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Technical Report No. 02-04

Aquatic Biomonitoring
At Red Dog Mine, 2001
National Pollution Discharge Elimination System
Permit NO. AK-003865-2

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May 2002

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

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Acknowledgements

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Executive Summary

The following tables compare results of invertebrate, periphyton, and fish sampling at each of the NPDES-monitored sites in 2001 with results from combined 1999-00. The NPDES permit has been in effect since 1999. Each table contains a page number of the section of the document where the respective result is presented in greater detail.

Table 1. Station 9, Ikalukrok Creek upstream of Red Dog Creek

		1999-00 Average	2001 Average	2001 compared to 1999-00 Higher	Lower	NSC*	Page #
Invertebrate Populations	Density, #/m^3 water	1.0	11.7	x			15
	Abundance, #/net	111.5	1777.5	x			15
	Total taxa	6.4	10	x			15
Periphyton	mg Chlor-a/m^2	0.676	0.130		x		17

Fish Populations		1999-00 Range	No. Caught in 2000	More than 1999-00	Less than 1999-00	Within Range	
Juvenile Dolly Varden		5-41	2		x		71-75

*NSC = No Significant Change, 2001 average within 95% confidence interval for 1999-00.

Table 2. Station 8: Ikalukrok Creek downstream of Red Dog Creek

		1999-00 Average	2001 Average	2001 compared to 1999-00 Higher	Lower	NSC*	Page #
Invertebrate Populations	Density, #/m^3 water	0.69	0.44			x	20
	Abundance, #/net	31.4	31			x	20
	Total taxa	5.7	6			x	21
Periphyton	mg Chlor-a/m^2	1.0	1.28			x	22

		1999-00 Range	No. Caught in 2000	More than 1999-00	Less than 199-00	Within Range	
Juvenile Dolly Varden		6-28	11			x	76-79

*NSC = No Significant Change, 2001 average within 95% confidence interval for 1999-00.

Table 3. Ikalukrok Creek upstream of Dudd Creek

		1999-00 Average	2001 Average	2001 compared to 1999-00 Higher	Lower	NSC*	Page #
Invertebrate Populations	Density, #/m^3 water	1.0	11.7	x			26
	Abundance, #/net	111.5	1777.5	x			26
	Total taxa	6.4	10	x			27
Periphyton	mg Chlor-a/m^2	0.676	0.130		x		28

		1999-00 Range	No. Caught in 2000	More than 1999-00	Less than 1999-00	Within Range	
Juvenile Dolly Varden		14-37	0		x		76-79

*NSC = No Significant Change, 2001 average within 95% confidence interval for 1999-00.

Table 4. Station 7, Ikalukrok Creek downstream of Dudd Creek

		1999-00 Average	2001 Average	2001 compared to 1999-00 Higher	Lower	NSC*	Page #
Invertebrate Populations	Density, #/m^3 water	3.5	4.0			x	34
	Abundance, #/net	293	467			x	34
	Total taxa	7.4	13.6	x			35
Periphyton	mg Chlor-a/m^2	2.65	1.98			x	36

		1999-00 Range	No. Caught in 2000	More than 1999-00	Less than 1999-00	Within Range	
Juvenile Dolly Varden		31-55	6		x		76-79

*NSC = No Significant Change, 2001 average within 95% confidence interval for 1999-00.

Table 5. Station 10, Main Stem Red Dog Creek

		1999-00 Average	2001 Average	2001 compared to 1999-00 Higher	Lower	NSC*	Page #
Invertebrate Populations	Density, #/m^3 water	1.23	3.21	x			42
	Abundance, #/net	147.3	830.2	x			42
	Total taxa	5.9	13.4	x			43
Periphyton	mg Chlor-a/m^2	0.71	1.45	x			44

		1999-00 Range	No. Caught in 2000	More than 1999-00	Less than 1999-00	Within Range	
Juvenile Dolly Varden		1-66	3			x	76-79

*NSC = No Significant Change, 2001 average within 95% confidence interval for 1999-00.

Table 6. Station 20, Middle Fork Red Dog Creek

		1999-00 Average	2001 Average	2001 compared to 1999-00: Higher	Lower	NSC*	Page #
Invertebrate Populations	Density, $\#/m^3$ water	1.29	1.64			x	49
	Abundance, #/net	101.8	286.2	x			50
	Total taxa	8.7	13.2	x			50
Periphyton	mg Chlor-a/m^2	0.01	0.25	x			51

*NSC = No Significant Change, 2001 average within 95% confidence interval for 1999-00.

Table 7. Station 12, North Fork Red Dog Creek.

		1999-00 Average	2001 Average	2001 compared to 1999-00: Higher	Lower	NSC*	Page #
Invertebrate Populations	Density, $\#/m^3$ water	4.9	12.6	x			55
	Abundance, #/net	456.6	645.8			x	56
	Total taxa	8.6	12.6			x	56
Periphyton	mg Chlor-a/m^2	3.03	3.27			x	58

		1999-00 Range	No. Caught in 2000	More than 1999-00	Less than 1999-00	Within Range	
Juvenile Dolly Varden		1-17	1			x	80

*NSC = No Significant Change, 2001 average within 95% confidence interval for 1999-00.

Table 8. Wulik River: Metals Concentrations in Dolly Varden Tissues. Refer to pages 60-64.

Tissue	Analyte mg/kg	1999-00 Average	2001 Average	2001 compared to 1999-00 Higher	Lower	NS*
Gills	Al	54.57	37.3			x
	Cd	0.17	0.20	x, p=0.04		
	Cu	4.02	2.58		x	
	Pb	0.14	0.09		x	
	Se	3.04	3.25			x
	Zn	75.09	83.86			x
Kidney	Al	2.72	2.72			x
	Cd	1.43	1.59			x
	Cu	7.48	4.34			x
	Pb	0.10	0.05			x
	Se	8.42	8.25			x
	Zn	92.30	87.59			x
Muscle	Al	1.16	2.08	X, p<0.02		
	Cd	0.035	0.05**			x
	Cu	2.27	2.61			x
	Pb	0.06	0.05			x
	Se	0.84	1.157**			x
	Zn	15.51	17.08			x
Liver	Al	1.27	2.26	x, p<0.01		
	Cd	.34	0.43			x
	Cu	45.1	38.66			x
	Pb	0.08	0.05			x
	Se	3.39	3.99			x
	Zn	82.05	101.40	x, p=0.02		
Reproductive	Al	1.83	2.76			x
	Cu	20.02	13.52			x
	Pb	0.05	0.05			x
	Se	5.68	4.73			x
	Zn	253.91	181.86			x

*NS = No Significant difference, Two-tailed T-Test, p=0.05.
**Higher method detection limit in 2001.

Table 9. Fish Populations in Wulik River

	1995-1999* Range	2001 Count	2001 compared to 1999-00 Higher	Lower	Within Range	Page #
Chum Salmon spawning populations	45-780	2,250**	x			70
Adult Dolly Varden overwintering population	70,704 to 104,043	92,614			x	69

*No surveys were done in 2000 because of poor weather conditions.
**Numerous counts were made (refer to text), this number represents the highest count for one day's survey.

Table 10. Juvenile Dolly Varden Whole Body Tissues

Tissue	Analyte	1999-00 Average	2001 Average	2001 compared to 1999-00 Higher	Lower	NS*	Page #
Main Stem Red Dog Creek							
	Cd	3.41	3.41			x, p=0.99	65-67
	Pb	8.29	15.20			x, p=0.22	65-67
	Se	7.84	11.36	x, p=0.01			65-67
North Fork Red Dog Creek	No fish found in 2001						
Anxiety Ridge Creek	No fish found in 2001						

*NS = No Significant difference, Two-tailed T-Test, p=0.05.

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, Ott, and Morris 2001.

In July 1998, the US Environmental Protection Agency (US EPA) issued National Pollution Discharge Elimination System (NPDES) Permit No. AK-003865-2 to TeckCominco Alaska Inc. (TeckCominco) 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 the year 2001 biomonitoring studies conducted by the Alaska Department of Fish and Game (ADF&G).

