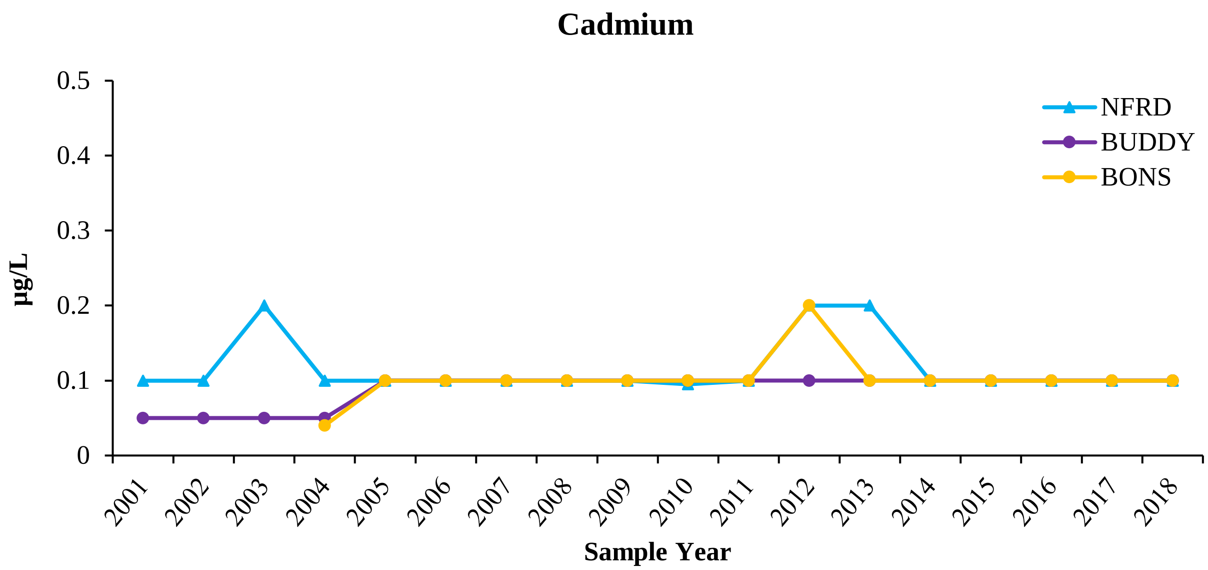




**Figure 16. Median cadmium concentrations in Mainstem Red Dog (MSRD), North Fork Red Dog (NFRD), and Buddy creeks and Bons Pond (2001 to 2018). Two graphs are presented, the bottom graph uses a different scale as it does not include Mainstem Red Dog Creek.**

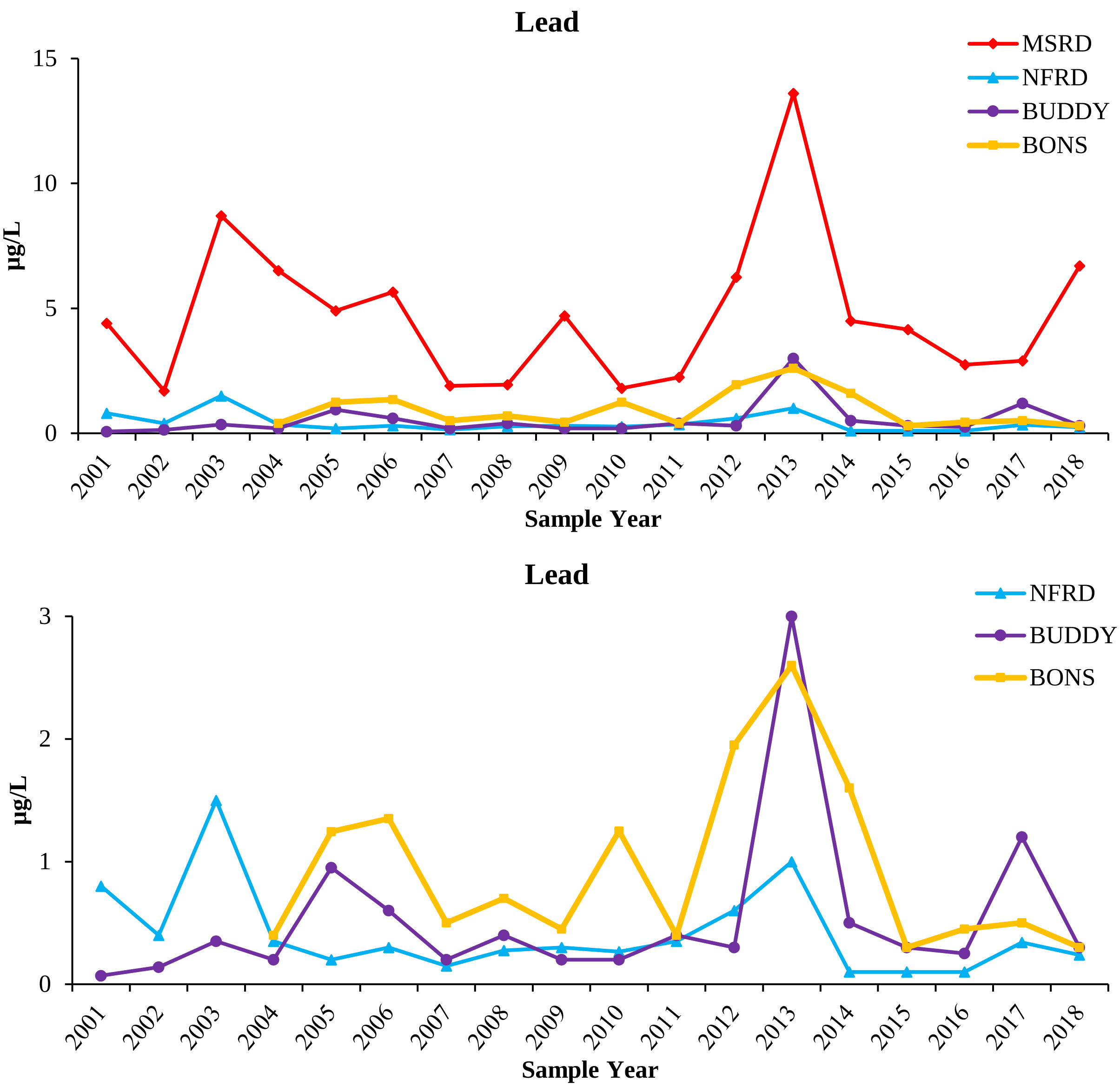



**Figure 17. Median lead concentrations in Mainstem Red Dog (MSRD), North Fork Red Dog (NFRD), and Buddy creeks and Bons Pond (2001 to 2018). Two graphs are presented, the bottom graph uses a different scale as it does not include Mainstem Red Dog Creek.**

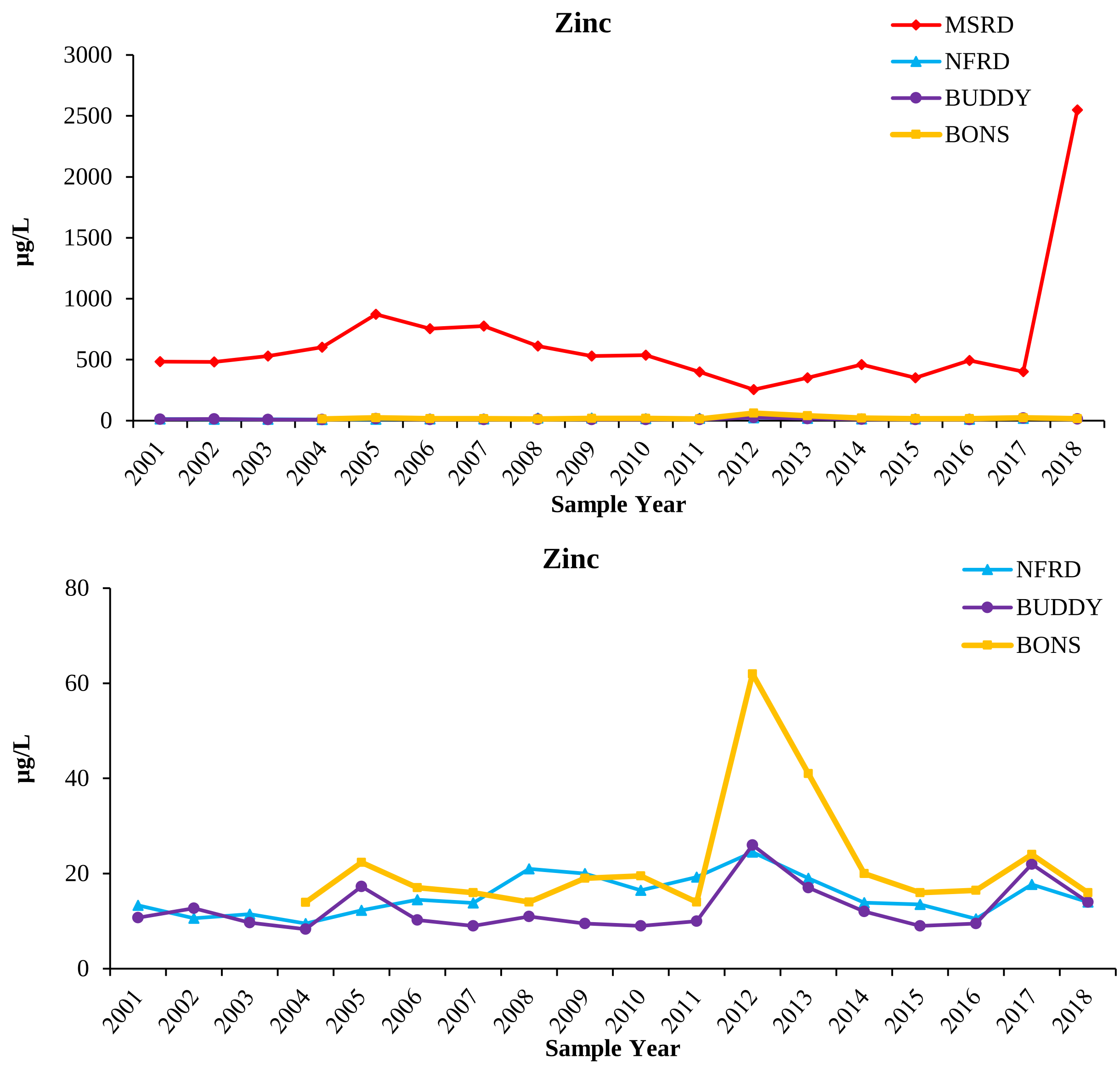



**Figure 18. Median zinc concentrations in Mainstem Red Dog (MSRD), North Fork Red Dog (NFRD), and Buddy creeks and Bons Pond (2001 to 2018). Two graphs are presented, the bottom graph uses a different scale as it does not include Mainstem Red Dog Creek.**

Differences in selenium among these sites are not substantial (Figure 19). Most of the selenium concentrations range from 1 µg/L (the detection limit) to 3.0 µg/L. The median selenium concentrations in Mainstem Red Dog, North Fork Red Dog, and Buddy creeks and Bons Pond in summer 2018 were 2.85, 2.45, 2.20, and 1.70 µg/L respectively.

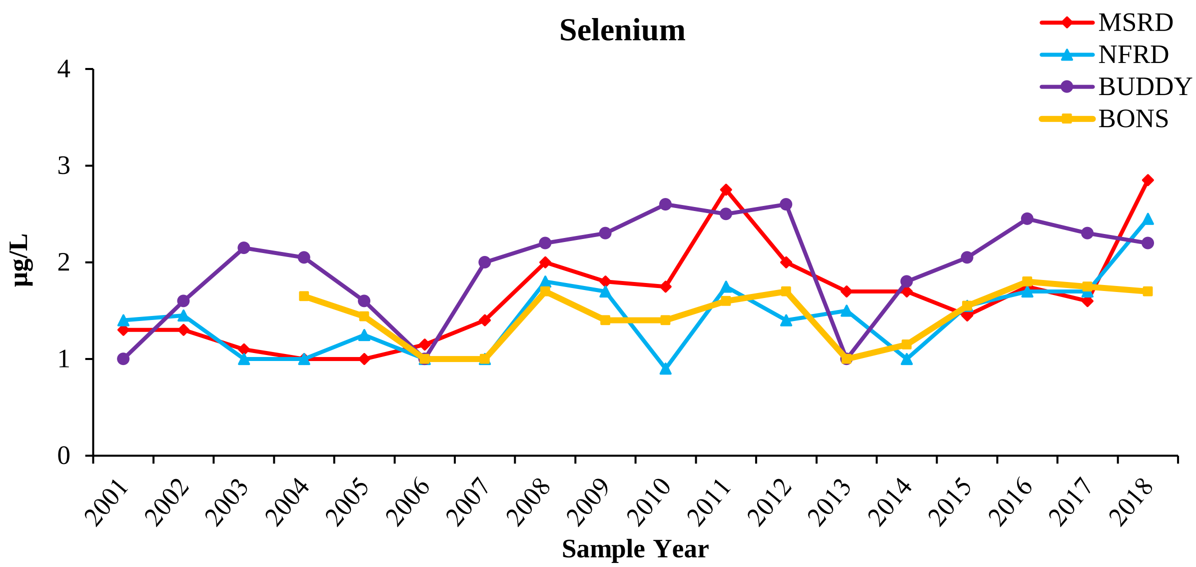



**Figure 19. Median selenium concentrations in Mainstem Red Dog (MSRD), North Fork Red Dog (NFRD), and Buddy creeks and Bons Pond (2001 to 2018).**

### 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 2). In 2018, 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 determined as $mg/m^2$ chlorophyll-a.

Average chlorophyll-a concentration in 2018 was highest in Bons Creek below Bons Pond (9.43 $mg/m^2$) and lowest in Middle Fork Red Dog Creek (0.05 $mg/m^2$) (Figure 20). Periphyton standing crops were also high (>5 $mg/m^2$) in Mainstem Red Dog Creek. Generally, chlorophyll-a concentration is lowest in Middle Fork Red Dog Creek and highest in Bons Creek (below Bons Pond) and Buddy Creek (below falls).

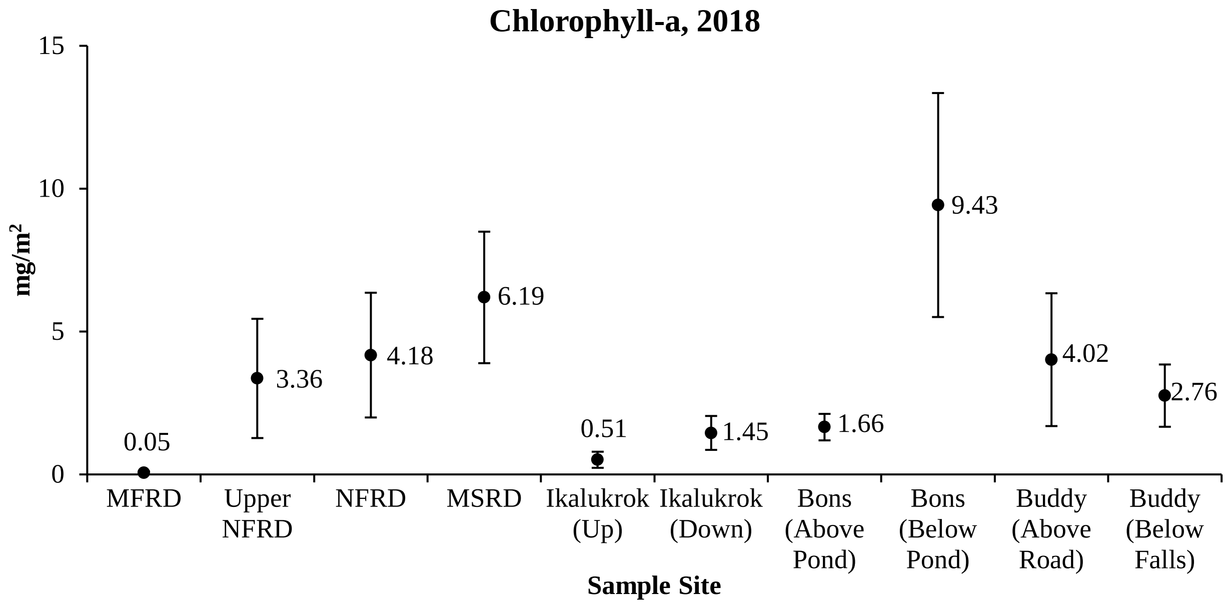



**Figure 20. Average concentration of chlorophyll-a (± 1SD) at Red Dog Mine sample sites, 2018. Sites in the Red Dog Creek drainage include Middle Fork Red Dog (MFRD), Upper North Fork Red Dog (Upper NFRD), North Fork Red Dog (NFRD), and Mainstem Red Dog (MSRD).**

Average chlorophyll-a concentration in Middle Fork Red Dog (MFRD), Mainstem Red Dog (MSRD), and North Fork Red Dog (NFRD) creeks is presented in Figure 21. Generally, average chlorophyll-a concentrations are higher in Mainstem Red Dog and North Fork Red Dog creeks as compared with Middle Fork Red Dog Creek. In 12 of 19 years, average chlorophyll-a concentration in North Fork Red Dog Creek was equal to or higher than Mainstem Red Dog Creek. Lower chlorophyll-a concentration in Middle Fork Red Dog Creek is probably related to higher metals concentrations and higher TDS 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 waste water discharge from Outfall 001 are low. Most of the TDS in Middle Fork Red Dog Creek are from the waste water discharge at Outfall 001.

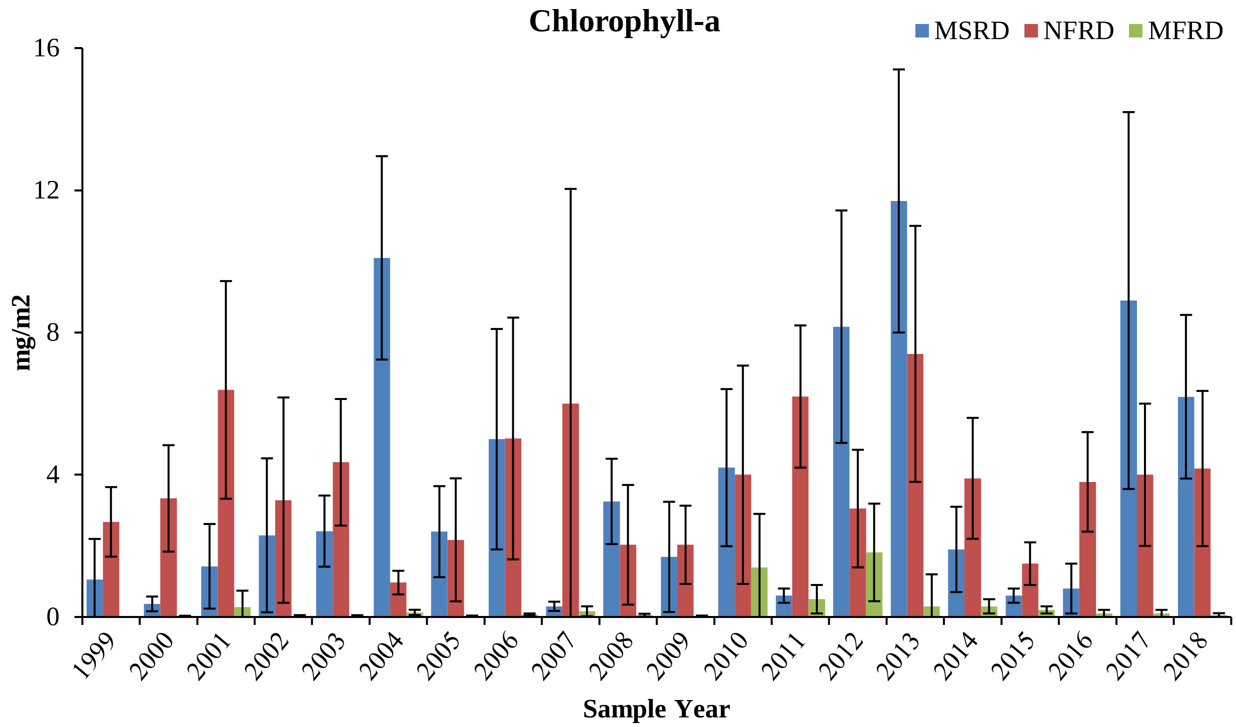



**Figure 21. Average concentration (± 1SD) of chlorophyll-a in Mainstem Red Dog Creek (MSRD, Sta 10/151), North Fork Red Dog Creek (NFRD, Sta 12), and Middle Fork Red Dog Creek (MFRD, Sta 20), 1999-2018.**

Periphyton standing crop tracks closely 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 facility 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 (Figures 22 and 23). Both zinc and cadmium increased in 2018, and chlorophyll-a concentration dropped. The variability in chlorophyll-a concentration from 2002 to 2017 may be natural as both cadmium and zinc concentrations remained low and consistent during this time frame. We believe the major source of zinc and cadmium to Ikalukrok Creek is the Cub Creek seep, but there are other seeps along Ikalukrok Creek (Figure 24).

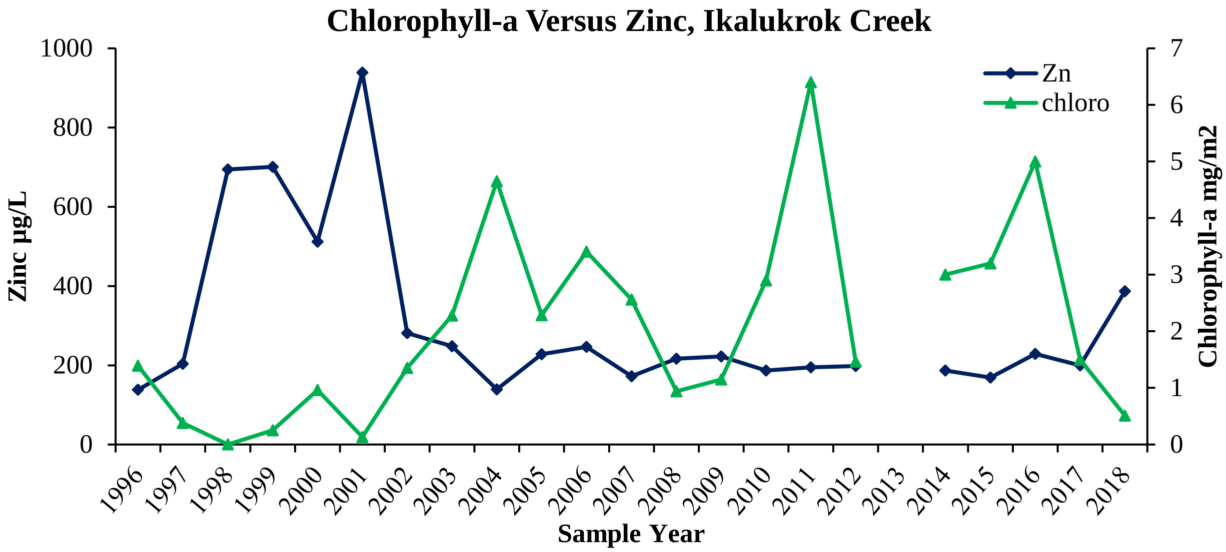



**Figure 22. Average concentrations of chlorophyll-a and zinc in Ikalukrok Creek, 1996–2018.**

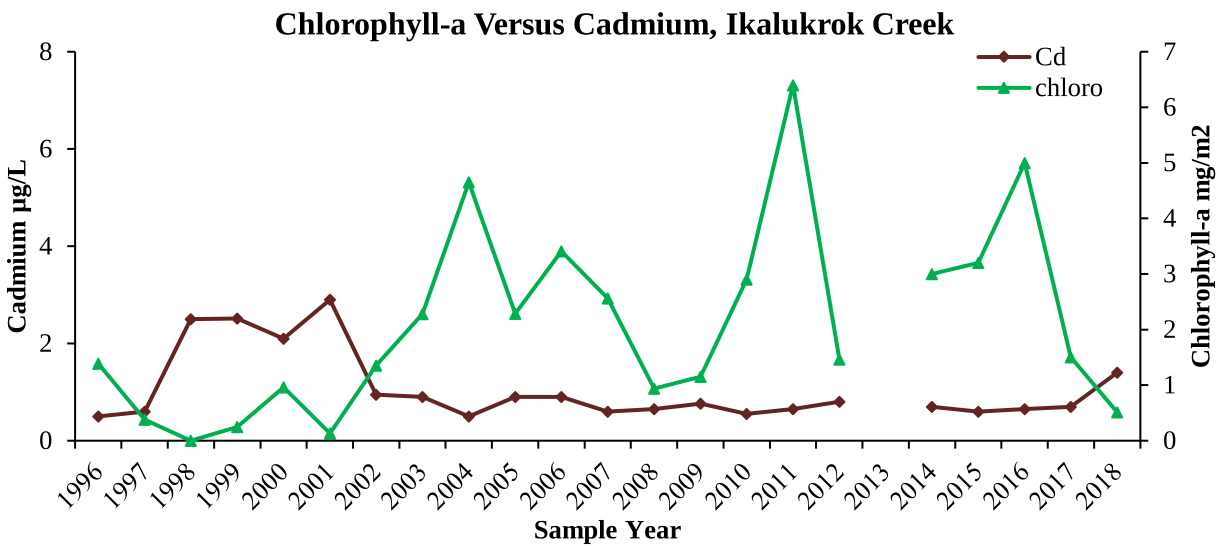



**Figure 23. Average concentrations of chlorophyll-a and cadmium in Ikalukrok Creek. 1996-2018.**

**Figure 24. Ikalukrok Creek at the Cub Creek seep about 10 km upstream of Station 9. Station 9 is just upstream of the mouth of Mainstem Red Dog Creek – note mineral staining in and along the edge of Cub Creek, July 2017.**

### Aquatic Invertebrates

Aquatic invertebrate samples are collected annually using drift nets (Appendix 3). The purpose of this effort is: (1) to determine if differences exist in the macroinvertebrate populations among the sample sites; and (2) to track changes over time.

In 2018, flows were low at many of the sample sites. Average aquatic invertebrate densities were highest in Bons Creek (above the pond) with 17.15 aquatic invertebrates per $m^3$, followed closely by Buddy Creek (below the falls) with 17.05 per $m^3$ (Figure 25).

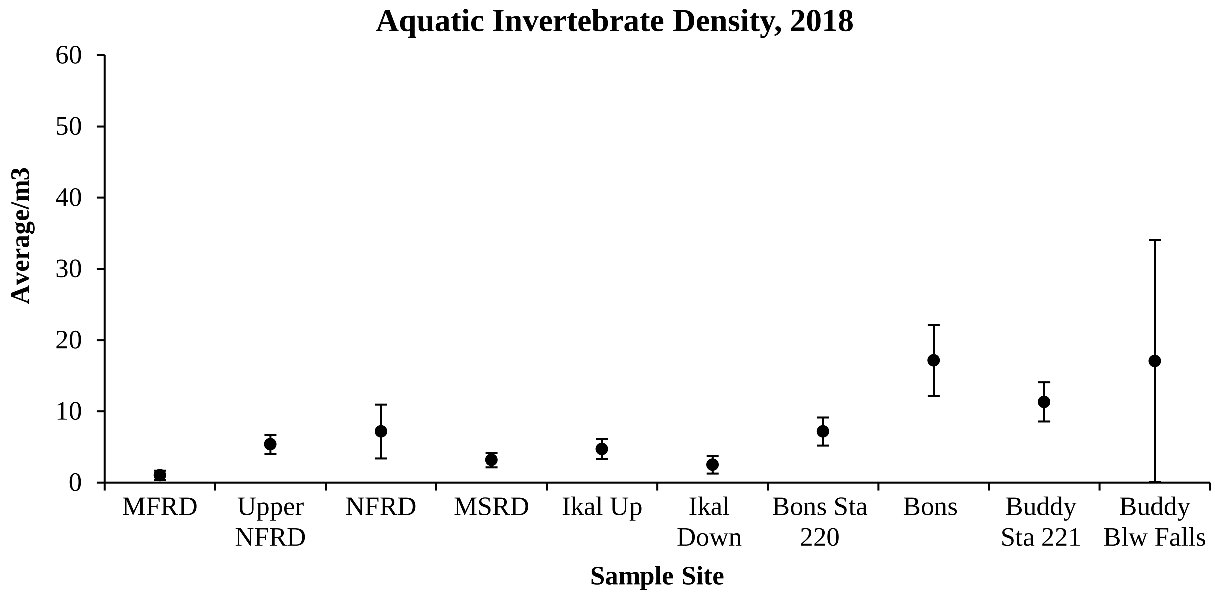



**Figure 25. Average aquatic invertebrate densities (± 1SD) in all sample sites near the Red Dog Mine, July 2018.**

Buddy Creek (Sta 221, above the haul road) generally has higher aquatic invertebrate densities than other sample sites in most years; however, in 2018 the Bons Creek (above the pond) and Buddy Creek (below the falls) sites had higher densities. The average aquatic invertebrate density in Buddy Creek (above road) has varied from a low of 3.8 to a high of 164.5 invertebrates per $m^3$ (Figure 26). In 2018, average aquatic invertebrate density was 11.33 invertebrates per $m^3$.

