Technical Report No. 04-02

Aquatic Biomonitoring at Red Dog Mine, 2003

National Pollution Discharge Elimination System
Permit No. AK-003865-2

by Alvin G. Ott

Mainstem Red Dog Creek, Station 10
Photograph by Al Townsend 1999

April 2004

Alaska Department of Natural Resources
Office of Habitat Management and Permitting

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Acknowledgements

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We also want to acknowledge that previous biomonitoring for the Red Dog Mine was done by the Alaska Department of Fish and Game (ADF&G) via a contract with TCAK. The biomonitoring project, along with funding, was transferred from ADF&G to the ADNR when Habitat and Restoration Division was moved in May 2003 under Executive Order 107. We continue to work cooperatively with ADF&G on the Red Dog project.

Executive Summary

The following tables compare results of water quality, invertebrate communities, periphyton, and fish sampling at each of the NPDES monitored sites in 2003 with results from combined data from 1999 through 2001 and relative to baseline data when available.

Station 9, Ikalukrok Creek upstream of Mainstem Red Dog Creek

Factor	Changes Observed
Water Quality	Cd, Ni, and Zn lower in 2002 and 2003
Invertebrate Communities	Abundance - higher in 2000 through 2003 Density - higher in 2000 through 2003 Taxa Richness - higher in 2000 through 2003 - most taxa found in 2003 %EPT - highest in 1999, 2000, and 2002
Periphyton Communities	Highest in 2002 and 2003
Larval Arctic Grayling	Present in 1997, 1999, 2000
Arctic Grayling	Low numbers all years 1999 to 2003
Juvenile Dolly Varden	Highest catch 41 in 1999, varied from 2 to 15 in late July-early August for other years
Adult Dolly Varden	None have been observed

Station 8, Ikalukrok Creek downstream of Mainstem Red Dog Creek

Factor	Changes Observed
Water Quality	Ikalukrok and Mainstem not mixed, data unreliable all years
Invertebrate Communities	Abundance - higher in 2001 and 2003 Density - higher in 2001 and 2003 Taxa Richness - higher in 2001 and 2003 %EPT - relatively stable - higher proportion Chironomidae all years
Periphyton Communities	Highest in 2002 and 2003
Larval Arctic Grayling	Present in 2000 and 2002
Arctic Grayling	Generally low numbers, but in some years adults concentrated (up to 50) in Ikalukrok at mouth of Mainstem Red Dog Creek
Juvenile Dolly Varden	Highest catch 18 in 2002, varied from 3 to 11 in late July-early August for other years
Adult Dolly Varden	None have been observed

Ikalukrok Creek upstream of Dudd Creek

Factor	Changes Observed
Water Quality	General trend, decreasing metals concentrations Baseline Cd, Pb, and Zn higher than 1999-2003 1999-2003, metals higher in 2000
Invertebrate Communities	Abundance - higher in 2001 and 2003 Density - higher in 2000 and 2003 Taxa Richness - similar, but highest in 2001 %EPT - relatively stable - Simulidae high in 2002 and 2003
Periphyton Communities	Slightly lower in 2002 and 2003 after high water
Larval Arctic Grayling	Present in 2000, 2002, and 2003
Arctic Grayling	In some years, small numbers of adults present in deep water habitat or observed moving upstream through this reach of Ikalukrok Creek
Juvenile Dolly Varden	Highest catch 37 in 1999, zero in 2001, varied from 14 to 27 in late July-early August for other years
Adult Dolly Varden	None have been observed

Station 7, Ikalukrok Creek downstream of Dudd Creek

Factor	Changes Observed
Water Quality	Cd, Pb, Se, and Zn similar 1999 to 2003
Invertebrate Communities	Abundance - higher in 2000, 2001, and 2003 Density - higher in 2000, 2001, and 2003 Taxa Richness - higher in 2001 and 2003 %EPT - highest in 2001 - Simulidae high in 2002 and 2003
Periphyton Communities	Similar all years, but highest in 2000
Larval Arctic Grayling	Present in 2000, 2002, and 2003
Arctic Grayling	Generally some adults are present in Ikalukrok at mouth of Dudd Creek, but in some years adults concentrated (100 to 300) in Ikalukrok just below Dudd Creek
Juvenile Dolly Varden	Highest catch 55 in 1999, only 5 in 2001, varied from 17 to 31 in late July-early August for other years
Adult Dolly Varden	Generally, from 30 to 60 adults present in Ikalukrok just below Dudd Creek in July/August, appear to stage in this area and later move up Dudd and Buddy Creeks to spawn

Station 10, Mainstem Red Dog Creek

Factor	Changes Observed
Water Quality	Cd, Ni, Se, Zn decreasing with time (1999-2003)
Invertebrate Communities	Abundance - higher in 2001 and 2003 Density - higher in 2001, 2002, and 2003 Taxa Richness – highest 2001 and 2003 %EPT - highest in 2003
Periphyton Communities	Higher in 2001, 2002, and 2003
Larval Arctic Grayling	Present in 1999, 2000, 2002, and 2003
Arctic Grayling	Some adults present in most years throughout the summer months, active spawning in spring, usually about 10 to 30 fish present in lower 3 km of creek
Juvenile Dolly Varden	Highest catch 12 in 1999, 2002, and 2003, only 1 in 2000 and 3 in 2001
Adult Dolly Varden	None have been observed

Station 20, Middle Fork Red Dog Creek

Factor	Changes Observed
Water Quality	pH higher than premining due to effluent Cd and Zn lower than premining Pb lower than premining, but with some peaks Se appears to be gradually decreasing decreases due to effluent and water from the clean water bypass system
Invertebrate Communities	Abundance - highest in 2003 Density - highest in 2003 Taxa Richness - highest in 2003 %EPT - low, varying from 7 to 20% of sample
Periphyton Communities	Below detection limits all years except 2001
Larval Arctic Grayling	Not found at this site, fish barrier downstream
Arctic Grayling	Not found at this site, fish barrier downstream
Juvenile Dolly Varden	Not found at this site, fish barrier downstream
Adult Dolly Varden	Not found at this site, fish barrier downstream

Station 12, North Fork Red Dog Creek

Factor	Changes Observed
Water Quality	Al slighty higher than premining Median Cd and Pb lower than premining Al, Fe, Ni, Se, and Zn no apparent changes
Invertebrate Communities	Abundance – higher in 2001 and 2003 Density – fairly consistent among years Taxa Richness - highest in 2003 %EPT – low all years except 2002 when 57%
Periphyton Communities	Chlorophyll-a concentrations high in all years
Larval Arctic Grayling	Present in 1997, 1999, 2000, and 2001
Arctic Grayling	Arctic grayling have spawned successfully in all years of sampling including baseline, in most years adults leave after spawning leaving only age-0 fish
Juvenile Dolly Varden	Highest catch 17 in 1999, varied from 0 to 1 in late July-early August for other years
Adult Dolly Varden	None have been observed, but in 1995 Dolly Varden that had been to the ocean were present

Wulik River, Metals Concentrations in Dolly Varden Tissues

Al concentrates primarily in gill tissue

Cd concentrates in kidney tissue

Cu concentrates in liver tissue

Pb concentrates in gill tissue

Se concentrates in kidney and reproductive tissues

Zn concentrates in reproductive tissue

Hg is not concentrated in any of the tissues sampled

Ca concentrates in gill tissue

None of the analytes appear to concentrate in muscle tissue

Fish Resources in Wulik River Drainage

Dolly Varden adults continue to overwinter in the Wulik River downstream of the mouth of Ikalukrok Creek and numbers, although variable, are comparable with those found during premining surveys.

Chum salmon spawning numbers for the NPDES reporting period (1999 to 2003) comparable with those found during baseline data collection except for 1981 when the numbers of spawners were substantially higher.

Juvenile Dolly Varden captures continue to be highest in Buddy and Anxiety Ridge creeks. Higher numbers in any given year generally are reflected at all sample reaches (i.e., when numbers are high in Anxiety Ridge Creek they also are higher in Mainstem Red Dog Creek).

Introduction

The Red Dog Zn and Pb deposit is located in northwest Alaska, about 130 km north of Kotzebue and 75 km inland from the coast of the Chukchi Sea (Figure 1). The mine operation and facilities and the surrounding vegetation and wildlife are described in Weber Scannell and Ott (1998). A chronicle of development and operation of the Red Dog Mine is contained in Appendix 1. Aquatic resources in the Wulik River drainage are described in Weber Scannell et al. (2001).

In July 1998, the US Environmental Protection Agency (USEPA) issued National Pollution Discharge Elimination System Permit No. AK-003865 (NPDES Permit) to Teck-Cominco Alaska Inc. to allow discharge of up to 2.418 billion gallons of treated effluent per year. The Alaska Department of Environmental Conservation (ADEC) issued a Certificate of Reasonable Assurance and the NPDES Permit became effective August 28, 1998. The NPDES Permit required biomonitoring of fish, aquatic invertebrates, and periphyton in streams downstream and adjacent to the Red Dog Mine. This report contains the results of biomonitoring studies conducted by the Alaska Department of Natural Resources (ADNR) in 2003. The NPDES Permit was modified effective August 22, 2003, to include ADEC's authorizations of two mixing zones for total dissolved solids in Mainstem Red Dog and Ikalukrok creeks.

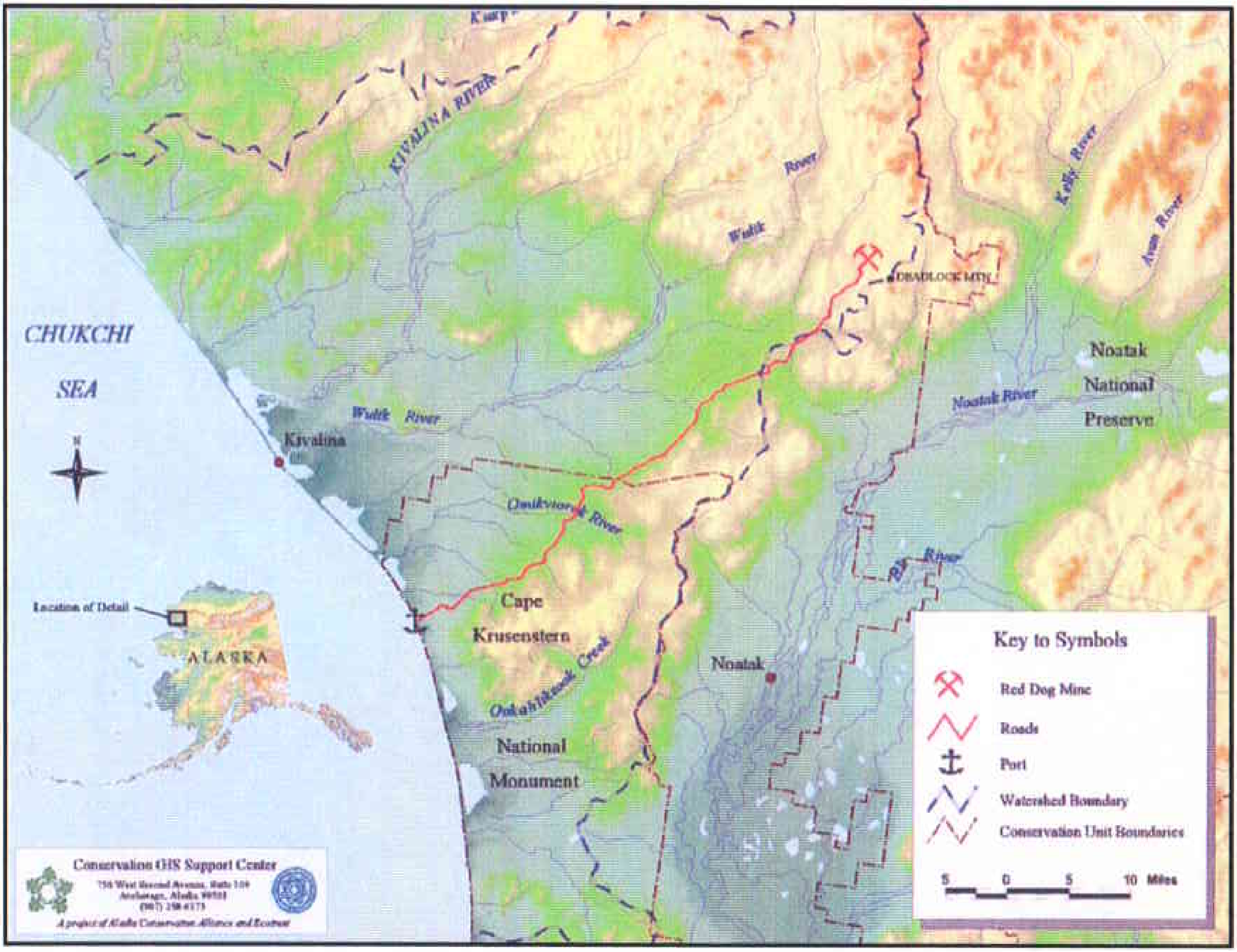


Figure 1. Location of the Red Dog Mine in northwest Alaska. Map used with permission of Conservation GIS Support Center, Anchorage, AK.

Structure of Report

Results of water quality monitoring, aquatic invertebrate sampling, and estimates of periphyton standing crop are given for each site for the years sampled (1999-2003). Following presentation of these results is a table summarizing changes in biotic communities and water quality conditions. Biomonitoring results for juvenile and adult fish are presented after discussion of these sample sites. Appendix 1 provides a chronology of significant events beginning with 1982.

Location of Sample Sites

Biomonitoring was conducted in streams adjacent to and downstream of the Red Dog Mine as required under USEPA NPDES Permit No. AK-003865-2 (Table 1, Figure 2). A description of the sites included in this study followed by the Station Number where available is listed below.

Table 1. Location of sample sites for NPDES biomonitoring.

Stream or Site Name	Station Number
Ikalukrok Creek upstream of Mainstem Red Dog Creek	Station 9
Ikalukrok Creek downstream of Mainstem Red Dog Creek	Station 8
Ikalukrok Creek upstream of Dudd Creek	-----------
Ikalukrok Creek downstream of Dudd Creek	Station 7
Mainstem Red Dog Creek	Station 10
Middle Fork Red Dog Creek	Station 20
North Fork Red Dog Creek	Station 12

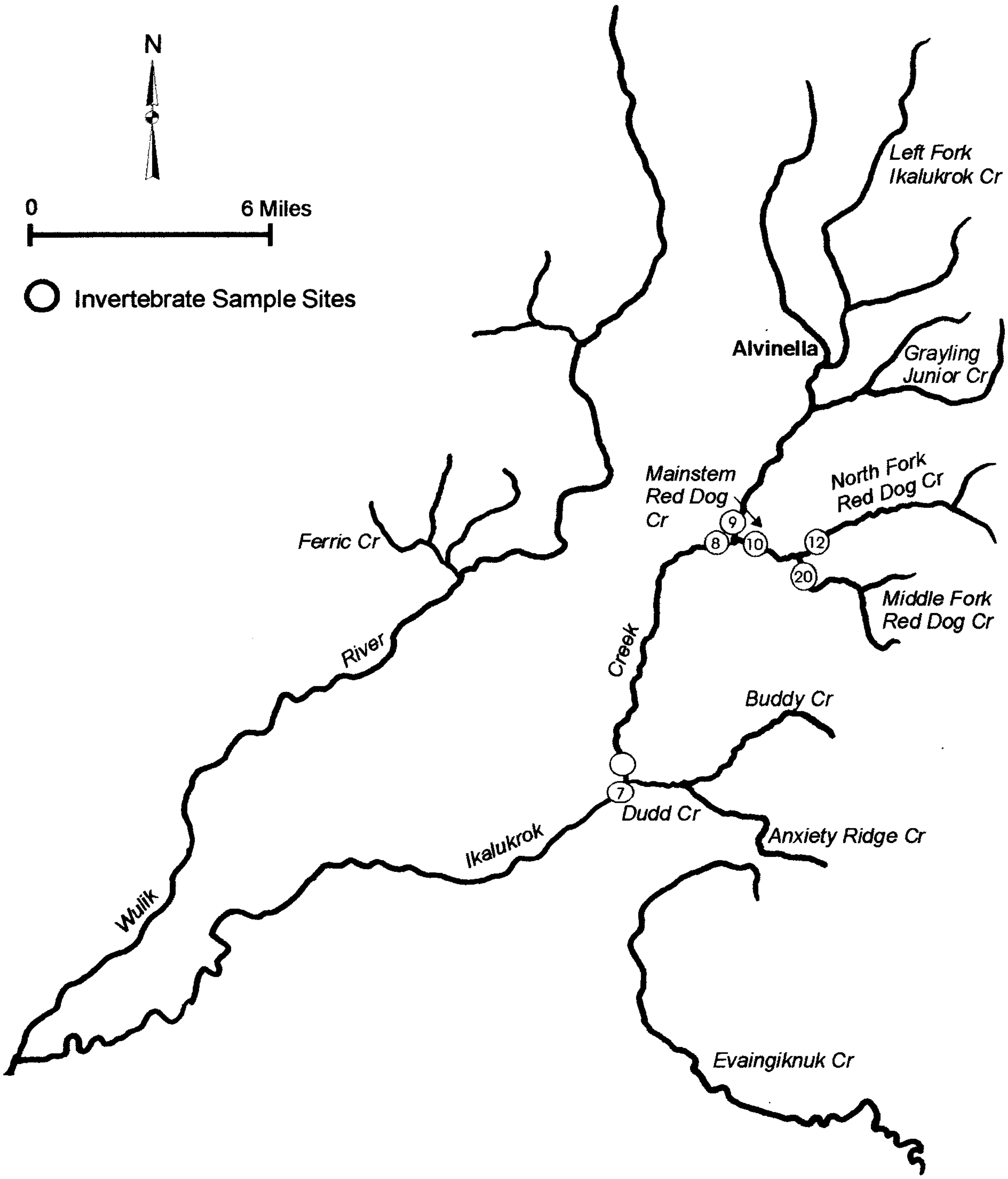


Figure 2. Locations of sites in the Red Dog Creek drainage for aquatic sampling.

Description of Streams

All streams in this study are in the Wulik River watershed, except for Evaingiknuk Creek that is in the Noatak River drainage. Station Numbers correspond to the numbers used by Dames and Moore (1983) during baseline studies and the current water sampling program being conducted by Teck-Cominco Alaska Inc. (TCAK). Water quality and fisheries data collected during baseline studies (1979 to 1982) represent pre-mining conditions. Each component and location listed in Table 2 is required by NPDES Permit No. AK-003865-2. ADNR and ADF&G conduct additional sampling that is supplemental to the requirements under the NPDES Permit to further our understanding of the aquatic communities (Table 3). Additional sampling is not done annually, but opportunistically based on time and logistical support.

Table 2. Locations and components of studies required under NPDES Permit No. AK-003865-2.

Middle Fork Red Dog Creek	Periphyton (as chlorophyll-a concentrations) Aquatic invertebrates (taxa richness and abundance)
North Fork Red Dog Creek	Periphyton (as chlorophyll-a concentrations) Aquatic invertebrates (taxa richness and abundance) Fish presence and use
Mainstem Red Dog Creek	Periphyton (as chlorophyll-a concentrations) Aquatic invertebrates (taxa richness and abundance) Fish presence and use
Ikalukrok Creek Stations 8, 9, and 7; and Upstream of Dudd Creek	Periphyton (as chlorophyll-a concentrations) Aquatic invertebrates (taxa richness and abundance) Fish presence and use
Ikalukrok Creek	Fall aerial survey chum salmon
Wulik River	Metals concentrations in adult Dolly Varden (gill, liver, muscle, and kidney)
Anxiety Ridge Creek	Fish presence and use
Evaingiknuk Creek	Fish presence and use
Buddy Creek	Fish presence and use

Table 3. Locations and components of supplemental biomonitoring studies.

North Fork Red Dog Creek	Juvenile Dolly Varden for whole body metals Fish movement with fyke-nets Condition of Arctic grayling (spent, ripe, etc.) Mark-recapture Arctic grayling Juvenile Dolly Varden use in headwaters
Mainstem Red Dog Creek	Juvenile Dolly Varden for whole body metals Fish movement with fyke-nets Condition of Arctic grayling (spent, ripe, etc.) Mark-recapture Arctic grayling
Ikalukrok Creek (Dudd Creek upstream to headwaters, including Grayling Junior Creek)	Juvenile Dolly Varden for whole body metals Mark-recapture Arctic grayling Aerial Arctic grayling surveys
Buddy Creek	Juvenile Dolly Varden for whole body metals Mark-recapture Arctic grayling
Anxiety Ridge Creek	Juvenile Dolly Varden for whole body metals
Ferric Creek	Juvenile Dolly Varden for whole body metals
Aufeis Creek	Juvenile Dolly Varden for whole body metals
Omikviorok River	Juvenile Dolly Varden for whole body metals
Bons Pond (Red Dog freshwater reservoir)	Mark-recapture Arctic grayling

Methods used for NPDES Biomonitoring

All methods used for the NPDES biomonitoring study were described by ADF&G (1998) and submitted to USEPA for their approval and comment. Only minor modifications, as described by Ott and Weber Scannell (2003), have been made to the methods specified by ADF&G (1998).

The method detection limit (MDL) in 2000 for Ni, Pb, and Se was 100, 20, and 50 *u*g/L, respectively, for some of the early samples. MDL's were changed part way through the summer for Ni, Pb, and Se to 0.5, 2, and 1 *u*g/L. In the water quality figures presented for the various sample sites, the MDL for these metals is shown as a circle and the median and minimum values are from data collected after the MDL's were changed.

Results and Discussion

Ikalukrok Creek at Station 9

Site Description

Station 9 is located in Ikalukrok Creek upstream of the confluence with Mainstem Red Dog Creek and near the US Geological Survey gauging station (Figure 3). The creek at this site divides around a large gravel bar into two channels; the right channel (facing downstream) contains most of the stream flow. Invertebrate and periphyton samples were collected in the left channel.

Figure 3. Ikalukrok Creek upstream of Mainstem Red Dog Creek, Station 9.

Water Quality

The water quality at Station 9 is characterized as having low to moderate hardness (median values of 60 to 197 mg/L of $CaCO_3$) and relatively low sulfate concentrations during the ice-free season (median values of 32 to 128 mg/L). Both hardness and sulfate have decreased annually since 1999. Median pH has remained relatively stable with a slight increase from 1999 to 2003. The median conductance has varied with a high of 267 uS/cm in 1999 to a low of 130.5 in 2003 uS/cm. Higher values for hardness, pH, and conductance usually occur in fall (September and October) during low flow (Weber Scannell et al. 2000).

Due to improvements in analytical methods since baseline data were collected, recent data are likely a better representation of water quality conditions (Ott and Weber Scannell 2003). Comparisons to baseline conditions are relative; i.e., concentrations have generally increased or decreased during the NPDES monitoring period. Concentrations of Al, Cd, Fe, Ni, Pb, Se, and Zn are presented in Figures 4 through 10 (data are from Teck-Cominco).

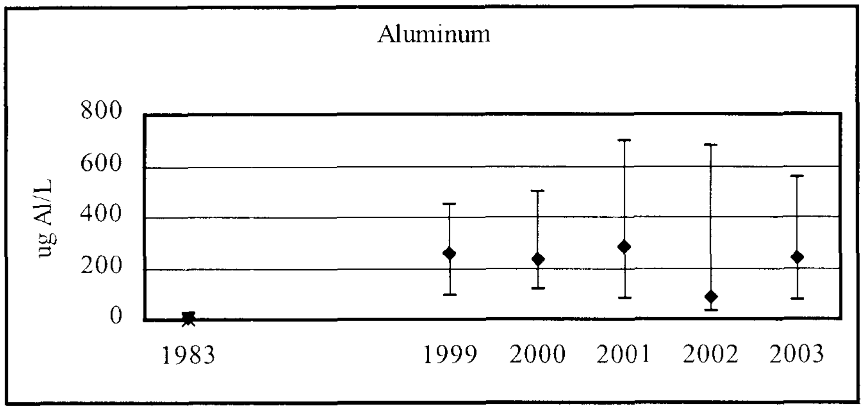


Figure 4. Median, maximum, and minimum concentrations of Al at Station 9.

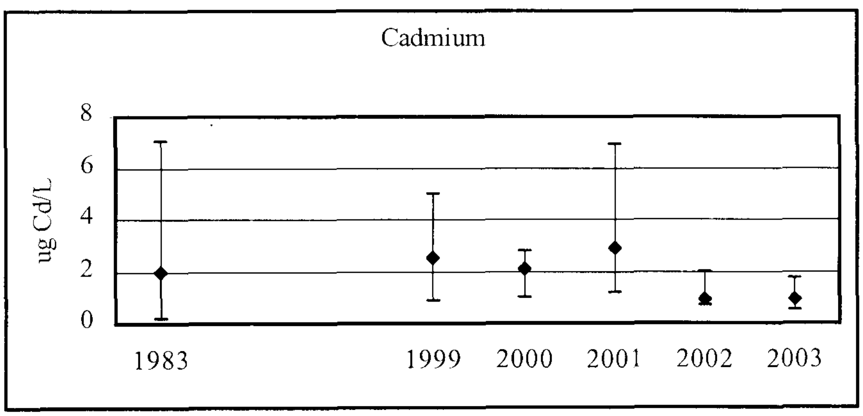


Figure 5. Median, maximum, and minimum concentrations of Cd at Station 9.

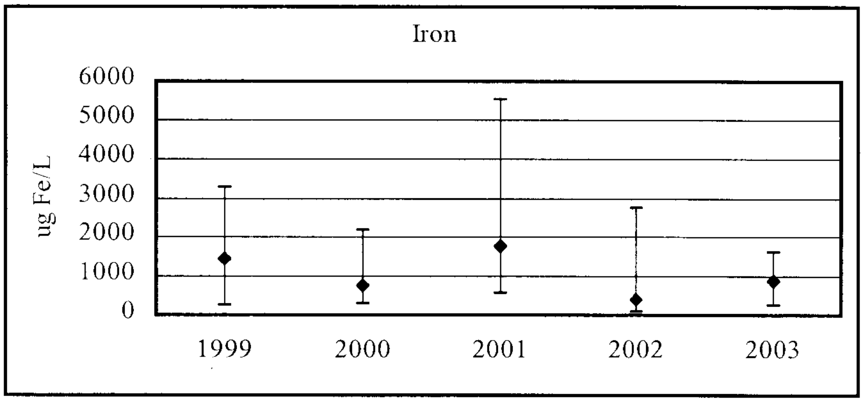


Figure 6. Median, maximum, and minimum concentrations of Fe at Station 9. There are no baseline data for Fe.

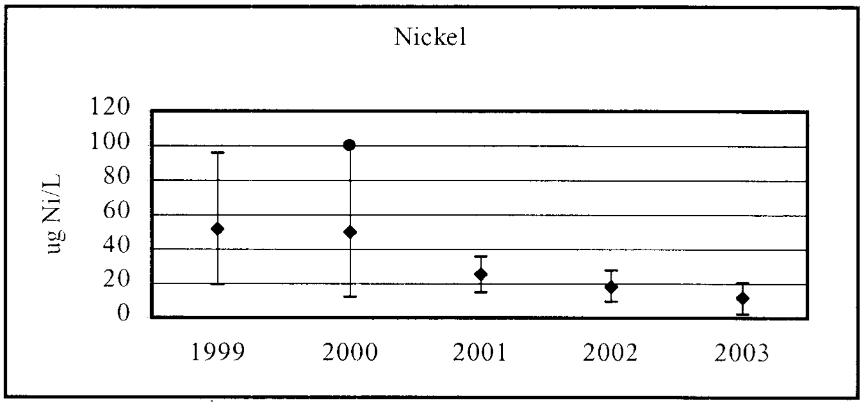


Figure 7. Median, maximum, and minimum concentrations of Ni at Station 9. The circle represents a MDL, not a concentration. There are no baseline data for Ni.

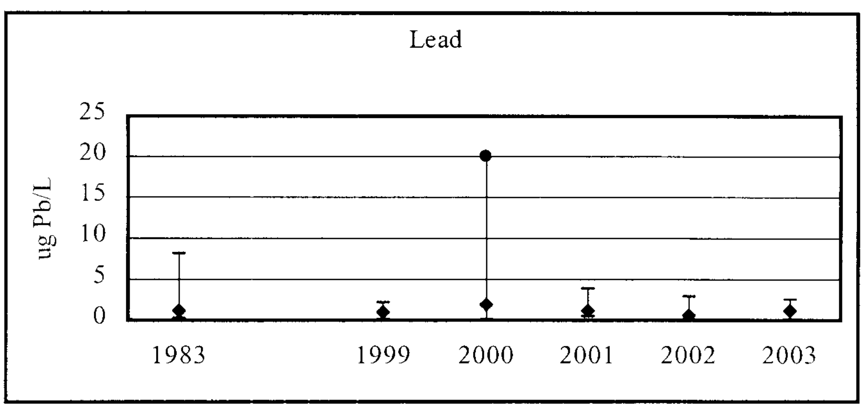


Figure 8. Median, maximum, and minimum concentrations of Pb at Station 9. The circle represents a MDL, not a concentration.

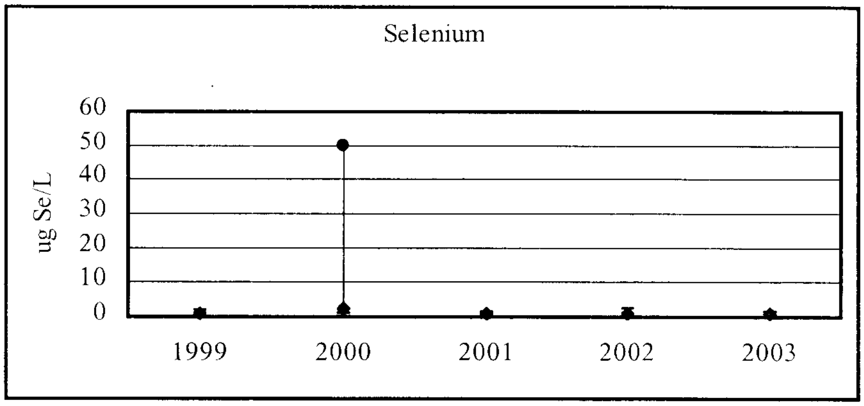


Figure 9. Median, maximum, and minimum concentrations of Se at Station 9. The circle represents a MDL, not a concentration. There are no baseline data for Se.

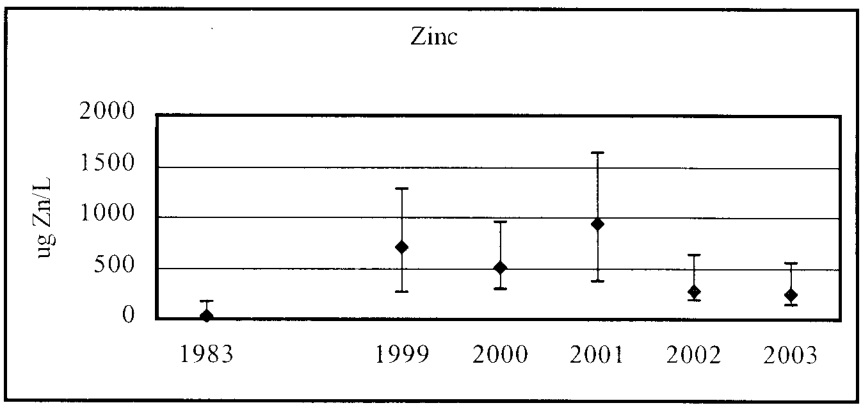


Figure 10. Median, maximum, and minimum concentrations of Zn at Station 9.

Invertebrate Community (Abundance, Density, and Taxa Richness)

Both invertebrate abundance (average number of aquatic invertebrates per net) and densities (average number of aquatic invertebrates/m3 of water) were highest in 2001. Invertebrate abundance and density in 2001, 2002, and 2003 were higher than in 1999 or 2000 (Figures 11 and 12). The taxa richness, as total number of aquatic taxa collected during each sample period, was similar for all years, but highest in 2003 when 20 different taxa were collected (Figure 13). Higher abundance, density, and taxa richness in 2001 through 2003 probably is due to decreased metal concentrations related to a reduction in Cub Creek flow to Ikalukrok Creek. The Cub Creek seep located on Ikalukrok Creek upstream of Station 9 has been a major source of metals input in past years, but effects to the system have been declining for the past several years.

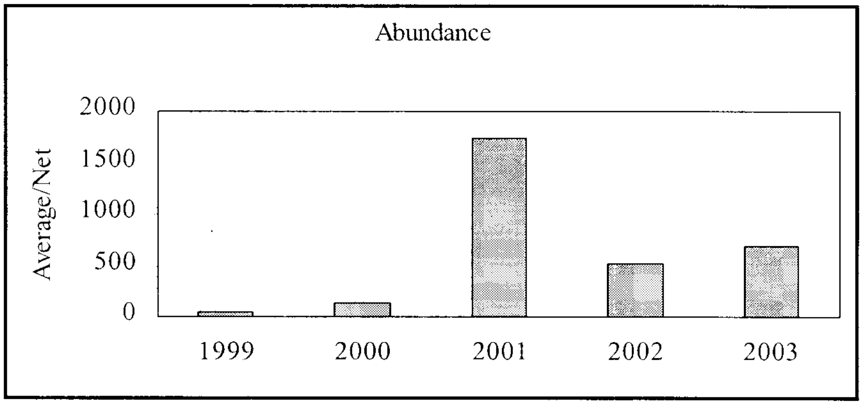


Figure 11. Abundance of aquatic invertebrates collected in Ikalukrok Creek at Station 9.

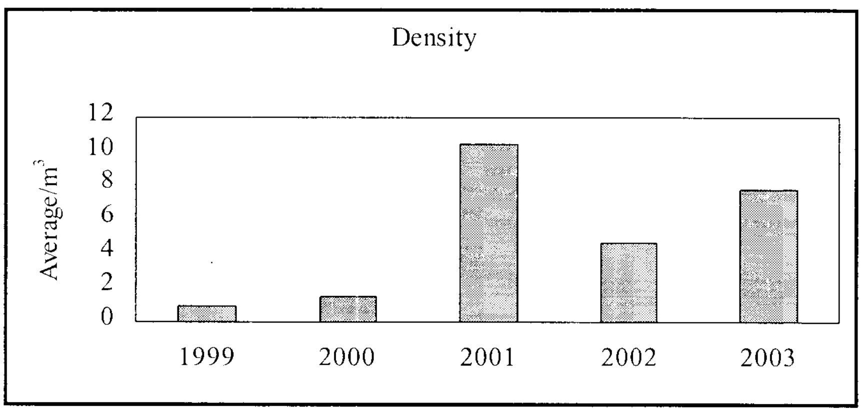


Figure 12. Density of aquatic invertebrates collected in Ikalukrok Creek at Station 9.

