Technical Report No. 03-03

Aquatic Biomonitoring At Red Dog Mine, 2002

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

by **Alvin G. Ott**
Phyllis Weber Scannell

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

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Juneau, AK

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Acknowledgements

We thank TeckCominco Alaska Inc. for the financial and logistical support that allowed us to conduct this biomonitoring project. In particular, we acknowledge the support of Mr. Jim Kulas, Mr. Mark Thompson, Mr. Wayne Hall, Mr. John Martinisko, and Mr. Austin Swan of TeckCominco Alaska. We also thank personnel at ADF&G for their help: Mr. Al Townsend and Ms. Laura Jacobs assisted with both laboratory analysis and field work; Ms. April Behr and Mr. Shannon Spring sorted invertebrate samples and Mr. Fred DeCicco conducted aerial surveys of adult fish, collected adult Dolly Varden, and helped prepare tissues for metals analysis. Ms. Lisa Ingalls and Ms. Behr provided extensive editing to bring the report to final form; however, any errors remain the responsibility of the authors. The University of Alaska, Cooperative Fish and Wildlife Research Unit allowed us to use their laboratory facilities for chlorophyll analysis.

Executive Summary

The following tables compare results of invertebrate, periphyton, and fish sampling at each of the NPDES-monitored sites in 2002 with results from combined data from 1999 through 2001. The NPDES permit has been in effect since 1999. Refer to the Results section for graphical presentation and discussion of data.

Station 9, Ikalukrok Creek upstream of Red Dog Creek

	Metric	**Comparison of 2002 to previous years**
Water Quality		Metals lower in 2002
Invertebrate Populations	Density, #/m^3 water	Highest in 2001, lower in 1999 and 2000.
	Abundance, #/net	Similar or higher in 2002.
	Total taxa	Similar all years.
Periphyton	mg Chlor *a*/m^2	Lower in 2002/
Arctic grayling		Low numbers adults and juveniles, all years.
Juvenile Dolly Varden Populations		2002 higher than 2000 and 2001, lower than in 1999.
Larval Arctic grayling		Found in 1999 and 2000.

Station 8, Ikalukrok Creek downstream of Red Dog Creek

	Metric	**Comparison of 2002 to previous years**
Water Quality		Metals lower in 2002
Invertebrate Populations	Density, #/m^3 water	2002 higher than 1999 and 2000, lower than 2001.
	Abundance, #/net	2002 higher than 1999 and 2000, lower than 2001.
	Total taxa	Similar all years.
Periphyton	mg Chlor *a*/m^2	Highest in 2002.
Arctic grayling s		Low numbers adults and juveniles, all years, limited spawning.
Juvenile Dolly Varden populations		2002 higher than 2000 and 2001, lower than in 1999.
Larval Arctic grayling		Found in 2000 and 2002.

Ikalukrok Creek upstream of Dudd Creek

	Metric	**Comparison of 2002 to previous years**
Water Quality		Metals low all years
Invertebrate Populations	Density, #/m^3 water	Low in 2002.
	Abundance, #/net	Low in 2002.
	Total taxa	Similar all years.
Periphyton	mg Chlor *a*/m^2	Low in 2002.
Arctic grayling		Rearing, migration, limited spawning.
Juvenile Dolly Varden		2002 higher than 2001, lower than in 1999 and 2000..
Larval Arctic grayling		Found in 2000 and 2002.

Station 7, Ikalukrok Creek downstream of Dudd Creek

	Metric	**Comparison of 2002 to previous years**
Water Quality		TDS less than 500 mg/L in 2002, metals low all years.
Invertebrate Populations	Density, #/m^3 water	Low in 2002.
	Abundance, #/net	Low in 2002.
	Total taxa	Low in 2001, similar other years.
Periphyton	mg Chlor *a*/m^2	Low in 2002.
Arctic grayling		Rearing, migration, limited spawning.
Juvenile Dolly Varden		2002 numbers higher than 2001, lower than 1999 and 2000.
Larval Arctic grayling		Found in 2000 and 2002.

Station 10, Mainstem Red Dog Creek

	Metric	Comparison of 2002 to previous years
Water Quality		Metals lower in 2002
Invertebrate Populations	Density, #/m^3 water	Density high in 2002.
	Abundance, #/net	Low in 2002.
	Total taxa	Similar all years.
Periphyton	mg Chlor *a*/m^2	High in 2002.
Arctic grayling Populations		Spawning and summer rearing all years.
Juvenile Dolly Varden		2002 similar to 2000 and 2001, lower then 1999.
Larval Arctic grayling		Found in 1999 and 2000.

Station 20, Middle Fork Red Dog Creek

	Metric	Comparison of 2002 to previous years
Water Quality		Metals similar 1999 through 2002
Invertebrate Populations	Density, #/m^3 water	Highest in 2002.
	Abundance, #/net	2002 similar to 1999 and 2000, lower than 2001.
	Total taxa	Similar all years.
Periphyton	mg Chlor *a*/m^2	Low all years.
Arctic grayling		No fish present*.
Juvenile Dolly Varden		No fish present*.
Larval Arctic grayling		No fish present*.

*At request of ADF&G, a fish weir was installed in 1997 to exclude fish.

Station 12, North Fork Red Dog Creek

	Metric	**Comparison of 2002 to previous years**
Water Quality		Metals low all years.
Invertebrate Populations	Density, #/m^3 water	Similar all years.
	Abundance, #/net	Lowest in 2002.
	Total taxa	Highest in 2001 and 2002.
Periphyton	mg Chlor *a*/m^2	2002 similar all years.
Arctic grayling		Successful spawning all years.
Juvenile Dolly Varden		Low all years.
Larval Arctic grayling		Found in 1999, 2000, and 2001.

Fish Populations in Wulik River

	Comparison of 2002 counts to previous years.
Chum Salmon spawning populations	Numbers similar in 1999, 2001 and 2002.
Adult Dolly Varden overwintering population	Numbers lower in 2002 than in 1999 and 2001. Highest proportion of fish found in Wulik River downstream of Ikalukrok Creek, all years.

Note: No surveys were done in 2000 because of poor weather conditions.

Wulik River: Metals Concentrations in Dolly Varden Tissues.

Tissue	**Analyte**	**Comparison of median concentrations of metals in tissues in 2002 to previous years**
Gills	Al	Low in Spring, 2002, highest in Fall, 2002.
	Cd	Low in Spring, high in Fall, all years.
	Cu	Low except Spring 2000.
	Pb	Highest in Fall, 2002, low in Spring 2002.
	Se	Higher in Fall than Spring, all years.
	Zn	Similar all years.
Kidney	Al	Low in 2002.
	Cd	Similar all years.
	Cu	Low all years except Spring 2000.
	Pb	Low all years.
	Se	Low all years.
	Zn	Similar all years.
Muscle	Al	Lowest in 2002.
	Cd	Low all years.
	Cu	Low all years.
	Pb	Low all years.
	Se	Low all years.
	Zn	Similar all years.
Liver	Al	Similar all years.
	Cd	Similar all years.
	Cu	Higher in Spring than Fall, all years.
	Pb	Low all years.
	Se	Low all years.
	Zn	Similar all years.
Reproductive	Al	Low all years.
	Cu	Similar all years.
	Pb	Low all years.
	Se	Highest in Fall, 2002.
	Zn	Higher in Fall than Spring, all years.

INTRODUCTION

The Red Dog Zn and Pb deposit is located in northwest Alaska, approximately 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 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-003865-2 (NPDES Permit) to Teck-Cominco Alaska Inc. (Teck-Cominco) 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 Fish and Game (ADF&G) in 2001.

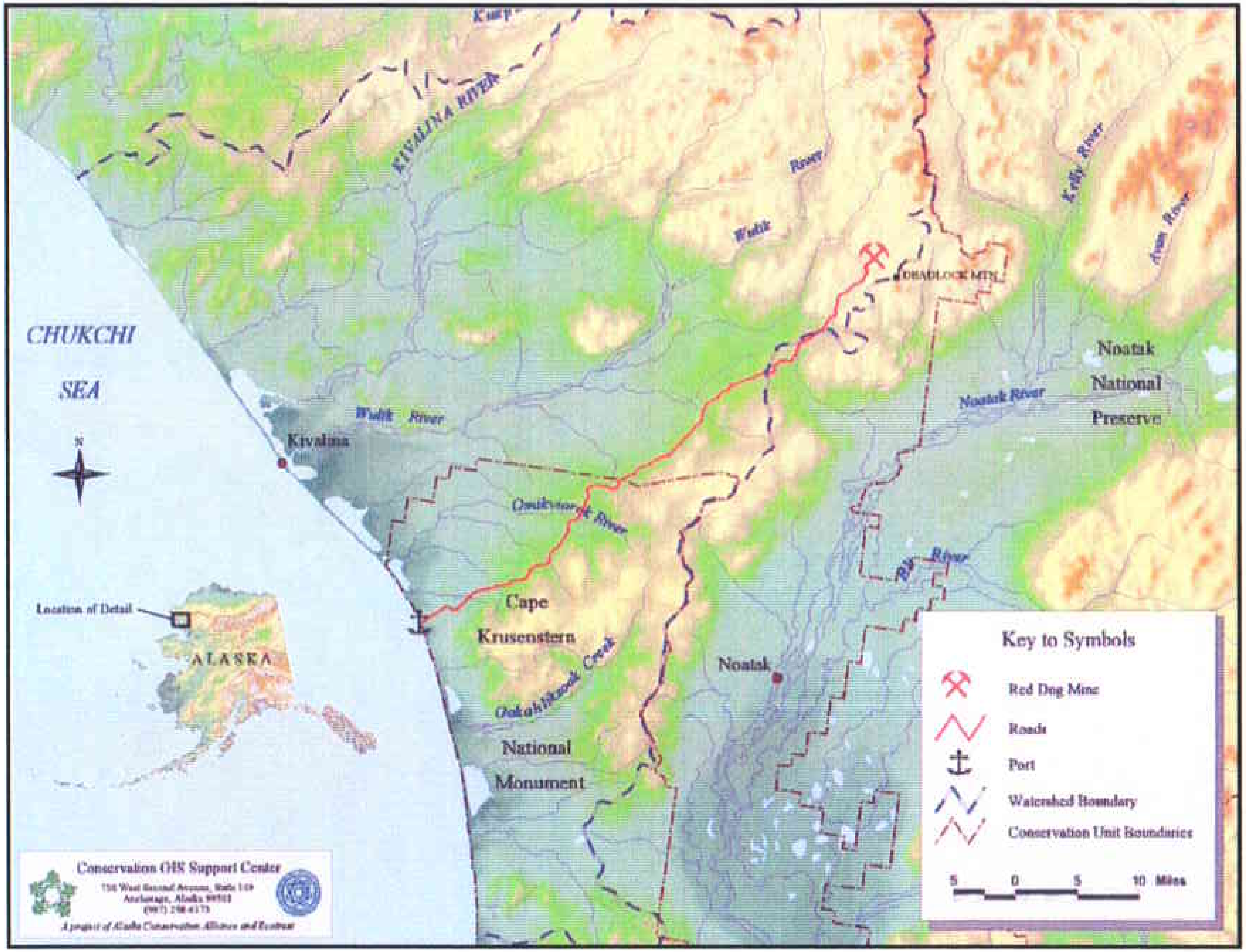


Figure 1. Location of the Red Dog Mine in northwest Alaska. Map used with permission of Conservation GIS Support Center, Anchorage, AK.

STRUCTURE OF THIS REPORT

Results of water quality monitoring, aquatic invertebrate sampling, and estimates of periphyton standing crop are given for each site for the years sampled (usually 1996–2001). Following presentation of these results is a table summarizing changes in biotic communities and water quality conditions between 2001 and previous monitoring years. Biomonitoring results for juvenile and adult fish are presented after discussions of the sample sites.

LOCATIONS 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 11, Figure 2). A description of the sites included in this study followed by the station number is listed below.

Table 1. Locations of Sample Sites for NPDES biomonitoring.

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

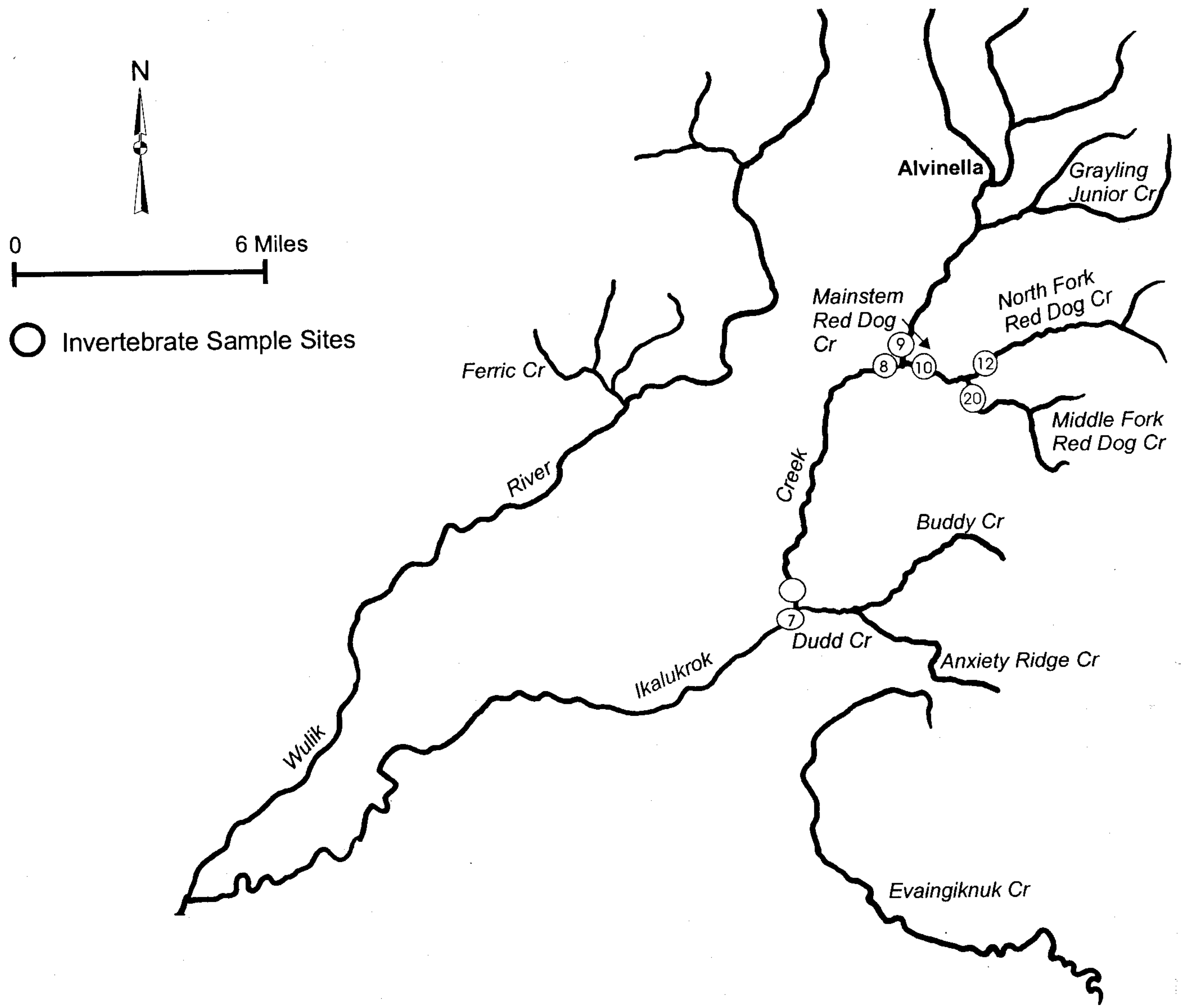


Figure 2. Locations of sites in the Red Dog Creek drainage for aquatic sampling.

DESCRIPTION OF STREAMS

All of the streams in this study are in the Wulik River watershed, except Eviangiknuk Creek which is in the Noatak River watershed. Station numbers correspond to the numbers used by Dames and Moore (1983) during their baseline studies and the current water sampling program being conducted by Teck-Cominco. Water quality and fisheries data collected during baseline studies (1979–1982) represent pre-mining conditions because minimal disturbance had occurred in this drainage during that time. Each sample component and location listed in Table 12 is required in NPDES Permit No. AK-003865-2. ADF&G conducts additional sampling which is supplemental to the requirements under the NPDES Permit to further our understanding of the aquatic communities (Table 13).

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
Main Stem Red Dog Creek	Periphyton (as Chlorophyll *a* concentrations) Aquatic invertebrates: taxa richness and abundance Fish presence and use
Ikalukrok Creek, Stations 9, 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 of returning chum salmon
Wulik River	Metals concentrations in Dolly Varden gill, liver, muscle and kidney Fall aerial survey of overwintering Dolly Varden
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, near mouth	Collected juvenile fish for whole body concentrations of Cd, Pb and Zn Collected adult Arctic grayling, analyze liver and reproductive tissues for Se Determine fish movement with fyke net traps Mark-recapture Arctic grayling (1999-2001)
North Fork Red Dog Creek near headwaters	Presence of juvenile fish Collected juvenile fish for whole body concentrations of Cd, Pb and Zn
Main Stem Red Dog Creek	Collected juvenile fish for whole body concentrations of Cd, Pb, Se and Zn Determine fish movement with fyke net traps Mark-recapture Arctic grayling (1999-2001)
Ikalukrok Creek: Stations 9, 7; and upstream of Dudd Creek	Fish presence and use Mark-recapture Arctic grayling (1999-2001)
Ikalukrok Creek upstream of Red Dog Creek	Aerial surveys to determine distribution of adult Arctic grayling
Wulik River	Fish presence and use
Ferric Creek	Collected juvenile fish for whole body concentrations of Cd, Pb and Zn (1999)
Anxiety Ridge Creek	Collected juvenile fish for whole body concentrations of Cd, Pb and Zn
Evaingiknuk Creek	Fish presence and use
Buddy Creek	Fish presence and use Mark-recapture Arctic grayling (1999-2001)
Graying Creek Jr.	Mark-recapture Arctic grayling (2000-2001) Collected juvenile fish for whole body Concentrations of Cd, Pb, Se and Zn (2001)

METHODS USED FOR NPDES MONITORING

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 below, have been made to the methods specified by ADF&G (1998).

PERIPHYTON STANDING CROP

Objectives

Periphyton, or attached micro-algae, is sensitive to changes in water quality and is often used in monitoring studies to detect early changes in aquatic communities. The presence of periphyton in a stream system documents continued in situ productivity. Periphyton standing crop was monitored to detect changes to in situ productivity in receiving waters of the Red Dog Mine effluent. Reference sites were sampled to detect variations due to other factors, such as climate.

Modifications in 2001

In 2001 we acidified all chlorophyll samples with 0.1 ml 0.1 N hydrochloric acid to estimate concentrations of phaeophytin. Low phaeophytin concentrations demonstrate that periphyton samples were taken and preserved correctly to minimize decomposition of chlorophyll pigments and that the chlorophyll in the samples is from live algae. We compared results from all acidified samples (equal to chlorophyll *a* minus phaeophytin) to pre-acidified samples (chlorophyll *a* calculated with tri-chromatic equations and including phaeophytin.) There was no difference in amounts of chlorophyll determined before and after acidification (Wilcoxon rank Sum Test, $p = 0.486$). We concluded that periphyton samples had been adequately frozen and that chlorophyll pigments had not decomposed.

AQUATIC INVERTEBRATES: TAXA RICHNESS AND ABUNDANCE

Objectives

The invertebrate community was sampled below the Red Dog Mine effluent to document the continued biological integrity of these communities and to detect changes to in situ productivity. Reference sites were used to detect variations due to other factors, such as climate.

Modifications in 2001

In 2001 we used an invertebrate subsampler to more accurately divide samples. Analysis of sample partitions showed variability within subsamples to be within acceptable ranges (Chi-square test, $p=0.05$) and that subsamples were representative of each stream community. Quality control checks on invertebrate sorting (based on four samples) showed that less than 2% of the invertebrates were missed.

METALS CONCENTRATIONS IN DOLLY VARDEN TISSUES

Objective

Since 1990, ADF&G has sampled adult Dolly Varden from the Wulik River to determine concentrations of Al, Cd, Cu, Pb and Zn in muscle, gill, liver and kidney tissue. Beginning in 1997, tissue samples also were analyzed for Se. The objective of this sampling effort was to detect any changes in metals concentrations during operation of the Red Dog Mine. Fish tissue sampling is required by NPDES Permit No. AK-003865-2.

Modifications in 2001

No modifications were made to this sampling method in 2001.

FISH PRESENCE AND USE IN TRIBUTARY STREAMS

Objectives

Fish monitoring focused on the distribution and relative abundance of juvenile Dolly Varden and Arctic grayling downstream of the Red Dog Mine and in tributaries to waters potentially affected by the mine. Reference streams were monitored to detect annual variations in distribution and abundance that are independent of mine operation.

Modifications in 2001

No modifications were made to this sampling method in 2001.

Fall Aerial Survey of Overwintering Dolly Varden

Objective

ADF&G has conducted a fall survey of overwintering Dolly Varden in the Wulik River since 1979, except in 1983, 1985, 1986 and 1990 when weather limited visability. The objective of aerial surveys is to estimate the abundance and assess the distribution of overwintering adult Dolly in the Wulik River. Changes in the use of this river system (for example, relative proportion of fish upstream and downstream of Ikalukrok Creek) are documented.

Modifications in 2002

None.

Chum Salmon Spawning

Objectives

The abundance and distribution of adult chum salmon spawning in Ikalukrok Creek downstream of Dudd Creek are assessed using aerial surveys to document any changes in the use of this spawning area. These aerial surveys are conducted each fall unless poor weather conditions limit visibility and increase safety concerns.

Modifications in 2002

None.

Water Quality

Teck-Cominco samples for water quality and metals concentrations according to the methods specified under NPDES Permit AK-003865-2. Data are presented in this biomonitoring report to complement information on aquatic populations and to aid in identification of long-term trends.

Water quality monitoring has been conducted throughout the Wulik River drainage since 1979, 10 years before initial development of the Red Dog Mine; sampling is done at many of the same stations (using the same station numbers) as baseline monitoring conducted by Dames and Moore.

RESULTS AND DISCUSSION

Four segments of Ikalukrok Creek are monitored under the NPDES Permit: Ikalukrok Creek upstream of Red Dog Creek (Station 9), Ikalukrok Creek below the confluence with Red Dog Creek (Station 8) and Ikalukrok Creek above (no station number) and below Dudd Creek (Station 7). Two stations are monitored in Red Dog Creek. Station 10 near the mouth and Station 20 upstream of North Fork Red Dog Creek. Station 12 in North Fork Red Dog Creek is a control site. Detailed site descriptions, including average seasonal flows, channel morphology and baseline water quality conditions were presented in Weber Scannell et al. (2000).

Figure 3. Ikalukrok Creek at Station 160.

IKALUKROK CREEK AT STATION 9

Site Description

Station 9 is located in Ikalukrok Creek upstream of the confluence with Red Dog Creek and near the US Geological Survey gauging station (Figure 4). 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. All sampling was done in the right channel.

Figure 4. Ikalukrok Creek upstream of Red Dog Creek, Station 9.

Water Quality

The water quality at Station 9 is characterized as having moderate hardness (approximately 150 mg/L of $CaCO_3$) and relatively low sulfate concentrations during the ice-free season (median concentrations for each year range from 40 to 130 mg/L). The conductance ranged from 10 to 700 μS/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 an improvement in analytical methods since baseline data were collected, recent data is likely a better representation of water quality conditoins. Comparisons to baseline conditions are relative comparisons; i.e., the concentrations have generally increased or decreased during the NPDES monitoring period. Concentrations of Al (Figure 5) and Zn (Figure 11) were higher at Station 9 than reported during baseline. Concentrations of Cd (Figure 6) and Pb (Figure 9) were unchanged from baseline measurements. There are no baseline data for Ni, Se or Fe. Concentrations of Fe (Figure 7) and Se (Figure 10) were similar among all NPDES years and concentrations of Ni were lower in 2001 and 2002 than the previous two years (Figure 8). Water quality data for years between 1982 to 1983 and 1999 are presented in Weber Scannell and Ott (2002).

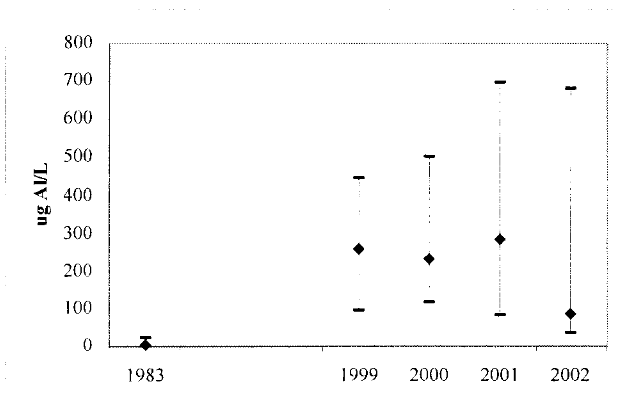


Figure 5. Median, maximum and minimum concentrations of Al at Station 9. Data from Teck-Cominco.

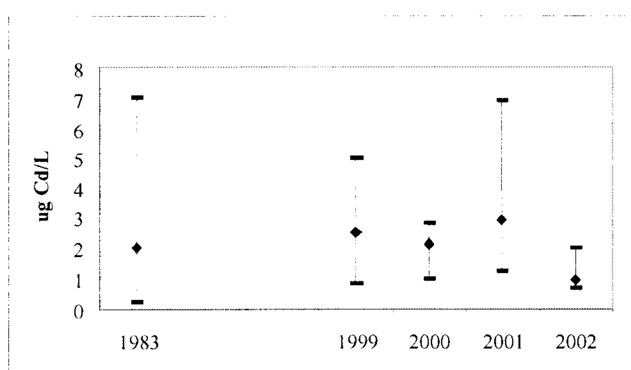


Figure 6. Median, maximum and minimum concentrations of Cd at Station 9. Data from Teck-Cominco.

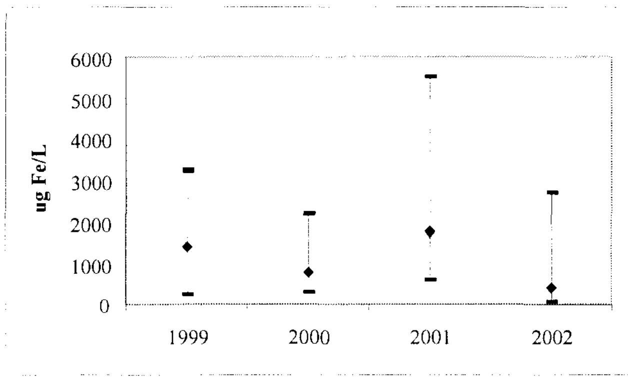


Figure 7. Median, maximum and minimum concentrations of Fe at Station 9. There were no baseline data for Fe. Data from Teck-Cominco.

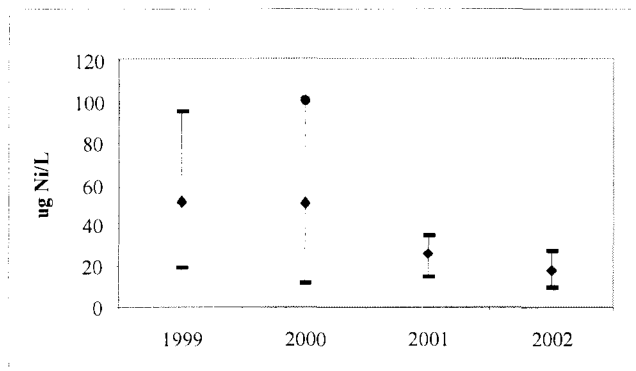


Figure 8. Median, maximum and minimum concentrations of Ni at Station 9. The circle represents a MDL, not a concentration. There were no baseline data for Ni. Data from Teck-Cominco.

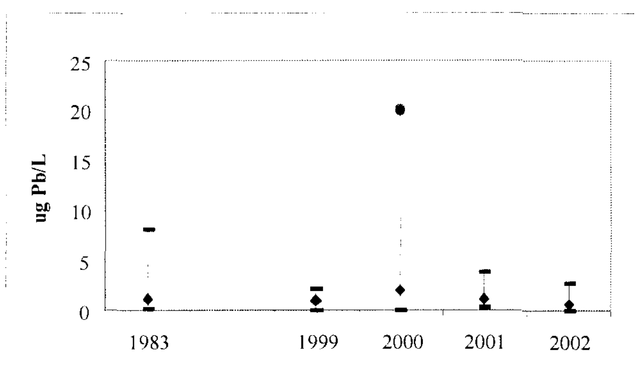


Figure 9. Median, maximum and minimum concentrations of Pb at Station 9 concentrations. The circle represents a MDL, not a concentration. Data from Teck-Cominco.

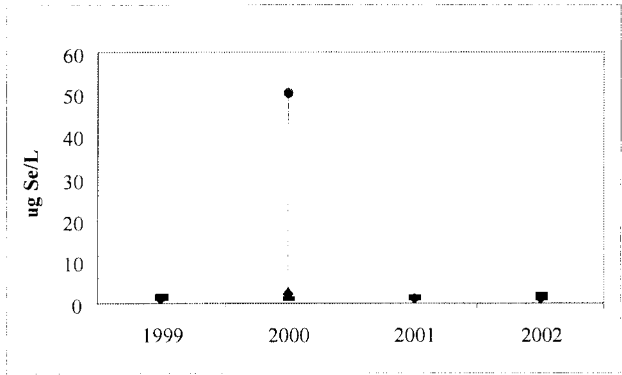


Figure 10. Median, maximum and minimum concentrations of Se at Station 9. The circle represents a MDL, not a concentration. There were no baseline data for Se. Data from Teck-Cominco.

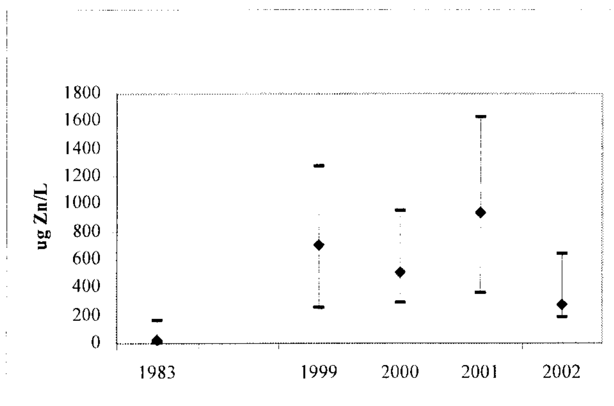


Figure 11. Median, maximum and minimum concentrations of Zn at Station 9 concentrations. Data from Teck-Cominco.