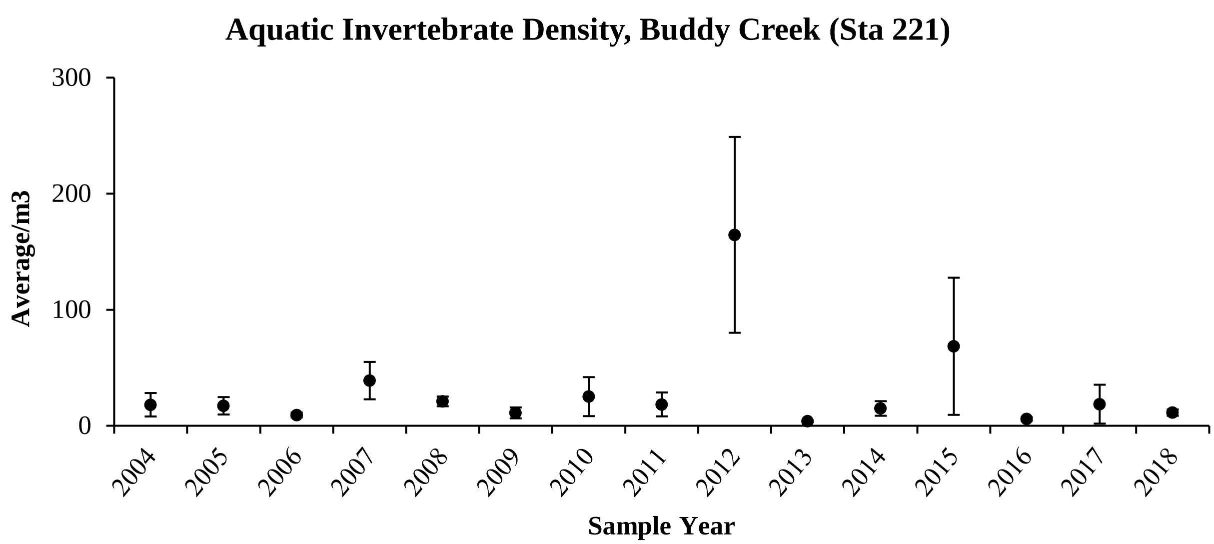



**Figure 26. The average aquatic invertebrate density (± 1SD) in Buddy Creek (Station 221) upstream of the road 2004 – 2018.**

Aquatic invertebrate densities are typically higher in North Fork Red Dog Creek than in Mainstem Red Dog Creek, and this was also the case in 2018 (Figure 27). In 19 out of 20 years, the aquatic invertebrate density was higher in North Fork Red Dog Creek than in Mainstem Red Dog Creek.

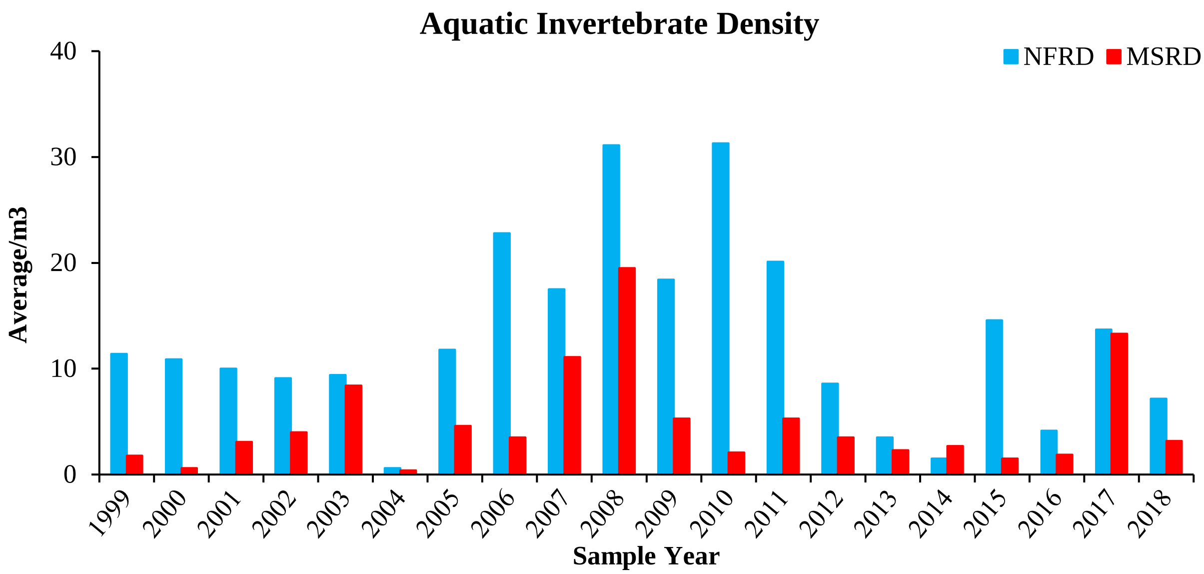



**Figure 27. Average aquatic invertebrate densities in North Fork Red Dog and Mainstem Red Dog creeks 1999 – 2018.**

The percent Ephemeroptera, Plecoptera, and Trichoptera (EPT) and the percent Chironomidae for sample sites in 2018 are presented in Figure 28. All sites except for Ikalukrok Creek Upstream (Sta 9) contained a higher percentage of Chironomidae in 2018, which is the general pattern seen most years. Trichoptera are not common in the samples and are not a substantial contributor to EPT. Generally, the aquatic systems in the Red Dog Mine area are dominated by Chironomidae which is one of the primary food items of the fish species (e.g. Arctic grayling and Dolly Varden) using these creeks.

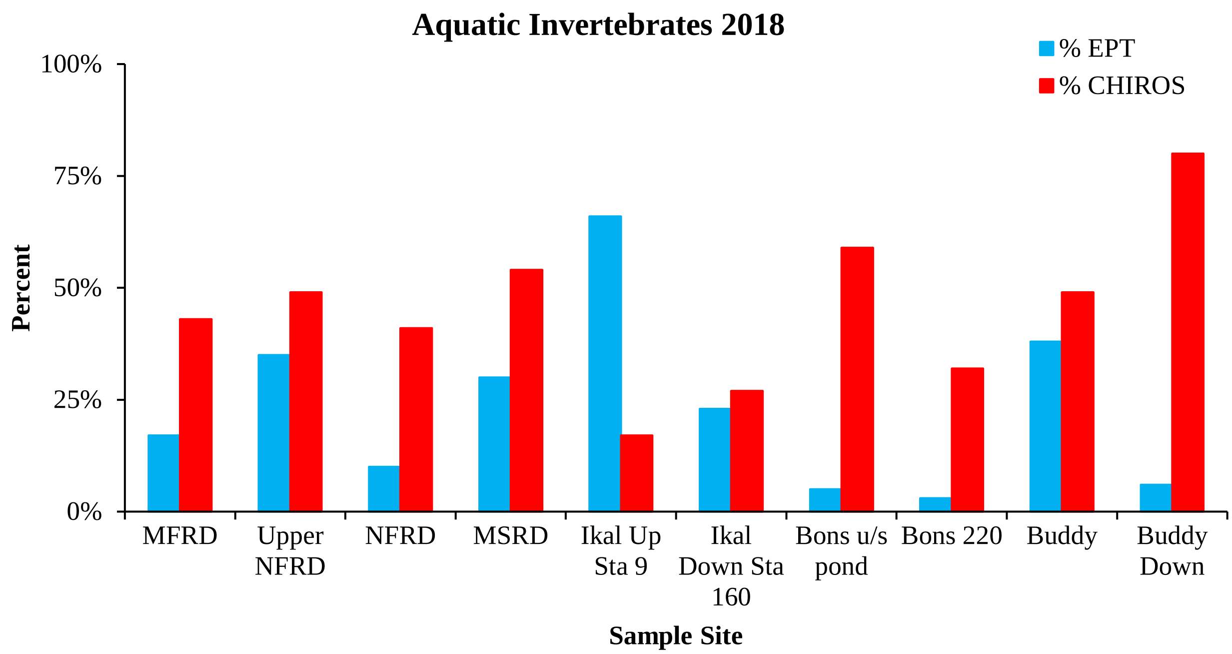



**Figure 28. Percent EPT and Chironomidae in the aquatic invertebrate samples at all sample sites Red Dog Mine, July 2018.**

The percent EPT in North Fork Red Dog and Mainstem Red Dog creeks was low in 2001 and from 2008 to 2011 (Figure 29). Buddy Creek (Sta 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, 2015, and 2016) (Figure 29). In most years since 1999, the percent Chironomidae in North Fork Red Dog and Mainstem Red Dog Creeks has been higher than the percent EPT. In Buddy Creek, percent Chironomidae has been higher than the percent EPT 10 out of 15 years.

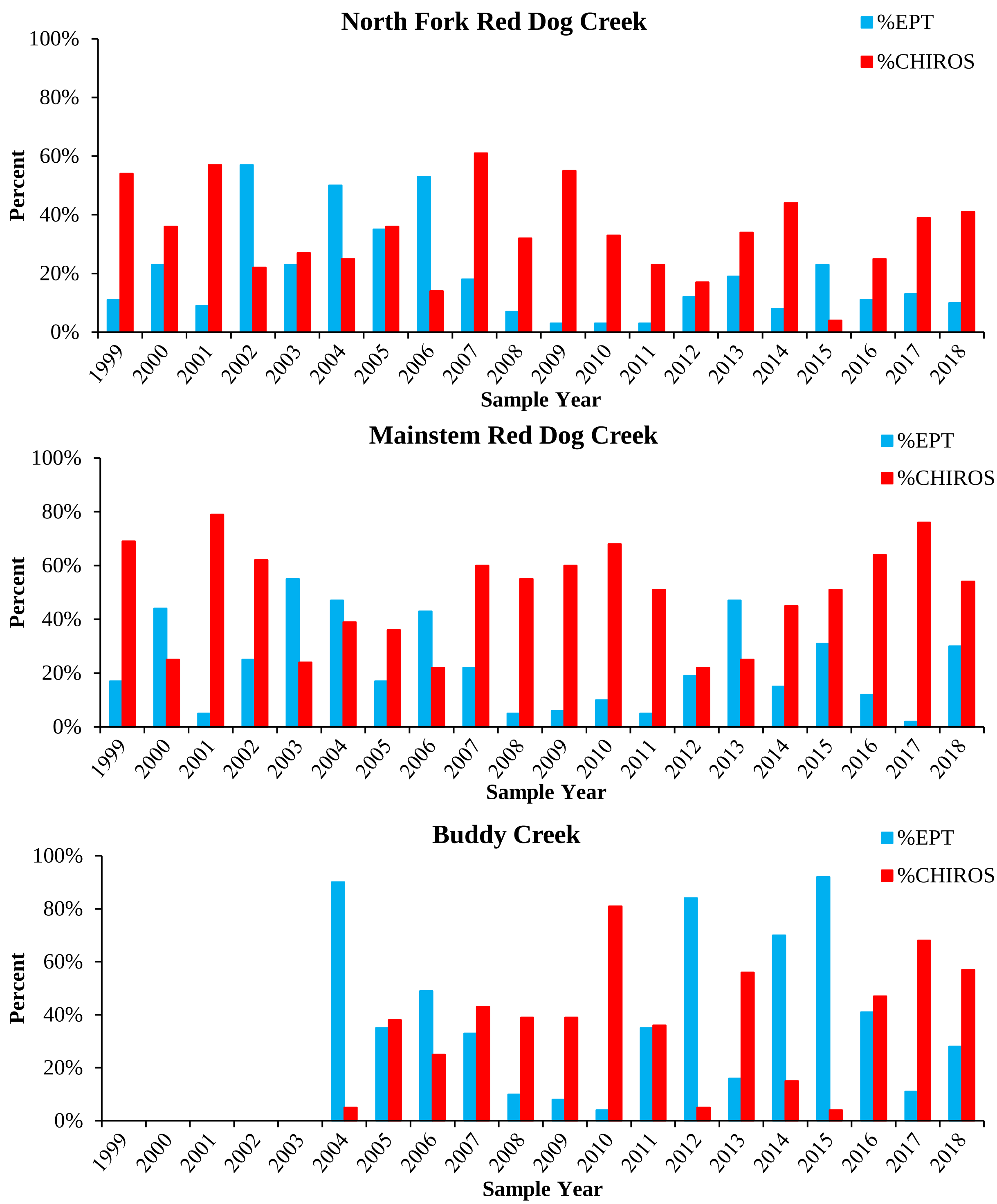



**Figure 29. Percent EPT and Chironomidae in North Fork Red Dog Creek (top), Mainstem Red Dog Creek (middle), and Buddy Creek (bottom) 1999 – 2018. Aquatic invertebrate sampling in Buddy Creek drainage began in 2004.**

Taxa richness was compared for the three sample sites in North Fork Red Dog, Mainstem Red Dog, and Buddy creeks (Figure 30). Richness is the total number of taxa seen in the sample and includes mayflies, stoneflies, and caddisflies (to genus when possible), diptera (to family or genus), coleoptera (to family), hemiptera (to family), collembola (to family or genus), lepidoptera (to family), and other taxa to order. Taxa richness was highest in Mainstem Red Dog Creek in 2014 and lowest in 2000. The highest taxa richness in North Fork Red Dog Creek occurred in 2003, and the lowest was in 1999 and 2000. In 2018, Buddy Creek (Sta 221) had the highest taxa richness since aquatic invertebrate sampling began in 2004. The lowest taxa richness at Buddy Creek was seen in 2009 and 2010.

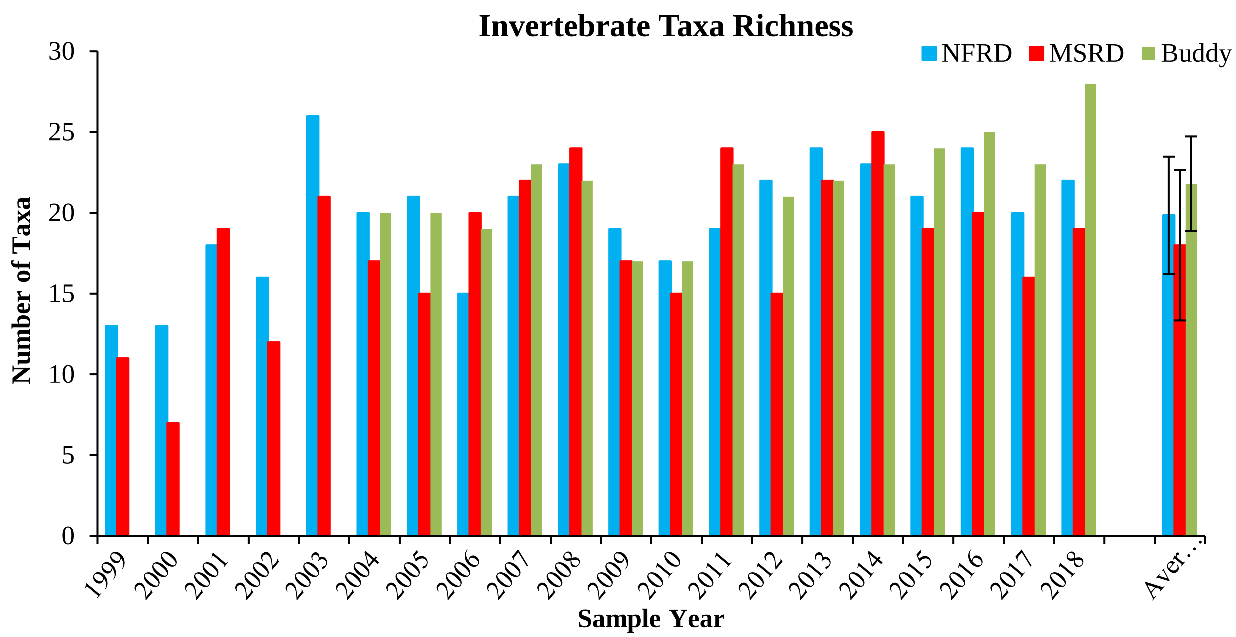



**Figure 30. Aquatic invertebrate taxa richness in North Fork Red Dog and Mainstem Red Dog Creek 1999 – 2018 and Buddy Creek 2004 – 2018. The running average (± 1 SD) is included for each site.**

### Metal Concentrations in Juvenile Arctic Grayling and Dolly Varden

Juvenile Arctic grayling and Dolly Varden 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 the 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 change over time in Bons Pond. Fish samples are typically collected during the spring sampling event when fish are moving from Bons Pond into Bons Creek. However, catches of juvenile Arctic grayling were low in spring 2018 so most of the samples were collected in July and August with a fyke net in Bons Pond.

Juvenile Dolly Varden were selected as a target species because of their wide distribution in the Red Dog area streams, their residence in freshwater for two to four years before smolting, and their rearing in the selected sample sites only during the ice-free season. Juvenile Dolly Varden were collected opportunistically from Mainstem Red Dog, Anxiety Ridge, and Buddy creeks during the minnow trap sample event in late summer. These locations have been sampled annually since 2005, except for in 2012 and 2013 when water levels were too high to effectively sample.

Three juvenile Arctic grayling were captured in Bons Creek just upstream of Bons Pond in June, two were captured in Bons Pond in July, and seven were captured in Bons Pond in early August (Appendix 4). The average length of these fish was 154.1 mm FL ± 21.1 mm (1 SD). These fish were all analyzed for cadmium, lead, selenium, zinc and mercury, and all results are for whole body in mg/kg (dry weight).

In 2018, the average cadmium concentration in Bons Pond juvenile Arctic grayling was 0.17 mg/kg (Figure 31). The highest average cadmium concentration was 0.27 mg/kg in 2014.

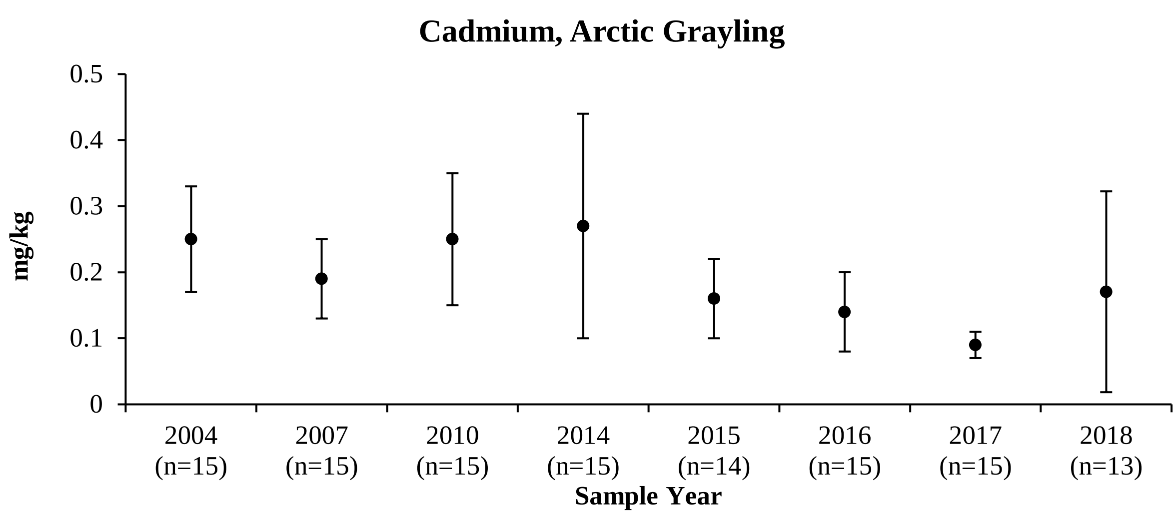



**Figure 31. Average cadmium concentrations (± 1 SD) in juvenile Arctic grayling collected from Bons Pond drainage (whole body dry weight).**

In 2018, the average lead concentration was 0.71 mg/kg in juvenile Arctic grayling from Bons Pond (Figure 32). This was an increase from 2017 but was not quite as high as 2014 to 2016 when average lead concentration was highest.

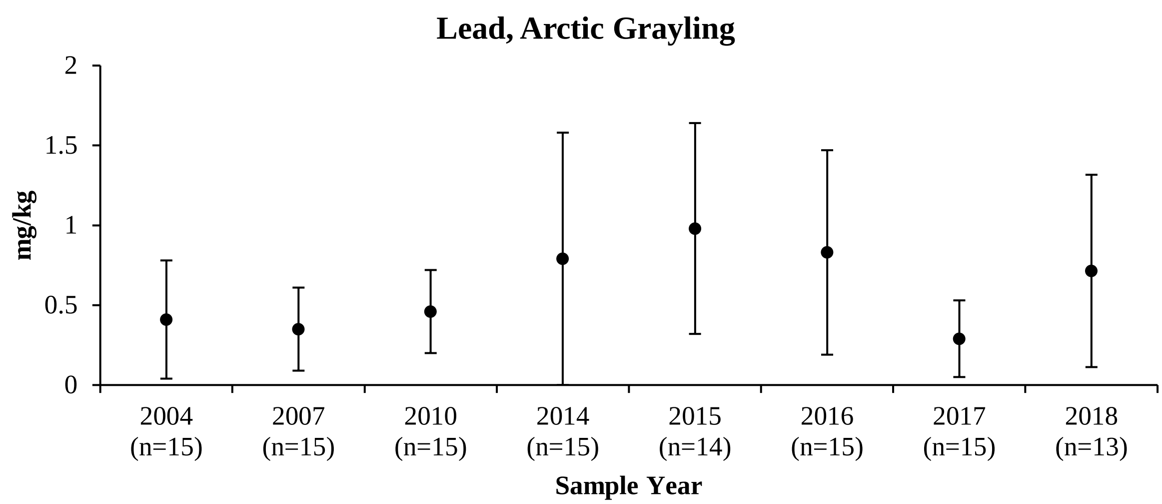



**Figure 32. Average lead concentrations (± 1 SD) in juvenile Arctic grayling collected from Bons Pond drainage (whole body dry weight).**

Average selenium concentrations in juvenile Arctic grayling from Bons Pond have slightly decreased since 2014 (Figure 33). Average values in 2018 were 13.3 mg/kg, a slight increase from 2017 but still lower than the average concentration in 2014.

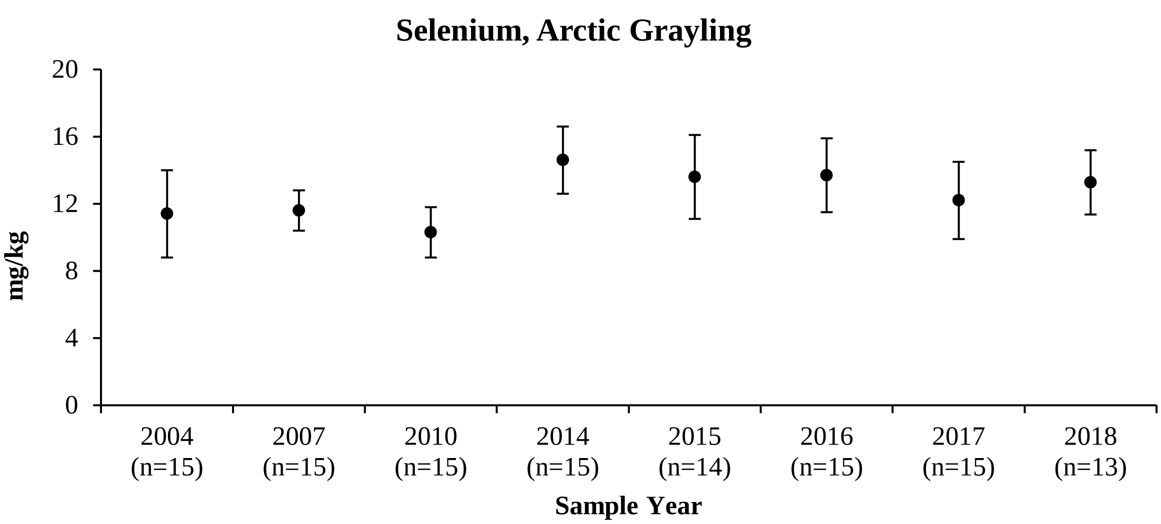



**Figure 33. Average selenium concentrations (± 1 SD) in juvenile Arctic grayling collected from Bons Pond drainage (whole body dry weight).**

Similar to cadmium and lead, average zinc concentrations in juvenile Arctic grayling from Bons Pond in 2018 (95.1 mg/kg) increased after a low in 2017 (Figure 34). Average concentrations have varied from a high of 104 mg/kg in 2016 to a low of 60 mg/kg in 2017.

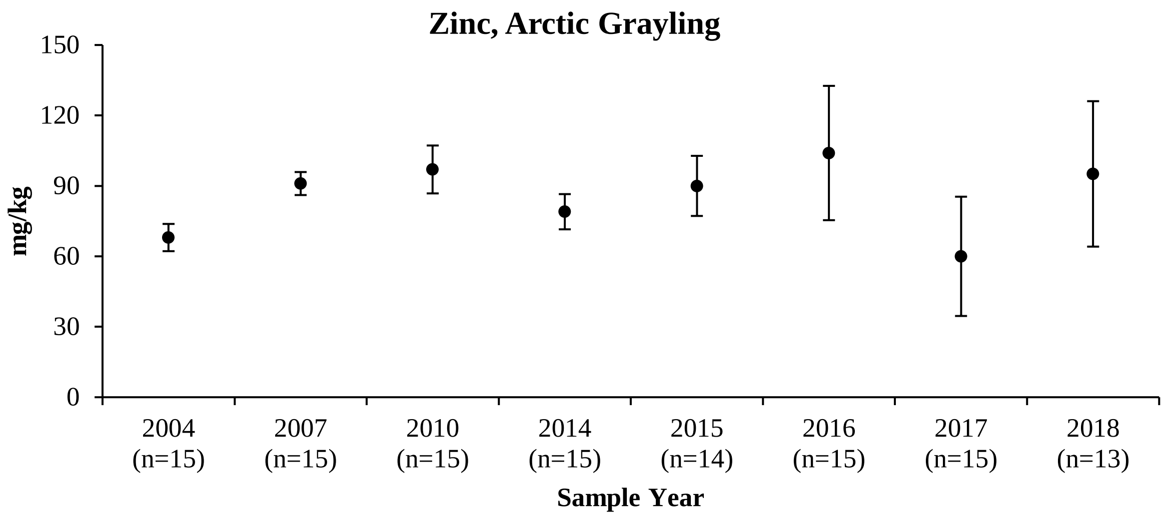



**Figure 34. Average zinc concentrations (± 1 SD) in juvenile Arctic grayling collected from Bons Pond drainage (whole body dry weight).**

Average mercury concentrations in juvenile Arctic grayling from Bons Pond have been variable and ranged from a high of 0.06 mg/kg in 2018 to a low of the detection limit of 0.02 mg/kg in 2004 and 2014 (Figure 35).

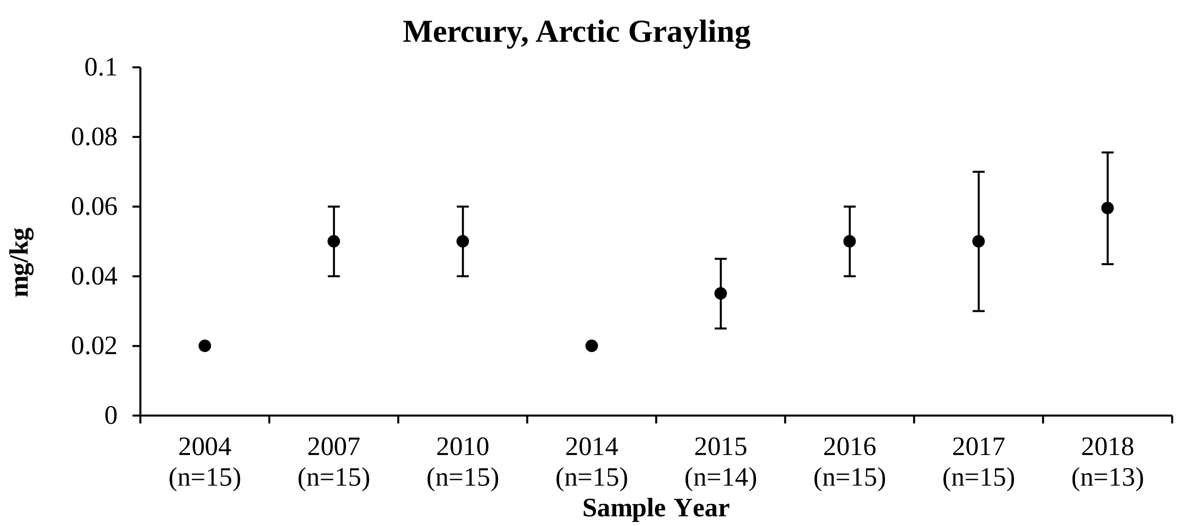



**Figure 35. Average mercury concentrations (± 1 SD) in juvenile Arctic grayling collected from Bons Pond drainage (whole body dry weight). In 2004 and 2014 all samples were ≤ Method Detection Limit (MDL).**

In August 2018, juvenile Dolly Varden were collected from Mainstem Red Dog (n = 11), Buddy (n = 15), and Anxiety Ridge creeks (n = 15) for whole body element analysis (Appendix 5).