PREVIOUS REPORTS DESCRIBING AQUATIC RESOURCES

Ott and Weber Scannell 1994

Results of a three-year study in the Wulik River drainage to document short-term changes in fish distribution during mine development and operation, and following construction of the water bypass and collection system. The report focused on the distribution and relative abundance of juvenile Dolly Varden (*Salvelinus malma*), use of North Fork Red Dog Creek by Arctic grayling (*Thymallus arcticus*), metals concentrations in adult Dolly Varden tissues, and the population size of adult Dolly Varden in the Wulik River.

Weber Scannell and Ott (1995); Ott and Weber Scannell (1996.)

These two reports present results of a 5-year study to document changes in fish distribution, relative abundance, fish species composition, and metals concentrations in adult Dolly Varden tissues.

The scope of the five-year study was expanded in 1996 to include aerial counts of chum salmon (*Onchorynchus keta*) in Ikalukrok Creek and biomonitoring of aquatic invertebrate abundance and community composition and periphyton standing crop. In 1997, we added Se to the laboratory tissue analyses.

Weber Scannell and Andersen 1999.

ADF&G conducted in-depth biomonitoring of benthic macroinvertebrates and periphyton from selected sites downstream from the Red Dog Mine water treatment plant in 1997 and 1998. The study focused on stream habitats that were directly exposed to mining activity or treated mine effluent and sites that, although not influenced by mining activity, were located in areas of known mineralization.

Weber Scannell, et al. (2000)

This report contains a summary of results from biomonitoring studies conducted at the Red Dog Mine through 1999. The study compared the then current conditions with baseline and early mining conditions in the Red Dog and Wulik River drainage.

Weber Scannell, Ott, and Morris (2001)

This report presents results of the 2000 biomonitoring conducted under the NPDES permit. Comparisons are made with previous monitoring and earlier water quality conditions.

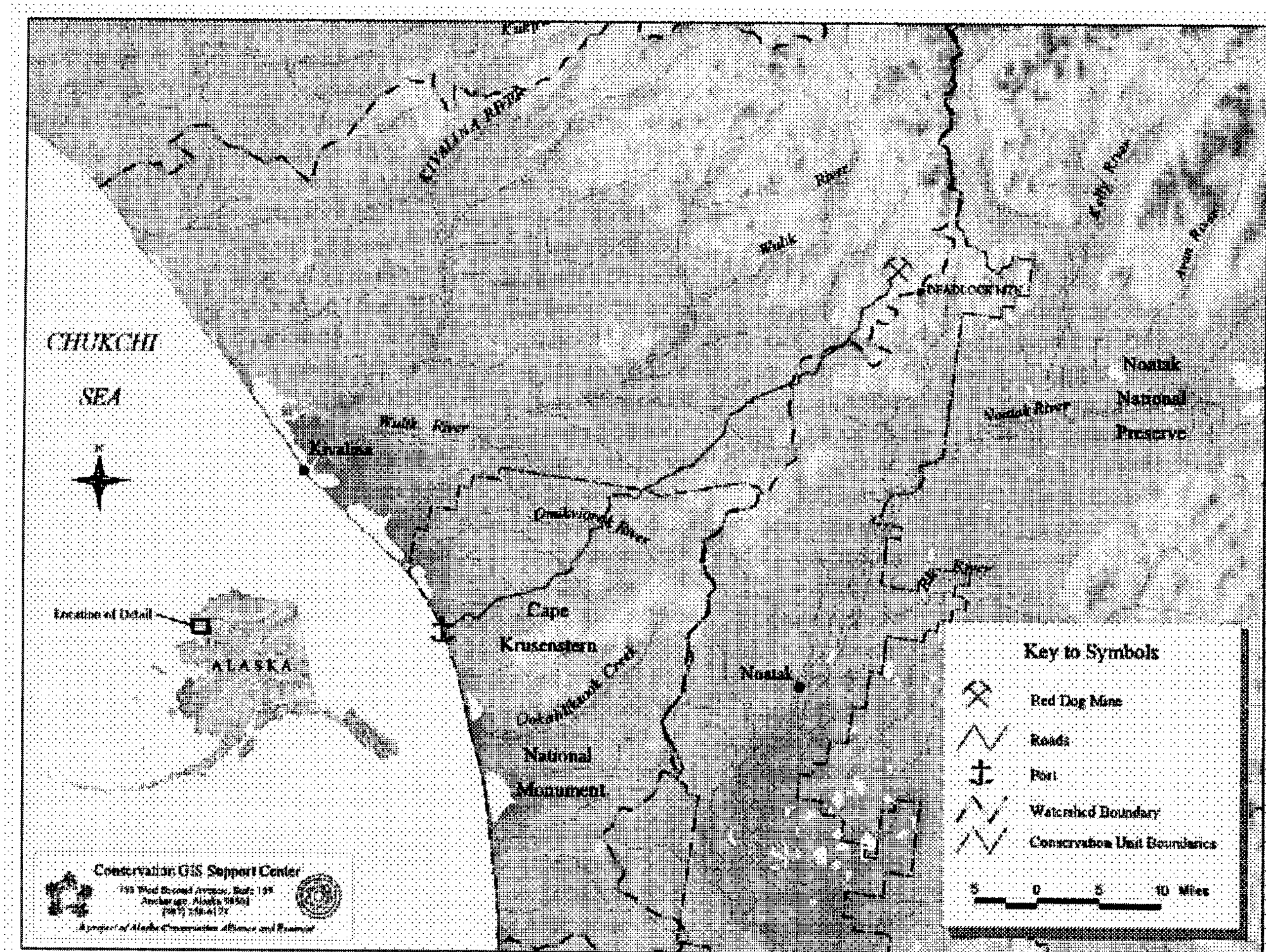


Figure 1. Location of the Red Dog Mine in northwest Alaska Map used with permission of Conservatin GIS Support Center, Anchorage, AK.

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 US EPA NPDES Permit No. AK-003865-2 (Table 11, Figure 2). A description of the sites included in this study is listed below, followed by the station number.

Table 11. 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

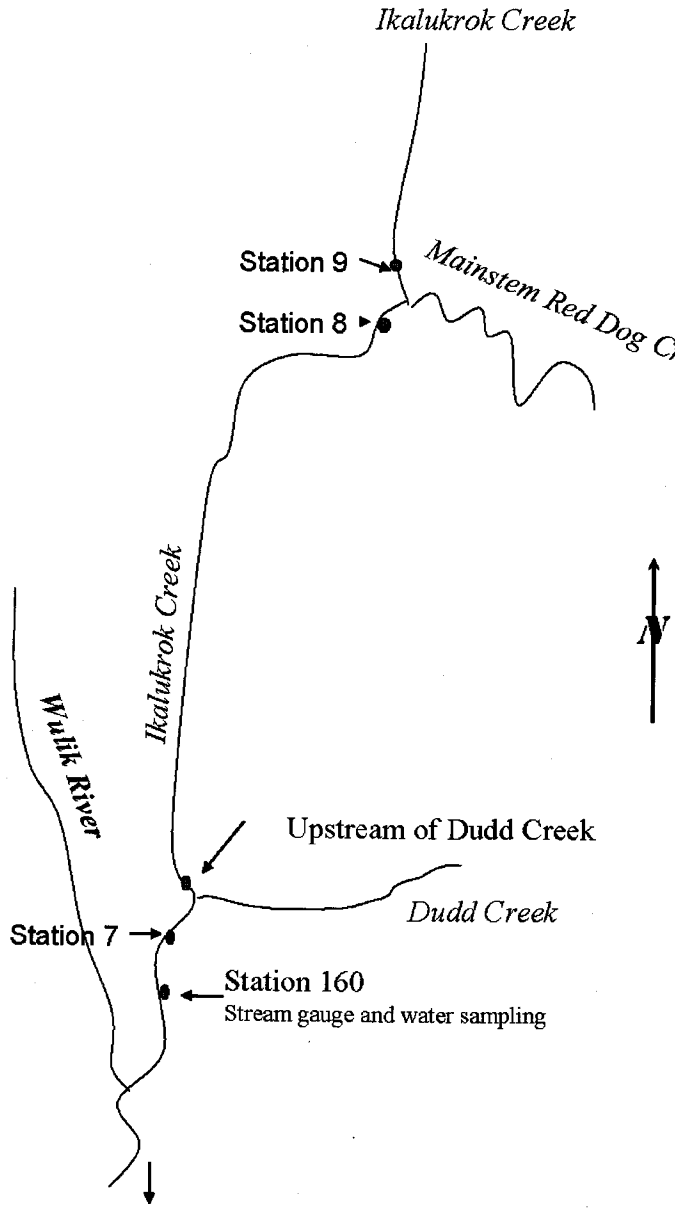


Figure 2. Locations of sites in the Red Dog Creek drainage for aquatic sampling.