Invertebrate Community

Abundance, density and taxa richness

Both invertebrate abundance (average number of aquatic invertebrates per net) and densities (average number of aquatic invertebrates/m^3 of water) were highest in 2001. Invertebrate abundance and density in 2002 were similar to 1997 and 1998 (Figures 12 and 13).

The taxa richness, as total number of aquatic taxa collected during each sample period, was similar for all years, except 1996 when fewer taxa were found (Figure 14).

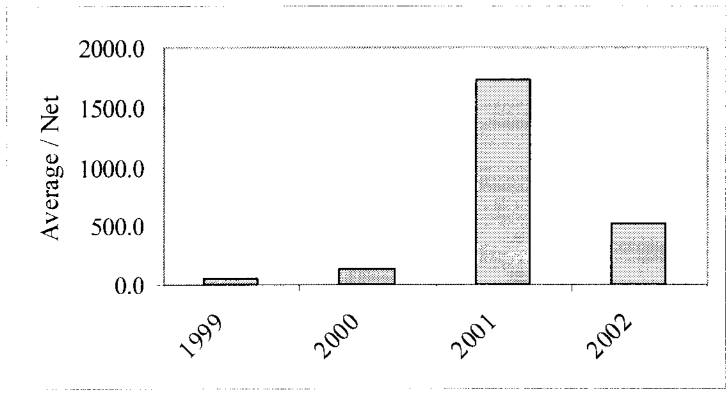


Figure 12. Abundance of aquatic invertebrates collected in Ikalukrok Creek at Station 9.

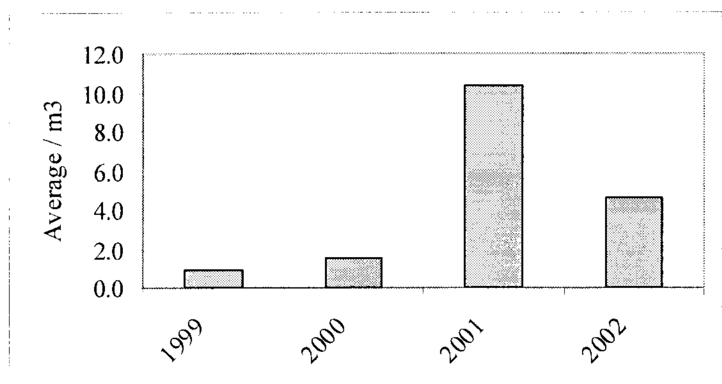


Figure 13. Density of aquatic invertebrates collected in Ikalukrok Creek at Station 9.

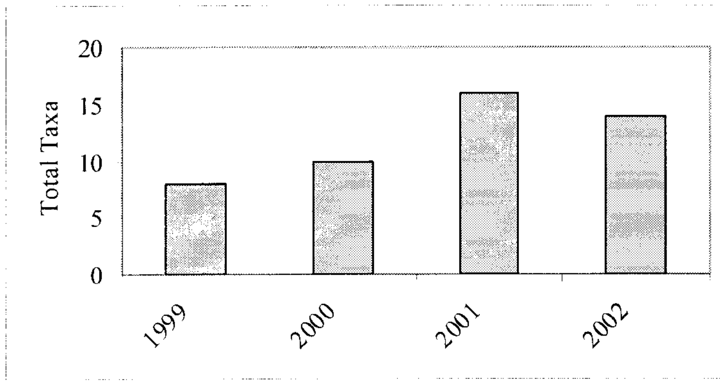


Figure 14. Taxa richness of aquatic invertebrates collected in Ikalukrok Creek at Station 9.

Community Structure

Invertebrate samples contained a high proportion of Ephemeroptera, Plecoptera and Trichoptera (EPT taxa) in all years, except 2001 when only 24% of samples were EPT (Figure 15). The abundance of EPT (mostly Ephemeroptera; Baetidae and Plecoptera: Capniidae) corresponded with their emergence; these taxa are especially abundant when they reach maturity and are ready to emerge as adults. Chironomidae larvae were the most frequently collected invertebrates in 2001 (Figure 15).

Aquatic Diptera were the predominant group in 1998 – 2002. The aquatic community at Station 9 is a diverse and complex community. During the period of NPDES monitoring (1996 – 2002), we have found a total of 25 distinct taxonomic groups, including 2 Ephemeroptera genera, 4 Plecoptera genera, 4 aquatic Diptera genera (plus the diverse family Chironomidae) and 7 Collembola genera. Miscellaneous Ostracoda, Nematoda, Oligachaeta, Acarii and aquatic Coleoptera were found. Trichoptera were absent in all years.

Larval Arctic grayling were found in aquatic nets in 1997, 1999 and 2000. The presence of larval Arctic grayling indicates that spawning has occurred in the vicinity of Station 9.

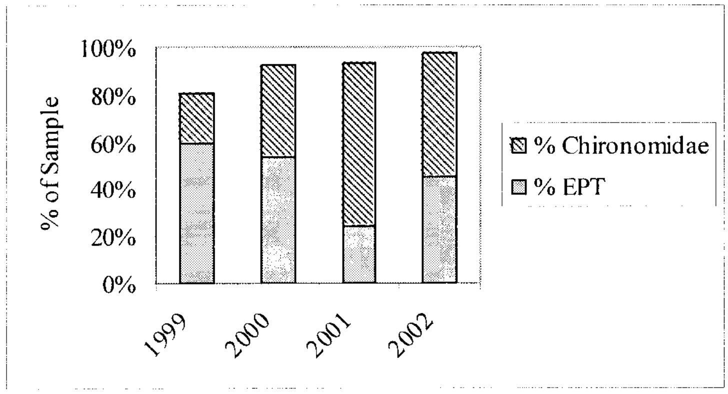


Figure 15. Relative proportions of EPT and Chironomidae larvae in invertebrate samples from Ikalukrok Creek at Station 9, 1996 – 2002.

Periphyton Standing Crop

Concentrations of chlorophyll *a* were higher in 2002 than in 2001 and similar to concentrations reported in 2000 (Figure 16). 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.

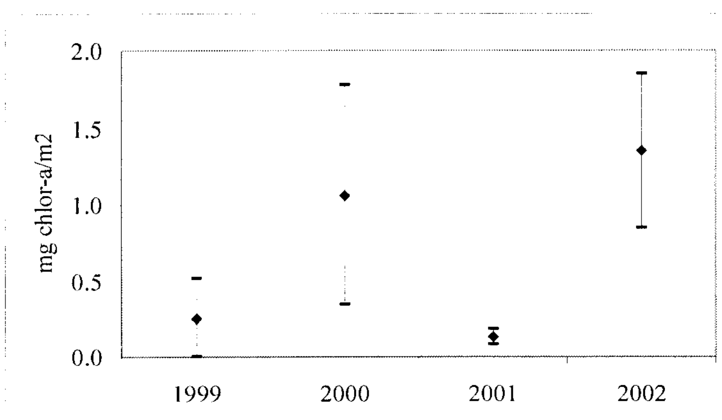


Figure 16. Average concentrations of chlorophyll *a*, plus and minus 1 standard deviation, in Ikalukrok Creek at Station 9.

Composition of Algal Communities

The algal community at Station 9 consists of a mixture of diatoms (Figure 17) with little indication of chlorophyll *b*, a pigment found in green algae, Chlorophyta and plants. In 2002, we found 1.35 06 mg/m^2 chlorophyll *a*, 0.001 mg/m^2 chlorophyll *b* and 0.07 mg/m^2 chlorophyll *c*.

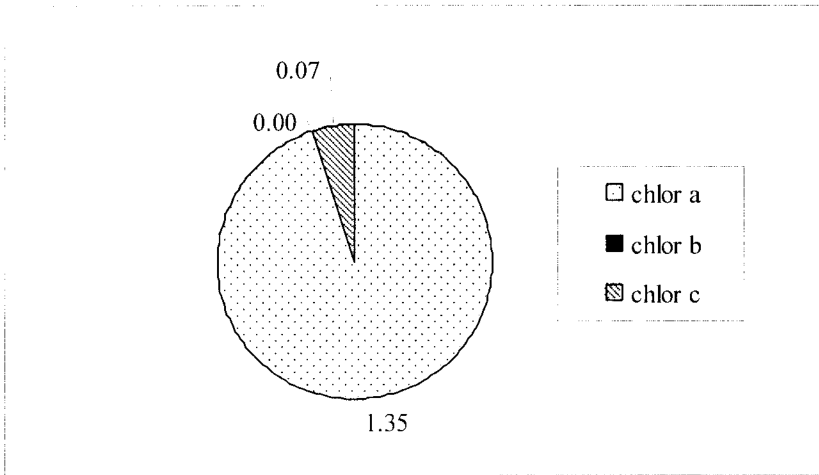


Figure 17. Proportions of chlorophyll *a*, b and c in Ikalukrok Creek at Station 9, 2002.

Summary of Biomonitoring

Changes in water quality, periphyton and the invertebrate community that have been documented over time are summarized in Table 4.

Table 4. Summary of biomonitoring, Station 9, 1996 through 2000.

Factor	Changes Observed
Water Quality	Higher Cd, Fe, Ni and Zn in 1996-2000; lower in 2002
Periphyton Communities	Concentrations were lowest in 2001; 2002 concentrations high, similar to 2000
Invertebrates Communities:	2002 Abundance similar to 1997 and 1998, higher than 1999 and 2000 Density lowest in 1999 and 2000, highest in 2001 No change in Taxa Richness since 1996
Larval Arctic grayling	Found in 1997, 1999 and 2000

IKALUKROK CREEK AT STATION 8

Site Description

Ikalukrok Creek below Red Dog Creek is a relatively fast flowing stream with medium sized gravel to small cobble substrate (Figure 18). 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 18. Ikalukrok Creek downstream of Red Dog Creek, Station 8.

Water Quality

Water samples have not been collected from this site in recent years because the water from Red Dog Creek and Ikalukrok Creek is not mixed.

Invertebrate Community

Abundance, density and taxa richness

Both density and abundance of aquatic invertebrates found in Ikalukrok Creek at Station 8 was highest in 1998 and 2001 and lowest in 1999 and 2000 (Figures 19 and 20). An average of 143 organisms per net and 1.3 organisms per m^3 of water was found in 2002. In 2002, we found a total of 13 distinct taxonomic groups, compared with 22 in 2001 (Figure 21).

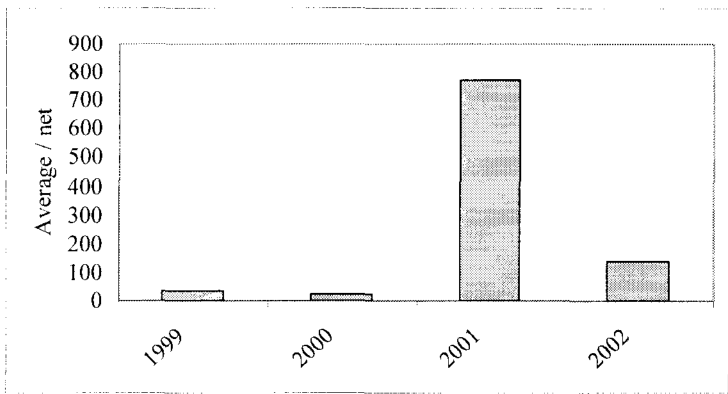


Figure 19. Abundance of aquatic invertebrates in Ikalukrok Creek at Station 8.

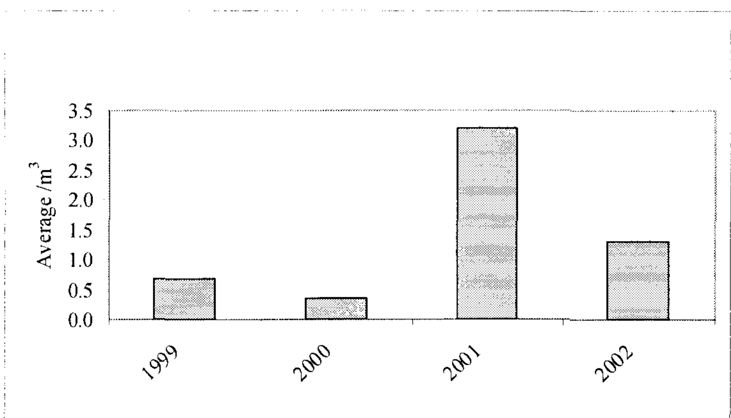


Figure 20. Density of aquatic invertebrates in Ikalukrok Creek at Station 8.

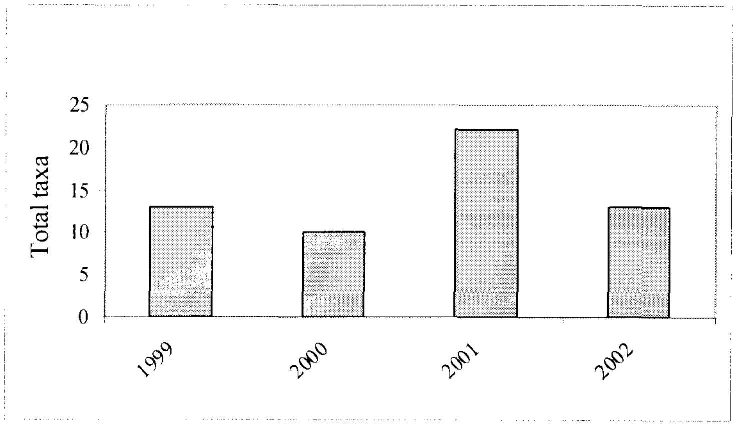


Figure 21. Taxa richness of the invertebrate community in Ikalukrok Creek at Station 8:

Community Structure

The invertebrate community contained a large proportion of EPT taxa in 1998 (71%) when the stonefly Capnia was mature and prevalent in drift samples. In other years, the proportion of EPT taxa was lower, with an overall average of 40% EPT and 40% Chironomidae (Figure 22).

The invertebrate community at Station 8 is dominated by Diptera: Chironomidae. During the period of NPDES sampling, we have found 30 distinct taxonomic groups with 2 genera of Ephemeroptera, 5 genera of Plecoptera, 6 genera of Collembola and 4 genera of Diptera, plus the family Chironomidae.

Larval Arctic grayling were found in samples collected in 1997, 2000 and 2002. The presence of larval Arctic grayling indicates that spawning has occurred in the vicinity of Station 8.

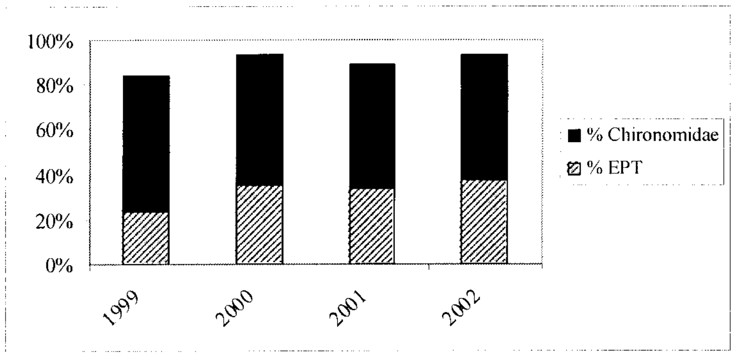


Figure 22. Proportion of EPT taxa and Chironomidae larvae in aquatic invertebrate samples collected in Ikalukrok Creek at Station 8.

Periphyton Standing Crop

The abundance of attached algae, estimated by chlorophyll-*a* concentrations, was highest in June 1999 when we measured an average of 7 mg chlorophyll *a* per m^2 of stream substrate (Figure 23). Median concentrations were similar in the other years sampled.

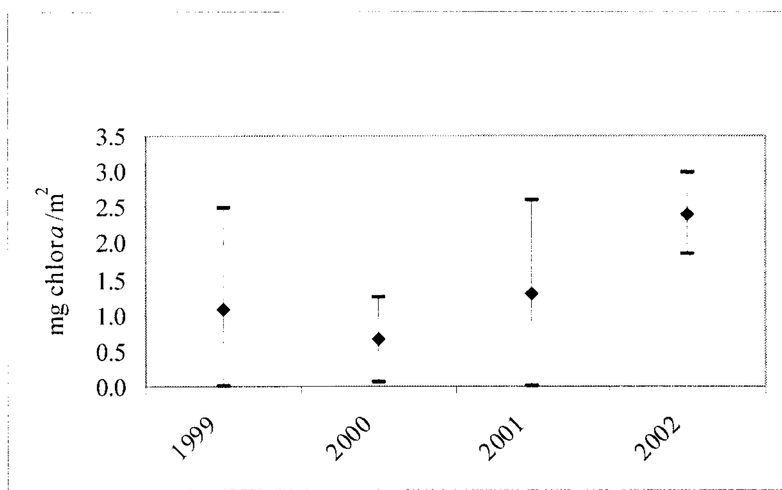


Figure 23. Concentrations of chlorophyll *a* in Ikalukrok Creek at Station 8.

Composition of Algal Communities

Of the 80 samples collected since 1995, only 26 had sufficient chlorophyll pigments to estimate amounts of chlorophylls *b* and *c*. 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* (Figure 24). The dominance of chlorophyll *c* over chlorophyll *b* suggests the importance of diatoms in the periphyton communities at Station 8.

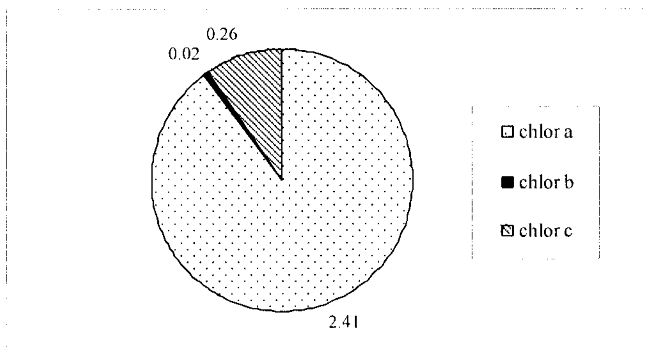


Figure 24. Proportions of chlorophyll *a*, *b* and *c* in Ikalukrok Creek at Station 8, 2002.

Summary of Biomonitoring

Changes in water quality, invertebrate and periphyton communities and fish populations documented over the biomonitoring period are summarized in Table 5.

Table 5. Summary of biomonitoring, Station 8, 1995-2000

Factor	Changes Observed
Water Quality	Ikalukrok Creek and Red Dog Creek not mixed, data unreliable
Concentration of Toxic elements	Ikalukrok Creek and Red Dog Creek not mixed, data unreliable
Invertebrate Community	Abundance highest in 2001, 2002 similar to 1997 and 1998
	Density highest in 2001, 2002 similar to 1997-98.
	Total of 30 distinct taxonomic groups found
Algal Communities	Chlorophyll *a* concentrations similar in all years except 1999
Larval Arctic grayling	Found in 1997, 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 25). The substrate contains mostly small cobble with medium-sized gravel. The banks are thickly vegetated with willows and herbaceous plants and grasses.

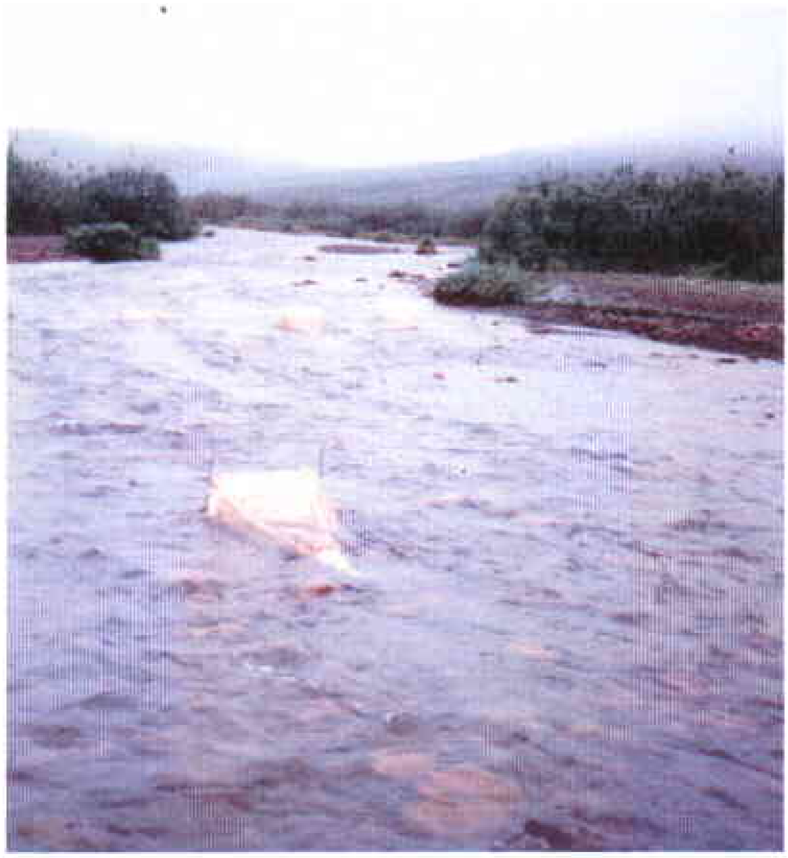


Figure 25. Ikalukrok Creek upstream of Dudd Creek.

Water Quality

Water is not sampled in Ikalukrok Creek upstream of Dudd Creek; however, samples collected upstream at Station 73 are a good representation of the water quality at this site.

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 (6.4) was in June 1998. The mine effluent influences water quality by increasing the hardness and concentrations of total dissolved solids (TDS) and sulfate. Metals concentrations are historically low at this site, compared to sites in Red Dog Creek (Weber Scannell et al. 2001). Concentrations of Al, Cd, Fe, Ni, Pb, Se and Zn in 2002 were among the lowest measured during the NPDES Permit period (Figures 26 through 32).

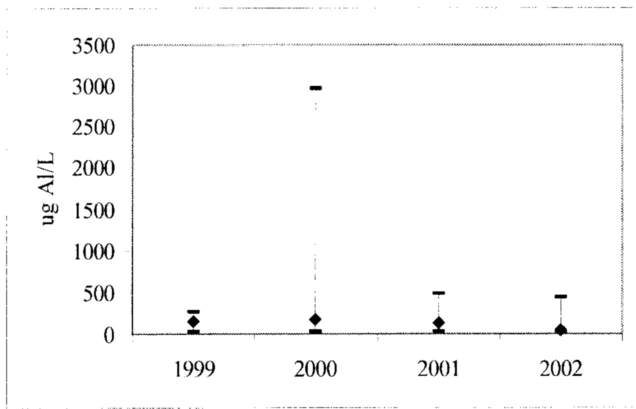


Figure 26. Median, maximum and minimum concentrations of Al in Ikalukrok Creek at Station 73. There were no baseline data for Al.

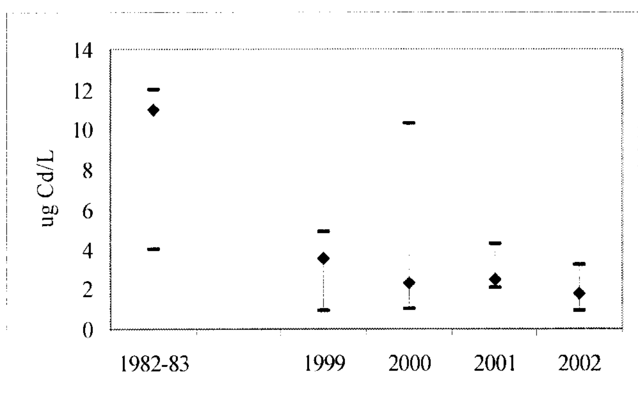


Figure 27. Median, maximum and minimum concentrations of Cd in Ikalukrok Creek at Station 73 compared to concentration measurements during baseline sampling. Data from Teck-Cominco.

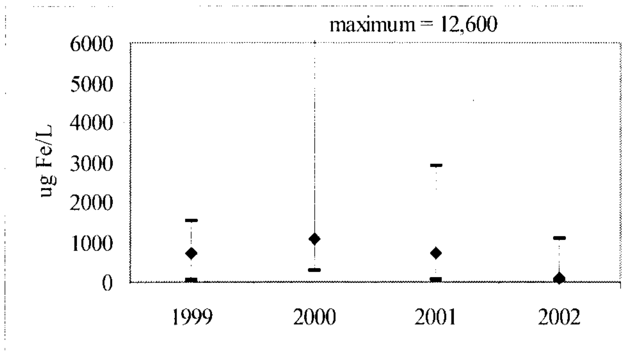


Figure 28. Median, maximum and minimum concentrations of Fe in Ikalukrok Creek at Station 73. Data from Teck-Cominco.

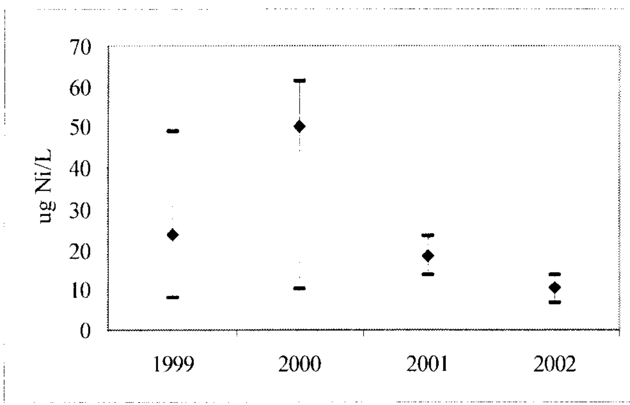


Figure 29. Median, maximum and minimum concentrations of Ni in Ikalukrok Creek at Station 73. Data from Teck-Cominco.

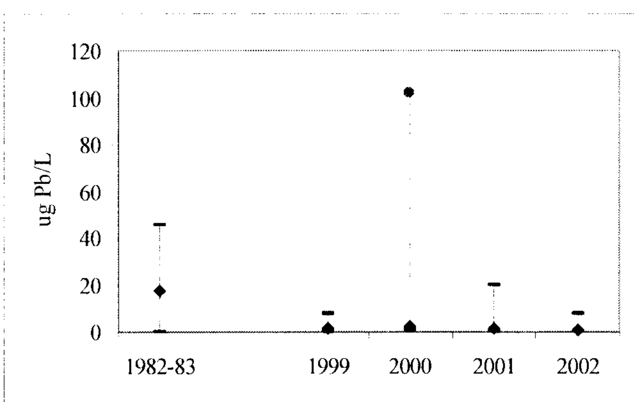


Figure 30. Median, maximum and minimum concentrations of Pb in Ikalukrok Creek upstream of Dudd Creek at Station. The circle represents the MDL. Data from Teck-Cominco.

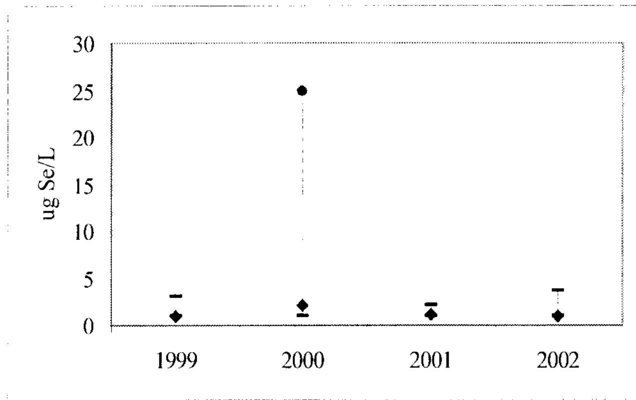


Figure 31. Median, maximum and minimum concentrations of Se in Ikalukrok Creek at Station 73. The circle represents the MDL. Data from Teck-Cominco.

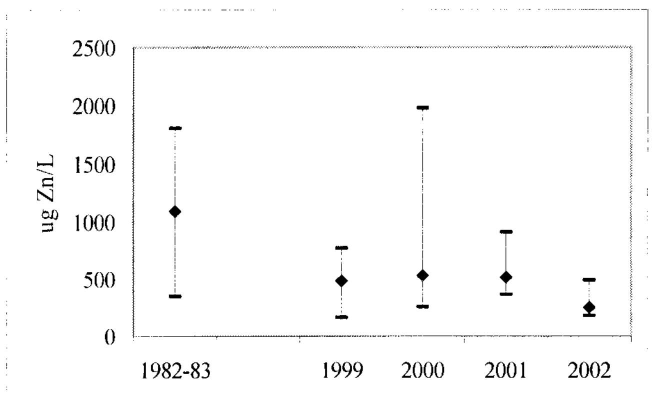


Figure 32. Median, maximum and minimum concentrations of Zn in Ikalukrok Creek at Station 73 compared to concentrations during baseline sampling. Data from Teck-Cominco.

Invertebrate Community

Abundance, Density and Taxa Richness

Invertebrate abundance gradually increased throughout 1999 and 2000, peaked in 2001 and declined substantially in 2002. Invertebrate density was very low in 1999, highest in 2000 and declined substantially in 2001 and 2002 (Figures 33 and 34).

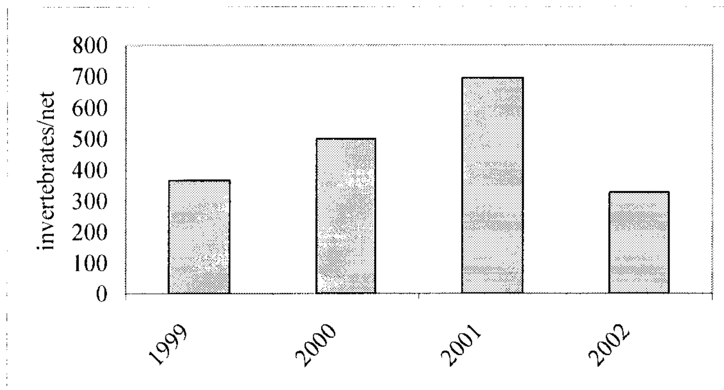


Figure 33. Abundance of aquatic invertebrates collected in Ikalukrok Creek upstream of Dudd Creek.