Since water quality concentrations of cadmium, lead, and zinc are highest in Mainstem Red Dog Creek, higher concentrations of these metals in whole body samples of juvenile Dolly Varden were expected. The main source of cadmium, lead, and zinc to Mainstem Red Dog creek is the waters from the clean water bypass.

Whole body cadmium concentrations (median value) are highest in juvenile Dolly Varden collected from Mainstem Red Dog Creek and consistently lowest in Anxiety Ridge Creek (Figure 36). Peak median cadmium concentrations occurred at all three sites in 2006. Median cadmium concentrations have been below 1 mg/kg in fish from Buddy Creek since 2007 and Anxiety Ridge Creek since 2005. Among data for Mainstem Red Dog Creek, changes in whole body cadmium concentrations generally track with the water quality data, although the sharp increase in cadmium in the 2018 water quality data is not quite as pronounced in the whole-body cadmium concentration (Figure 37).

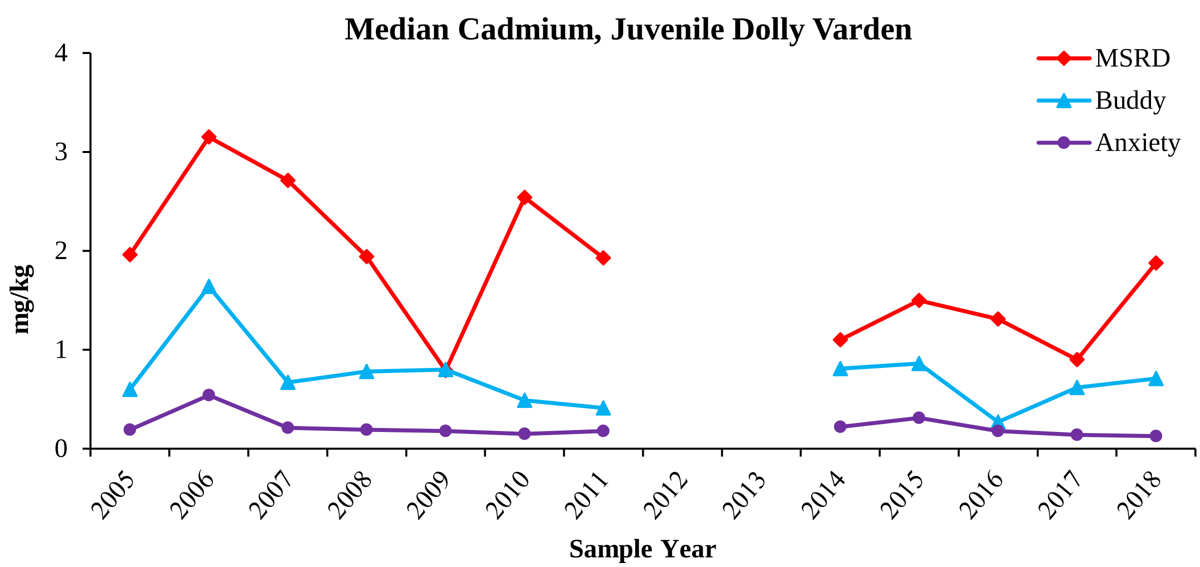



**Figure 36. Median cadmium whole body (dry weight) concentrations in juvenile Dolly Varden from 2005 to 2018.**

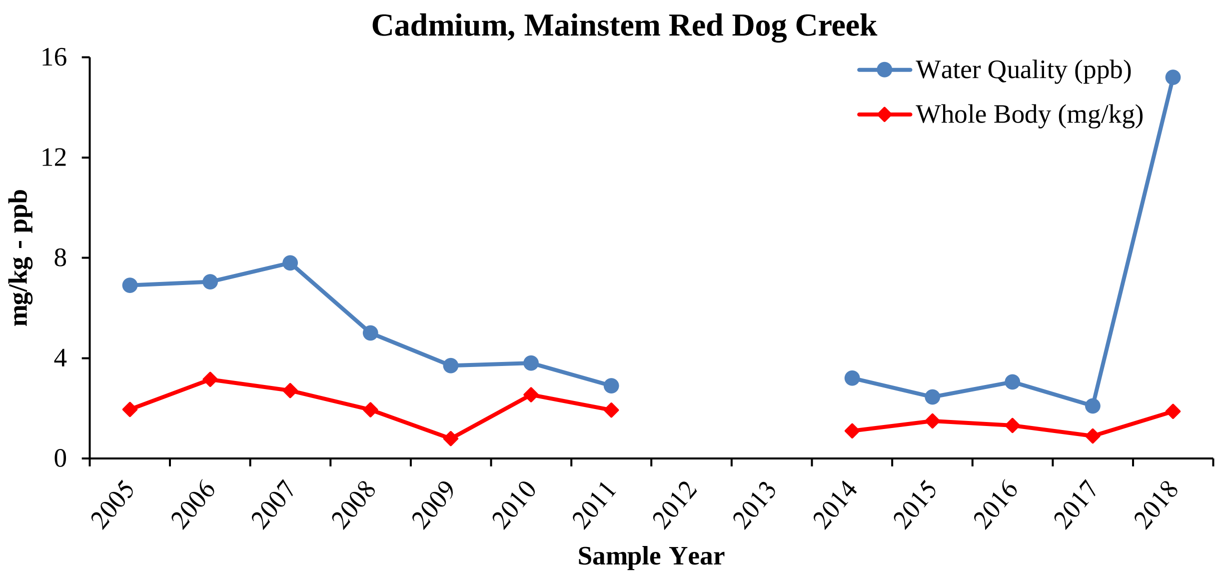



**Figure 37. Median whole body (dry weight) cadmium concentrations in juvenile Dolly Varden and median cadmium water quality data for Mainstem Red Dog Creek.**

Median whole-body lead concentrations in juvenile Dolly Varden are consistently higher in Mainstem Red Dog Creek than in Buddy and Anxiety Ridge creeks, which have similar lead concentrations (Figure 38). Lead concentrations in the water of Mainstem Red Dog Creek have been highly variable since 2005 and there does not seem to be any relationship between lead in the water and lead in whole body samples from Mainstem Red Dog Creek juvenile Dolly Varden (Figure 39).

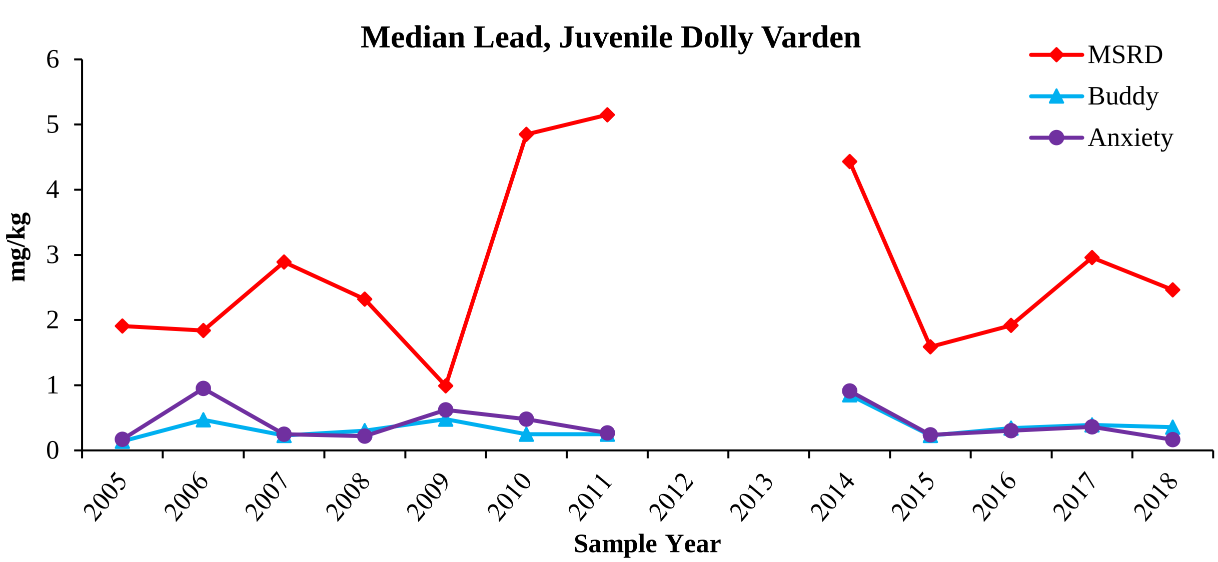



**Figure 38. Median lead whole body (dry weight) concentrations in juvenile Dolly Varden from 2005 to 2018.**

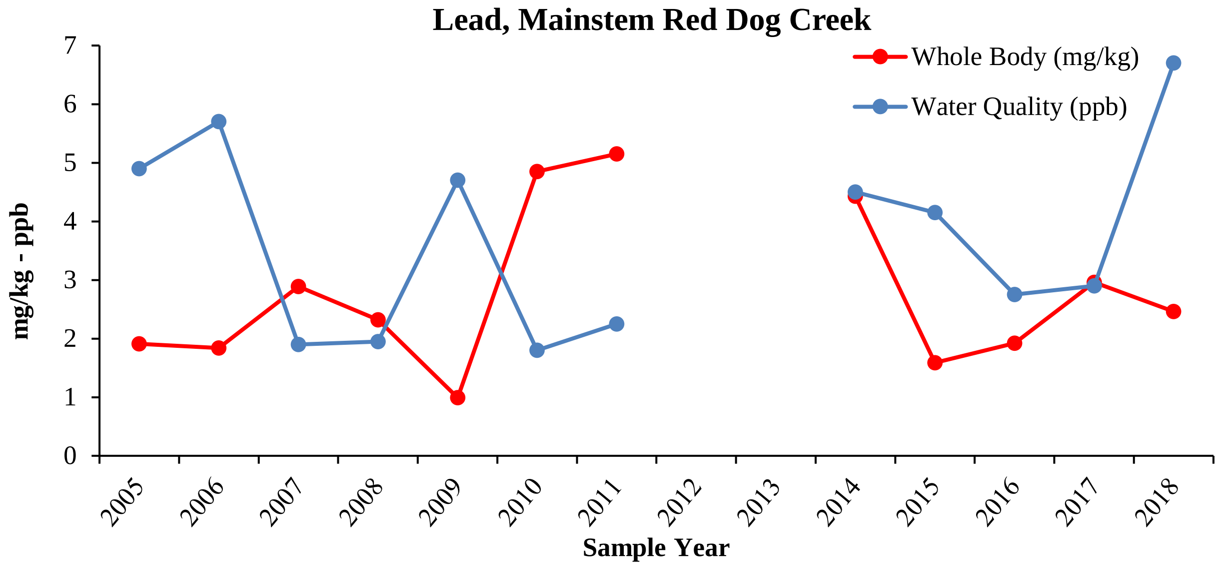



**Figure 39. Median whole body (dry weight) lead concentrations in juvenile Dolly Varden and median lead water quality data for Mainstem Red Dog Creek.**

Median whole-body selenium concentrations in juvenile Dolly Varden are generally lowest in fish from Anxiety Ridge Creek (Figure 40). Whole body selenium concentrations in juvenile Dolly Varden from Mainstem Red Dog Creek increased from 2009 to 2015, and slightly decreased from 2016 to 2018. There is no clear relationship in Mainstem Red Dog Creek between selenium concentrations in the water and in whole body juvenile Dolly Varden (Figure 41).

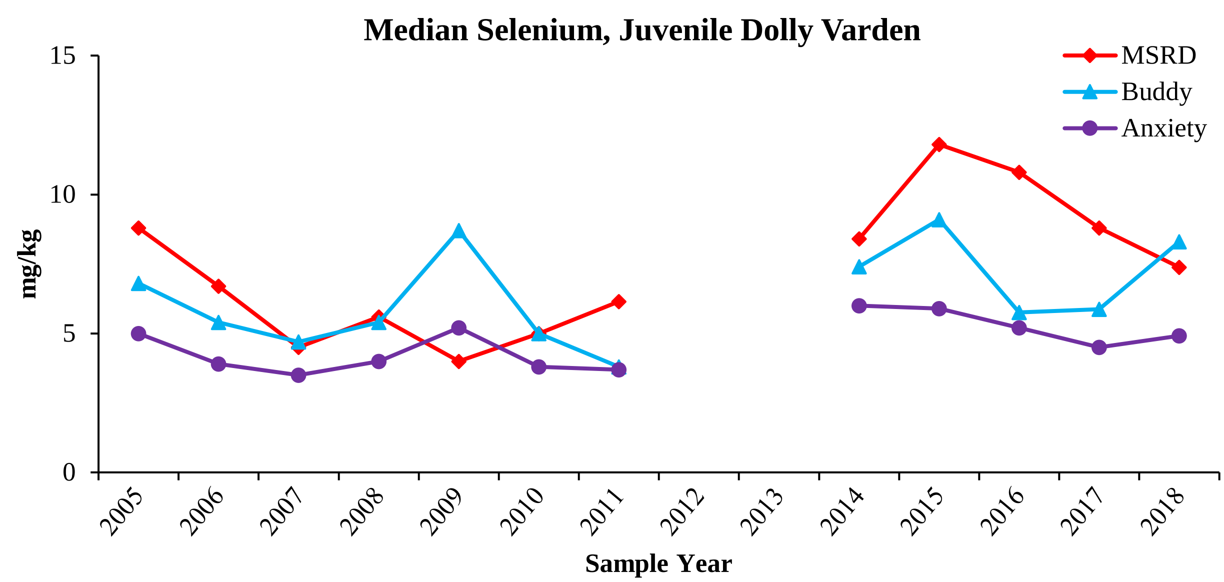



**Figure 40. Median selenium whole body (dry weight) concentrations in juvenile Dolly Varden from 2005 to 2018.**

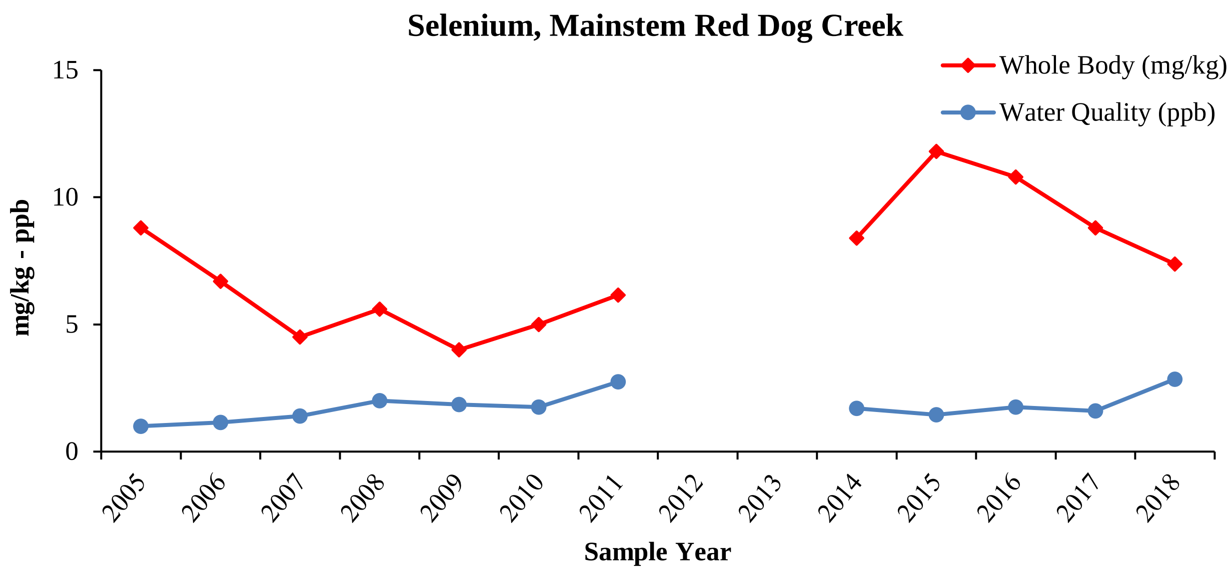



**Figure 41. Median whole body (dry weight) selenium concentrations in juvenile Dolly Varden and median selenium water quality data for Mainstem Red Dog Creek.**

Median zinc whole body concentrations are generally highest in fish from Mainstem Red Dog Creek and lowest in fish from Anxiety Ridge Creek (Figure 42). Zinc whole body concentrations in Mainstem Red Dog Creek decreased from a high of 351 mg/kg in 2007 to a low of 154 mg/kg in 2017, but then increased in 2018 to 232 mg/kg. Whole body zinc concentrations in fish from Mainstem Red Dog Creek have generally mirrored the trends in water concentration, although the sharp increase in the water in 2018 was not reflected as steeply in the whole-body concentration (Figure 43).

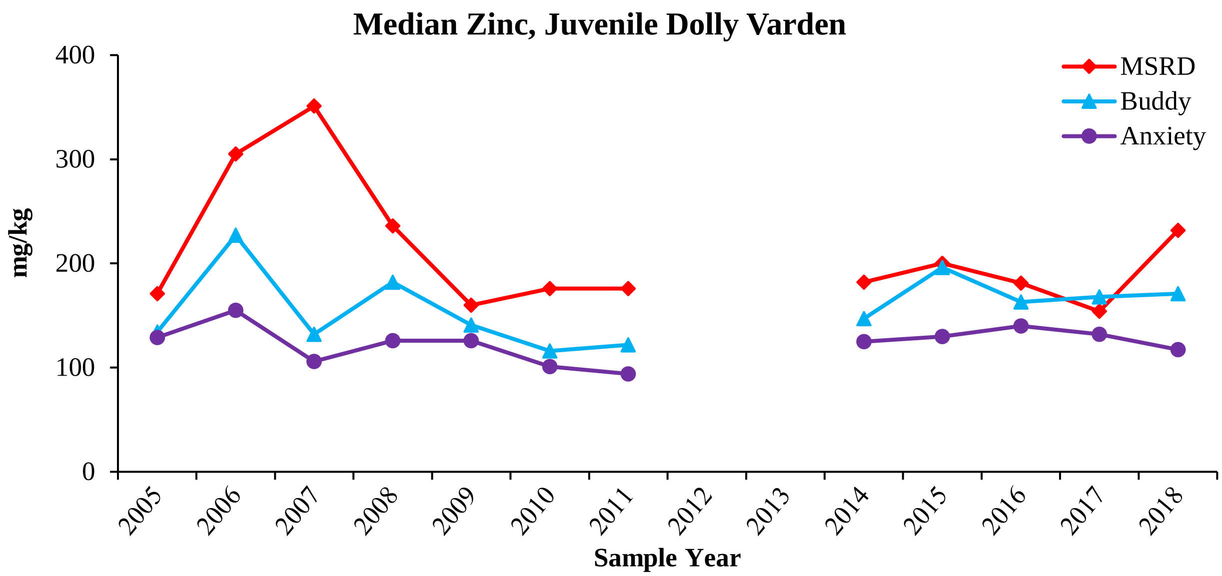



**Figure 42. Median zinc whole body (dry weight) concentrations in juvenile Dolly Varden from 2005 to 2018.**

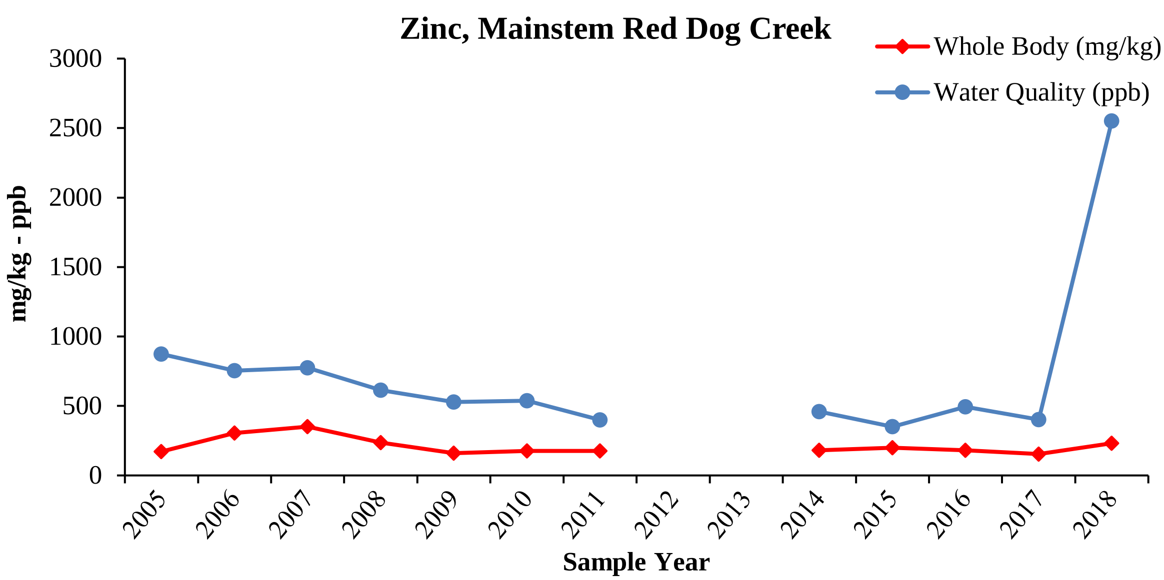



**Figure 43. Median whole body (dry weight) zinc concentrations in juvenile Dolly Varden and median zinc water quality data for Mainstem Red Dog Creek.**

Median mercury concentrations in juvenile Dolly Varden are consistently higher in Anxiety Ridge Creek and very similar between Buddy and Mainstem Red Dog creeks (Figure 44). The highest recorded median of mercury was detected in 2018 in Anxiety Creek at 0.13 mg/kg, slightly higher than the 2016 median value of 0.12 mg/kg.

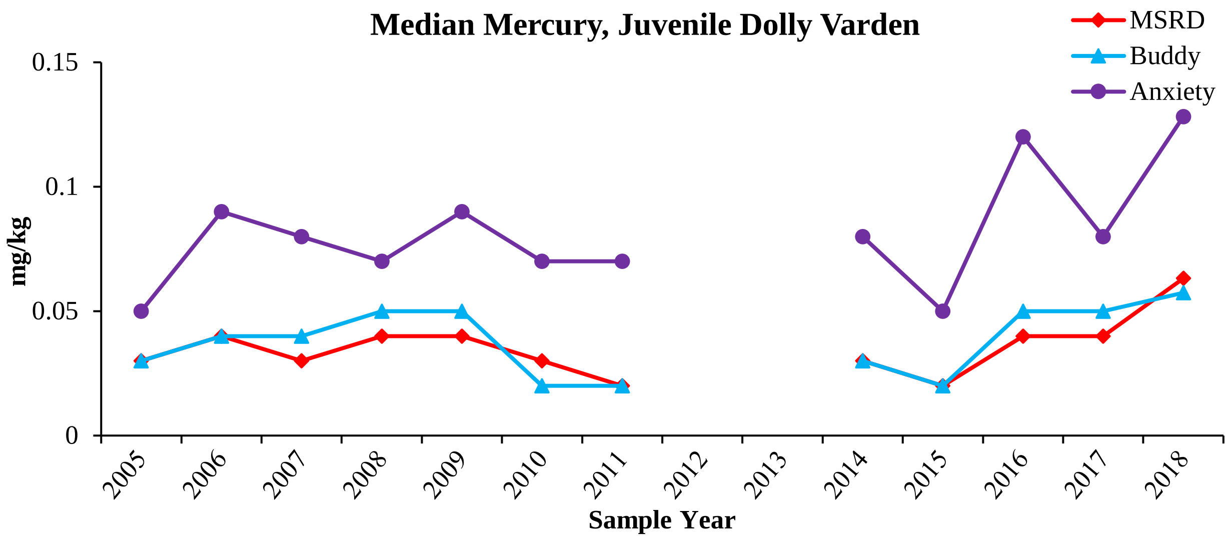



**Figure 44. Median mercury whole body (dry weight) concentrations in juvenile Dolly Varden from 2005 to 2018.**

### Selenium Concentrations in Adult Arctic Grayling

In spring 2018, Arctic grayling females were collected from Bons Pond and North Fork Red Dog Creek near the Red Dog Mine. In spring 1999, and 2014 – 2018, samples were collected from the Chena River (Fairbanks), the water supply reservoir (upper Fish Creek) at the Fort Knox Mine, and from Bons Pond and North Fork Red Dog Creek near the Red Dog Mine.

The purpose of these collection efforts is to compare the selenium concentration in the ovaries of Arctic grayling among sites and over time. Literature suggests that selenium concentrates in the ovaries of fishes and can have adverse effects on reproductive success. Selenium accumulation in the eggs of fish has been shown to yield the most robust relationship with the occurrence of deformities and reduced survival of offspring.

Bons Pond and the Fort Knox water supply reservoirs support Arctic grayling. Both populations occur upstream of a barrier to upstream movement of fish. At Fort Knox, the Arctic grayling overwinter in the water supply reservoir and spawn in tributaries, primarily in the developed wetland complex (Ott and Bradley, 2017). In Bons Pond, the Arctic grayling overwinter in the pond and spawn in Bons Creek and in the outlet of Bons Pond. The Arctic grayling ovary samples from these two sites are from fish that have spent their entire life history in these waterbodies.

Fort Knox Arctic grayling mature at a younger age and smaller size than Bons Pond Arctic grayling. The Fort Knox Arctic grayling collected in 1999, 2015 and 2017 had an average age of

8 ± 1 year (1 SD) while the Bons Pond fish collected in 2017 averaged 11.8 ± 3.1 years (1 SD). The five fish retained from Mainstem Red Dog Creek in 2017 averaged 9.8 ± 4.6 years (1 SD). The Arctic grayling collected from Bons Pond and North Fork Red Dog Creek in 2018 were smaller, younger, and did not have well developed egg masses, indicating they were unlikely to spawn in 2018. Bons Pond fish collected in 2018 averaged 4.1 ± 0.9 years (1 SD) and the 2018 North Fork Red Dog Creek fish averaged 4.25 ± 0.4 years (1 SD).

Selenium concentrations in Arctic grayling ovaries were highest in Bons Pond, while concentrations in Arctic grayling ovaries from the North Fork Red Dog Creek remain the second highest (Figure 45). Arctic grayling from Fish Creek at Fort Knox contained the lowest concentration of selenium in ovaries. Selenium concentrations Arctic grayling ovaries from Bons Pond and North Fork Red Dog Creek were higher in 2018, but since the size and age of sampled fish was inconsistent with previous years' samples, and the fish were not mature, results are not directly comparable between years. Large, mature spawners will be collected in 2019 to be compared to the 2014 to 2017 results.