Description of Streams

All of the streams in this study are in the Wulik River watershed, except Eviangiknuk Creek 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 TeckCominco. Water quality and fisheries data collected during baseline studies (1979-1982) represent pre-mining conditions because minimal disturbance had occurred in this drainage at 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 that is supplemental to the requirements under the NPDES permit to further our understanding of the aquatic communities (Table 13).

Table 12. 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 13. 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 US EPA 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 the 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 compare metals concentrations of fish tissues to concentrations found since beginning of operation of the Red Dog Mine and to detect any changes in concentrations of fish tissues that can be related to changes in metals concentrations in receiving waters below the mine. Sampling under the current NPDES permit for the Red Dog Mine effluent is a continuation of this effort.

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

Aerial surveys for adult Dolly Varden are conducted each year if weather permits. 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.

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 conditions did not permit aerial surveys (DeCicco 1997; Weber Scannell and Ott 1998).

Modifications in 2001

To more clearly define the fall spawning periods, we conducted aerial surveys throughout fall 2001 on August 7, 28, and 29, September 23, and October 8.

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 2001

To more clearly define the fall spawning periods, we conducted aerial surveys throughout fall 2001 on August 7, 28, and 29, September 23, and October 8.

Water Quality and Metals Concentrations

TeckCominco. samples for water quality and metals concentrations according 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, ten 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

Ikalukrok Creek

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 (Station 7) Dudd Creek (Figure 3). Detailed site descriptions, including average seasonal flows, channel morphology, and baseline water quality conditions were presented in Weber Scannell, Ott, and Morris 2000.

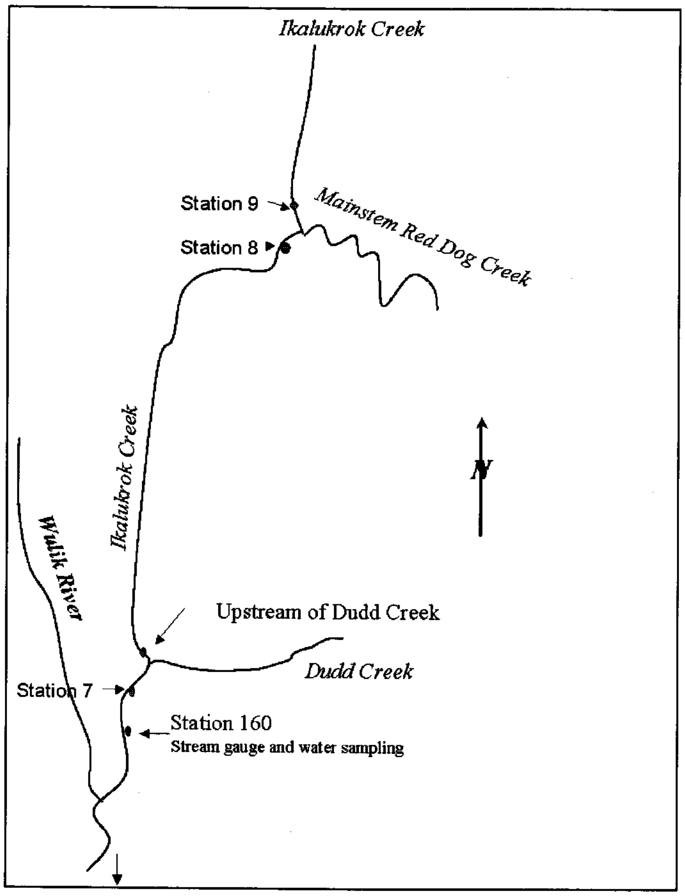


Figure 3. Location of sites in Ikalukrok Creek: Stations 9, 8, 7, and Ikalukrok Creek upstream of Dudd Creek. Figure not to scale.

STATION 9

SITE LOCATION

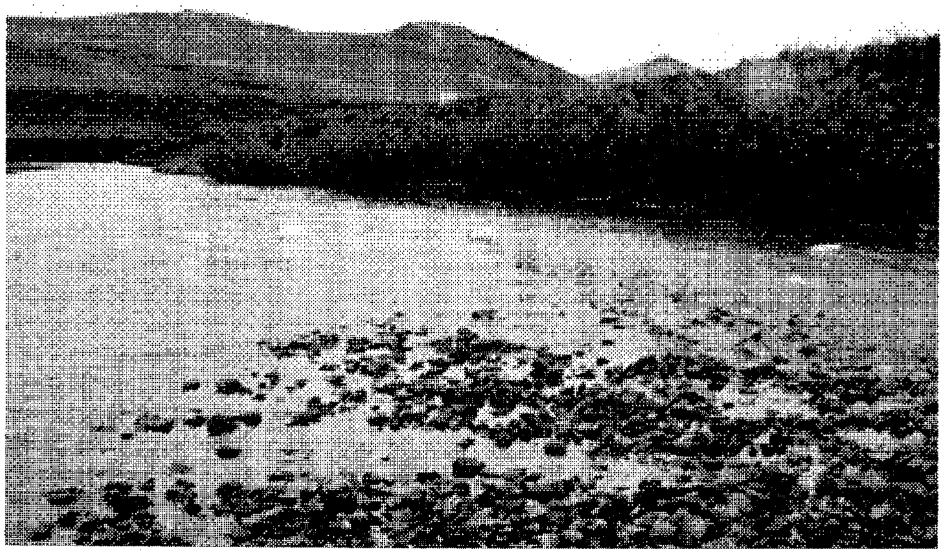


Figure 4. Ikalukrok Creek upstream of Red Dog Creek, Station 9.

WATER QUALITY

The water quality at Station 9 is characterized as having moderate hardness (approximately 150 mg/L as $CaCO_3$). Sulfate concentrations are relatively low (median concentrations for each year range from 40 to nearly 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 periods and low levels occur during periods of high flows (Weber Scannell, Ott, and Morris 2000).

CONCENTRATIONS OF HEAVY ELEMENTS

Maximum concentrations of Cd were similar in 1996 through 2001. Both median and maximum concentrations of Zn were higher in 2001 than in previous years (Figure 5). Concentrations of Pb were low in 2001.