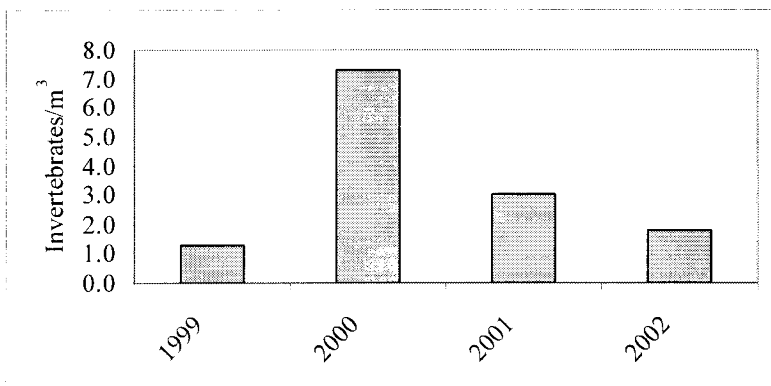


Figure 34. Density of aquatic invertebrates collected in Ikalukrok Creek upstream of Dudd Creek.

Taxa richness was similar during all sample periods except 1998 (Figure 35), when fewer taxa were found. Samples collected in 2002 contained 18 distinct taxa.

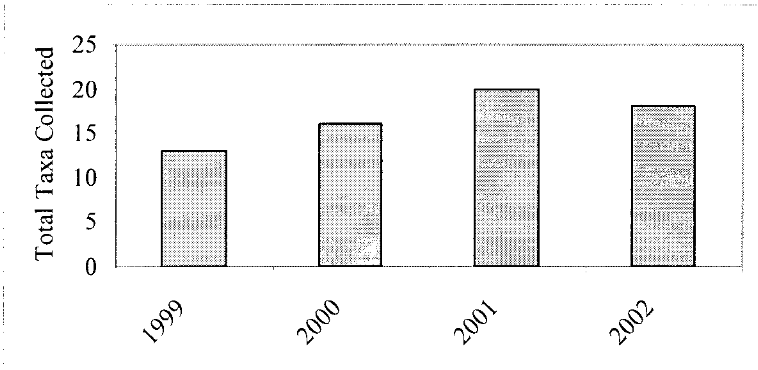


Figure 35. Taxa richness of invertebrate samples collected in Ikalukrok Creek upstream of Dudd Creek.

Community Structure

There was a low proportion of EPT taxa compared to the proportions of Chironomidae during four of the six years sampled (Figure 36). In 2002 the proportions of EPT and Chironomidae were low because of the high proportion of Simuliidae.

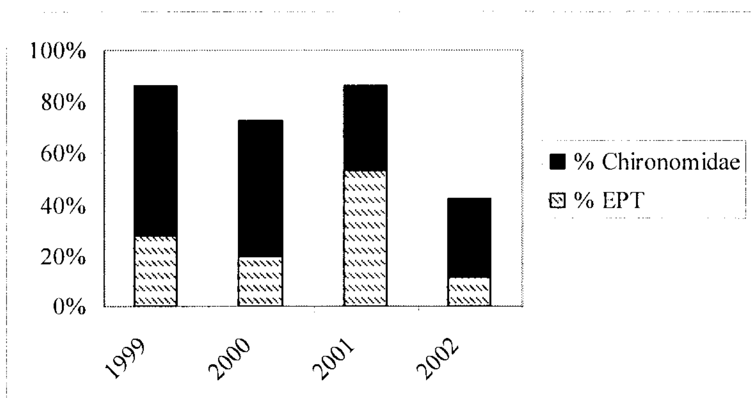


Figure 36. Proportions of EPT taxa and Chironomidae collected from Ikalukrok Creek upstream of Dudd Creek.

The invertebrate community in Ikalukrok Creek upstream of Dudd Creek is among the richest and most diverse of any of the sites. During the NPDES sampling period, we found 32 different taxonomic groups, including 2 Trichoptera families, 2 Ephemeroptera genera, 5 Plecoptera genera, 7 different Diptera genera plus Chironomidae and 7 different Collembola.

Larval Arctic grayling were found in drift nets in 1997, 2000 and 2002. The presence of larval Arctic grayling indicates that spawning has occurred in the vicinity of this site.

Periphyton Standing Crop

Periphyton was sampled from benthic substrates in Ikalukrok Creek upstream of Dudd Creek during the last week of June through the first week of July in 1999 through 2002. Median concentrations of periphyton were similar among all years sampled during the NPDES Permit period, except in 2002, when they were slightly lower (Figure 37). Differences among years is likely a result of stream flow and water temperatures; 2002 sampling was done after several high water events.

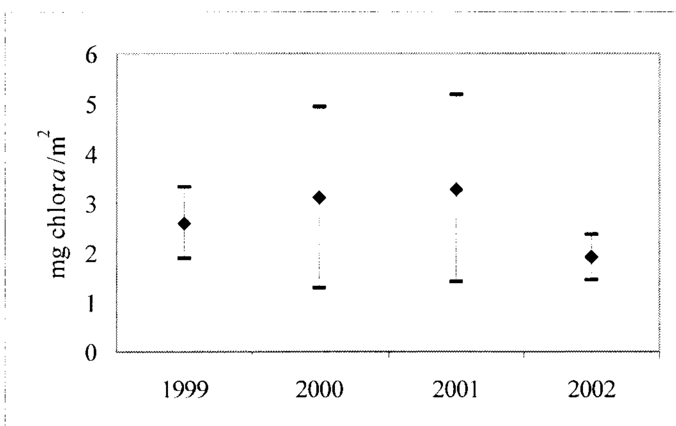


Figure 37. Median, maximum and minimum concentrations of chlorophyll *a* in Ikalukrok Creek upstream of Dudd Creek, 1997-2002.

Composition of Algal Communities

All periphyton samples collected in Ikalukrok Creek upstream of Dudd Creek contained sufficient concentrations of chlorophyll *a* to analyze with a spectrophotometer, allowing measurement of the three main pigments. In 2002 periphyton samples from this site contained more chlorophyll *c* (0.18 mg/m^2) than chlorophyll *b* (0.05 mg/m^2) (Figure 38).

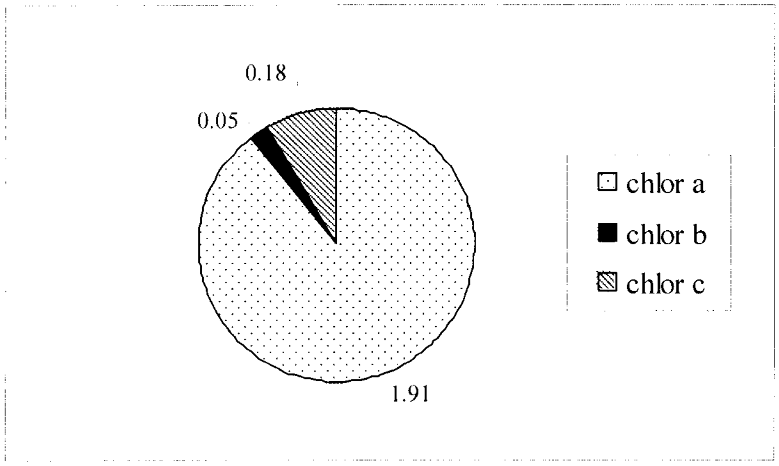


Figure 38. Proportions of chlorophyll *a*, *b* and *c* in Ikalukrok Creek upstream of Dudd Creek, 2002.

Summary of Biomonitoring

Changes in water quality, invertebrate and periphyton communities and fish populations documented over the biomonitoring period are summarized in Table 6.

Table 6. Summary of biomonitoring, Ikalukrok Creek upstream of Dudd Creek, 1996-2001.

Factor	Changes Observed
Concentrations of metallic elements	Concentrations of Al, Cd, Fe, Ni, Pb, Se and Zn low in 2002
Invertebrate Abundance	Both density and abundance low in 2002
Invertebrate Community	Trichoptera found in 1998, 1999 and 2001 50% EPT species in 2001 Abundance and richness highest in 2001
Algal Communities	Algal biomass lower in 2002 than in 2001
Larval Arctic grayling	Found in 1997, 2000 and 2002

IKALUKROK CREEK AT STATION 7

Site Description

Ikalukrok Creek below Dudd Creek (Station 7, Figure 39) has stream widths from approximately 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 lower flow rates. Ikalukrok Creek and Dudd Creek are not mixed at this sampling station; complete mixing of the two creeks does not occur until approximately 8 km downstream.

Figure 39. 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 Creek and Ikalukrok Creek and in a more stable area of the stream channel. Although Teck-Cominco Inc. has continued water quality sampling at Station 7 near the NPDES sampling 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 from 1999 through 2002 is presented in this report; earlier reports (e.g., Weber Scannell et al. 2002) present data from Station 7.

In 2002 the water at Station 160 had neutral pH (from 7.0 to 7.9, with a median value of 7.6). Concentrations of TDS are low in May before the mine begins discharging treated effluent (Figure 40) and increase during summer. TDS concentrations remained below 500 mg/L during the salmonid spawning period of
July 25 through October 31.

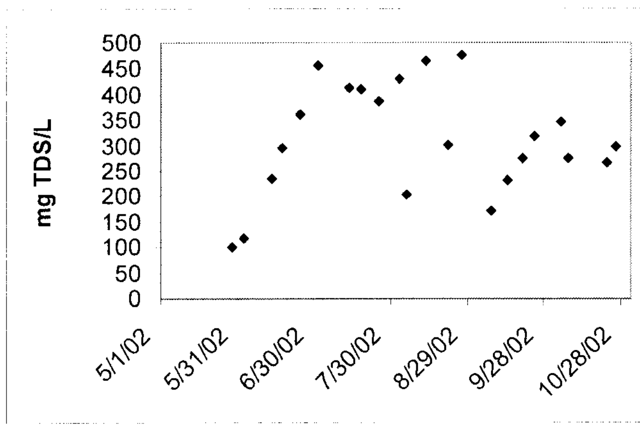


Figure 40. Seasonal variation in TDS concentrations at Station 160, 2002.

Consistent baseline sampling for heavy elements at Station 7 was limited to Cd, Pb and Zn. Concentrations of these three elements were low before development of the Red Dog Mine. Concentrations of Cd at Station 7 remained low after 1990 (Weber Scannell et al. 2002). Concentrations of Cd, Pb, and Zn at Station 160 in 2002 were lower than baseline concentrations (Figures 42, 44 and 46). There are no baseline data for Al, Ni, or Se; however, the median concentrations of these elements are similar among years (Figures 41, 43 and 45) except in 2000 when the MDLs were too high to make comparisons. The MDL for Se in 2000 was 50 µg/L for samples collected early in the summer: these samples cannot be compared with samples of lower detection limits (1-2 µg/L).

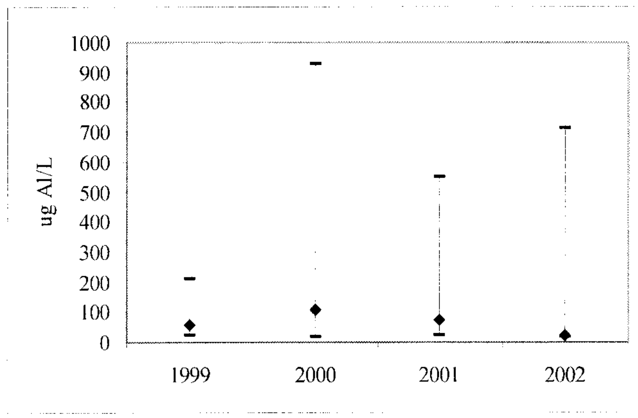


Figure 41. Median, maximum and minimum concentrations of Al at Station 160. There are no baseline data for Al at this site. Data from Teck-Cominco.

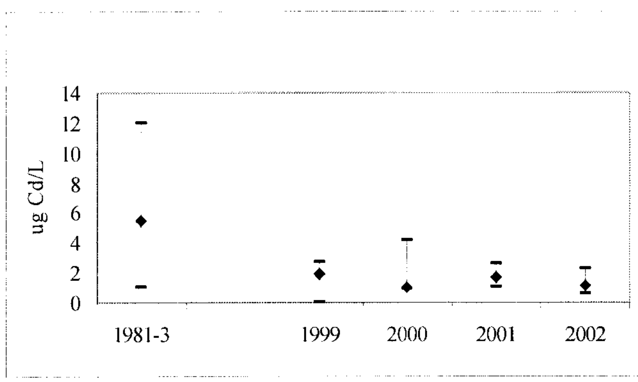


Figure 42. Median, maximum and minimum concentrations of Cd in Ikalukrok Creek, Station 160. Baseline data are from Station 7, below Dudd Creek. Data from Teck -Cominco.

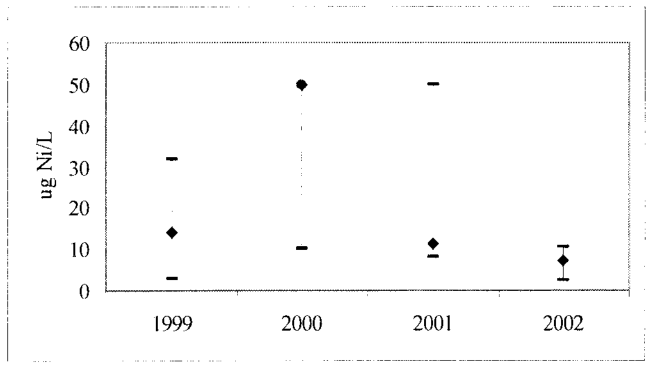


Figure 43. Median, maximum and minimum concentrations of Ni in Ikalukrok Creek, Station 160. Circle represents the MDL. Data from Teck -Cominco.

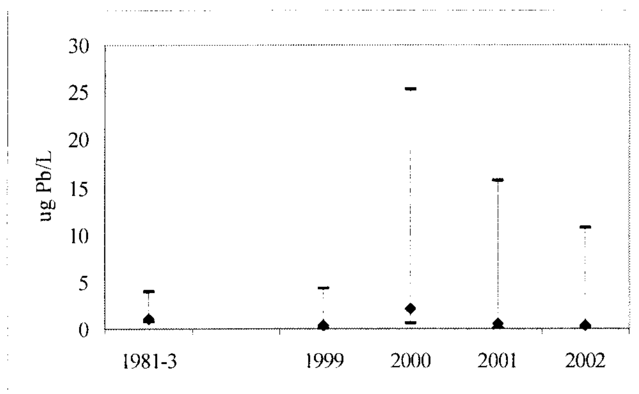


Figure 44. Median, maximum and minimum concentrations of Pb in Ikalukrok Creek, Station 160. Baseline data are from Station 7. Data from Teck -Cominco.

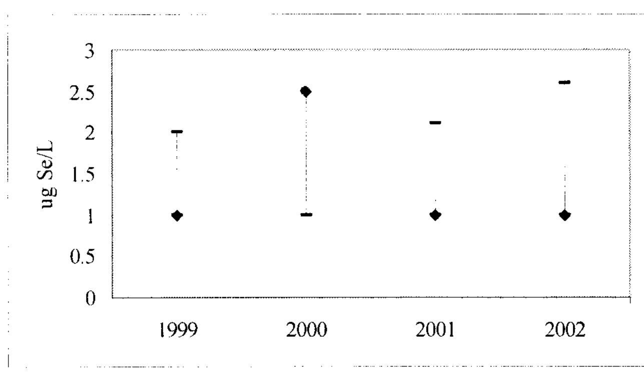


Figure 45. Median, maximum and minimum concentrations of Se in Ikalukrok Creek, Station 160. The circle represents the MDL. There are no baseline data for Se. Data from Teck -Cominco.

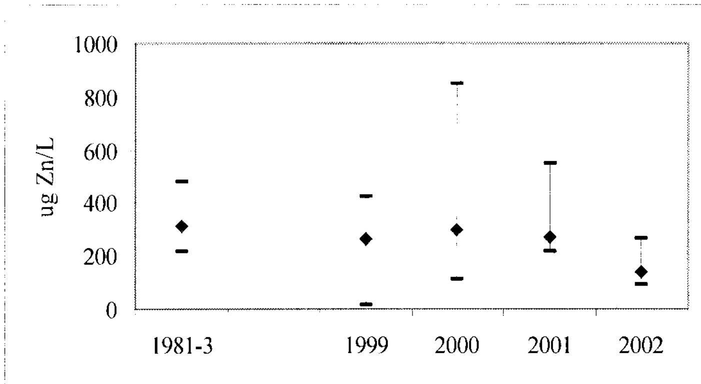


Figure 46. Median, maximum and minimum concentrations of Zn in Ikalukrok Creek, Station 160. Baseline data are from Station 7. Data from Teck -Cominco.

Invertebrate Community

Abundance, Density and Taxa Richness

Invertebrate abundance and density were lower in 2002 than in 2000 and 2001, but higher than in 1999 (Figures 47 and 48).

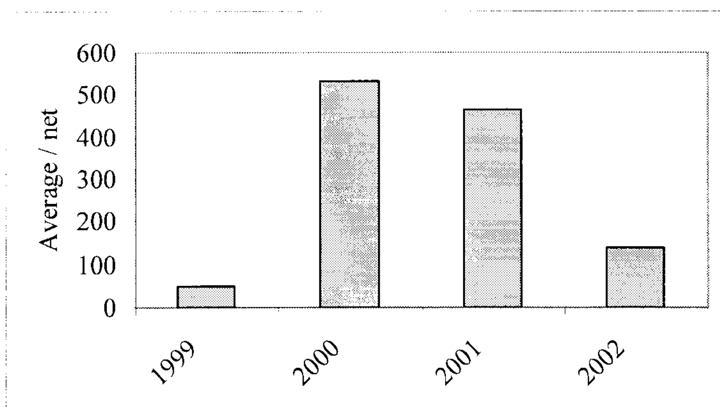


Figure 47. Abundance of aquatic invertebrates collected in Ikalukrok Creek, Station 7.

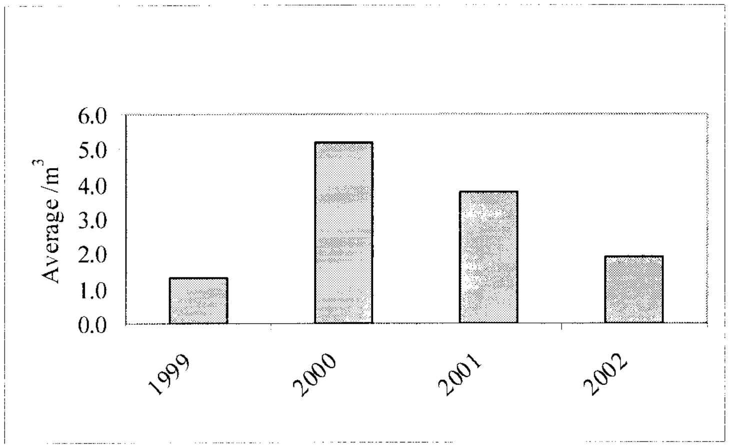


Figure 48. Density of aquatic invertebrates collected in Ikalukrok Creek, Station 7.

We identified 27 different aquatic taxa (usually to genus level) at Station 7 during the NPDES sampling period from 1996 through 2002. In 2002 (Figure 49) we found 10 distinct taxa, compared to 20 in 2001 samples.

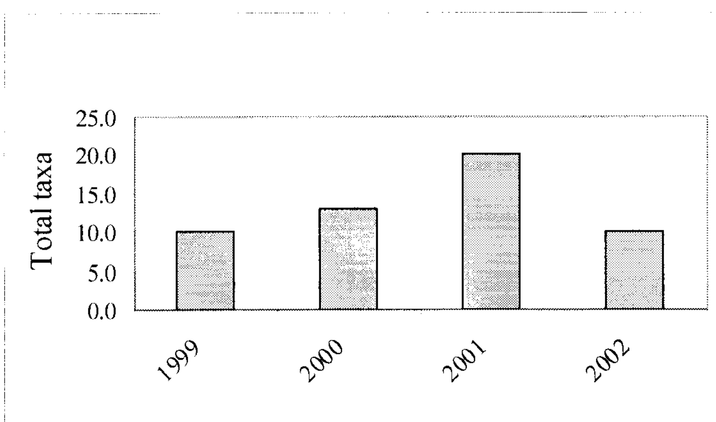


Figure 49. Total aquatic invertebrate taxa collected from Ikalukrok Creek, Station 7.

Structure of Community

In the 2002 invertebrate samples, only 17% of invertebrate samples were EPT taxa and 36% were larval Chironomidae (Figure 50). The dominant invertebrate family was Diptera: Simuliidae. Since 1996, we have found 27 different invertebrate taxa. Samples contained numerous taxa. Ephemeroptera: Heptageniidae (*Cinygmula*); Plecoptera: Capniidae (*Allocapnia),* Simuliidae (*Simulium)* and Acari (Acarina); Collembola: Isotomidae (*Axelsonia),* Onychiuridae (*Lophognathella) and* Sminthuridae (*Sminthurus)* were common in these samples. Although rare, two different families of Trichoptera were found.

Larval Arctic grayling were found in drift nets in 2000 and 2002.

Figure 50. Proportions of EPT and Chironomidae in samples from Station 7, Ikalukrok Creek.

Periphyton Standing Crop

Algal biomass, as estimated by chlorophyll *a* concentrations, was slightly lower in 2002 than in 2001; however, concentrations were similar to those in 1999 (Figure 51).

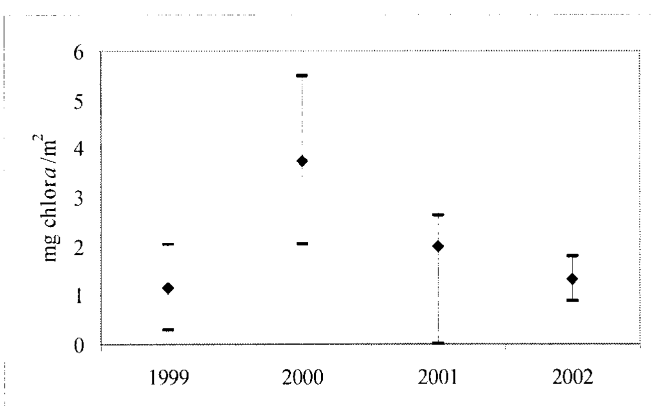


Figure 51. Median, maximum and minimum concentrations of chlorophyll *a* in Ikalukrok Creek, Station 7, 1996–2001.

Composition of Algal Communities

In 2002, periphyton samples from this site were mostly chlorophyll *a* (an average 1.32 mg/m^2), with 0.03 mg/m^2 chlorophyll *b* and 0.11 mg/m^2 chlorophyll *c* (Figure 52). The higher amounts of chlorophyll *c* (compared to chlorophyll *b*) suggest a community dominated by diatoms.

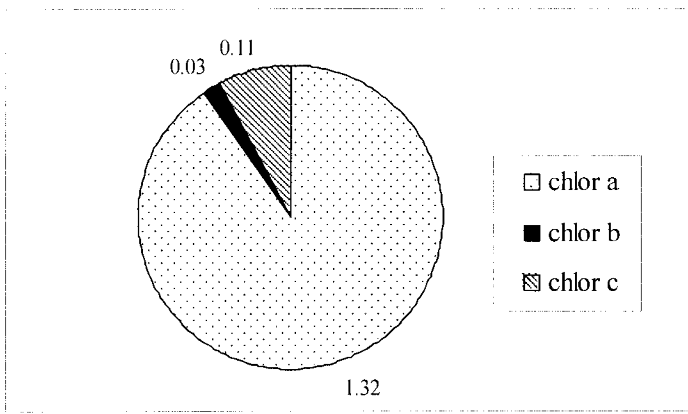


Figure 52. Proportion of concentrations of chlorophyll *a*, *b* and *c* in Ikalukrok Creek, Station 7, 1996–2001.

Summary of Biomonitoring

Changes in water quality, invertebrate and periphyton communities and fish populations documented over the biomonitoring period are summarized in Table 7.

Table 7. Summary of biomonitoring, Ikalukrok Creek at Station 7, 1996-2000.

Factor	Changes Observed
Water Quality	pH levels are unchanged
Concentrations of metallic elements	Median concentrations of Al, Cd, Pb and Zn remained low in 2001
Invertebrate Community	The abundance and taxa richness of aquatic invertebrates in 2002 was lower than in 2001. The percent of EPT taxa was lower in 2002 than in 2001.
Algal Communities	Concentrations of chlorophyll *a* in 2002 were similar to the previous year.
Larval Arctic grayling	Found in 2000 and 2002

MAIN STEM RED DOG CREEK AT STATION 10

Description of Site

The Main Stem 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 from 0.06 to 0.5 m. The streambed consists mostly of gravel, small cobble and small boulders. The creek has some meander and areas where it has shifted locations.

Figure 53. Main Stem Red Dog Creek, Station 10.

Water Quality

Median pH levels have ranged between 7.0 and 7.8 since 1991 (Figure 54). In 2001, pH ranged from 6.7 (in early June, during breakup flows) to 8.1 (in early August).

The volume of effluent from the mine controls concentrations of TDS in Main Stem Red Dog Creek. Concentrations of TDS are limited in Mainstem Red Dog Creek to less than 500 mg/L until Arctic grayling have completed spawning. ADF&G sets fyke nets in both

Red Dog Creek and the North Fork Red Dog Creek (Figure 55) in early spring (usually late May) to monitor Arctic grayling spawning. After spawning is complete, ADF&G authorizes Teck-Cominco to discharge higher volumes of water and TDS concentrations at Station 10 increase (Figure 56). During periods of no discharge from the mine, TDS in the creek quickly reaches background concentrations of 150 mg/L or less.

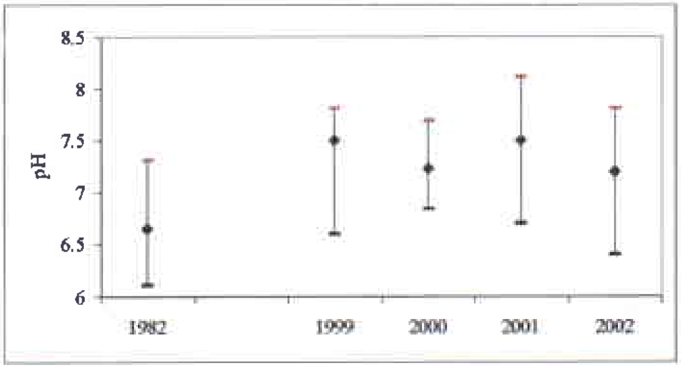


Figure 54. Median, maximum and minimum pH levels in Red Dog Creek at Station 10.

Figure 55. ADF&G monitors Arctic grayling spawning in Mainstem Red Dog Creek and North Fork Red Dog Creek (pictured).

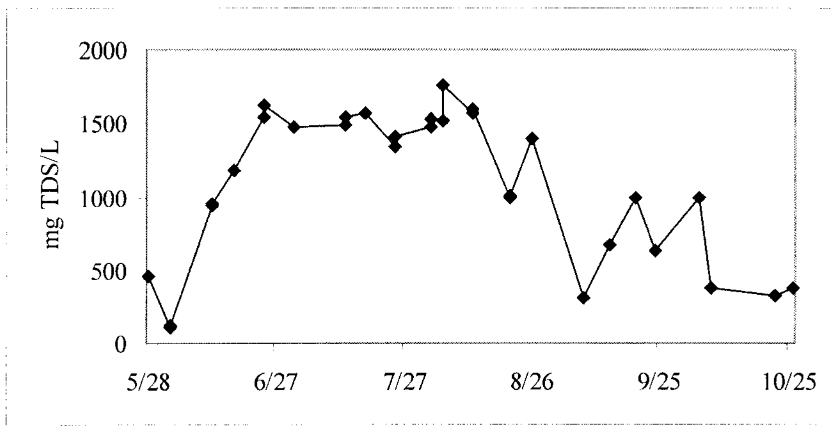


Figure 56. Seasonal variations in TDS concentrations in Red Dog Creek at Station 10, 2002.

Concentrations of all metals in Red Dog Creek at Station 10 were highest in 1989 and 1990, before construction of the clean water bypass and mine drainage collection system. In 2002, median concentrations of all metals were among the lowest reported since 1992 (Figures 57 through 62).

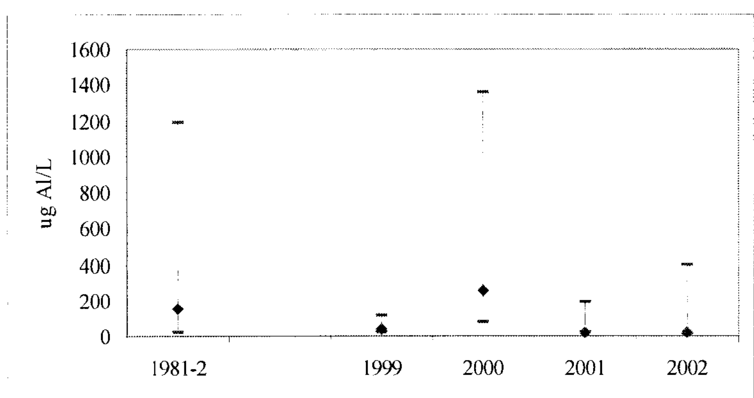


Figure 57. Median, maximum and minimum concentrations of Al in. Red Dog Creek at Station 10. Data from Teck-Cominco.

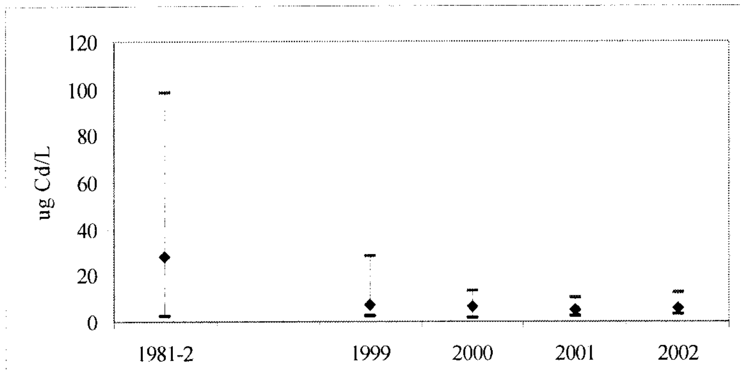


Figure 58. Median, maximum and minimum concentrations of Cd in Red Dog Creek at Station 10. Data from Teck-Cominco.

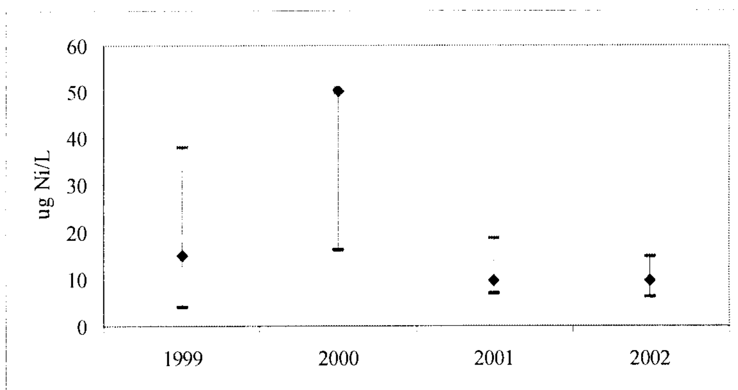


Figure 59. Median, maximum and minimum concentrations of Ni in Red Dog Creek at Station 10. The circle represents the MDL. Data from Teck-Cominco.