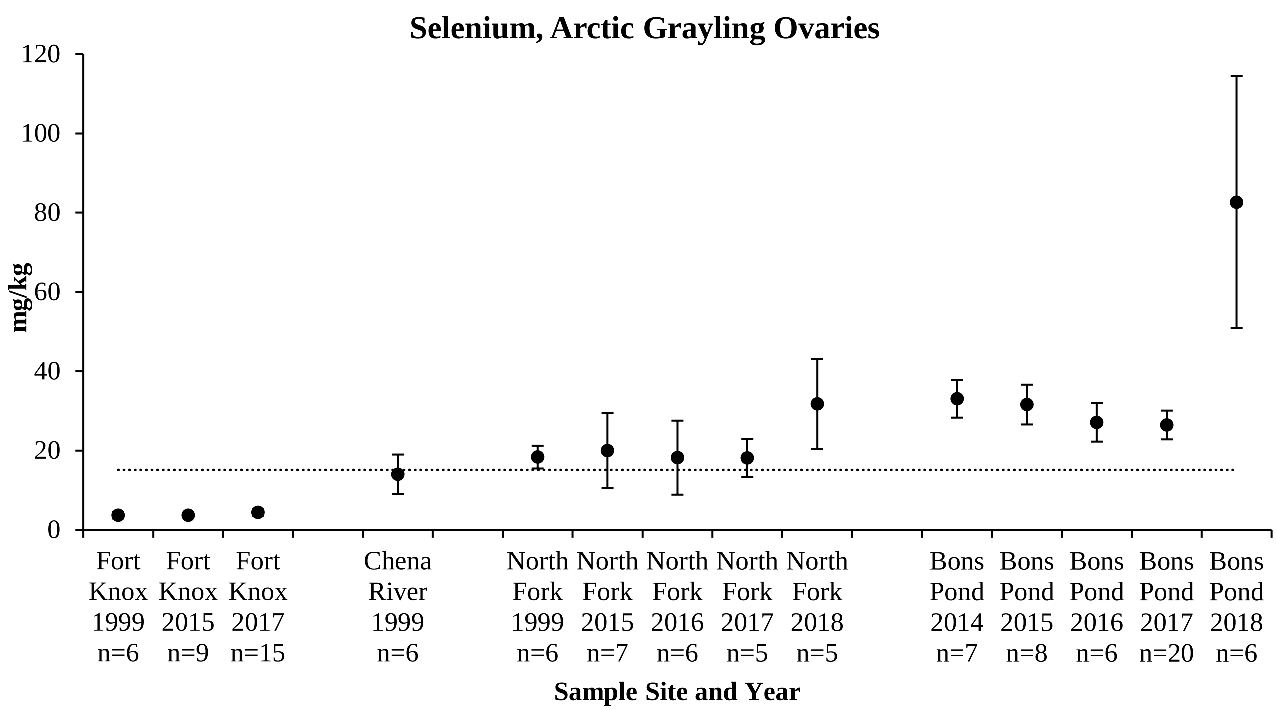



**Figure 45. Average selenium (± 1SD) concentrations (dry weight) in Arctic grayling ovaries from Fort Knox, Chena River, North Fork Red Dog Creek, and Bons Pond. The dotted line is the EPA criterion of 15.1 mg/kg dry weight in ovary tissue. Fish collected in 2018 were younger and smaller than previous years' samples, so results are not directly comparable.**

Selenium concentrations found in the ovaries of Bons Pond Arctic grayling are higher than the EPA's final chronic aquatic life criterion for fresh water (15.1 mg/kg – dry weight) (EPA, 2016), while selenium concentrations in Fort Knox Arctic grayling are substantially lower. Selenium concentrations in ovaries of Arctic grayling from North Fork Red Dog Creek are equal to or slightly higher than the EPA criterion. Selenium concentrations were stable from 2014 to 2017 in North Fork Red Dog Creek, Bons Pond, and Fort Knox (Fish Creek); however, abundance estimates of Arctic grayling in Bons Pond steadily decreased from 2007 to 2014, then increased from 2015 to 2017. The decrease in the Bons Pond Arctic grayling population might have been due to elevated selenium in the ovaries, but it also may have been related to the fact that this introduced population expanded rapidly after their introduction in 1994 and 1995. The decrease in the number of Arctic grayling in Bons Pond may be related to predation of larger fish on age-0 recruits since there is no separation of age classes by habitat type. Recent sampling in Bons Pond indicates that there is an increasing number of smaller fish; therefore, the population of adult fish (≥ 200 mm FL) may continue to increase in the future.

The North Fork Red Dog Creek Arctic grayling population has been relatively stable over time and recruitment of new fish has been strong since 2007 except for spring 2017 when the North Fork was inundated in aufeis. The population could not be estimated in 2018 as there were not enough recaptured fish. The Arctic grayling population in Fish Creek at Fort Knox has been variable over the sample years and population changes have been linked closely with access to spawning habitat and access from spawning and rearing habitat to overwintering which can be adversely affected by beaver activity (Ott and Bradley, 2016).

**Metal Concentrations in Adult Dolly Varden**

In 2018, adult Dolly Varden were collected from the Wulik River (Station 2) 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 2018, half in the spring and half in the fall.

The purposes 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 the majority of Dolly Varden growth occurs in the marine environment. All laboratory work was done with Level III Quality Assurance. Data for 2018 are presented in Appendix 7 and 8.

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 metals vary with season, age, size, weight, and feeding habits of fish (Jenkins 1980) and in the case of anadromous Dolly Varden, the metals concentrations vary with exposure to freshwater and marine environments. None of the analytes measured appear to concentrate in muscle tissue (Figure 46). In Wulik River Dolly Varden sampled from 1999 to 2018, cadmium was highest in kidney samples, copper was highest in liver samples, lead was slightly higher in testes tissue, zinc was highest in reproductive tissues, selenium was highest in ovaries and kidneys, and mercury was highest in kidneys.

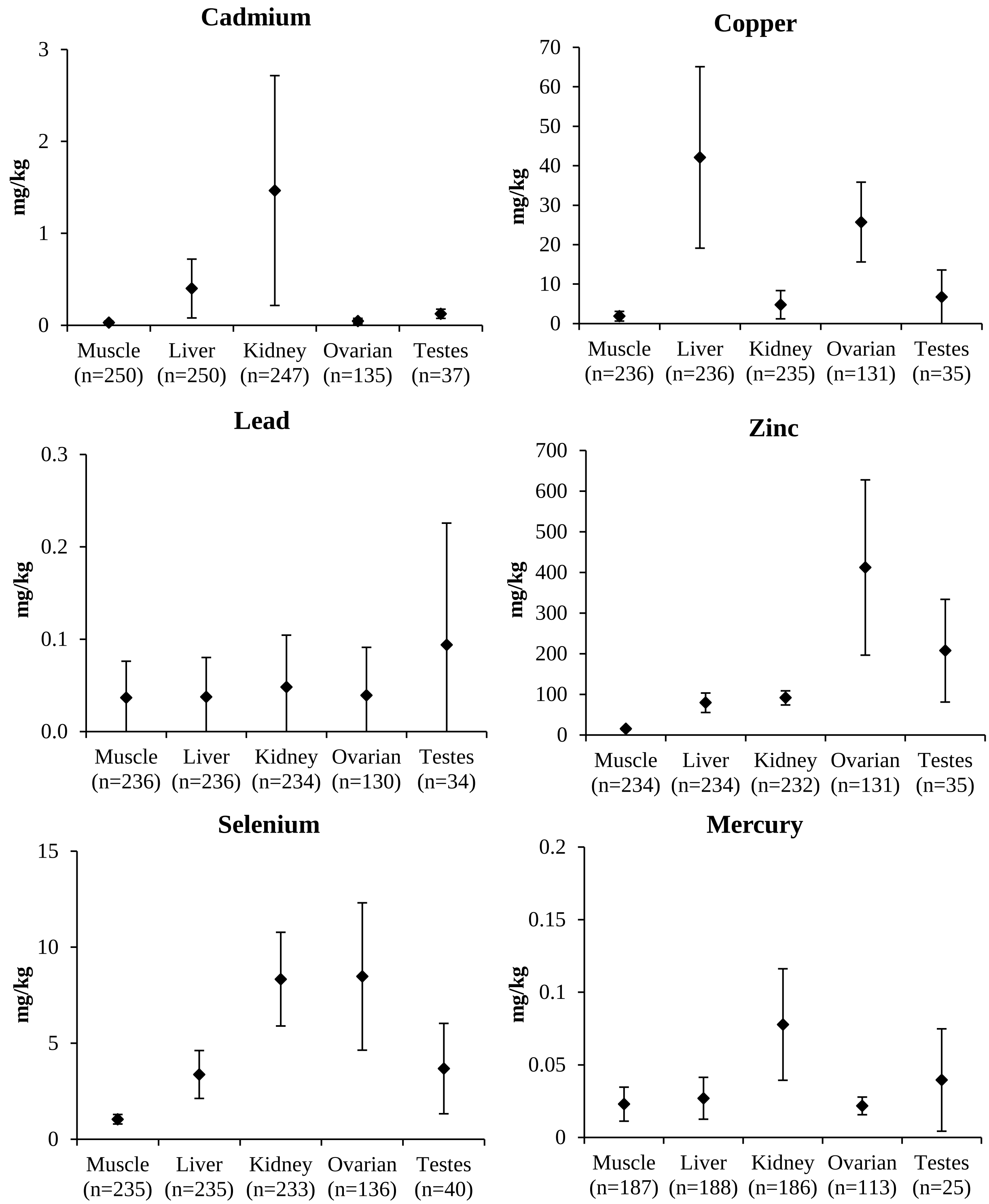



**Figure 46. Average element concentration (dry weight) ± 1 SD in adult Dolly Varden tissues, Wulik River (1999–2018[3]).**

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

Cadmium concentrations in adult Dolly Varden kidney tissue have been variable since 1999 (Figure 47). Concentrations of cadmium slightly increased from 1999 to 2002, then abruptly decreased and remained around 1 mg/kg through spring of 2009. Average cadmium concentrations doubled in fall of 2009 to 1.99 mg/kg, reached a high of 2.96 mg/kg in spring 2011, and have since been slowly decreasing.

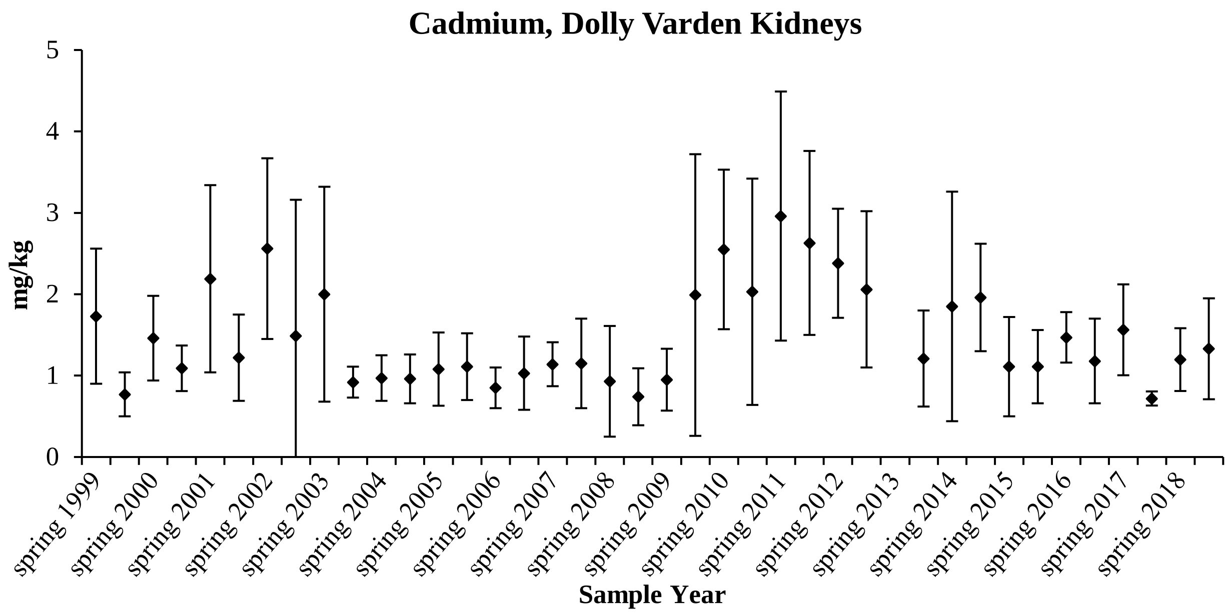


**Figure 47. Average cadmium (± 1SD) concentrations (dry weight) in adult Dolly Varden kidney tissues from 1999 to 2018.**

Average selenium concentrations in Dolly Varden ovaries are higher for fish sampled in the fall (10.5 mg/kg) than for fish sampled in the spring (6.3 mg/kg) (Figure 48). The Dolly Varden sampled in the fall would have recently returned from the marine environment, which may be where they acquired the selenium.

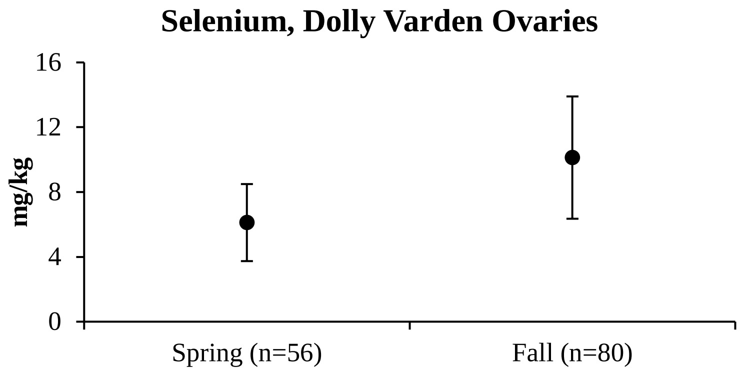


**Figure 48. Average selenium (± 1SD) concentrations (dry weight) in Dolly Varden ovaries from 1999 to 2018.**

**Dolly Varden, Overwintering**

An aerial survey was conducted using an R-66 helicopter provided by Teck on October 5, 2018 to estimate the number of overwintering Dolly Varden in the Wulik River (Figure 49). Weather conditions were good with clear skies and light winds. Estimated stream flow in the Wulik River was 490 cfs on October 5. Survey results in 2018 found that 98% of the fish observed were downstream of the mouth of Ikalukrok Creek (Table 2). Continued use of this section of the Wulik River by the majority of overwintering Dolly Varden suggests that conditions have not changed to alter their distribution.

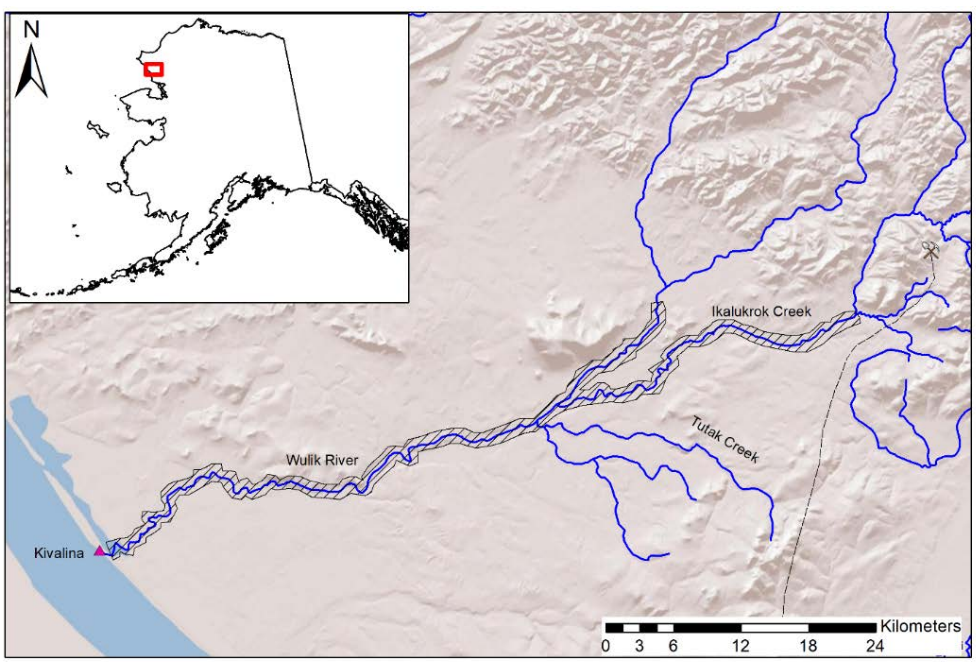


**Figure 49. Dolly Varden and chum salmon aerial survey area. The striped polygon denotes the surveyed portion of the drainage.**

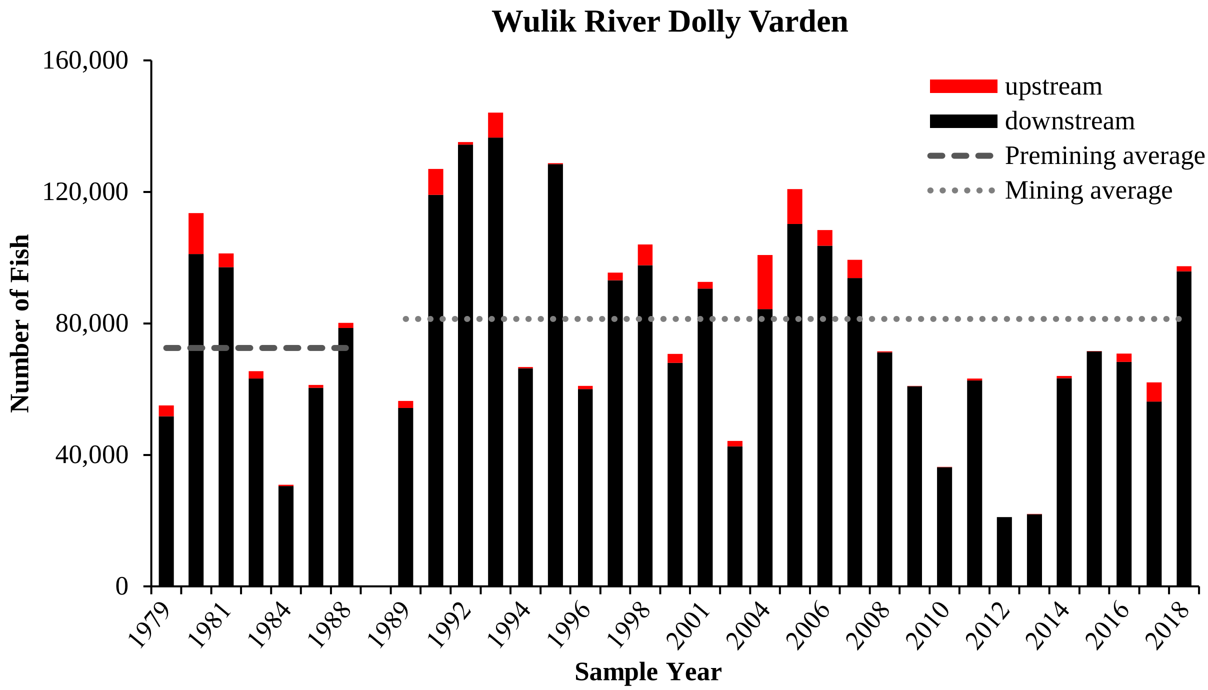


**Figure 50. Aerial survey estimates of the number of Dolly Varden in the Wulik River just prior to freeze up, 1979-2018. Red indicates fish that were upstream of the mouth of Ikalukrok Creek, and black denotes fish that were downstream.**

Fall estimates of Dolly Varden have varied annually and reached their lowest (21,084 fish) number in 2012, but then increased in fall 2014 (63,951 fish) and were relatively stable through 2017 (Figure 50 and Table 2). The fall 2018 estimate was 97,385 fish, the highest estimate since 2008. This year's numbers are from the October 5 survey, but another survey was conducted earlier in the year, September 22 – 23. The estimated number of Dolly Varden from that survey was 74,487 fish. Around 23,000 additional overwintering Dolly Varden moved into the Wulik River in the 12-day span between surveys, indicating that later surveys may be more accurate in estimating the overwintering population.

**Table 2. Estimated number of Dolly Varden in the Wulik River, for select years prior to and after mining began at the Red Dog Mine, 1979-2018.**

| Year | Wulik River upstream of Ikalukrok Creek | Wulik River downstream of Ikalukrok Creek | Total Fish | % of fish downstream 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 |
| 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 |

[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

Annual chum salmon escapement is estimated in Ikalukrok Creek from its confluence with the Wulik River upstream to Dudd Creek (Figure 51). An aerial survey was flown using an R-66 helicopter on October 5, 2018 and an estimated 1,229 live and dead chum salmon were observed in Ikalukrok Creek. Weather conditions were excellent with mostly clear skies and light winds. All chum salmon were located below Station 160 on Ikalukrok Creek, the furthest downstream location at which the instream TDS limits apply (500 mg/L TDS from July 25 through the end of the discharge season).

Counts of chum salmon in Ikalukrok Creek in 1990 and 1991 (mine discharge began in 1989) were lower than reported in baseline studies in 1981 and 1982. It should be noted that the reported number of chum salmon in 1981 was an extrapolation based on aerial photographs, and therefore, is not comparable to the aerial survey dataset.

Annual post-mining aerial surveys were initiated in 1990. Based on the number of chum salmon counted in the Ikalukrok Creek drainage during 1981 and 1982 and recognizing that the 1981 estimate was an extrapolation, data collected suggest that the chum salmon population has recovered to its pre-mining level.

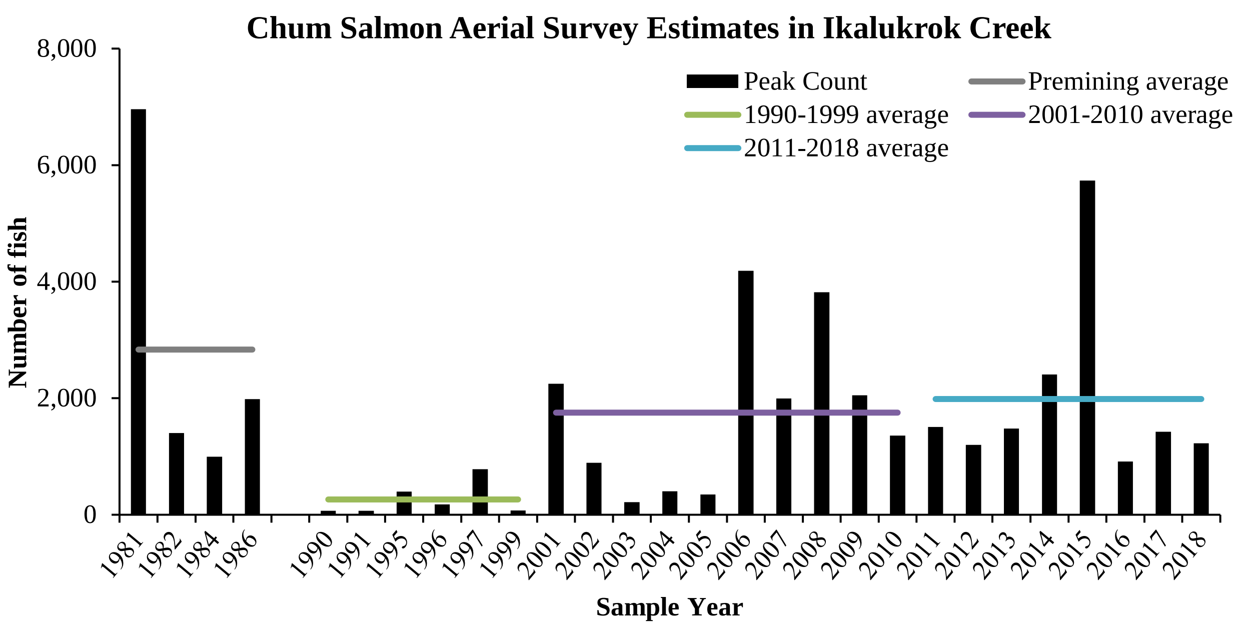


**Figure 51. Peak estimates of chum salmon escapement in Ikalukrok Creek. Note that the 1981 count was an estimate based on extrapolation from aerial photographs. The chum salmon spawning reaches are concentrated in select areas along the surveyed reach of the creek.**

## Dolly Varden, Juveniles

Limited pre-mining juvenile Dolly Varden distribution data are available for streams in the Red Dog Mine area. Houghton and Hilgert (1983) identified Anxiety Ridge Creek as the most productive system in the project area. They also reported finding only one Dolly Varden in the North Fork Red Dog Creek drainage and presumed it was a resident fish. Surveys along Mainstem Red Dog Creek reported either few fish or no fish, and in some cases mortalities of small juvenile Dolly Varden and Arctic grayling fry (Ward and Olson 1980, EVS Consultants Ltd and Ott Water Engineers 1983).

Juvenile Dolly Varden have been sampled in streams within the Red Dog Mine area since 1990. In 1992, new sample sites were added, and the number of minnow traps was increased to 10 per sample reach. Under the modified program that began in 2010, nine sites are now sampled with 10 minnow traps per sample reach, typically with around 24 hrs of effort in early-to-mid August (Table 3, Appendix 10). Seven of these sites are unchanged in location and the new Station 160 corresponds to Station 7 – instead of being immediately downstream of Dudd Creek, it is now located about 7 km downstream.

**Table 3. Location of juvenile Dolly Varden sample sites.[1]**

| Site Name | Station No. | Year Sampling Began |
|---|---|---|
| Evaingiknuk Creek | | 1990 |
| Anxiety Ridge Creek | | 1990 |
| Buddy Creek | | 1996 |
| North Fork Red Dog Creek | 12 | 1993 |
| Mainstem Red Dog Creek | 151 | 1995 |
| Mainstem Red Dog Creek | 10 | 1996 |
| Ikalukrok Creek above Mainstem | 9 | 1996 |
| Ikalukrok Creek below Dudd | 7/160 | 1990 |
| Upper North Fork Red Dog Creek | | 2014 |

[1]Sampling has been performed annually at each of these sites except in 2012 and 2013, when water levels were too high to effectively sample.

## Dolly Varden Catches and Metrics

The relative abundance of juvenile Dolly Varden varies considerably among sample years (Appendix 12); however, the catches among the sample sites follow similar patterns. Generally, the CPUE (number of fish caught in 10 traps per 24-hour period) in Anxiety and Buddy creeks is higher than at the other sample reaches. In 2018, the CPUE was highest in Buddy Creek (104.3

fish/24 hours), Anxiety Ridge Creek (56.4 fish/24 hours) and Evaingiknuk Creek (10.0 fish/24 hours) and lowest in North Fork Red Dog Creek where no fish were caught (Figure 52).

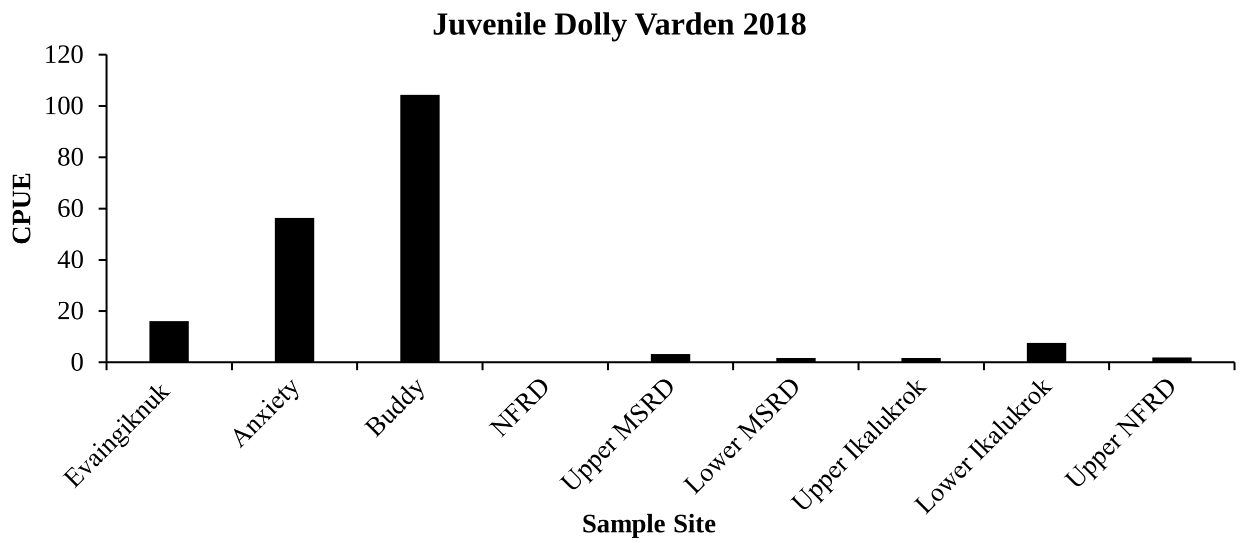


**Figure 52. CPUE for juvenile Dolly Varden in the Red Dog sample reaches in 2018.**

Natural environmental variability such as duration of breakup, patterns and magnitude of rainfall, ambient air temperatures, and the strength of the age-1 cohort affect distribution of juveniles and relative abundance. The most important factor is probably the strength of the age-1 cohort, which is directly related to number of spawners, spawning success, and survival the previous winter. The CPUE for juvenile Dolly Varden in Anxiety Ridge and Buddy creeks from 1997 to 2018 reflects the high degree of variability among sample years (Figure 53).