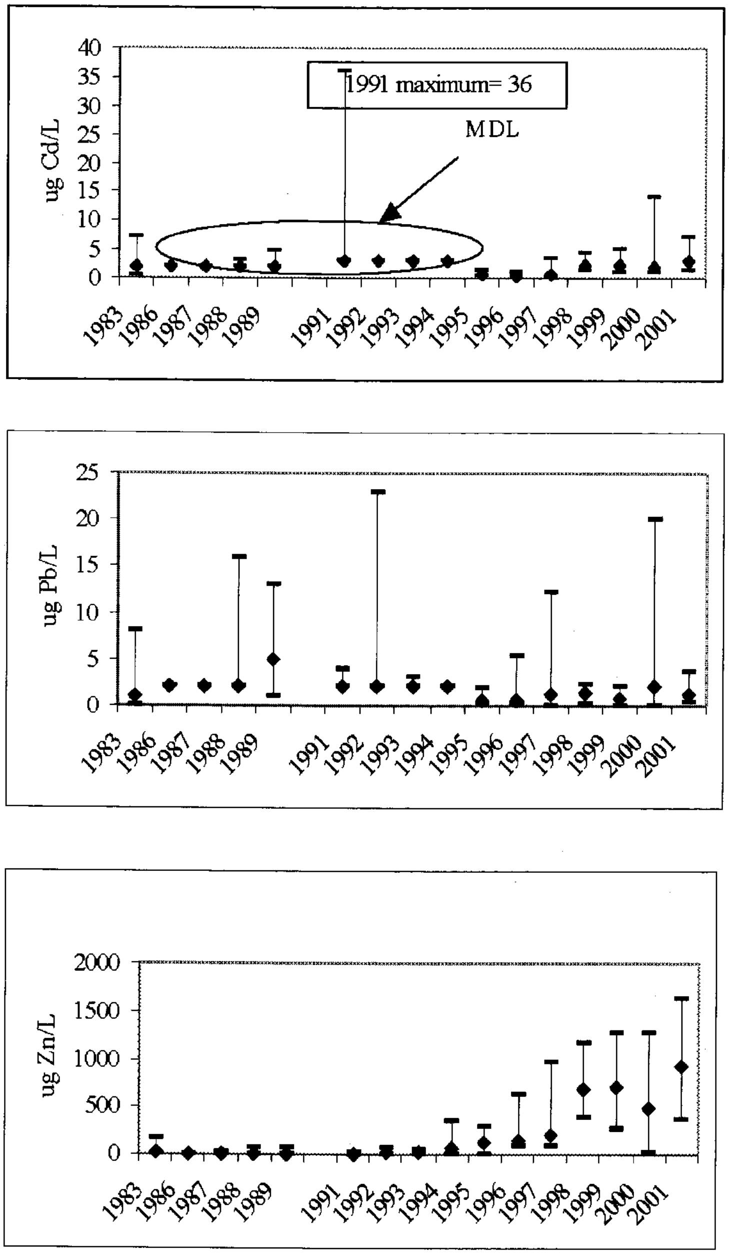


Figure 5. Median, maximum, and minimum concentrations of Cd, Pb, and Zn measured during the open water periods in Ikalukrok Creek at Station 9. Data from TeckCominco. MDL = method detection limit.

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 higher in 2001 than in 1999 or 2000 (Figures 6 and 7).

The taxa richness, as total number of aquatic taxa collected during each sample period, was similar for all years, except 1996 when few taxa were found (Figure 8).

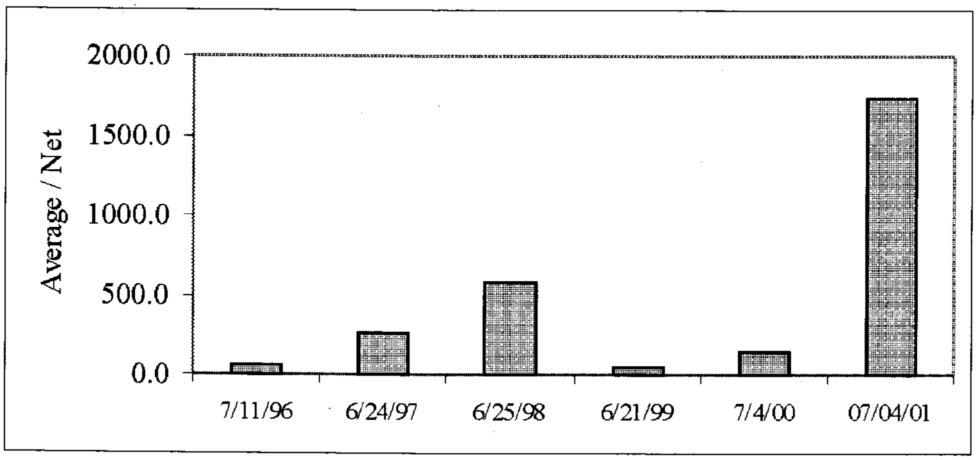


Figure 6. Abundance of aquatic invertebrates collected in Ikalukrok Creek at Station 9.

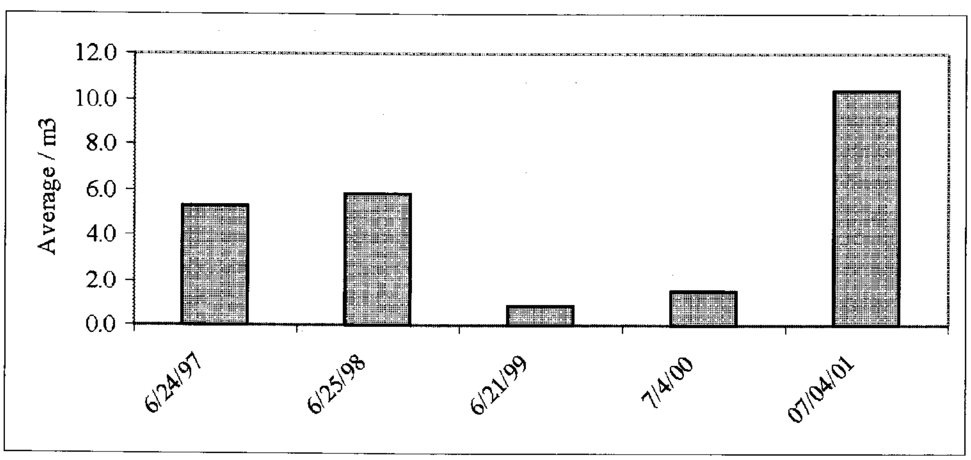


Figure 7. Density of aquatic invertebrates collected in Ikalukrok Creek at Station 9.

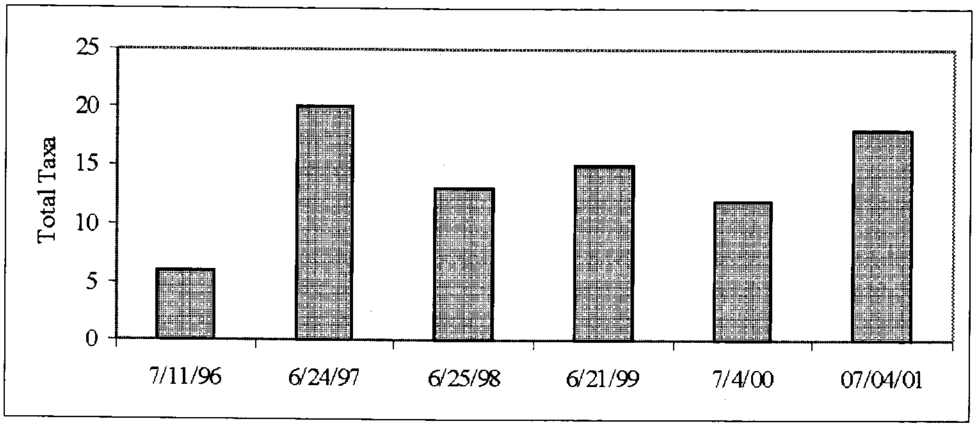


Figure 8. Taxa richness of aquatic invertebrates collected in Ikalukrok Creek at Station 9.

STRUCTURE OF COMMUNITY

Invertebrate samples contained a high proportion of Ephemeroptera, Plecoptera, and Trichoptera (EPT taxa) in 1996-1998 and in 2000 when 48% to 62% of the aquatic invertebrates were EPT taxa. The proportion of EPT taxa was lower in 2001, when only 24% of samples were EPT (Figure 9). 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.

Aquatic Diptera were the predominant group in 1998 – 2001. The aquatic community at Station 9 is a diverse and complex community. In 2001, we found two Ephemeroptera genera, two Plecoptera genera, five aquatic Diptera genera, and 3 Collembola genera. Miscellaneous Ostracoda, Nematoda, Oligachaeta, Acarii, and aquatic Coleoptera were also found with Trichoptera rare or absent in all samples. Larval Arctic grayling were found in aquatic nets in previous years (1997, 1999, and 2000), but not in 2001.