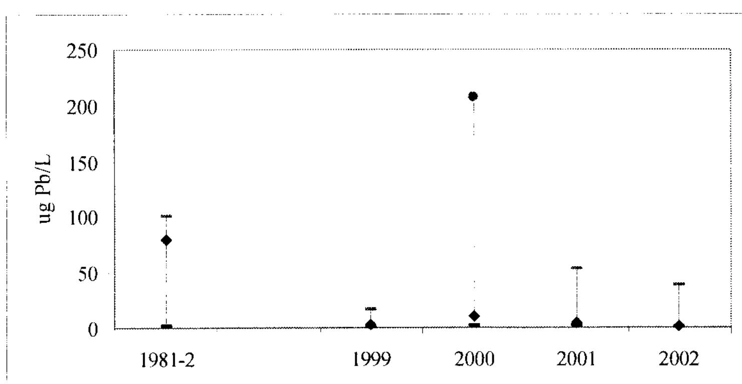


Figure 60. Median, maximum and minimum concentrations of Pb in Red Dog Creek at Station 10. The circlerepresents the MDL. Data from Teck-Cominco.

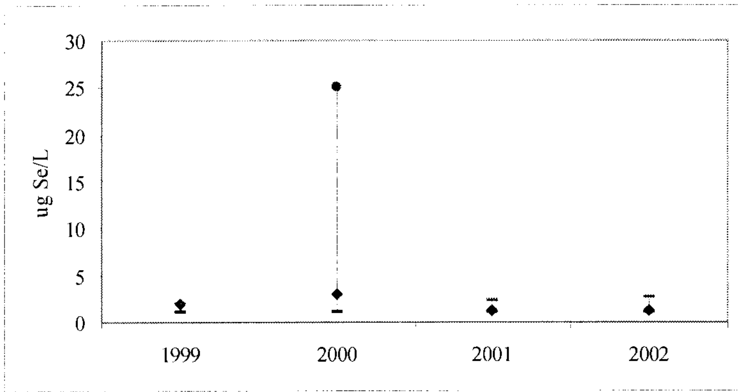


Figure 61. Median, maximum and minimum concentrations of Se in Red Dog Creek at Station 10. Data from Teck-Cominco.

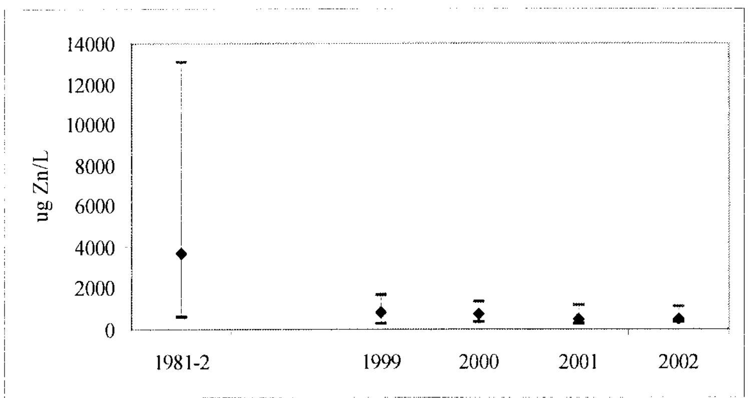


Figure 62. Median, maximum and minimum concentrations of Zn in Red Dog Creek at Station 10. Data from Teck-Cominco.

Invertebrate Community

Abundance, Density and Taxa Richness

In 2002, abundance of aquatic invertebrate populations was lower than in 2001 (Figure 63), but invertebrate density was similar (Figure 64). The difference between abundance and density in 2002 is likely due to lower volumes of water flowing through the nets. In 2002, we estimated an average of 50.9 m^3 water per net, and in 2001 the average per net was 264 m^3. Since invertebrate density is a function of water volume, the higher volumes in 2001 would result in lower densities. Taxonomic richness was higher in 2001 than any other year sampled during the NPDES Permit (Figure 65); taxonomic richness in 2002 was comparable to 1999 and 2000 levels.

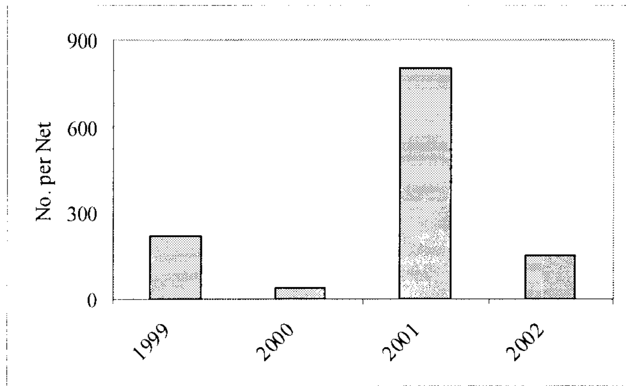


Figure 63. Abundance of aquatic invertebrates collected in Red Dog Creek at Station 10.

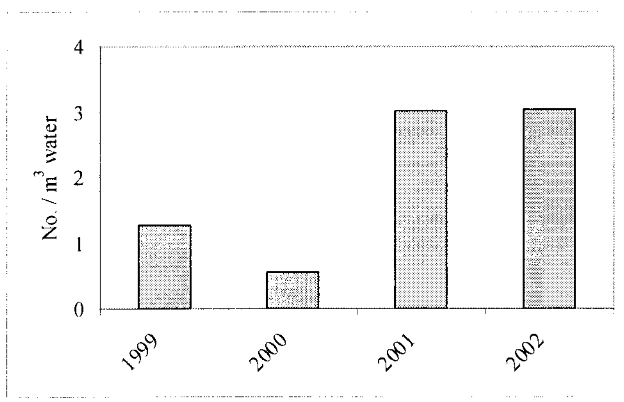


Figure 64. Density of aquatic invertebrates collected in Red Dog Creek at Station 10.

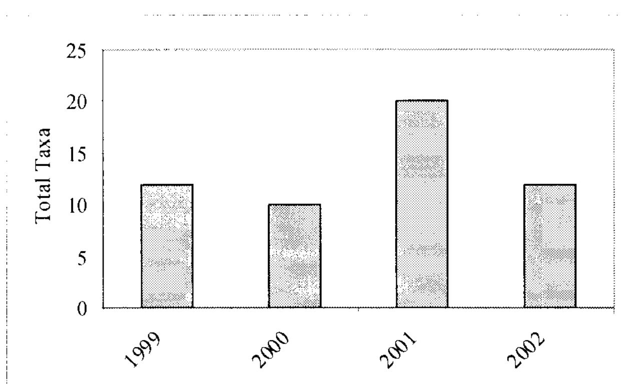


Figure 65. Taxa richness of invertebrate samples collected in Red Dog Creek at Station 10.

Community Structure

The proportions of EPT taxa fluctuate each year (Figure 66) and are likely influenced by timing of species emergence. In 2001, only 5% of invertebrate samples were EPT taxa, while 79% were Chironomidae larvae (Figure 40); in 2002, we found a slightly higher percentage of EPT taxa. The invertebrate community in Main Stem Red Dog Creek was dominated by Diptera in most years. Trichoptera, although rare, were most plentiful in samples collected in July 2000.

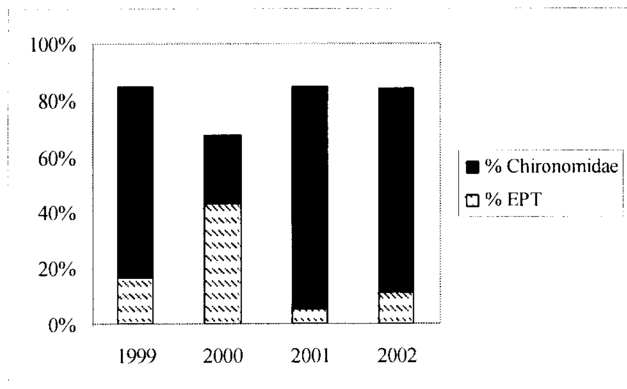


Figure 66. Percent EPT taxa and percent Chironomidae in Red Dog Creek at Station 10.

Periphyton Standing Crop

In 2002, the abundance of attached algae, estimated by chlorophyll *a* concentrations, was the highest measured during the NPDES Permit period and substantially higher than amounts found in 2000 (Figure 67).

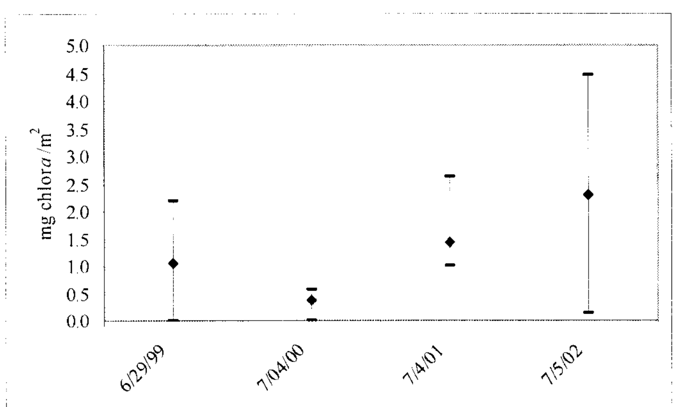


Figure 67. Concentrations of chlorophyll *a* in Red Dog Creek at Station 10.

Composition of Algal Communities

No measurable amounts of chlorophyll *b* or c were found in samples from Station 10 before 2001. In 2002, algal samples contained an average of 0.22 mg/m^2 of chlorophyll *c* and only 0.11 mg/m^2 chlorophyll *b*, indicating a diverse algal community dominated by diatoms (Figure 68).

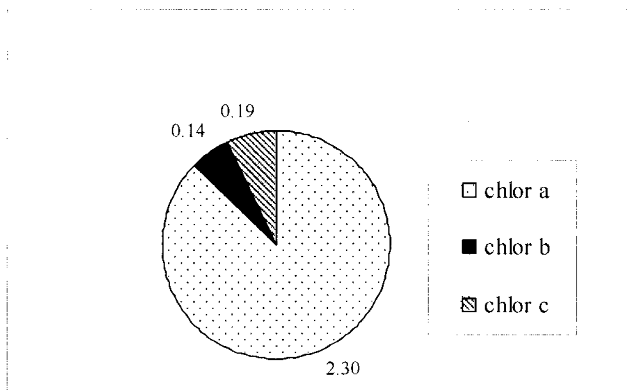


Figure 68. Proportions of chlorophyll *a*, *b* and *c* in Red Dog Creek at Station 10, 1995-2002.

Summary of Biomonitoring

Changes in water quality, invertebrate and periphyton communities and fish populations documented over the biomonitoring period are summarized in Table 8.

Table 8. Summary of NPDES Permit Biomonitoring, Red Dog Creek at Station 10, 1999-2002.

Factor	Changes Observed
Water Quality	Median concentrations of TDS high during discharge, pH circumneutral
Concentrations of metallic elements	Median concentrations of Al, Pb, Cu, Se, Cd and Zn in 2002 among lowest measured at this site.
Invertebrate Community	Abundance lower in 2002 than 2001, but density higher. Taxonomic richness (as number of taxa) lower than 2001, but similar to 1999 – 2000. Community dominated by Diptera during most years sampled.
Algal Communities	Chlorophyll *a* concentrations high in 2002, mixture of Chlorophyll a, b and c indicate a diverse algae community.
Larval Arctic grayling	Found in 1997-2000.

Middle Fork Red Dog Creek at Station 20

Description of Site

Middle Fork Red Dog Creek has a drainage area of 12 km^2 with the flow coming from the clean water bypass ditch (Station 140) and treated mine effluent. Upper Red Dog Creek and tributaries Rachael, Connie and Shelly creeks, flow into the bypass channel. 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). Stream flows range from about 1500 cfs at break up to less than 1 cfs during summer low flows. Migration of fish into this portion of Red Dog Creek is blocked by a gabion basket weir structure located just about North Fork Red Dog Creek.

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

Water Quality

Station 20 was not sampled regularly for water quality. The available data suggests that, before mining, pH ranged from 5.7 to 6.9 (Figure 70). In 2002, the pH ranged from a low of 6.5 in mid-August to a high of 9.3 in mid-July. Higher 2002 pH values correspond to periods of higher discharge of treated effluent (treated waste water has pH levels in the

10 to 10.5 range). Conductivity at Station 20 is elevated by the treated effluent (Figure 71).

Median concentrations of Al, Cd, Pb and Zn in Middle Fork Red Dog Creek were similar among all years of the NPDES Permit monitoring (1999–2002, Figures 72 through 78). Median concentrations of Al, Cd, Pb and Zn were lower during 1999–2002 than during baseline (1981 through 1983). There were no baseline data for Fe, Ni or Se.

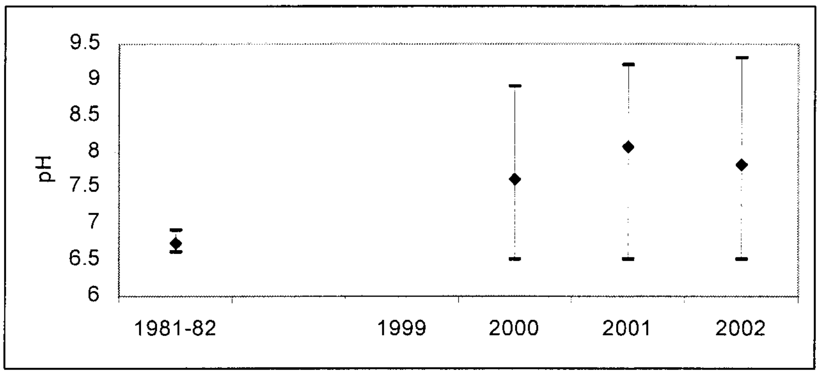


Figure 70. Median, maximum and minimum pH levels in Middle Fork Red Dog Creek at Station 20.

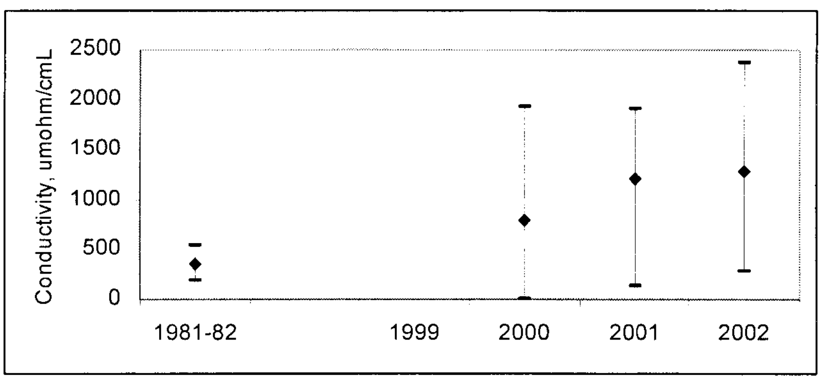


Figure 71. Median, maximum and minimum conductivity in Middle Fork Red Dog Creek at Station 20. Data from Teck-Cominco.

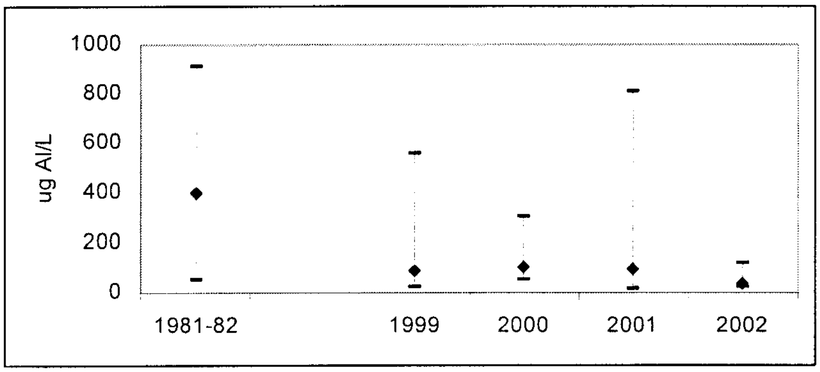


Figure 72. Median, maximum and minimum concentrations of Al in Middle Fork Red Dog Creek at Station 20. Data from Teck-Cominco.

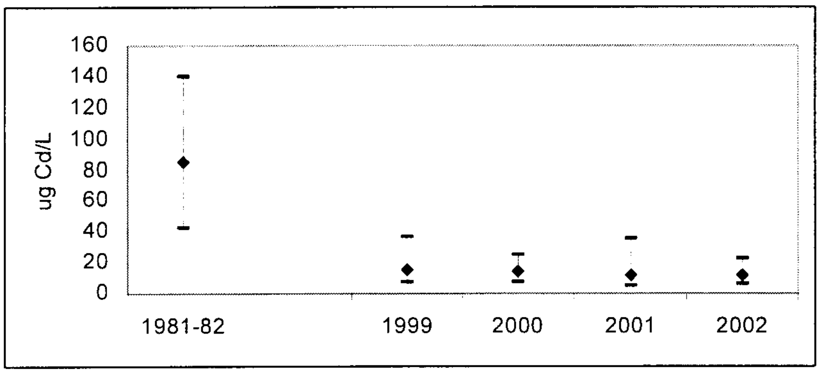


Figure 73. Median, maximum and minimum concentrations of Cd in Middle Fork Red Dog Creek at Station 20. Data from Teck-Cominco.

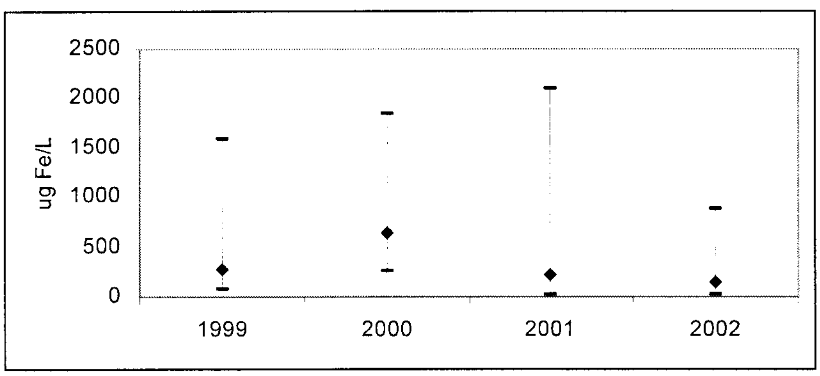


Figure 74. Median, maximum and minimum concentrations of Fe in Middle Fork Red Dog Creek at Station 20. There are no baseline data for Fe. Data from Teck-Cominco.

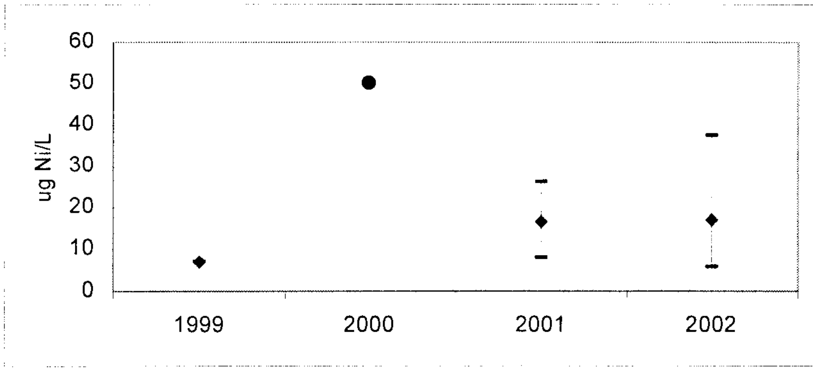


Figure 75. Median, maximum and minimum concentrations of Ni in Middle Fork Red Dog Creek at Station 20. The circle represents the MDL. Data from Teck-Cominco.

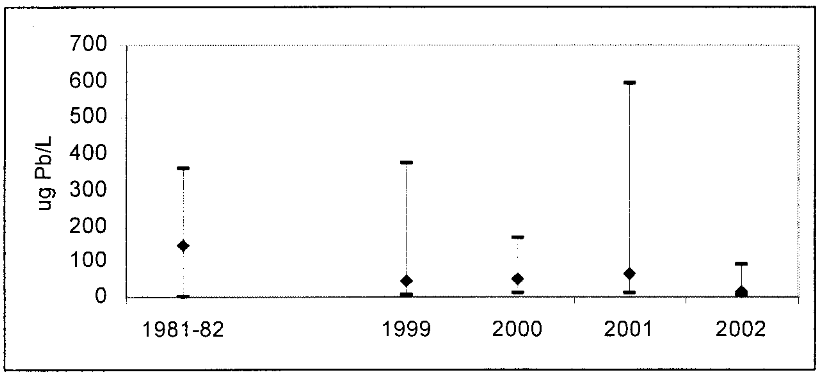


Figure 76. Median, maximum and minimum concentrations of Pb in Middle Fork Red Dog Creek at Station 20. Data from Teck-Cominco.

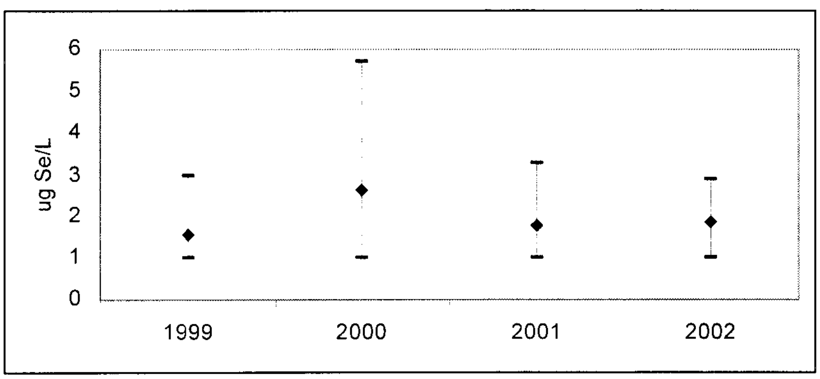


Figure 77. Median, maximum and minimum concentrations of Se in Middle Fork Red Dog Creek at Station 20. Data from Teck-Cominco.

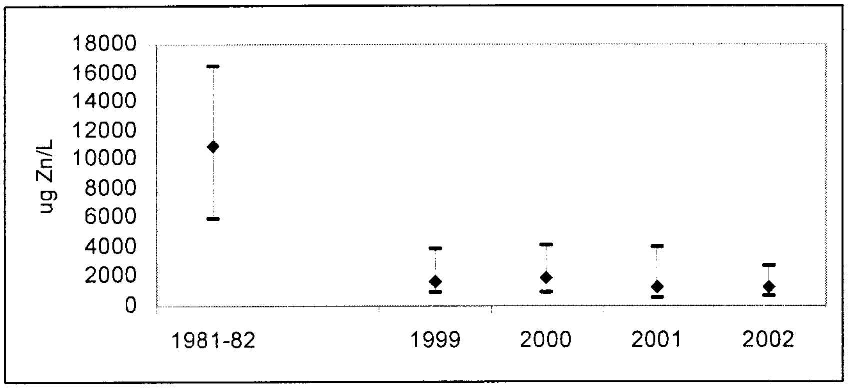


Figure 78. Median, maximum and minimum concentrations of Zn in Middle Fork Red Dog Creek at Station 20. Data from Teck-Cominco.

Invertebrate Community

Abundance, density and taxa richness

Invertebrate abundance was highest at Station 20 during 2001 (Figure 79); however, invertebrate density was higher in 2002 than in any other year sampled during the NPDES Permit biomonitoring (Figure 80). As at Station 10, we believe that invertebrate density in 2002 was primarily a function of lower volumes of water flowing through sample nets during sampling than in 2001. In 2001, we estimated an average water volume of 186 m^3 flowing through each sample net: in 2002, the average volume of water per net was only 62 m^3.

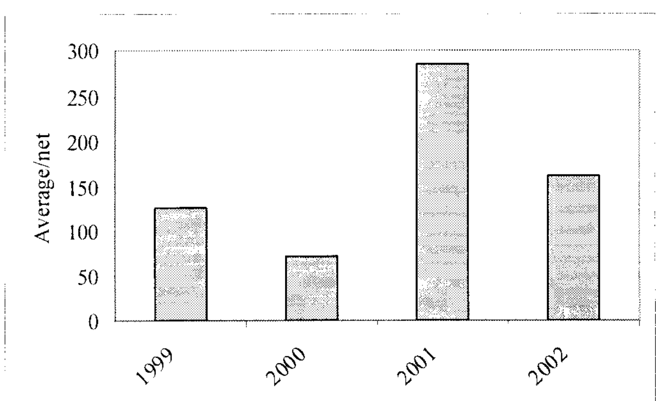


Figure 79. Abundance of aquatic invertebrates (average/net) in Middle Fork Red Dog Creek at Station 20.

Taxonomic richness was highest in 2001, when samples contained a total of 20 distinct taxonomic groups. Samples from 2002 contained 16 different taxa, similar to 1999 and 2000 samples (Figure 81).

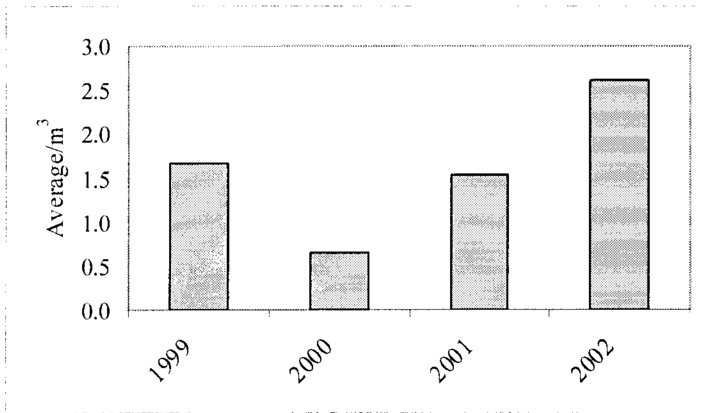


Figure 80. Density of aquatic invertebrates in Middle Fork Red Dog Creek at Station 20.

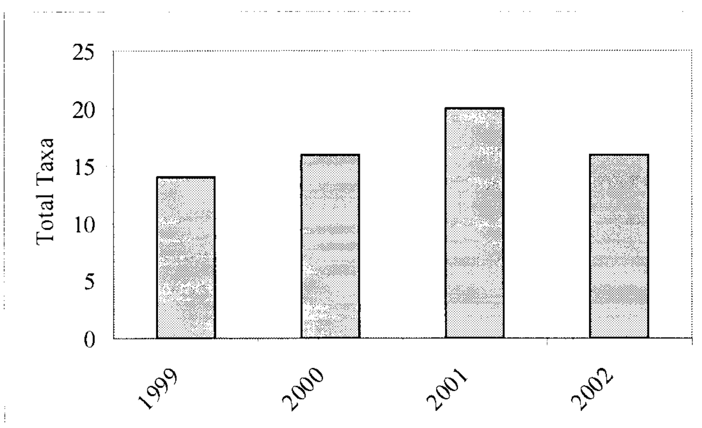


Figure 81. Total aquatic invertebrate taxa collected in Middle Fork Red Dog Creek at Station 20.

Community Structure

The invertebrate community at Station 20 contained from 2%-11% EPT taxa in all years sampled except 2001 (Figure 82). In 2001, samples contained 21% EPT taxa, most of these were Ephemeroptera: Heptageniidae, *Cinygmula*; and Plecoptera: Capniidae, *Allocapnia*. Chironomidae were the most commonly found taxa at this site. Trichoptera were rarely collected.

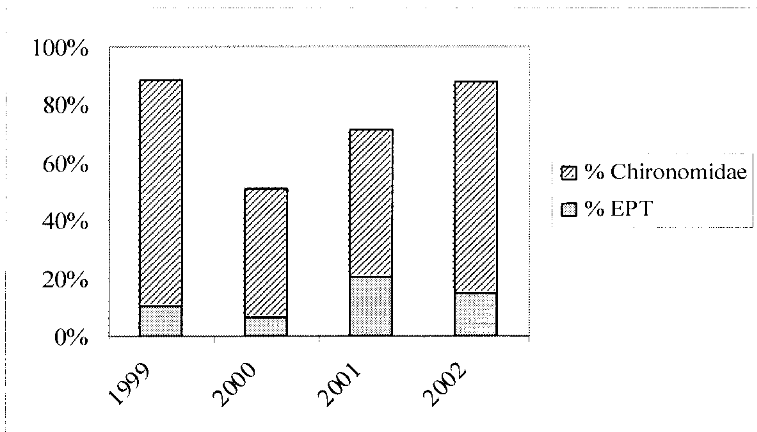


Figure 82. Percent EPT and percent Chironomidae larvae in the invertebrate community in Middle Fork Red Dog Creek at Station 20.

Periphyton Standing Crop

The concentration of chlorophyll *a* in Middle Fork Red Dog Creek at Station 20 was consistently lower than any of the sites sampled; during most sample events the concentrations were below the limit of detection, 0.01 mg/m^2 (Figure 83). In 2002, samples did not have sufficient amounts of chlorophyll to distinguish the three major pigments.

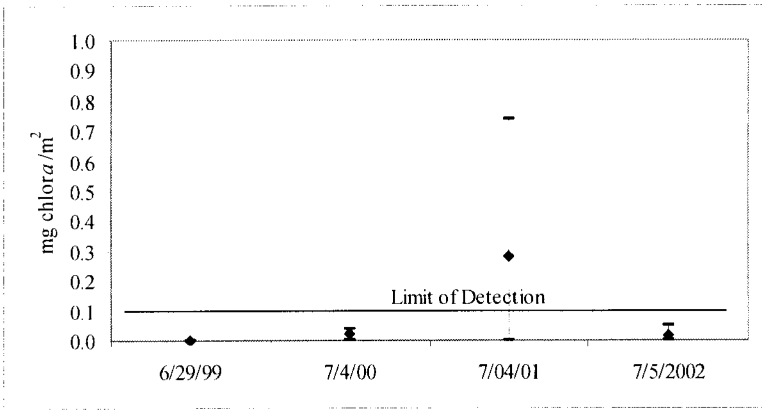


Figure 83. Concentration of chlorophyll *a* in Middle Fork Red Dog Creek at Station 20 1995–2001.