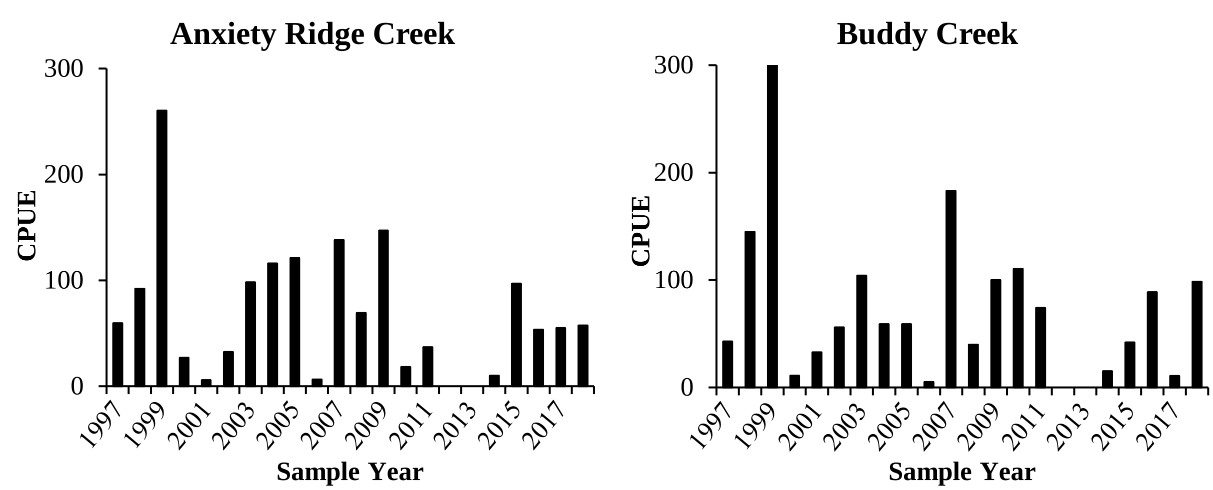


**Figure 53. CPUE of juvenile Dolly Varden in Anxiety Ridge and Buddy creeks, 1997–2018.**

CPUE in lower Mainstem Red Dog Creek has ranged from a low of 0.0 in 2004 to a high of 73.3 in 1999 (Figure 54). The highest catches in Anxiety Ridge and Buddy creeks also occurred in 1999. Catches since 2000 in lower Mainstem Red Dog Creek have remained low, but relatively consistent. Use of lower Mainstem Red Dog Creek by juvenile Dolly Varden is substantially greater than what was found by Houghton and Hilgert (1983) during baseline studies before mine development.

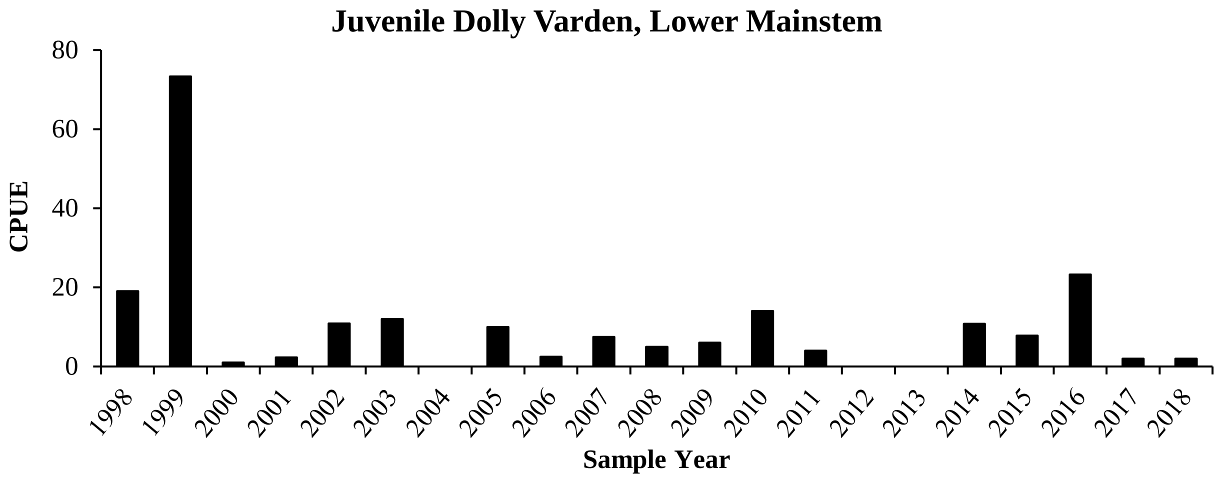


**Figure 54. CPUE of juvenile Dolly Varden in Lower Mainstem Red Dog Creek.**

Anadromous Dolly Varden spend at least one year in freshwater before their migration to the marine environment (DeCicco 1990). Adult Dolly Varden collected from the Wulik River (1999 to 2018) had an average freshwater residency of 2.9 ± 0.6 years (1 SD, n = 159). Based on length frequency distributions for juvenile Dolly Varden captured in 2018, it is likely most fish were age 1+. Small Dolly Varden (< 70 mm FL) captured in late July and August are likely age 0 fish. In 2018 only four captured fish were < 70 mm FL (Figure 55).

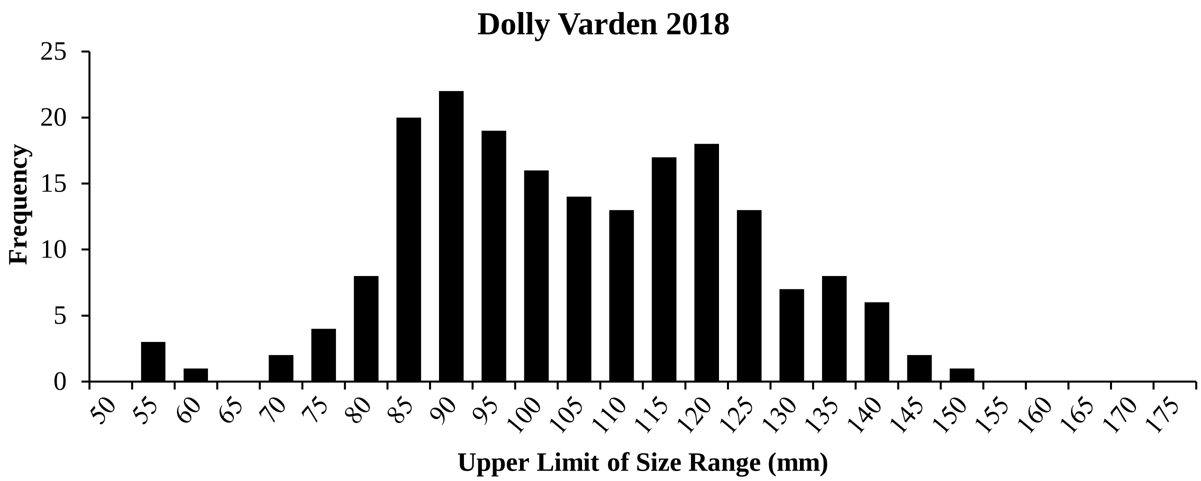


**Figure 55. Length frequency distribution of Dolly Varden in the Ikalukrok Creek drainage in fall 2018.**

In the Ikalukrok Creek drainage, some Dolly Varden are occasionally captured that are > 145 mm FL and sexually mature. Most of these fish are residents that have not out-migrated to the marine environment. These resident fish are identified by their coloration (orange spots and white edges on the pelvic fins) and sexual condition (milt observed). These sexually mature resident Dolly Varden can be contrasted to the anadromous form, which can attain over 600 mm FL and has very distinctive coloration in the fall, prior to spawning.

During spring each year, fyke net(s) are fished in North Fork Red Dog Creek for the primary purpose of catching Arctic grayling. However, Dolly Varden are also caught in the fyke nets and these fish are generally larger than those caught later in the summer in minnow traps, due in part to the inability of larger fish to enter the minnow traps. In spring 2018, six Dolly Varden were caught in the fyke nets ranging from 75 mm to 295 mm, with an average size of 166 mm FL (Figure 56). Many of the Dolly Varden caught in North Fork Red Dog Creek in the spring are the resident form.

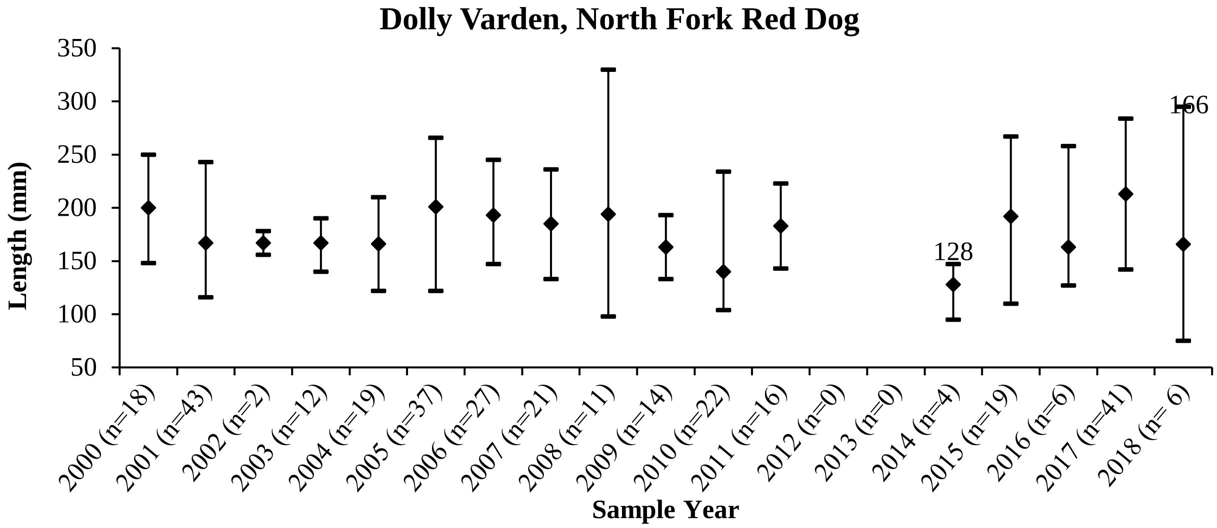


**Figure 56. Dolly Varden caught in fyke nets fished in North Fork Red Dog Creek in spring during the Arctic grayling spawning run. Average, maximum, and minimum lengths are shown for each sample year. Selected average lengths are shown.**

### Arctic Grayling, Red Dog Creek Drainage

Pre-mining, Middle Fork Red Dog Creek flowed through naturally occurring near-surface ore bodies, and as a result, had degraded water quality with high metals content. Fish avoided Middle Fork Red Dog Creek but used North Fork Red Dog Creek as it had lower metals concentrations. The water quality in Mainstem Red Dog Creek was negatively impacted by input from Middle Fork Red Dog Creek, although that impact was somewhat ameliorated by North Fork Red Dog Creek. Arctic grayling adults migrated through Mainstem Red Dog Creek in the spring when flows were high and metals concentrations were low to reach spawning grounds in North Fork Red Dog Creek (Ward and Olsen 1980, EVS and Ott Water Engineers 1983, and Houghton and Hilgert 1983). None of the historical reports indicated that Arctic grayling spawned in Mainstem Red Dog Creek. Arctic grayling fry reared in North Fork Red Dog Creek and were displaced downstream by high-water events or outmigrated as water temperatures cooled in the fall. Only a few juvenile Arctic grayling were collected in North Fork Red Dog Creek prior to mine development. Dolly Varden and Arctic grayling fry mortality was reported in Mainstem Red Dog Creek before mine development by Ward and Olsen (1980) and EVS Consultants and Ott Water Engineers (1983). Since 1994 Arctic grayling have been documented using Mainstem Red Dog Creek and no fish mortality events have been observed. Presently, spawning occurs in both Mainstem Red Dog and North Fork Red Dog creeks.

Arctic grayling spawning has been monitored during the spring in North Fork Red Dog and Mainstem Red Dog creeks since 2001. The goals of this sampling effort are to document when spawning has been substantially completed in Mainstem Red Dog Creek and to monitor Arctic grayling return to North Fork Red Dog Creek. Spring water temperatures and timing of warming appear to be the key variables in determining spawning success, spawning time, fry emergence, first year growth, and likely survival. High flows during or immediately following spawning can have a negative effect on fry survival (Clark 1992).

Discharge volume and quality from the wastewater treatment facility at the Red Dog Mine are regulated to meet permit conditions. From 2001 to 2007, TDS concentrations were regulated to be less than 500 mg/L at Station 151 (Station 10) during Arctic grayling spawning. During that time frame, monitoring of Arctic grayling spawning was performed to determine when spawning was substantially completed in Mainstem Red Dog Creek, thus allowing Teck to regulate the discharge rate to comply with the post-spawning TDS limit of 1,500 mg/L at Station 151 for the rest of the ice-free season.

A TDS site-specific criterion (SSC) of 1,500 mg/L during Arctic grayling spawning was issued by ADEC and became effective on February 15, 2006. The EPA approved the 1,500 mg/L TDS SSC on April 21, 2006. The SSC developed by ADEC was based on field and laboratory studies conducted with Arctic grayling at the Red Dog Mine site (Brix and Grosell 2005). Teck regulates the wastewater discharge to ensure that TDS concentrations do not exceed the ADEC approved TDS limit of 1,500 mg/L at Station 151.

In 2018, one fyke net was set to capture Arctic grayling in North Fork Red Dog Creek from June 12 to June 18. An additional fyke net was placed upstream from June 13 to June 18. Water flow decreased throughout the fishing period, which allowed the fyke net to effectively capture fish for the duration of the sampling event. Peak daily water temperatures ranged from 3.6 to 8.3°C. Unlike 2017, there was not substantial aufeis buildup on North Fork Red Dog Creek, so the net was set in its usual location near Station 12.

Limited spawning in Mainstem Red Dog Creek could have started on June 2, when the peak daily water temperature reached 3°C (Figure 57, Table 4). Females captured in the fyke net were judged to be green or ripe and none were determined to be spent. Spawning completion date is determined based on catch of spent females in the North Fork Red Dog Creek fyke net and water temperature data and could not be determined in 2018 as no spent females were captured before sampling ended.

**Table 4. Summary of Arctic grayling spawning in Mainstem Red Dog Creek.**

| Year | Date When Limited Spawning Began (3°C) | Date When Spawning Complete | # of Days[a] Peak Temp > 4°C |
|---|---|---|---|
| 2001 | June 6 | June 15 | 6 |
| 2002 | May 29 | June 8 | 8 |
| 2003 | June 7 | June 14 | 6 |
| 2004 | May 25 | May 31 | 4 |
| 2004 | May 27 | June 6 | 9 |
| 2006 | May 30 | June 15 | 10 |
| 2007 | May 26 | June 3 | 8 |
| 2008 | June 1 | June 9 | 9 |
| 2009 | June 8 | June 13 | 4 |
| 2010[b] | May 21 | May 29 | 6 |
| 2011 | June 6 | June 9 | 4 |
| 2012 | May 27 | June 4 | 7 |
| 2013[c] | | | |
| 2014 | June 5 | June 11 | 4 |
| 2015 | May 28 | June 1 | 4 |
| 2016 | May 12 | May 20 | 8 |
| 2017 | May 31 | [d] | |
| 2018 | June 2 | [d] | |

[a]The number of days peak temperature exceeded 4°C does not include the day spawning was judged to be complete, since the fyke net is worked in the early morning prior to peak temperatures on that day.
[b]The date spawning was judged to be substantially complete was based solely on water temperature data
[c]Arctic grayling sampling was not conducted in spring 2013 due to extremely high water throughout the spring sampling period.
[d]The end of spawning could not be judged, spent females were not captured in the fyke net.

Water temperatures were consistently higher in Mainstem Red Dog Creek than in North Fork Red Dog Creek (Figure 57). This pattern has been observed for multiple years and may be due to a lack of aufeis in Middle Fork Red Dog Creek while massive aufeis exists each spring in North Fork Red Dog Creek. Lack of aufeis in Middle Fork Red Dog Creek is because baseline ground water flow has been reduced by the tailing impoundment and the excavated mine cuts with water elevations lower than the creek.

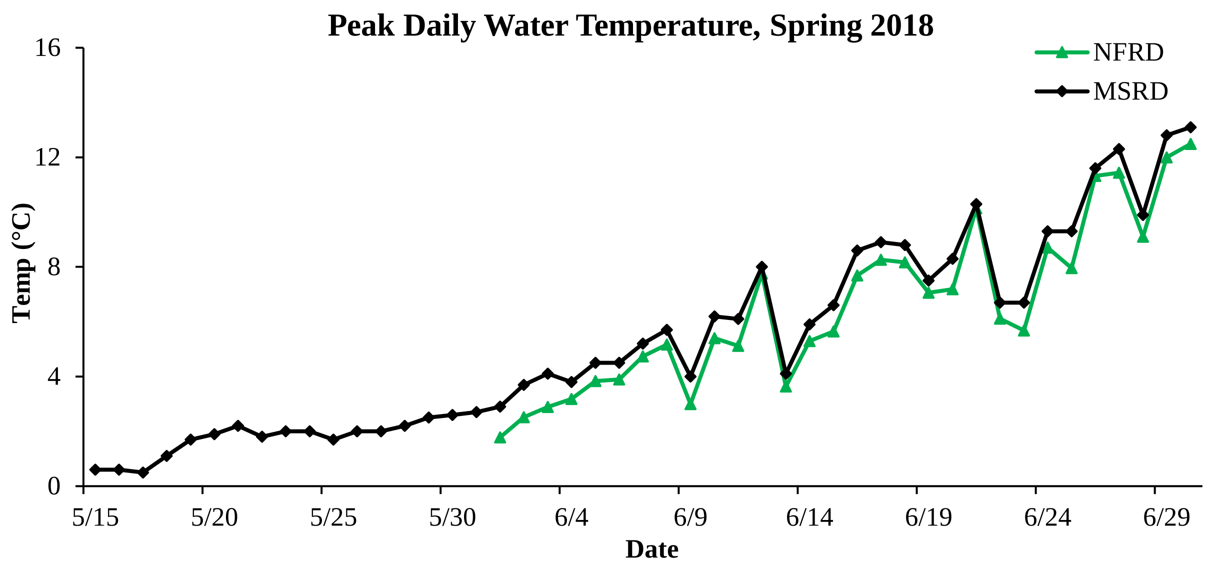


**Figure 57. Peak daily water temperatures in North Fork Red Dog (Station 12) and Mainstem Red Dog (Station 151) creeks, May and June 2018.**

In spring 2018, the catches of Arctic grayling were low, with catches peaking June 15, then leveling off for the remainder of the sampling event (Figure 58). The fyke net in North Fork Red Dog Creek captured 77 Arctic grayling, ten of which were immature. Water temperatures did not exceed 3.0°C until June 5 in North Fork Red Dog Creek, and June 2 in Mainstem Red Dog Creek.

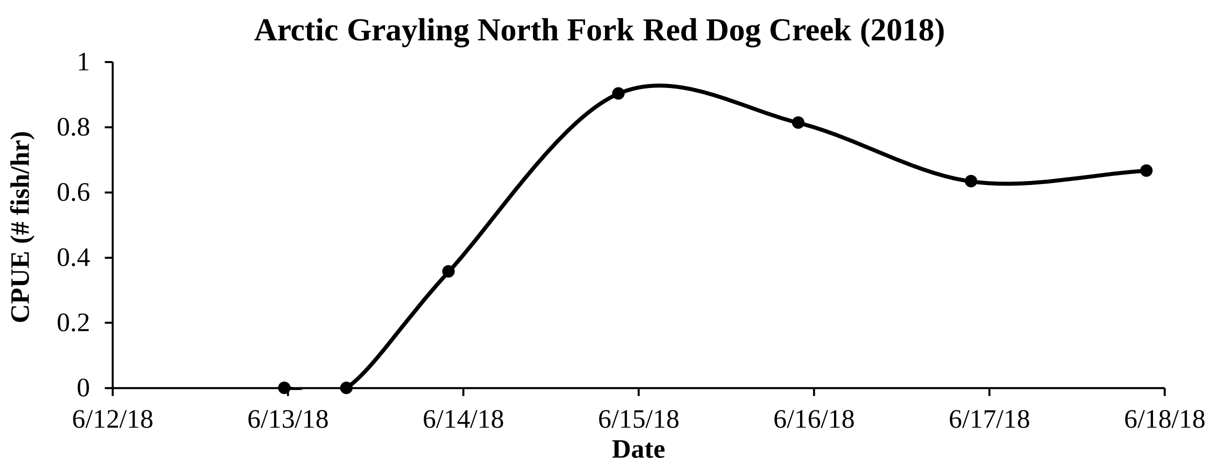


**Figure 58. The CPUE of Arctic grayling in North Fork Red Dog Creek in spring 2018.**

Drift net sampling in early July in Mainstem and North Fork Red Dog creeks resulted in the capture of six larval Arctic grayling in Mainstem Red Dog Creek and one larval Arctic grayling in North

Fork Red Dog Creek. These captures confirm successful spawning by Arctic grayling in Mainstem Red Dog and North Fork Red Dog creeks in 2018.

Recruitment of immature fish to North Fork Red Dog Creek was strong from 2007 to 2016 but was low in 2017 and 2018 (Figure 59). Recruitment may be due in part to juvenile fish leaving Bons Pond and returning to North Fork Red Dog Creek. The low catches in 2017 were likely a result of very cold water from the substantial aufeis in the North Fork Red Dog Creek, and low recruitment in 2018 could be due in part to less successful spawning in 2017 due to the aufeis.

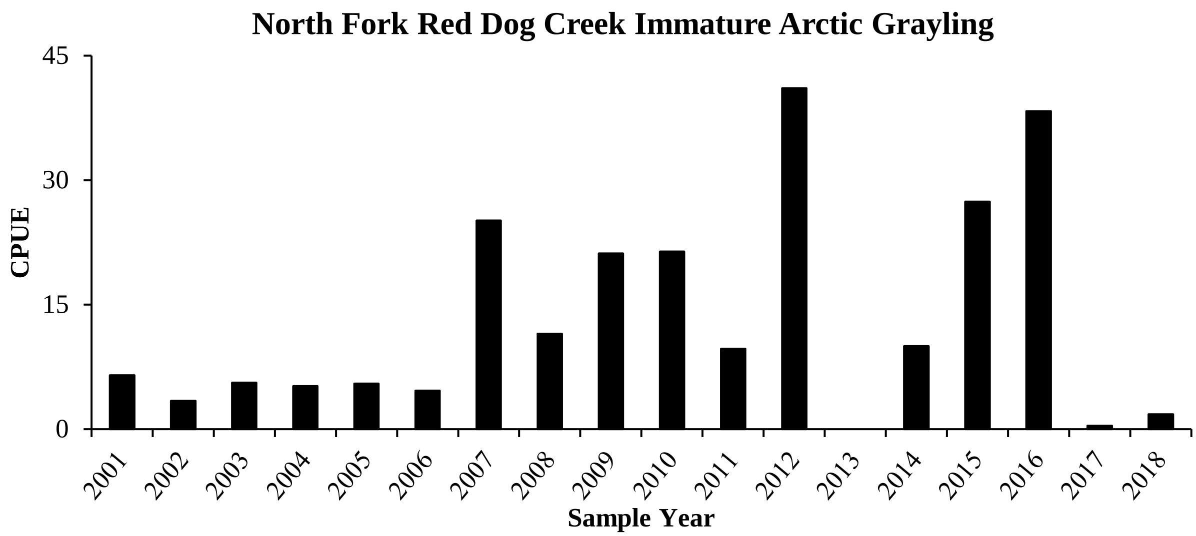


**Figure 59. Average CPUE of immature Arctic grayling in North Fork Red Dog Creek**

Catches of mature Arctic grayling in North Fork Red Dog Creek have been relatively stable since 2001, with a few exceptions (Figure 60). The highest CPUE of mature fish was 37.6 fish/day in 2007 and the lowest was 1.3 fish/day in 2014. Most of the variability in the catches is related to temporal variability in spring breakup, warming water temperatures, and sampling efficiency. Sampling events are limited to times of lower discharge (≤ 100 cfs) when fyke nets can be set, maintained, and fished effectively.

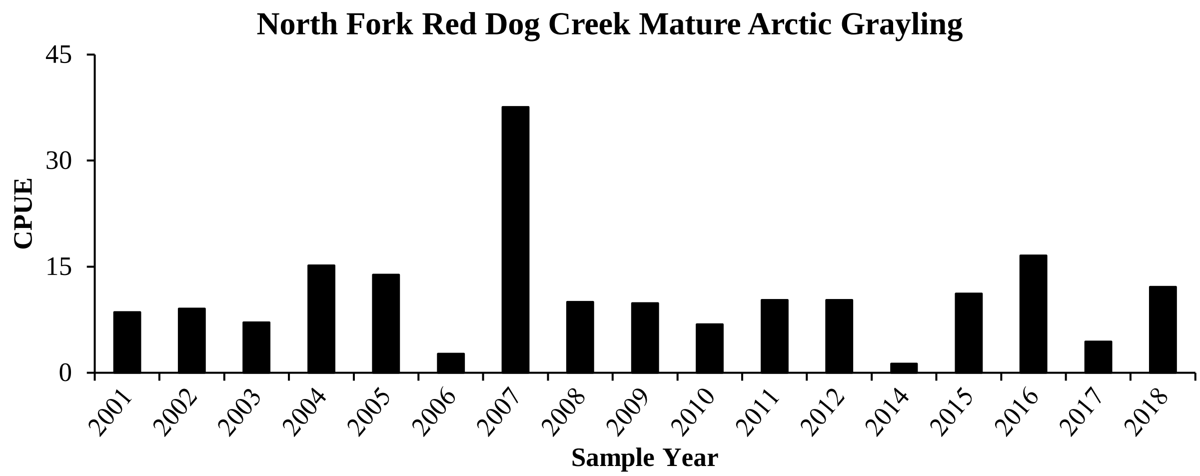


**Figure 60. Average CPUE (fish/day) of mature ("ripe" or "spent") Arctic grayling in North Fork Red Dog Creek from spring 2001 to spring 2018.**

Some of the Arctic grayling caught in the North Fork Red Dog Creek are fish that were originally tagged in Bons Pond. In 2018, two out of the six (33%) of the marked fish captured in North Fork Red Dog Creek were Bons Pond tagged fish (Figure 61). This is the highest proportion of Bons Pond tagged fish captured in the North Fork Red Dog Creek spring tagging event since 2007.

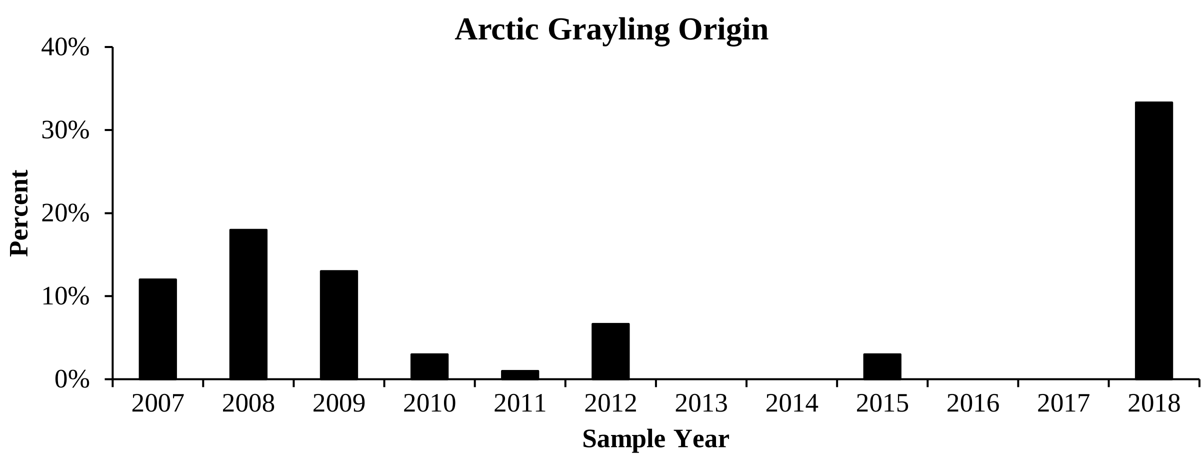


**Figure 61. Percent of Bons Pond marked fish caught in North Fork Red Dog Creek.**

The average growth rate (mm/year) for Arctic grayling between 250- and 300-mm FL when marked and at large for about one year is presented in Figure 62. Fish growth data includes only those fish captured the previous year and recaptured the following spring. Recapture numbers in any given year are low (0 to 7 fish per year).