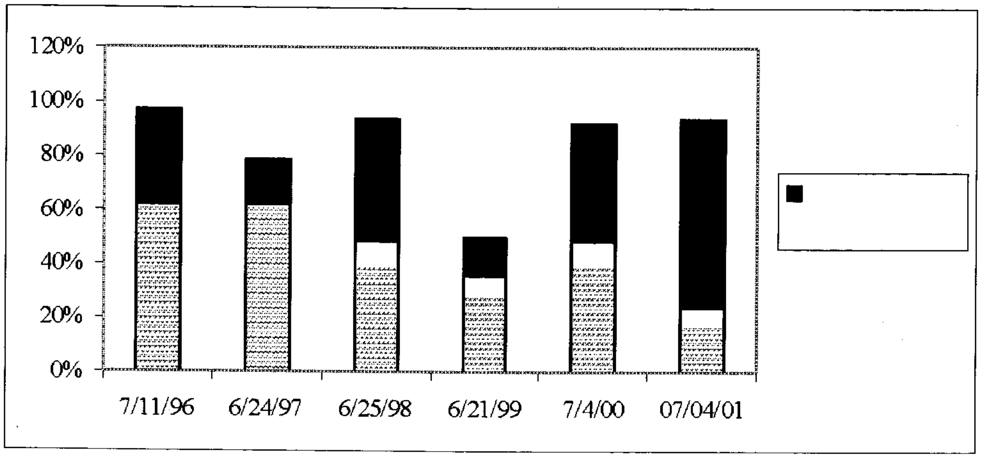


Figure 9. Relative proportions of EPT and Chironomidae larvae in invertebrate samples from Ikalukrok Creek at Station 9, 1996 – 2001.

PERIPHYTON STANDING CROP

Concentrations of chlorophyll-a were low in all samples and ranged from 0 to less than 3 mg/m^2 (Figure 10). No substantial changes have occurred within this community among the years sampled.

COMPOSITION OF ALGAL COMMUNITIES

The algal community at Station 9 consists of a mixture of green algae and diatoms: on average, chlorophyll samples contained 78% chlorophyll-a, 13% chlorophyll-b, and 9% chlorophyll-c.

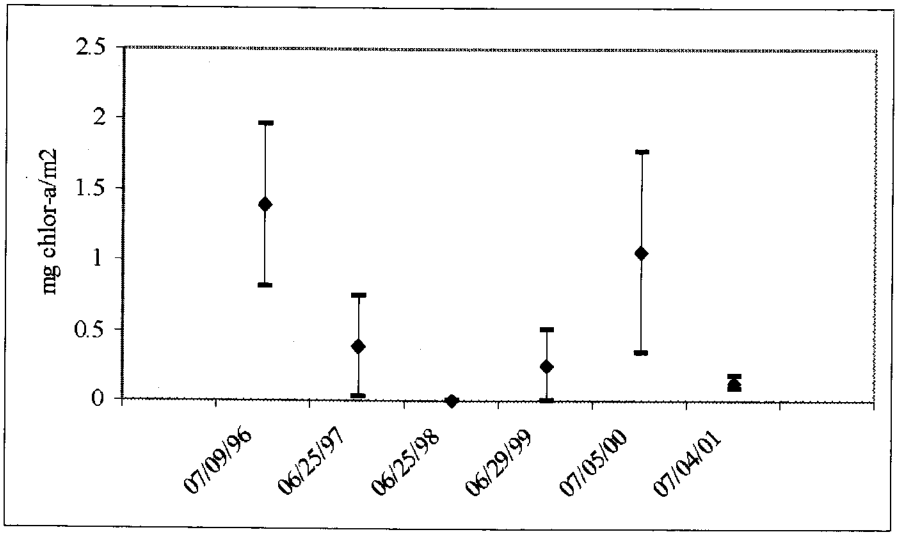


Figure 10. Average concentrations of chlorophyll-a, plus and minus 1 standard deviation, measured in Ikalukrok Creek at Station 9.

SUMMARY OF BIOMONITORING, STATION 9

Changes in water quality, periphyton and the invertebrate community that have been documented over time are summarized in Table 14.

Table 14. Summary of biomonitoring, Station 9, 1996 through 2000.

Factor	Changes Observed
Water Quality	Increase in Cd and Zn since 1996.
Periphyton Communities	Concentrations were lower in 2001.
Invertebrates Communities:	Abundance lowest in 1996, and 1999-00, high in 2001. 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

Station 8

Description of Site

Figure 11. Ikalukrok Creek downstream of Red Dog Creek, Station 8.

Ikalukrok Creek below Red Dog Creek is a relatively fast flowing stream with medium sized gravel to small cobble substrate (Figure 11). 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.

Water Quality

Water Quality and Heavy Elements

Water quality and metals sampling were done intermittently at Station 8 and more consistently at Station 73, downstream. In summer 1999, we sampled conductivity across transects at Station 8 and verified that Ikalukrok and Red Dog creeks are not completely mixed at this site. Earlier data on water quality and metals concentrations are not reliable because there is no documentation of the degree of mixing or exact sample locations. Water samples have not been collected from this site in recent years.

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 12 and 13). In 2001, we found a total of 22 distinct taxonomic groups (usually genus) at this site. In previous sampling years we collected from 11 to 13 different taxa, except in 1996 when only 5 taxa were found (Figure 14).

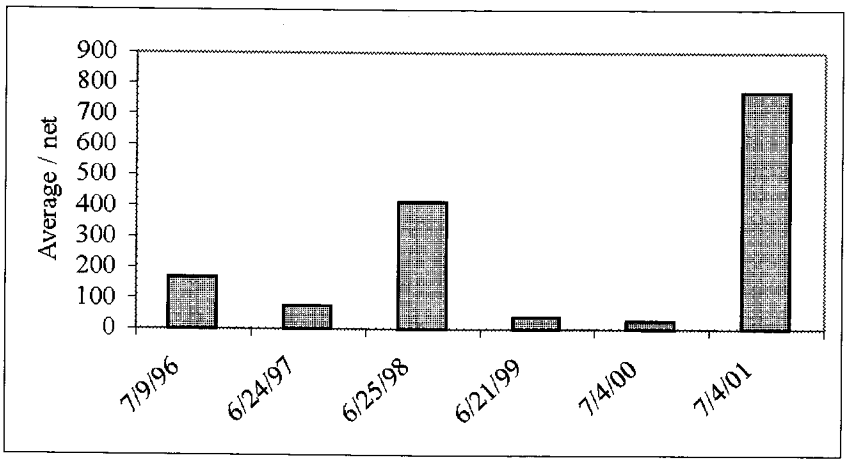


Figure 12. Abundance of aquatic invertebrates in Ikalukrok Creek at Station 8.

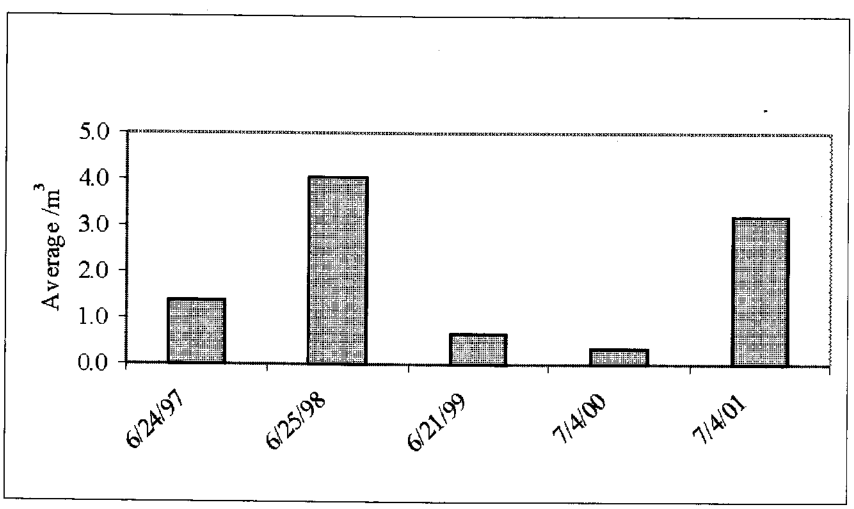


Figure 13. Density of aquatic invertebrates in Ikalukrok Creek at Station 8.