Summary of Biomonitoring

The changes observed in the water quality conditions and aquatic communities are summarized in Table 9. Overall, this site has the lowest productivity (as estimated by invertebrate abundance and concentrations of chlorophyll) of any of the sites sampled. We found no consistent pattern in abundance, density of aquatic invertebrates or taxa richness that could be related to operations of the Red Dog Mine.

Table 9. Summary of Biomonitoring in Middle Fork Red Dog Creek at Station 20, 1995–2000

Factor	Changes Observed
Water Quality	Conductivity and pH influenced by discharge..
Concentrations of metallic elements	Median concentrations of metals were similar from 1999 through 2002.
Invertebrate Community	Abundance and density usually low at this site Communities dominated by Diptera at most times. Ephemeroptera and Plecoptera occasionally common.
Algal Communities	Chlorophyll *a* concentrations low in all years, concentrations of chlorophyll *b* and c usually below detection.
Larval Arctic grayling	Not found at this site.

North Fork Red Dog Creek at Station 12

Site Description

The North Fork Red Dog Creek, a tributary to Main Stem 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 both Arctic grayling and Dolly Varden juveniles rear in this creek.

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 (Teck-Cominco data files). In 2002, pH ranged from 6.2 to 7.7 (Figure 85); pH is lowest during spring breakup and snowmelt.

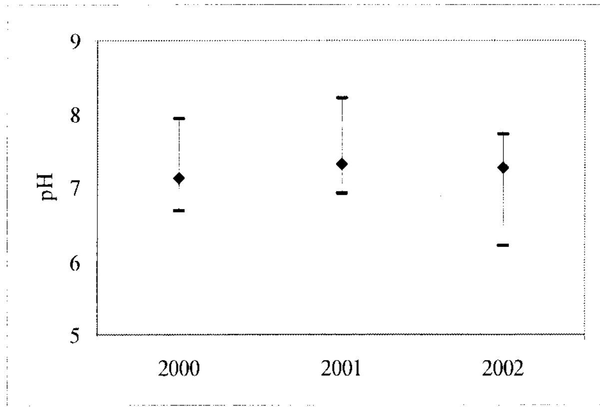


Figure 85. Median, maximum and minimum pH in North Fork Red Dog. Data from Teck-Cominco.

Concentrations of metals at the monitoring site are usually below the USEPA standard for aquatic life (Weber Scannell and Andersen 1999), although occasional samples showed elevated concentrations (Figures 86 through 91). In 2002, concentrations of Al, Cd,, Ni, Pb, Se and Zn were lower in the North Fork Red Dog Creek than any other creeks sampled.

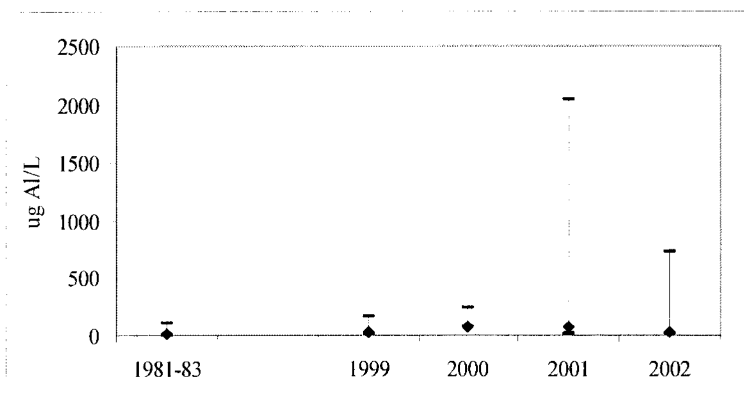


Figure 86. Median, maximum and minimum concentrations of Al in North Fork Red Dog. Data from Teck-Cominco.

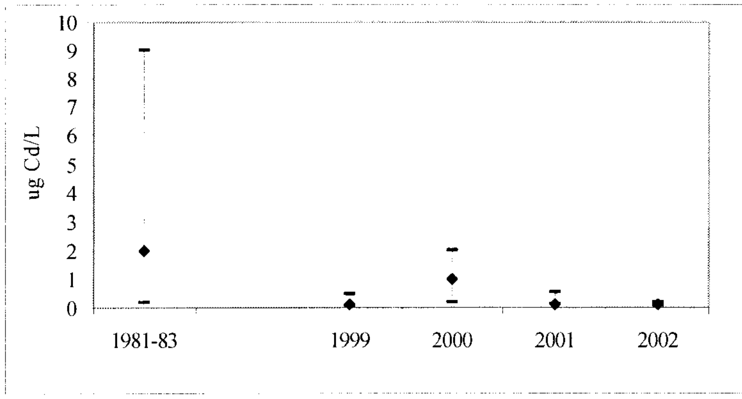


Figure 87. Median, maximum and minimum concentrations of Cd in North Fork Red DogCreek. Data from Teck-Cominco.

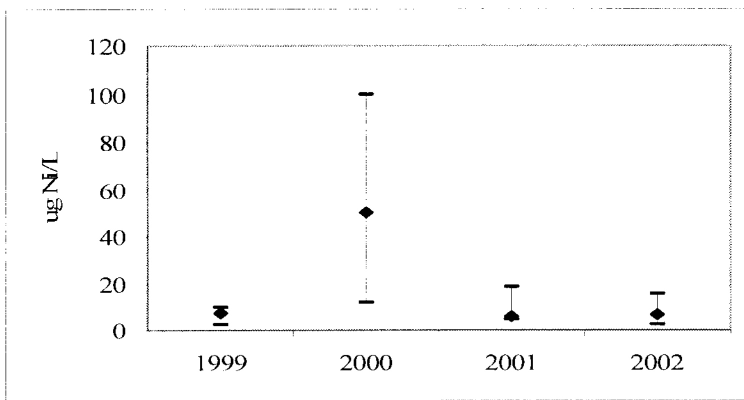


Figure 88. Median, maximum and minimum concentrations of Ni in North Fork Red DogCreek. Data from Teck-Cominco.

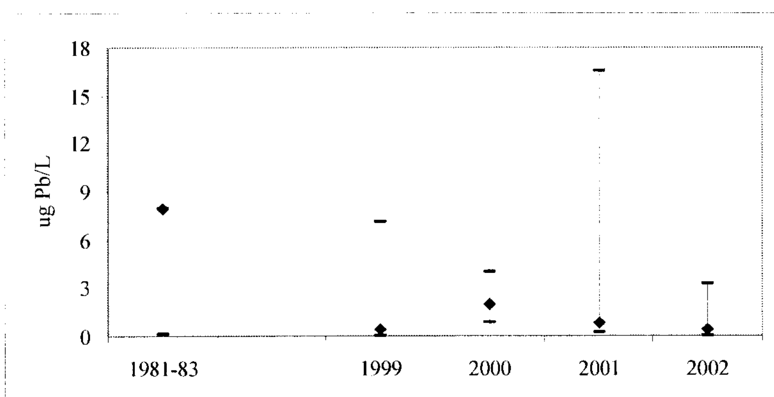


Figure 89. Median, maximum and minimum concentrations of Pb in North Fork Red DogCreek. Data from Teck-Cominco.

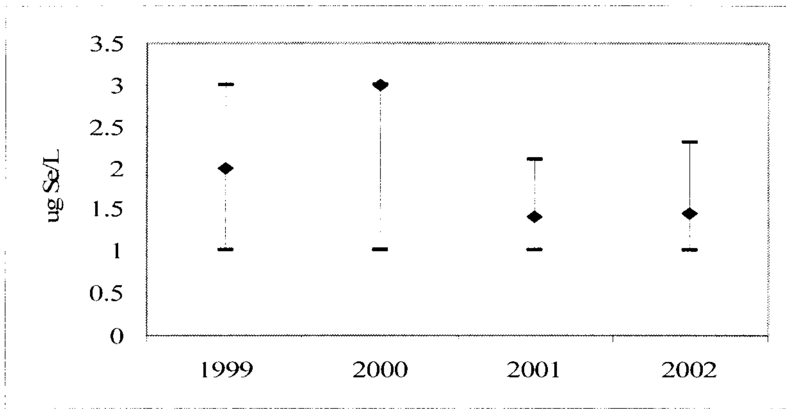


Figure 90. Median, maximum and minimum concentrations of Se in North Fork Red DogCreek. Data from Teck-Cominco.

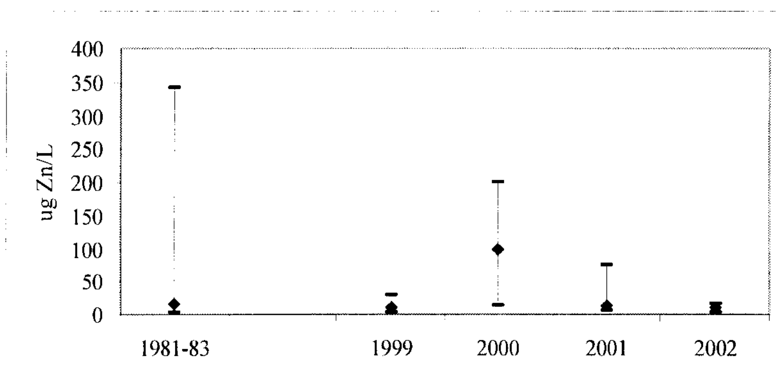


Figure 91. Median, maximum and minimum concentrations of Zn in North Fork Red DogCreek. Data from Teck-Cominco.

Invertebrate Community

Abundance, density and taxa richness

Invertebrate abundance in the North Fork Red Dog Creek at Station 12 ranged from a maximum count of 1500 invertebrates per net to a low of about 100 per net (Figure 92). The highest abundance occurs when different taxa reach final developmental stages and enter the drift just before hatch. As with samples collected in Ikalukrok Creek at Stations 8 and 9, numbers were highest in 2001. In 2002, invertebrate abundance was low, as were numbers at the other NPDES Permit monitoring sites (Figure 92). Invertebrate densities in 2002 were slightly lower than in 2001 (Figure 93), but have been influenced primarily by lower flows. In 2002, we measured an average 45 m^3 per sample net, compared to 149 m^3 per net in 2001.

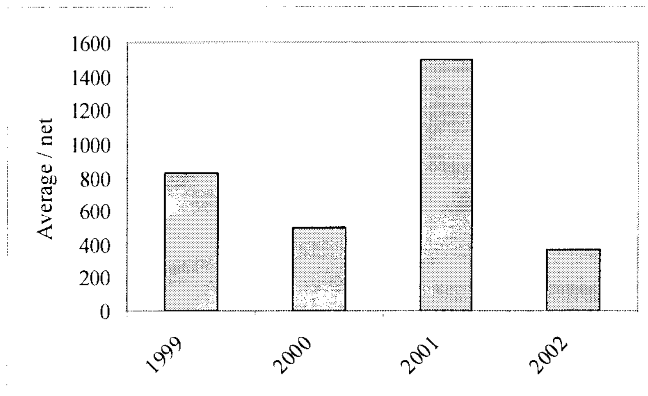


Figure 92. Abundance of aquatic invertebrates collected in North Fork Red Dog.

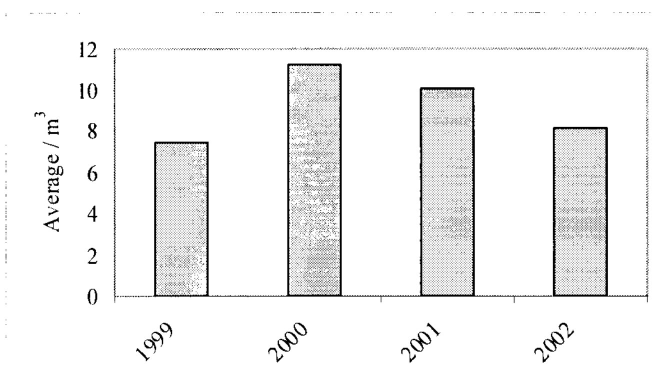


Figure 93. Density of aquatic invertebrates collected in North Fork Red Dog.

Taxa richness in aquatic invertebrate samples from the North Fork Red Dog Creek showed little fluctuation among the years sampled (Figure 94). In 2002, we identified a total of 17 genera plus the family Chironomidae.

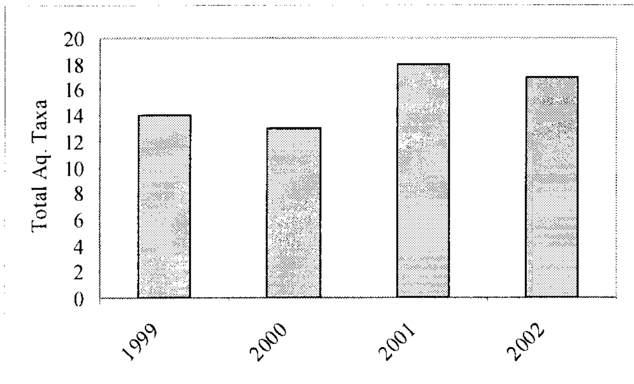


Figure 94. Total aquatic invertebrate taxa in North Fork Red Dog.

Community Structure

Invertebrate samples contained low proportions (usually < 20%) EPT taxa in most of the sample events (Figure 95), except in 2002 when 60% of the samples were EPT taxa.

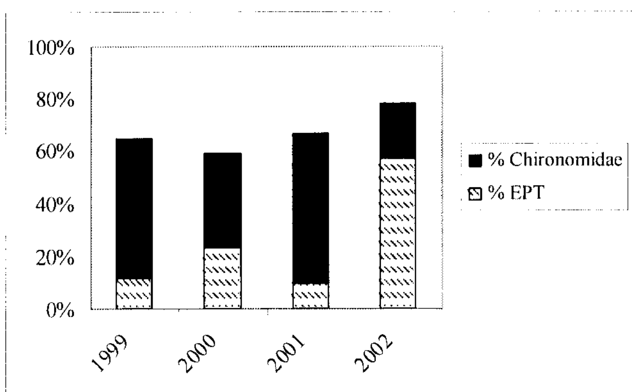


Figure 95. Proportions of EPT taxa and Chironomidae larvae in aquatic invertebrate samples from Station 12, North Fork Red Dog Creek.

The invertebrate community was dominated by Diptera in all years sampled except 2002. Chironomidae larvae were the most abundant taxa in years 1999 through 2001, with an average of 854 Chironomidae larvae/net in 2001. The most common taxa in 2002 were Simuliidae: *Simulium,* Ephemeroptera: Baetidae (*Baetis*); Plecoptera: Capniidae (*Capnia*), Collembola: Isotomidae (*Axelsonia*) and Onychiuridae (*Lophognathella*), Acari: Acarina; and Ostracoda.

Periphyton Standing Crop

The North Fork Red Dog Creek at Station 12 contained abundant attached algae (Figure 96). Concentrations in 2002 were similar to those in1999 through 2001.

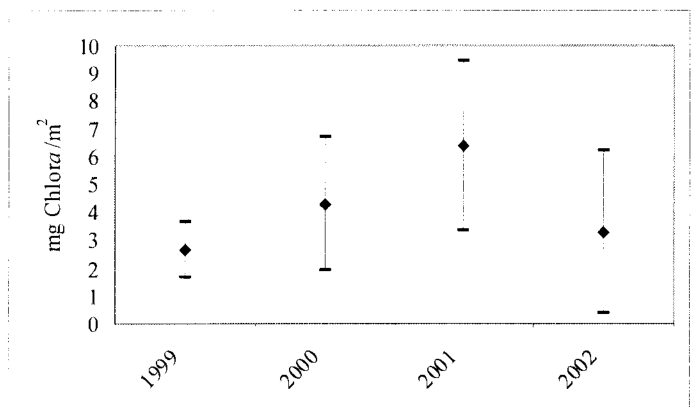


Figure 96. Concentration of chlorophyll *a* (mg/m^2) from attached algae collectedin North Fork Red Dog.

Composition of Algal Communities

Algal communities in the North Fork Red Dog Creek are a mixture of diatoms and green algae (Figure 97). The proportions of chlorophyll *b* and c are nearly equal or higher at this site than in any of the other sites sampled under the NPDES biomonitoring program, indicating a biological diverse community.

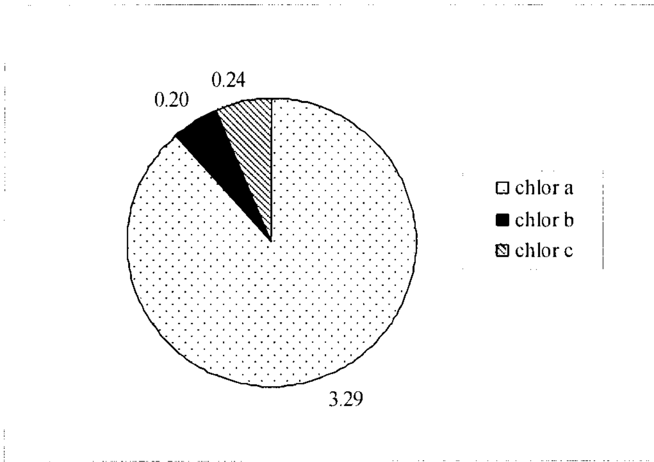


Figure 97. Concentrations of chlorophyll *a*, *b* and *c*, mg/m^2, from attached algae collected in North Fork Red Dog.

Summary of Biomonitoring

Although mining has not occurred in this drainage, ADF&G conducts biomonitoring at this site to provide a comparison of an unaffected site with sites potentially affected by mining or mine discharge. The North Fork Red Dog Creek is a productive site for aquatic invertebrates and periphyton and contains low concentrations of metals (Table 10).

Table 10. Summary of biomonitoring, North Fork Red Dog Creek, 1995-2000.

Factor	Changes Observed
Water Quality	Water contains neutral pH, low TDS and low sulfate.
Concentrations of metallic elements	Concentrations of Al, Cd, Pb and Zn are low and water quality is excellent.
Invertebrate Community	Abundance is high at this site; however, proportions of EPT taxa were high in 2002. Year-to-year variability is high.
Algal Communities	Chlorophyll *a* concentrations high. Periphyton community contains abundant diatoms.
Larval Arctic grayling	Found in 1997, 1999, 2000 and 2001.

METALS CONCENTRATIONS IN ADULT DOLLY VARDEN, WULIK RIVER

Since 1990, ADF&G has 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. The purpose of sampling adult Dolly Varden for metals concentrations is to monitor their long-term condition over the operation of the Red Dog Mine and to identify any changes in tissue concentrations that may be related to mining operations. All laboratory analysis 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 the fish (Jenkins 1980) and in the case of anadromous Dolly Varden, the metals vary with exposure to freshwater or marine environments. Our data from Wulik River Dolly Varden tissues suggest that aluminum concentrates primarily in gill tissue; cadmium in kidney tissue; copper in liver and kidney tissues; lead in gill tissue and to a lesser degree, in kidney tissue; selenium in kidney and reproductive tissues; and zinc in reproductive tissues (Figure 95). None of the analytes was shown to concentrate in muscle tissues. To determine trends in metals concentrations during the NPDES Permit monitoring period (1999-2002), we focused on these metal-tissue relationships: Al in kidney tissue; Cd in kidney tissue; Cu in liver tissue; Pb in liver, muscle and kidney tissues; Zn in reproductive tissue; and Se in liver, kidney and reproductive tissues.

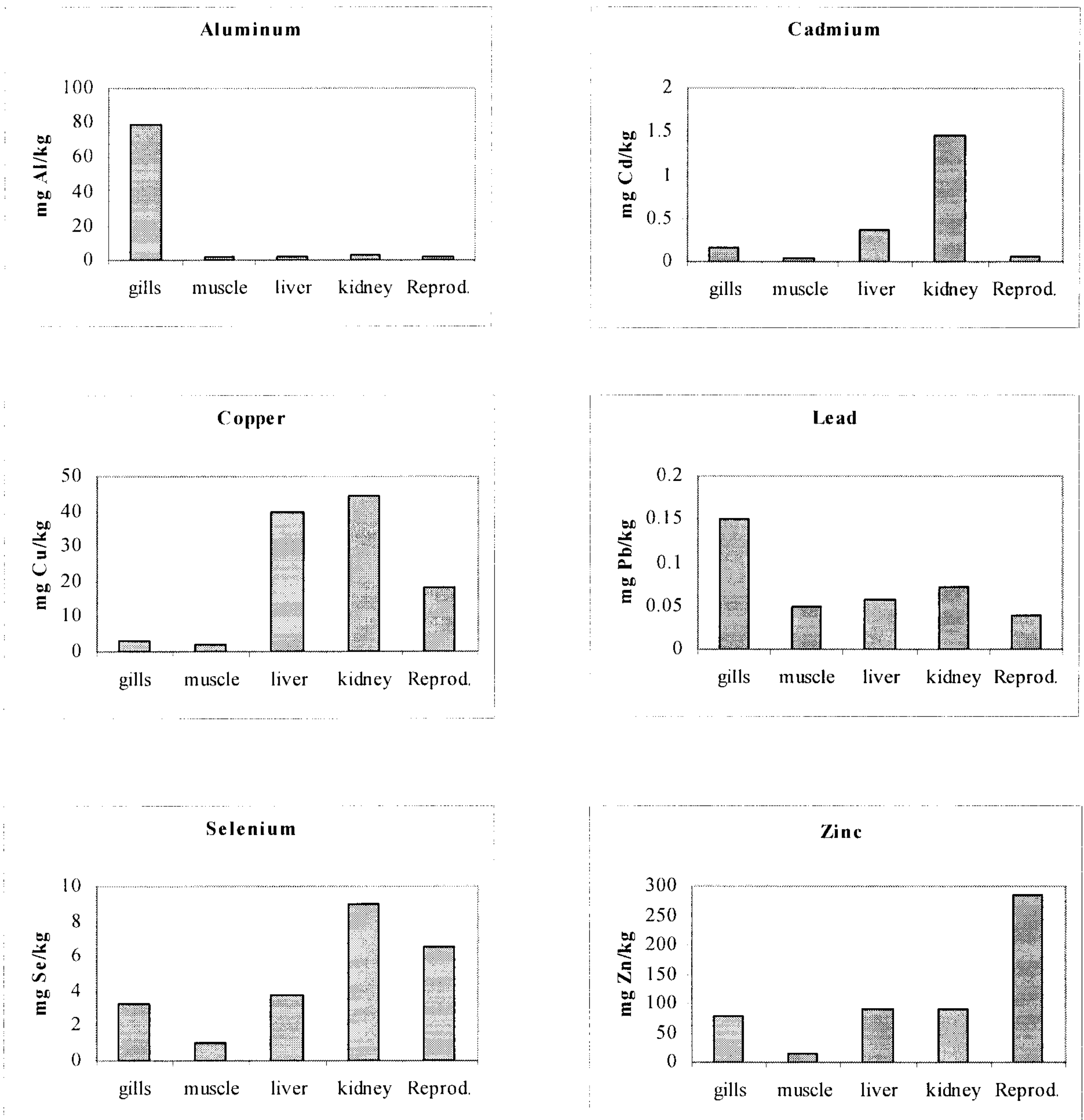


Figure 98. Concentration of various analytes in Dolly Varden gill, liver, kidney, muscle and reproductive tissues. Values are the average of all fish collected during the NPDES permit sampling period.

Aluminum

Median concentrations of Al in gill tissues from Dolly Varden collected in Spring and Fall 2002 were similar to concentrations in Fall 2000 and higher than the other sampling times (Figure 99). Two fish from the Fall 2002 sampling time contained elevated Al concentrations that were higher than in previous years. These fish also contained elevated Al concentrations in liver and kidney tissues (ADF&G Data Files). Concentrations of Al in spring-caught fish from 2002 were low. There were no baseline data for Al in fish tissues.

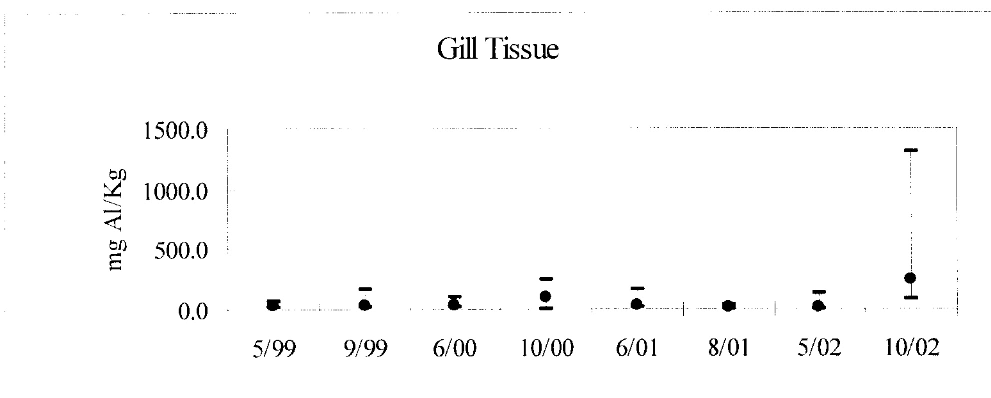


Figure 99. Median, maximum and minimum concentrations of Al (dry weight basis) in adult Dolly Varden gill tissue, Wulik River, 1999–2002.

Cadmium

Median cadmium concentrations in Dolly Varden kidney tissues in 2002 were within the range found in 1999 and 2001 and lower than concentrations reported in baseline sampling (Figure 100). Cadmium concentrations in kidney tissues of fall-caught fish were lower in 2002 than in all previous years, except Fall 1999.

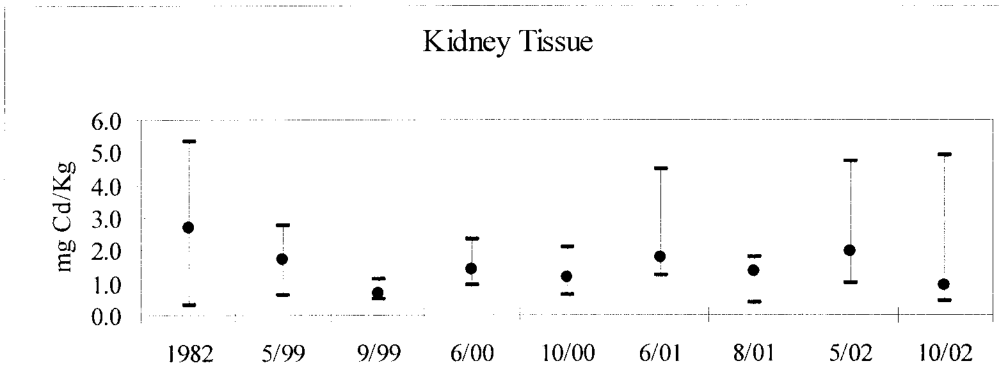


Figure 100. Median, maximum and minimum concentrations of Cd (dry weight basis) in adult Dolly Varden kidney tissue, Wulik River, 1982–2002.

Copper

Median Cu concentrations reported in Spring 2002 were within the ranges found from 1999–2001 (Figure 101) and Fall 2002 Cu concentrations were among the lowest reported during the NPDES sampling period.

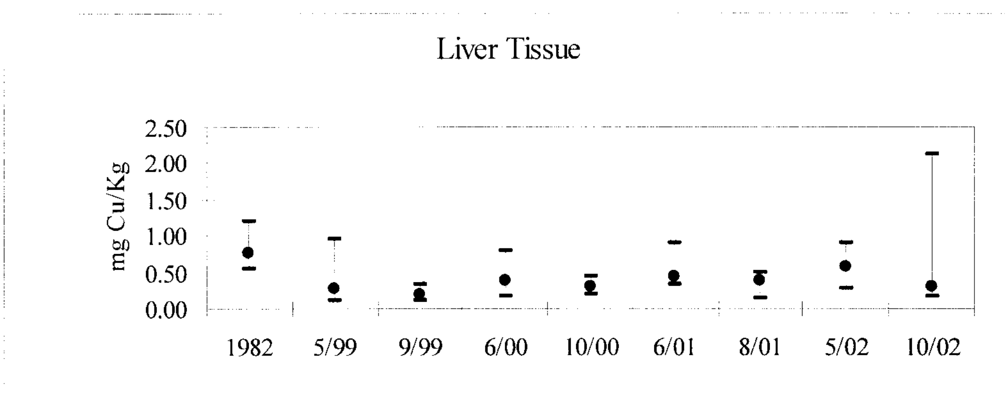


Figure 101. Median, maximum and minimum concentrations of Cu (dry weight basis) in adult Dolly Varden liver tissue, Wulik River, 1982–2001.

Lead

Median Pb concentrations in liver (Figure 102), muscle (Figure 103) and kidney (Figure 104) in 2002 were among the lowest measured. One fish collected in Fall 2002 had slightly elevated Pb concentrations in the kidney tissue (Figure 104).

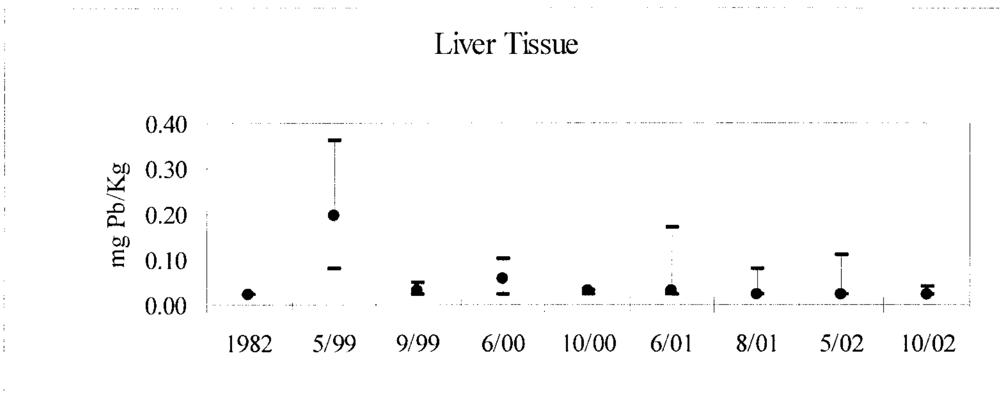


Figure 102. Median, maximum and minimum concentrations of Pb (dry weight basis) in adult Dolly Varden liver tissues, Wulik River, 1982–2002.