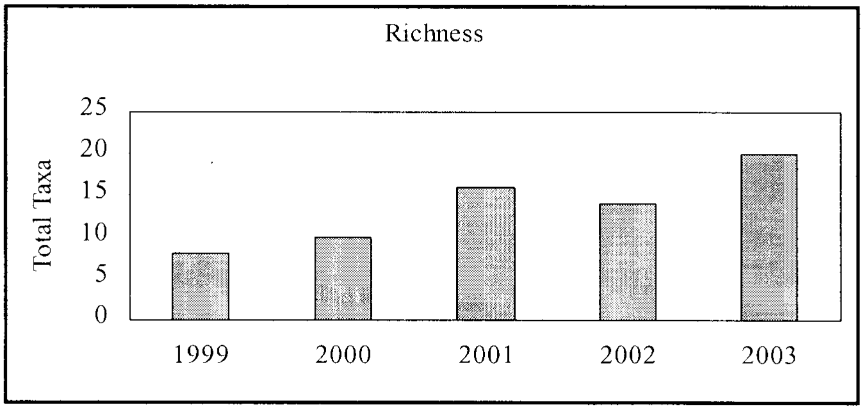


Figure 13. Taxa richness of aquatic invertebrates collected in Ikalukrok Creek at Station 9.

Community Structure

Invertebrate samples contained a high proportion of Ephemeroptera, Plecoptera, and Trichoptera (EPT taxa) in all years, except 2001 and 2003 when only 25 and 27% of the samples were EPT (Figure 14).

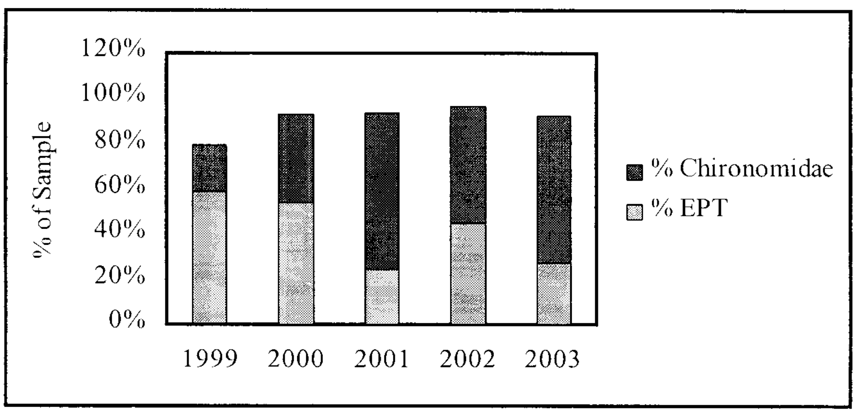


Figure 14. Proportions of EPT and Chironomidae larvae in invertebrate samples from Ikalukrok Creek at Station 9.

Periphyton Standing Crop

Concentrations of chlorophyll-a were highest in 2003 and lowest in 2001 (Figure 15). Chlorophyll-a concentrations are a measure of algal standing crop and give a relative indication of the primary productivity. Year-to-year variation in algal standing crop is due to differences in weather conditions, including light and temperature, and may be reduced by high water events.

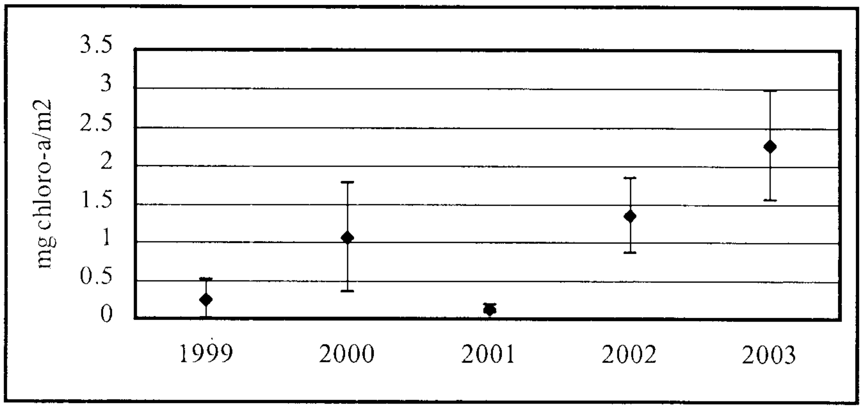


Figure 15. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in Ikalukrok Creek at Station 9.

Composition of Algal Communities

The algal community at Station 9 consists of a mixture of diatoms with little indication of chlorophyll-b, a pigment found in green algae, Chlorophyta, and plants. In 2002, we found a similar pattern with 1.35 mg/m^2 chlorophyll-a, 0.001 mg/m^2 chlorophyll-b, and 0.07 mg/m^2 chlorophyll c. The pattern of higher chlorophyll-a as compared with b or c, was the same in 2003 (Figure 16).

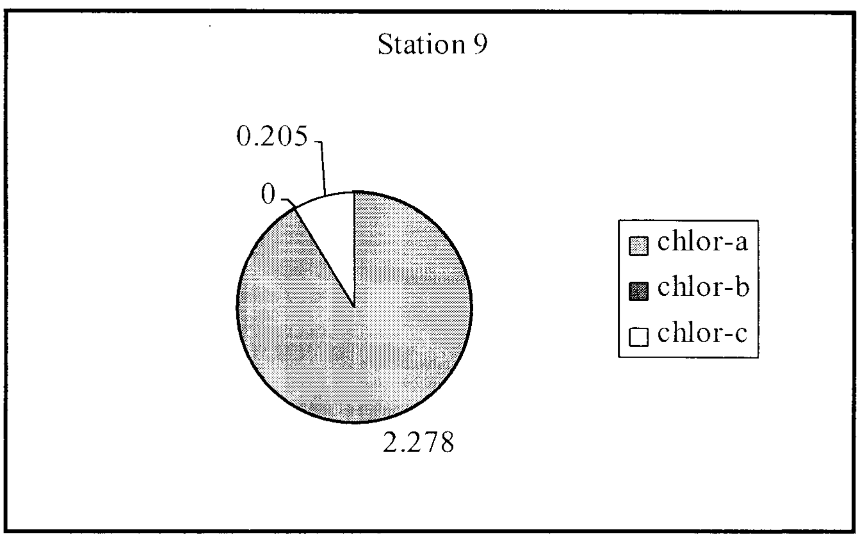


Figure 16. Proportions and values of chlorophyll-a, b, and c (mg/m^2) in Ikalukrok Creek at Station 9 in 2003.

Summary of Biomonitoring, Station 9, 1999-2003

Changes in water quality, invertebrates, periphyton, and presence of larval Arctic grayling that have been documented over time are summarized in Table 4.

Table 4. Summary of biomonitoring, Ikalukrok Creek at Station 9, 1999-2003.

Factor	Changes Observed
Water Quality	Cd, Ni, and Zn lower in 2002 and 2003
Invertebrate Communities	Abundance - higher in 2000 through 2003 Density - higher in 2000 through 2003 Taxa Richness - higher in 2000 through 2003 - most taxa found in 2003 %EPT - highest in 1999, 2000, and 2002
Periphyton Communities	Highest in 2002 and 2003
Larval Arctic Grayling	Present in 1997, 1999, 2000

Ikalukrok Creek at Station 8

Site Description

Ikalukrok Creek below Mainstem Red Dog Creek is a relatively fast flowing stream with medium sized gravel to small cobble substrate (Figure 17). Stream banks are covered with various species of willows and gravel bars are exposed at lower flows. During summer months, the stream bottom is frequently covered with filamentous algae stained red from precipitated iron.

Figure 17. Ikalukrok Creek downstream of Mainstem Red Dog Creek, Station 8.

Water Quality

Water samples have not been collected from this site in recent years because the water from Mainstem Red Dog Creek and Ikalukrok Creek is not mixed. Water quality samples are now collected at Station 150 about 0.5 km below original Station 8.

Invertebrate Community (Abundance, Density, and Taxa richness)

Abundance, density, and taxa richness of aquatic invertebrates found in Ikalukrok Creek at Station 8 was highest in 2003 (Figures 18, 19, and 20). An average of 1,280 aquatic organisms per net and 9.9 organisms per m^3 of water was found in 2003. In 2003, we found a total of 24 distinct taxonomic groups, compared with 22 in 2001 (Figure 20).

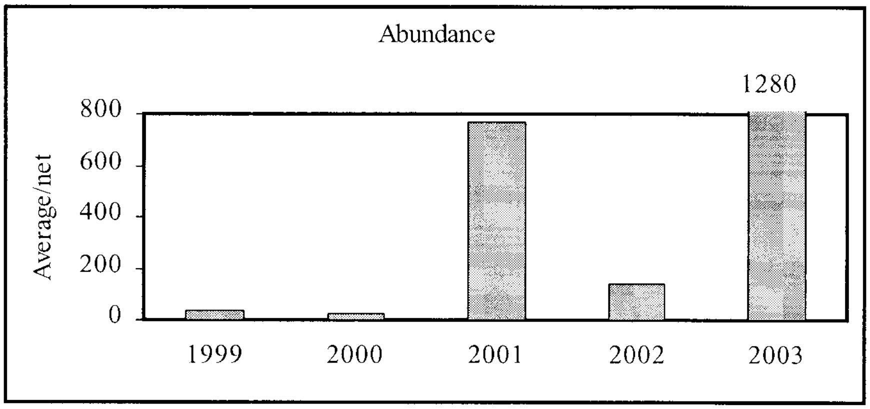


Figure 18. Abundance of aquatic invertebrates in Ikalukrok Creek at Station 8.

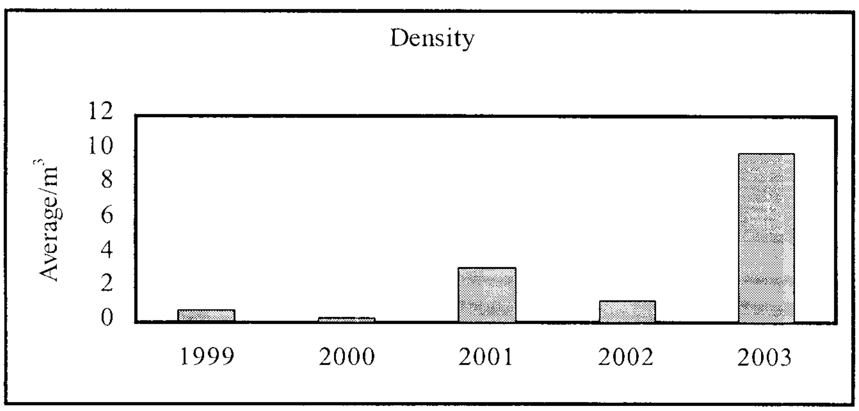


Figure 19. Density of aquatic invertebrates in Ikalukrok Creek at Station 8.

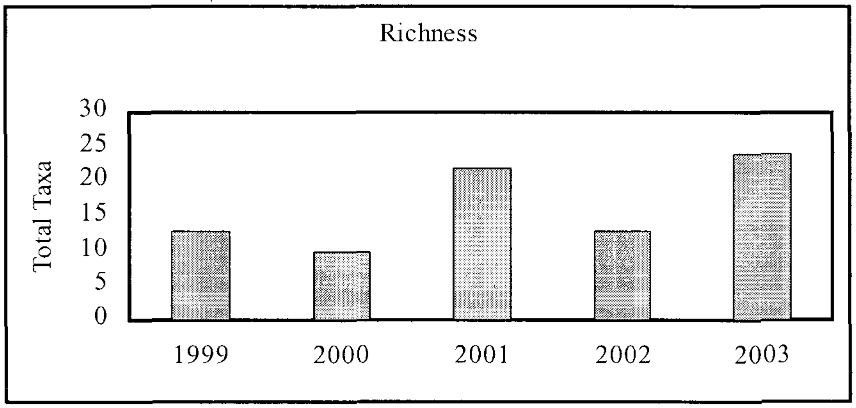


Figure 20. Taxa richness of the invertebrate community in Ikalukrok Creek at Station 8.

Community Structure

The invertebrate community contained a large proportion of EPT in 1998 (71%) when the stonefly Capnia was mature and prevalent in drift samples (Weber Scannell et al. 2000). From 1999 through 2003, the proportion of EPT taxa was lower than in 1998, with an overall average of 31% EPT and 59% Chironomidae (Figure 21). The invertebrate community at Station 8 is dominated by Diptera: Chironomidae.

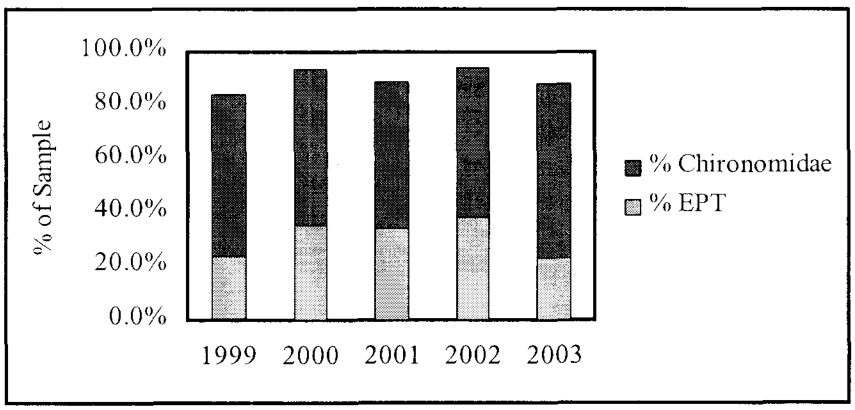


Figure 21. Proportions of EPT taxa and Chironomidae larvae in invertebrate samples collected in Ikalukrok Creek at Station 8.

Periphyton Standing Crop

The abundance of attached algae, estimated by chlorophyll-a concentrations was highest in July 2002 and 2003 when we measured an average of 2.40 and 2.22 mg chlorophyll-a per m^2 of stream substrate (Figure 22).

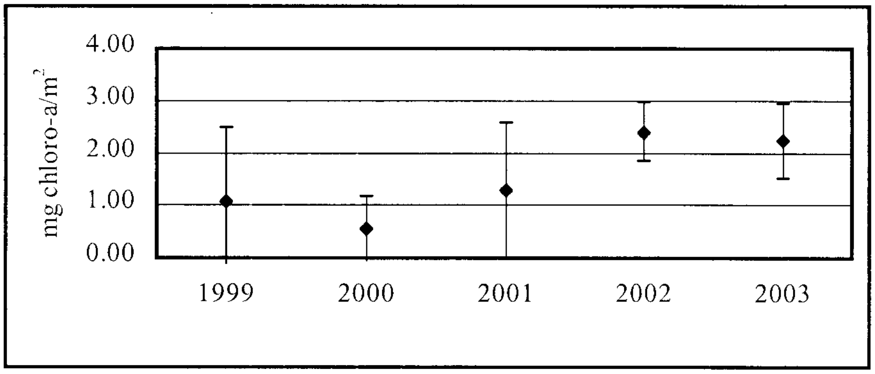


Figure 22. Average concentrations of chlorophyll-a, plus and minus 1 standard deviation, in Ikalukrok Creek at Station 8.

Composition of Algal Communities

In 2002 algal communities in Ikalukrok Creek at Station 8 were dominated by chlorophyll-a (average 2.41 mg/m^2) with an average of 0.02 mg/m^2 chlorophyll-b and 0.26 mg/m^2 chlorophyll-c (Ott and Weber Scannell 2003). Algal communities at Station 8 in 2003 were very similar to those found in 2002 (Figure 23).

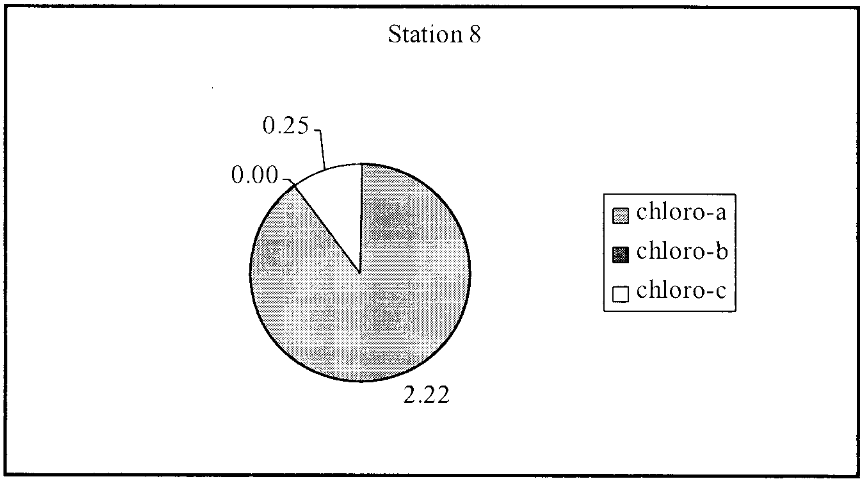


Figure 23. Proportions and values of chlorophyll-a, b, and c (mg/m^2) in Ikalukrok Creek at Station 8, 2003.

Summary of Biomonitoring at Station 8, 1999-2003

Changes in water quality, invertebrates, periphyton, and presence of larval Arctic grayling that have been documented over time at Station 8 are summarized in Table 5.

Table 5. Summary of biomonitoring, Ikalukrok Creek at Station 8, 1999-2003.

Factor	Changes Observed
Water Quality	Ikalukrok and Mainstem not mixed, data unreliable all years
Invertebrate Communities	Abundance - higher in 2001 and 2003 Density - higher in 2001 and 2003 Taxa Richness - higher in 2001 and 2003 %EPT - relatively stable - higher proportion Chironomidae all years
Periphyton Communities	Highest in 2002 and 2003
Larval Arctic Grayling	Present in 2000 and 2002

Ikalukrok Creek Upstream of Dudd Creek

Site Description

Ikalukrok Creek, upstream of Dudd Creek, is a wide, fairly shallow channel up to 40 m wide and 0.5 to 1.5 m deep during summer low flows (Figure 24). Pools along cut banks or adjacent to rock bluffs are 2 to 4 m deep. The substrate contains mostly small cobble with medium sized gravel. Streambanks are thickly vegetated with willows and herbaceous plants and grasses.

Figure 24. Ikalukrok Creek upstream of Dudd Creek.

Water Quality

Water is not sampled in Ikalukrok Creek near our sample site for invertebrates and periphyton; however, water samples are collected at Station 73 and are a good representation of the water quality at our sample site. Station 73 is located about 6 km upstream of the sample site and there are no defined tributaries to Ikalukrok Creek in this reach.

Ikalukrok Creek at Station 73 during mine operation (data for 1993 to present) has hard water with circumneutral to basic pH (Weber Scannell and Ott 2000). The lowest pH (6.3) was in June 2003. The general trend is for decreasing hardness and sulfate from 1999 through 2003. The mine effluent influences water quality by increasing the hardness and concentrations of TDS and sulfate. Median concentrations for hardness and sulfate at Station 73 are about double those found for the same time period at Station 9 (Ikalukrok Creek upstream of Mainstem Red Dog Creek). Metals concentrations are historically low at this site, compared to sites in the Red Dog Creek drainage (Weber Scannell et al. 2001). For those analytes (Cd, Pb, Zn) with premining data, median concentrations from 1999 through 2003 were lower. Median concentrations of Al and Se were similar, and Fe and Ni decreased during the NPDES Permit period from 1996 to 2003 (Figures 25 through 31), with the exception of some peaks in 2000.

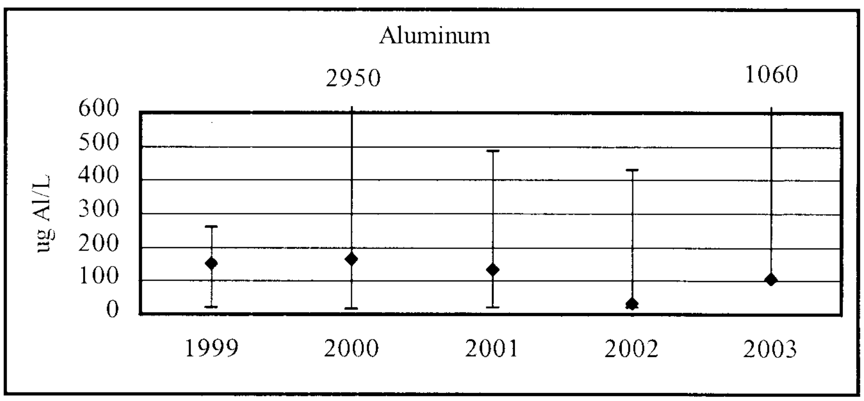


Figure 25. Median, maximum, and minimum concentrations of Al at Station 73. There were no baseline data for Al.

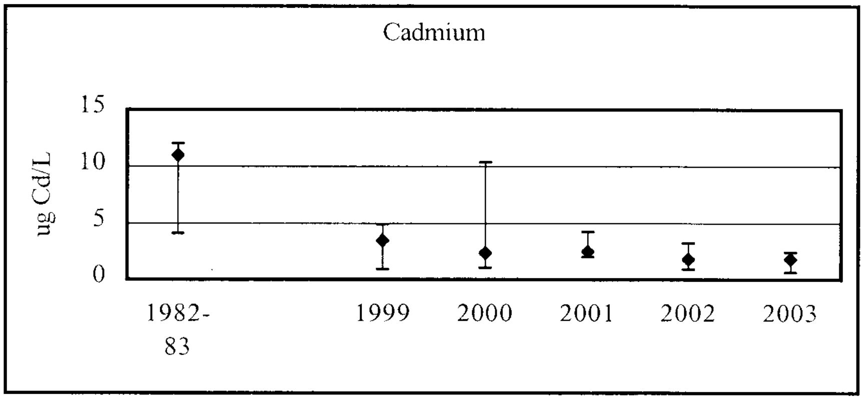


Figure 26. Median, maximum, and minimum concentrations of Cd at Station 73.

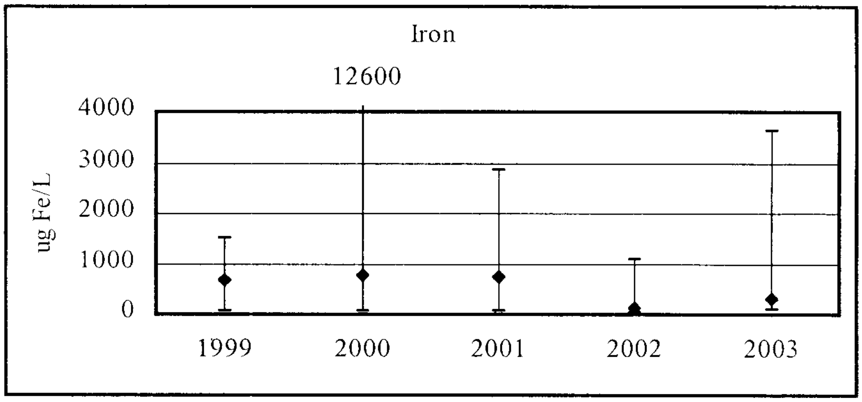


Figure 27. Median, maximum, and minimum concentrations of Fe at Station 73. There were no baseline data for Fe.

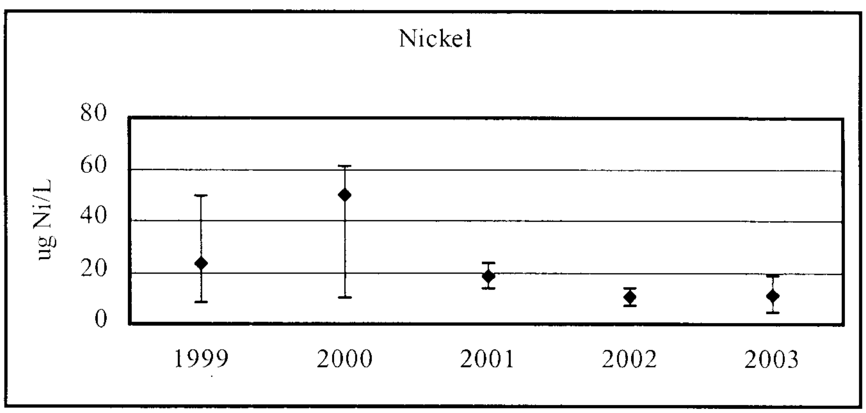


Figure 28. Median, maximum, and minimum concentrations of Ni at Station 73. There were no baseline data for Ni.

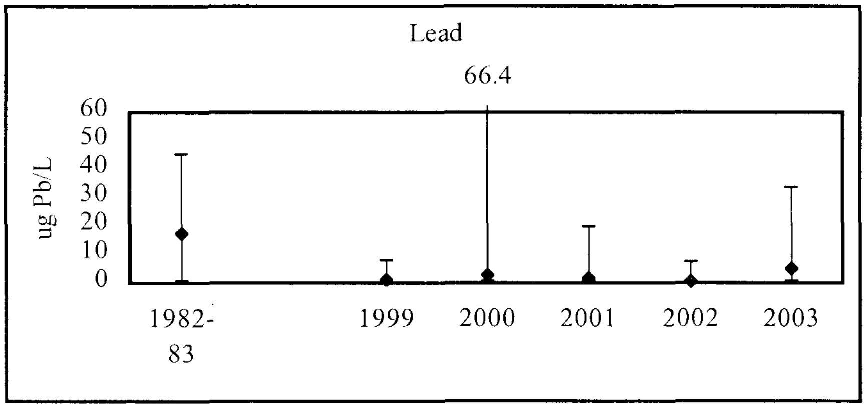


Figure 29. Median, maximum, and minimum concentrations of Pb at Station 73.

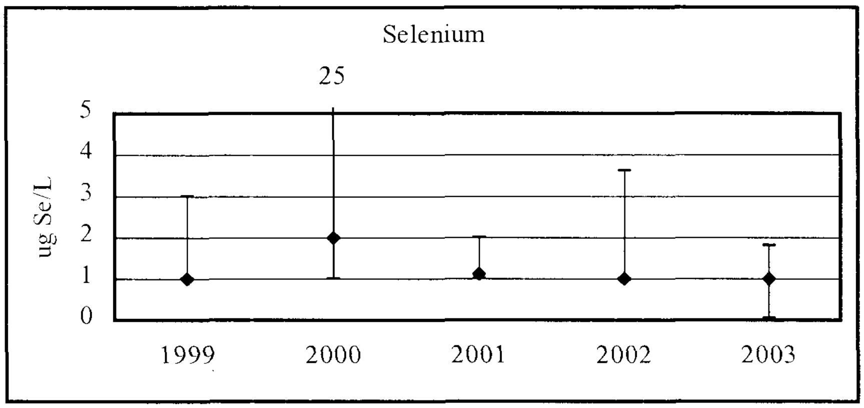


Figure 30. Median, maximum, and minimum concentrations of Se at Station 73. The 25 *u*g Se/L represents the method detection limit. There were no baseline data for Se.

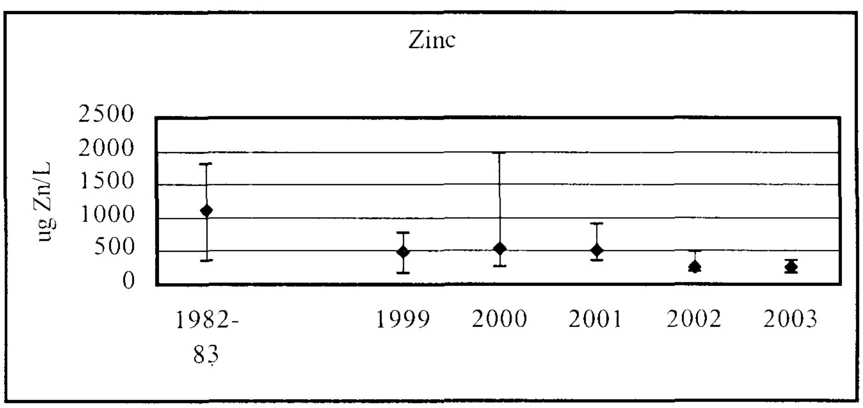


Figure 31. Median, maximum, and minimum concentrations of Zn at Station 73.

Invertebrate Community (Abundance, Density, and Taxa richness)

Invertebrate abundance gradually increased from 1999 through 2001, decreased slightly in 2002, and was the highest in 2003 (Figure 32). Density of aquatic invertebrates was similar in 1999, 2001, and 2002, but highest in 2000 and 2003 (Figure 33). Taxa richness varied from a low of 13 in 1999 to a high of 20 in 2001 (Figure 34).

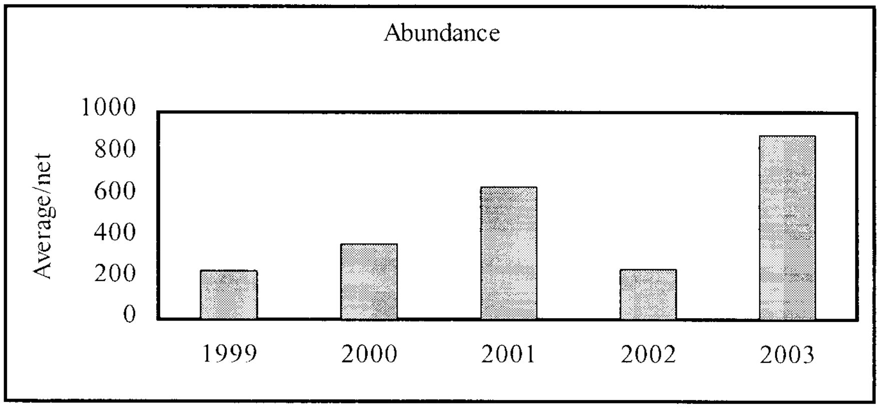


Figure 32. Abundance of aquatic invertebrates collected in Ikalukrok Creek upstream of Dudd Creek.

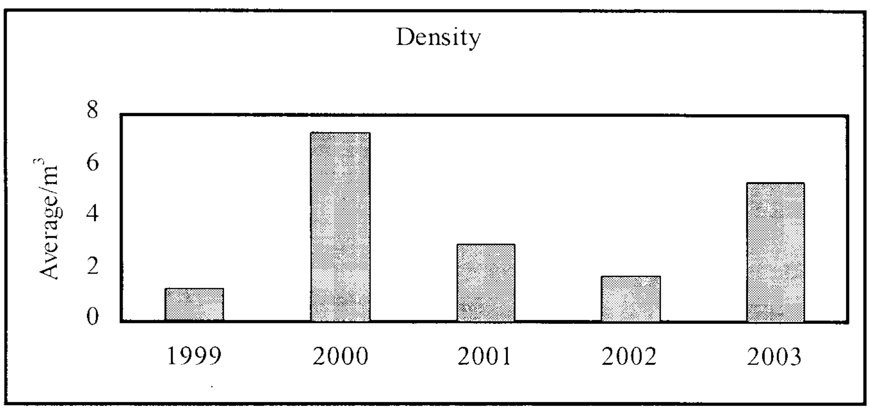


Figure 33. Density of aquatic invertebrates collected in Ikalukrok Creek upstream of Dudd Creek.

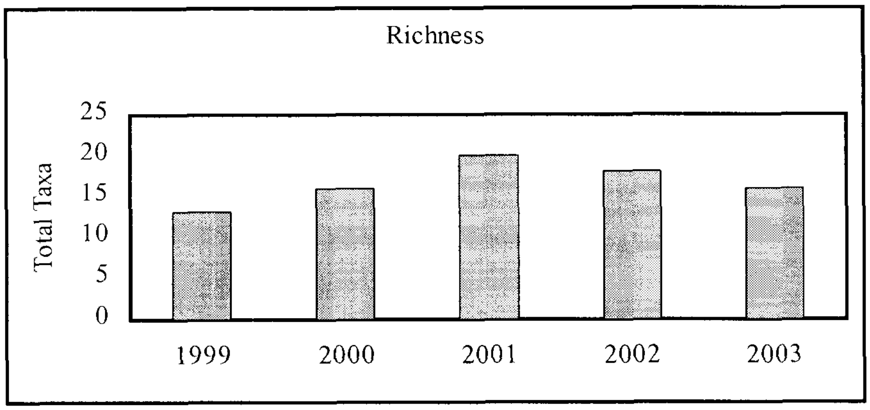


Figure 34. Taxa richness of invertebrate samples collected in Ikalukrok Creek upstream of Dudd Creek.

Community Structure

There were a low proportion of EPT taxa compared to the proportions of Chironomidae during four of the five years of sampling (Figure 35). In 2002 and 2003, the proportions of EPT and Chironomidae were low due to the high proportion of Simulidae.

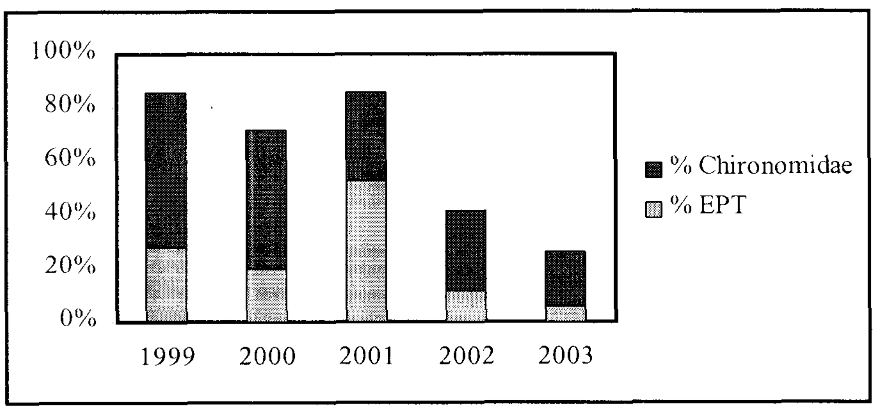


Figure 35. Proportions of EPT taxa and Chironomidae collected from Ikalukrok Creek upstream of Dudd Creek.

Periphyton Standing Crop

Periphyton was sampled from benthic substrates in Ikalukrok Creek just upstream of Dudd Creek during the last week of June or first week of July in 1999 through 2003. Median concentrations of periphyton were similar among all years sampled during the NPDES Permit period, except in 2002 and 2003, when they were slightly lower (Figure 36). Differences among years are likely a result of stream flow and water temperatures; in 2002 and 2003 sampling occurred after a high-water event.