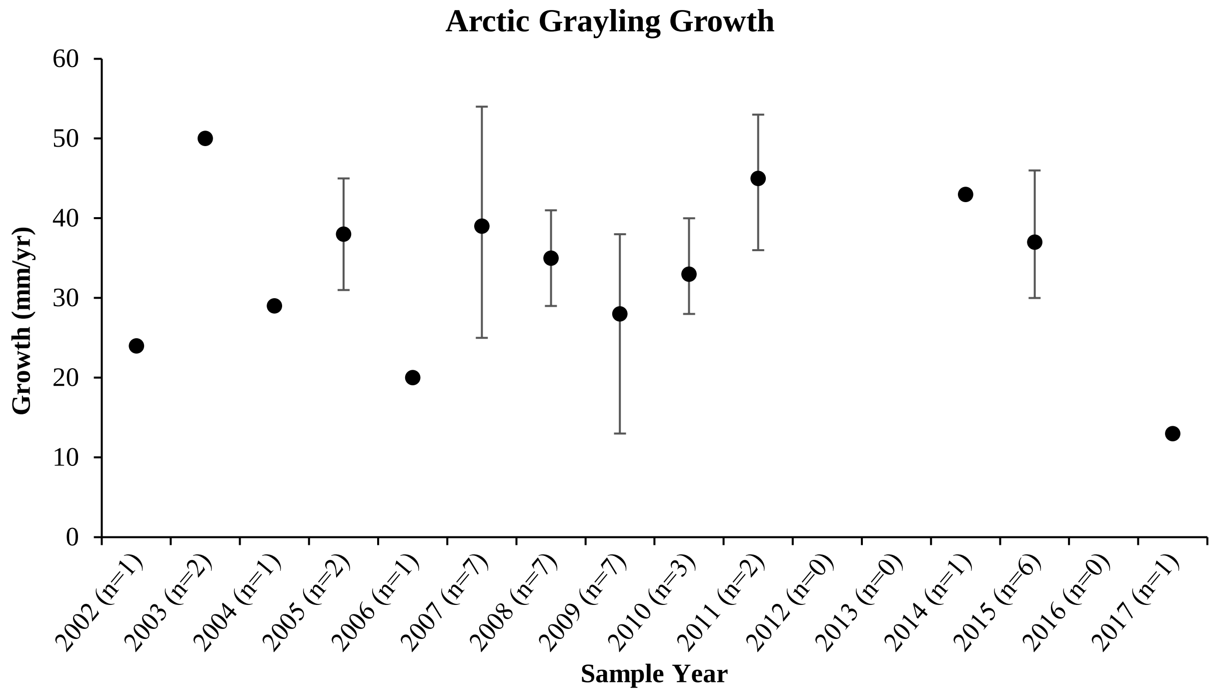


**Figure 62. Average, maximum, and minimum annual growth of Arctic grayling in North Fork Red Dog Creek for fish between 250- and 300-mm FL when marked.**

The population of Arctic grayling in North Fork Red Dog Creek, pre-mining, is not known. The highest population estimate post-mining was 1,422 fish ≥ 200 mm FL in 2010 and the lowest estimate was 905 fish ≥ 200 mm FL in 2015 (Figure 63). The confidence limits overlap for all the population estimates suggesting that there are no substantial differences among years. The population could not be estimated for 2017, as there was only one recapture in 2018.

The mean size of captured Arctic grayling in North Fork Red Dog Creek was 276 mm FL in 2018. Sizes ranged from 110 mm FL to 439 mm FL (Figure 64). Only fish over 200 mm FL were tagged.

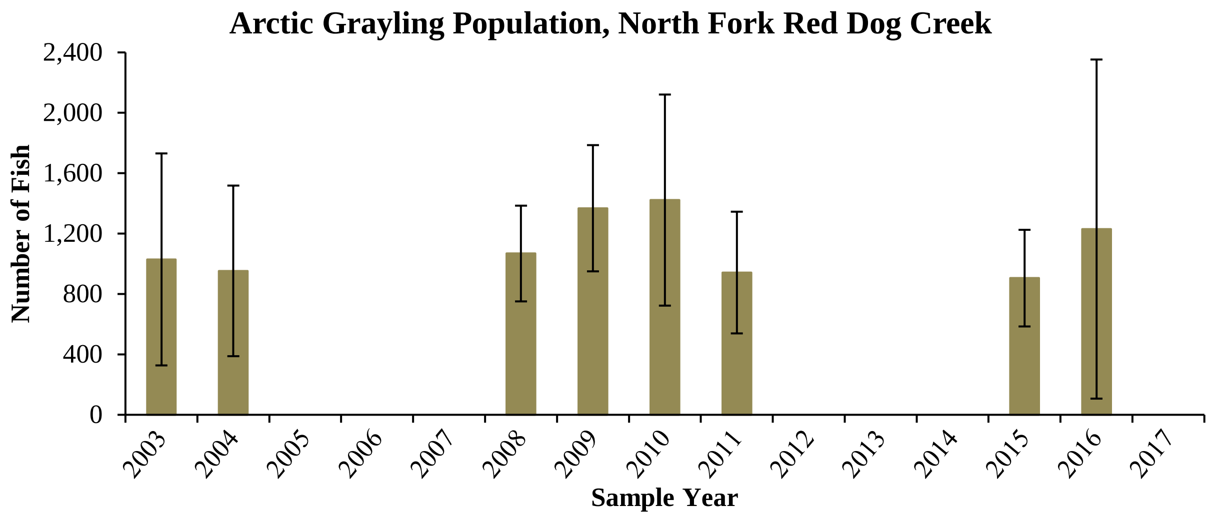


**Figure 63. The estimated Arctic grayling population (95% CI) in North Fork Red Dog Creek for fish $\geq$ 200 mm FL.**

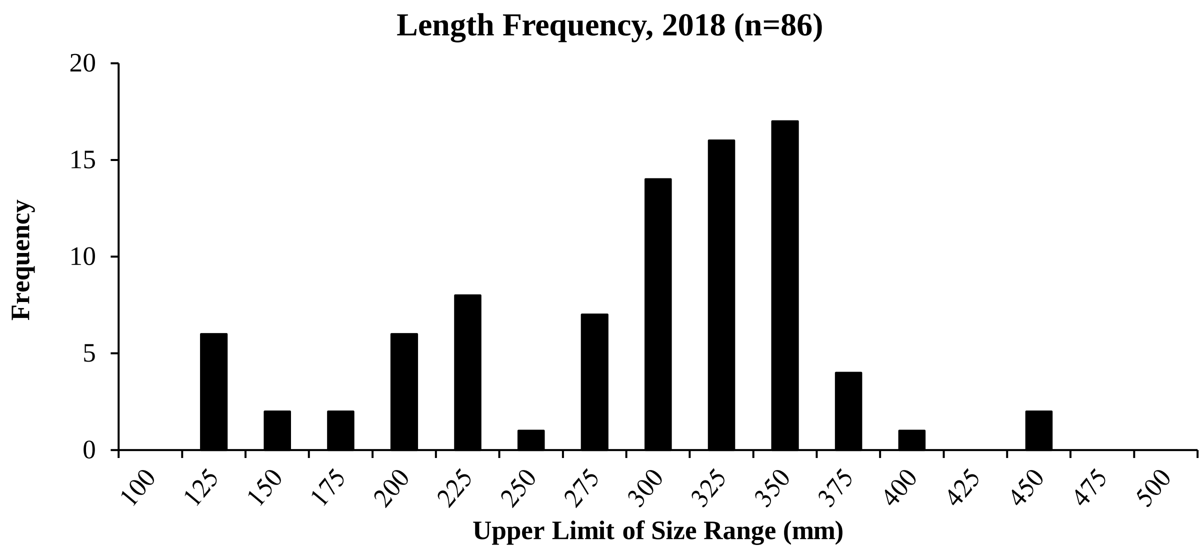


**Figure 64. Length frequency distribution of Arctic grayling (n = 86) in North Fork Red Dog Creek, spring 2018**

### Arctic Grayling, Bons Pond

Bons Pond is an impoundment created by construction of an earthen dam placed on Bons Creek. The dam was built in 1987/1988 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 65). Bons Creek flows into Buddy Creek and eventually into Ikalukrok Creek.

**Figure 65. 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 a fish transplant 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. However, in 2001 and 2002 Arctic grayling juveniles were observed in Bons Creek immediately downstream of the blast road. In summer 2003, fish sampling was conducted in Bons Pond to determine fish use and the estimated Arctic grayling population was 6,773 fish $\geq$ 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. 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 15 juvenile Arctic grayling for whole body element analysis.

Bons Creek, upstream of Bons Pond, is incised with streambanks vegetated with willows and sedges, and measures 1 to 2 m wide with depths from 0.3 to 1 m. In the sample reach, located about 200 m upstream of Bons Pond, the substrate consists of gravel in riffles, with fine sediments and organics in the pools.

A diversion ditch was constructed 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. Most of the Bons Creek drainage area is in ice-rich permafrost with thermal erosion and sediment/organic input that varies with seasonal conditions. Generally, there is a high input of sediments and organics to Bons Creek, particularly during rainfall events.

The aquatic invertebrate sampling methodology that was described earlier in this report also is simultaneously used to sample larval fish. In Bons Creek, upstream of Bons Pond, catches of Arctic grayling fry have been zero in seven of the 15 years of sampling. The highest number of Arctic grayling fry caught in the drift nets was 78 in 2007 (Figure 66).

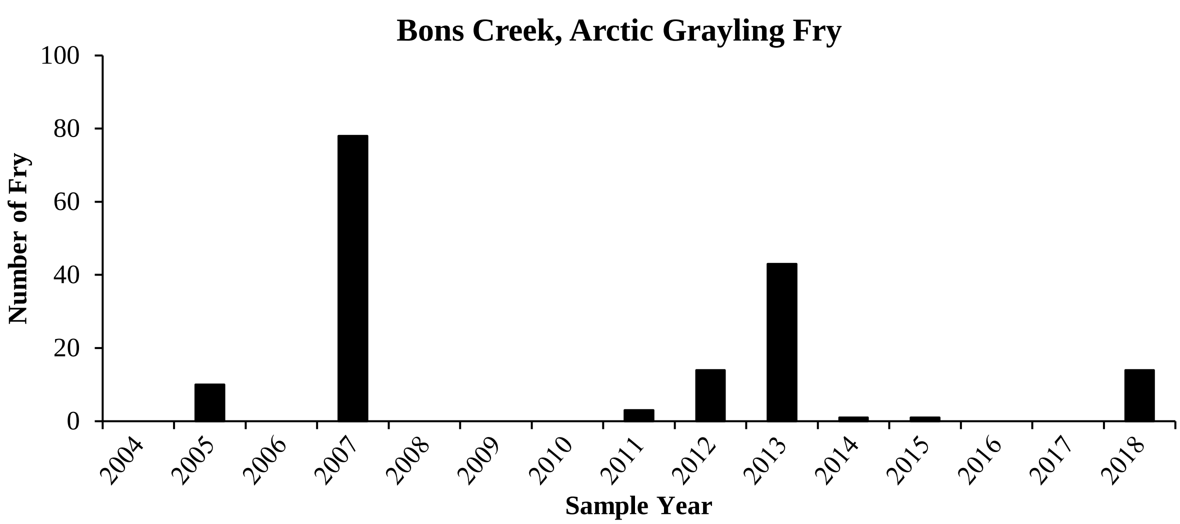


**Figure 66. Number of Arctic grayling fry caught in drift nets 2004–2018.**

A fyke net fished in Bons Creek from June 12 – 18, 2018 caught 176 unique Arctic grayling; five of these fish were too small to tag (< 200 mm FL). A fyke net set in Bons Pond resulted in the capture of three Arctic grayling too small to tag. Of the 171 fish that were ≥ 200 mm FL, seven females were retained for selenium analysis, 38 were recaptures, and 126 were tagged. The mean

CPUE (#fish/day) for the fyke net in 2018 was 29 (Figure 67). The CPUE for Arctic grayling < 200 mm FL has ranged from 1 to 38 since 2006 and catch rates in 2006, 2012, and 2014 were the highest (Figure 68).

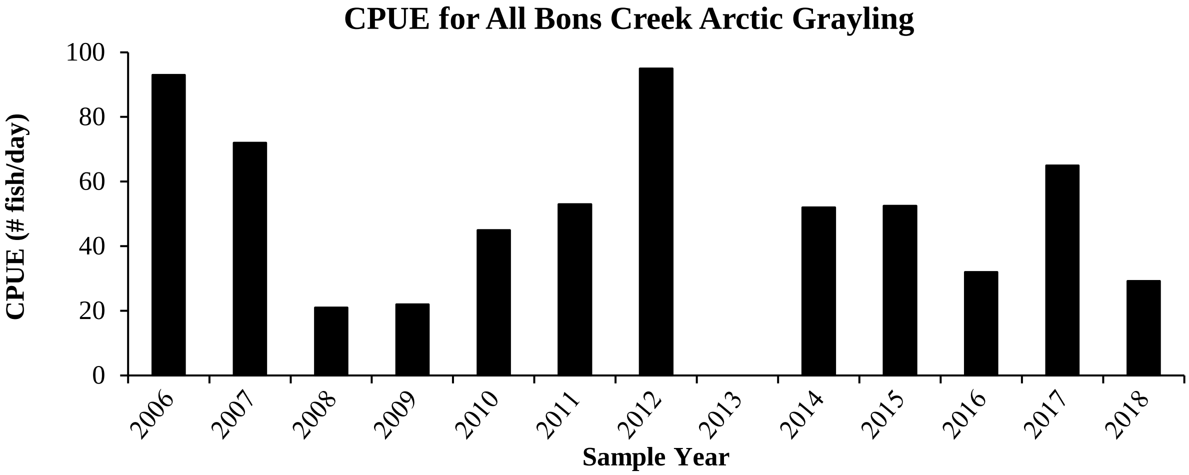


**Figure 67. CPUE for all Arctic grayling in Bons Creek 2006–2018. Sampling was not done in 2013 due to high water.**

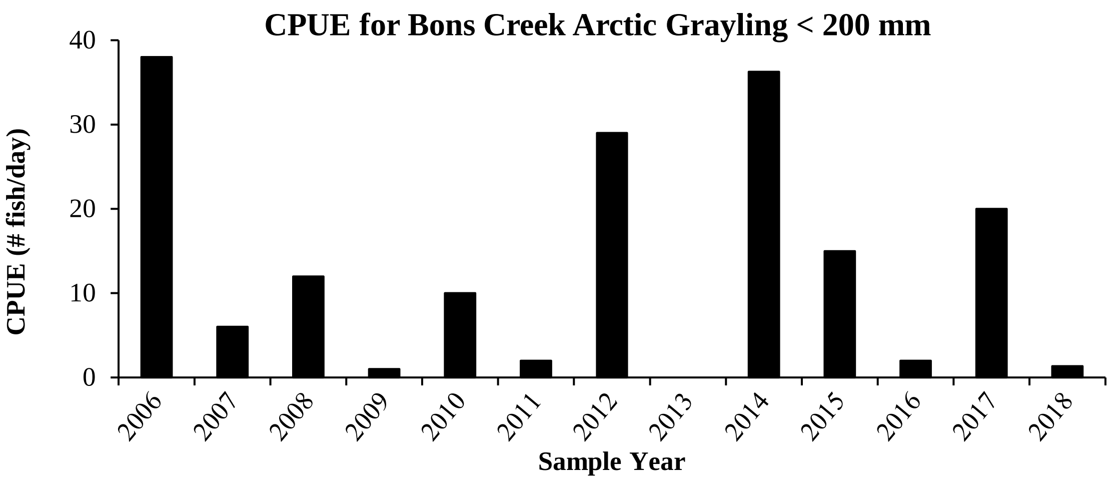


**Figure 68. CPUE for Arctic grayling < 200 mm FL in Bons Creek 2006–2018. Sampling was not done in 2013 due to high water.**

The length frequency distribution for Arctic grayling caught in fyke nets and by angling in spring 2018 is presented in Figure 69. The length frequency distribution in Bons Pond fish had been relatively consistent over the past several years, with a stable population of mature fish 300 – 390 mm. In 2017, a relatively large number of fish 80 – 100 mm (n = 45) were captured, which were likely age-1 fish. This was not the case in 2018, where very few fish <250 mm FL were captured.

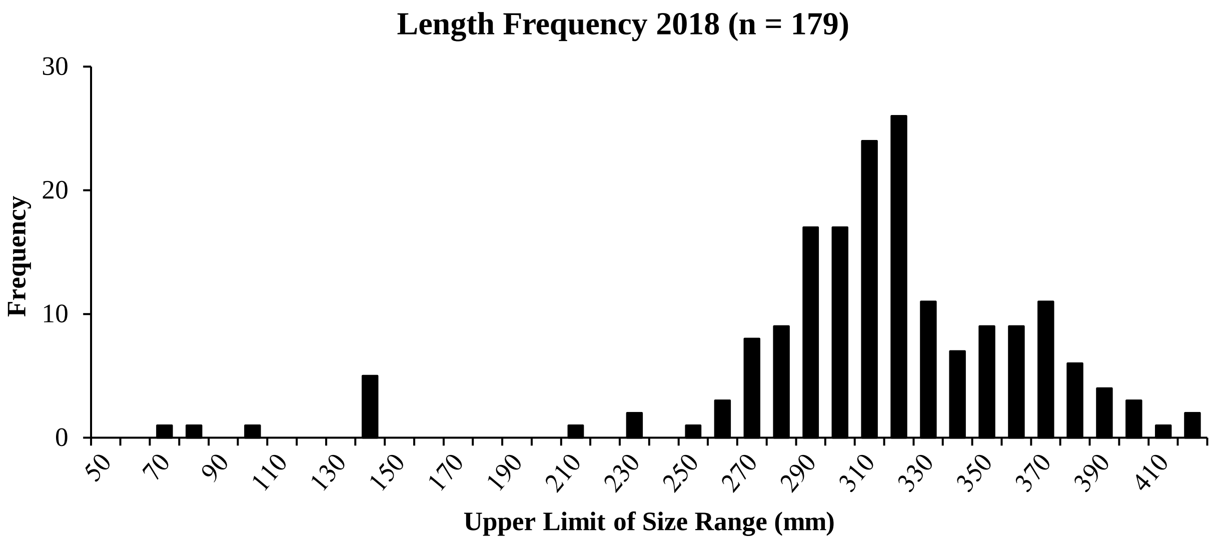


**Figure 69. Length frequency distribution of Arctic grayling in Bons Pond in spring 2018.**

Growth rates for Arctic grayling from Bons Pond are lower than for comparable sized fish from North Fork Red Dog Creek. 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 70). The average annual growth rate of 26 mm for 2017 is the highest since sampling began. Higher growth rates since 2011 could be related to the population decline which has resulted in increased food availability.

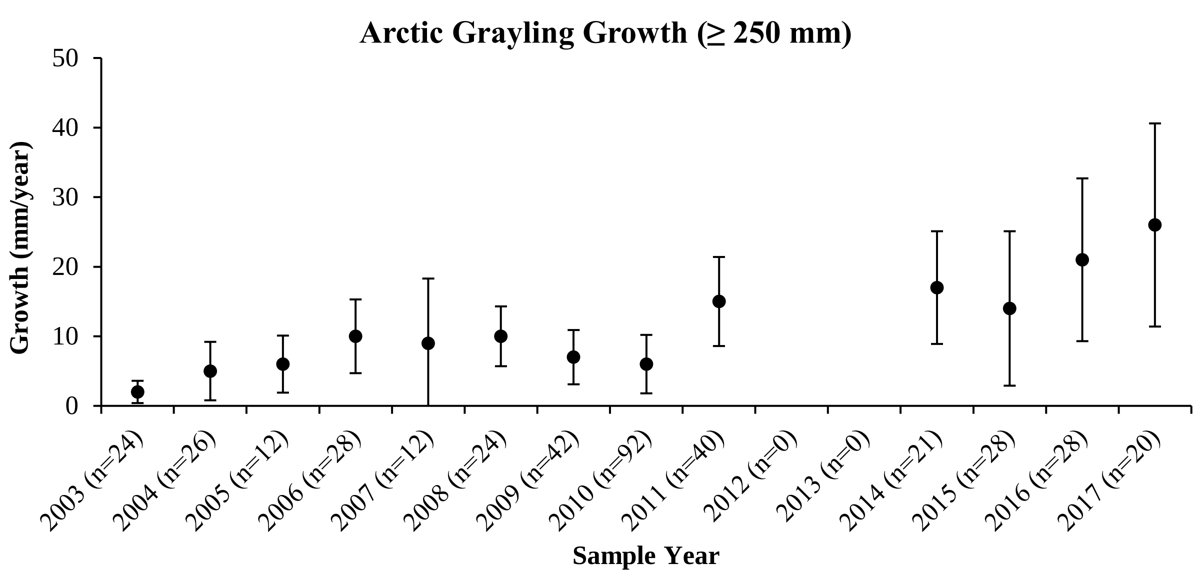


**Figure 70. Average annual growth (± 1 SD) of Arctic grayling ≥ 250 mm FL at time of marking.**

The 2017 Arctic grayling population in Bons Pond was estimated by using 2017 as the mark event (n = 198) and spring 2018 as the recapture event (n = 165). In spring 2018, 20 of the fish were recaptures from the spring 2017 mark event. Based on these values, the estimated Arctic grayling population for 2018 was 1,572 fish (95% CI, 991 to 2,153 fish) $\geq$ 200 mm FL. The population estimates show a gradual increase in the population beginning in 2014 (Figure 71).

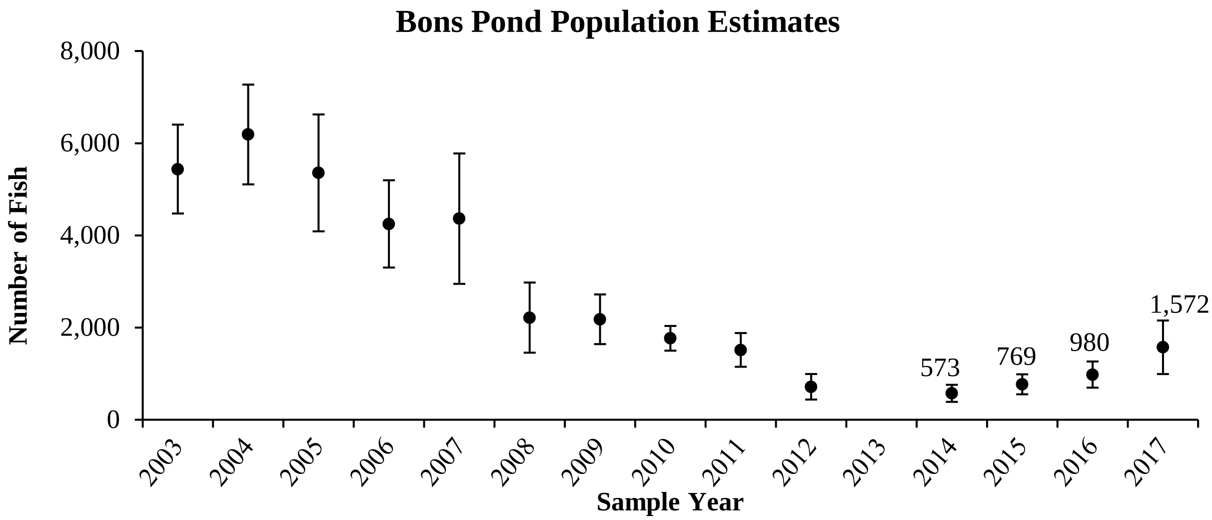


**Figure 71. Estimated Arctic grayling population (95% CI) in Bons Pond for fish $\geq$ 200 mm FL.**

### Slimy Sculpin

Prior to development of the Red Dog Mine, Houghton and Hilgert (1983) found slimy sculpin in Ikalukrok and Dudd creeks, but none were observed or caught in the Red Dog Creek drainage. However, in 1995, slimy sculpin were captured in both Mainstem Red Dog and North Fork Red Dog creeks (Weber Scannell and Ott 1998). Large (> 120 mm total length (TL)) slimy sculpin were caught with fyke nets in North Fork Red Dog Creek in some years during spring Arctic grayling sampling events. In spring 2018, one slimy sculpin was caught. Large sculpin are likely following the Arctic grayling to feed on their eggs and they may spawn in North Fork Red Dog Creek.

Minnow trap data (CPUE is for 10 minnow traps fished for 24 hr) since 1997 for lower Mainstem Red Dog Creek is presented in Figure 72. There is no apparent trend with CPUE which ranges from zero to a high of 8 in 2018.

In 2010, the minnow trap sample reach from Station 7 on Ikalukrok Creek was moved to a new site on the same system, upstream of Station 160. The new sample reach in Ikalukrok Creek has multiple channels, similar to the original sample site at Station 7. The water quality monitoring station was moved downstream in 2010 to ensure waters from Dudd and Ikalukrok creeks were completely mixed.

Slimy sculpin CPUE has varied from a low of 0 to a high of 24 in 2004 (Figure 72). Catches of slimy sculpin are generally higher in Ikalukrok Creek than in the other sample reaches located in North Fork Red Dog, Mainstem Red Dog, upper Ikalukrok (Station 9), Buddy, Anxiety, and Evaingiknuk creeks. These data are consistent with findings by Houghton and Hilgert (1983) in the early 1980s prior to development of the Red Dog Mine when they reported slimy sculpin to be numerous in Ikalukrok Creek. The main difference is that slimy sculpin are now also captured in the Red Dog Creek drainage.

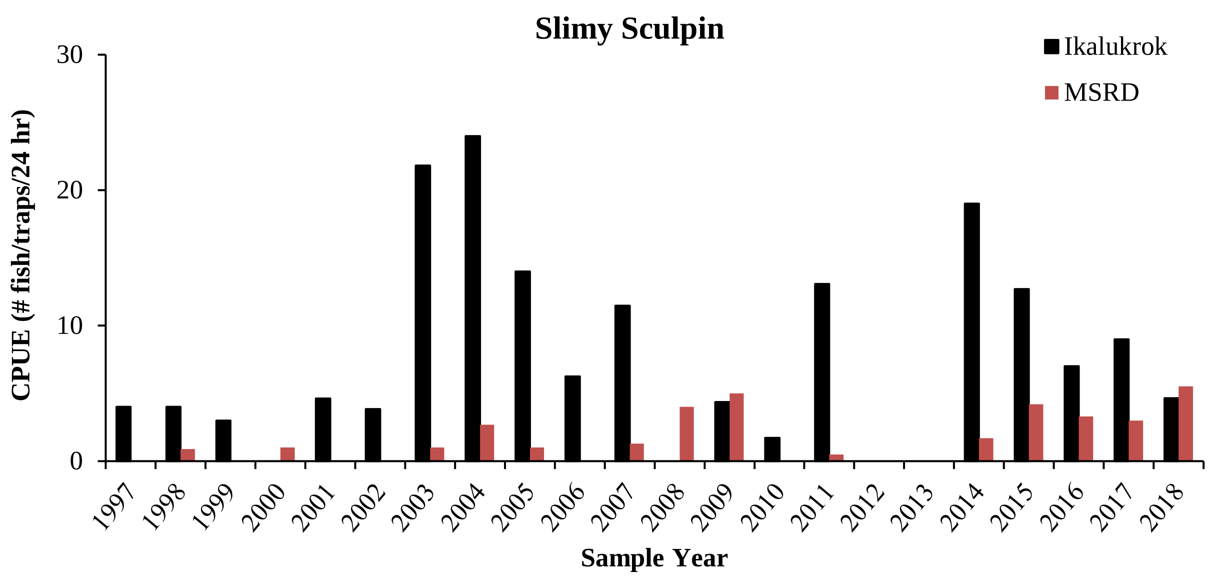


**Figure 72. CPUE of slimy sculpin caught in Ikalukrok Creek and Mainstem Red Dog Creek. No sampling was performed in 2012 or 2013 due to high water.**

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# Appendix 1. Summary of Red Dog Mine Development and Operations, 2014-2018.[a]

## 2014

- Technical Report No. 14-02 titled "Aquatic biomonitoring at Red Dog Mine, 2013 National Pollution Discharge Elimination System Permit (NPDES) No. AK-003865-2" was submitted to EPA and ADEC on February 28, 2014.
- April 8, ADEC issued Modification #1 to the APDES Permit (AK0038652) which authorized a mixing zone for selenium and adjusts Outfall 001 effluent limits for selenium. The modification became effective on May 8, 2014.
- Discharge through Outfall 001 to Middle Fork Red Dog Creek began on May 1, 2014 and ended on September 20, 2014.
- May 5, TDS concentrations at Station 151 as measured with a conductance probe exceeded the TDS limit of 1,500 mg/L – measures will be implemented (during episodic freezing conditions conductance probes will be removed and washed and checks will be made with calibrated, hand-held instruments).
- May 28, ice buildup in the clean water bypass culvert caused water to overflow. The water was collected and pumped back into the creek for about 24 hr until it was determined that it may have mixed with mine contact water. Pumping was then diverted to the mine water drainage containment system. Water quality changes downstream during this 24 hr period were undetectable at monitoring stations.
- A DIDSON® side-scanning sonar was operated in the lower Wulik River from May 30 to June 6 – over this time period 229 fish moved downstream and 52 moved upstream – water remained high and turbid during the entire sample period.
- June 5, Teck filed a court report stating that it was exercising their option not to build a pipeline to the coast.
- The spring spawning migration of Arctic grayling in Bons Pond/Bons Creek and North Fork Red Dog Creek was sampled from June 7 to 16. Adult Dolly Varden were collected for metals analyses in tissues and adult Arctic grayling were retained from Bons Creek for selenium analysis of ovaries.
- July 26 to August 2, periphyton, aquatic invertebrate, and juvenile fish sampling was done at all nine sites in accordance with permit requirements. In addition, aquatic biomonitoring was conducted in Volcano, Competition, Sourdock, and Upper North Fork Red Dog creeks.
- Two aerial surveys of Dolly Varden in the Wulik River were flown (September 21 and October 7, 2014). The chum salmon survey in Ikalukrok Creek also was done on September 21. Radio-tags were placed in 15 adult Dolly Varden in the Wulik River – these fish will be monitored next year during the spring outmigration.
- December 1, DNR administratively extended the Final Reclamation Plan approval (F20099958) to July 2, 2015.