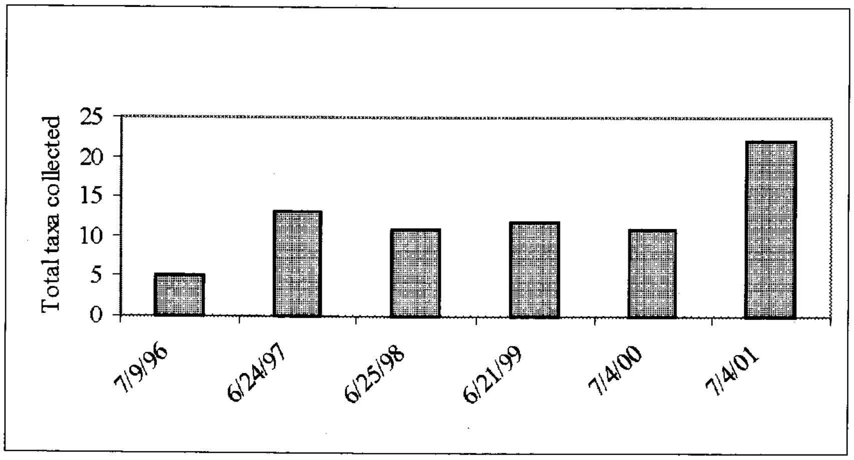


Figure 14. Taxa richness of the invertebrate community in Ikalukrok Creek at Station 8: total number of different taxa collected during each sample time.

Structure of Invertebrate Community

The invertebrate community contained a large proportion of EPT taxa (>50%) in 1998 (71%); in other years, the proportion of EPT taxa was lower (17% in 1997 to 34% in 2001). Chironomidae larvae were the predominate taxonomic group in most years when they were over 50% of the invertebrate samples (Figure 15).

The invertebrate community at Station 8 is dominated by Diptera: Chironomidae. Trichoptera, although rare, were most plentiful in samples collected in 1999 and 2000. Most of the Trichoptera were *Brachycentrus*, a case-building caddisfly common in northern streams. In 2001, we found two different Ephemeroptera genera, three Plecoptera genera, one Trichoptera genus, five aquatic Diptera genera, and four Collembola genera. Larval Arctic grayling were found in samples collected in 1997, but not in other years.

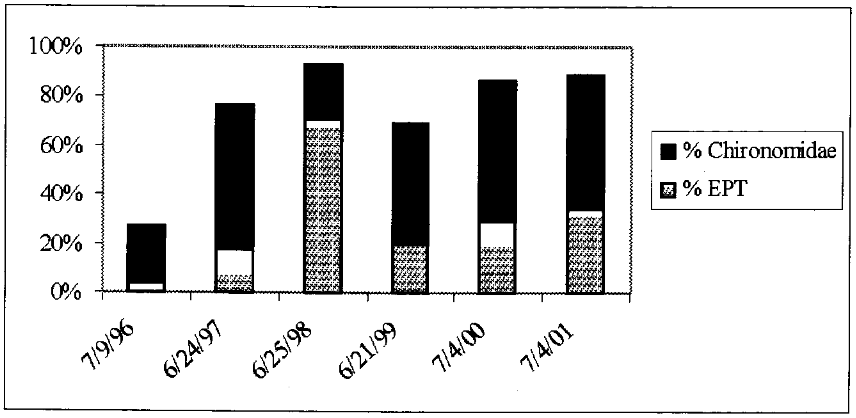


Figure 15. Proportion of EPT taxa and Chironomidae larvae in aquatic invertebrate samples collected in Ikalukrok Creek at Station 8.

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 16). Median concentrations were similar in the other years sampled, including 2001.

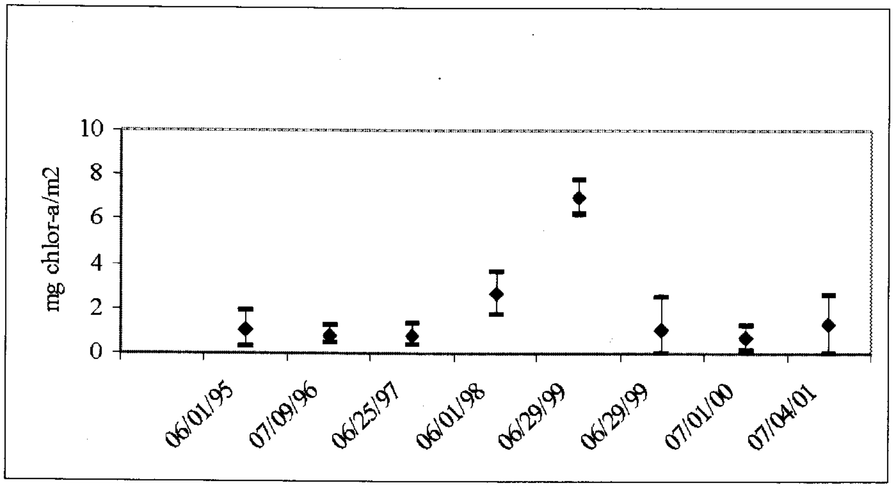


Figure 16. Concentrations of chlorophyll-a measured in Ikalukrok Creek at Station 8.

Composition of Algal Communities

Eighty-seven periphyton samples have been collected and analyzed from Ikalukrok Creek since 1995; of these, only 20 samples had sufficiently high concentrations to determine chlorophyll-b and only 16 had sufficient concentrations to determine chlorophyll-c. The algal communities in Ikalukrok Creek at Station 8 are dominated by chlorophyll-a (61%) with 27% as chlorophyll-b and 12% as chlorophyll-c. Green algae, including filamentous algae, are more abundant than diatoms.

Summary of Biomonitoring, Station 8

Changes in water quality, invertebrate and periphyton communities, and fish populations documented over the biomonitoring period are summarized in Table 15.

Table 15. 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.
	Density highest in 2001.
	Trichoptera most common in 1999 and 2000.
Algal Communities	Chlorophyll-a concentrations low in all years except 1999.
Larval Arctic grayling	Found in 1997 only.

Ikalukrok Creek upstream of Dudd Creek

SITE DESCRIPTION

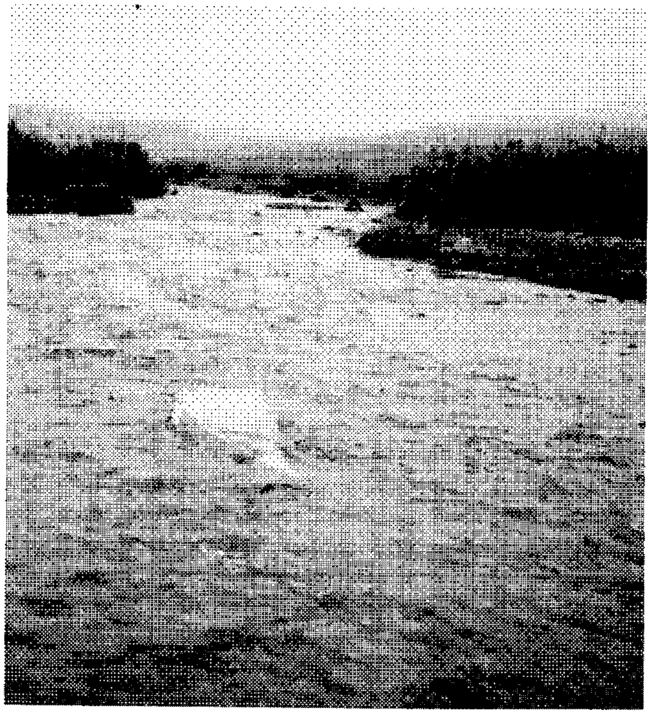


Figure 17. Ikalukrok Creek upstream of Dudd Creek.