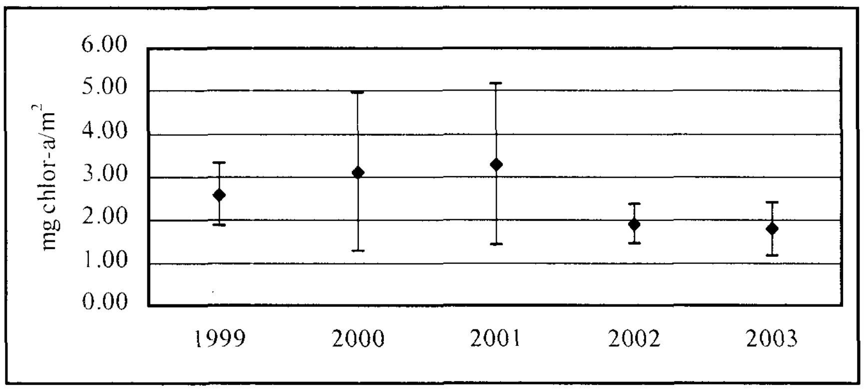


Figure 36. Average concentrations of chlorophyll-a, plus and minus 1 standard deviation, in Ikalukrok Creek upstream of Dudd Creek.

Composition of Algal Communities

All periphyton samples collected in Ikalukrok Creek upstream of Dudd Creek contained sufficient concentrations of chlorophyll-a to allow measurements of the three main pigments. In 2002, chlorophyll-a (1.91 mg/m^2) was highest in the periphyton samples and chlorophyll-c (0.18 mg/m^2) was higher than chlorophyll-b (0.05 mg/m^2) (Ott and Weber Scannell 2003). Chlorophyll-b in 2003 was not measurable and chlorophyll-a was the highest (1.79 mg/m2) (Figure 37).

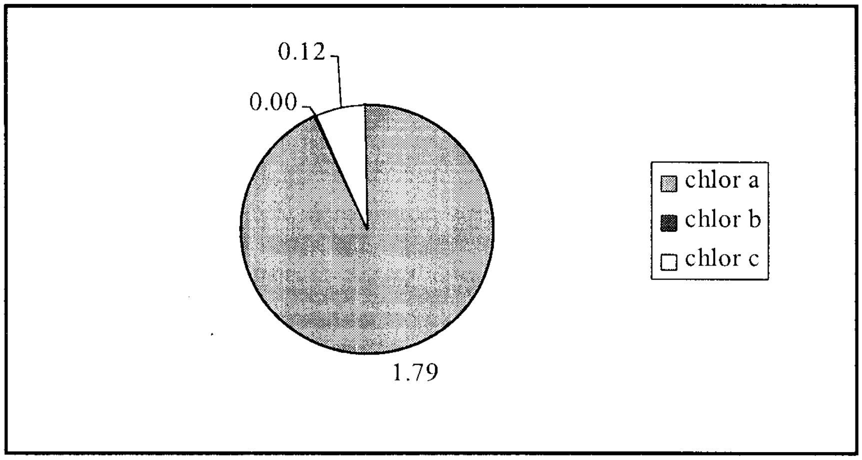


Figure 37. Proportions and values of chlorophyll-a, b, and c (mg/m^2) in Ikalukrok Creek upstream of Dudd Creek, 2003.

Summary of Biomonitoring, Ikalukrok Upstream of Dudd Creek, 1999-2003

Changes in water quality, invertebrates, periphyton, and presence of larval Arctic grayling that have been documented over time in Ikalukrok Creek upstream of Dudd Creek are summarized in Table 6.

Table 6. Summary of biomonitoring, Ikalukrok Creek upstream of Dudd Creek, 1999-2003.

Factor	Changes Observed
Water Quality	General trend, decreasing metals concentrations Baseline Cd, Pb, and Zn higher than 1999-2003 1999-2003, metals higher in 2000
Invertebrate Communities	Abundance - higher in 2001 and 2003 Density - higher in 2000 and 2003 Taxa Richness - similar, but highest in 2001 %EPT - relatively stable - Simulidae high in 2002 and 2003
Periphyton Communities	Slightly lower in 2002 and 2003 after high water
Larval Arctic Grayling	Present in 2000, 2002, and 2003

Ikalukrok Creek at Station 7

Site Description

Ikalukrok Creek below Dudd Creek (Station 7, Figure 38) has stream widths from about 10 to 40 m and depths from 0.3 to 1.2 m. The substrate consists of small to medium sized gravel with prevalent gravel bars exposed at low flows. Ikalukrok and Dudd creeks are not mixed completely at Station 7; complete mixing of the two creeks does not occur until about 8 km downstream.

Figure 38. Ikalukrok Creek downstream of Dudd Creek, Station 7.

Water Quality

In May 1999, the stream gauge and monitoring station was moved from Station 7 near Dudd Creek downstream to Station 160. The new sampling station is located below complete mixing of Dudd and Ikalukrok creeks and in a more stable reach. Although TCAK has continued water quality sampling at Station 7 (i.e., the NPDES sample station), data from Station 160 where the water is mixed provides a more accurate representation of water quality conditions in lower Ikalukrok Creek. Only data from

Station 160 (1999 to 2003) are presented in this report; earlier reports (e.g., Weber Scannell et al. 2002) presented data collected at Station 7.

In 2003, the water at Station 160 had a pH that ranged from 6.4 (early May) to 8 (mid-August) with a median value of 7.5. Concentrations of TDS are low in May and early June because TCAK regulates the discharge to be at or below 500 mg/L TDS at Station 10 (Mainstem Red Dog Creek) during Arctic grayling spawning (Figure 39). TDS concentrations also are lower at this time of the year due to flows associated with spring breakup. TDS concentrations also remained below 500 mg/L during the spawning period (July 25 through October 31) for chum salmon and Dolly Varden.

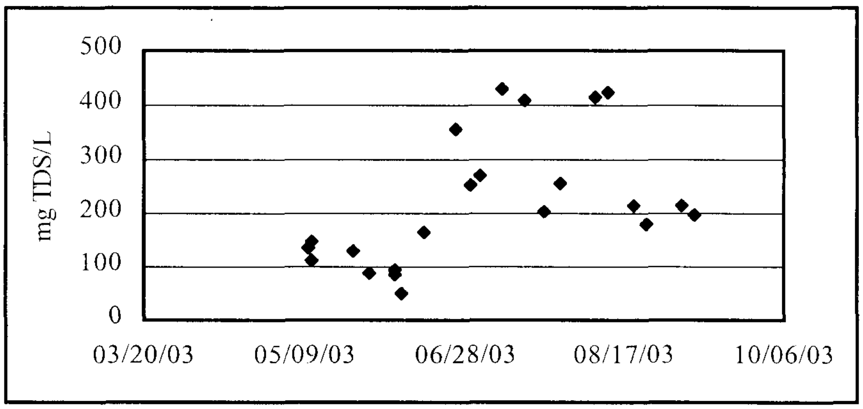


Figure 39. Seasonal variation in TDS concentrations in Ikalukrok Creek at Station 160.

With the exception of 2000, hardness and sulfate median concentrations have steadily decreased at Station 160. Median concentrations for 2003 for hardness and sulfate were 117 and 75 mg/L. Concentrations of Al, Cd, Fe, Ni, Pb, Se, and Zn are presented in Figures 40 through 47).

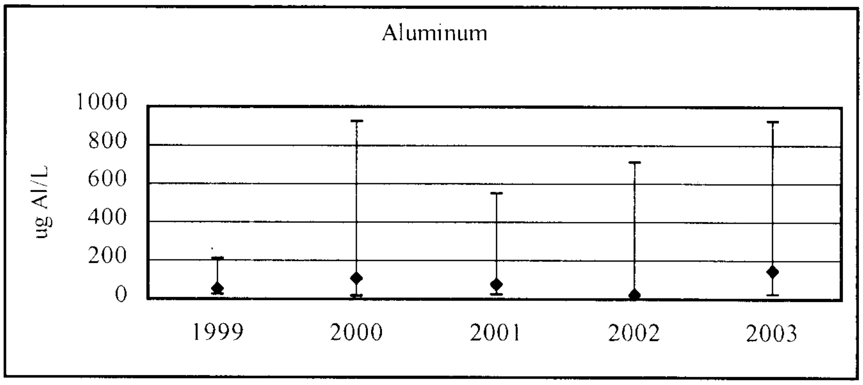


Figure 40. Median, maximum, and minimum concentrations of Al at Station 160. There are no baseline data for Al.

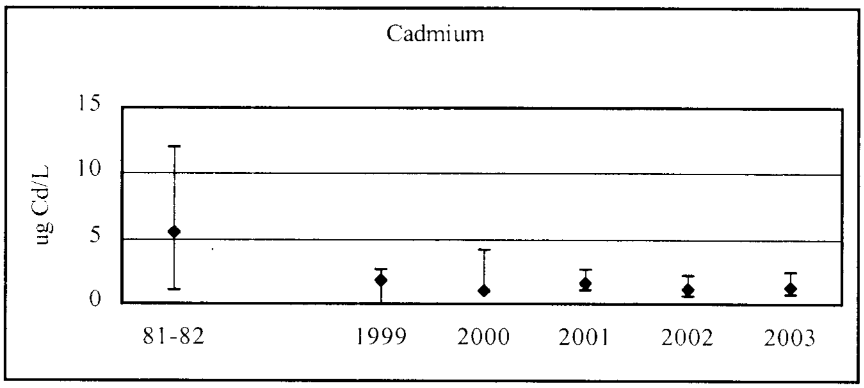


Figure 41. Median, maximum, and minimum concentrations of Cd at Station 160.

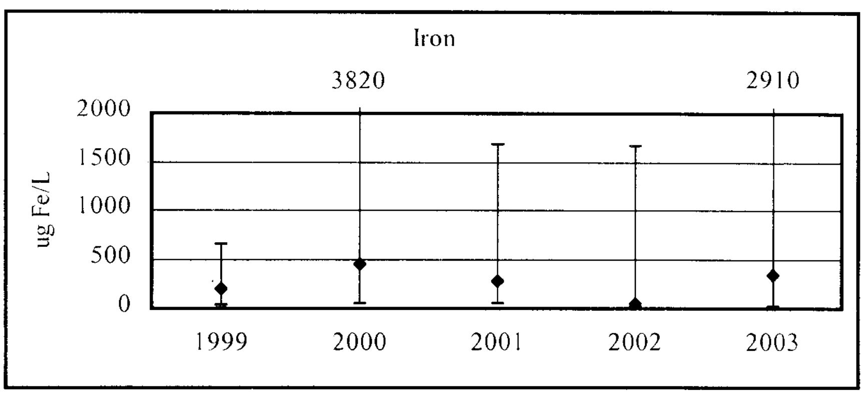


Figure 42. Median, maximum, and minimum concentrations of Fe at Station 160. There are no baseline data for Fe.

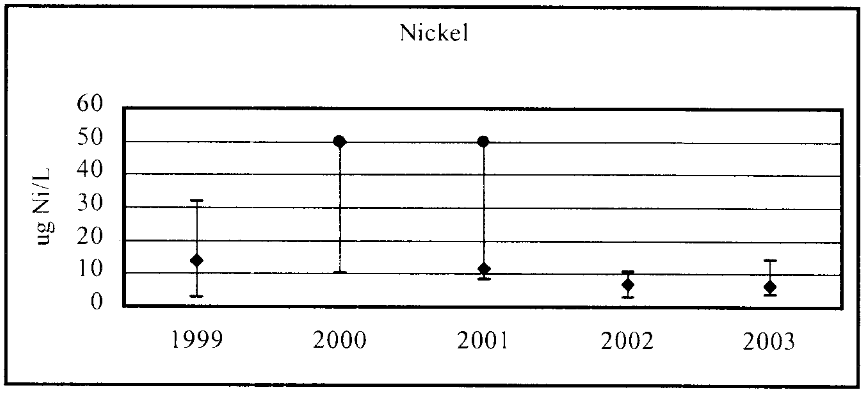


Figure 43. Median, maximum, and minimum concentrations of Ni at Station 160. The circle represents a MDL, not a concentration. There are no baseline data for Ni.

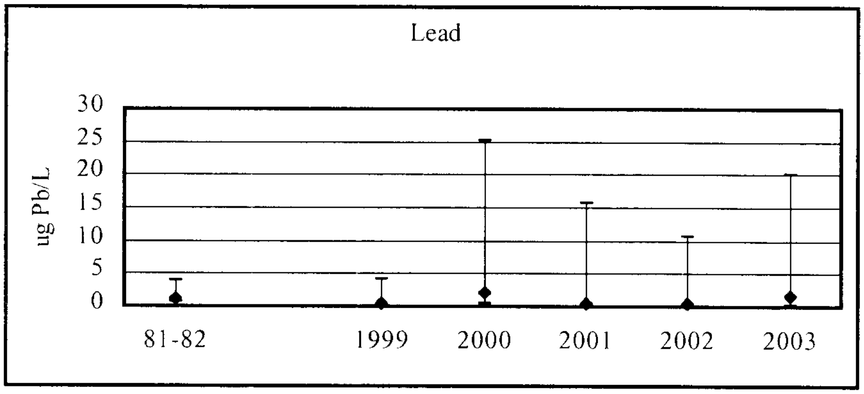


Figure 44. Median, maximum, and minimum concentrations of Pb at Station 160.

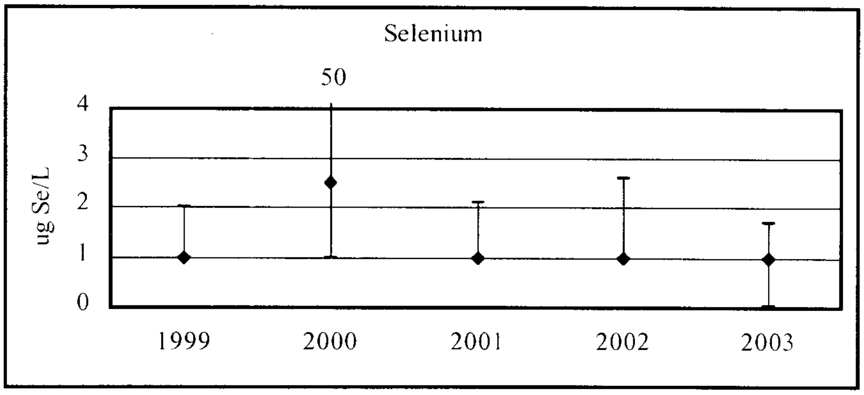


Figure 45. Median, maximum, and minimum concentrations of Se at Station 160. The 50 represents a MDL, not a concentration. There are no baseline data for Se.

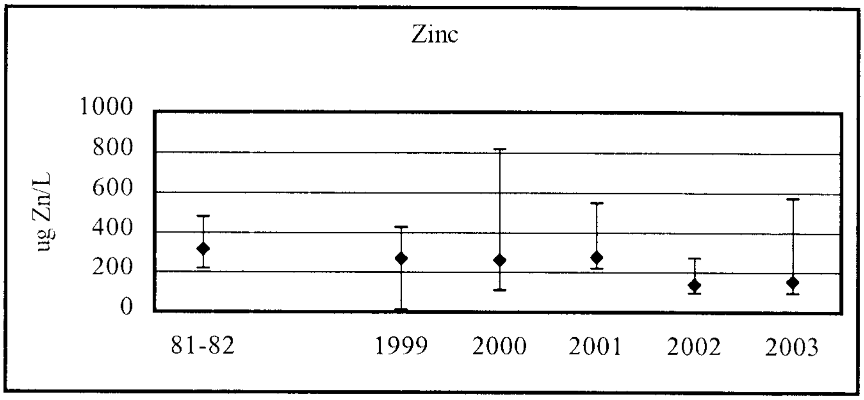


Figure 46. Median, maximum, and minimum concentrations of Zn at Station 160.

Invertebrate Community (Abundance, Density, and Taxa Richness)

Both invertebrate abundance and density were highest in 2003 and lowest in 1999 and 2002 (Figures 47 and 48). Taxa richness has varied from a low of 10 (in 1999 and 2002) to a high of 20 in 2001 (Figure 49).

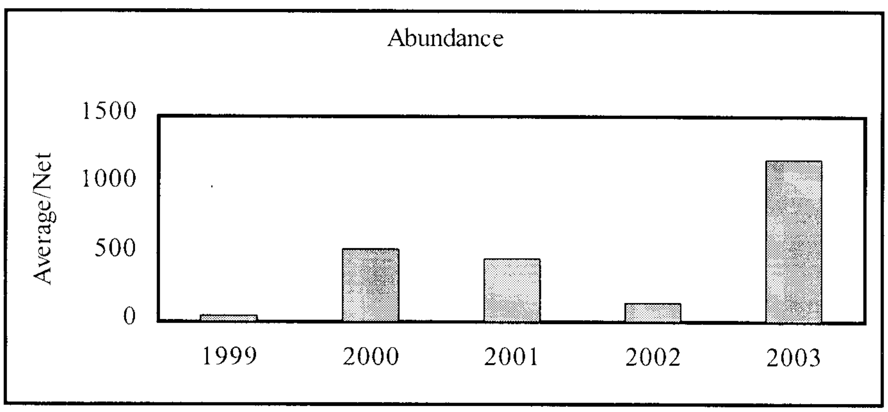


Figure 47. Abundance of aquatic invertebrates collected in Ikalukrok Creek at Station 7.

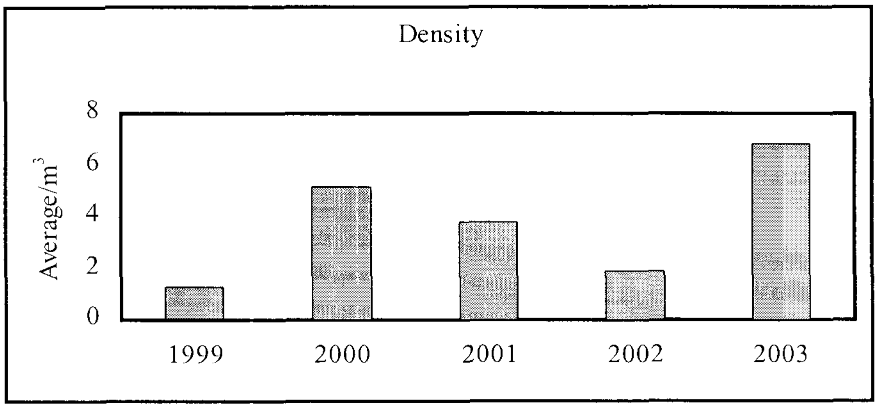


Figure 48. Density of aquatic invertebrates collected in Ikalukrok Creek at Station 7.

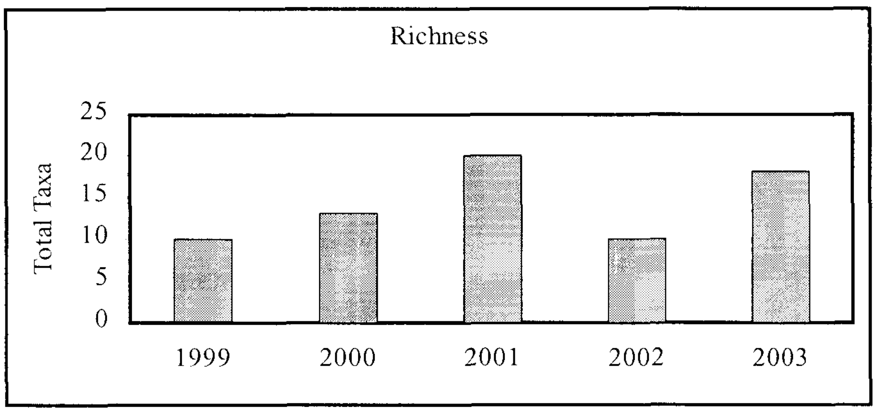


Figure 49. Taxa richness of aquatic invertebrates collected in Ikalukrok Creek at Station 7.

Community Structure

In both 2002 and 2003 invertebrate samples, the dominant invertebrate family was Diptera: Simulidae (Figure 50).

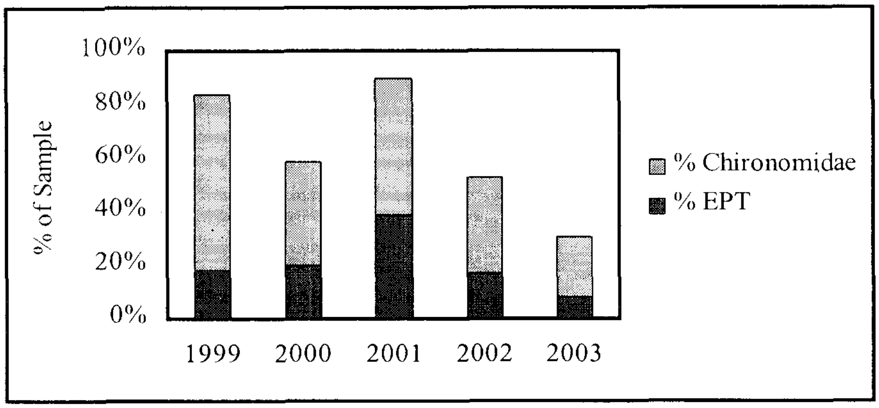


Figure 50. Proportions of EPT and Chironomidae larvae in invertebrate samples from Ikalukrok Creek at Station 7.

Periphyton Standing Crop

Algal biomass, as estimated by chlorophyll-a concentrations has been fairly consistent over the years with the highest average concentrations found in 2000 (Figure 51).

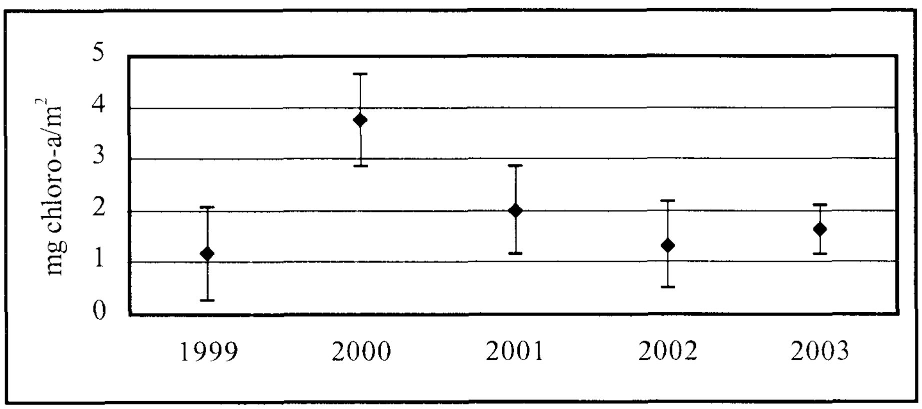


Figure 51. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in Ikalukrok Creek at Station 7.

Composition of Algal Communities

The algal community at Station 7 in Ikalukrok Creek consists of a mixture of diatoms with little indication of chlorophyll-b, a pigment found in green algae. In 2002 and 2003, the pattern was the same, with chlorphyll-a being the highest and chlorophyll-b being the lowest (Figure 52).

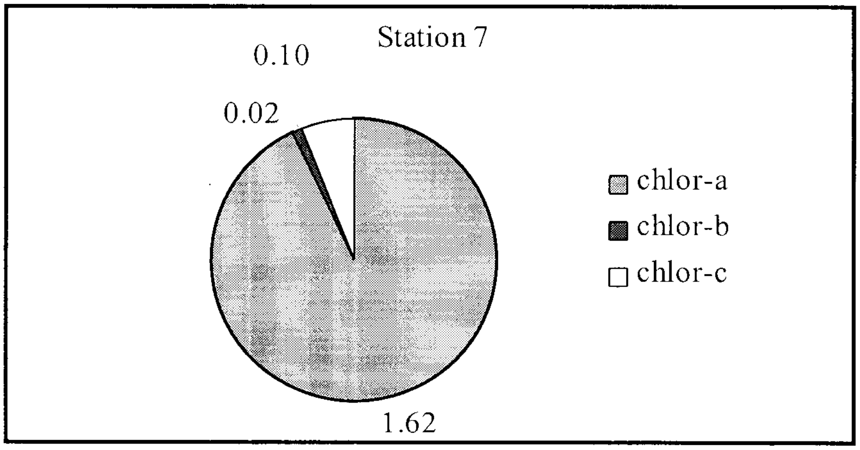


Figure 52. Proportions and values of chlorophyll-a, b, and c (mg/m^2) in Ikalukrok Creek at Station 7 in 2003.

Summary of Biomonitoring, Ikalukrok Creek at Station 7, 1999 to 2003.

Changes in water quality, invertebrates, periphyton, and presence of larval Arctic grayling that have been documented over time in Ikalukrok Creek at Station 7 downstream of Dudd Creek are summarized in Table 7.

Table 7. Summary of biomonitoring, Ikalukrok Creek at Station 7, 1999 to 2003.

Factor	Changes Observed
Water Quality	Cd, Pb, Se, and Zn similar 1999 to 2003
Invertebrate Communities	Abundance - higher in 2000, 2001, and 2003 Density - higher in 2000, 2001, and 2003 Taxa Richness - higher in 2001 and 2003 %EPT - highest in 2001 - Simulidae high in 2002 and 2003
Periphyton Communities	Similar all years, but highest in 2000
Larval Arctic Grayling	Present in 2000, 2002, and 2003

Mainstem Red Dog Creek at Station 10

Site Description

Mainstem Red Dog Creek (Figure 53) drains an area of 64 km^2. Widths of the creek range from 3.5 to 18 m and water depths range from 0.06 to 2.5 m in depth. The streambed consists mostly of gravel, small cobble, and boulders. The creek has some meanders and areas where the channel has shifted location.

Figure 53. Mainstem Red Dog Creek, Station 10

Water Quality

The volume of the effluent from the mine controls concentrations of TDS in Mainstem Red Dog Creek. Concentrations of TDS are limited in the creek to less than 500 mg/L during Arctic grayling spawning. Arctic grayling are sampled, depending upon flow and ice conditions, with fyke-nets and by angling in both Mainstem Red Dog and North Fork Red Dog creeks. After spawning has been completed in Mainstem Red Dog Creek, the TDS concentrations can be increased to not exceed 1,500 mg/L at Station 10 (Figure 54).

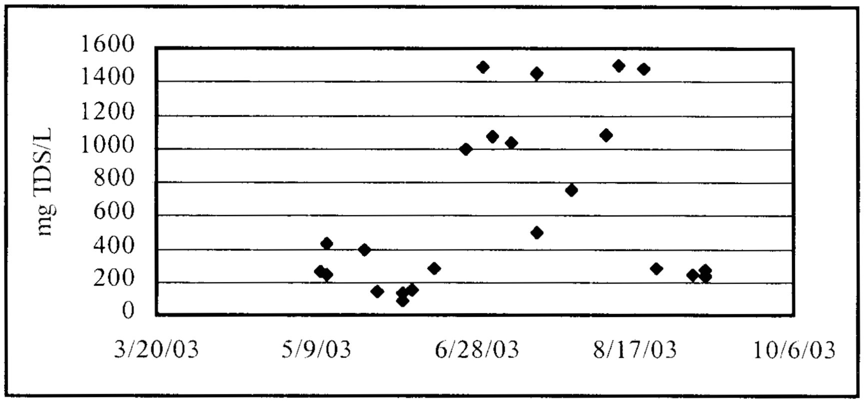


Figure 54. Seasonal variation in TDS concentrations in Mainstem Red Dog Creek at Station 10.

Concentrations of certain metals in Mainstem Red Dog Creek at Station 10 were high before mining, highest in 1989 and 1990, and lower after construction of the clean water bypass in March/April of 1991. The pH values also reflect these conditions with the lowest pH measured in 1990 (Figure 55). Concentrations of Al, Cd, Fe, Ni, Pb, Se, and Zn are presented in Figures 56 through 62.

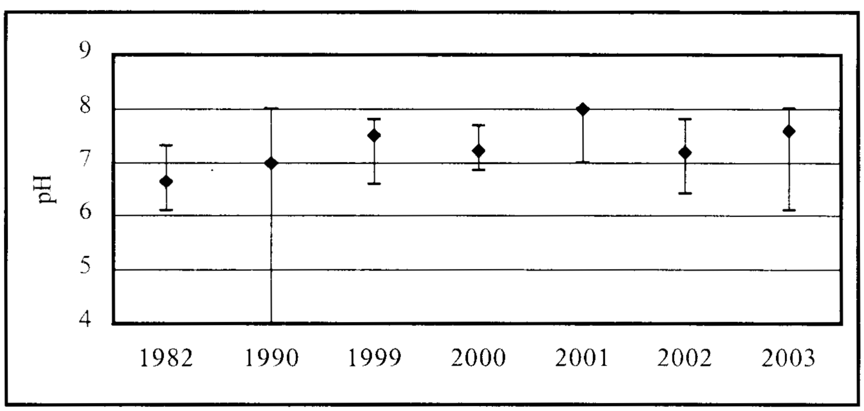


Figure 55. Median, maximum, and minimum pH values in Mainstem Red Dog Creek at Station 10.

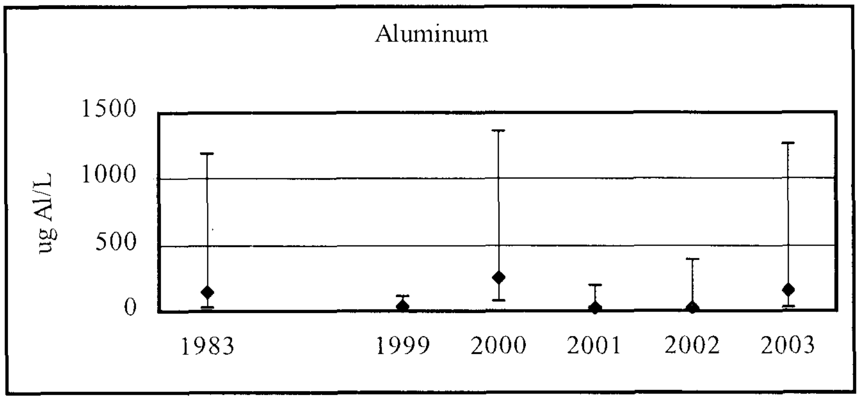


Figure 56. Median, maximum, and minimum concentrations of Al at Station 10.

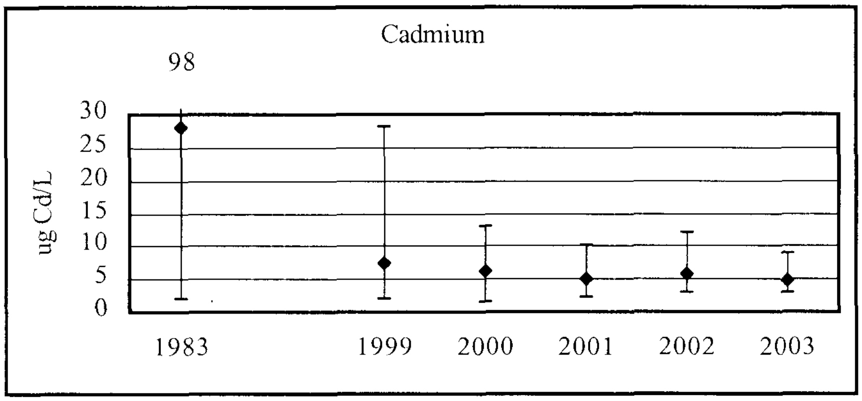


Figure 57. Median, maximum, and minimum concentrations of Cd at Station 10.

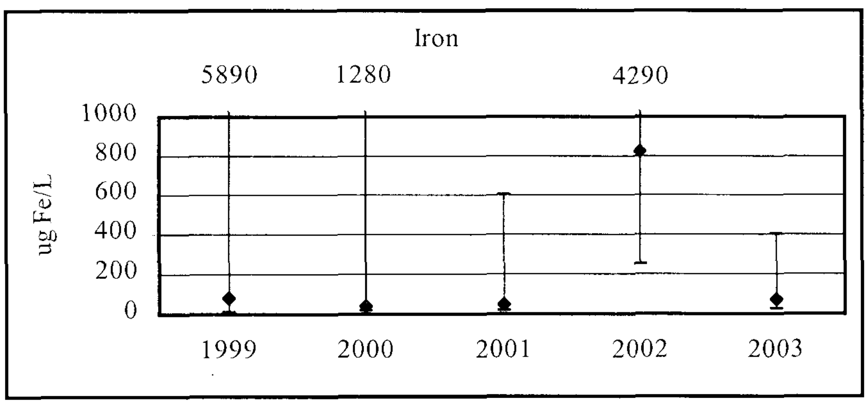


Figure 58. Median, maximum, and minimum concentrations of Fe at Station 10. There are no baseline data for Fe.

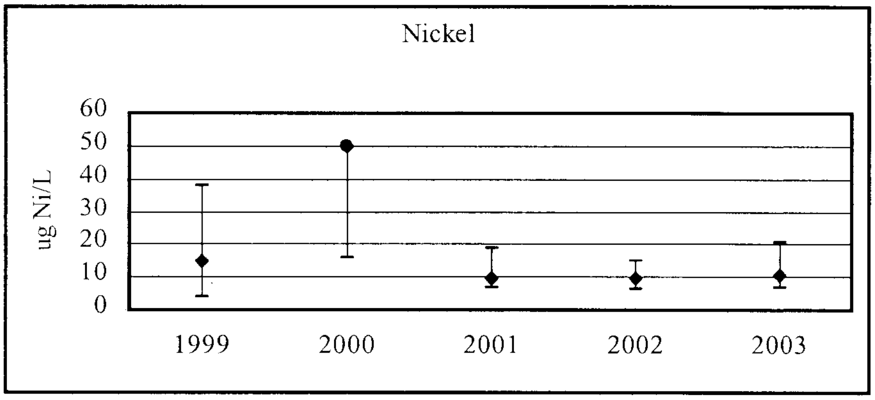


Figure 59. Median, maximum, and minimum concentrations of Ni at Station 10. The circle represents a MDL, not a concentration. There are no baseline data for Ni.

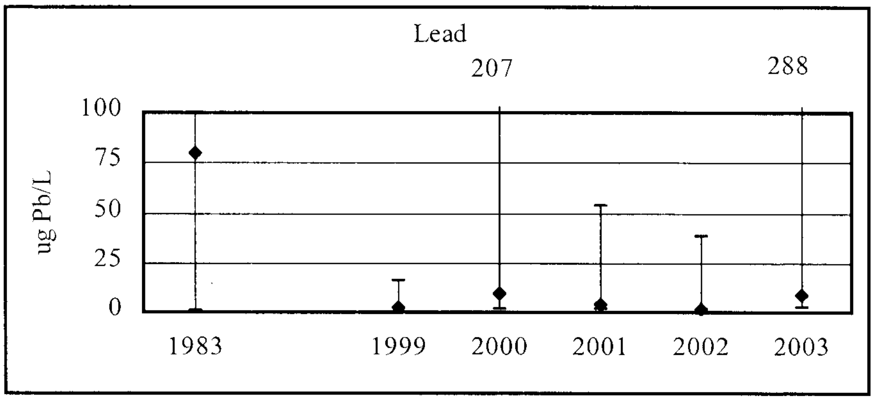


Figure 60. Median, maximum, and minimum concentrations of Pb at Station 10.