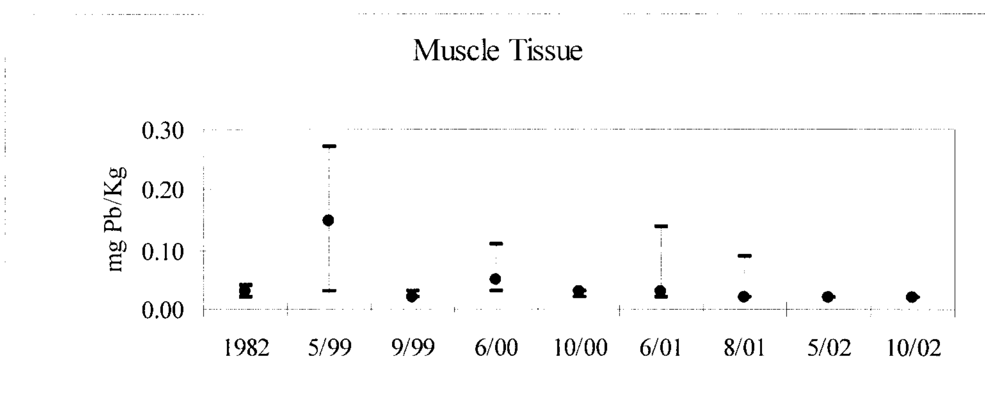


Figure 103. Median, maximum and minimum concentrations of Pb (dry weight basis) in adult Dolly Varden muscle tissues, Wulik River, 1982–2002.

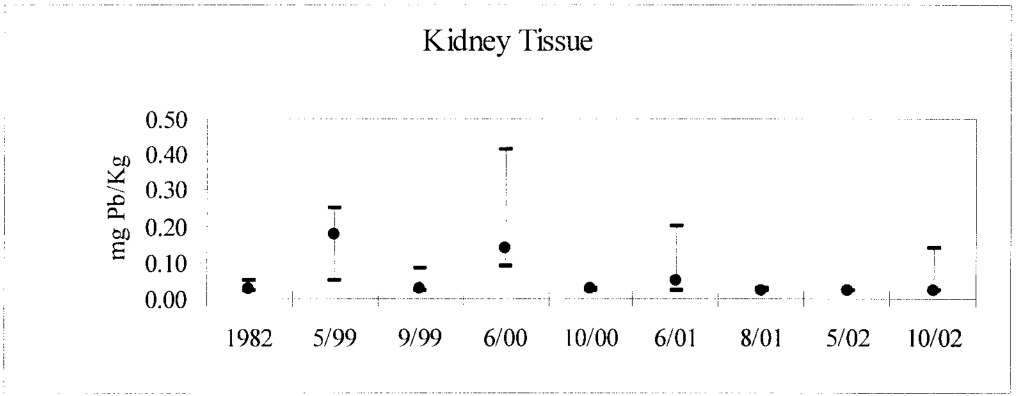


Figure 104. Median, maximum and minimum concentrations of Pb (dry weight basis) in adult Dolly Varden kidney tissues, Wulik River, 1982–2002.

Zinc

Median and maximum Zn concentrations in Dolly Varden reproductive tissue (Figure 105) were slightly higher in Fall 2002 than other samples; however, spring caught fish had Zn concentrations that were within the range of other samples collected from 2000 through 2001. We did not sample reproductive tissues for Zn until 2000.

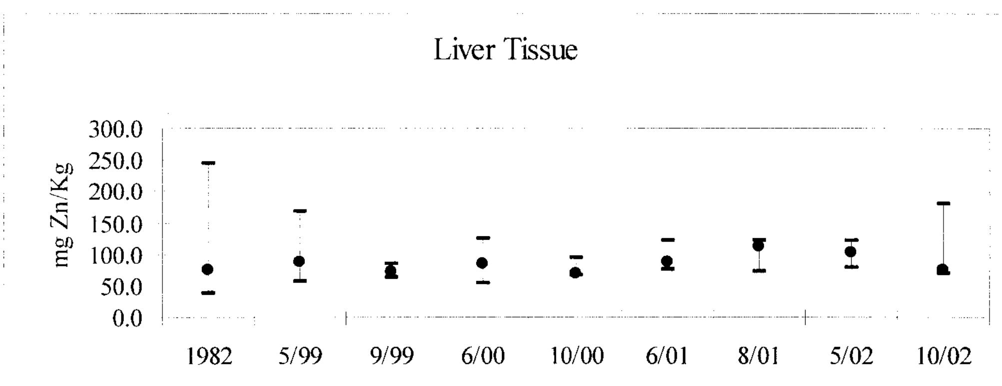


Figure 105. Median, maximum and minimum concentrations of Zn (dry weight basis) in adult Dolly Varden liver, Wulik River, 1982–2002.

Selenium

Dolly Varden caught in Fall 2002 had higher concentrations of Se in kidney, liver and reproductive tissues than other fish (Figures 106, 107 and 108); however, fish caught in Spring 2002 had similar concentrations of Se as fish caught and tested in 1999 through 2001. Concentrations of Se in fish collected in fall, particularly in reproductive tissues, are likely a reflection of accumulations in the marine environment because these fish were collected soon after returning to fresh water.

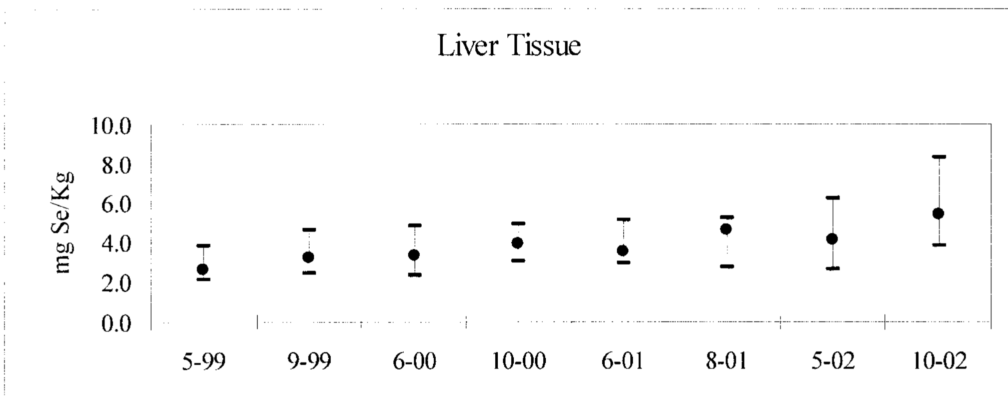


Figure 106. Concentration of Se in adult Dolly Varden liver tissues, Wulik River, 1999–2002.

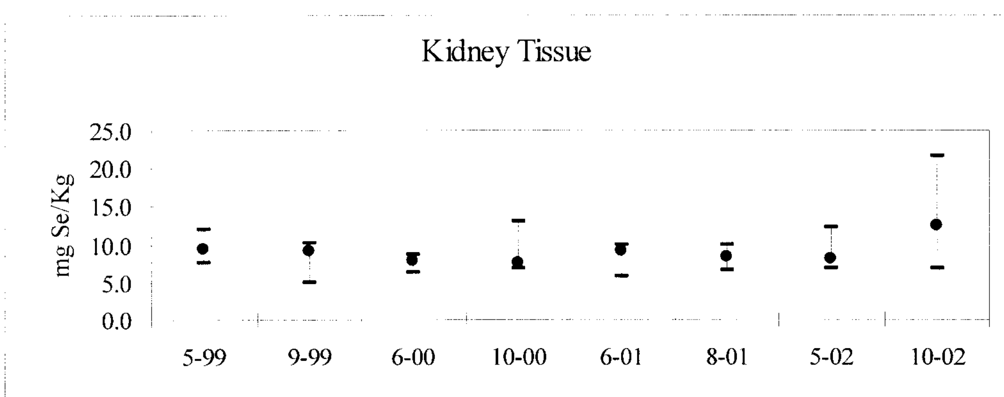


Figure 107. Concentration of Se in adult Dolly Varden kidney tissues, Wulik River, 1999–2002.

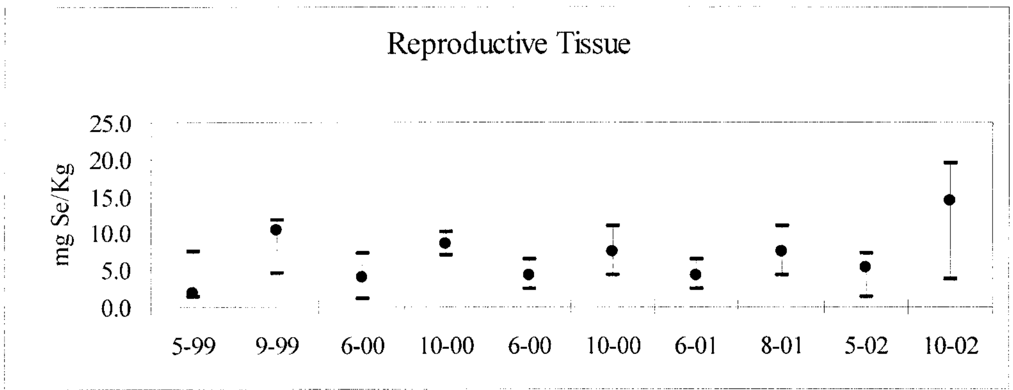


Figure 108. Concentration of Se in adult Dolly Varden reproductive tissues, Wulik River, 1999–2002.

Comparisons of Dolly Varden Caught in Spring and Fall

We divided the results of fish tissue sampling into two groups: fish caught in the fall shortly after returning from the ocean and fish caught in the spring, after spending at least 9 months in the Wulik River. We compared concentrations of specific metals in the tissues to determine if there were differences between the two groups that could be related to their recent residence in the ocean or Wulik River. We used the Wilcoxon Rank Sum Test (a non-parametric median test) to detect differences.

We found no difference between fish caught in fall and fish caught in spring for the concentrations of Al in gill tissues (P=0.5474, Fig. 109) and Se in kidney tissues (P=0.4186, Fig. 110). Spring-caught Dolly Varden had significantly higher concentrations of Cd in kidney (P<0.001, Fig. 111) and liver (P=0.0091, Fig. 112) tissues, Pb in kidney (P=0.0064, Fig. 113) and muscle (P=0.0156, Fig. 114) tissues and Cu in liver tissues (P<0.0001, Fig. 115).

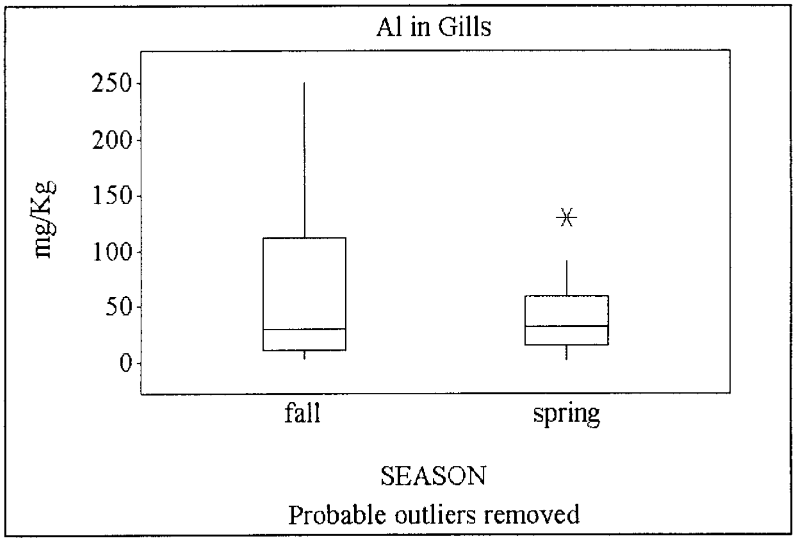


Figure 109. Comparison of Al concentrations in gill tissues between spring and fall caught Dolly Varden. * = possible outlier.

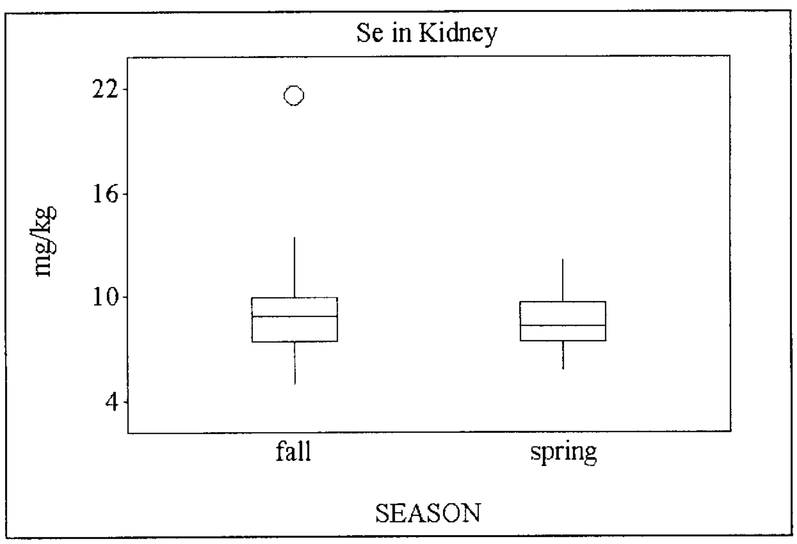


Figure 110. Comparison of Se concentrations in kidney tissues between spring and fall caught Dolly Varden. ° = probable outlier.

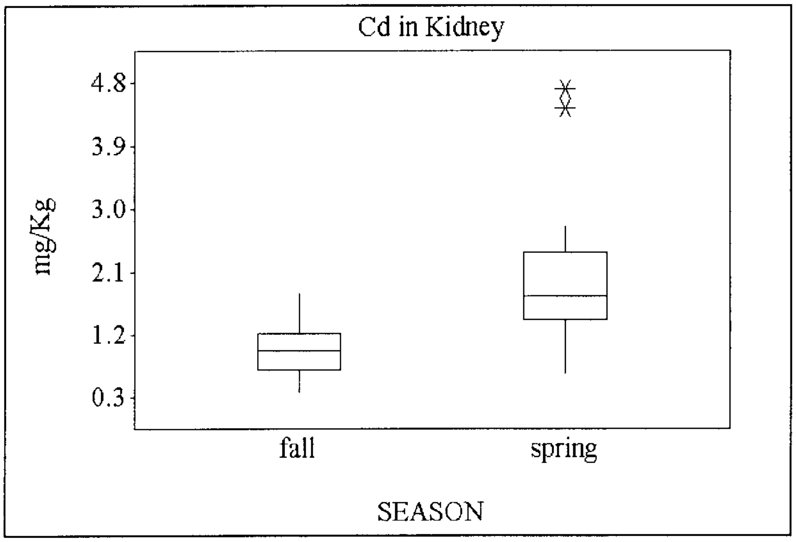


Figure 111. Comparison of Cd concentrations in kidney tissues between spring and fall caught Dolly Varden.

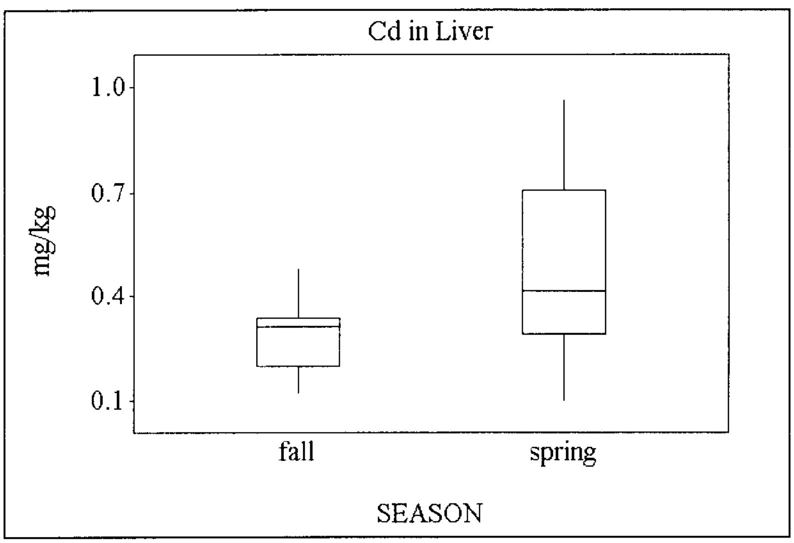


Figure 112. Comparison of Cd concentrations in liver tissues between spring and fall caught Dolly Varden.

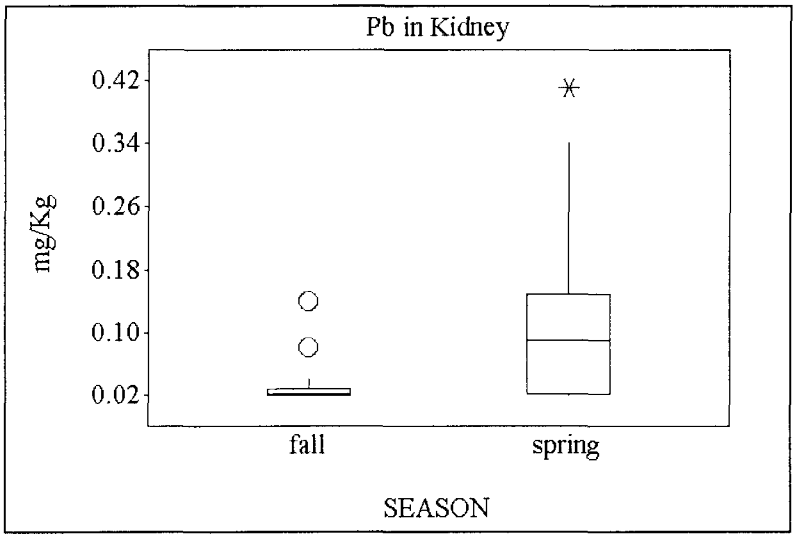


Figure 113. Comparison of Pb concentrations in kidney tissues between spring and fall caught Dolly Varden. * = possible outlier.

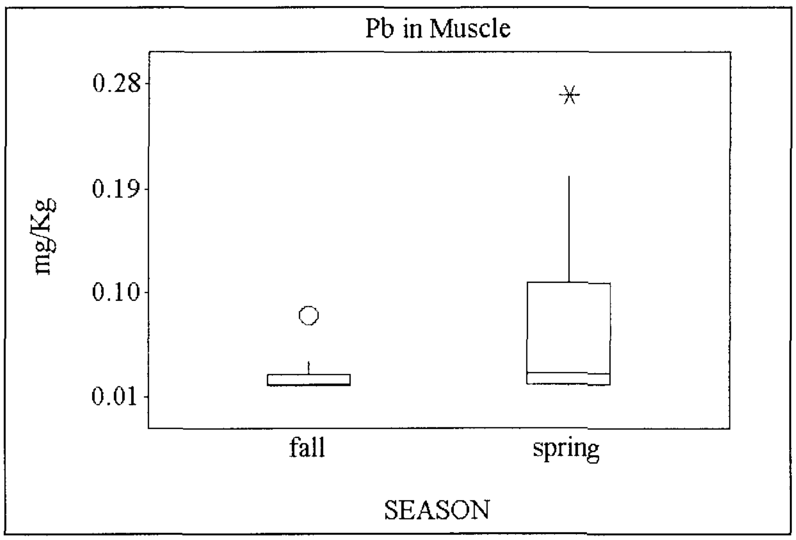


Figure 114. Comparison of Pb concentrations in muscle tissues between spring and fall caught Dolly Varden. ° = probable outlier, * = possible outlier.

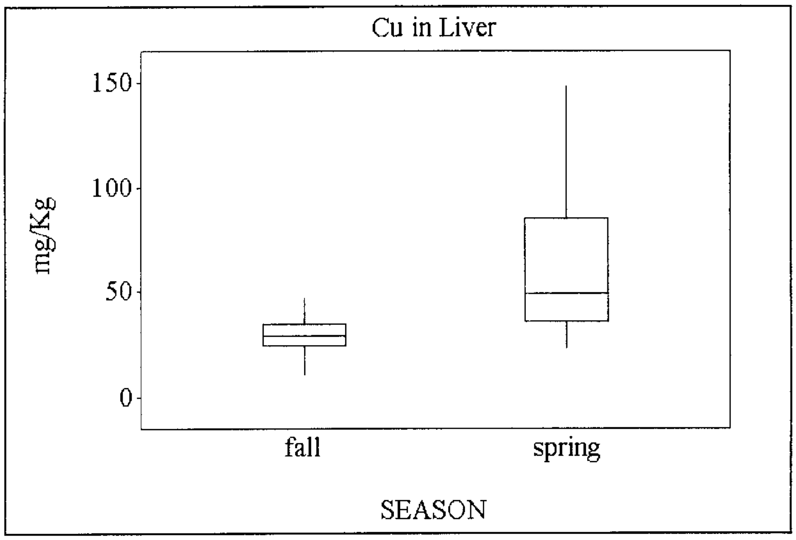


Figure 115. Comparison of Cu concentrations in liver tissues between spring and fall caught Dolly Varden.

Adult Dolly Varden caught in the fall after returning from the marine environment had significantly higher concentrations of Se in reproductive tissues (P=0.0001, Fig. 116) and Zn in reproductive tissues (P=0.0064, Fig. 117). Comparisons between Pb in liver of spring-caught and fall-caught fish were inclusive with the Wilcoxon Rank Sum Test.

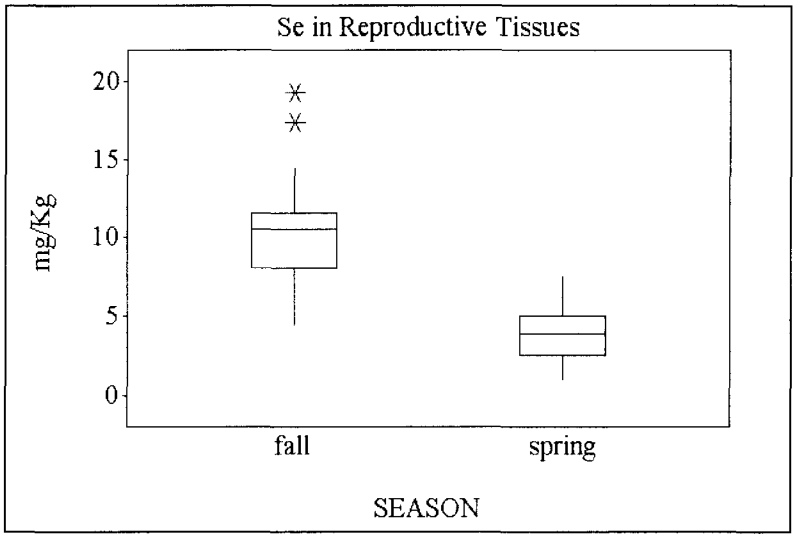


Figure 116. Comparison of Se concentrations in reproductive tissues between spring and fall caught Dolly Varden. * = possible outlier.

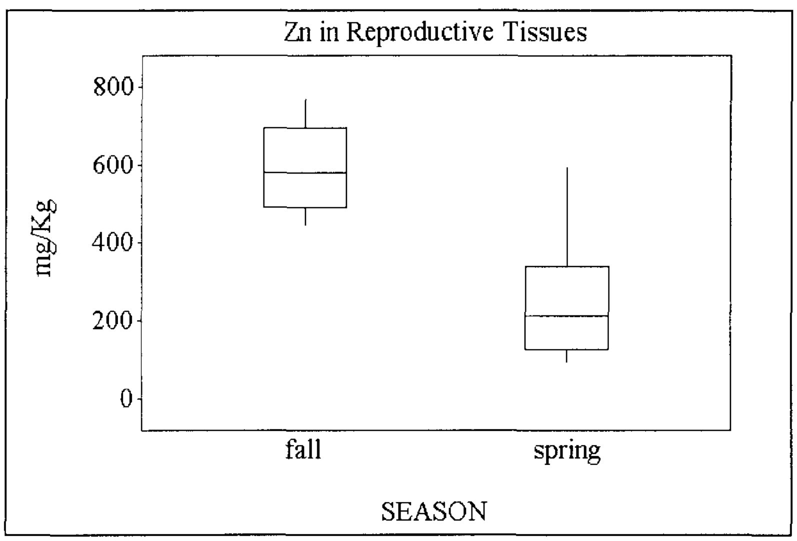


Figure 117. Comparison of Zn concentrations in reproductive tissues between spring and fall caught Dolly Varden. * = possible outlier.

DISTRIBUTION OF FISH THROUGHOUT DRAINAGE

Overwintering Dolly Varden

The Dolly Varden fall aerial survey in the Wulik River was flown on October 10, 2002 in a fixed-wing aircraft (Appendix 2, Appendix 3) – Survey visibility was limited by overcast skies and algal growth on the river bottom. DeCicco (2002) estimated 44,257 Dolly Varden in the Wulik River from the lagoon to about 3.2 km upstream of Ikalukrok Creek. There were large groups of small Dolly Varden in the lower two thirds of the river, only some of which could be counted. Fish were spread throughout the length of the survey area with larger fish in the upper reaches. Because of limited visibility, the aerial survey gives a minimum estimate of the total fish in the Wulik River.

The number of Dolly Varden counted in fall has varied annually (Figure 118, Appendix 2). Fluctuations in numbers appear to be related to weather conditions during the survey 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 may be missed during the annual survey. Surveys conducted through Fall 2002 suggest that over 90% of Dolly Varden in the Wulik River remain below the mouth of Ikalukrok Creek in late September and early October.

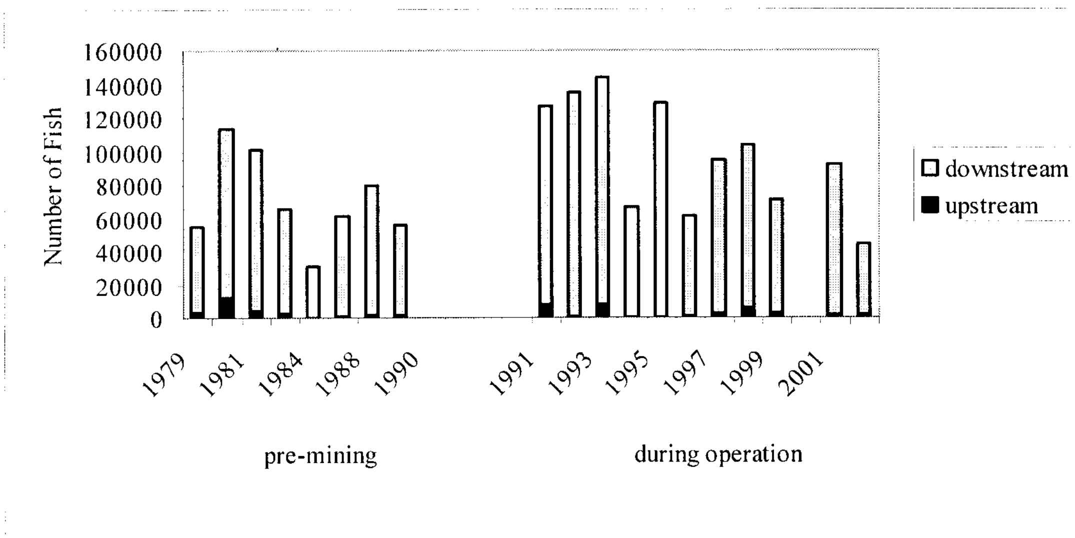


Figure 118. The number of adult Dolly Varden counted in aerial surveys in the Wulik River upstream and downstream of Ikalukrok Creek.

Chum Salmon Spawning

ADF&G attempts annual surveys to assess the distribution of adult chum salmon in Ikalukrok Creek downstream of Dudd Creek (Table 11, Appendix 3); but in some years surveys are limited or prevented by poor weather conditions. In Fall 2002, a helicopter survey was done on August 5 (Ott and Townsend 2002). Survey conditions were fair to good with reduced visibility in some reaches due to sun glare. In the lower portion of Ikalukrok Creek 890 adult chum salmon spawners were counted. Active spawning was observed and several carcasses were seen on August 5. In late August 2002 active spawning was observed again.

Since 1995 numbers of chum salmon observed in Ikalukrok Creek have been higher than in 1990 and 1992, except in 1996 (Table 11). Counts of chum salmon made after mine development generally have been lower than reported in baseline studies by ADF&G and Dames and Moore (1983). Weber Scannell and Ott (2001) reported that although numbers of chum salmon have remained lower than before mining, the population appears to be increasing over numbers observed in 1990 and 1991. The large numbers of chum salmon (about 2,000) in Ikalukrok Creek in Fall 2001 and a good return in Fall 2002 (about 890) are good indications that the population has recovered from the low numbers reported in the early 1990s.

Chum salmon spawning occurs in the lower portion of Ikalukrok Creek below Station 160. In 1997 a few chum salmon were seen spawning further upstream in Ikalukrok Creek near Dudd Creek.

Table 11. Number of adult chum salmon in Ikalukrok Creek downstream of Dudd Creek.

Survey Time	Number of Chum Salmon	Reference
Sept. 1981	3,520 - 6,960	Houghton and Hilgert 1983
Aug.-Sept. 1982	353	Houghton and Hilgert 1983
Sept. 1981	1400	Houghton and Hilgert 1983
Aug. 1984	994	DeCicco 1990b
Aug. 1986	1,985	DeCicco 1990b
Aug. 1990	<70	Ott et al. 1992
Aug. 1991	<70	Ott et al. 1992
Aug. 1995	49	Townsend and Lunderstadt 1995
Aug. 1995	300 - 400	DeCicco 1995
Aug. 1996	180	Townsend and Hemming 1996
Aug. 1997	730 to 780	Ott and Simpers 1997
Aug.-Sept. 1998	no survey	
Aug. 1999	75	Ott and Morris 1999
Sept. 1999	145	DeCicco 1999
Aug. 1900	no survey	
Aug, 7, 2001	850	Morris and Ott 2001
Aug. 28, 2001	2,250	DeCicco 2001b
Aug. 29, 2001	1,836	DeCicco 2001b
Sept. 23, 2001	500	DeCicco 2001c
Oct. 8, 2001	232	DeCicco 2001a
Aug. 5, 2002	890	Ott and Townsend 2002

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. ADF&G found 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).

ADF&G has done annual studies 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 sampled additional creeks (Table 12). The second sample site in North Fork Red Dog Creek is located near the headwaters of the drainage and upstream of all known potential development. Appendix 4 shows the locations of the juvenile fish sampling sites.

Table 12. Locations of juvenile fish trap sites

Site Name	**Station No.**	**Year First Sampled**
Evaingiknuk Creek	no Sta. No.	1990
Anxiety Ridge Creek	no Sta. No.	1990
Buddy Creek	no Sta. No.	1996
North Fork Red Dog Creek	Sta. 12	1993
North Fork Red Dog Creek, upstream site	No Sta. No.	1999
Red Dog Creek, below North Fork Red Dog Cr	Sta. 11	1995
Red Dog Creek, at Ikalukrok Cr	Sta. 10	1996
Ikalukrok Creek above Mainstem Red Dog	Sta. 9	1996
Ikalukrok Creek below Mainstem Red Dog	Sta. 8	1996
Ikalukrok Creek above Dudd Creek	no Sta. No.	1990
Ikalukrok Creek below Dudd Creek	Sta. 7	1990

Numbers of Dolly Varden vary considerably among years, due in part to natural environmental variables, including timing and 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 Anxiety Ridge, Buddy, North Fork Red Dog, Mainstem Red Dog and Ikalukrok creeks from late July to mid-August.