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 17). The substrate contains mostly small cobble with medium-sized gravel. The banks are thickly vegetated with willows and herbaceous plants and grasses.

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, Ott, and Morris 2000). The lowest pH (6.4) was measured in June 1998. The mine effluent influences water quality by increasing the hardness and concentrations of total dissolved solids and sulfate. Metals concentrations are historically low at this site, compared to sites in Red Dog Creek (Weber Scannell, Ott, and Morris 2001) and remained low in 2001 (Figure 18).

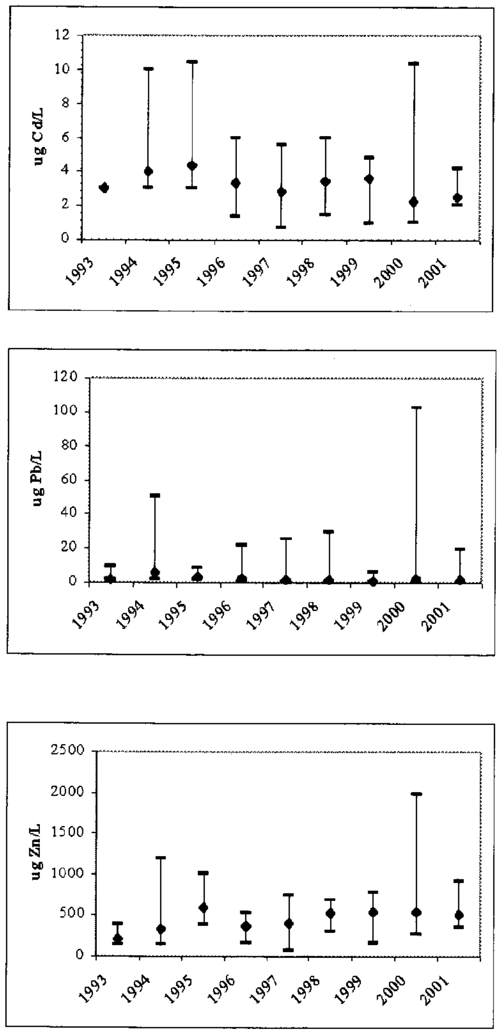


Figure 18. Median, maximum, and minimum concentrations of Cd, Pb, and Zn in Ikalukrok Creek at Station 73, 1993 through 2001.

INVERTEBRATE COMMUNITY

ABUNDANCE, DENSITY, AND TAXA RICHNESS

Invertebrate abundance and density have fluctuated since June 1997, when this site was first sampled. Both abundance and density were lowest in 1998 and 1999 (Figures 19 and 20). In 2001, invertebrate abundance was high at this site while density was low; the lower density resulted from higher water velocities at the 2001 net sites.

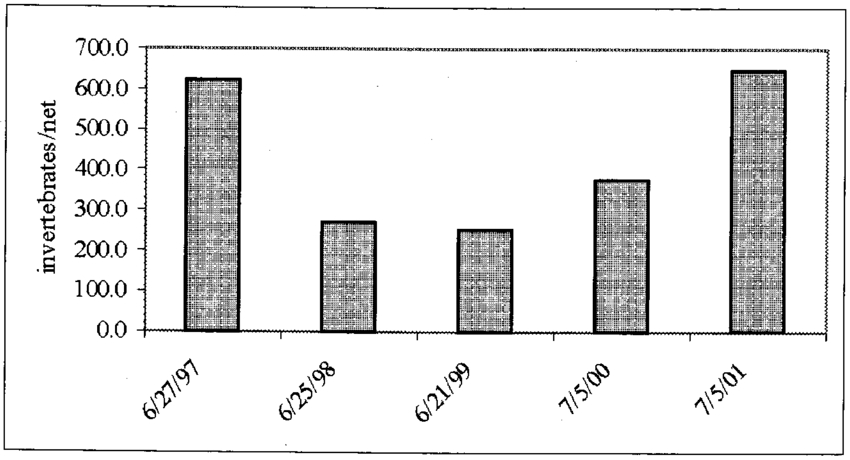


Figure 19. Abundance of aquatic invertebrates collected in Ikalukrok Creek upstream of Dudd Creek.

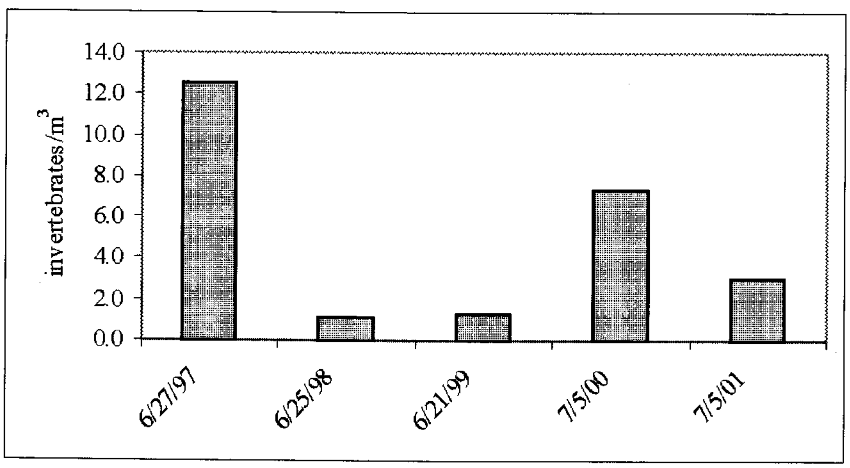


Figure 20. Density of aquatic invertebrates collected in Ikalukrok Creek upstream of Dudd Creek.

Taxa richness was similar during all sample periods except June 1998 (Figure 21). Samples collected in 2001 contained the highest numbers of taxa among the years this site has been sampled.

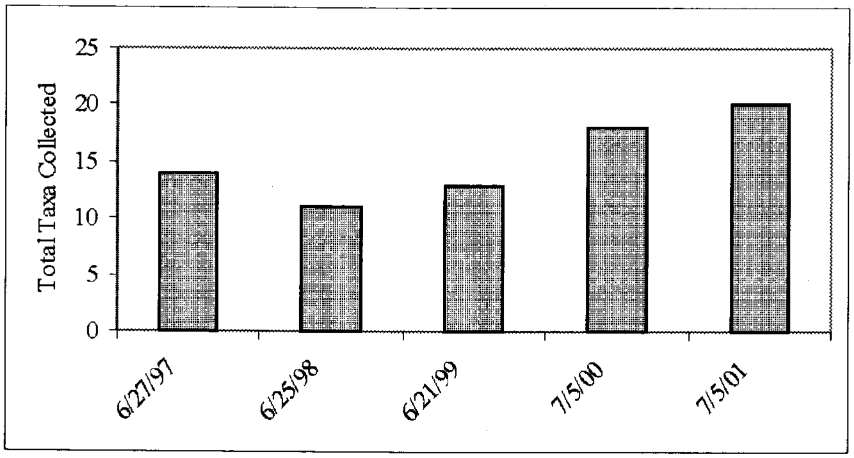


Figure 21. Taxa richness of invertebrate samples collected in Ikalukrok Creek upstream of Dudd Creek.

STRUCTURE OF COMMUNITY

There was a low proportion of EPT taxa compared to the proportions of Chironomidae during three of the five years sampled (Figure 22). In 2001, there was a dominance of EPT taxa (50%).