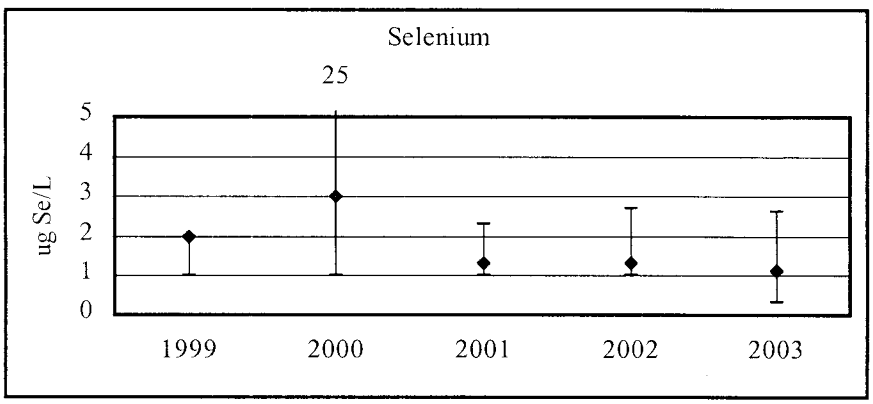


Figure 61. Median, maximum, and minimum concentrations of Se at Station 10. 25 *u*g/L represents a MDL, not a concentration. There are no baseline data for Se.

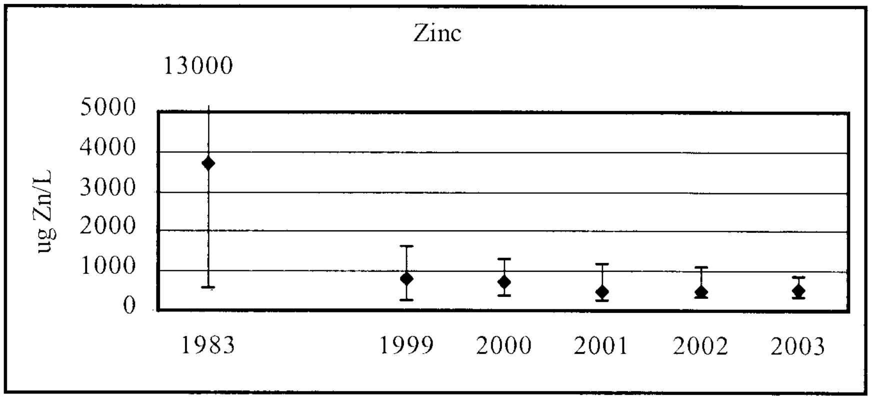


Figure 62. Median, maximum, and minimum concentrations of Zn at Station 10.

Invertebrate Community (Abundance, Density, and Taxa Richness)

Invertebrate abundance and density were highest in 2003 (Figures 63 and 64). Taxa richness was highest in 2001 and 2003 when 20 different taxa were collected (Figure 64).

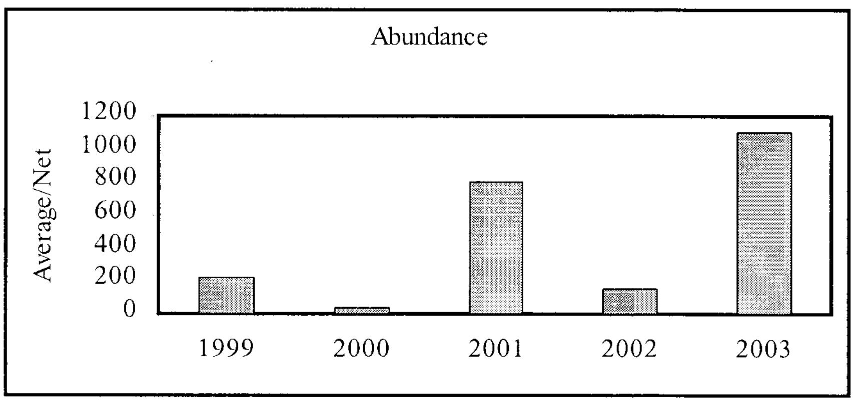


Figure 63. Abundance of aquatic invertebrates collected in Mainstem Red Dog Creek at Station 10.

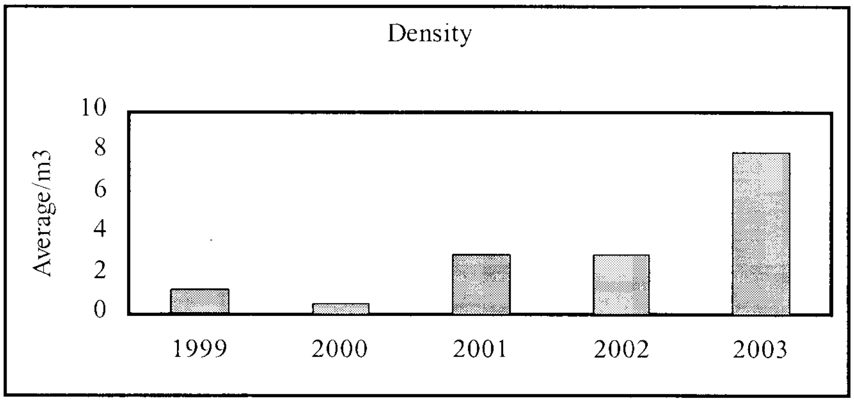


Figure 64. Density of aquatic invertebrates collected in Mainstem Red Dog Creek at Station 10.

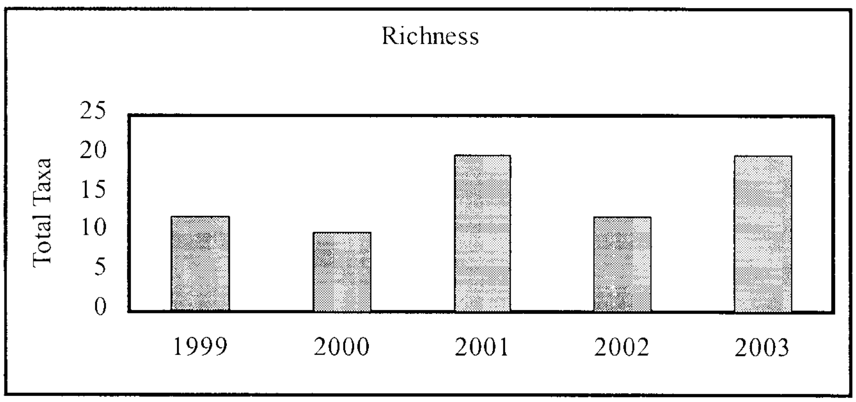


Figure 65. Taxa richness of aquatic invertebrates collected in Mainstem Red Dog Creek at Station 10.

Community Structure

Invertebrate samples from Mainstem Red Dog Creek contained a high proportion of EPT in 2000 and in 2003 (Figure 66). In 2003, the EPT represented 55% of the invertebrates in the sample (Figure 66).

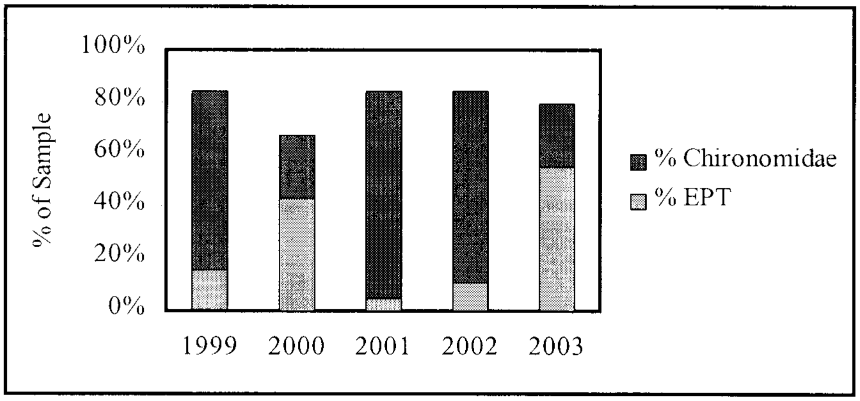


Figure 66. Proportions of EPT and Chironomidae larvae in invertebrate samples from Mainstem Red Dog Creek at Station 10.

Periphyton Standing Crop

In 2002 and 2003, the abundance of attached algae, estimated by cholophyll-a concentrations, was higher than in the 1999 through 2001 sample period (Figure 67).

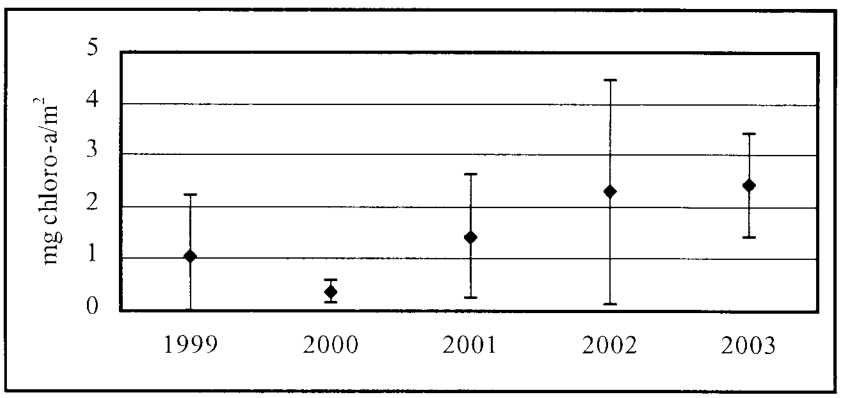


Figure 67. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in Mainstem Red Dog Creek at Station 10.

Composition of Algal Communities

No measurable amounts of chlorphyll-b or c were found in samples from Station 10 before 2001 (Ott and Weber Scannell 2003). Chlorophyll-a, b, and c concentrations in 2003 were very similar to those found in 2002, except that chlorophyll-b was not found in 2003 (Figure 69).

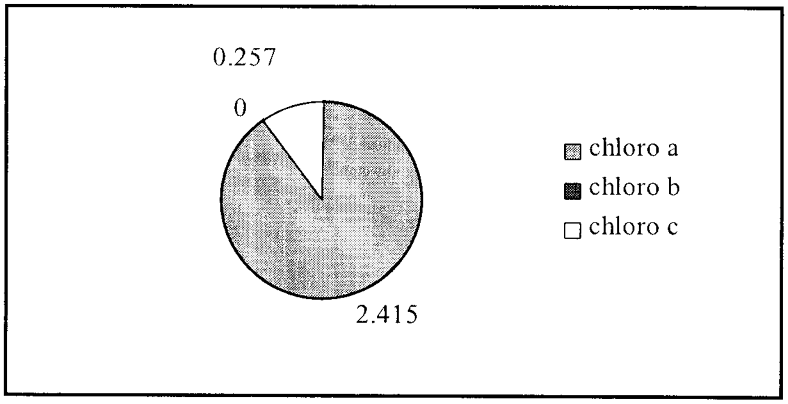


Figure 68. Proportions and values of chlorophyll-a, b, and c (mg/m^2) in Mainstem Red Dog Creek at Station 10 in 2003.

Summary of Biomonitoring, Station 10, 1999-2003

Changes in water quality, invertebrates, periphyton, and presence of larval Arctic grayling that have been documented over time are summarized in Table 8.

Table 8. Summary of biomonitoring, Mainstem Red Dog Creek at Station 10, 1999 to 2003.

Factor	Changes Observed
Water Quality	Cd, Ni, Se, Zn decreasing with time (1999-2003)
Invertebrate Communities	Abundance - higher in 2001 and 2003 Density - higher in 2001, 2002, and 2003 Taxa Richness – highest 2001 and 2003 %EPT - highest in 2003
Periphyton Communities	Higher in 2001, 2002, and 2003
Larval Arctic Grayling	Present in 1999, 2000, 2002, and 2003

Middle Fork Red Dog Creek at Station 20

Site Description

Middle Fork Red Dog Creek has a drainage area of 12 km^2 with the flow coming from the clean water bypass channel (Station 140) and the treated mine effluent. Upper Middle Fork Red Dog Creek and tributaries (Rachael, Connie, Shelly, and Sulfur creeks) flow into the clean water bypass system. Sulfur Creek flows intermittently. Middle Fork Red Dog Creek has wide meanders with channel widths from 3 to 10 m and depths from 0.03 to 0.45 m (Figure 69). Migration of fish into Middle Fork Red Dog Creek is blocked by a gabion basket weir structure located just above the confluence of North Fork and Middle Fork Red Dog creeks.

Figure 69. Middle Fork Red Dog Creek, Station 20.

Water Quality

Station 20 was not sampled regularly for water quality. Before mining, pH ranged from 5.7 to 6.9 (Figure 70). The pH values from 2000 through 2003 are higher than values that were recorded before mining. Higher pH values are directly related to higher pH values in the effluent from the water treatment plant.

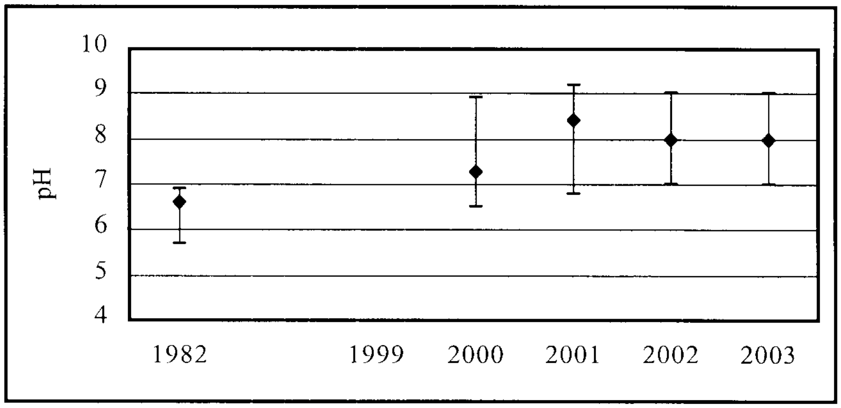


Figure 70. Median, maximum, and minimum pH values in Middle Fork Red Dog Creek at Station 20.

Median concentrations of metals in Middle Fork Red Dog Creek were similar among all years of the NPDES Permit monitoring period (1999-2003, Figures 71 through 77).

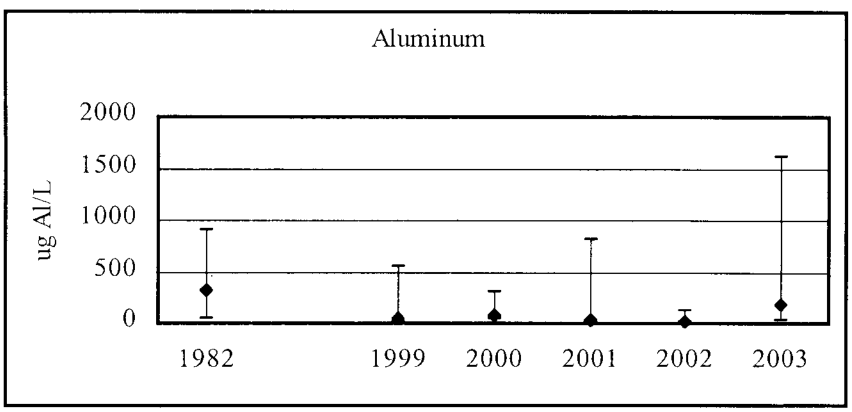


Figure 71. Median, maximum, and minimum concentrations of Al at Station 20.

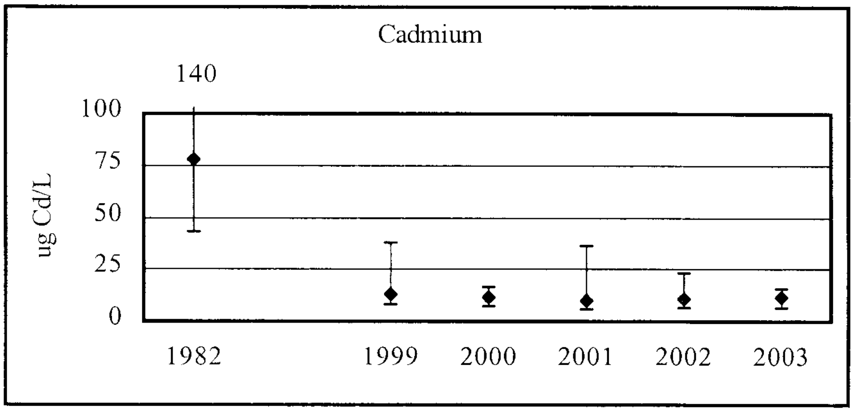


Figure 72. Median, maximum, and minimum concentrations of Cd at Station 20.

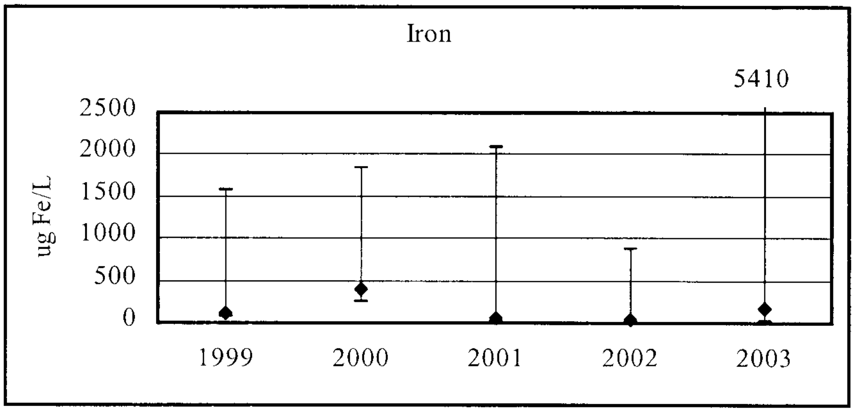


Figure 73. Median, maximum, and minimum concentrations of Fe at Station 20. There are no baseline data for Fe.

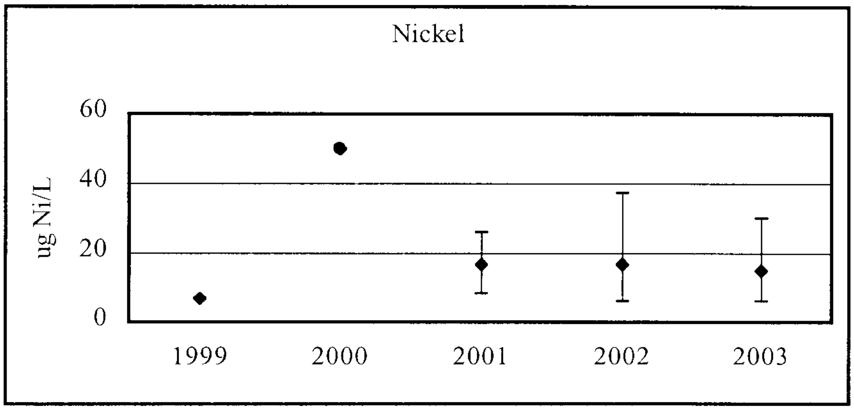


Figure 74. Median, maximum, and minimum concentrations of Ni at Station 20. The circle represents a MDL, not a concentration. There are no baseline data for Ni. The 1999 datum is a single measurement.

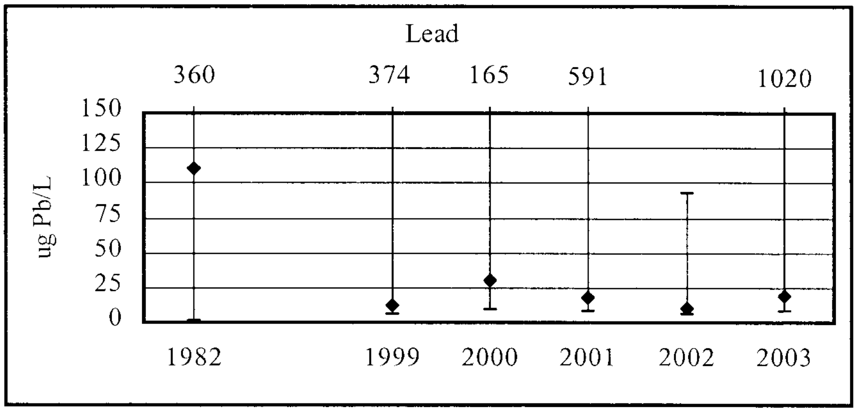


Figure 75. Median, maximum, and minimum concentrations of Pb at Station 20.

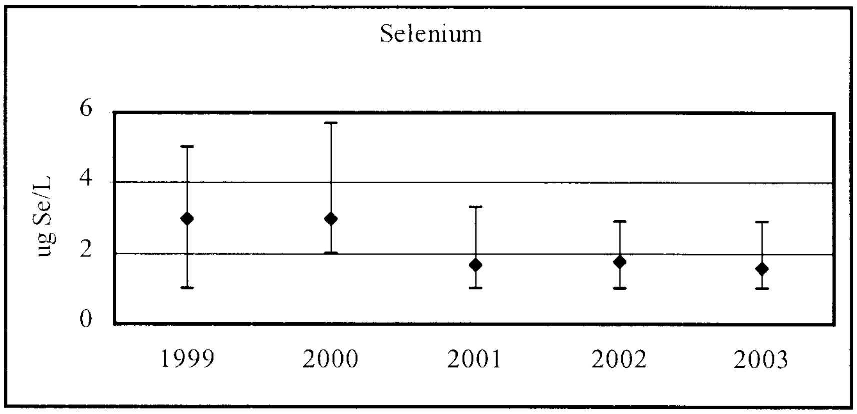


Figure 76. Median, maximum, and minimum concentrations of Se at Station 20. There are no baseline data for Se.

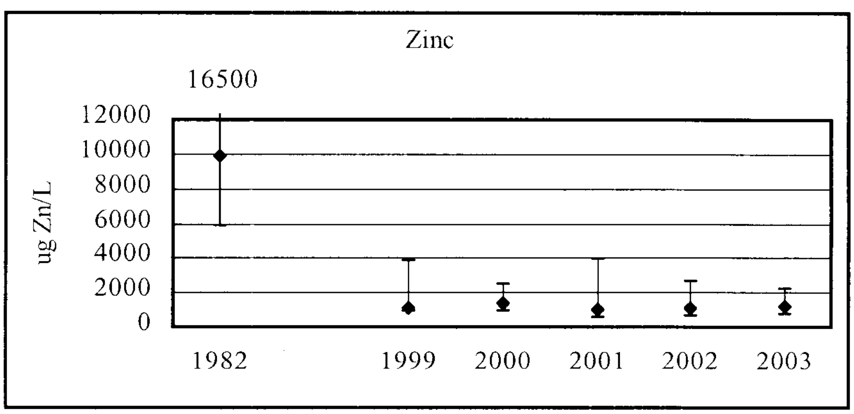


Figure 77. Median, maximum, and minimum concentrations of Zn at Station 20.

Invertebrate Community (Abundance, Density, and Taxa Richness)

Invertebrate abundance (average number of aquatic invertebrates per net), density (average number of aquatic invertebrates/m3 of water), and total number of taxa were highest in 2003 (Figures 78, 79, and 80).

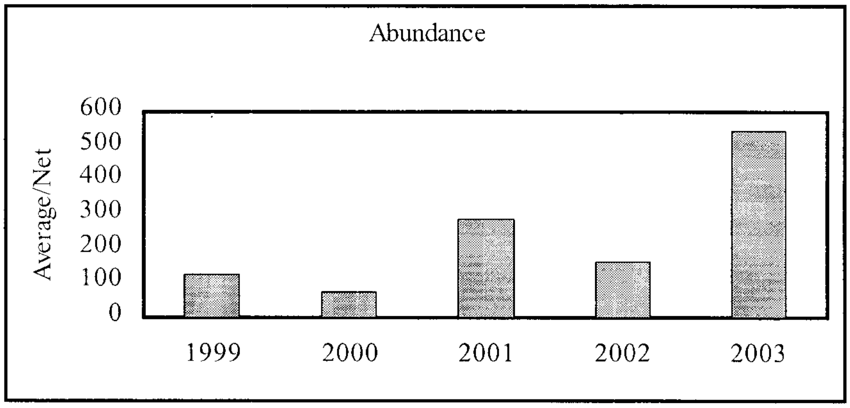


Figure 78. Abundance of aquatic invertebrates collected in Middle Fork Red Dog Creek at Station 20.

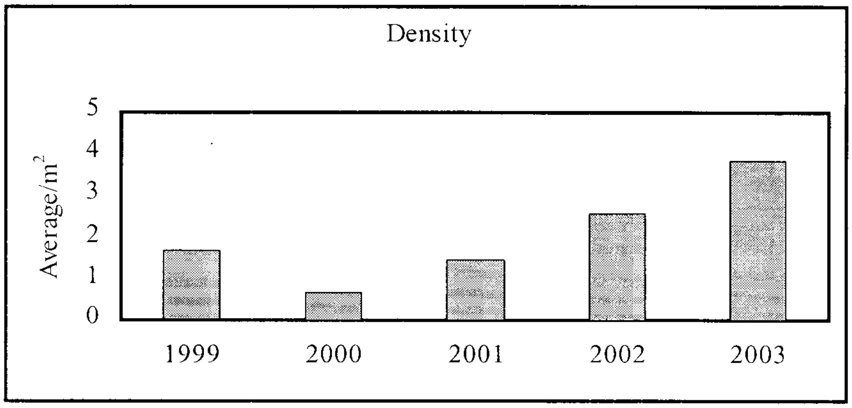


Figure 79. Density of aquatic invertebrates collected in Middle Fork Red Dog Creek at Station 20.

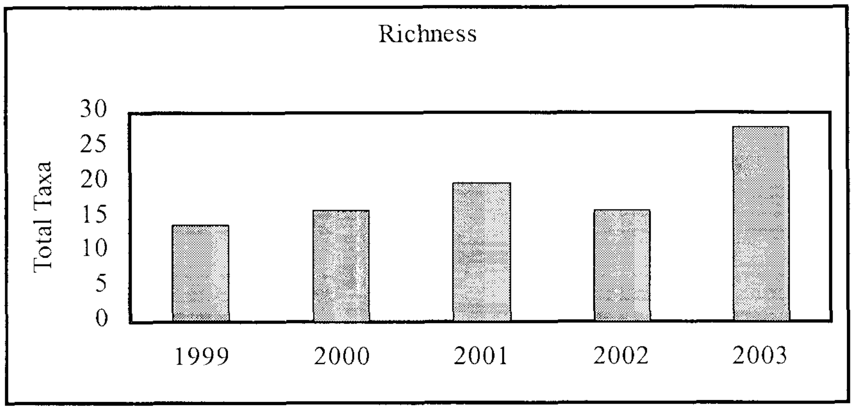


Figure 80. Taxa richness of aquatic invertebrates collected in Middle Fork Red Dog Creek at Station 20.

Community Structure

The invertebrate community in Middle Fork Red Dog Creek contained from a low of 7% to a high of 20% EPT taxa from 1999 through 2003 (Figure 81). Chironomidae were the most commonly found taxa at this site. In the 2003 samples, representatives of Ephemeroptera (Baetidae and Heptageniidae), Plecoptera (Capniidae and Nemouridae), and Tricoptera (Brachycentridae and Limnephilidae) were present.

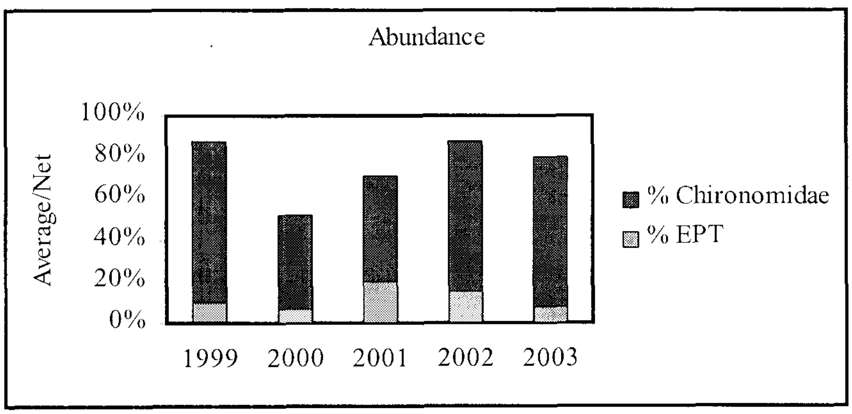


Figure 81. Proportions of EPT and Chironomidae larvae in invertebrate samples from Middle Fork Red Dog Creek at Station 20.

Periphyton Standing Crop

The concentration of chlorophyll-a in Middle Fork Red Dog Creek at Station 20 has been consistently lower than any of the other NPDES sample sites for Red Dog (Figure 82). Only in 2001 did samples have sufficient amounts of chlorophyll to distinguish the three major pigments (Ott and Weber Scannell 2003).

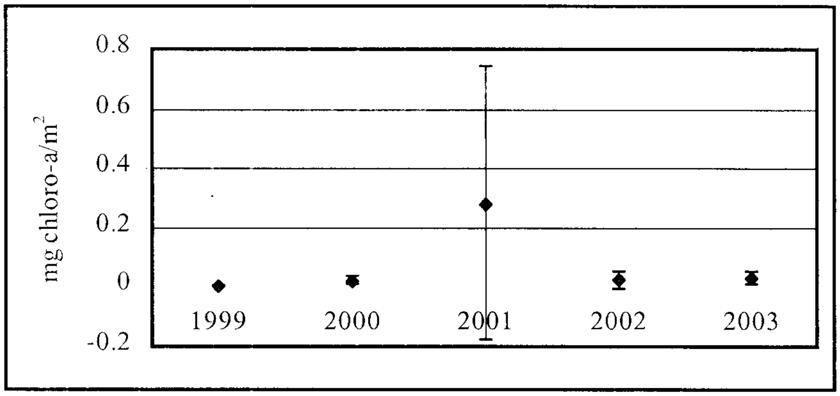


Figure 82. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in Middle Fork Red Dog Creek at Station 20. Note, the detection limit is 0.1 mg chloro-a/m^2.

Composition of Algal Communities

The relative proportions of chlorophyll-a, b, and c in Middle Fork Red Dog Creek is similar to the other NPDES sample sites, but concentrations measured were below the detection limit of 0.1 mg chlorophyll-a/m^2 (Figure 83).

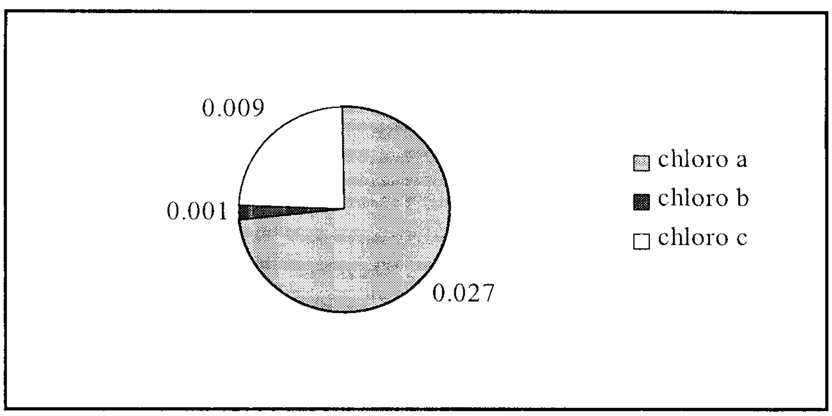


Figure 83. Proportions and values of chlorphyll-a, b, and c (mg/m^2) in Middle Fork Red Dog Creek at Station 20 in 2003.

Summary of Biomonitoring, Station 20, 1999-2003

Changes in water quality, invertebrates, periphyton, and presence of larval Arctic grayling that have been documented over time are summarized in Table 9.

Table 9. Summary of biomonitoring, Middle Fork Red Dog Creek at Station 20, 1999 to 2003.

Factor	Changes Observed
Water Quality	pH higher than premining due to effluent Cd and Zn lower than premining Pb lower than premining, but with some peaks Se appears to be gradually decreasing Decreases due to effluent and water from the clean water bypass system
Invertebrate Communities	Abundance - highest in 2003 Density - highest in 2003 Taxa Richness - highest in 2003 %EPT - low, varying from 7 to 20% of sample
Periphyton Communities	Below detection limits all years except 2001
Larval Arctic Grayling	Not found at this site

North Fork Red Dog Creek at Station 12

Site Description

North Fork Red Dog and Middle Fork Red Dog creeks merge to form Mainstem Red Dog Creek. North Fork Red Dog Creek has a drainage area of 41 km^2, abundant streamside vegetation, deep pools, and wide riffle areas (Figure 84). Widths range from 7 to 15 m and depths from 0.09 to 2 m. Arctic grayling spawn in North Fork Red Dog Creek and juvenile Dolly Varden and adult and juvenile Arctic grayling rear in the system during the ice-free season.

Figure 84. North Fork Red Dog Creek, Station 12.

Water Quality

North Fork Red Dog Creek is a clear water stream with moderate hardness and TDS and low sulfate. The stream drains an area containing ice-rich soils and thermal degradation in the upper part of the watershed has caused periodic increased turbidity in the system. Increased turbidities were first seen in early June of 2000, but North Fork Red Dog Creek was flowing clear during our early July 2000 field trip. Turbid water conditions were again seen in summer 2003. Concentrations of metals at Station 12, located about 100 m upstream from its confluence with Middle Fork Red Dog Creek, usually are below the USEPA standard for aquatic life (Weber Scannell and Andersen 1999). In 2003, concentrations of Al, Cd, Fe, Ni, Pb, Se, and Zn were lower in North Fork Red Dog Creek than at any of the other NPDES sample sites. Concentrations of Al, Cd, Fe, Ni, Pb, Se, and Zn are presented in Figures 85 through 91.