[a] The summary of previous years of mine development and operations (1982 to 2013) can be found in Ott and Morris 2014

## 2015

- January 6, ADF&G by email indicated that we would be willing to assume regulatory oversight over Teck's maintenance of the fish weir on Middle Fork Red Dog Creek.
- January 22, ADF&G by letter reported a summary of selenium data (ovaries and livers) collected on Arctic grayling females at the Red Dog Mine, Fort Knox Mine, and from the Chena River near Fairbanks.
- February 10, Habitat (Parker Bradley) gave a presentation at the Alaska Center for the Environment Forum in Anchorage on biomonitoring at Red Dog, Fort Knox, and Greens Creek.
- Technical Report No. 15-01 titled "Aquatic biomonitoring at Red Dog Mine, 2014 Alaska Pollution Discharge Elimination System Permit (APDES) No. AK00038652" was submitted to EPA and ADEC.
- Discharge through Outfall 001 to Middle Fork Red Dog Creek began on May 12 and ended on September 19.
- April 21, ADF&G by letter proposed to collect Arctic grayling females in Fish Creek (Fort Knox Mine) and at several sites (North Fork Red Dog, Bons, and Tutak creeks) near the Red Dog Mine and have the ovaries analyzed for selenium.
- A DIDSON® side-scanning sonar was operated in the lower Wulik River from May 30 to June 13 – over this time period 26,613 fish moved downstream and 26,577 moved upstream, with much milling behavior observed.
- The spring spawning migration of Arctic grayling in Bons Pond/Bons Creek and North Fork Red Dog Creek was sampled from May 28 to June 3. Adult Dolly Varden were collected for metals analyses in tissues and adult Arctic grayling were retained from Bons, North Fork Red Dog, and Tutak creeks for selenium analysis of ovaries.
- June 30, the fish protection barrier on Middle Fork Red Dog Creek was inspected by Teck
- July 9 - 12, periphyton and aquatic invertebrate sampling was done at all nine sites in accordance with permit requirements. In addition, aquatic biomonitoring was conducted at seven sites near the Anarraaq Prospect and at one site in Upper North Fork Red Dog creek.
- July 29 - August 3, juvenile fish sampling was done at all nine sites in accordance with permit requirements. In addition, juvenile fish sampling was conducted at seven sites near the Anarraaq Prospect.
- September 13 and 15, two aerial surveys were conducted: one on the Wulik River and the second on Ikalukrok Creek. The estimated number of Dolly Varden in the Wulik River was 71,484. The estimated number of chum salmon in Ikalukrok Creek was 5,733.
- September 30, DNR by letter extended the approval of the Red Dog Mine Reclamation Plan.
- October 22, ADF&G by letter provided a summary of Wulik River and Ikalukrok Creek aerial surveys for Dolly Varden and chum salmon.
- November 18, ADF&G by letter provided a copy of the report titled "Red Dog Mine June 2015 Wulik River Dolly Varden Enumeration Report" that summarized work done by Sport Fish Division in spring 2014 and 2015.

## 2016

- Technical Report No. 16-01 titled "Aquatic biomonitoring at Red Dog Mine, 2015 Alaska Pollution Discharge Elimination System Permit (APDES) No. AK00038652" was submitted to EPA and ADEC on February 27.
- April 15, ADF&G, by letter, submitted the work plan for fish and aquatic taxa studies to be conducted from July 1, 2016 to June 30, 2017.
- Discharge through Outfall 001 to Middle Fork Red Dog Creek began on May 1 and ended on September 24.
- The spring spawning migration of Arctic grayling in Bons Pond/Bons Creek and North Fork Red Dog Creek was sampled from May 18 to 23. Adult Dolly Varden were collected for element analyses in tissues and adult Arctic grayling were retained from Bons and North Fork Red Dog creeks for selenium analysis of ovaries.
- July 2 to 5, periphyton and aquatic invertebrate sampling were done at all nine sites in accordance with permit requirements. In addition, aquatic biomonitoring (periphyton and aquatic invertebrates) was conducted at several sites near the Anarraaq Prospect and at one site in Upper North Fork Red Dog creek.
- August 4 to 7, juvenile fish sampling using minnow traps was conducted at all the APDES sample sites and at sites located in the vicinity of the Anarraaq Prospect.
- September 28, DNR issued the reclamation plan approval.
- September 28, Teck, by letter, submitted their field inspection of the Fish Protection Barrier on Middle Fork Red Dog Creek.
- Aerial surveys for Dolly Varden and chum salmon were conducted in September and October. Chum salmon numbers (live and dead) in Ikalukrok Creek were estimated at 913 fish on September 15. The total count of Dolly Varden in the Wulik River was 56,818 in September and 70,802 in October.

## 2017

- February 8, ADEC notified Teck that the aquatic biomonitoring report for 2016 data deadline was extended to May 15.
- March 17, ADF&G by email provided comments regarding operation of a new water treatment plant for the construction camp.
- March 21, ADF&G by email asked questions about an ore spill in the vicinity of Buddy Creek.
- May 7, discharge through Outfall 001 to Middle Fork Red Dog Creek began, ended on September 23.
- May 15, ADF&G emailed Technical Report No. 17-07 "Aquatic Biomonitoring at Red Dog Mine, 2016" to DEC.
- May 23, ADF&G by email provided input to Teck regarding the expansion of the waste rock dump to the south – recommendation was to stay north of Bons Creek making sure a buffer remained.
- May 28 - June 4, 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 element analyses in tissues and adult Arctic grayling were retained from Bons and North Fork Red Dog creeks for selenium analysis of ovaries.
- The spring sampling effort for Arctic grayling also included Little Creek, a Tutak River tributary. Little Creek was added as a sample site for female Arctic grayling as North Fork Red Dog Creek was completely inundated with aufeis.
- June 8, DNR by email notified the COE that changes to state permits (DNR and DEC) would be required for expansion of the waste rock storage facility.
- July 10, Teck notified ADF&G by letter of snow/ice work at bridges and culverts conducted during spring.
- July 2 - 5, periphyton and aquatic invertebrate sampling were done at all nine sites in accordance with permit requirements. In addition, aquatic biomonitoring (periphyton and aquatic invertebrates) was conducted at several sites near the Anarraaq Prospect and at one site in Upper North Fork Red Dog creek.
- July 12, ADF&G by email provided input to Teck regarding access, exploratory road, to the Anarraaq and Aktigiruq prospects which involves multiple stream crossings of Ikalukrok Creek and one crossing of North Fork Red Dog Creek.
- July 27, a drill cuttings spill was reported near Barb Creek.
- July 28, ADEC issued the new APDES permit (AK0038652) for discharge of water at Outfall 001 to Middle Fork Red Dog Creek.
- August 2 - 9, juvenile Dolly Varden sampling performed at all the APDES sample sites and all sites located in the vicinity of the Anarraaq/Aktigiruq prospect. Water levels at all sites were unusually high.
- September 1, renewed APDES Permit No. AK0038652 became effective.
- October 2, DeCicco provided a summary of aerial surveys for Dolly Varden in Wulik River and chum salmon in Ikalukrok Creek and he collected seven adult Dolly Varden for tissue analyses.
- October 30, ADF&G by email to DEC distributed Technical Report 17-09 titled "Methods for Aquatic Life Monitoring at the Red Dog Mine Site" to satisfy a condition in the new APDES permit issued by ADEC.

## 2018

- January 9, ADF&G by email provided comments to ADNR regarding material extractions at Red Dog MS-9 and Red Dog DD-2.
- April 25, ADF&G by email provided information to Teck on mercury in fish tissues in regards to human consumption.
- May 7, ADF&G by email transmitted Technical Report No. 18-06 “Aquatic Biomonitoring at Red Dog Mine, 2017” to DEC.
- June 12-18, 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 element analyses in tissues and adult Arctic grayling were retained from Bons and North Fork Red Dog creeks for selenium analysis of ovaries.
- June 25, ADNR DMLW issued Red Dog Mine Reclamation Plan Amendment Approval F20169958.01 (RPA) to expand the Tailings Storage Facility and Main Waste Dump.
- July 13, ADNR DMLW issued a Certificate of Approval to Modify a Dam to Teck for the Stage XI raise on the Red Dog Tailings Main Dam (NID ID# AK00201).
- July 9 - 16, periphyton and aquatic invertebrate sampling were done at all nine sites in accordance with permit requirements. In addition, aquatic biomonitoring (periphyton and aquatic invertebrates) was conducted at sites near the Anarraaq Prospect and at one site in Upper North Fork Red Dog creek.
- August 1, Teck issued a file note regarding orange precipitate in Red Dog Creek apparently caused by one or both of two natural seeps above the diversion system.
- August 13, Teck issued a 5-day notification letter to ADEC explaining the cause of the exceedance of allowed TDS values at Station 151.
- August 2 - 9, juvenile Dolly Varden sampling performed at all the APDES sample sites and sites located in the vicinity of the Anarraaq/Aktigiruq prospect.
- October 4 - 5, ADF&G and DeCicco conducted aerial surveys for Dolly Varden in Wulik River and chum salmon in Ikalukrok Creek and collected seven adult Dolly Varden for tissue analyses.

## Appendix 2. Periphyton Standing Crop, Red Dog Mine Monitoring Sites, 2018.

| 2018 Chloro Results - Red Dog | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| IDL = 0.05 mg/m2 | | | Linear Check Max = 13.39 mg/m2 | | | | | |
| EDL = 0.19 mg/m2 | | | | Phaeo Corrected | | | | |
| Daily Vial # | Site | Date Analyzed | Vial Chl a | **Chl a mg/m$^2$** | **Chl a mg/m$^2$** | **664/665 Ratio** | Chl b mg/m$^2$ | Chl c mg/m$^2$ |
| 3 | blank | 11/30/18 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 |
| 21 | Bons u/s Buddy Sta 220 | 11/30/18 | 1.29 | 5.18 | 4.38 | 1.53 | 2.66 | 0.25 |
| 23 | Bons u/s Buddy Sta 220 | 11/30/18 | 4.81 | 19.23 | 13.99 | 1.44 | 5.53 | 0.69 |
| 25 | Bons u/s Buddy Sta 220 | 11/30/18 | 2.56 | 10.24 | 8.54 | 1.53 | 3.28 | 0.37 |
| 27 | Bons u/s Buddy Sta 220 duplicate | 11/30/18 | 2.58 | 10.31 | 8.33 | 1.51 | 3.45 | 0.66 |
| 29 | Bons u/s Buddy Sta 220 | 11/30/18 | 3.29 | 13.17 | 10.36 | 1.49 | 4.38 | 0.43 |
| 31 | Bons u/s Buddy Sta 220 | 11/30/18 | 3.21 | 12.84 | 10.89 | 1.55 | 3.85 | 0.27 |
| 33 | Bons u/s Buddy Sta 220 | 11/30/18 | 4.79 | 19.15 | 15.91 | 1.54 | 3.70 | 0.67 |
| 35 | Bons u/s Buddy Sta 220 | 11/30/18 | 1.86 | 7.43 | 5.87 | 1.50 | 1.76 | 0.81 |
| 37 | Bons u/s Buddy Sta 220 | 11/30/18 | 1.01 | 4.02 | 3.42 | 1.56 | 0.48 | 0.23 |
| 39 | Bons u/s Buddy Sta 220 | 11/30/18 | 4.75 | 19.00 | 14.31 | 1.46 | 6.24 | 0.11 |
| 41 | Bons u/s Buddy Sta 220 | 11/30/18 | 2.51 | 10.04 | 7.69 | 1.47 | 2.31 | 0.15 |
| 43 | Buddy u/s road Sta 221 | 11/30/18 | 2.03 | 8.13 | 7.37 | 1.62 | 1.08 | 0.48 |
| 45 | Buddy u/s road Sta 221 | 11/30/18 | 1.07 | 4.28 | 3.84 | 1.62 | 0.03 | 0.41 |
| 47 | Buddy u/s road Sta 221 | 11/30/18 | 0.51 | 2.05 | 1.71 | 1.55 | 0.02 | 0.19 |
| 49 | Buddy u/s road Sta 221 | 11/30/18 | 2.34 | 9.36 | 8.44 | 1.63 | 0.00 | 0.85 |
| 51 | Buddy u/s road Sta 221 | 11/30/18 | 0.56 | 2.24 | 1.92 | 1.58 | 0.00 | 0.26 |
| 53 | Buddy u/s road Sta 221 | 11/30/18 | 0.60 | 2.41 | 2.24 | 1.66 | 0.08 | 0.24 |
| 55 | Buddy u/s road Sta 221 | 11/30/18 | 0.96 | 3.83 | 3.42 | 1.62 | 0.00 | 0.41 |
| 57 | Buddy u/s road Sta 221 | 11/30/18 | 1.79 | 7.15 | 6.19 | 1.59 | 0.14 | 0.50 |
| 59 | Buddy u/s road Sta 221 | 11/30/18 | 0.88 | 3.52 | 3.10 | 1.60 | 0.00 | 0.32 |
| 61 | Buddy u/s road Sta 221 | 11/30/18 | 0.51 | 2.05 | 1.92 | 1.67 | 0.02 | 0.19 |
| 123 | blank | 11/30/18 | -0.01 | 0.00 | 0.00 | | 0.00 | 0 |
| 3 | blank | 12/04/18 | 0.00 | 0.00 | 0.00 | | 0.00 | 0 |
| 55 | Upper NF Red Dog | 12/04/18 | 1.66 | 6.65 | 5.98 | 1.62 | 0.06 | 0.49 |
| 57 | Upper NF Red Dog duplicate | 12/04/18 | 1.70 | 6.78 | 6.41 | 1.67 | 0.14 | 0.71 |
| 61 | Upper NF Red Dog | 12/04/18 | 0.62 | 2.46 | 2.24 | 1.64 | 0.00 | 0.26 |
| 63 | Upper NF Red Dog | 12/04/18 | 1.15 | 4.61 | 4.06 | 1.60 | 0.00 | 0.34 |
| 65 | Upper NF Red Dog | 12/04/18 | 0.55 | 2.19 | 1.92 | 1.60 | 0.00 | 0.26 |
| 67 | Upper NF Red Dog | 12/04/18 | 0.51 | 2.06 | 1.82 | 1.61 | 0.00 | 0.22 |
| 69 | Upper NF Red Dog | 12/04/18 | 0.03 | 0.14 | 0.11 | 1.50 | 0.01 | 0.05 |
| 71 | Upper NF Red Dog | 12/04/18 | 0.54 | 2.18 | 2.03 | 1.66 | 0.11 | 0.20 |
| 73 | Upper NF Red Dog | 12/04/18 | 1.84 | 7.37 | 6.73 | 1.64 | 0.27 | 0.47 |
| 75 | Upper NF Red Dog | 12/04/18 | 1.04 | 4.15 | 3.63 | 1.60 | 0.02 | 0.37 |
| 77 | Upper NF Red Dog | 12/04/18 | 0.60 | 2.42 | 2.03 | 1.56 | 0.00 | 0.37 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 99 | Bons Ck u/s pond | 12/04/18 | 0.41 | 1.65 | 1.50 | 1.64 | 0.00 | 0.00 |
| 101 | Bons Ck u/s pond | 12/04/18 | 0.31 | 1.23 | 1.07 | 1.59 | 0.03 | 0.07 |
| 103 | Bons Ck u/s pond | 12/04/18 | 0.48 | 1.91 | 1.71 | 1.62 | 0.01 | 0.14 |
| 105 | Bons Ck u/s pond | 12/04/18 | 0.43 | 1.72 | 1.50 | 1.58 | 0.18 | 0.14 |
| 107 | Bons Ck u/s pond | 12/04/18 | 0.35 | 1.42 | 1.28 | 1.63 | 0.00 | 0.14 |
| 109 | Bons Ck u/s pond | 12/04/18 | 0.69 | 2.78 | 2.46 | 1.61 | 0.06 | 0.22 |
| 111 | Bons Ck u/s pond | 12/04/18 | 0.70 | 2.78 | 2.46 | 1.61 | 0.00 | 0.15 |
| 113 | Bons Ck u/s pond | 12/04/18 | 0.41 | 1.64 | 1.50 | 1.64 | 0.07 | 0.11 |
| 115 | Bons Ck u/s pond | 12/04/18 | 0.54 | 2.14 | 1.92 | 1.62 | 0.00 | 0.17 |
| 117 | Bons Ck u/s pond | 12/04/18 | 0.33 | 1.32 | 1.17 | 1.61 | 0.00 | 0.05 |
| 119 | blank | 12/04/18 | 0.00 | 0.00 | 0.00 | | 0.00 | 0 |
| 3 | blank | 12/05/18 | 0.01 | 0.05 | 0.11 | | 0.00 | 0.09 |
| 4 | Ikalukrok u/s Red Dog Sta 9 | 12/05/18 | 0.11 | 0.45 | 0.43 | 1.67 | 0.08 | 0.20 |
| 6 | Ikalukrok u/s Red Dog Sta 9 | 12/05/18 | 0.32 | 1.27 | 1.17 | 1.65 | 0.07 | 0.23 |
| 8 | Ikalukrok u/s Red Dog Sta 9 | 12/05/18 | 0.15 | 0.59 | 0.53 | 1.63 | 0.01 | 0.18 |
| 10 | Ikalukrok u/s Red Dog Sta 9 | 12/05/18 | 0.09 | 0.37 | 0.43 | 2.00 | 0.00 | 0.08 |
| 12 | Ikalukrok u/s Red Dog Sta 9 | 12/05/18 | 0.04 | 0.18 | 0.32 | 4.00 | 0.06 | 0.11 |
| 14 | Ikalukrok u/s Red Dog Sta 9 | 12/05/18 | 0.18 | 0.73 | 0.64 | 1.60 | 0.03 | 0.13 |
| 16 | Ikalukrok u/s Red Dog Sta 9 | 12/05/18 | 0.01 | 0.04 | 0.00 | 1.00 | 0.05 | 0.06 |
| 18 | Ikalukrok u/s Red Dog Sta 9 | 12/05/18 | 0.16 | 0.63 | 0.53 | 1.56 | 0.06 | 0.24 |
| 20 | Ikalukrok u/s Red Dog Sta 9 | 12/05/18 | 0.16 | 0.63 | 0.64 | 1.75 | 0.07 | 0.15 |
| 22 | Ikalukrok u/s Red Dog Sta 9 | 12/05/18 | 0.14 | 0.54 | 0.43 | 1.50 | 0.04 | 0.09 |
| 24 | Buddy blw falls | 12/05/18 | 0.42 | 1.68 | 1.60 | 1.65 | 0.67 | 0.15 |
| 26 | Buddy blw falls | 12/05/18 | 0.72 | 2.90 | 2.67 | 1.63 | 0.88 | 0.06 |
| 28 | Buddy blw falls | 12/05/18 | 1.33 | 5.32 | 4.91 | 1.63 | 1.34 | 0.24 |
| 30 | Buddy blw falls | 12/05/18 | 0.45 | 1.81 | 1.50 | 1.54 | 0.13 | 0.22 |
| 32 | Buddy blw falls | 12/05/18 | 0.51 | 2.04 | 1.92 | 1.67 | 0.10 | 0.16 |
| 34 | Buddy blw falls | 12/05/18 | 0.95 | 3.79 | 3.52 | 1.63 | 1.14 | 0.24 |
| 36 | Buddy blw falls | 12/05/18 | 0.88 | 3.54 | 3.20 | 1.61 | 0.88 | 0.14 |
| 38 | Buddy blw falls duplicate | 12/05/18 | 0.92 | 3.67 | 3.31 | 1.61 | 0.96 | 0.25 |
| 40 | Buddy blw falls | 12/05/18 | 0.72 | 2.89 | 2.67 | 1.64 | 0.32 | 0.18 |
| 42 | Buddy blw falls | 12/05/18 | 0.30 | 1.18 | 1.17 | 1.73 | 0.04 | 0.17 |
| 44 | Buddy blw falls | 12/05/18 | 1.03 | 4.11 | 3.84 | 1.67 | 0.00 | 0.50 |
| 46 | Middle Fork Red Dog Creek Sta 20 | 12/05/18 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 |
| 47 | Middle Fork Red Dog Creek Sta 20 | 12/05/18 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 |
| 48 | Middle Fork Red Dog Creek Sta 20 | 12/05/18 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 |
| 49 | Middle Fork Red Dog Creek Sta 20 | 12/05/18 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 |
| 50 | Middle Fork Red Dog Creek Sta 20 | 12/05/18 | 0.01 | 0.04 | 0.11 | | 0.05 | 0.06 |
| 51 | Middle Fork Red Dog Creek Sta 20 | 12/05/18 | 0.02 | 0.09 | 0.11 | 2.00 | 0.02 | 0.15 |
| 53 | Middle Fork Red Dog Creek Sta 20 | 12/05/18 | 0.01 | 0.04 | 0.11 | | 0.05 | 0.06 |
| 54 | Middle Fork Red Dog Creek Sta 20 | 12/05/18 | 0.02 | 0.09 | 0.11 | 2.00 | 0.03 | 0.05 |
| 56 | Middle Fork Red Dog Creek Sta 20 | 12/05/18 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 |
| 57 | Middle Fork Red Dog Creek Sta 20 | 12/05/18 | 0.01 | 0.04 | 0.11 | | 0.05 | 0.06 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 58 | Ikalukrok d/s Dudd Sta 160 | 12/05/18 | 0.33 | 1.32 | 1.07 | 1.53 | 0.00 | 0.25 |
| 63 | Ikalukrok d/s Dudd Sta 160 | 12/05/18 | 0.18 | 0.72 | 0.75 | 1.78 | 0.10 | 0.20 |
| 65 | Ikalukrok d/s Dudd Sta 160 | 12/05/18 | 0.73 | 2.92 | 2.78 | 1.68 | 0.00 | 0.33 |
| 67 | Ikalukrok d/s Dudd Sta 160 | 12/05/18 | 0.30 | 1.19 | 1.07 | 1.63 | 0.00 | 0.20 |
| 69 | Ikalukrok d/s Dudd Sta 160 | 12/05/18 | 0.56 | 2.23 | 2.03 | 1.63 | 0.00 | 0.33 |
| 71 | Ikalukrok d/s Dudd Sta 160 | 12/05/18 | 0.40 | 1.60 | 1.50 | 1.67 | 0.01 | 0.15 |
| 73 | Ikalukrok d/s Dudd Sta 160 | 12/05/18 | 0.46 | 1.83 | 1.71 | 1.67 | 0.00 | 0.28 |
| 75 | Ikalukrok d/s Dudd Sta 160 | 12/05/18 | 0.47 | 1.87 | 1.71 | 1.64 | 0.00 | 0.27 |
| 77 | Ikalukrok d/s Dudd Sta 160 | 12/05/18 | 0.33 | 1.32 | 1.07 | 1.53 | 0.00 | 0.25 |
| 79 | Ikalukrok d/s Dudd Sta 160 | 12/05/18 | 0.25 | 1.00 | 0.85 | 1.57 | 0.00 | 0.16 |
| 81 | NF Red Dog Stn 12 | 12/05/18 | 0.92 | 3.67 | 3.20 | 1.59 | 0.26 | 0.24 |
| 83 | NF Red Dog Stn 12 | 12/05/18 | 0.34 | 1.36 | 1.28 | 1.67 | 0.12 | 0.18 |
| 85 | NF Red Dog Stn 12 | 12/05/18 | 0.95 | 3.80 | 3.10 | 1.53 | 0.44 | 0.13 |
| 87 | NF Red Dog Stn 12 | 12/05/18 | 1.60 | 6.41 | 5.55 | 1.58 | 0.92 | 0.15 |
| 89 | NF Red Dog Stn 12 | 12/05/18 | 0.41 | 1.65 | 1.50 | 1.64 | 0.00 | 0.00 |
| 91 | NF Red Dog Stn 12 | 12/05/18 | 2.48 | 9.91 | 8.44 | 1.56 | 1.02 | 0.41 |
| 93 | NF Red Dog Stn 12 | 12/05/18 | 0.73 | 2.92 | 2.67 | 1.64 | 0.00 | 0.20 |
| 95 | NF Red Dog Stn 12 | 12/05/18 | 1.24 | 4.95 | 4.06 | 1.53 | 0.91 | 0.15 |
| 97 | NF Red Dog Stn 12 | 12/05/18 | 1.58 | 6.33 | 5.23 | 1.54 | 0.14 | 0.47 |
| 99 | NF Red Dog Stn 12 | 12/05/18 | 2.05 | 8.21 | 6.73 | 1.53 | 1.17 | 0.70 |
| 101 | Mainstem Red Dog Stn 10 | 12/05/18 | 1.68 | 6.73 | 6.19 | 1.65 | 0.00 | 0.44 |
| 103 | Mainstem Red Dog Stn 10 | 12/05/18 | 1.58 | 6.32 | 5.66 | 1.62 | 0.00 | 0.27 |
| 105 | Mainstem Red Dog Stn 10 | 12/05/18 | 0.77 | 3.06 | 2.67 | 1.60 | 0.00 | 0.38 |
| 107 | Mainstem Red Dog Stn 10 | 12/05/18 | 1.53 | 6.12 | 5.77 | 1.68 | 0.00 | 0.76 |
| 109 | Mainstem Red Dog Stn 10 | 12/05/18 | 2.08 | 8.33 | 7.80 | 1.67 | 0.00 | 0.82 |
| 111 | Mainstem Red Dog Stn 10 | 12/05/18 | 0.97 | 3.89 | 3.63 | 1.67 | 0.00 | 0.43 |
| 113 | Mainstem Red Dog Stn 10 | 12/05/18 | 2.01 | 8.04 | 7.26 | 1.63 | 0.00 | 0.93 |
| 115 | Mainstem Red Dog Stn 10 | 12/05/18 | 1.15 | 4.61 | 4.17 | 1.63 | 0.00 | 0.73 |
| 117 | Mainstem Red Dog Stn 10 | 12/05/18 | 2.98 | 11.90 | 11.00 | 1.65 | 0.05 | 0.71 |
| 119 | Mainstem Red Dog Stn 10 | 12/05/18 | 2.05 | 8.19 | 7.80 | 1.69 | 0.00 | 0.84 |
| 121 | blank | 12/05/18 | 0.01 | 0.04 | 0.11 | | 0.05 | 0.061 |

# Appendix 3. Aquatic Invertebrate Drift Samples, 2018.

| | Middle Fork Red Dog | North Fork Red Dog | Upper North Fork Red Dog | Mainstem Red Dog | Ikalukrok Up | Ikalukrok below Dudd | Bons u/s Bons Pond | Bons u/s Buddy | Buddy u/s Haul Road | Buddy below falls |
|---|---|---|---|---|---|---|---|---|---|---|
| Station Number | 20 | 12 | N/A | 10 | 9 | 160 | N/A | 220 | 221 | N/A |
| Total aquatic invert taxa/site | 22 | 22 | 18 | 19 | 24 | 20 | 23 | 24 | 24 | 20 |
| Tot. Ephemeroptera | 7 | 72 | 169 | 7 | 543 | 30 | 14 | 49 | 350 | 68 |
| Tot. Plecoptera | 6 | 47 | 270 | 114 | 155 | 15 | 6 | 4 | 509 | 15 |
| Tot. Trichop. | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 21 | 1 | 1 |
| Total Aq. Diptera | 43 | 899 | 686 | 236 | 232 | 97 | 331 | 877 | 1193 | 1276 |
| Misc.Aq.sp | 23 | 185 | 114 | 42 | 129 | 56 | 45 | 1603 | 230 | 179 |
| % Ephemeroptera | 9% | 6% | 14% | 2% | 51% | 15% | 3% | 2% | 15% | 4% |
| % Plecoptera | 8% | 4% | 22% | 29% | 15% | 8% | 2% | 0% | 22% | 1% |
| % Trichoptera | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% |
| % Chironomidae | 43% | 41% | 49% | 54% | 17% | 27% | 59% | 32% | 49% | 80% |
| % Aq. Diptera | 54% | 75% | 55% | 59% | 22% | 49% | 83% | 34% | 52% | 83% |
| % other | 29% | 15% | 9% | 10% | 12% | 28% | 11% | 63% | 10% | 12% |
| % Dominant Taxon | 29% | 35% | 48% | 35% | 31% | 23% | 38% | 23% | 45% | 68% |
| Volume of water (m3) | 718 | 966 | 1238 | 661 | 1195 | 434 | 287 | 774 | 1025 | 772 |
| Average vol.water/net | 144 | 193 | 248 | 132 | 239 | 87 | 57 | 155 | 205 | 154 |
| StDev of Water Volume/Net | 130 | 151 | 131 | 39 | 101 | 40 | 12 | 42 | 34 | 126 |
| Estimated total inverts/m3 water | 1.85 | 7.46 | 5.74 | 4.06 | 6.49 | 4.88 | 8.08 | 18.78 | 16.47 | 10.95 |
| Estimated aquatic inverts/m3 water | 0.56 | 6.23 | 5.00 | 3.02 | 4.43 | 2.29 | 6.90 | 16.56 | 11.19 | 9.99 |
| Average invertebrates/m3 water | 3.09 | 9.11 | 6.17 | 4.24 | 7.14 | 5.22 | 8.38 | 19.25 | 16.74 | 19.01 |
| Average aq. invertebrates/m3 water | 1.02 | 7.17 | 5.37 | 3.16 | 4.70 | 2.51 | 7.17 | 17.15 | 11.33 | 17.05 |
| StDev of Aq. Invert Density | 0.66 | 3.78 | 1.33 | 1.02 | 1.41 | 1.24 | 1.97 | 4.99 | 2.75 | 17.00 |
| Total aquatic invertebrates | 399 | 6019 | 6192 | 1998 | 5300 | 995 | 1981 | 12822 | 11470 | 7713 |
| Total. terrestrial invertebrates | 928 | 1188 | 917 | 688 | 2459 | 1124 | 341 | 1716 | 5415 | 744 |
| **Total invertebrates** | 1327 | 7207 | 7109 | 2686 | 7759 | 2119 | 2323 | 14538 | 16885 | 8456 |
| % Sample aquatic | 30% | 84% | 87% | 74% | 68% | 47% | 85% | 88% | 68% | 91% |
| % Sample terrestrial | 70% | 16% | 13% | 26% | 32% | 53% | 15% | 12% | 32% | 9% |
| Average # aquatic inverts / net | 80 | 1204 | 1238 | 400 | 1060 | 199 | 396 | 2564 | 2294 | 1543 |
| StDev of Aq. Inv./Net | 31 | 822 | 492 | 129 | 341 | 87 | 56 | 782 | 536 | 645 |
| Average # terr. inverts / net | 186 | 238 | 183 | 138 | 492 | 225 | 68 | 343 | 1083 | 149 |
| Average # inverts / net | 265 | 1441 | 1422 | 537 | 1552 | 424 | 465 | 2908 | 3377 | 1691 |
| StDev of Inv./Net | 108 | 853 | 579 | 171 | 509 | 162 | 79 | 976 | 929 | 677 |
| Total Larval Arctic Grayling/site | 0 | 1 | 0 | 6 | 0 | 1 | 14 | 0 | 0 | 0 |
| Total Larval Slimy Sculpin/site | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Larval Dolly Varden/site | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## Appendix 4. Juvenile Arctic Grayling from Bons Creek, Whole Body Element Concentrations, 2018.