Late summer catches of juvenile Dolly Varden were higher at most sites in 2002 than in 2001 or 2000 (Figures 119 through 121) and comparable to catches in 1997. Juvenile fish numbers follow similar annual variations among the different creeks sampled: years with high numbers of fish in reference creeks also have high numbers in sites downstream of the mine. Conversely, years with low numbers of fish in reference streams also have low numbers at other creeks. We caught a total of 207 Dolly Varden in late July 2002, compared with our highest catch of 945 fish in early August 1999.

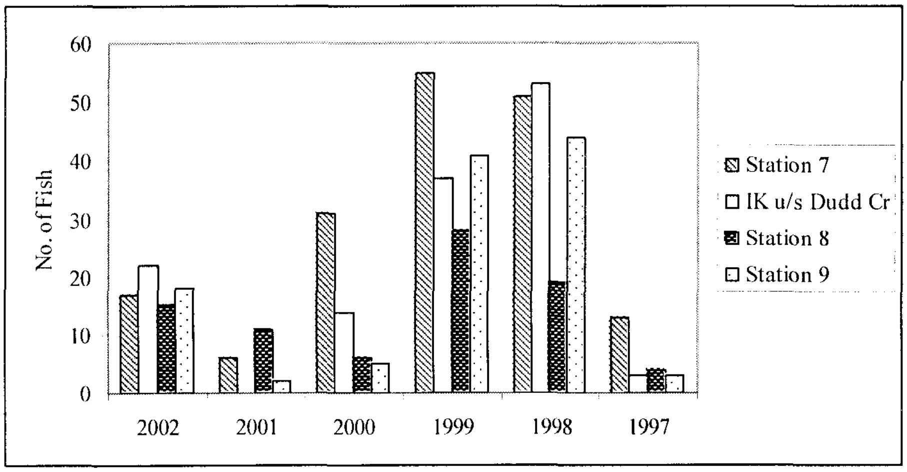


Figure 119. Catches of juvenile fish in Ikalukrok Creek. 1997–2002.

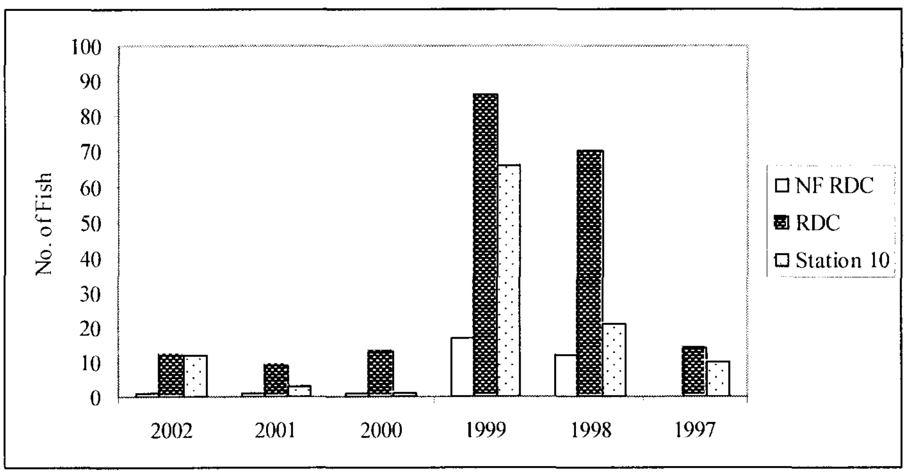


Figure 120. Juvenile fish in Red Dog Creek below the North Fork (RDC), North Fork Red Dog Creek (NF RDC) and Red Dog Creek at Station 10, 1997 – 2002.

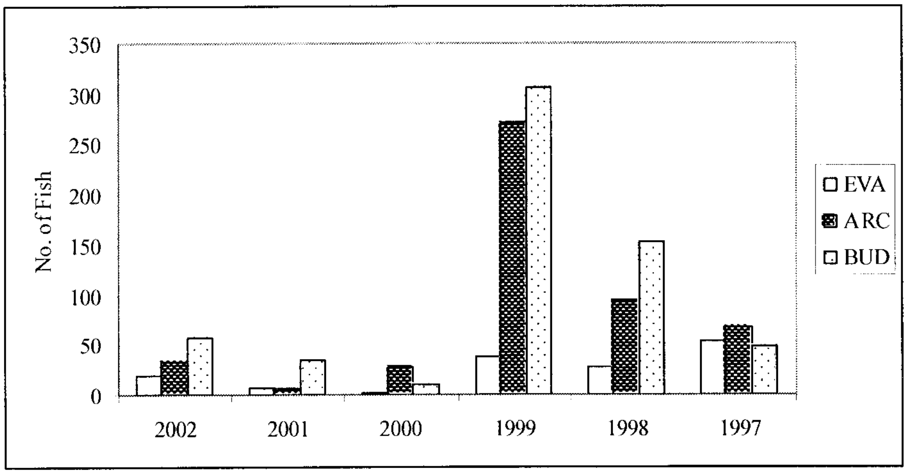


Figure 121. Juvenile fish in Evaingiknuk Creek (EVA, tributary to the Noatak River), Anxiety Ridge Creek (ARC) and Buddy Creek (BUD), 1997–2002.

The length frequency distribution of fish, especially the presence of age-0 fish, indicates successful reproduction (Figure 122). The number of age-0 Dolly Varden was high in both 1997 and 1998 and likely explains the high catch of age-1 and age-2 Dolly Varden in 1999 (DeCicco, ADF&G Sport Fish Biologist, pers. comm. 2000). Overall numbers of juvenile Dolly Varden captured increased substantially from 1997 to 1998 and from 1998 to 1999.

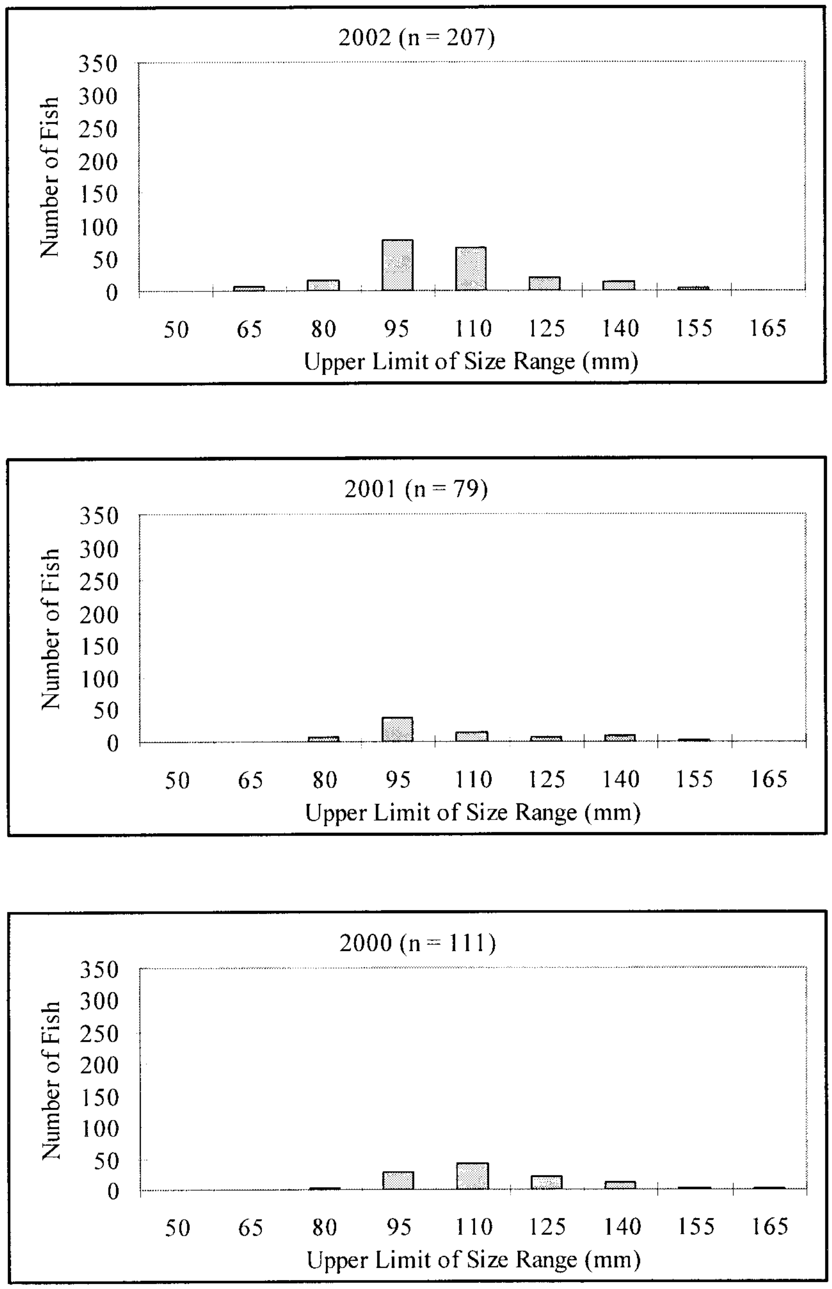


Figure 122. Juvenile Dolly Varden captured from 1997 through 2002, all sites combined.

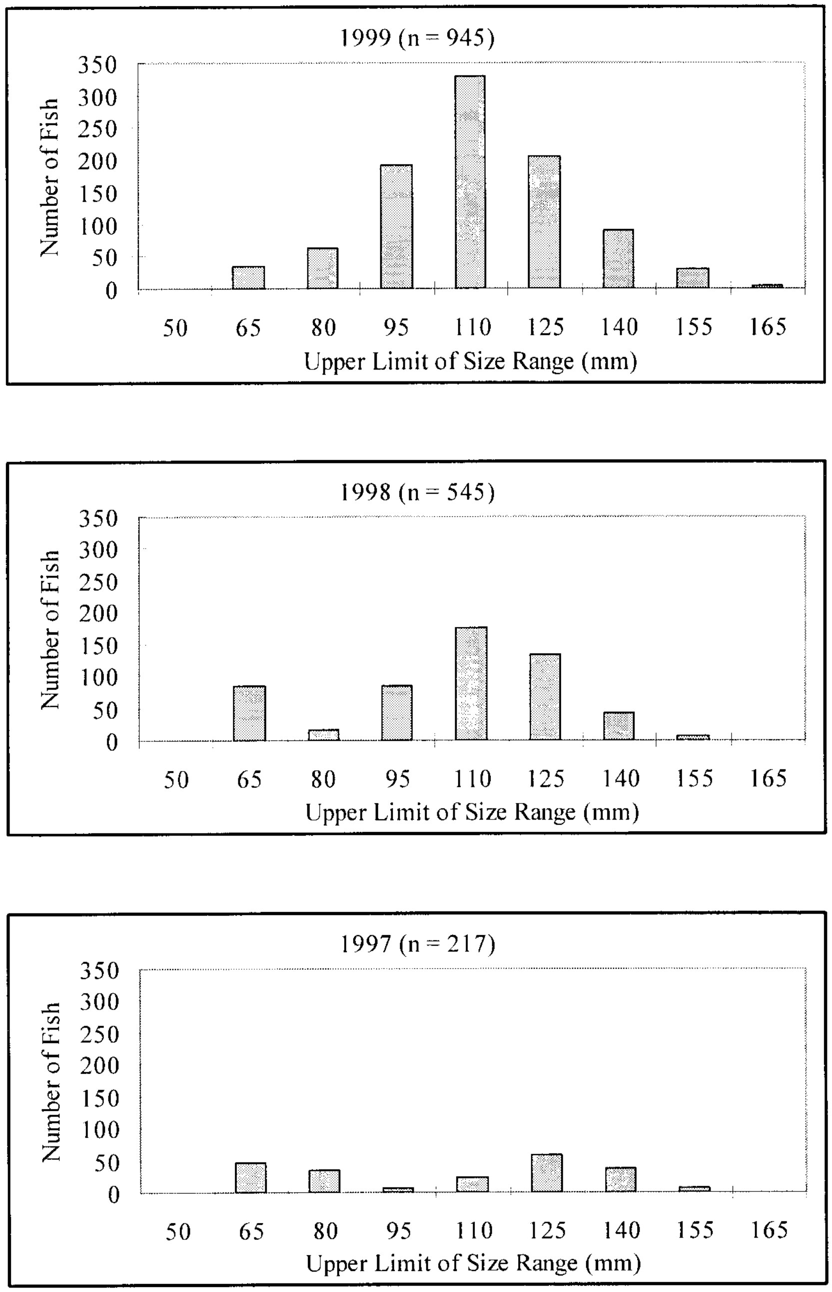


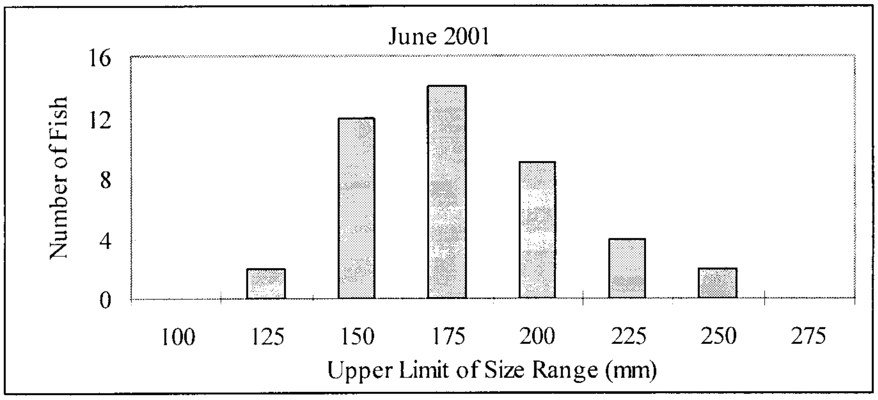
Figure 122. Juvenile Dolly Varden captured from 1997 through 2002, concluded.

Numbers of fish doubled with strong age-0 recruitment in both 1997 and 1998; age-0 recruitment was less in 1999. Catches of age-0 Dolly Varden remained low in Summers 2000 and 2001, but increased in Fall 2002 with some age-0 fish present in the sample. The length-distribution figures show declines in larger juvenile Dolly Varden as they smolt and migrate to marine water. Smolting can occur as early as age 2, but more commonly at age 3 (DeCicco 1990a).

Fyke Net sampling for Dolly Varden

Fyke nets were set in North Fork Red Dog Creek to assess the timing of migration into the creek for summer rearing. Fyke nets were fished from May 30 through June 8, 2002, but only two juvenile Dolly Varden (156mm, 178 mm) were caught. The catch of juvenile Dolly Varden in 2002 is considerably lower than previous years: 43 juvenile Dolly Varden were captured in early June 2001 and 18 were caught in early June 2000 (Figure 123). In 2002, fyke nets were pulled immediately after the Arctic grayling spawning migration was over and probably before the peak movement of juvenile Dolly Varden.

In baseline studies, Houghton and Hilgert (1983) only found juvenile Dolly Varden in the headwaters of North Fork Red Dog Creek. Our spring and mid-summer sampling found larger Dolly Varden Throughout the system. These resident Dolly Varden may preferentially select streams also used by Arctic grayling for spawning to feed on the eggs and age-0 Arctic grayling.



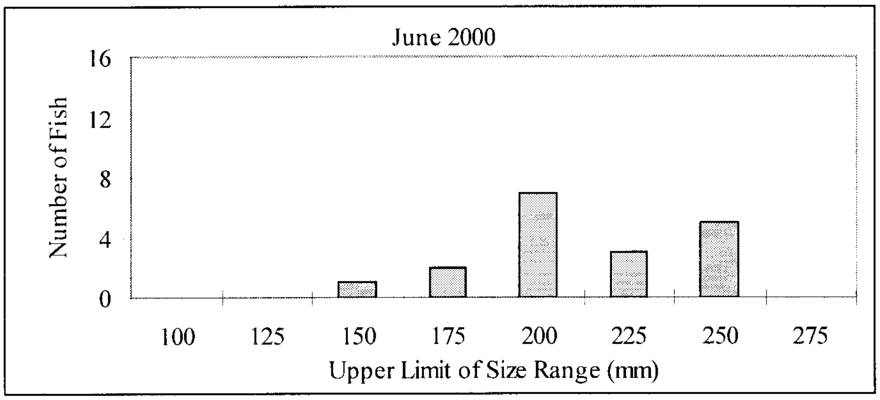


Figure 123. Dolly Varden in North Fork and Mainstem Red Dog creeks in June 2000 (n=18) and 2001 (n=43).

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. Age-0 Arctic grayling left as water temperatures cooled in fall or were displaced by summer high-water events.

Since 1993, we have found adult and age-0 Arctic grayling in North Fork Red Dog Creek. The presence of age-0 fish confirms spawning (Table 13). High numbers of juvenile Arctic grayling in Summer 1999 indicate spawning and survival in 1996 and

1997. In July 2000, we had high catches of small Arctic grayling in the North Fork Red Dog Creek fyke net (Figure 124), however high catches were not observed in Summer 2001. In Summer 2002, the catch of smaller Arctic grayling was higher than in 2001 but less than Summer 2000 (Figure 124). The cohorts of Arctic grayling produced in 1996 and 1997 have been observed each year. These groups of juvenile fish should recruit to the spawning population of fish using Mainstem Red Dog and North Fork Red Dog creeks within the next two years.

Table 13. Relative number of age-0 Arctic grayling observed in North Fork Red Dog Creek (1992–2002).

Year	Relative Number of Age-0 Fish	Comments
1992	high	100s 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 10 mm > same time 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% complete by June 14.
		age-0 fish small (<25 mm) and rare in mid-July
2001	low	cold water, late breakup, spawning 90% complete by June 19.
		age-0 fish small (<25 mm) and rare in late-July
2002	low	high flows, spawning 90% complete by June 8, age-0 fish small
		(<35 mm) in early August and rare, more age-0 fish seen
		in Ikalukrok in early July, probably displaced by high water

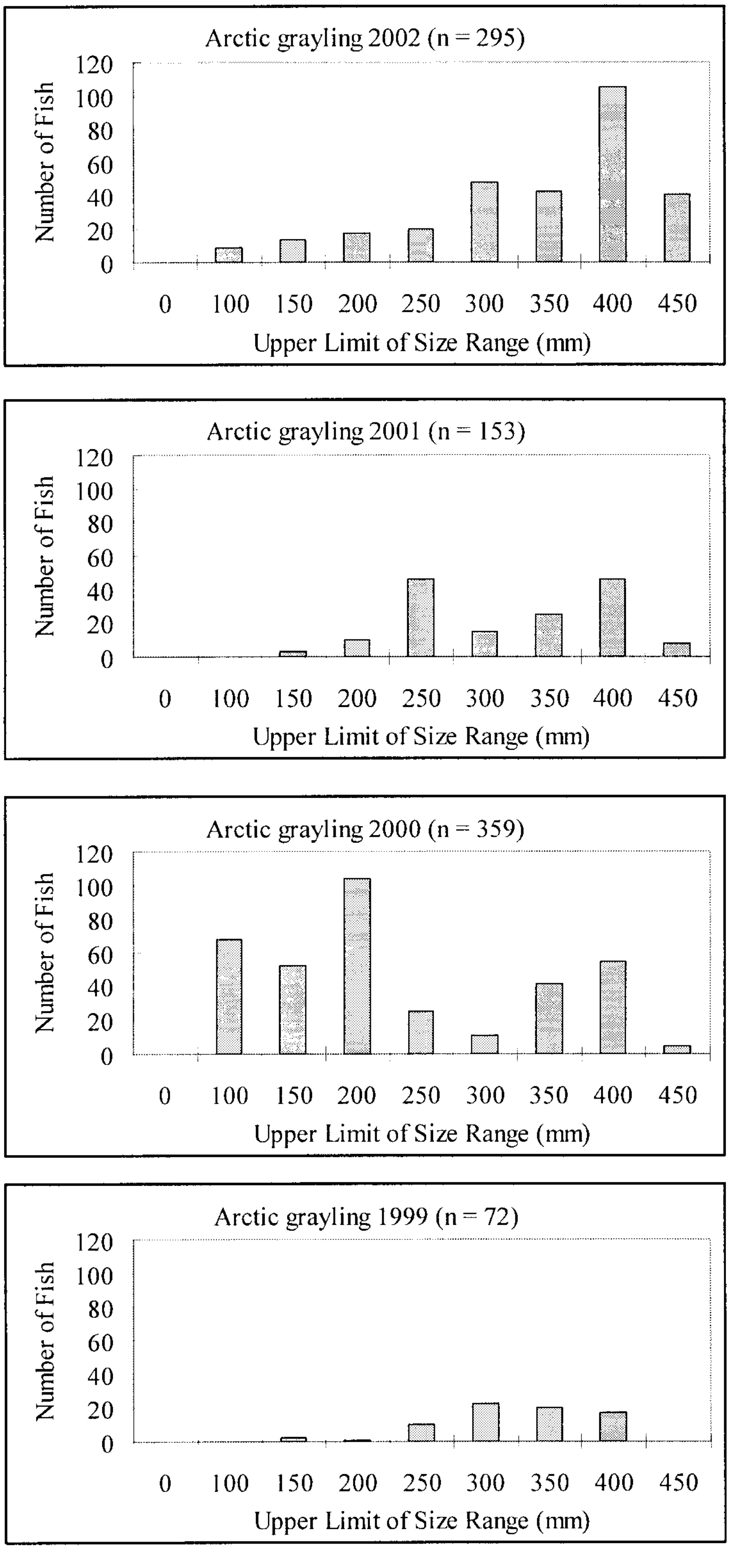


Figure 124. Summer caught Arctic grayling 1999-2002, in North Fork and Mainstem Red Dog creeks.

Timing of Arctic Grayling Spawning

Water temperature is a likely factor in determining spawning time, emergence of age-0 fish and potential first year growth. Or the past four years, ADF&G has monitored water temperatures and Arctic grayling spawning condition during spring breakup. The North Fork Red Dog Creek warmed earlier in 1999 and 2002 than the other two years (Figure 125). Earlier breakup was correlated with earlier spawning and, in 1999, with higher survival of young of the year fish. Summer sampling in 1999 found numerous age-0 fish throughout North Fork Red Dog Creek. In 2002 age-0 fish were fairly abundant in Ikalukok Creek; these fish may have been displaced from spawning areas in North Fork Red Dog Creek by high water.

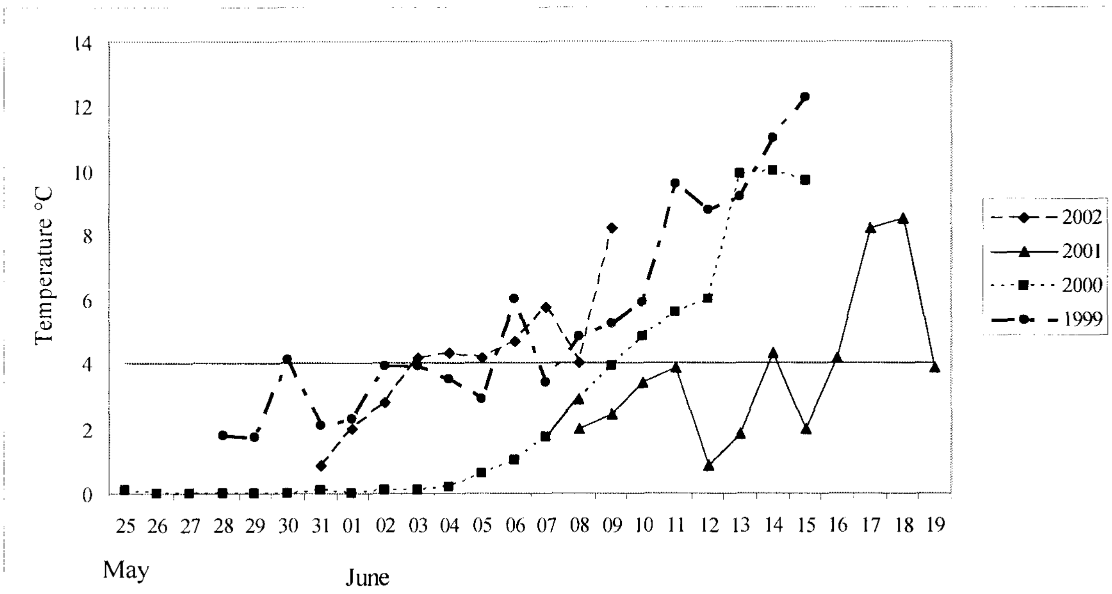


Figure 125. Water temperature (°C) in North Fork Red Dog Creek during spring breakup in 1999, 2000, 2001 and 2002.

In Spring 2002, severe icing conditions and high flows reduced fyke-net efficiency on several days. Nets were first set on May 29 in North Fork Red Dog Creek and May 30 in Mainstem Red Dog Creek. Migration of spawning sized male Arctic grayling had already begun and females were beginning to moveupstream. Eighty percent of the fish collected in Fyke nets in the first two days were males. Adult females moved into the system shortly after, followed by juvenile fish. When caught in North Fork Red Dog Creek fyke nets, adult females already were ripe. By June 5, 2002 almost all females captured in North Fork Red Dog Creek were spent, indicating spawning had occurred in this area (Figure 126). The high proportion of spent and partially spent fish in the North Fork Red Dog Creek Fyke net indicates that spawning has already occurred in downstream Red Dog Creek. While the relative number of females showing signs of having spawned in Mainstem Red Dog Creek generally remained above 70% after June 5, A few ripe females were collected in North Fork Red Dog Creek on June 7, these fish likely moved farther upstream to spawn..

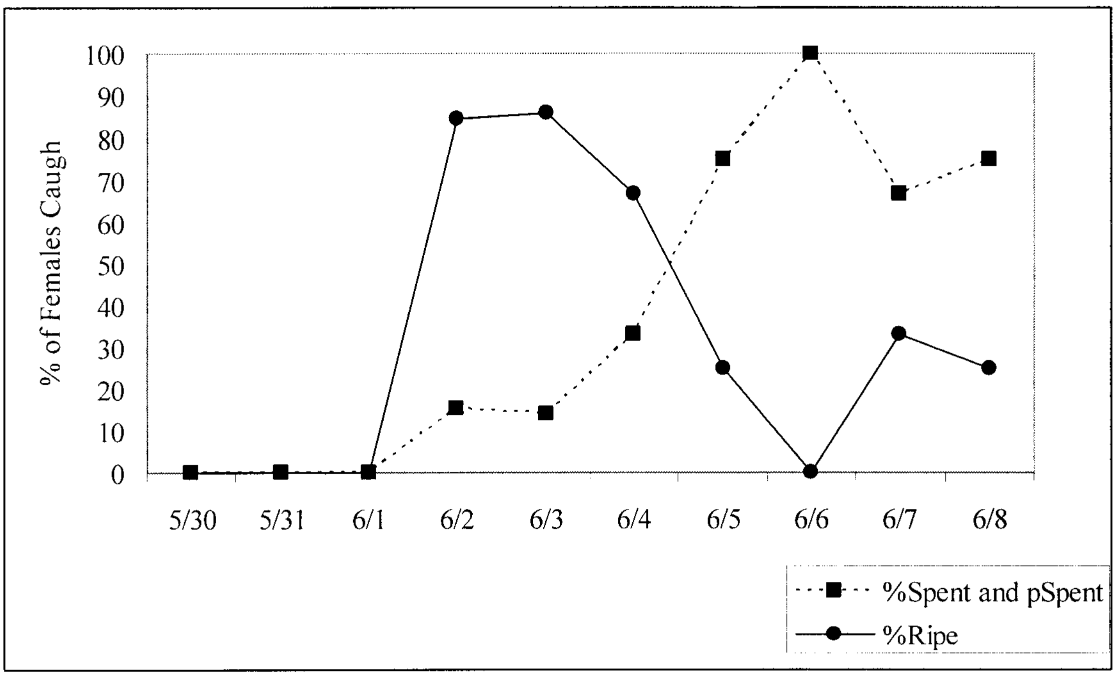


Figure 126. Percent of adult Arctic grayling females ripe and spent or partially spent (p/spent) in North Fork Red Dog Creek.

Visual observation and angling in Mainstem Red Dog Creek on June 7, 2002 confirmed that the majority of spawning was complete. With this confirmed completion of spawning Teck-Cominco received authorization to increase the effluent discharge.

Water temperatures in North Fork Red Dog Creek (Station 12) and Mainstem Red Dog Creek (Station 10) in Spring 2001 (Fig. 127) and 2002 (Fig. 128) explain, in large part, the timing and completion of spawning in these two creeks. Temperatures warm earlier in Mainstem Red Dog Creek and are consistently higher than in North Fork Red Dog Creek.

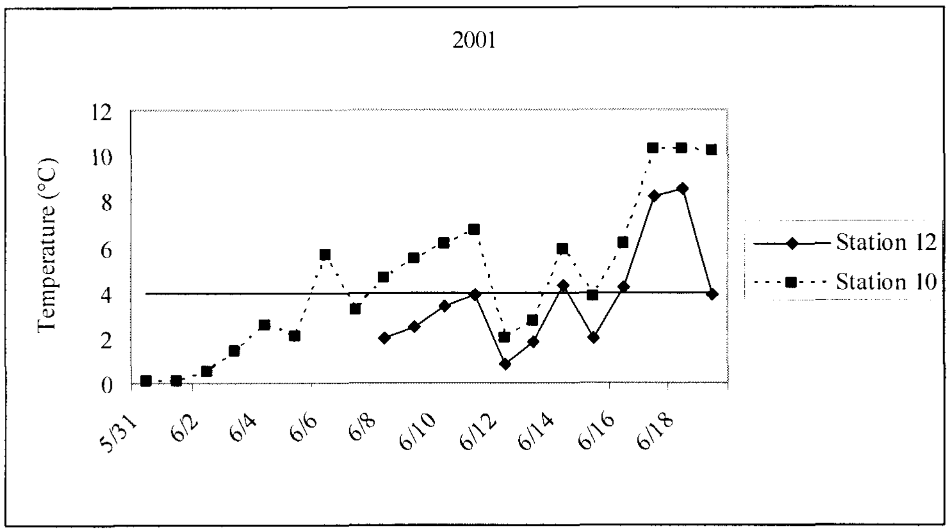


Figure 127. Water temperature (°C) in North Fork Red Dog and Mainstem Red Dog creeks in Spring 2001.