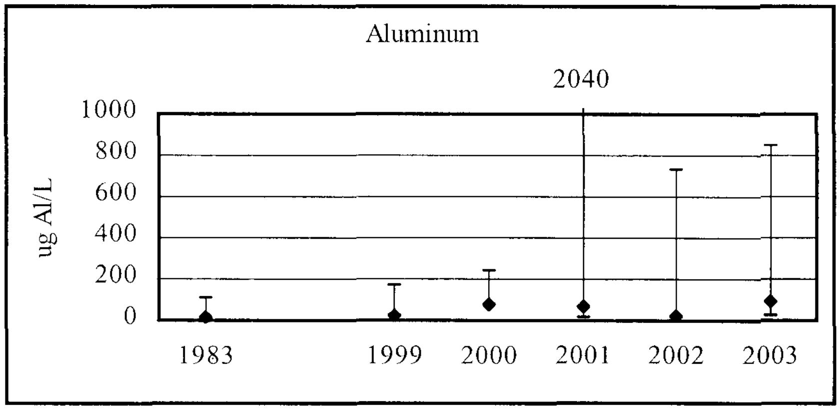


Figure 85. Median, maximum, and minimum concentrations of Al at Station 12.

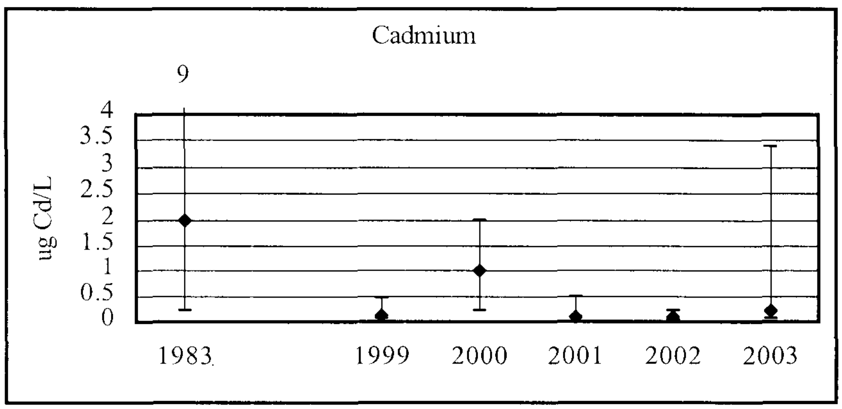


Figure 86. Median, maximum, and minimum concentrations of Cd at Station 12.

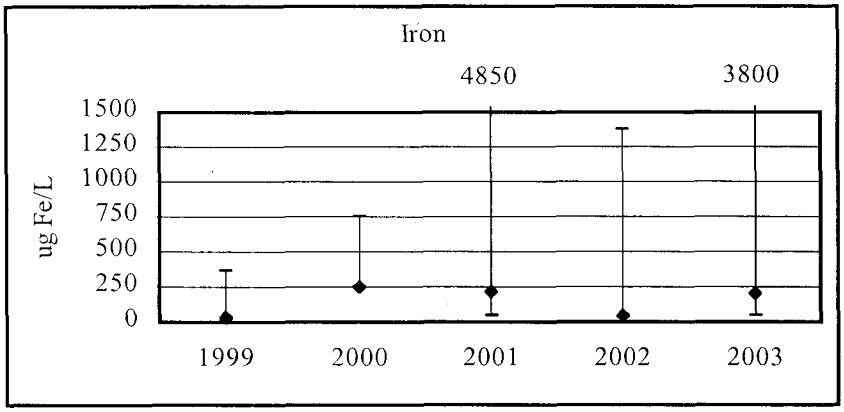


Figure 87. Median, maximum, and minimum concentrations of Fe at Station 12. There are no baseline data for Fe.

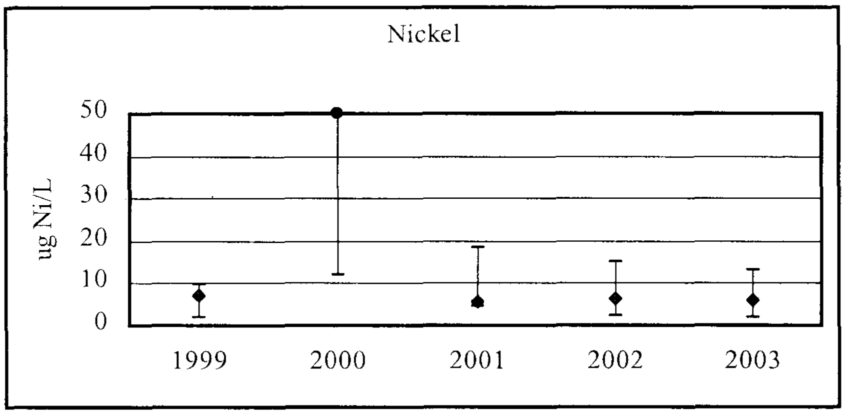


Figure 88. Median, maximum, and minimum concentrations of Ni at Station 12. The circle represents a MDL, not a concentration. There are no baseline data for Ni.

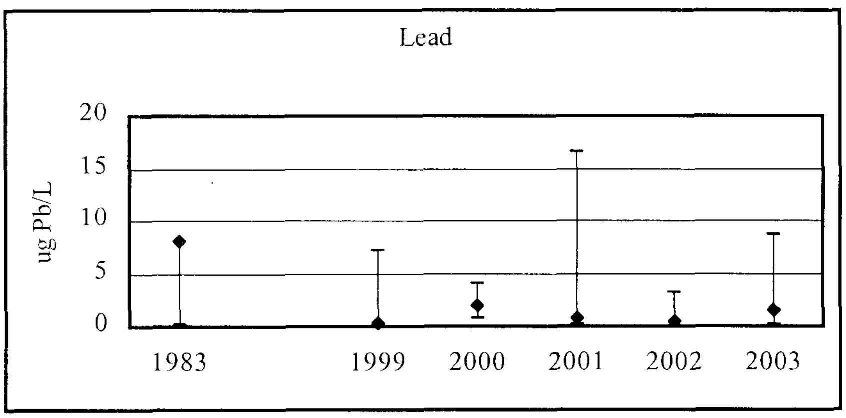


Figure 89. Median, maximum, and minimum concentrations of Pb at Station 12.

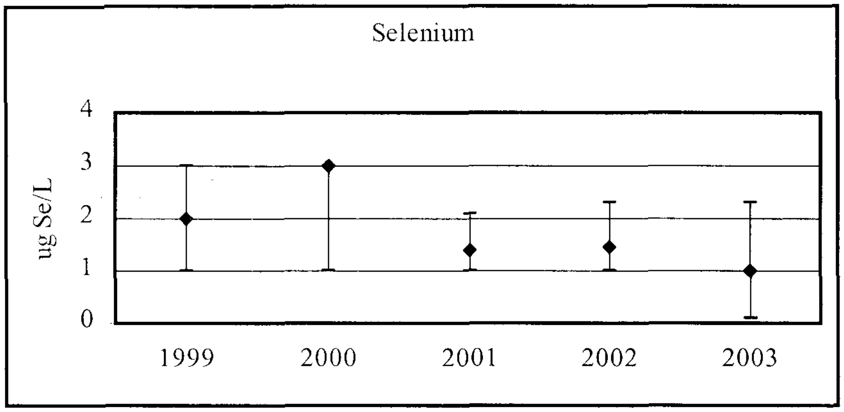


Figure 90. Median, maximum, and minimum concentrations of Se at Station 12. There are no baseline data for Se.

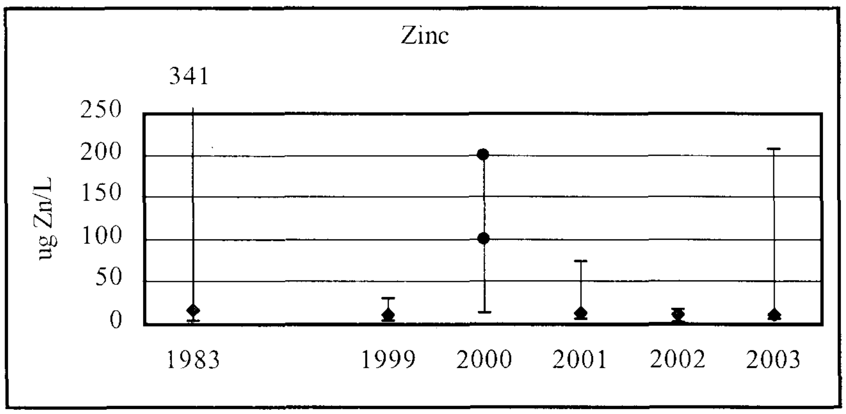


Figure 91. Median, maximum, and minimum concentrations of Zn at Station 12. The circles represent a MDL, not a concentration.

Invertebrate Community (Abundance, Density, and Taxa Richness)

Invertebrate abundance in North Fork Red Dog Creek at Station 12 ranged from a low of 368 in 2002 to a high of 1,502 in 2001 (Figure 92). Densities per m^3 of water of aquatic invertebrates were fairly consistent among the sample years with a low of 7 to a high of 11 (Figure 93). Number of taxa collected was highest in 2003 when we found 26 different taxa (Figure 94).

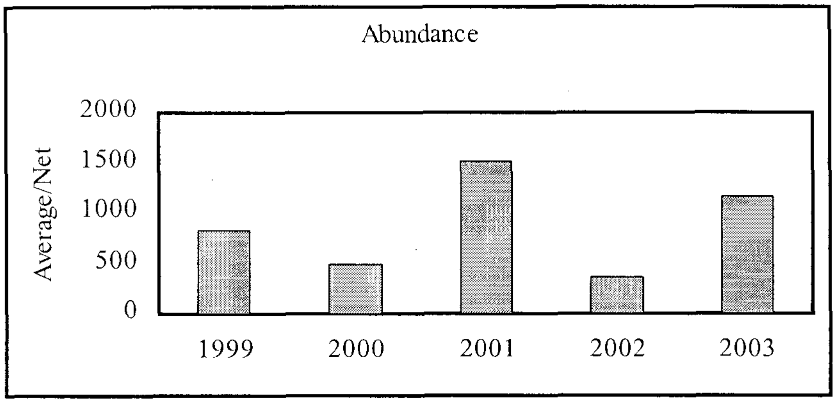


Figure 92. Abundance of aquatic invertebrates collected in North Fork Red Dog Creek at Station 12.

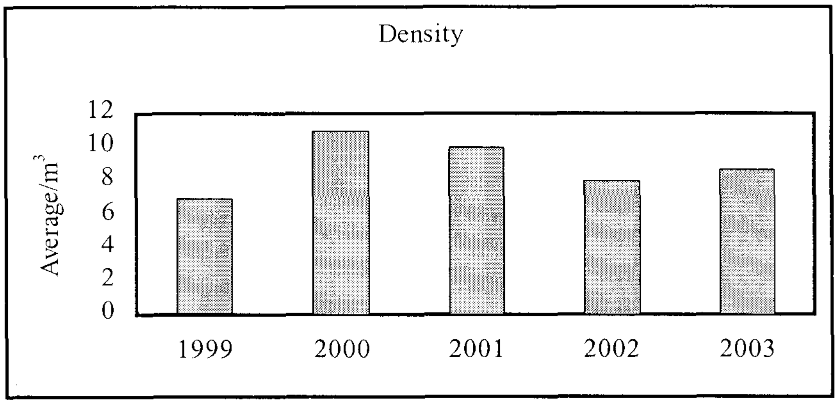


Figure 93. Density of aquatic invertebrates collected in North Fork Red Dog Creek at Station 12.

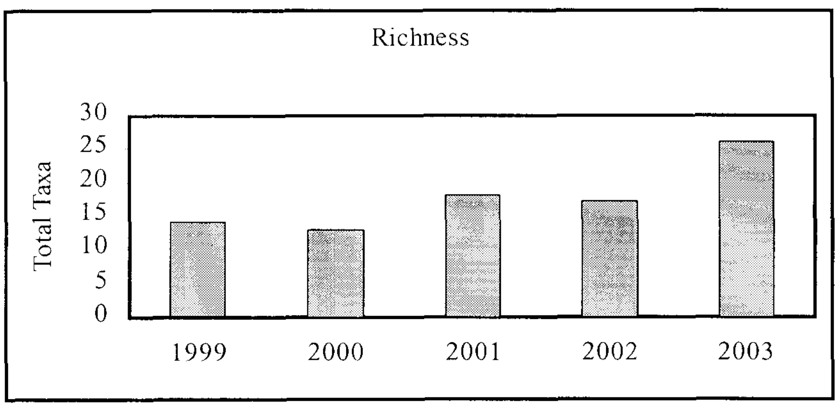


Figure 94. Taxa richness of aquatic invertebrates collected in North Fork Red Dog Creek at Station 12.

Community Structure

Invertebrate samples contained low proportions of EPT (less than 25%) taxa in most of the sample events (Figure 95), except in 2002 when 57% of the sample was EPT taxa. The invertebrate community was dominated by Diptera in all years sampled except 2002. The most common taxa in both 2002 and 2003 was Simuliidae.

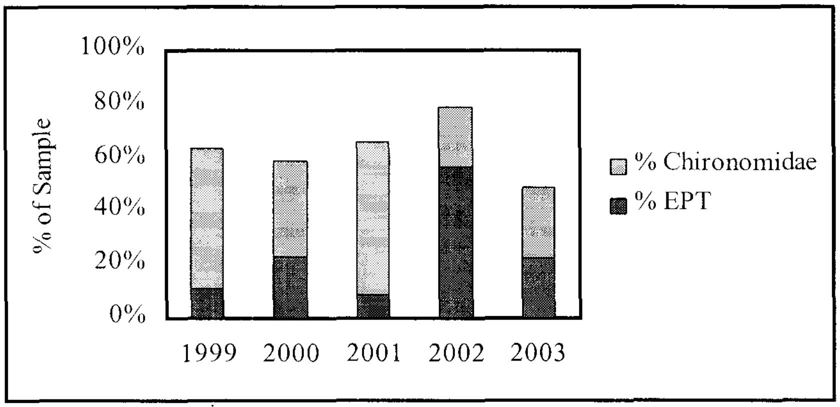


Figure 95. Proportions of EPT and Chironomidae larvae in invertebrate samples from North Fork Red Dog Creek at Station 12.

Periphyton Standing Crop

North Fork Red Dog Creek at Station 12 contained abundant attached algae (Figure 96). Concentrations in all years are similar with summer 2001 having the highest average concentrations of chlorophyll-a (6.4 mg/m^2).

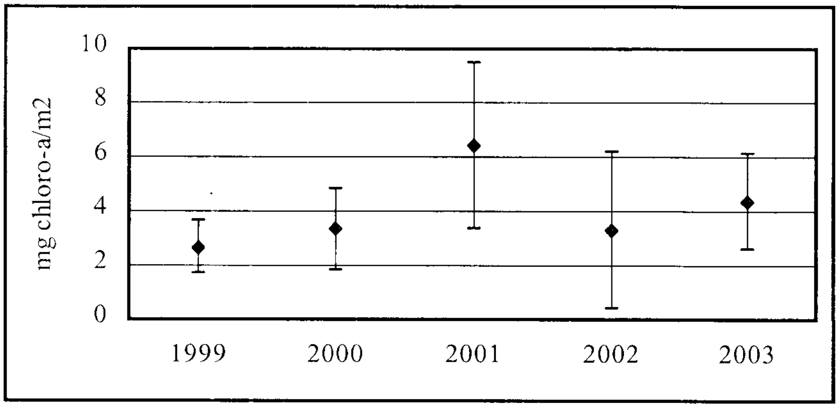


Figure 96. Average concentrations of chlorophyll-a, plus and minus one standard deviation, in North Fork Red Dog Creek at Station 12.

Composition of Algal Communities

The algae community at Station 12 (North Fork Red Dog Creek) consists of a mixture of diatoms and green algae (Figure 97). Proportions of chlorophyll-b and c are nearly equal to or higher than any of the other NPDES monitoring sites, indicating a biologically diverse community.

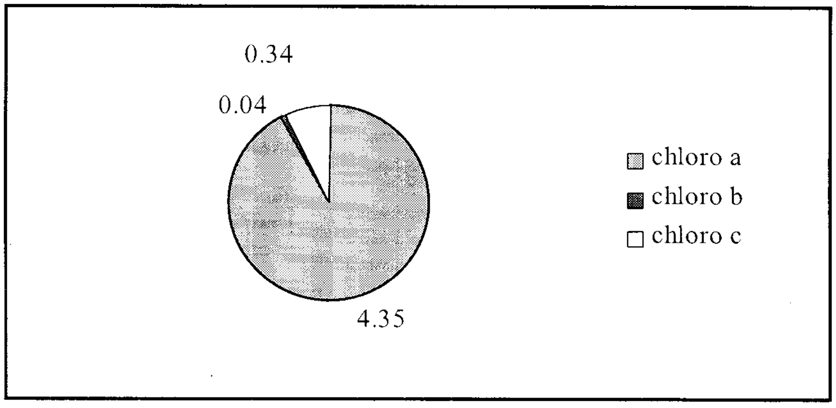


Figure 97. Proportions and values of chlorophyll-a, b, and c (mg/m^2) in North Fork Red Dog Creek at Station 12 in 2003.

Summary of Biomonitoring, Station 12, 1999-2003

Changes in water quality, invertebrates, periphyton, and presence of larval Arctic grayling that have been documented over time are summarized in Table 10.

Table 10. Summary of biomonitoring, North Fork Red Dog Creek at Station 12, 1999 to 2003.

Factor	Changes Observed
Water Quality	Al slightly higher than premining Median Cd and Pb lower than premining Al, Fe, Ni, Se, and Zn no apparent changes
Invertebrate Communities	Abundance – higher in 2001 and 2003 Density – fairly consistent among years Taxa Richness - highest in 2003 %EPT – low all years except 2002 when 57%
Periphyton Communities	Chlorophyll-a concentrations high in all years
Larval Arctic Grayling	Present in 1997, 1999, 2000, and 2001

Middle Fork Red Dog Creek at Station 140

Site Description

Station 140 is located in Middle Fork Red Dog Creek downstream of the clean water bypass ditch and upstream of the wastewater effluent. Fish, invertebrate, and periphyton sampling is not done at Station 140, but water quality data are collected by TCAK. Concentrations of Al, Cd, Fe, Ni, Pb, Se, and Zn are presented in Figures 98 through 103.

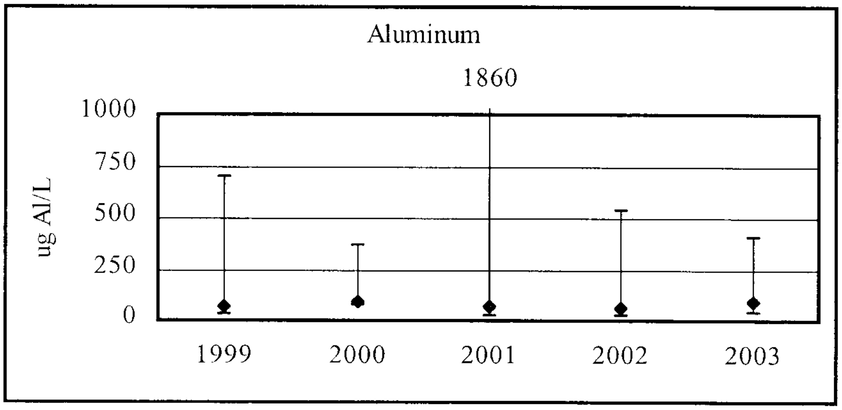


Figure 98. Median, maximum, and minimum concentrations of Al at Station 140.

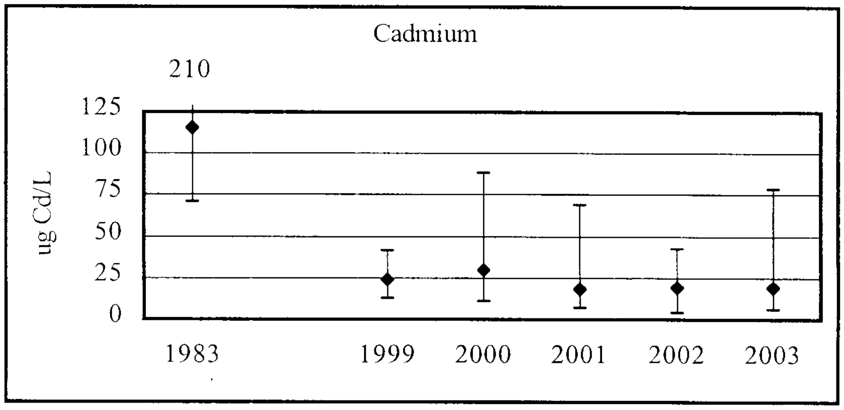


Figure 99. Median, maximum, and minimum concentrations of Cd at Station 140.

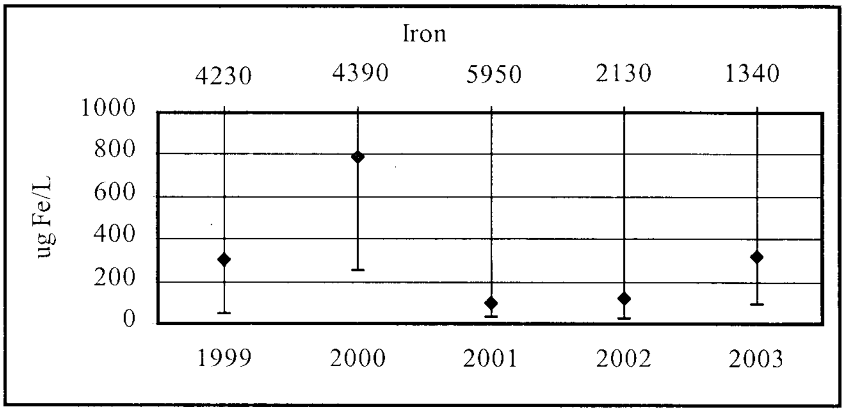


Figure 100. Median, maximum, and minimum concentrations of Fe at Station 140. There are no baseline data for Fe.

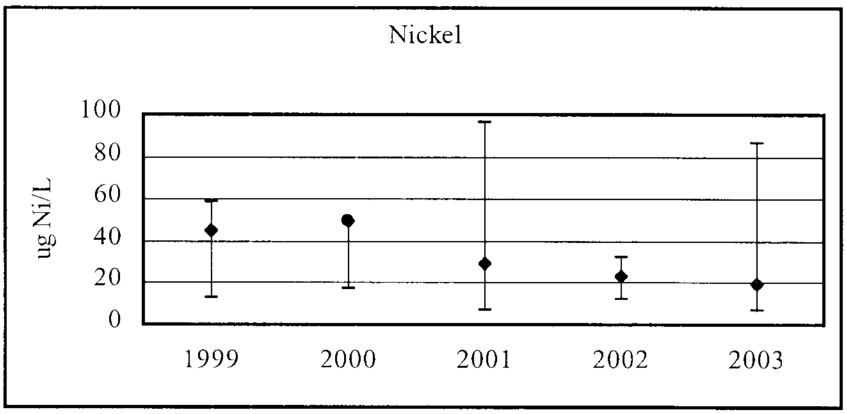


Figure 101. Median, maximum, and minimum concentrations of Ni at Station 140. The circle represents a MDL, not a concentration. There are no baseline data for Ni.

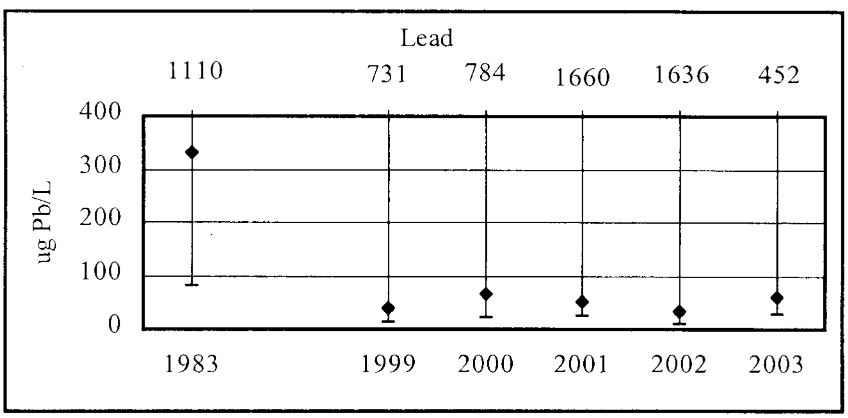


Figure 102. Median, maximum, and minimum concentrations of Pb at Station 140.

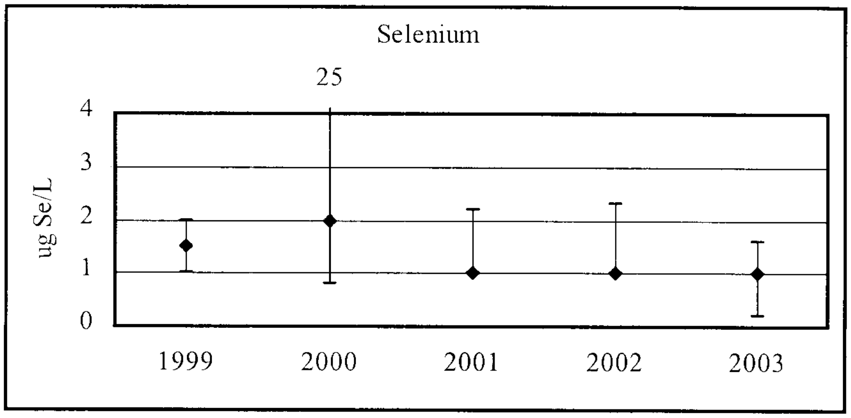


Figure 103. Median, maximum, and minimum concentrations of Se at Station 140. The 25 *u*g/L represents a MDL, not a concentration. There are no baseline data for Se.

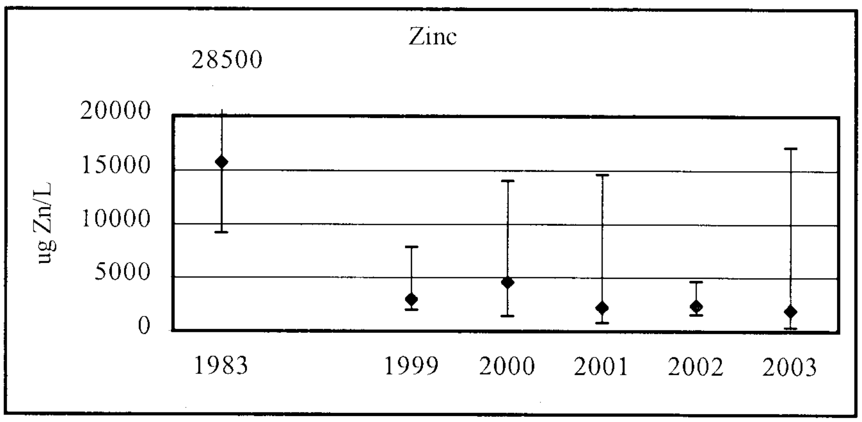


Figure 104. Median, maximum, and minimum concentrations of Zn at Station 140.

Summary of Water Quality, Station 140, 1999-2003

Changes in water quality that have been documented over time are summarized in Table 11.

Table 11. Summary of Water Quality, Middle Fork Red Dog Creek at Station 140, 1999 to 2003.

Factor	Changes Observed
Water Quality	Cd, Pb, and Zn lower than premining Pb with some peaks comparable to baseline Al similar with peaks, probably Rachel Creek Ni and Se show signs of decreasing with time Fe variable with some high peaks decreases due to clean water bypass system including improvements that have been made

Metals Concentrations in Adult Dolly Varden, Wulik River

Since 1990, we have sampled adult Dolly Varden from the Wulik River for metals concentrations (Al, Cd, Cu, Pb, and Zn) in gill, kidney, liver, and muscle (Weber Scannell et al. 2000). In 1997, we included Se analysis and in 1998 we started sampling reproductive tissues when available. In 2003, we added Hg and Ca to the analytes being tested in Dolly Varden tissues. The number of Dolly Varden in each sample period was six, except for fall 2002 when only five fish were caught.

The purpose of sampling adult Dolly Varden for metals concentrations is to monitor long-term condition over the life of the Red Dog Mine and to identify any changes in metals concentrations in tissues that may be related to mining operations. All laboratory work was done with Level III Quality Assurance.

Metals are known to concentrate preferentially in certain organs; however, the relationship of organ concentrations of metals to the ambient environmental concentrations is not known. Concentrations of metals vary with season, age, size, weight, and feeding habits of fish (Jenkins 1980) and in the case of anadromous Dolly Varden, the metals vary with exposure to freshwater and marine environments. Our data from Wulik River Dolly Varden suggest the following:

(1) Al concentrates primarily in gill tissue (Figure 105);

(2) Cd concentrates in kidney tissue (Figure 106);

(3) Cu concentrates in liver tissue (Figure 107);

(4) Pb concentrates in gill tissue (Figure 108);

(5) Se concentrates in kidney and reproductive tissues (Figure 109);

(6) Zn concentrates in reproductive tissue (Figure 110);

(7) Hg is not concentrated in any of the tissues sampled (Figure 111);

(8) Ca concentrates in gill tissue (Figure 112); and

(9) None of the analytes appear to concentrate in muscle tissue.

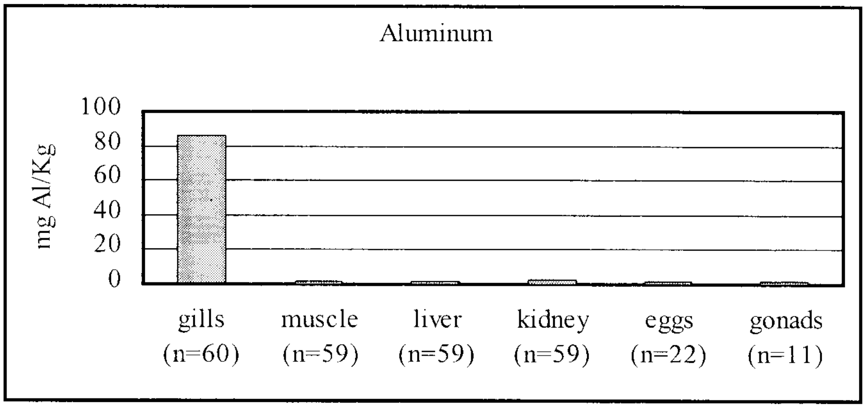


Figure 105. Concentration of Al in Dolly Varden tissues. Values are the average of all fish collected during the NPDES sample period (1999 through 2003).

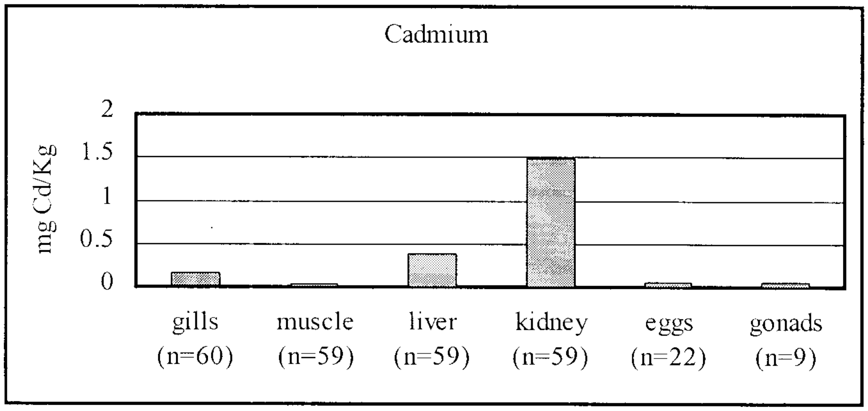


Figure 106. Concentration of Cd in Dolly Varden tissues. Values are the average of all fish collected during the NPDES sample period (1999 through 2003).

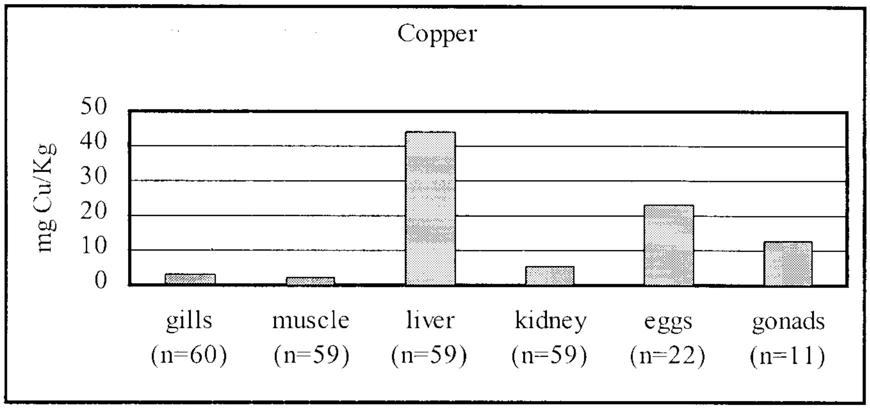


Figure 107. Concentration of Cu in Dolly Varden tissues. Values are the average of all fish collected during the NPDES sample period (1999 through 2003).

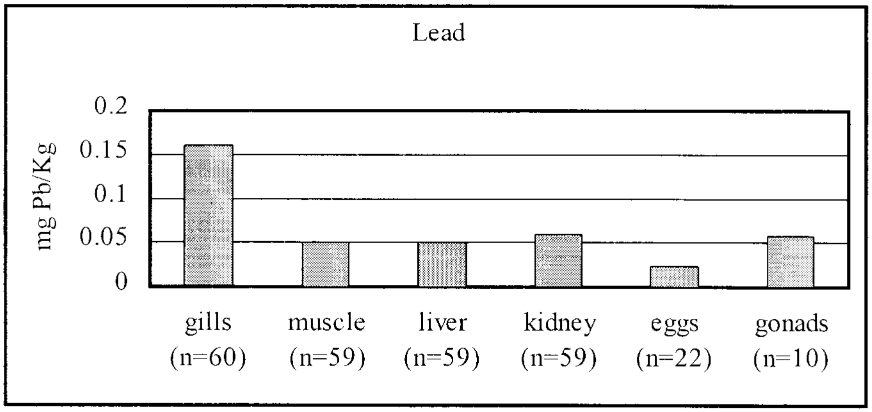


Figure 108. Concentration of Pb in Dolly Varden tissues. Values are the average of all fish collected during the NPDES sample period (1999 through 2003).

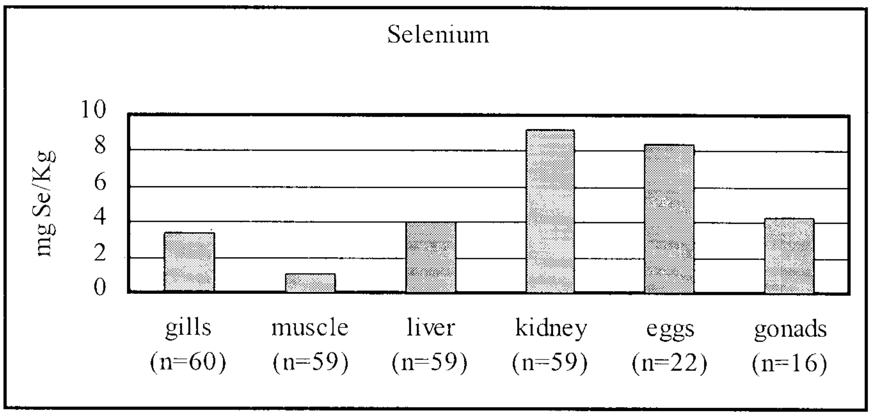


Figure 109. Concentration of Se in Dolly Varden tissues. Values are the average of all fish collected during the NPDES sample period (1999 through 2003).