Shaded cells 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. Mean MDL for cadmium was 0.04 mg/kg, lead was 0.08 mg/kg, mercury was 0.009 mg/kg, selenium was 0.08 mg/kg, and zinc was 3.12 mg/kg.

| Sample Number | Date Collected | Length (mm) | Weight (g) | Cadmium (mg/kg) | Lead (mg/kg) | Mercury (mg/kg) | Selenium (mg/kg) | Zinc (mg/kg) | % Solids |
|---|---|---|---|---|---|---|---|---|---|
| 18BPAGJ01 | 6/18/2018 | 137 | 24.0 | 0.37 | 1.99 | 0.07 | 14.56 | 117.84 | 24.1 |
| 18BPAGJ02 | 6/18/2018 | 133 | 21.2 | 0.05 | 0.26 | 0.09 | 11.13 | 88.30 | 26.5 |
| 18BPAGJ03 | 6/18/2018 | 138 | 24.7 | 0.03 | 0.31 | 0.05 | 16.10 | 92.12 | 29.2 |
| 18BPAGJ04 | 7/15/2018 | 189 | 66.1 | 0.21 | 2.09 | 0.07 | 12.51 | 87.66 | 23.5 |
| 18BPAGJ05 | 7/16/2018 | 183 | 60.5 | 0.11 | 0.50 | 0.06 | 11.93 | 75.00 | 28.0 |
| 18BPAGJ06 | 8/3/2018 | 133 | 19.8 | 0.09 | 0.50 | 0.03 | 12.36 | 133.18 | 22.0 |
| 18BPAGJ07 | 8/3/2018 | 173 | 50.8 | 0.17 | 0.29 | 0.05 | 14.14 | 70.71 | 23.9 |
| 18BPAGJ08 | 8/3/2018 | 155 | 35.0 | 0.07 | 0.35 | 0.04 | 12.00 | 48.08 | 26.0 |
| 18BPAGJ09 | 8/3/2018 | 190 | 69.9 | 0.60 | 0.40 | 0.08 | 12.65 | 63.05 | 24.9 |
| 18BPAGJ10 | 8/3/2018 | 150 | 33.0 | 0.15 | 0.41 | 0.08 | 11.29 | 83.82 | 24.1 |
| 18BPAGJ11 | 8/6/2018 | 144 | 25.7 | 0.05 | 0.34 | 0.05 | 16.11 | 93.16 | 23.4 |
| 18BPAGJ12 | 8/6/2018 | 145 | 27.5 | 0.12 | 0.83 | 0.04 | 11.20 | 170.66 | 24.2 |
| 18BPAGJ13 | 8/6/2018 | 133 | 21.5 | 0.18 | 1.01 | 0.07 | 16.61 | 112.78 | 22.7 |

## Appendix 5. Juvenile Dolly Varden from Buddy, Anxiety, and Mainstem Red Dog Creeks, Whole Body Element Concentrations, 2018.

Shaded cells indicate value was at or below method detection limit (MDL), so MDL is reported. Detection limits for identified metals were based on % solids which varied for each fish. Mean MDL for cadmium was 0.04 mg/kg, lead was 0.09 mg/kg, mercury was 0.008 mg/kg, selenium was 0.09 mg/kg, and zinc was 3.39 mg/kg.

| Sample Number | Date Collected | Length (mm) | Weight (g) | Cadmium (mg/kg) | Lead (mg/kg) | Mercury (mg/kg) | Selenium (mg/kg) | Zinc (mg/kg) | % Solids |
|---|---|---|---|---|---|---|---|---|---|
| 18MSRDDVJ01 | 8/3/2018 | 140 | 23.9 | 1.88 | 1.10 | 0.05 | 11.22 | 274.03 | 18.1 |
| 18MSRDDVJ02 | 8/3/2018 | 136 | 18.1 | 1.32 | 0.66 | 0.06 | 4.20 | 174.53 | 21.2 |
| 18MSRDDVJ03 | 8/3/2018 | 140 | 24.2 | 0.79 | 0.61 | 0.06 | 7.29 | 178.04 | 21.4 |
| 18MSRDDVJ04 | 8/3/2018 | 119 | 14.6 | 2.22 | 0.45 | 0.05 | 7.38 | 131.22 | 22.1 |
| 18MSRDDVJ05 | 8/3/2018 | 142 | 24.5 | 7.01 | 3.18 | 0.08 | 15.45 | 322.27 | 21.1 |
| 18MSRDDVJ06 | 8/3/2018 | 94 | 7.5 | 3.45 | 2.76 | 0.05 | 11.34 | 184.48 | 23.2 |
| 18MSRDDVJ07 | 8/3/2018 | 118 | 16.9 | 11.36 | 14.14 | 0.08 | 14.39 | 575.76 | 19.8 |
| 18MSRDDVJ08 | 8/3/2018 | 129 | 20.2 | 3.60 | 6.75 | 0.08 | 13.84 | 576.35 | 20.3 |
| 18MSRDDVJ09 | 8/3/2018 | 90 | 6.7 | 1.40 | 3.33 | 0.03 | 5.17 | 231.88 | 20.7 |
| 18MSRDDVJ10 | 8/3/2018 | 93 | 7.2 | 1.05 | 0.79 | 0.06 | 7.32 | 288.95 | 19.0 |
| 18MSRDDVJ11 | 8/3/2018 | 94 | 8.5 | 1.08 | 2.46 | 0.07 | 6.85 | 223.65 | 20.3 |
| 18BCDVJ01 | 8/4/2018 | 114 | 14.5 | 0.72 | 0.17 | 0.06 | 9.45 | 149.37 | 23.7 |
| 18BCDVJ02 | 8/4/2018 | 117 | 18 | 0.38 | 0.17 | 0.05 | 7.28 | 100.85 | 23.5 |
| 18BCDVJ03 | 8/4/2018 | 116 | 14.9 | 1.20 | 0.27 | 0.05 | 8.33 | 200.00 | 22.1 |
| 18BCDVJ04 | 8/4/2018 | 132 | 17.3 | 0.36 | 0.92 | 0.06 | 7.80 | 154.40 | 25.0 |
| 18BCDVJ05 | 8/4/2018 | 115 | 16.2 | 0.35 | 0.44 | 0.09 | 6.78 | 137.8855 | 22.7 |
| 18BCDVJ06 | 8/4/2018 | 113 | 13.8 | 0.65 | 0.65 | 0.05 | 8.48 | 170.87 | 23.0 |
| 18BCDVJ07 | 8/4/2018 | 119 | 15.5 | 0.55 | 0.36 | 0.05 | 8.30 | 147.32 | 22.4 |
| 18BCDVJ08 | 8/4/2018 | 111 | 13.8 | 1.23 | 13.20 | 0.08 | 8.30 | 277.18 | 24.1 |
| 18BCDVJ09 | 8/4/2018 | 133 | 21 | 0.46 | 0.30 | 0.07 | 8.33 | 196.15 | 23.4 |
| 18BCDVJ10 | 8/4/2018 | 103 | 10.9 | 0.83 | 0.63 | 0.05 | 7.46 | 171.25 | 24.0 |
| 18BCDVJ11 | 8/4/2018 | 114 | 13.6 | 0.57 | 0.51 | 0.09 | 8.72 | 203.42 | 23.4 |
| 18BCDVJ12 | 8/4/2018 | 110 | 11.7 | 0.92 | 0.36 | 0.05 | 10.71 | 177.33 | 22.5 |
| 18BCDVJ13 | 8/4/2018 | 117 | 14.3 | 0.71 | 0.17 | 0.07 | 8.13 | 158.33 | 24.0 |
| 18BCDVJ14 | 8/4/2018 | 97 | 9.5 | 1.16 | 0.18 | 0.07 | 7.81 | 151.79 | 22.4 |
| 18BCDVJ15 | 8/4/2018 | 99 | 9.5 | 0.71 | 0.27 | 0.06 | 6.68 | 180.0885 | 22.6 |
| 18AXDVJ01 | 8/4/2018 | 130 | 21.4 | 0.06 | 0.10 | 0.04 | 4.20 | 60.00 | 29.5 |
| 18AXDVJ02 | 8/4/2018 | 121 | 18.7 | 0.09 | 0.08 | 0.10 | 7.36 | 88.51 | 26.1 |
| 18AXDVJ03 | 8/4/2018 | 109 | 14.7 | 0.13 | 0.82 | 0.14 | 3.28 | 103.69 | 24.4 |
| 18AXDVJ04 | 8/4/2018 | 106 | 13.4 | 0.14 | 0.12 | 0.08 | 5.78 | 117.21 | 24.4 |
| 18AXDVJ05 | 8/4/2018 | 90 | 9.1 | 0.09 | 0.09 | 0.08 | 6.16 | 94.91 | 21.6 |
| 18AXDVJ06 | 8/4/2018 | 98 | 11.5 | 0.08 | 0.12 | 0.19 | 4.74 | 86.64 | 24.7 |
| 18AXDVJ07 | 8/4/2018 | 125 | 22.5 | 0.09 | 0.23 | 0.21 | 4.36 | 155.91 | 22.0 |
| 18AXDVJ08 | 8/4/2018 | 119 | 17.6 | 0.15 | 0.24 | 0.12 | 4.92 | 104.40 | 25.0 |
| 18AXDVJ09 | 8/4/2018 | 121 | 18.6 | 0.28 | 1.05 | 0.17 | 3.92 | 129.11 | 23.7 |
| 18AXDVJ10 | 8/4/2018 | 122 | 16.6 | 0.05 | 0.08 | 0.16 | 2.67 | 118.33 | 24.0 |
| 18AXDVJ11 | 8/4/2018 | 108 | 14 | 0.20 | 0.16 | 0.10 | 5.80 | 141.22 | 24.5 |
| 18AXDVJ12 | 8/4/2018 | 97 | 9.6 | 0.09 | 0.13 | 0.14 | 4.71 | 78.03 | 22.3 |
| 18AXDVJ13 | 8/4/2018 | 115 | 16.7 | 0.35 | 5.11 | 0.08 | 5.55 | 150.66 | 22.7 |
| 18AXDVJ14 | 8/4/2018 | 116 | 13.4 | 0.21 | 0.84 | 0.13 | 6.47 | 192.86 | 23.8 |
| 18AXDVJ15 | 8/4/2018 | 110 | 14 | 0.14 | 0.18 | 0.17 | 5.49 | 134.82 | 22.4 |

## Appendix 6. Arctic Grayling Ovaries Tested for Selenium from Red Dog Mine in 2018

Selenium data from locations near Red Dog and Fort Knox mines (1999, 2014 – 2017) are available in ADF&G Technical Report No. 18-06.

| Sample Identification | Collector | Location | Date | Length (mm) | Weight (g) | Age | Selenium (mg/kg) | % Solids |
|---|---|---|---|---|---|---|---|---|
| 061418NFAGA01 | ADF&G | North Fork Red Dog | 6/14/2018 | 324 | 363.1 | 5 | 29.2 | 10.1 |
| 061418NFAGA02 | ADF&G | North Fork Red Dog | 6/14/2018 | 286 | 226.1 | 4 | 39.5 | 7.6 |
| 061418NFAGA04 | ADF&G | North Fork Red Dog | 6/14/2018 | 304 | 286.3 | no age | 29.8 | 11.3 |
| 061518NFAGA05 | ADF&G | North Fork Red Dog | 6/15/2018 | 325 | 301.1 | 4 | 15.3 | 22.6 |
| 061518NFAGA06 | ADF&G | North Fork Red Dog | 6/15/2018 | 333 | 353.6 | 4 | 44.9 | 7.3 |
| | | | | | | | | |
| 061318BPAGA01 | ADF&G | Bons Pond | 6/13/2018 | 258 | 164.7 | 3 | 120.0 | 3.9 |
| 061318BPAGA02 | ADF&G | Bons Pond | 6/13/2018 | 310 | 324.4 | 5 | 70.6 | 9.7 |
| 061318BPAGA03 | ADF&G | Bons Pond | 6/13/2018 | 319 | 313.6 | 5 | 104.4 | 8.4 |
| 061318BPAGA04 | ADF&G | Bons Pond | 6/13/2018 | 272 | 224.2 | 5 | 29.0 | 20.9 |
| 061318BPAGA05 | ADF&G | Bons Pond | 6/13/2018 | 304 | 309.2 | 5 | 94.3 | 8.3 |
| 061318BPAGA06 | ADF&G | Bons Pond | 6/13/2018 | 274 | 224.5 | 3 | 77.5 | 7.5 |

## Appendix 7. Dolly Varden Element Data, Wulik River, June 2018.

Shaded cells indicate value was at or below method detection limit (MDL), so MDL is reported. All values reported in dry weight. Mercury results are excluded since samples were processed past holding times and results were unreliable.

| Tissue | Sample Identification | Sex | Weight (g) | Length (mm) | Cadmium (mg/kg) | Copper (mg/kg) | Lead (mg/kg) | Selenium (mg/kg) | Zinc (mg/kg) | % Solids |
|---|---|---|---|---|---|---|---|---|---|---|
| Kidney | 061418WUDVA01 | U | 2946 | 644 | 1.71 | 5.92 | 0.13 | 7.76 | 119.08 | 15.2 |
| Kidney | 061518WUDVA02 | M | 1907 | 541 | 1.33 | 5.13 | 0.10 | 6.51 | 74.36 | 19.5 |
| Kidney | 061518WUDVA03 | M | 3147 | 619 | 1.13 | 2.97 | 0.10 | 5.74 | 74.26 | 20.2 |
| Kidney | 061518WUDVA04 | F | 2705 | 616 | 0.59 | 3.08 | 0.08 | 3.62 | 59.13 | 38.9 |
| Kidney | 061618WUDVA05 | F | 1373 | 500 | 1.49 | 4.98 | 0.08 | 5.67 | 85.06 | 26.1 |
| Kidney | 061618WUDVA06 | M | 1595 | 548 | 1.42 | 4.55 | 0.11 | 7.44 | 112.50 | 17.6 |
| Kidney | 061618WUDVA07 | M | 4312 | 649 | 0.70 | 3.26 | 0.09 | 5.44 | 70.23 | 21.5 |
| Kidney | Duplicate of fish #07 | M | 4312 | 649 | 0.94 | 4.15 | 0.09 | 5.85 | 75.58 | 21.7 |
| | | | | | | | | | | |
| Liver | 061418WUDVA01 | U | 2946 | 644 | 0.30 | 26.08 | 0.01 | 2.18 | 58.06 | 37.2 |
| Liver | 061518WUDVA02 | M | 1907 | 541 | 0.16 | 13.74 | 0.02 | 2.09 | 65.38 | 36.4 |
| Liver | 061518WUDVA03 | M | 3147 | 619 | 0.27 | 30.09 | 0.02 | 2.77 | 76.11 | 33.9 |
| Liver | 061518WUDVA04 | F | 2705 | 616 | 0.39 | 74.40 | 0.02 | 3.48 | 137.20 | 20.7 |
| Liver | 061618WUDVA05 | F | 1373 | 500 | 0.45 | 43.07 | 0.02 | 3.30 | 126.22 | 26.7 |
| Liver | 061618WUDVA06 | M | 1595 | 548 | 0.33 | 37.36 | 0.02 | 2.44 | 73.60 | 35.6 |
| Liver | 061618WUDVA07 | M | 4312 | 649 | 0.05 | 17.05 | 0.01 | 0.95 | 29.46 | 51.6 |
| Liver | Duplicate of fish #07 | M | 4312 | 649 | 0.06 | 19.77 | 0.02 | 0.96 | 35.71 | 60.2 |
| | | | | | | | | | | |
| Muscle | 061418WUDVA01 | U | 2946 | 644 | 0.01 | 1.15 | 0.04 | 0.73 | 12.64 | 26.1 |
| Muscle | 061518WUDVA02 | M | 1907 | 541 | 0.02 | 2.00 | 0.06 | 0.63 | 13.71 | 35.0 |
| Muscle | 061518WUDVA03 | M | 3147 | 619 | 0.03 | 7.53 | 0.06 | 0.51 | 17.47 | 33.2 |
| Muscle | 061518WUDVA04 | F | 2705 | 616 | 0.04 | 2.53 | 0.03 | 0.53 | 12.92 | 35.6 |
| Muscle | 061618WUDVA05 | F | 1373 | 500 | 0.05 | 1.14 | 0.08 | 0.68 | 10.98 | 26.4 |
| Muscle | 061618WUDVA06 | M | 1595 | 548 | 0.06 | 1.82 | 0.06 | 0.67 | 15.76 | 33.0 |
| Muscle | 061618WUDVA07 | M | 4312 | 649 | 0.07 | 0.99 | 0.07 | 0.73 | 11.59 | 30.2 |
| Muscle | Duplicate of fish #07 | M | 4312 | 649 | 0.08 | 1.12 | 0.11 | 0.75 | 14.98 | 26.7 |
| | | | | | | | | | | |
| Reproductive | 061418WUDVA01 | U | 2946 | 644 | 0.01 | 1.19 | 0.02 | 1.55 | 86.31 | 16.8 |
| Reproductive | 061518WUDVA02 | M | 1907 | 541 | 0.01 | 9.69 | 0.01 | 2.81 | 110.31 | 32.0 |
| Reproductive | 061518WUDVA03 | M | 3147 | 619 | 0.04 | 2.86 | 0.08 | 1.71 | 338.10 | 21.0 |
| Reproductive | 061518WUDVA04 | F | 2705 | 616 | 0.01 | 2.34 | 0.03 | 1.64 | 186.92 | 21.4 |
| Reproductive | 061618WUDVA05 | F | 1373 | 500 | 0.01 | 18.13 | 0.02 | 3.45 | 136.26 | 34.2 |
| Reproductive | 061618WUDVA06 | M | 1595 | 548 | 0.01 | 1.96 | 0.02 | 2.16 | 128.43 | 20.4 |
| Reproductive | 061618WUDVA07 | M | 4312 | 649 | 0.01 | 1.52 | 0.02 | 1.62 | 81.22 | 19.7 |
| Reproductive | Duplicate of fish #07 | M | 4312 | 649 | 0.01 | 3.41 | 0.02 | 4.43 | 184.09 | 8.8 |

## Appendix 8. Dolly Varden Element Data, Wulik River, September 2018.

Shaded cells indicate value was at or below method detection limit (MDL), so MDL is reported. All values reported in dry weight. Mercury results are excluded since samples were processed past holding times and results were unreliable.

| Tissue | Sample Identification | Sex | Weight (g) | Length (mm) | Cadmium (mg/kg) | Copper (mg/kg) | Lead (mg/kg) | Selenium (mg/kg) | Zinc (mg/kg) | % Solids |
|---|---|---|---|---|---|---|---|---|---|---|
| Kidney | 092118WUDVA01 | F | 1159 | 489 | 0.58 | 3.51 | 0.12 | 5.91 | 97.66 | 17.1 |
| Kidney | 092118WUDVA02 | F | 1848 | 555 | 1.71 | 3.87 | 0.11 | 6.80 | 110.50 | 18.1 |
| Kidney | 092118WUDVA03 | F | 1983 | 576 | 1.80 | 3.83 | 0.11 | 6.01 | 126.23 | 18.3 |
| Kidney | 092118WUDVA04 | F | 2131 | 582 | 1.98 | 4.55 | 0.05 | 7.68 | 140.91 | 19.8 |
| Kidney | 092118WUDVA05 | F | 1198 | 518 | 0.37 | 2.07 | 0.08 | 4.85 | 55.60 | 24.1 |
| Kidney | 092118WUDVA06 | F | 2293 | 610 | | | | | | |
| Kidney | Duplicate of fish #06 | F | 2293 | 610 | 1.60 | 3.90 | 0.09 | 6.28 | 105.19 | 23.1 |
| Kidney | 092118WUDVA07 | F | 1378 | 534 | 1.52 | 5.96 | 0.13 | 9.07 | 150.99 | 15.1 |
| | | | | | | | | | | |
| Liver | 092118WUDVA01 | F | 1159 | 489 | 0.27 | 28.13 | 0.08 | 3.36 | 87.89 | 25.6 |
| Liver | 092118WUDVA02 | F | 1848 | 555 | 0.37 | 47.67 | 0.03 | 2.56 | 61.14 | 38.6 |
| Liver | 092118WUDVA03 | F | 1983 | 576 | 0.47 | 71.38 | 0.04 | 4.03 | 141.70 | 28.3 |
| Liver | 092118WUDVA04 | F | 2131 | 582 | 0.49 | 87.06 | 0.05 | 2.80 | 78.71 | 37.1 |
| Liver | 092118WUDVA05 | F | 1198 | 518 | 0.20 | 56.89 | 0.05 | 2.96 | 70.66 | 39.2 |
| Liver | 092118WUDVA06 | F | 2293 | 610 | 0.40 | 35.23 | 0.07 | 2.42 | 70.47 | 29.8 |
| Liver | Duplicate of fish #06 | F | 2293 | 610 | 0.45 | 42.29 | 0.05 | 2.04 | 65.17 | 40.2 |
| Liver | 092118WUDVA07 | F | 1378 | 534 | 0.24 | 102.28 | 0.06 | 3.36 | 86.04 | 35.1 |
| | | | | | | | | | | |
| Muscle | 092118WUDVA01 | F | 1159 | 489 | 0.04 | 1.08 | 0.07 | 0.69 | 13.36 | 27.7 |
| Muscle | 092118WUDVA02 | F | 1848 | 555 | 0.02 | 1.46 | 0.06 | 0.67 | 15.16 | 34.3 |
| Muscle | 092118WUDVA03 | F | 1983 | 576 | 0.02 | 0.92 | 0.06 | 0.73 | 13.46 | 32.7 |
| Muscle | 092118WUDVA04 | F | 2131 | 582 | 0.03 | 1.07 | 0.04 | 0.93 | 15.71 | 28 |
| Muscle | 092118WUDVA05 | F | 1198 | 518 | 0.03 | 0.93 | 0.06 | 0.75 | 12.46 | 32.1 |
| Muscle | 092118WUDVA06 | F | 2293 | 610 | 0.03 | 1.44 | 0.06 | 0.61 | 20.17 | 34.7 |
| Muscle | Duplicate of fish #06 | F | 2293 | 610 | 0.03 | 1.36 | 0.05 | 0.65 | 17.17 | 36.7 |
| Muscle | 092118WUDVA07 | F | 1378 | 534 | 0.02 | 0.91 | 0.06 | 0.67 | 13.03 | 33 |
| | | | | | | | | | | |
| Reproductive | 092118WUDVA01 | F | 1159 | 489 | 0.26 | 3.57 | <0.46 | 2.76 | 137.76 | 19.6 |
| Reproductive | 092118WUDVA02 | F | 1848 | 555 | 0.09 | 2.36 | <0.24 | 2.50 | 132.08 | 21.2 |
| Reproductive | 092118WUDVA03 | F | 1983 | 576 | 0.06 | 7.60 | <0.12 | 2.87 | 251.46 | 17.1 |
| Reproductive | 092118WUDVA04 | F | 2131 | 582 | 0.10 | 6.06 | <0.20 | 4.85 | 651.52 | 9.9 |
| Reproductive | 092118WUDVA05 | F | 1198 | 518 | 0.03 | 19.29 | <0.04 | 6.25 | 257.14 | 28 |
| Reproductive | 092118WUDVA06 | F | 2293 | 610 | | | | | | |
| Reproductive | Duplicate of fish #06 | F | 2293 | 610 | | | | | | |
| Reproductive | 092118WUDVA07 | F | 1378 | 534 | | | | | | |

## Appendix 9. Juvenile Dolly Varden Sampling Sites and the number of fish caught at each location, Red Dog Mine, 1997-2018.

| Sample Site | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Evaingiknuk (Noatak Tributary) | 54 | 27 | 38 | 2 | 7 | 20 | 64 | 71 | 29 | 4 | 67 | 21 | 16 | 48 | 36 | 17 | 13 | 8 | 2 | 16 |
| Anxiety Ridge | 68 | 94 | 271 | 27 | 6 | 33 | 98 | 116 | 121 | 8 | 115 | 75 | 147 | 18 | 43 | 7 | 93 | 61 | 47 | 57 |
| Buddy | 48 | 154 | 306 | 11 | 34 | 57 | 104 | 59 | 59 | 5 | 183 | 43 | 100 | 115 | 77 | 18 | 47 | 88 | 12 | 109 |
| North Fork Red Dog Creek (Sta 12) | 0 | 12 | 17 | 1 | 1 | 1 | 0 | 1 | 8 | 0 | 1 | 0 | 3 | 6 | 2 | 0 | 4 | 0 | 1 | 0 |
| Upper North Fork Red Dog Creek | | | | | | | | | | | | | | | | 2 | 32 | 0 | 0 | 2 |
| Mainstem (below North Fork) (Sta 151) | 14 | 70 | 86 | 13 | 9 | 12 | 2 | 2 | 6 | 8 | 2 | 13 | 7 | 13 | 7 | 1 | 3 | 19 | 1 | 9 |
| Mainstem (Sta 10) | 10 | 21 | 66 | 1 | 3 | 12 | 12 | 0 | 10 | 3 | 6 | 5 | 6 | 14 | 8 | 13 | 15 | 21 | 2 | 5 |
| Ikalukrok Creek (Sta 7/160) | 13 | 51 | 55 | 31 | 6 | 17 | 17 | 27 | 36 | 2 | 25 | 7 | 30 | 10 | 32 | 7 | 10 | 24 | 12 | 8 |
| Ikalukrok Creek (Sta 9) | 3 | 44 | 41 | 5 | 2 | 18 | 3 | 12 | 0 | 5 | 7 | 3 | 11 | 37 | 12 | 2 | 11 | 17 | 0 | 2 |
| Total Catch (Dolly Varden) | 210 | 473 | 880 | 91 | 68 | 170 | 300 | 288 | 269 | 35 | 406 | 167 | 320 | 261 | 217 | 65 | 196 | 238 | 77 | 208 |

No sampling occurred in 2012 and 2013 due to high water.
Total catch does not include Upper North Fork Red Dog Creek.
In 2016, a bear destroyed three deployed traps at Station 151 and one trap at Station 12.
In 2018, a bear destroyed two minnow traps in Anxiety Ridge Creek.