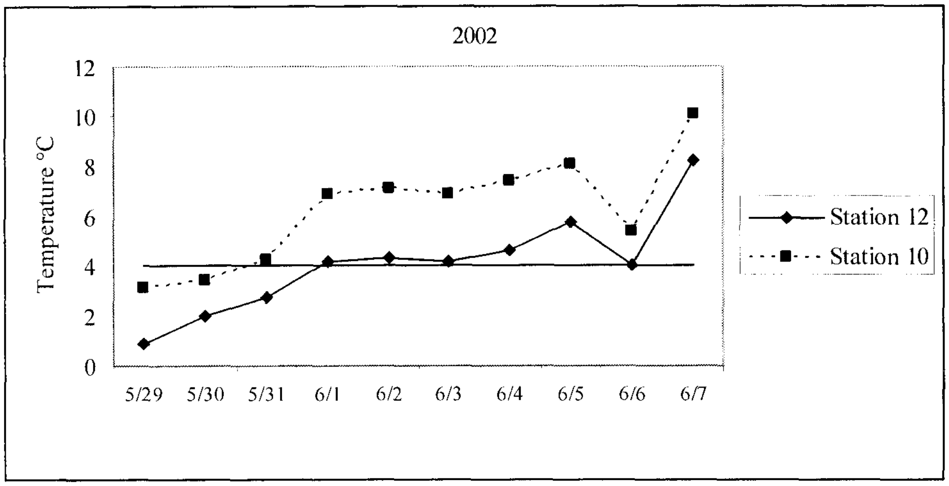


Figure 128. Water temperature (°C) in North Fork Red Dog and Mainstem Red Dog creeks in Spring 2002.

Warmer Middle Fork Red Dog Creek temperatures result, in part, from the warmer mine effluent; North Fork Red Dog Creek is cooler from extensive aufeis.

Arctic grayling mark/recapture

Since 1994 ADF&G has marked adult Arctic grayling with floy tags; in 2002 we recaptured 59 of these marked fish. Most of the fish recaptured in the Red Dog drainage had been originally marked in that drainage; however, a few had been tagged in Grayling Junior Creek.

In Summer 2002, we marked 200 Arctic grayling in the Ikalukrok Creek drainage (Appendix 6). In early July highest concentrations of adult Arctic grayling were in North Fork Red Dog, East Fork Ikalukrok and Buddy creeks. By early August 2002, the adult Arctic grayling had left Buddy Creek, but large numbers remained in North Fork Red Dog Creek. In 2000 and 2001 most of the post-spawning Arctic grayling were found in East Fork Ikalukrok Creek, Grayling Junior Creek, and Ikalukrok Creek at the mouths of Grayling Junior, Mainstem Red Dog and Dudd creeks.

The spawning migration of Arctic grayling was monitored in 2001 and fish were marked and recorded consistent with 2002 sampling methods. Data collected last spring provided adequate numbers of recaptured and new fish to produce an estimate of the number of adult Arctic grayling spawning in Mainstem Red Dog and North Fork Red Dog creeks. Using Chapman's modification of the simple Lincoln-Peterson Model we estimated a spawning population of about 870 fish (95% CI=202, Seber 1982).

Arctic grayling Mainstem Red Dog Creek

Visual surveys of Mainstem Red Dog Creek documented both adult and juvenile Arctic grayling in Spring 2002. However by June 7, 2002 few spent female Arctic grayling or age-0 fish were present in the lower portion of Mainstem Red Dog 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 Anxiety Ridge Creek (Weber Scannell and Ott 1998). The most slimy sculpin are found in Ikalukrok Creek above and below the mouth of Dudd Creek (Figure 129, Appendix 7). Observations indicate slimy sculpin overwinter in lower Ikalukrok Creek and the Wulik River, and probably do not migrate long distances from suitable overwintering habitats.

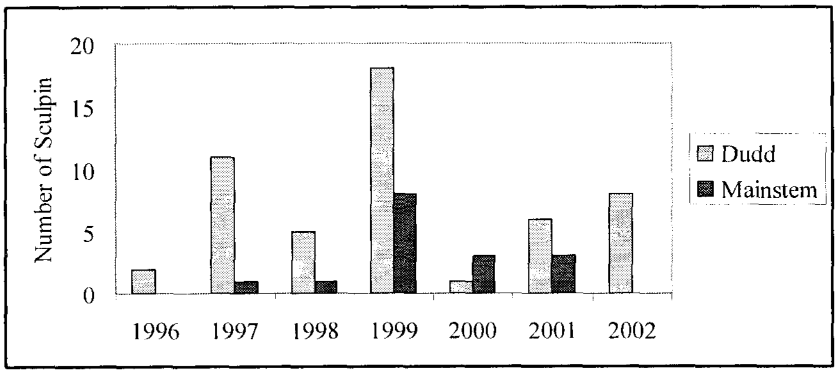


Figure 129. Slimy sculpin collected in Ikalukrok Creek at mouth of Dudd Creek and Mainstem Red Dog creek.

SUMMARY

We found no substantial changes in invertebrate populations, periphyton biomass, or fish migration and use of tributaries downstream of the Red Dog Mine during the NPDES Permit monitoring period (1999-2002). We did not observe fish kills in Mainstem Red Dog or Ikalukrok creeks.

Overall, we found that the number of juvenile Dolly Varden increased in 2002 in comparison with 2000 and 2001, but Dolly Varden were not as numerous in the catch as in 1998 and 1999. A few age-0 Dolly Varden were caught in Summer 2002 and numbers of adults and spawners in the Wulik River system were low. However, the number of adult spawners in Ikalukrok Creek, specifically at the mouth of Dudd Creek, was higher than previously observed.

Chum salmon adults in Ikalukrok Creek were lower than in 2001, but the count of about 890 adults represented a good return in comparison with previous years counts.

Survival of age-0 Arctic grayling in 2002 was suspected to be low due to high water during spawning; however, conditions were ideal after spawning with warm temperatures and low rainfall.

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

1982

- Baseline studies initiated, Teck-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

1989

- Agreement to close-out old solid waste site finalized with Teck-Cominco
- Civil work on ore body and surface water drainage control begun
- Complaints about water quality in Ikalukrok Creek received
- Tailing dam becomes full, Teck-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 Teck-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 Teck-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 Teck-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
- Teck-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 Teck-Cominco, approved by state agencies
- ADF&G fisheries study funded by Teck-Cominco
- Clean water bypass system built
- Clean water bypass system repaired
- Improvements to water quality were documented

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 Teck-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

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
- USEPA brings enforcement action for water quality violations; Teck-Cominco initiates Supplemental Environmental Projects
- Two-year aquatic community study in upper Ikalukrok Creek, above and below the Red Dog Mine discharge site initiated by ADF&G
- Ground water monitoring wells installed and monitored below tailing dam by Teck-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 USEPA
- Two-year aquatic community study completed
- Biomonitoring, including studies of fish and aquatic biota, required under 1998 NPDES Permit

1999

- Two-year drilling program (Shelly and Connie creeks) proposed
- Station 7 established on Ikalukrok Creek by Teck-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 Teck-Cominco
- Study of periphyton communities exposed to different concentrations of TDS in Mainstem Red Dog Creek done by ADF&G and Teck-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 north of dump
- Site-specific criteria for TDS requested by Teck-Cominco
- Biomonitorig study continued
- Baseline fish and aquatic biota studies in streams located in the vicinity of Anarraaq Prospect began

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 Bonns 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
- ADF&G is continuing to collect site-specific information on Arctic grayling spawning in relation to water temperature in North Fork Red Dog and Mainstem Red Dog creeks. Similar studies are being done 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 hard-covered trucks brought on site 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 TDS, 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

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, similar studies are being done at Ft. Knox Mine
- 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 through 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 clean-water overflow and direct it 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 information for TDS 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 TDS, 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 2. DOLLY VARDEN AERIAL SURVEYS

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

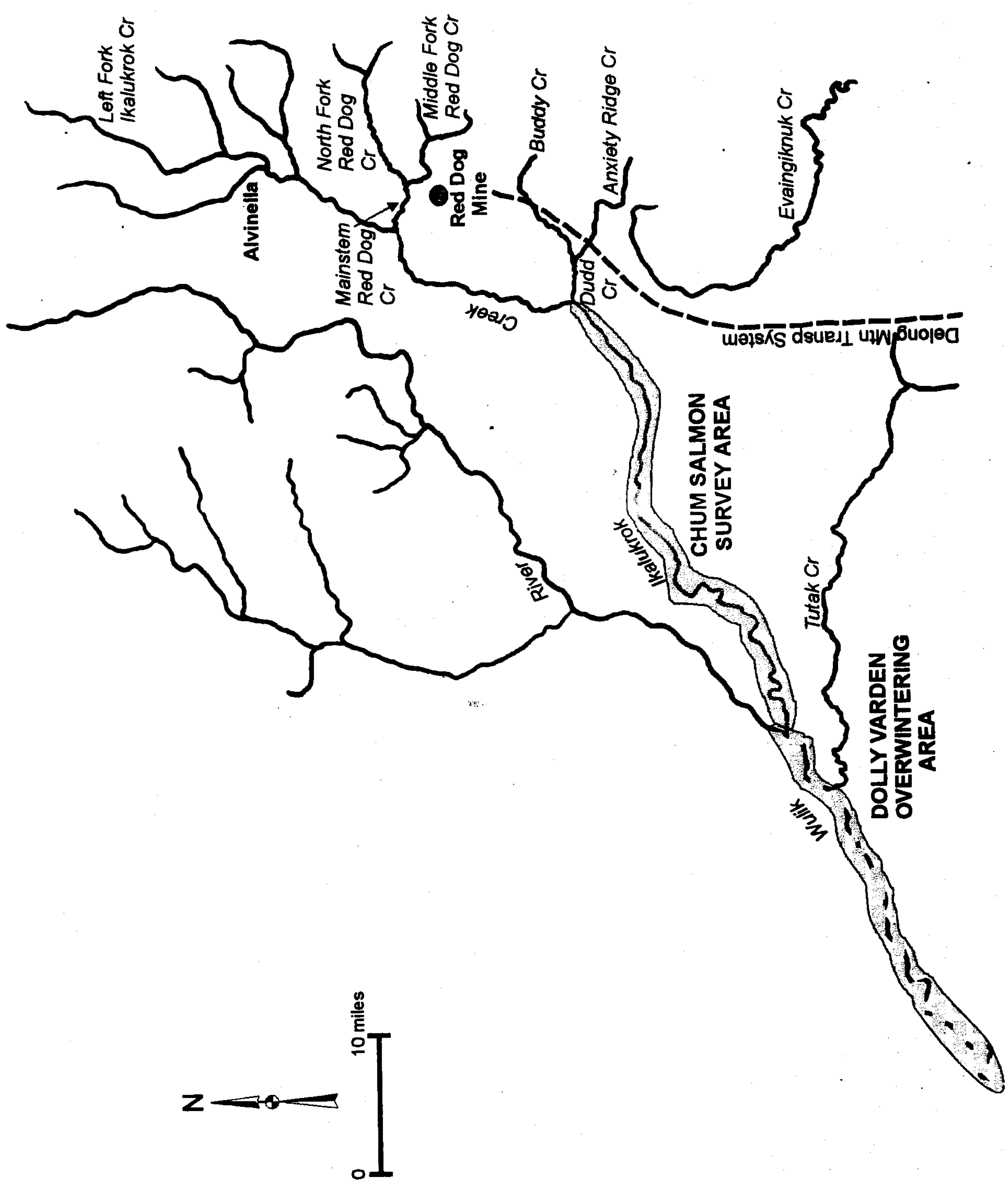
Year Surveyed	Wulik River upstream of Ikalukrok Creek	Wulik River downstream of Ikalukrok Creek	Total Fish	Percent of Fish downstream of Ikalukrok Creek
Before Mining				
1979	3,305	51,725	55,030	94
1980	12,486	101,067	113,553	89
1981	4,125	97,136	101,261	96
1982	2,300	63,197	65,497	97
1984	370	30,483	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

The population estimate (mark/recapture) for winter 1988/1989 for fish >400 mm was 76,892 (DeCicco 1990b).

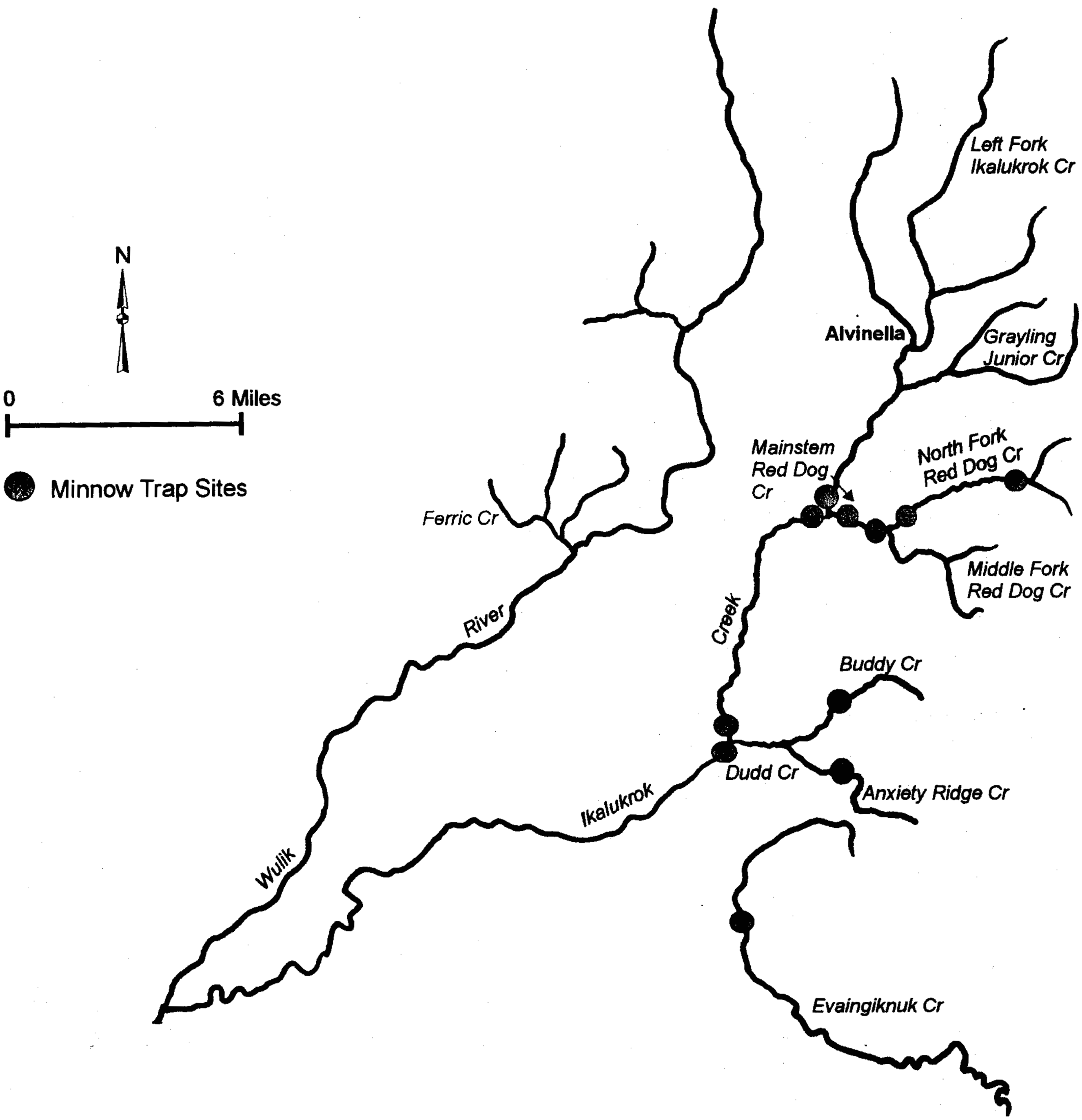
The population estimate (mark/recapture) for winter 1994/1995 for fish >400 mm was 361,599 (DeCicco 1996c)

Fall 2000 aerial survey was not made due to weather.

APPENDIX 3. ADULT DOLLY VARDEN AND CHUM SALMON SURVEY AREAS



APPENDIX 4. JUVENILE DOLLY VARDEN SAMPLE AREAS.



APPENDIX 5. FYKE-NET AND ANGLING

SUMMARY OF FISH TAGGED IN 2002

Mainstem Red Dog	47
Grayling Junior Creek	4
Buddy Creek	8
North Fork Red Dog	141

ARCTIC GRAYLING MARKED IN IKALUKROK CREEK DRAINAGE SUMMER 2002.

Tag Number	Color	Length (mm)	Tag Scar	Date Captured	Site Captured
13249	Green	399		5/30/2002	North Fork
13248	Green	381	OTS	5/30/2002	North Fork
13247	Green	400		5/30/2002	North Fork
13246	Green	415		5/30/2002	North Fork
13245	Green	383		5/30/2002	North Fork
13244	Green	382		5/31/2002	North Fork
13243	Green	383	OTS	5/31/2002	North Fork
13236	Green	410		5/31/2002	North Fork
13235	Green	385	OTS	5/31/2002	North Fork
13234	Green	406		5/31/2002	North Fork
13233	Green	381		5/31/2002	North Fork
13232	Green	400		5/31/2002	North Fork
13231	Green	383		5/31/2002	North Fork
13230	Green	396		5/31/2002	North Fork
13229	Green	410		6/1/2002	North Fork
13228	Green	390	FTS	6/1/2002	North Fork
13227	Green	372		6/1/2002	North Fork
13225	Green	387		6/1/2002	North Fork
13226	Green	389	FTS	6/1/2002	North Fork
13217	Green	290		6/1/2002	North Fork
13207	Green	365		6/1/2002	North Fork
13240	Green	348		6/1/2002	North Fork
13250	Green	343		6/2/2002	North Fork
13299	Green	340		6/2/2002	North Fork
13298	Green	402		6/2/2002	North Fork
13297	Green	372		6/2/2002	North Fork
13296	Green	355		6/2/2002	North Fork
13295	Green	350		6/2/2002	North Fork

Tag Number	Color	Length (mm)	Tag Scar	Date Captured	Site Captured
13294	Green	363		6/2/2002	North Fork
13288	Green	382		6/2/2002	North Fork
13287	Green	372		6/2/2002	North Fork
13286	Green	391		6/2/2002	North Fork
13285	Green	318		6/2/2002	North Fork
13284	Green	349		6/2/2002	North Fork
13283	Green	369		6/2/2002	North Fork
13282	Green	377		6/2/2002	North Fork
13281	Green	372		6/2/2002	North Fork
13280	Green	254		6/2/2002	North Fork
13279	Green	410		6/2/2002	North Fork
13278	Green	343		6/3/2002	North Fork
13275	Green	307		6/3/2002	North Fork
13324	Green	333	OTS	6/3/2002	North Fork
13323	Green	292		6/3/2002	North Fork
13322	Green	353		6/3/2002	North Fork
13321	Green	282		6/3/2002	North Fork
13320	Green	292		6/3/2002	North Fork
13319	Green	277		6/3/2002	North Fork
13318	Green	359		6/3/2002	North Fork
13312	Green	222		6/4/2002	North Fork
13311	Green	340		6/4/2002	North Fork
13310	Green	282		6/4/2002	North Fork
13309	Green	235		6/4/2002	North Fork
13308	Green	287		6/4/2002	North Fork
13307	Green	394		6/5/2002	North Fork
13306	Green	261		6/5/2002	North Fork
13305	Green	226		6/5/2002	North Fork
13304	Green	375	FTS	6/5/2002	North Fork
13303	Green	345		6/6/2002	North Fork
13302	Green	420		6/6/2002	North Fork
13301	Green	339		6/6/2002	North Fork
13300	Green	356		6/6/2002	North Fork
13349	Green	234		6/6/2002	North Fork
13348	Green	248		6/6/2002	North Fork
13347	Green	270		6/6/2002	North Fork
13346	Green	244		6/6/2002	North Fork
13345	Green	394		6/7/2002	North Fork
13344	Green	358		6/7/2002	North Fork
13343	Green	325		6/7/2002	North Fork
13342	Green	257		6/7/2002	North Fork

Tag Number	Color	Length (mm)	Tag Scar	Date Captured	Site Captured
13341	Green	260		6/7/2002	North Fork
13329	Green	386		6/7/2002	North Fork
13328	Green	252		6/7/2002	North Fork
13327	Green	375		6/8/2002	North Fork
13326	Green	277		6/8/2002	North Fork
13325	Green	350		6/8/2002	North Fork
13374	Green	320		6/8/2002	North Fork
13373	Green	303		6/8/2002	North Fork
13372	Green	266		6/8/2002	North Fork
13371	Green	304		6/8/2002	North Fork
13370	Green	248		6/8/2002	North Fork
13369	Green	216		6/8/2002	North Fork
13368	Green	204		6/8/2002	North Fork
13367	Green	210		6/8/2002	North Fork
13366	Green	250		6/8/2002	North Fork
13242	Green	352		5/31/2002	Mainstem
13241	Green	374		5/31/2002	Mainstem
13239	Green	360		5/31/2002	Mainstem
13238	Green	355		5/31/2002	Mainstem
13237	Green	420		5/31/2002	Mainstem
13274	Green	410		6/1/2002	Mainstem
13273	Green	420		6/1/2002	Mainstem
13272	Green	420		6/1/2002	Mainstem
13271	Green	390		6/1/2002	Mainstem
13270	Green	382		6/1/2002	Mainstem
13269	Green	420		6/1/2002	Mainstem
13268	Green	355		6/1/2002	Mainstem
13267	Green	380		6/1/2002	Mainstem
13266	Green	388		6/1/2002	Mainstem
13265	Green	420		6/1/2002	Mainstem
13264	Green	394		6/1/2002	Mainstem
13263	Green	410		6/1/2002	Mainstem
13262	Green	396		6/1/2002	Mainstem
13261	Green	420		6/1/2002	Mainstem
13260	Green	440		6/1/2002	Mainstem
13259	Green	420		6/1/2002	Mainstem
13258	Green	410		6/1/2002	Mainstem
13257	Green	361		6/1/2002	Mainstem
13256	Green	370		6/1/2002	Mainstem
13255	Green	415		6/1/2002	Mainstem
13254	Green	361		6/1/2002	Mainstem

Tag Number	Color	Length (mm)	Tag Scar	Date Captured	Site Captured
13205	Green	400		6/1/2002	Mainstem
13204	Green	383		6/1/2002	Mainstem
13203	Green	430		6/2/2002	Mainstem
13202	Green	385		6/2/2002	Mainstem
13201	Green	393		6/2/2002	Mainstem
13200	Green	285		6/2/2002	Mainstem
13253	Green	410	OTS	6/2/2002	Mainstem
13252	Green	382		6/2/2002	Mainstem
13251	Green	365		6/2/2002	Mainstem
13293	Green	338		6/2/2002	Mainstem
13292	Green	393		6/2/2002	Mainstem
13291	Green	415		6/2/2002	Mainstem
13290	Green	415		6/2/2002	Mainstem
13289	Green	256		6/2/2002	Mainstem
13277	Green	305		6/3/2002	Mainstem
13276	Green	260		6/3/2002	Mainstem
13317	Green	215		6/4/2002	Mainstem
13316	Green	268		6/4/2002	Mainstem
13315	Green	308		6/4/2002	Mainstem
13314	Green	325		6/4/2002	Mainstem
13313	Green	257		6/4/2002	Mainstem
13365	Green	290		7/7/2002	North Fork
13364	Green	270		7/7/2002	Buddy
13363	Green	356		7/7/2002	Buddy
13362	Green	260		7/7/2002	Buddy
13361	Green	248		7/7/2002	Buddy
13360	Green	366		7/7/2002	Buddy
13359	Green	264		7/7/2002	Buddy
13358	Green	236		7/7/2002	Buddy
13357	Green	278		7/7/2002	Buddy
13356	Green	264		7/8/2002	North Fork
13355	Green	264		7/8/2002	North Fork
13354	Green	238		7/8/2002	North Fork
13353	Green	265		7/9/2002	North Fork
13352	Green	249		7/9/2002	North Fork
13351	Green	240		7/9/2002	North Fork
13350	Green	276		7/9/2002	North Fork
13399	Green	246		7/9/2002	North Fork
13398	Green	330		7/9/2002	North Fork
13397	Green	350		7/9/2002	North Fork
13396	Green	318		7/9/2002	North Fork

Tag Number	Color	Length (mm)	Tag Scar	Date Captured	Site Captured
13395	Green	302		7/9/2002	North Fork
13394	Green	243		7/9/2002	North Fork
13393	Green	271		7/9/2002	North Fork
13392	Green	261		7/9/2002	North Fork
13391	Green	404		7/9/2002	North Fork
13390	Green	276		7/9/2002	North Fork
13389	Green	263		7/9/2002	North Fork
13388	Green	265		7/9/2002	North Fork
13387	Green	288		7/9/2002	North Fork
13386	Green	306		7/9/2002	North Fork
13385	Green	310		7/9/2002	North Fork
13384	Green	280		7/9/2002	North Fork
13383	Green	313		7/9/2002	North Fork
13382	Green	267		7/9/2002	North Fork
13381	Green	420		8/1/2002	Gray Jr. Mouth
13380	Green	293		8/1/2002	Gray Jr. Mouth
13379	Green	235		8/1/2002	Gray Jr. Mouth
13378	Green	412		8/1/2002	Gray Jr. Mouth
13377	Green	378		8/6/2002	North Fork
13376	Green	368		8/6/2002	North Fork
13375	Green	374		8/6/2002	North Fork
13449	Green	390		8/6/2002	North Fork
13448	Green	290		8/6/2002	North Fork
13447	Green	270		8/6/2002	North Fork
13446	Green	288		8/6/2002	North Fork
13445	Green	395		8/6/2002	North Fork
13444	Green	353		8/6/2002	North Fork
13443	Green	352		8/6/2002	North Fork
13442	Green	313		8/6/2002	North Fork
13441	Green	272		8/6/2002	North Fork
13440	Green	313		8/6/2002	North Fork
13439	Green	280		8/6/2002	North Fork
13436	Green	410		8/6/2002	North Fork
13437	Green	300		8/6/2002	North Fork
13438	Green	418		8/6/2002	North Fork
13435	Green	348		8/6/2002	North Fork
13434	Green	278		8/6/2002	North Fork
13433	Green	250		8/6/2002	North Fork
13432	Green	295		8/6/2002	North Fork
13431	Green	288		8/6/2002	North Fork
13430	Green	360		8/6/2002	North Fork

Tag Number	Color	Length (mm)	Tag Scar	Date Captured	Site Captured
13429	Green	300		8/6/2002	North Fork
13428	Green	295		8/6/2002	North Fork
13427	Green	274		8/6/2002	North Fork
13426	Green	355		8/6/2002	North Fork
13425	Green	290		8/6/2002	North Fork
13424	Green	310		8/6/2002	North Fork
13422	Green	385		8/6/2002	North Fork
13421	Green	345		8/6/2002	North Fork

APPENDIX 6. ARCTIC GRAYLING VISUAL OBSERVATIONS

Observations and captures 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)
7/28/2002	visual	adults present in lower 2 km, 3 to 4 per pool
7/27/2002	visual	few age-0 (less than 10)
6/7/2002	angling	10 adults and 3 juveniles captured, marked, released
		near Sta. 10, most females spent
6/4/2002	fyke	3 adults and 3 juveniles captured, marked, released
		near Sta. 10
6/3/2002	fyke	3 adults captured, marked, released near Sta. 10
6/2/2002	fyke	8 adults captured, marked, released near Sta. 10
6/1/2002	fyke	31 adults captured, marked, released near Sta. 10
5/31/2002	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
6/17/2001	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)
7/28/2000	visual	several age-0 in backwaters and along stream
		margins, not numerous
7/6/2000	visual	walked most of creek, tagged 3 adults near Sta. 10
		most pools held 1 to 3 adults
7/5/2000	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
5/30/1999	fyke	32 adults caught about 100 m below North Fork mouth
5/29/1999	angling	3 adults caught just below North Fork mouth
6/28/1998	visual	1 adult feeding at rock bluff 0.8 km below North Fork
		mouth

Sample Date	Sample Method	Comments on Arctic Grayling (age-0 = young of the year)
6/10/1998	visual	no fish seen between North Fork mouth and rock bluff
9/29/1997	traps	7 age-0 caught near Sta. 10
8/10/1997	visual	age-0 in backwaters
6/27/1997	visual	age-0 numerous at Sta. 10
6/26/1997	angling	15 adults captured, marked, released at mouth of
		creek, 8 were spent fish
6/25/1997	drift net	age-0 caught at Sta 10, 13-15 mm long
6/25/1997	visual	2 adults at rock bluff 0.8 km below North Fork mouth
8/12/1996	visual	age-0 near rock bluff about 0.8 km below North Fork
8/11/1996	visual	age-0 in shallow eddies at mouth
7/15/1996	angling	7 adults captured, marked, released about 2 km
		above mouth
6/19/1996	visual	1 adult near Sta. 10
8/14/1995	angling	11 adults captured, marked, released near rock bluff
		about 0.8 km below North Fork
8/11/1995	visual	age-0 (about 30) below North Fork
8/11/1995	visual	1 adult near rock bluff about 0.8 km below North Fork
7/20/1995	visual	1 adult near rock bluff about 0.8 km below North Fork
7/17/1995	angling	2 adults near rock bluff about 0.8 km below North Fork
6/29/1995	angling	1 adult just below North Fork
7/27/1994	visual	2 adults just below North Fork

APPENDIX 7. SLIMY SCULPIN

Collected in Ikalukrok Creek at the mouth of Dudd Creek and Mainstem Red Dog Creeks.

Creek	Year	No. of Sample Periods	No. of Traps Used	No. of Slimy Sculpin
Ikalukrok	2002	2	20	8
(at Dudd Cr.)	2001	2	20	6
	2000	2	20	1
	1999	2	20	18
	1998	2	20	5
	1997	2	20	11
	1996	2	20	2
	1995	3	20	8
	1994	1	20	8
	1993	2	10	2
	1992	3	10	3
	1991	4	5	3
	1990	3	5	0
Ikalukrok	2002	2	20	0
(at Red Dog)	2001	2	20	3
	2000	2	20	3
	1999	2	20	8
	1998	2	20	1
	1997	2	20	1
	1996	2	20	0