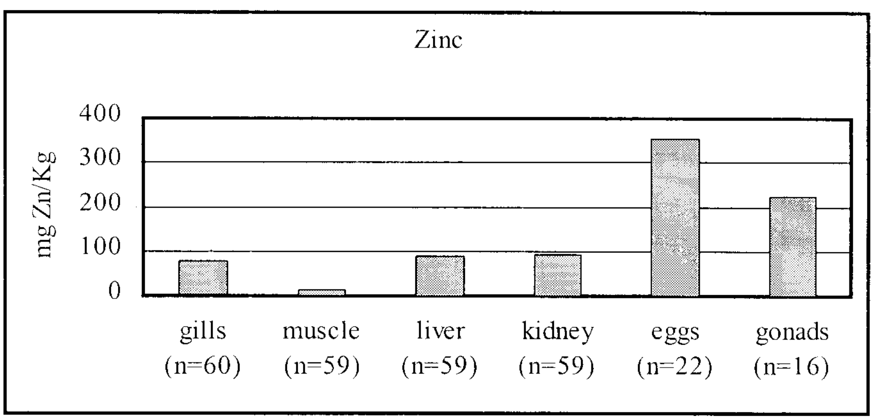


Figure 110. Concentration of Zn in Dolly Varden tissues. Values are the average of all fish collected during the NPDES sample period (1999 through 2003).

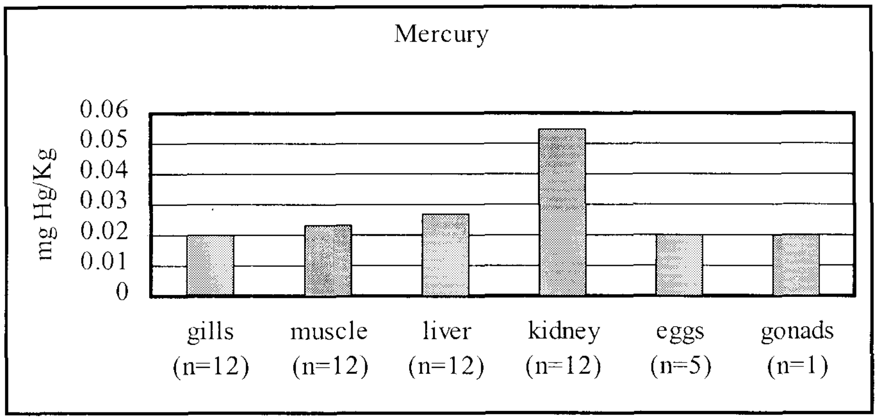


Figure 111. Concentration of Hg in Dolly Varden tissues. Values are the average of all fish collected during the NPDES sample period (only 2003).

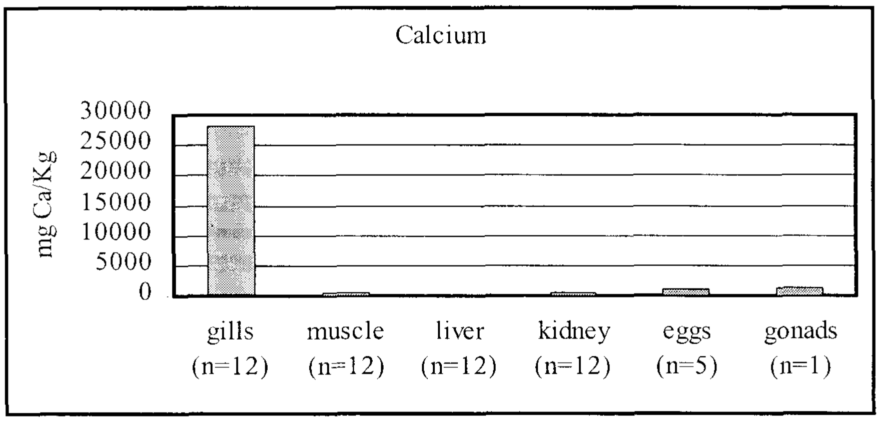


Figure 112. Concentration of Ca in Dolly Varden tissues. Values are the average of all fish collected during the NPDES sample period (only 2003).

To determine trends in metals concentrations during the NPDES monitoring period (1999-2003), we focused on these metal relationships: Al in gill tissue; Cd in kidney tissue; Cu in liver tissue; Pb in gill tissue; Se in kidney and reproductive tissue (eggs); and Zn in reproductive tissue (eggs). Only one year of data (12 fish) were available for Hg and Ca. Hg is not present in the ore body and Ca is ubiquitous and generally non-toxic.

Aluminum

Median concentrations of Al in gill tissue from Dolly Varden collected in fall 2000, fall 2002, and fall 2003 were higher than other sampling periods (Figure 113). In 2000, 2002, and 2003 Al was higher in the fall, but in 2001 fish were consistently lower in Al concentrations for all fall caught fish (Figure 113).

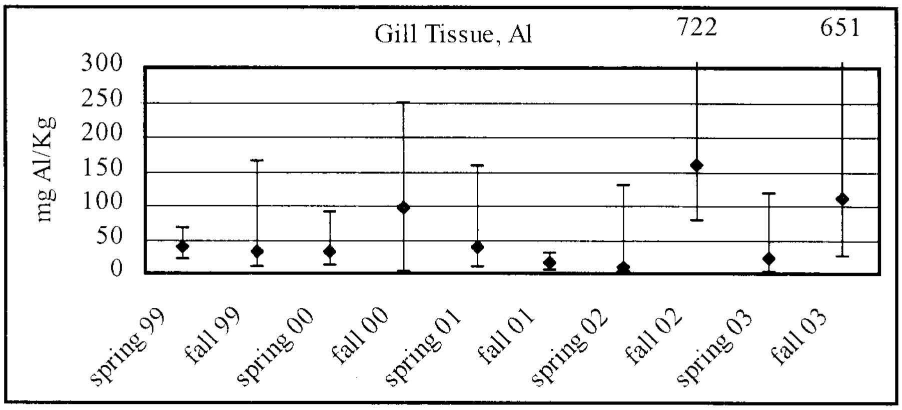


Figure 113. Median, maximum, and minimum concentrations of Al (dry weight basis) in adult Dolly Varden gill tissue, Wulik River, 1999-2003. There are no baseline data for Al.

Cadmium

Median Cd concentrations in Dolly Varden kidney tissues from 1999 through 2003, both spring and fall samples, were lower than those reported in the baseline sampling (Figure 114). Cd concentrations in fall-caught fish generally have been lower than spring-caught fish (Figure 114).

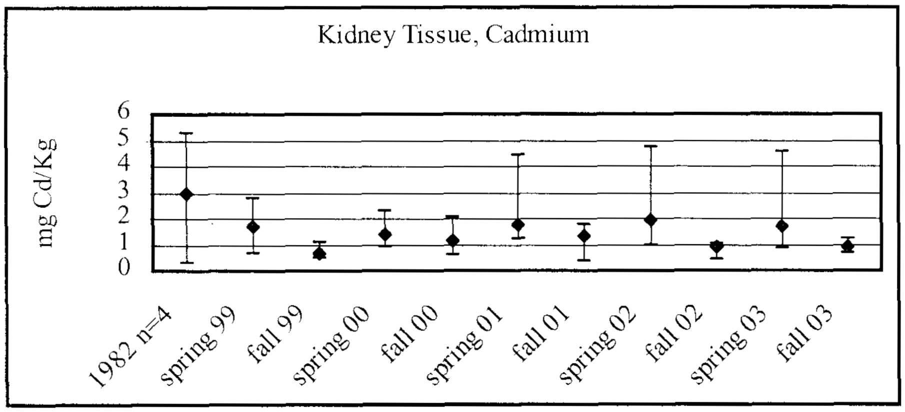


Figure 114. Median, maximum, and minimum concentrations of Cd (dry weight basis) in adult Dolly Varden kidney tissue, Wulik River, 1999-2003.

Copper

Median copper concentrations have been consistently higher from 1999 through 2003 than reported from baseline studies (Figure 115). Higher variability in fish samples occurred each year for spring-caught fish. Virtually no change (i.e., increase or decrease) has been observed over the NPDES sample period. Copper was not included in the water quality section of this report, because most results are below the detection limit.

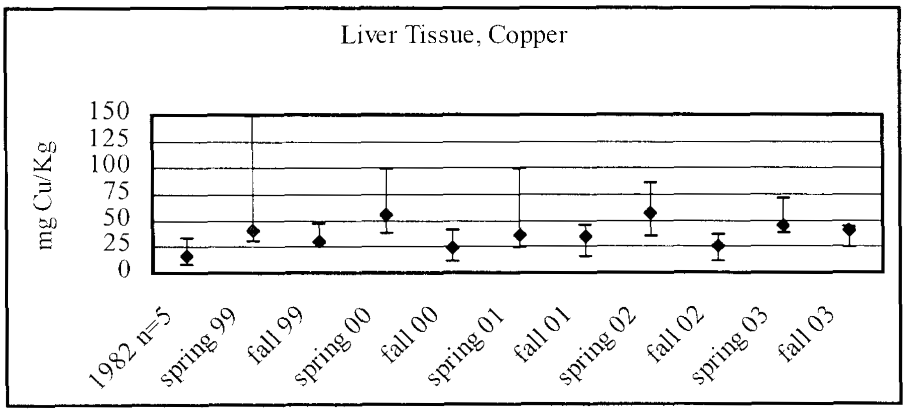


Figure 115. Median, maximum, and minimum concentrations of Cu (dry weight basis) in adult Dolly Varden liver tissue, Wulik River, 1999-2003.

Lead

The concentration of Pb in Dolly Varden gill tissue from fish collected prior to mining was below the detection limits used in 1982 and 1983 (.03 or .04 mg/Kg). Median concentrations of Pb in Dolly Varden gill tissue from 1999 through 2003 were higher than those found in baseline sampling (Figure 116).

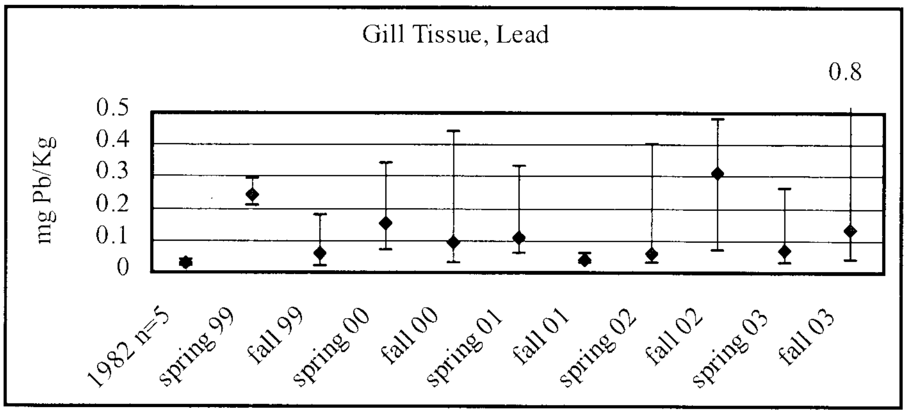


Figure 116. Median, maximum, and minimum concentrations of Pb (dry weight basis) in adult Dolly Varden gill tissue, Wulik River, 1999-2003.

Selenium

Median concentrations of Se in adult Dolly Varden kidney tissue were highest in the fall 2002 sample (Figure 117). Median concentrations of Se were similar for 1999 through spring 2002, highest in the fall 2002, and slightly higher in spring and fall 2003 (Figure 117).

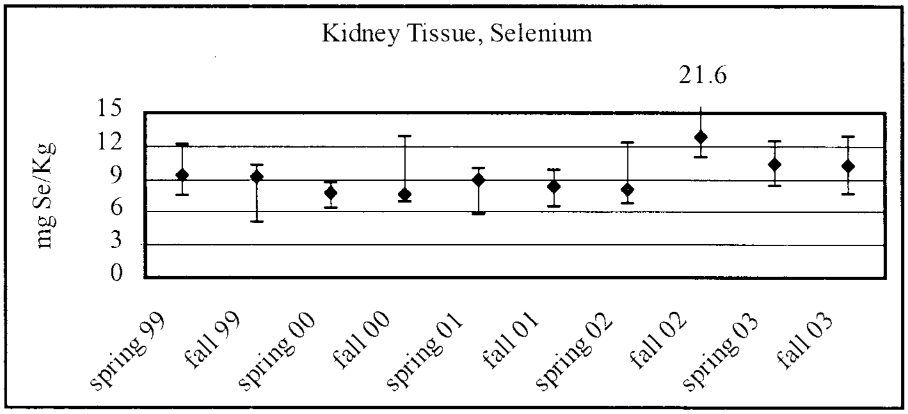


Figure 117. Median, maximum, and minimum concentrations of Se (dry weight basis) in adult Dolly Varden kidney tissue, Wulik River, 1999-2003. There are no baseline data for Se.

Median Se concentrations in Dolly Varden ovaries were consistently higher in fall caught Dolly Varden (Figure 118). The highest median concentrations of Se were found in the fall 2002 sample (Figure 118).

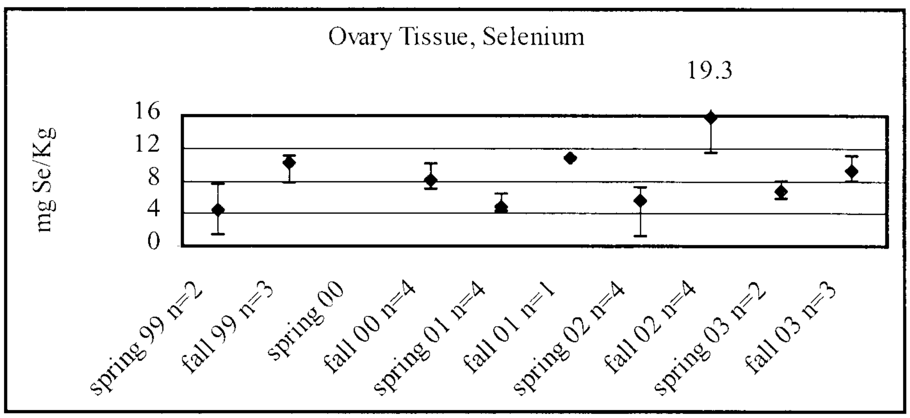


Figure 118. Median, maximum, and minimum concentrations of Se (dry weight basis) in adult Dolly Varden ovary tissue, Wulik River, 1999-2003. There are no baseline data for Se.

Zinc

Median Zn concentrations have remained fairly consistent during the time period of our sampling (Figure 119). Generally, Zn concentrations are higher in the fall sample.

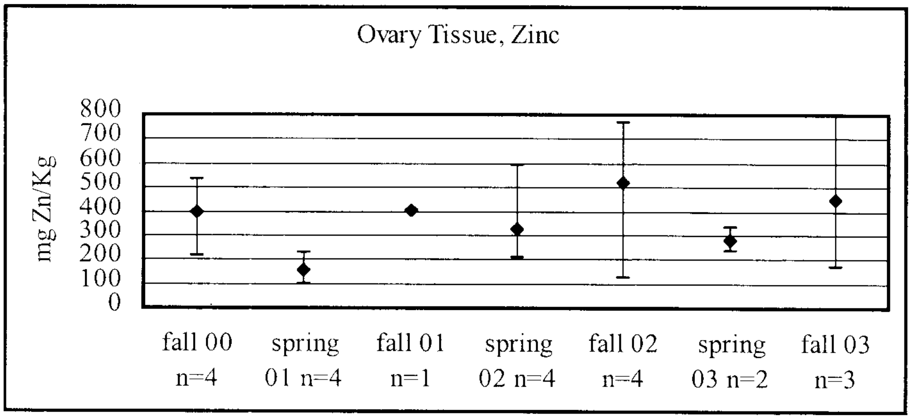


Figure 119. Median, maximum, and minimum concentrations of Zn (dry weight basis) in adult Dolly Varden ovary tissue, Wulik River, 1999-2003.

Distribution of Fish Throughout the Wulik River Drainage

Overwintering Dolly Varden

The Dolly Varden fall aerial survey in the Wulik River in 2003 was not conducted due to weather. A late summer storm followed by warming temperatures, snow melt, and high water prevented the fall survey.

The number of Dolly Varden counted in fall has varied annually (Figure 120, Appendix 2). Fluctuations in number counted are related to survey conditions and to the time these fish enter the Wulik River for overwintering. In some years, most of the fish appear to enter the river late in the fall and would be missed during that annual survey. Surveys conducted through fall 2002 suggest that over 90% of Dolly Varden in the Wulik River continue to remain below the mouth of Ikalukrok Creek in late September and early October.

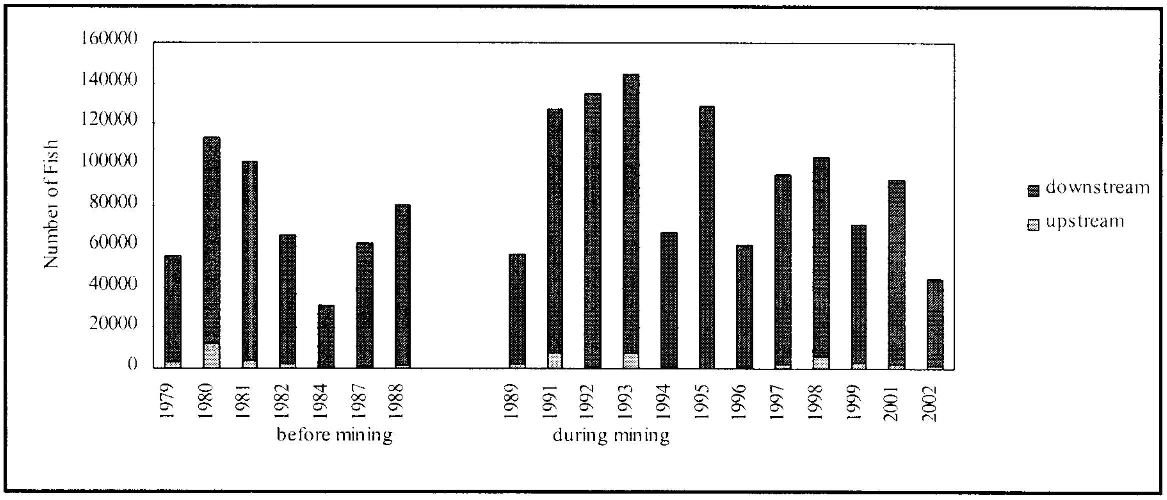


Figure 120. The number of Dolly Varden counted in aerial surveys in the Wulik River upstream and downstream of Ikalukrok Creek.

Chum Salmon Spawning

ADF&G attempts annual surveys to assess the distribution of adult chum salmon in Ikalukrok Creek from the mouth upstream to Dudd Creek (Table 12, Appendix 3). In some years surveys are limited or prevented by poor weather. In fall 2003, a helicopter survey was conducted by ADNR on August 11 (Townsend and Ingalls 2003). In the lower portion of Ikalukrok Creek, 213 live and 5 spawned-out chum salmon were observed. Survey conditions were marginal with overcast skies.

Counts of chum salmon in Ikalukrok Creek made after mine development in 1990 and 1991 were lower than reported in baseline studies by ADF&G and Dames and Moore (1983). Surveys were initiated again in 1995, with the highest reported return of chum salmon seen in 2001. Numbers of returning adult chum salmon were relatively high in 1997 and 2002. Large numbers of fish in recent years, particularly 2001 and 2002, are good indications that the population has recovered from the low numbers reported in the early 1990s.

Table 12. Number of adult chum salmon in Ikalukrok Creek downstream of Dudd Creek.

Survey Time	Number of Chum Salmon	Reference
September 1981	3,520 to 6,960	Houghton and Hilgert 1983
August September 1982	353 to 1,400	Houghton and Hilgert 1983
August 1984	994	DeCicco 1990b
August 1986	1,985	DeCicco 1990b
August 1990	<70	Ott et al. 1992
August 1991	<70	Ott et al. 1992
August 1995	49	Townsend and Lunderstadt 1996
August 1995	300 to 400	DeCicco 1995
August 1996	180	Townsend and Hemming 1996
August 1997	730 to 780	Ott and Simpers 1997
August 1998	no survey	
August 1999	75	Ott and Morris 1999
August 2000	no survey	
August 7, 2001	850	Morris and Ott 2001
August 28, 2001	2,250	DeCicco 2001b
August 29, 2001	1,836	DeCicco 2001b
September 23, 2001	500	DeCicco 2001c
October 8, 2001	232	DeCicco 2001a
August 2002	890	Ott and Townsend 2002
August 2003	218	Townsend and Ingalls 2003

Juvenile Dolly Varden

Limited pre-mining juvenile Dolly Varden distribution and use data were available for most of the streams in the vicinity of the Red Dog Mine, including Ikalukrok, Evaingiknuk, Buddy, Mainstem Red Dog, and North Fork Red Dog creeks. We found in the early 1990s that the highest use by juvenile Dolly Varden was in Anxiety Ridge Creek, also identified as the most productive stream system in the project area by Houghton and Hilgert (1983).

We have conducted annual surveys of juvenile Dolly Varden in Evaingiknuk, Anxiety Ridge, and Ikalukrok creeks since summer 1990 to determine seasonal patterns of fish use. Since 1990, we have added new sample sites and currently we sample annually at the ten creeks listed in Table 13.

Table 13. Locations of juvenile Dolly Varden fish trap sites.

Site Name	Station No.	Year First Sampled
Evaingiknuk Creek		1990
Anxiety Ridge Creek		1990
Buddy Creek		1996
North Fork Red Dog Creek	12	1993
Mainstem Red Dog Creek, below North Fork	11	1995
Mainstem Red Dog Creek, at Ikalukrok	10	1996
Ikalukrok Creek above Mainstem	9	1996
Ikalukrok Creek below Mainstem	8	1996
Ikalukrok Creek above Dudd Creek		1990
Ikalukrok Creek below Dudd Creek	7	1990

A second sample site in North Fork Red Dog Creek is located near the headwaters of the drainage and is upstream of all known potential development. Sampling at the Upper North Fork Red Dog Creek site was not done in summer 2003. Appendix 4 shows the location of the juvenile Dolly Varden sampling sites.

Numbers of Dolly Varden vary considerably among years, due in part to natural environmental variables, including timing of migration and sampling, length of breakup, patterns and magnitude of rainfall events, and how rapidly the water warms (Weber Scannell and Ott 2002). Juvenile Dolly Varden are most abundant in all the sample streams, particularly those sample sites located in the upper portion of a stream, from late July to mid August. In some years with mild weather conditions, peak usage of streams continues until the onset of freezeup when all the juvenile Dolly Varden outmigrate to overwintering habitats in the lower portion of Ikalukrok Creek and the Wulik River. The only stream sampled where we have documentation that all juvenile Dolly Varden do not outmigrate at freezeup is Anxiety Ridge Creek. The documentation we have is collection of smolts in Anxiety Ridge Creek in early summer.

Sampling of the ten NPDES sample sites in late July to early August was conducted each year since 1997. The highest catches recorded were in 1999 and the lowest were in 2001 (Appendix 5). Catches have increased each year since 2001.

Late summer catches of juvenile Dolly Varden were higher at most sites in 2003 than in 2002, 2001, and 2000, but not nearly as high as in 1998 and 1999 (Figures 121 and 122). Juvenile fish catches follow similar patterns among the different creeks sampled: years with high numbers of fish in reference creeks also have higher numbers in sites downstream of the mine's wastewater discharge. Conversely, years with low numbers of fish in reference streams also have low numbers in sites below the mine's wastewater discharge. We caught 330 Dolly Varden in early August 2003, compared with our highest catch of 945 fish in early August 1999.

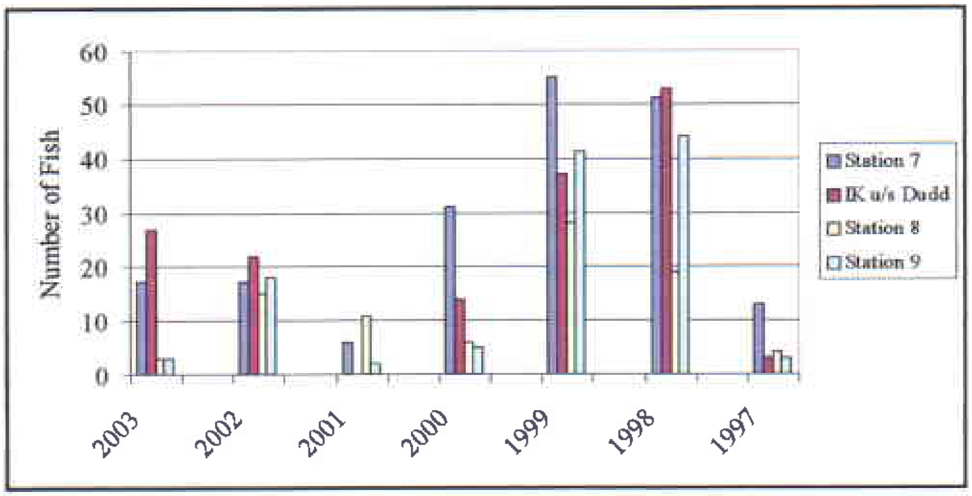


Figure 121. Catches of juvenile Dolly Varden in Ikalukrok Creek, 1997-2003.

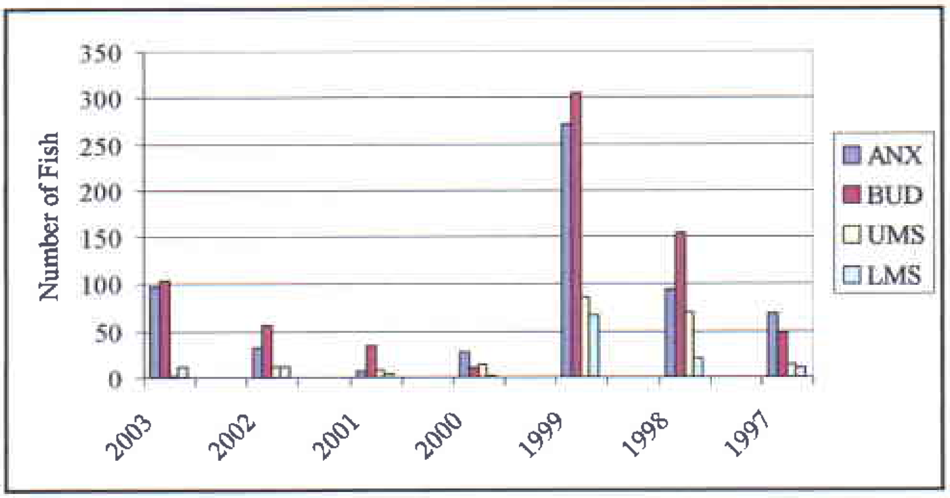
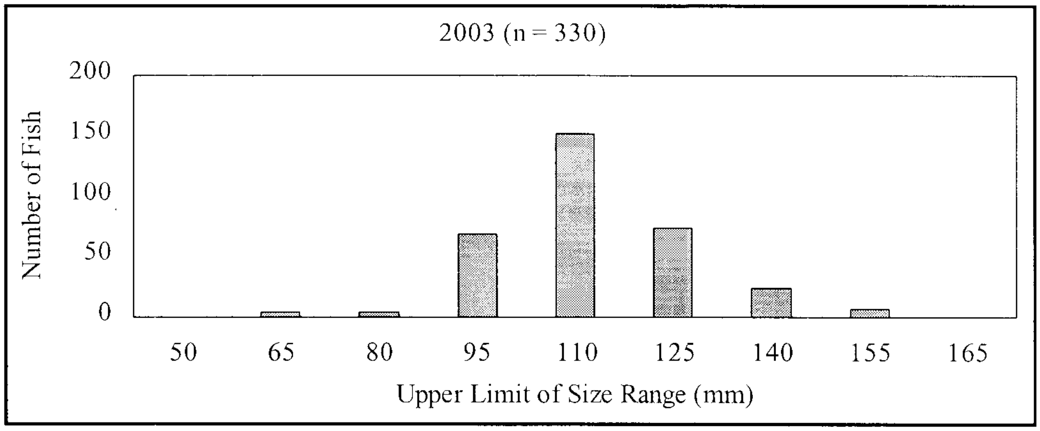


Figure 122. Catches of juvenile Dolly Varden in Anxiety Ridge (ANX), Buddy (Bud), Upper Mainstem Red Dog (UMS), and Lower Mainstem Red Dog (LMS) creeks, 1997-2003.

The length-frequency distribution of juvenile Dolly Varden, especially the presence of age 0 fish, indicates successful reproduction. Dolly Varden in late July to early August that are <65 mm are assumed to be age 0 fish. Highest catches of age 0 fish occurred in 1997, 1998, and 1999 (Figure 123). High numbers of age 0 fish in 1997 and 1998 likely explains the large catches of juveniles in fall 1999. Catches of Dolly Varden remained low in fall 2000 and 2001, but increased in both 2002 and 2003. The length-distribution figures show declines in larger juvenile Dolly Varden particularly between 1999 and 2000 as they smolt and migrate to marine water. Smolting can occur as early as age 2, but more commonly at age 3 (DeCicco 1990a).



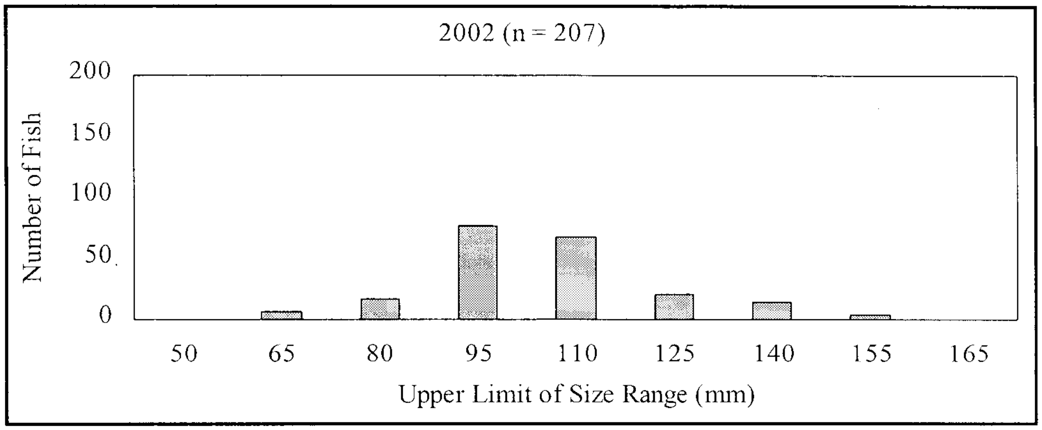


Figure 123. Length-frequency of juvenile Dolly Varden captured in fall 1997 through 2003.

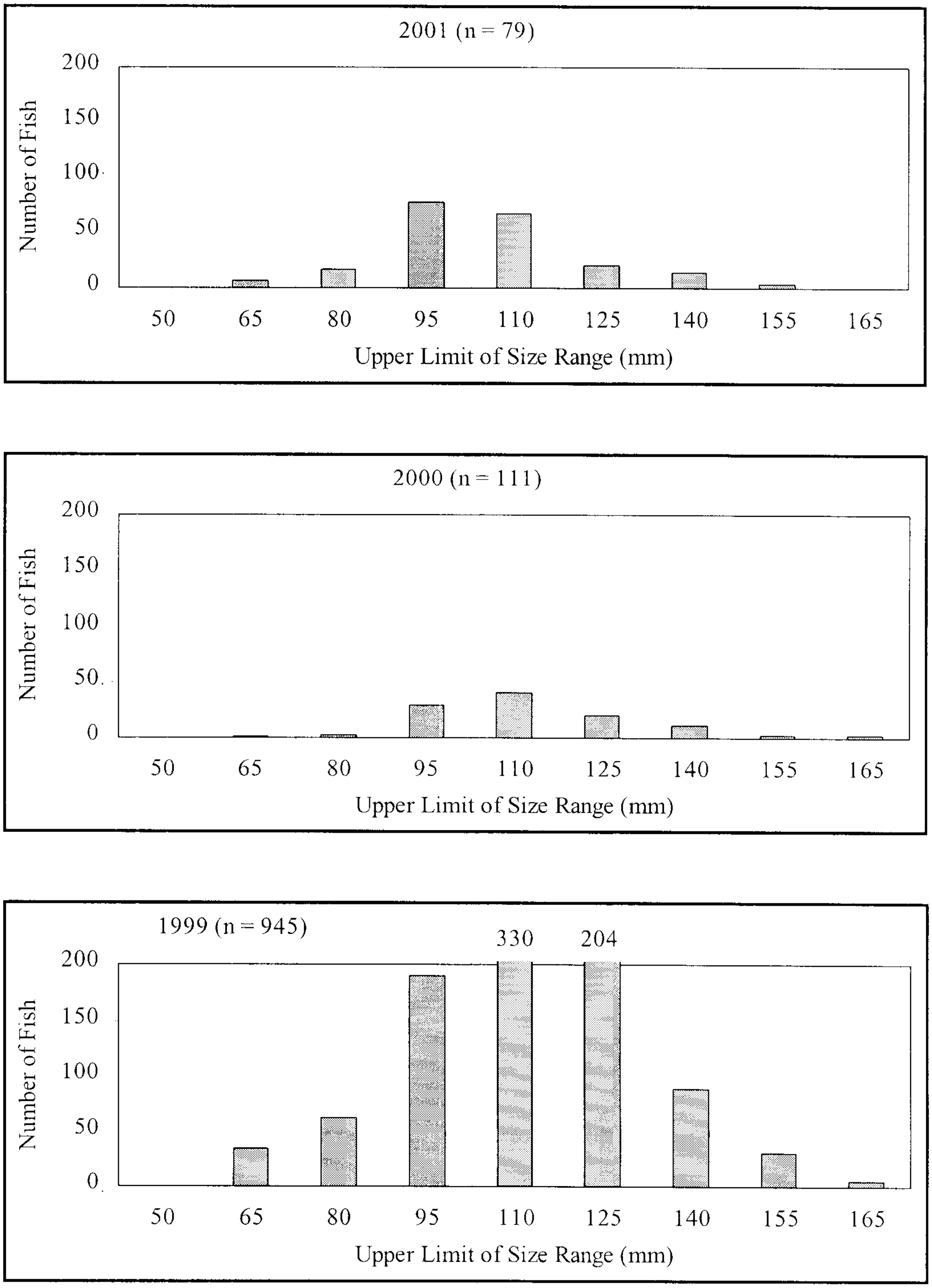
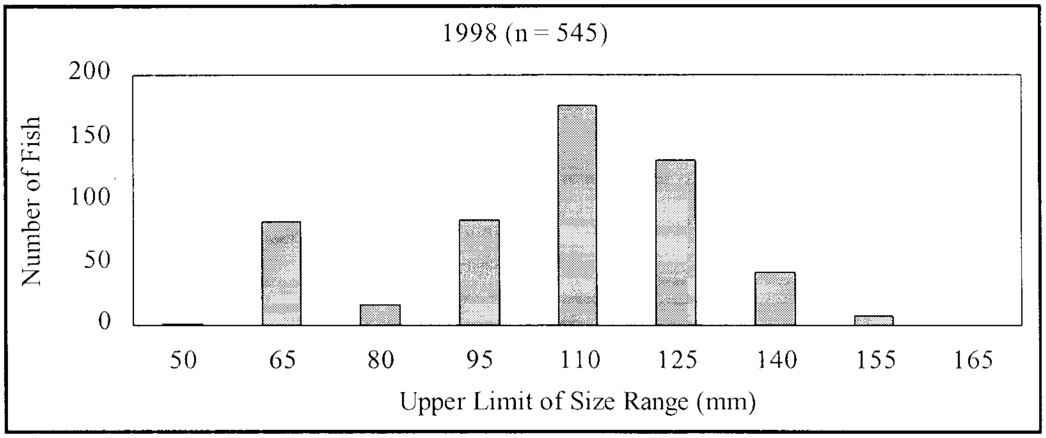


Figure 123. Length-frequency of juvenile Dolly Varden, continued.



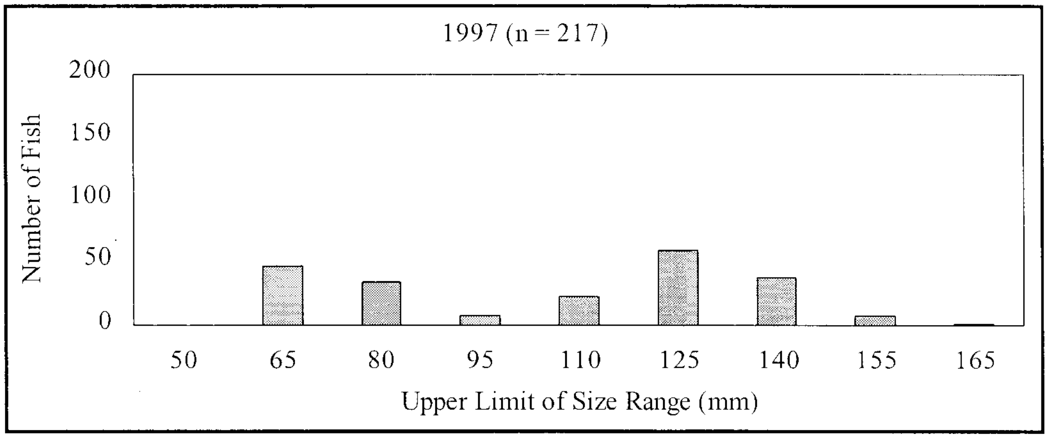


Figure 123. Length-frequency of juvenile Dolly Varden, concluded.

Juvenile Dolly Varden, North Fork Red Dog Creek

Fyke-nets were fished in North Fork Red Dog and Mainstem Red Dog creeks to gather information on Arctic grayling, but also have caught juvenile Dolly Varden. In early spring, during the Arctic grayling spawning migration, juvenile Dolly Varden captured have been larger and are believed to be stream resident based on coloration and size (Figure 124). In 2000, catches in mid-July clearly show that the juvenile fish captured then were smaller than those in spring (Figure 124). Larger stream resident fish probably were rearing in the headwaters of North Fork Red Dog Creek.

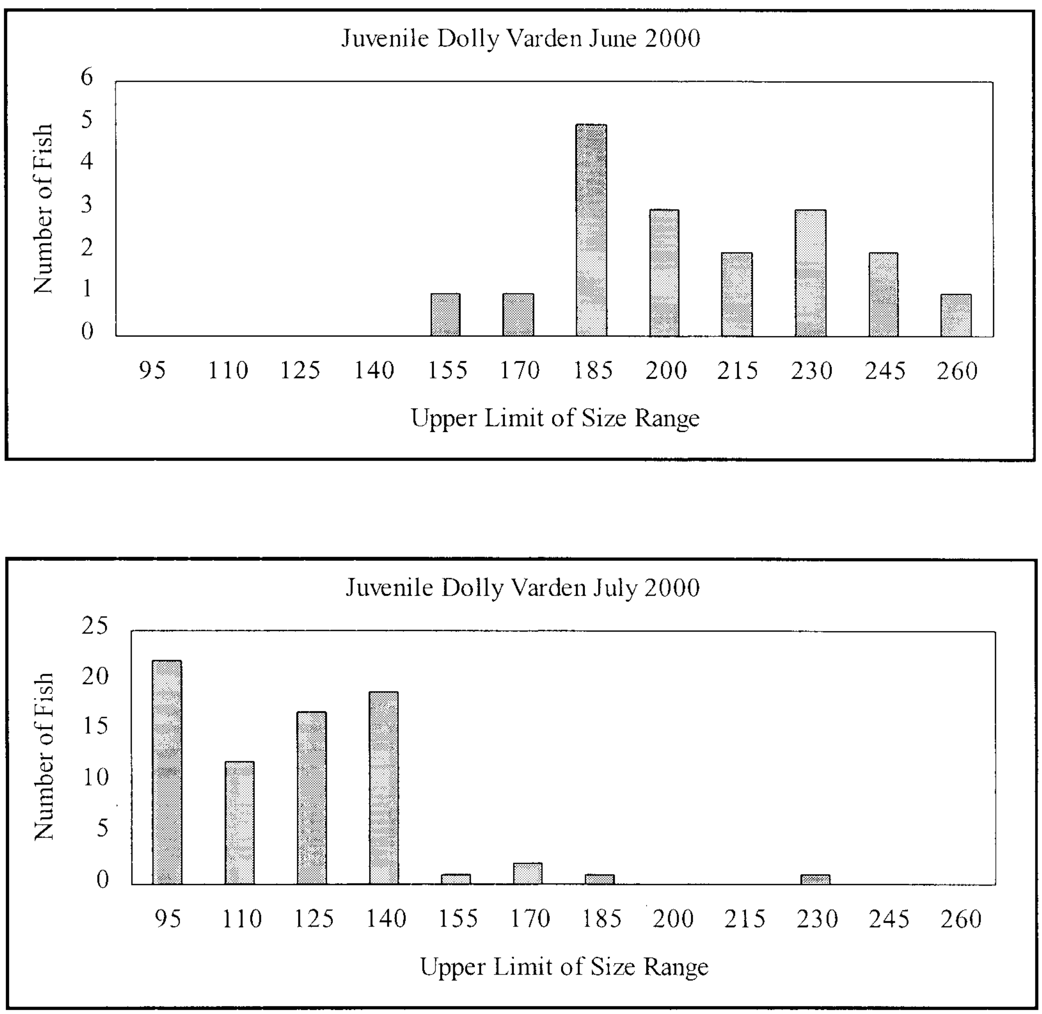


Figure 124. Juvenile Dolly Varden caught with fyke-nets in North Fork Red Dog Creek in June and July, 2000.

Catches of juvenile Dolly Varden with fyke-nets fished in the spring have varied annually, but the average size of these fish has consistently been larger than juvenile Dolly Varden caught later in the summer (Figure 125 versus 124).

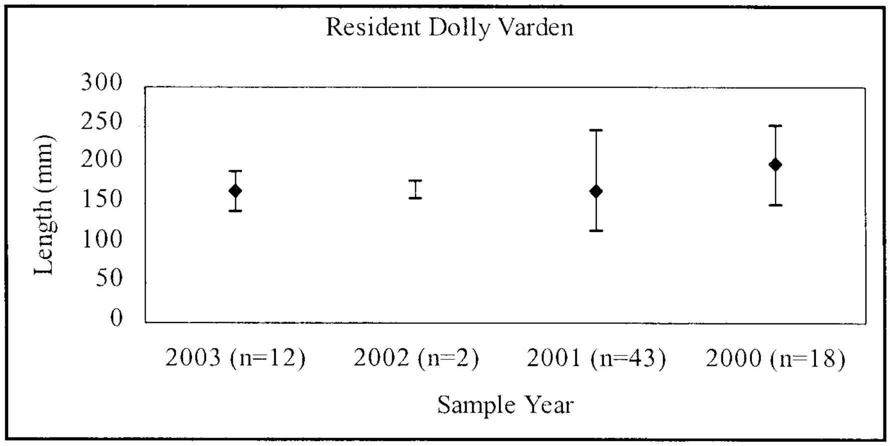


Figure 125. Length (maximum, average, and minimum) of Dolly Varden caught in spring with fyke-nets in North Fork Red Dog and Mainstem Red Dog creeks.

In baseline studies, Houghton and Hilgert (1983) only found juvenile Dolly Varden in the headwaters of North Fork Red Dog Creek. Our spring and summer sampling found larger Dolly Varden moving up the system in early spring and our minnow trap catches in late July and early August in the upper portion of the drainage reflect fairly high use in some years by smaller (90 to 140 mm) juvenile Dolly Varden. It is not known whether this change in use is due to general water quality improvements in Mainstem Red Dog Creek or simply reflects the greater sampling effort currently used and the use of fyke-nets that would catch the larger Dolly Varden.

Arctic Grayling

Before mine development, Arctic grayling adults were thought to migrate through Mainstem Red Dog Creek in early spring when discharges were high and metals concentrations were low (EVS and Ott Water Engineers 1983, Ward and Olson 1980, Houghton and Hilgert 1983). Migration of adults probably occurred during high-water events, and spawning was limited to North Fork Red Dog Creek. There is no indication in the baseline data that Arctic grayling spawned in Mainstem Red Dog Creek. Age 0 Arctic grayling reared in North Fork Red Dog Creek and outmigrated as water temperatures cooled in the fall or were displaced by summer high-water events.

Timing of Arctic Grayling Spawning

Water temperature is the most likely factor determining spawning time, emergence of age 0 fish, and potential first year growth. We have closely monitored the Arctic grayling during the spring spawning period in North Fork Red Dog and Mainstem Red Dog creeks since 2000. The purpose of monitoring the condition of female Arctic grayling is to determine when spawning in Mainstem Red Dog Creek is complete. Until spawning has been completed, the wastewater discharge from the treatment plant is controlled to ensure that the total dissolved solids (TDS) concentration in Mainstem Red Dog Creek, after mixing with North Fork Red Dog Creek, remains <500 mg/L.

In spring 2003, due to high water and ice, the fyke-net was not set until June 6. From June 6 to 10, the fyke-net was set and reset, but fished effectively only for short periods of time due to high water and ice. As flows decreased and most of the ice had flushed, the fyke-net fished effectively from June 11 until June 17 when sampling ended. Catches of Arctic grayling were low until June 15 (Table 14). All female Arctic grayling caught in North Fork Red Dog Creek from June 15 to 17 were spent. Field authorization to increase the wastewater discharge to 1,500 mg/L TDS was given effective at 1800 hours on June 14, 2003. In spring 2003, based on aerial and ground surveys, most of the Arctic grayling spawning occurred in Mainstem Red Dog Creek; however, an unknown number of fish probably moved past the fyke-net site when ice and high water limited fishing periods.

Table 14. Catches of adult and immature Arctic grayling in a fyke-net fished near Station 12 in North Fork Red Dog Creek in spring 2003.

Date	Females	Males	Immature	Spent Females
6/9/03	1	0	0	0
6/10/03	3	1	0	0
6/11/03	0	0	0	
6/12/03	0	0	0	
6/13/03	0	0	0	
6/14/03	1	1	1	0
6/15/03	8	9	15	8
6/16/03	13	17	25	13
6/17/03	4	6	9	4

A summary of our sample time period and when spawning was determined to be complete is presented in Table 15. In most of the years sampled, spawning was completed in Mainstem Red Dog Creek by mid-June.

Table 15. Spring sample time period and when spawning was determined to be complete in Mainstem Red Dog Creek.

Year	Sample Time Period	Date Spawning Complete
2003	June 9 to 17	June 14
2002	May 30 to June 8	June 8
2001	June 9 to 18	June 15
2000	June 10 to 14	June 14

Water temperatures in Mainstem Red Dog Creek warm earlier and have consistently been higher than in North Fork Red Dog Creek in 2001, 2002, and 2003 (Ott and Weber Scannell 2003) (Figure 126). The warmer water appears to be related to two factors: less aufeis in Middle Fork Red Dog Creek and warmer water in the discharge from the water treatment plant. Since Arctic grayling spawning is triggered by water temperature, and contrary to what occurred premining, some of these adults are now spawning in Mainstem Red Dog Creek.

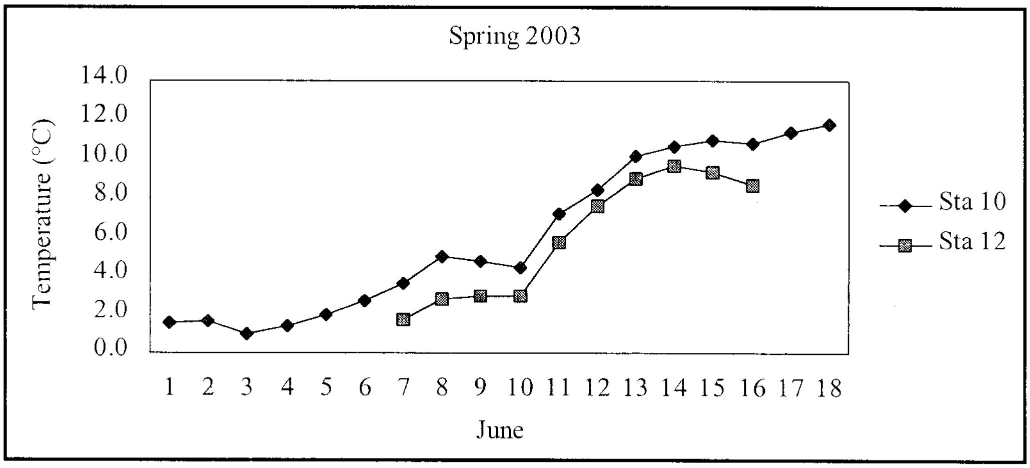


Figure 126. Water temperatures (°C) in North Fork Red Dog and Mainstem Red Dog Creeks in spring 2003.

Length-frequency distributions for Arctic grayling captured during the spring sample event are shown in Figure 127. Sampling began each spring as soon as a fyke-net could be set and was continued until spawning by Arctic grayling was judged to be complete. The number of adults captured in spring 2002 and 2001 was higher than in 2000 and 2003. Length-frequency distributions show that recruitment (i.e., fish 200 to 250 mm long) to the adult population occurred in 2001, with some in 2002 and 2003.

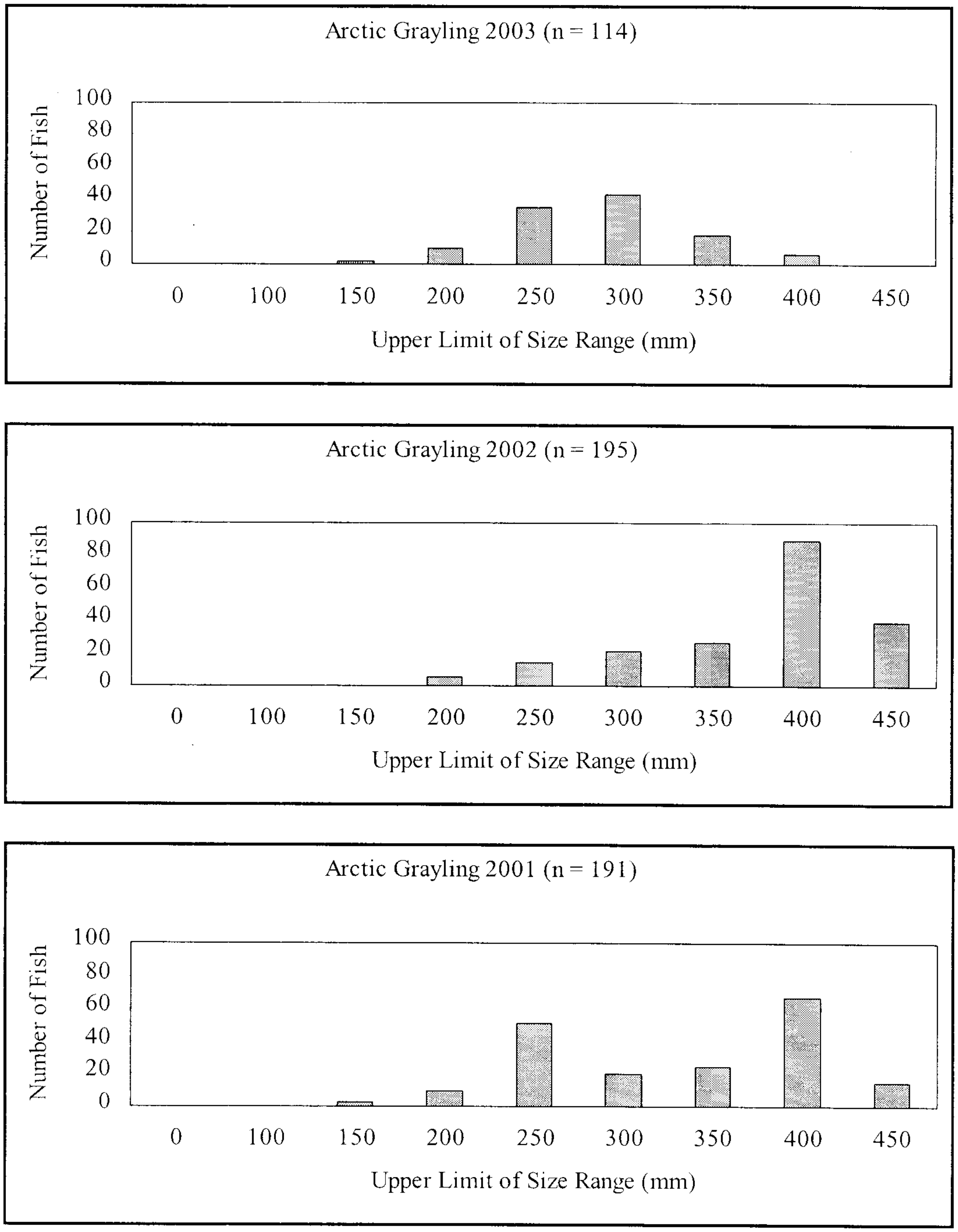


Figure 127. Length-frequency distribution of Arctic grayling caught mainly with fyke-nets in spring 2000 through 2003 in North Fork Red Dog and Mainstem Red Dog creeks.

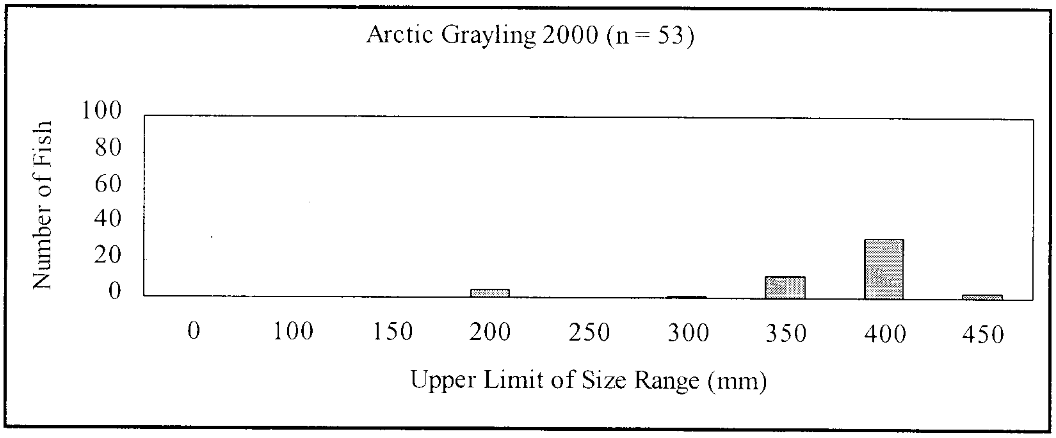


Figure 127. Length-frequency distribution of Arctic grayling, concluded.

Arctic Grayling Age 0

Since 1993, we have found adult and age 0 Arctic grayling in North Fork Red Dog Creek. We have visual observations of active spawning in North Fork Red Dog Creek and have captured age 0 Arctic grayling (12 to 15 mm long) in drift nets at Station 10 in Mainstem Red Dog Creek and at Station 12 in North Fork Red Dog Creek. We also conduct visual surveys along North Fork Red Dog Creek in July to document the relative number of age 0 fish. A summary of these observations is presented in Table 16. Relative number of age 0 fish appears to be directly related to the timing of breakup, high water events following breakup, and water temperatures during the summer. From 1992 to 2003, we have observed high numbers of age 0 fish in 1992, 1996, 1997, and 1999.

Arctic Grayling Mainstem Red Dog Creek

Visual surveys of Mainstem Red Dog Creek have been conducted annually from 1994 to 2003 (Appendix 6). The purpose of these surveys is to document use of Mainstem Red Dog Creek by Arctic grayling and compare it with information available from the baseline studies. Use of Mainstem Red Dog Creek prior to development of the mine was limited to migration, with some adult use of the lower portion of the creek. Arctic grayling use (adults and age 0 fish) of Mainstem Red Dog Creek currently is higher than that described in the baseline studies. Changes in use are likely related to overall improvement in water quality as compared with premining conditions.

Arctic Grayling Mark/Recapture and Distribution

Since 1994, we have marked Arctic grayling >200 mm with floy-tags. In 2003 we recaptured ten fish that had been marked in previous years. Only six of these ten were captured in spring 2002, and due to the low recapture rate, a population estimate was not possible. Nine of the ten fish captured in North Fork Red Dog Creek had been marked in either North Fork Red Dog or Mainstem Red Dog creeks in 1999, 2001, and 2002. One marked fish was recaptured in the Wulik River near Tutak Creek by fishermen from Kivalina. This fish was originally tagged in Ikalukrok Creek at the mouth of Grayling Junior Creek by ADF&G.

Table 16. Relative number of age 0 Arctic grayling observed in North Fork Red Dog Creek (1992-2003).

Year	Relative Number Age 0 Fish	Comments
1992	high	100's of age 0 fish, late July
1993	low	Few age 0 fish in early August, high water
1994	low	High water after spawning probably displaced age 0 fish
1995	low	Age 0 fish small (<25 mm) in mid-July
1996	high	Schools of 50 to 200 age 0 fish common
1997	high	Average size of age 0 fish was 10 mm greater than in 1996
1998	low	Cold water, late breakup, high water after spawning
1999	high	Low flows, warm water after spawning, schools of 50 to 100 Age 0 fish common
2000	low	Cold water, late breakup, spawning 90% done June 13/14, Age 0 fish small (<25 mm) and rare in mid-July
2001	low	Cold water, late breakup, spawning 90% done June 19, Age 0 fish small (<25 mm) and rare in mid-July
2002	low	High flows, spawning 90% done June 8, age 0 fish small (<35 mm) in early August and rare, more age 0 fish seen in Ikalukrok Creek in early July, probably displaced by high water
2003	low	Cold water, late breakup, spawning 90% done June 14, Age 0 fish small (<25 mm) and rare in early August

In spring 2003, we marked 92 Arctic grayling in the Ikalukrok Creek drainage (Appendix 7). All fish were marked in spring during the spawning migration in Mainstem Red Dog and North Fork Red Dog creeks.

Aerial surveys of the Ikalukrok Creek drainage conducted in summer 2003 did not locate concentrations of adult Arctic grayling normally found in the East Fork Ikalukrok Creek or at the mouths of Grayling Junior, Mainstem Red Dog, and Dudd creeks. In summers 2000 through 2002, large numbers of adult Arctic grayling were observed at the mouth of Grayling Junior Creek and/or in the East Fork Ikalukrok Creek.

Slimy Sculpin

Houghton and Hilgert (1983) found slimy sculpin in Ikalukrok and Dudd creeks, but none in the Red Dog Creek drainage. In 1995, we found slimy sculpin in Mainstem and North Fork Red Dog creeks (Weber Scannell and Ott 1998). Slimy sculpin are rare in the Red Dog Creek drainage and in Anxiety Ridge Creek. None have been caught in Buddy Creek. Most of the slimy sculpin are found in Ikalukrok Creek in the sample reaches located immediately upstream and downstream of Dudd Creek (Figure 128). Quantifiable baseline data on slimy sculpin distribution are not available thus no direct comparisons can be made with respect to premining and during mining.

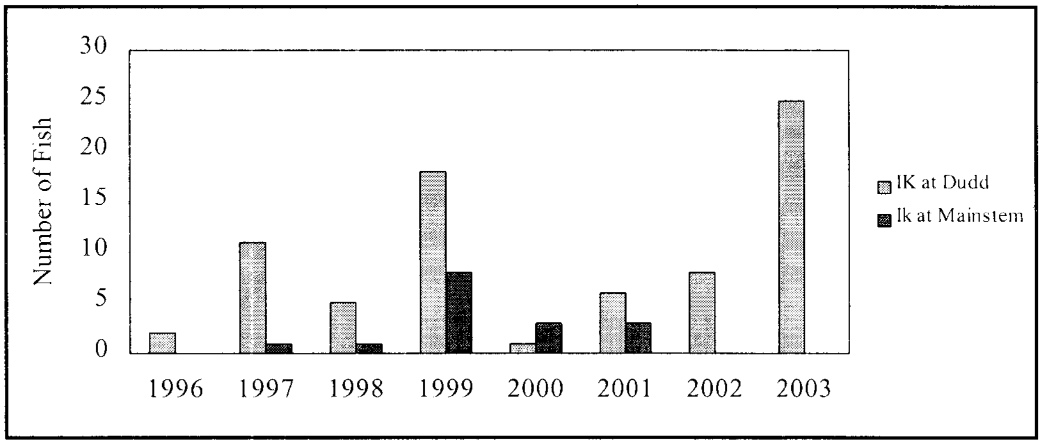


Figure 128. Slimy sculpin collected in Ikalukrok Creek at mouth of Dudd and Mainstem Red Dog Creeks.

Literature Cited

ADF&G. 1998. Methods for aquatic life monitoring to satisfy requirements under NPDES permit. NPDES AK-003865-2, Red Dog Mine Site. AK Dept. of Fish and Game. 23 pp.

Dames and Moore. 1983. Environmental baseline studies Red Dog Project.

DeCicco, A.L. 2002. 2002 Wulik River survey. October 14, 2002. Memorandum, Ak. Dept. of Fish and Game. 1 p.

DeCicco, A.L. 2001a. 2001 Wulik River Survey and Ikalukrok Creek, October 8, 2001. Memorandum, Ak. Dept. of Fish and Game. 1 p.

DeCicco, A.L. 2001b. Ikalukrok Creek Salmon, September 3, 2001. Memorandum, Ak. Dept. of Fish and Game. 2 pp.

DeCicco, A.L. 2001c. Ikalukrok Creek Salmon, September 28, 2001. Memorandum, Ak. Dept. of Fish and Game. 2 pp.

DeCicco, A.L. 2000. Personal communication to Habitat and Restoration Division. November, 2000.

DeCicco, A.L. 1999. Memorandum, 1999 Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. 1 p.

DeCicco, A.L. 1998. Memorandum, 1998 Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. 1 p.

DeCicco, A.L. 1997. Memorandum, Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. 1 p.

DeCicco, A.L. 1996a. Memorandum, Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. 1 p.

DeCicco, A.L. 1996b. Abundance of Dolly Varden overwintering in the Wulik River, Northwestern Alaska during 1994/1995. AK Dept. of Fish and Game, Sport Fish Fishery Data Series No. 96-3. Anchorage, AK.

DeCicco, A.L. 1995. Personal communication. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK.

DeCicco, A.L. 1994. Memorandum, Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 1 p.

DeCicco, A.L. 1993. Memorandum, Wulik River survey. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 1 p.

Literature Cited (continued).

DeCicco, A.L. 1992. Memorandum, Char surveys. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 2 pp.

DeCicco, A.L. 1991. Kotzebue trip report, August 16 to 27, 1991. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 5 pp.

DeCicco, A.L. 1990a. Life history of anadromous Dolly Varden (*S. malma*) in Northwestern Alaska. AK. Dept. of Fish and Game, Sport Fish Division. Prepared for the 1990 meeting of the International Society of Arctic char fanatics in Murmansk, USSR. September 1990. 19 pp.

DeCicco, A.L. 1990b. Northwest Alaska Dolly Varden study 1989. Federal Aid in Sport Fish Restoration Act. AK. Dept. of Fish and Game. Fishery Data Series No. 90-8. Fairbanks, AK. 42 pp.

DeCicco, A.L. 1990c. Trip report, Red Dog October 3 to 6, 1990. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 2 pp.

DeCicco, A.L. 1989. Memorandum, Wulik River char distribution. AK Dept. of Fish and Game, Sport Fish Division. Fairbanks, AK. 3 pp.

EVS Consultants Ltd and Ott Water Engineers. 1983. Toxicological, biophysical and chemical assessment of Red Dog, Delong Mountains, Alaska, 1982. Prepared for Alaska Department of Environmental Conservation, Juneau, by G. Vigers, J. Barrett, R. Hoffman, J. Humphrey, D. Kathman, D. Konasewich, R. Olmsted, and B. Reid. 245 pp.

Houghton, J.P. and P.J. Hilgert. 1983. In Environmental baseline studies Red Dog project. Dames and Moore. 82 pp.

Jenkins, D.W. 1980. Biological monitoring of toxic trace metals. Vol. 1. Biological Monitoring and Surveillance. J EPA-600/3-80-089. 215 pp.

Morris, W.A. and A.G. Ott. 2001. Red Dog Trip Report (July 28 to August 9, 2001). Ak. Dept. of Fish and Game. 9 pp.

Ott, A.G. and P. Weber Scannell. 2003. Aquatic biomonitoring at Red Dog Mine, 2002. National Pollution Discharge Elimination System Permit No. AK-003865-2. Technical Report No. 03-03. AK Dept. of Fish and Game, Habitat and Restoration Division. 116 pp.

Ott, A.G. and A.H. Townsend. Red Dog Trip Report (July 27 to August 7, 2002). AK Department of Fish and Game, Div. Habitat and Restoration, Fairbanks, AK. 7 pp.

Literature Cited (continued).

Ott, A.G. and W.A. Morris. 1999. Red Dog Mine Field Trip Report. August 7 - August 13, 1999. AK Department of Fish and Game, Div. Habitat and Restoration, Fairbanks, AK. 5 pp.

Ott, A.G. and S. Simpers. 1997. Red Dog Mine Field Trip Report. August 9 - August 15, 1997. AK Department of Fish and Game, Div. Habitat and Restoration, Fairbanks, AK. 9 pp.

Ott, A.G. and P. Weber Scannell. 1996. Fishery resources below the Red Dog Mine Northwest Alaska. 1990-1995. Technical Report No. 96-2. AK Dept. of Fish and Game, Habitat and Restoration Division. Juneau, AK. 89 pp.

Ott, A.G. and P. Weber Scannell. 1995. Baseline fish and aquatic habitat data for Fort Knox Mine, 1992 to 1995. Technical Report No. 96-5. AK Dept. of Fish and Game, Habitat and Restoration Division. Juneau, AK. 165 pp.

Ott, A.G. and P. Weber Scannell. 1994. Fish monitoring study, Red Dog Mine in the Wulik River drainage, emphasis on Dolly Varden (*Salvelinus malma*), summary report 1990-1993. Technical Report No. 94-1. AK Dept. of Fish and Game, Habitat and Restoration Division. Juneau, AK. 63 pp.

Ott, A.G. and P. Weber Scannell. 1993. Fish monitoring study, Red Dog Mine in the Wulik River drainage, emphasis on Dolly Varden (*Salvelinus malma*), 1992 progress report. Technical Report No. 93-10. AK Dept. of Fish and Game, Habitat and Restoration Division. Juneau, AK. 52 pp.

Ott, A.G., P.K. Weber Scannell, and M.H. Robus. 1992. Fish monitoring study, Red Dog Mine in the Wulik River drainage, emphasis on Dolly Varden (*Salvelinus malma*). Technical Report No. 91-4. AK Dept. of Fish and Game, Habitat Division. Juneau, AK. 67 pp.

Scannell, D. 2000. A comparison of two toxicity tests: Microtox and WET. AP Biology Research Project, Lathrop High School, Fairbanks, AK.

Townsend, A.H. and L. Ingalls. 2003. Red Dog Field Trip Report. August 6 to 13, 2003. Alaska Department of Natural Resources, Office of Habitat Management and Permitting, Fairbanks, AK. 3 pp.

Townsend, A.H. and C. Hemming. 1996. Red Dog Field Trip Report. August 9 - August 15, 1996. Alaska Department of Fish and Game, Habitat and Restoration Division, Fairbanks, AK.

Townsend, A.H., and C. Lunderstadt. 1995. Trip report, August 11 to 16, 1995. AK Dept. of Fish and Game, Habitat and Restoration Division, Fairbanks, AK. 7 pp.

Literature Cited (concluded).

Ward, D.L. and T.J. Olson. 1980. Baseline aquatic investigations of fishes and heavy metal concentrations in the Kivalina and Wulik Rivers, 1978-79. LGL Ecological Research Associates, Inc. Prepared for GCO Minerals Company. 89 pp.

Weber Scannell, P. and A.G. Ott. 2002. Aquatic biomonitoring at Red Dog Mine, 2001. National Pollution Discharge Elimination System Permit No. AK-003865-2. Technical Report No. 02-04. AK Dept. of Fish and Game, Habitat and Restoration Division. 114 pp.

Weber Scannell, P. and A.G. Ott. 2001. Aquatic biomonitoring at Red Dog Mine, 2000. National Pollution Discharge Elimination System Permit No. AK-003865-2. Technical Report No. 01-04. AK Dept. of Fish and Game, Habitat and Restoration Division. 163 pp.

Weber Scannell, P., A.G. Ott, and W.A. Morris. 2000. Fish and aquatic taxa report at Red Dog Mine, 1998-1999. Technical Report No. 00-3. AK Dept. of Fish and Game, Habitat and Restoration Division. Juneau, AK. 136 pp.

Weber Scannell, P. and S. Andersen. 2000. Aquatic taxa monitoring study at Red Dog Mine, 1997-1998. Technical Report No. 00-2. AK Dept. of Fish and Game, Habitat and Restoration Division. Juneau, AK. 214 pp.

Weber Scannell, P. and A.G. Ott. 1998. Fisheries resources and water quality, Red Dog Mine. Technical Report No. 98-2. AK Dept. of Fish and Game, Habitat and Restoration Division. Juneau, AK. 136 pp.

Weber Scannell, P. 1997. Red Dog Creek use attainability analysis aquatic life component. Technical Report No. 97-3. AK Dept. of Fish and Game, Habitat and Restoration Division. Juneau, AK. 35 pp.

Weber Scannell, P. and A.G. Ott. 1995. Fishery resources below the Red Dog Mine northwestern Alaska. Technical Report No. 95-5. AK Dept. of Fish and Game, Habitat and Restoration Division. Juneau, AK. 61 pp.

Appendix 1. A Summary of Mine Development and Operations with Emphasis on Biological Factors

1982

- Baseline studies initiated, Cominco agreement with NANA finalized

1983

- EIS process initiated, alternatives for mine and road to port site identified

1984

- Stream surveys conducted along proposed road by private consultant

1985

- Permit applications prepared for regulatory agencies
- Implementation of wastewater treatment plant deferred to ADEC by ADF&G
- Wastewater discharge limited to summer
- Potential for acid rock drainage and metals mobilization not recognized

1986

- ADEC solid waste permit and bonding not required
- ADEC permit preceded solid waste regulations
- AIDEA bonds to build road and port site issued

1987

- Construction of road began, budget request to AIDEA prepared by ADF&G
- Reimbursement agreement for logistics with ADF&G to monitor construction made by AIDEA

1988

- Ore body developed
- Road and port site construction began
- Notice of Violation issued to AIDEA by ADF&G for failed road crossing by-passes
- Uniform Summons and Complaint issued for illegal water removal
- AIDEA provided funding to ADF&G for monitoring
- Rehabilitation plans for streams developed and implemented

Appendix 1 (continued).

1989

- Agreement to close-out old solid waste site finalized with Cominco
- Civil work on ore body and surface water drainage control begun
- Complaints about water quality in Ikalukrok Creek received
- Tailing dam becomes full, Cominco's request to siphon untreated water over the dam denied by State
- Elevated metals concentrations identified by red precipitation, were observed in Ikalukrok Creek below the mine
- Winter discharge of treated water authorized by State
- State regulatory agencies and Cominco in disagreement over whether metals exceeded background conditions

1990

- Biomonitoring of fish populations proposed and initiated by ADF&G
- Dead fish from the Wulik River were discovered by the public
- ADF&G sampling indicated very few fish remaining in Ikalukrok Creek
- Installation of sumps and pumps by Cominco prevented metals-laden water from entering Red Dog Creek
- Baseline and current water quality data reviewed by ADF&G
- Clean water bypass system requested by ADF&G
- Zinc levels in Ikalukrok Creek exceeded 40 mg/L
- State regulatory agencies and Cominco in disagreement over cause and extent of water quality problems
- Compliance Order by Consent for water quality violations affecting anadromous fish issued by ADEC
- Notice of Violation for water quality violations affecting anadromous fish issued by ADF&G
- Cominco directed to design and construct a clean water bypass system
- Perceived impairment to the subsistence fishery initiated involvement by the community of Kivalina

1991

- Clean water bypass system designed by Cominco, approved by state agencies
- ADF&G fisheries study funded by Cominco
- Clean water bypass system built
- Clean water bypass system repaired
- Improvements to water quality were documented

Appendix 1 (continued).

1992

- Fish study continued
- Water quality improvements to downstream receiving water continued
- Increasing water volume in tailing impoundment continued
- Water from dirty water collection system entering tailing impoundment increased volume
- Water treatment plant modifications made

1993

- Fish study continued
- Sand filters to remove particulate zinc installed

1994

- Fish study continued
- Use attainability studies of several streams initiated for reclassification
- Water treatment capacity increased by thickening tank conversion
- Wastewater discharge increased from 7.5 cfs to 23 cfs
- Ore processing capability expanded by Cominco

1995

- Fish study expanded to include other aquatic biota
- Work on stream reclassification and site-specific criteria continued by ADF&G
- Metals concentrations in the clean water bypass system increased; contributing sources were identified: Hilltop Creek (Zn), Shelly Creek (Cd), and Rachel Creek (Al)
- Clean water bypass system extended to collect water from Hilltop Creek
- Reserves were doubled after exploration drilling located more ore
- Possible metals contamination in Bons Creek identified by ADF&G

1996

- Public notice for stream reclassification sent out
- Bons Creek water samples from above and below the Kivalina shale dump collected
- Fish and aquatic biota study continued

Appendix 1 (continued).

1997

- Stream reclassification incorporated into regulation (18 AAC 70.50)
- Fish barrier constructed across Middle Fork Red Dog Creek
- Water bypass around the Kivalina shale dump and interceptor trench at the head of the tailing impoundment built
- Gray-white precipitate observed in Middle Fork Red Dog Creek
- Heavy red staining and precipitate seen in Ikalukrok Creek; originated from seep near headwaters of Ikalukrok Creek, located upstream of mining activity
- Laboratory experiments of TDS on egg fertilization and early egg development initiated
- Fish and aquatic biota studies continue
- US EPA brings enforcement action for water quality violations; Cominco initiates Supplemental Environmental Projects
- Two-year aquatic community study in upper Ikalukrok Creek, above and below the Red Dog Mine discharge initiated by ADF&G
- Ground water monitoring wells installed and monitored below tailing dam by Cominco

1998

- Wet fertilization studies to test effects of TDS on fish embryos continued
- Draft 401 certification for a new NPDES permit prepared by ADEC and reviewed by ADF&G
- Discussed extension of the clean water bypass system up Shelly and Connie Creeks to ensure bypass of clean water and collection of seepage water from newly disturbed areas
- Heavy red staining in headwaters of Ikalukrok Creek, originating from seep in headwaters of Ikalukrok Creek, upstream of mining activity, staining extends downstream about 30 km
- Site-specific criteria for Zn in Mainstem Red Dog and Ikalukrok Creeks approved by EPA
- Heavy rains cause an unanticipated release of water into Bons Creek from the Kivalina stockpile
- Plans to increase port site capacity for direct loading of ships released to public
- NPDES permit reissued by US EPA
- Two-year aquatic community study completed
- Biomonitoring, including studies of fish and aquatic biota, required under 1998 NPDES permit

Appendix 1 (continued).

1999

- Two-year drilling program (Shelly and Connie Creeks) proposed
- New station 7 on Ikalukrok Creek established by Cominco, USGS, and ADF&G
- Fish and aquatic biota study expanded to upper North Fork Red Dog, Ikalukrok, and Ferric creeks
- Biomonitoring and USGS gauging work proposals submitted to Cominco
- Study of periphyton communities exposed to different concentrations of TDS in Mainstem Red Dog Creek done by ADF&G and Cominco Alaska Inc.
- Request to increase TDS for periphyton colonization experiment not approved
- Effects to Ikalukrok Creek from Alvinella Creek seepage water continued to below Dudd Creek mouth
- Arctic grayling females in ripe spawning condition collected from North Fork Red Dog Creek for selenium analysis of livers and ovaries

2000

- Effects to Ikalukrok Creek from Alvinella seepage continued; red stain and precipitate observed several km below mouth of Mainstem Red Dog Creek
- North Fork Red Dog Creek silty at breakup, previously not observed
- Minimal precipitate in Middle Fork Red Dog Creek below effluent outfall observed
- Civil work performed in Connie Creek to isolate surface from subsurface flows and bypass flow through disturbed areas
- Effectiveness of pump back system at the Kivalina rock dump verified by presence of juvenile Arctic grayling in creek immediately south of dump
- Site-specific criteria for TDS requested by Cominco
- Biomonitoring study continued
- Baseline fish and aquatic biota studies in streams located in the vicinity of the Anarraaq Prospect begun

Appendix 1 (continued).

2001

- Effects to Ikalukrok Creek from Alvinella seepage continued, red stain and precipitate observed in Ikalukrok Creek to Station 8 below Mainstem Red Dog Creek, affects minor near mouth of Dudd Creek
- North Fork Red Dog Creek, siltation (natural) less than in summer 2000
- Minimal precipitate in Middle Fork Red Dog Creek below effluent outfall
- Water quality was monitored in Shelley, Rachel, Connie, and Middle Fork Red Dog creeks upstream and downstream of surface disturbance, catch-box and pipeline (about 430 m) placed in Shelley Creek to move water pass disturbance
- Juvenile Arctic grayling observed in Bons Creek just south of the Kivalina rock dump, pump-back system working based on fish use
- Fish weir repairs made during 2000, no problems observed in 2001
- Stream survey of cross drainage structures made along the Delong Mountains Transportation System, some minor work at some crossings identified
- Site-specific criteria for TDS still being worked, data on Arctic grayling spawning/water temperature collected in North Fork Red Dog and Mainstem Red Dog creeks, supplemental data gathered at the Ft. Knox mine
- Studies expanded to include the Delong Mountains Transportation System based on a National Park Service report that metals concentrations adjacent to road were elevated, water sites established upstream and downstream of road and sampled by Teck Cominco, juvenile Dolly Varden samples collected in Omikviorok River and Aufeis Creek, vegetation sampling started by Teck Cominco
- New haul trucks brought on site, hard-covered trucks to minimize loss of zinc and lead concentrates during transport
- Exploratory drilling (ore and shallow gas) continued, focus on North Fork Red Dog Creek and Wulik River basins near Anarraaq and Lik, including west of the Wulik River, another ore prospect found northwest of Anarraaq, shallow gas results promising
- State and Teck Cominco agree to start the state's large mine team to work on issues, key issue identified was development of a solid waste permit with bonding for the tailing dam, other issues include site-specific criterion for total dissolved solids, clean-water bypass system, waste rock dumps (acid-rock drainage, and truck wash to minimize metal transport)
- Biomonitoring study continued, baseline fish and aquatic biota studies in streams located in the vicinity of the Anarraaq Prospect continued for the second field season, four new sites added to study tributaries on west side of Wulik in the area of the Lik Deposit and potential shallow gas development

Appendix 1 (continued).

2002

- Effects to Ikalukrok Creek from Alvinella seepage continued, red stain and precipitate observed in Ikalukrok Creek to Station 8 below Mainstem Red Dog Creek, affects minor near mouth of Dudd Creek
- North Fork Red Dog Creek, siltation minor during summer 2002
- Minor precipitate in Middle Fork Red Dog Creek below effluent outfall
- Fish weir operating as designed during summer 2002
- Data on Arctic grayling spawning/water temperature collected in North Fork Red Dog Creek, supplemental data gathered at Ft. Knox
- Pit expansion continues to the north of the clean-water bypass system, road crossing added for access
- A bypass was installed for Connie Creek during winter 2001/2002. The bypass captures the upstream creek and carries the water in a pipe to the clean-water bypass system
- The bypass system for Shelly Creek was modified during summer 2002 to correct an overflow problem that occurred during breakup (the overflow water was captured in the pit and did not affect downstream waters). The modification involved adding a lined ditch to contain overflowing clean water and direct the water to the clean-water bypass system
- Juvenile Dolly Varden collected at eight sites located upstream and downstream of the Delong Mountains Regional Transportation System, whole body metals analyses for Cd, Pb, Se, and Zn
- Site-specific criteria for total dissolved solids is still being worked
- State and Teck Cominco continue to work on key issues, e.g., solid waste permit with bonding for the tailing dam, site-specific criterion for total dissolved solids, clean-water bypass system, waste rock dumps (acid-rock drainage, and truck wash to minimize metal transport)
- Biomonitoring study continued, baseline fish and aquatic biota studies in streams located in the vicinity of the Anarraaq Prospect and shallow gas exploration
- Arctic grayling adults remained in North Fork Red Dog Creek through early August, only the second time since 1992 that most of the adults stayed in the creek during summer, most years adults outmigrate shortly after spawning in spring
- Arctic grayling adults present in Buddy Creek just below the falls, about 50 adult fish in sample reach (0.3 km) in early July, all gone by early August
- About 50 to 60 adult Dolly Varden in Ikalukrok Creek at mouth of Dudd Creek from early July through late August
- Effluent discharge ceased on October 5, 2002, to allow time to winterize the water treatment plant

Appendix 1 (concluded).

2003

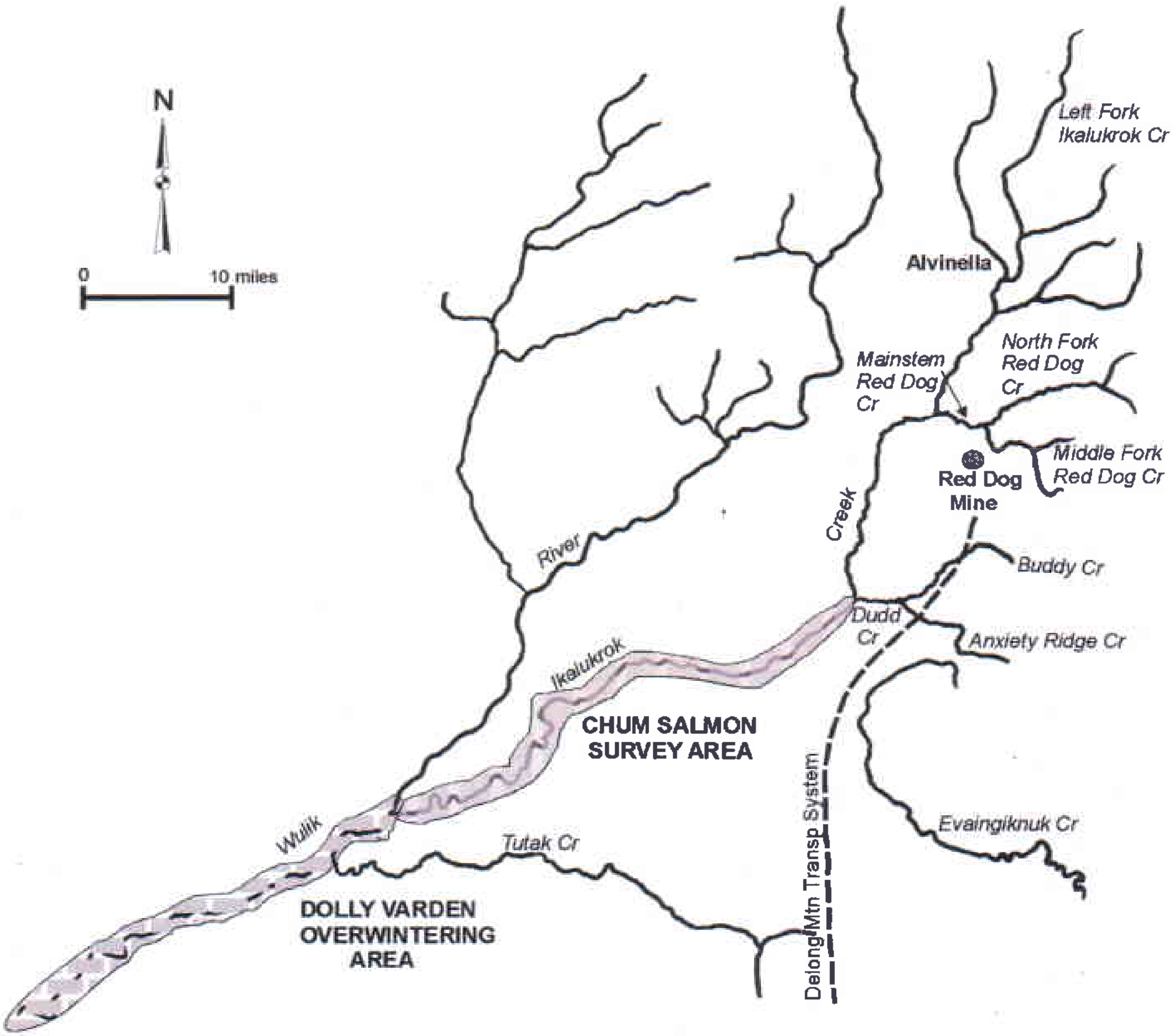
- Effects to Ikalukrok Creek from Alvinella seepage continued but were much less than seen in the last two to three years
- North Fork Red Dog Creek, natural siltation throughout most of the summer was minor in summer 2003
- Minor precipitate in Middle Fork Red Dog Creek below effluent outfall
- Fish weir operating as designed during summer 2003
- Data on Arctic grayling spawning/water temperature collected in North Fork Red Dog Creek, supplemental data gathered at Ft. Knox
- Site-specific criteria for total dissolved solids was finalized
- USEPA modified the NPDES effective August 22, 2003, to incorporate the ADEC Site Specific Criteria and mixing zones for total dissolved solids in Mainstem Red Dog and Ikalukrok creeks with conditions that ensure total dissolved solids are at or below 500 mg/L during Arctic grayling spawning in Mainstem Red Dog Creek and during chum salmon and Dolly Varden spawning in Ikalukrok Creek, the modified permit was appealed by the Kivalina Relocation Planning Committee
- State and Teck Cominco continue to work on key issues, e.g., solid waste permit with financial assurance for the tailing dam, site-specific criterion for total dissolved solids, clean-water bypass system, waste rock dumps (acid-rock drainage, and truck wash to minimize metal transport)
- Arctic grayling adult returns to North Fork Red Dog Creek were low, number of adult Arctic grayling seen in the Ikalukrok Creek drainage was the lowest seen since aerial surveys were begun in the late 1990s
- Arctic grayling population estimate was completed for Bons Pond the site of a fish transplant made in 1994 and 1995, estimated population in the reservoir was 6,773
- Modification to Shelly Creek bypass ditch completed, a better designed and constructed lined ditch was built and commissioned in August, 2003
- In 2003, a permanent lined ditch was constructed parallel to the Connie Creek diversion pipeline to avoid spring freeze-up issues
- In 2003, a permanent monitoring station was established at the end of the mixing zone in Mainstem Red Dog Creek, the location designation is Station 151, and is fitted with real time total dissolved solids and flow determination equipment and telemetry to link the station directly into the mill process control system
- Station 150, at the end of the mixing zone in Ikalukrok Creek, was fitted with real time total dissolved solids and flow determination equipment and telemetry to link the station directly into the mill process control system

Appendix 2. Dolly Varden Aerial Surveys

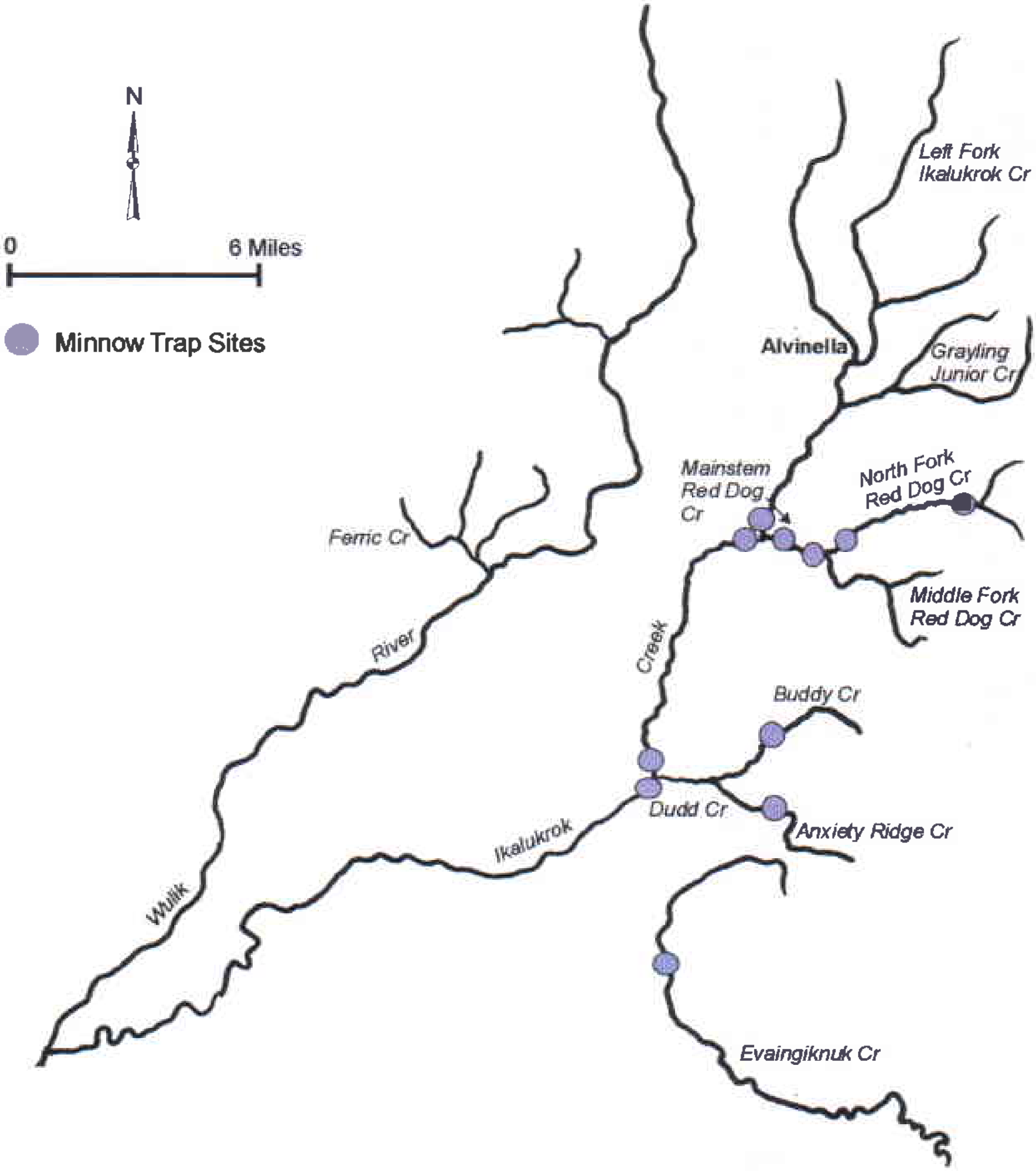
Number of overwintering Dolly Varden in the Wulik River before freezeup. Surveys conducted by ADF&G (DeCicco 1989, 1991-1999, and 2001-2002.

Year	Wulik River upstream of Ikalukrok Creek	Wulik River downstream of Ikalukrok Creek	Total Fish	Percent 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	1,500	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	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				
2001	2,020	90,594	92,614	98
2002	1,675	42,582	44,257	96
2003				
The population estimate (mark/recapture) for winter 1988/1989 for fish >400 mm				
was 76,892 (DeCicco 1990b)				
The population estimate (mark/recapture) for winter 1994/1995 for fish >400 mm				
was 361,599 (DeCicco 1996c)				
Fall 2000 aerial survey was not made due to weather.				
Fall 2003 aerial survey was not made due to weather.				

APPENDIX 3. ADULT DOLLY VARDEN AND CHUM SALMON SURVEY AREAS



APPENDIX 4. JUVENILE DOLLY VARDEN SAMPLING AREAS



Appendix 5. Juvenile Dolly Varden Catches at NPDES Sample Sites

Number of Dolly Varden Caught in Late-July/Early August with ten minnow traps per sample site							
Sample Site Description	Date 8/8-10/03	Date 7/28-29/02	Date 7/30-8/5/01	Date 7/28-8/1/00	Date 8/9-10/99	Date 8/7-10/98	Date 8/10-13/97
Evaingiknuk (Noatak Tributary)	64	20	7	2	38	27	54
Anxiety Ridge	98	33	6	27	271	94	68
Buddy	104	57	34	11	306	154	48
North Fork Red Dog Creek (Sta 12)	0	1	1	1	17	12	0
Mainstem (below North Fork)	2	12	9	13	86	70	14
Mainstem (Station 10)	12	12	3	1	66	21	10
Ikalukrok Creek (below Dudd)	17	17	6	31	55	51	13
Ikalukrok Creek (above Dudd)	27	22	0	14	37	53	3
Ikalukrok Creek (below Mainstem)	3	15	11	6	28	19	4
Ikalukrok Creek (above Mainstem)	3	18	2	5	41	44	3
Total Catch Dolly Varden	330	207	79	111	945	545	217

Appendix 6. Arctic Grayling, Mainstem Red Dog Creek

Observations and catches in Mainstem Red Dog Creek below confluence of North Fork and Middle Fork Red Dog Creeks since 1994.

Sample Date	Sample Method	Comments on Arctic Grayling (age 0 = young of the year)
9/7/03	Visual	2 adults, five age 0 fish
7/8/03	Visual	10 adults near Station 10
7/7/03	Visual	Age 0 in backwaters near Station 10, one group of 30
6/14/03	Angling	8 adults, caught one spent male
6/12/03	Visual	10 adults, three active spawning pairs observed
6/11/03	Aerial	48 adults, two spawning pairs seen
7/28/02	Visual	Adults present in lower 2 km, 3 to 4 per pool
7/27/02	Visual	Few age 0 (less than 10)
6/7/02	Angling	10 adults and 3 juveniles captured, marked, released
		near Sta. 10, most females spent
6/4/02	Fyke	3 adults and 3 juveniles captured, marked, released
		near Sta. 10
6/3/02	Fyke	3 adults captured, marked, released near Sta. 10
6/2/02	Fyke	8 adults captured, marked, released near Sta. 10
6/1/02	Fyke	31 adults captured, marked, released near Sta. 10
5/31/02	Fyke	7 adults captured, marked, released near Sta. 10
7/29-31/01	Visual	Very few age 0 seen (about 20 mm), late breakup,
		Cold temperatures resulted in late spawning
6/17/01	Angling	11 adults captured, marked, and released in lower
		1.6 km of creek, all females spent
6/15-18/01	Visual	Walked creek to check for spawners in proposed
		mixing zone, none observed, one adult seen feeding
		at rock bluff (0.8 km below North Fork)
7/28/00	Visual	Several age 0 in backwaters and along stream
		margins, not numerous
7/6/00	Visual	Walked most of creek, tagged 3 adults near Sta. 10
		most pools held 1 to 3 adults

Appendix 6, continued.

Sample Date	Sample Method	Comments on Arctic Grayling (age 0 = young of the year)
7/5/00	Visual	Two adults feeding at rock bluff (0.8 km below North
		Fork), juvenile observed
6/11-12/00	Fyke	Adults captured, marked, and released
8/9-10/99	Visual	Numerous age 0 fish in backwaters and along stream
		margins
7/8-9/99	Angling	2 adults captured, marked, released near Sta 10
7/8-9/99	Visual	12 adults and some age 0 fish near Sta 10
7/8-9/99	Visual	2 adults at rock bluff 0.8 km below North Fork mouth
7/8-9/99	Visual	2 adults at rock bluff 0.1 km below North Fork mouth
5/30/99	Fyke	32 adults caught about 100 m below North Fork mouth
5/29/99	Angling	3 adults caught just below North Fork mouth
6/28/98	Visual	1 adult feeding at rock bluff 0.8 km below North Fork
6/10/98	Visual	No fish seen between North Fork mouth and rock bluff
9/29/97	Traps	7 age 0 caught near Sta. 10
8/10/97	Visual	Age 0 in backwaters
6/27/97	Visual	Age 0 numerous at Sta. 10
6/26/97	Angling	15 adults captured, marked, released at mouth of
		creek, 8 were spent fish
6/25/97	Drift net	Age 0 caught at Sta 10, 13-15 mm long
6/25/97	Visual	2 adults at rock bluff 0.8 km below North Fork mouth
8/12/96	Visual	Age 0 near rock bluff about 0.8 km below North Fork
8/11/96	Visual	Age 0 in shallow eddies at mouth
7/15/96	Angling	7 adults captured, marked, released about 2 km
		above mouth
6/19/96	Visual	1 adult near Sta. 10
8/14/95	Angling	11 adults captured, marked, released near rock bluff

Appendix 6, concluded.

Sample Date	Sample Method	Comments on Arctic Grayling (age 0 = young of the year)
		about 0.8 km below North Fork
8/11/95	Visual	Age 0 (about 30) below North Fork
8/11/95	Visual	1 adult near rock bluff about 0.8 km below North Fork
7/20/95	Visual	1 adult near rock bluff about 0.8 km below North Fork
7/17/95	Angling	2 adults near rock bluff about 0.8 km below North Fork
6/29/95	Angling	1 adult just below North Fork
7/27/94	Visual	2 adults just below North Fork

Appendix 7. Arctic Grayling Marked in 2003

Tag Number	Color	Gear	Length (mm)	Date Captured	Site Captured
13418	Green	Fyke	347	6/10/03	North Fork
13417	Green	Fyke	374	6/10/03	North Fork
9185	Orange	Fyke	232	6/14/03	North Fork
9184	Orange	Fyke	305	6/14/03	North Fork
9183	Orange	Fyke	275	6/15/03	North Fork
9182	Orange	Fyke	275	6/15/03	North Fork
9181	Orange	Fyke	270	6/15/03	North Fork
9180	Orange	Fyke	284	6/15/03	North Fork
9179	Orange	Fyke	290	6/15/03	North Fork
9178	Orange	Fyke	279	6/15/03	North Fork
9177	Orange	Fyke	259	6/15/03	North Fork
9176	Orange	Fyke	234	6/15/03	North Fork
9175	Orange	Fyke	214	6/15/03	North Fork
9324	Orange	Fyke	221	6/15/03	North Fork
9323	Orange	Fyke	238	6/15/03	North Fork
9322	Orange	Fyke	210	6/15/03	North Fork
9321	Orange	Fyke	214	6/15/03	North Fork
9320	Orange	Fyke	211	6/15/03	North Fork
9319	Orange	Fyke	220	6/15/03	North Fork
9318	Orange	Fyke	226	6/15/03	North Fork
9337	Orange	Fyke	289	6/15/03	North Fork
9336	Orange	Fyke	293	6/15/03	North Fork
9335	Orange	Fyke	252	6/15/03	North Fork
9334	Orange	Fyke	298	6/15/03	North Fork
9333	Orange	Fyke	276	6/15/03	North Fork
9332	Orange	Fyke	269	6/15/03	North Fork
9331	Orange	Fyke	232	6/15/03	North Fork
9397	Orange	Fyke	312	6/15/03	North Fork
9396	Orange	Fyke	312	6/15/03	North Fork
9395	Orange	Fyke	282	6/15/03	North Fork
9394	Orange	Fyke	270	6/15/03	North Fork
9393	Orange	Fyke	218	6/15/03	North Fork
9392	Orange	Fyke	198	6/15/03	North Fork

Appendix 7, continued.

Tag Number	Color	Gear	Length (mm)	Date Captured	Site Captured
9391	Orange	Fyke	333	6/16/03	North Fork
9390	Orange	Fyke	273	6/16/03	North Fork
9389	Orange	Fyke	322	6/16/03	North Fork
9388	Orange	Fyke	298	6/16/03	North Fork
9387	Orange	Fyke	288	6/16/03	North Fork
9386	Orange	Fyke	279	6/16/03	North Fork
9385	Orange	Fyke	272	6/16/03	North Fork
9384	Orange	Fyke	286	6/16/03	North Fork
9383	Orange	Fyke	288	6/16/03	North Fork
9382	Orange	Fyke	260	6/16/03	North Fork
9381	Orange	Fyke	238	6/16/03	North Fork
9380	Orange	Fyke	273	6/16/03	North Fork
9379	Orange	Fyke	245	6/16/03	North Fork
9378	Orange	Fyke	264	6/16/03	North Fork
9377	Orange	Fyke	251	6/16/03	North Fork
9376	Orange	Fyke	260	6/16/03	North Fork
9375	Orange	Fyke	264	6/16/03	North Fork
9724	Orange	Fyke	236	6/16/03	North Fork
9723	Orange	Fyke	210	6/16/03	North Fork
9722	Orange	Fyke	221	6/16/03	North Fork
9721	Orange	Fyke	209	6/16/03	North Fork
9720	Orange	Fyke	224	6/16/03	North Fork
9719	Orange	Fyke	202	6/16/03	North Fork
9718	Orange	Fyke	211	6/16/03	North Fork
9717	Orange	Fyke	211	6/16/03	North Fork
9716	Orange	Fyke	212	6/16/03	North Fork
9715	Orange	Fyke	222	6/16/03	North Fork
9714	Orange	Fyke	222	6/16/03	North Fork
9799	Orange	Fyke	355	6/16/03	North Fork
9798	Orange	Fyke	330	6/16/03	North Fork
9797	Orange	Fyke	300	6/16/03	North Fork
9796	Orange	Fyke	290	6/16/03	North Fork
9795	Orange	Fyke	248	6/16/03	North Fork

Appendix 7, concluded.

Tag Number	Color	Gear	Length (mm)	Date Captured	Site Captured
9794	Orange	Fyke	306	6/16/03	North Fork
9793	Orange	Fyke	370	6/16/03	North Fork
9792	Orange	Fyke	364	6/16/03	North Fork
9791	Orange	Fyke	310	6/16/03	North Fork
9790	Orange	Fyke	301	6/16/03	North Fork
9789	Orange	Fyke	270	6/16/03	North Fork
9788	Orange	Fyke	297	6/16/03	North Fork
9787	Orange	Fyke	253	6/16/03	North Fork
9786	Orange	Fyke	282	6/16/03	North Fork
9785	Orange	Fyke	246	6/16/03	North Fork
9784	Orange	Fyke	208	6/16/03	North Fork
9783	Orange	Fyke	214	6/16/03	North Fork
9782	Orange	Fyke	292	6/17/03	North Fork
9781	Orange	Fyke	315	6/17/03	North Fork
9780	Orange	Fyke	270	6/17/03	North Fork
9779	Orange	Fyke	278	6/17/03	North Fork
9778	Orange	Fyke	318	6/17/03	North Fork
9777	Orange	Fyke	288	6/17/03	North Fork
9776	Orange	Fyke	289	6/17/03	North Fork
9775	Orange	Fyke	285	6/17/03	North Fork
27024	Gray	Fyke	245	6/17/03	North Fork
27023	Gray	Fyke	255	6/17/03	North Fork
27022	Gray	Fyke	247	6/17/03	North Fork
27021	Gray	Fyke	236	6/17/03	North Fork
27020	Gray	Fyke	235	6/17/03	North Fork
27019	Gray	Fyke	230	6/17/03	North Fork