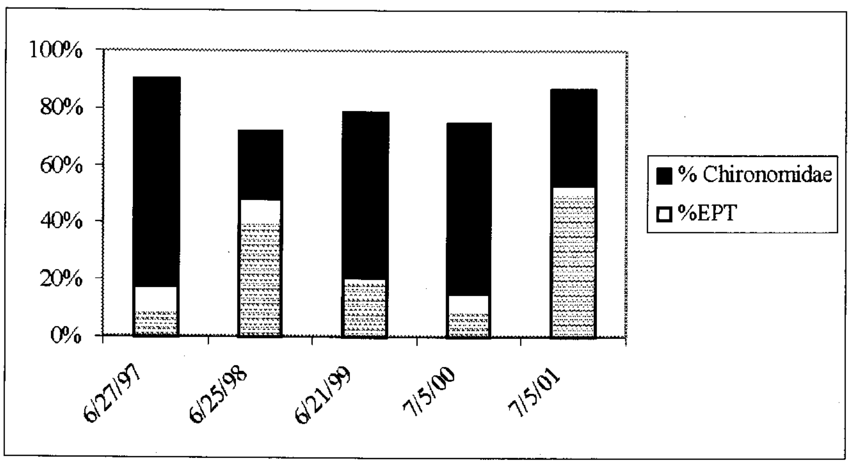


Figure 22. Proportions of EPT taxa and Chironomidae collected from Ikalukrok Creek upstream of Dudd Creek.

The invertebrate community in Ikalukrok Creek upstream of Dudd Creek is frequently dominated by aquatic Diptera (primarily Chironomidae, Empididae, and Simuliidae, with occasional Tipulidae). Ephemeroptera or Plecoptera become more common in the drift when they are reaching the final instars and ready to emerge. In 2001, samples contained high proportions of Ephemeroptera; nearly all of them were Heptageniidae: Cingymula. Trichoptera, although rare, were most plentiful in samples collected in 1999. All the Trichoptera were *Brachycentrus,* a case-building caddisfly common in northern streams.

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 1997 through 2001. Median concentrations of periphyton were similar in all sample events (approximately 2 mg/m^2) except June 1998 when median concentrations were 6 mg/m^2 (Figure 23). Samples collected in 2001 were similar to 1996-97 and 1999-00.

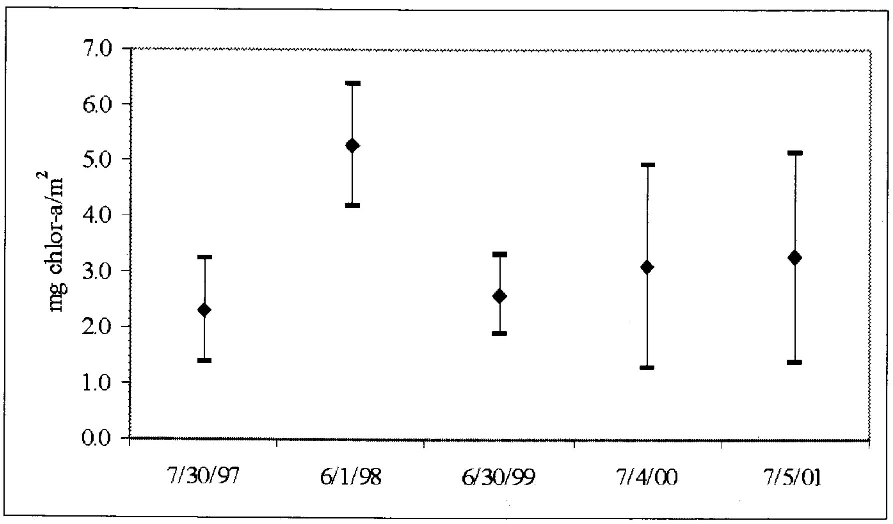


Figure 23. Median, maximum, and minimum concentrations of chlorophyll-a measured in Ikalukrok Creek upstream of Dudd Creek, 1997-2001.

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. Periphyton samples from this site contained slightly more chlorophyll-c (7%) than chlorophyll-b (6%). Chlorophyll-a was the predominant pigment (87%), indicating a predominance of green algae over diatoms and blue-green bacteria.

Summary of Biomonitoring, Ikalukrok Creek upstream of Dudd Creek

Changes in water quality, invertebrate and periphyton communities, and fish populations documented over the biomonitoring period are summarized in Table 16.

Table 16. Summary of biomonitoring, Ikalukrok Creek upstream of Dudd Creek, 1996-2001.

Factor	Changes Observed
Water Quality	No pre-mining data.
Concentrations of metallic elements.	Concentrations of Al, Cd, Cu, Fe, Pb, Se, and Zn relatively unchanged since 1996 at Station 73, upstream.
Invertebrate Community	Trichoptera found in 1998, 1999, and 2001. 50% EPT species in 2001. Abundance and richness highest in 2001.
Algal Communities	Algal biomass unchanged in 2001 from previous years.
Larval Arctic grayling	Found in 1997 and 2000

Station 7

SITE DESCRIPTION

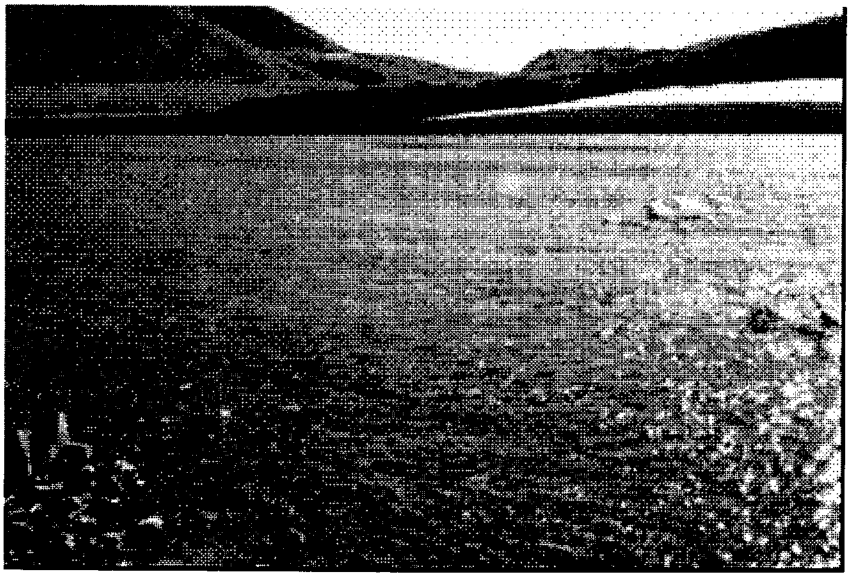


Figure 24. Ikalukrok Creek downstream of Dudd Creek, Station 7.

Ikalukrok Creek below Dudd Creek (Station 7, Figure 24) 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. Streamside vegetation consisted of willow shrubs.

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. Water quality samples from 1999 through 2001 were collected at Station 160; previous samples are from Station 7.

In 2001, the water at Station 160 had neutral pH (from 7.0 to 7.9, with a median value of 7.6 (Figure 25). Concentrations of total dissolved solids are low in May before the mine begins discharging treated effluent (Figure 26) and increase during summer. Limited pre-mining sampling at Station 73 showed summer concentrations of TDS in the 130 to 185 mg/L range (there were no TDS samples from Station 7 during baseline sampling).

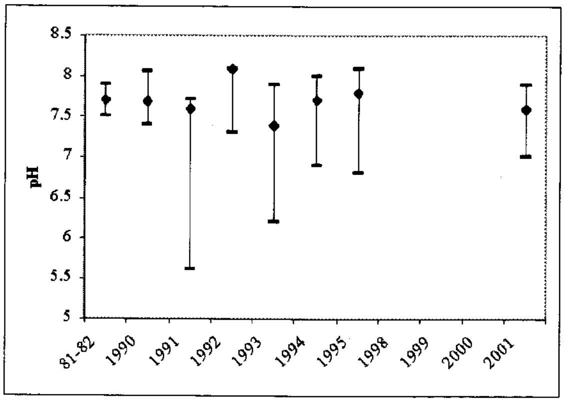


Figure 25. pH levels at Station 7 (1981-1998) and Station 160 (1999-2001).

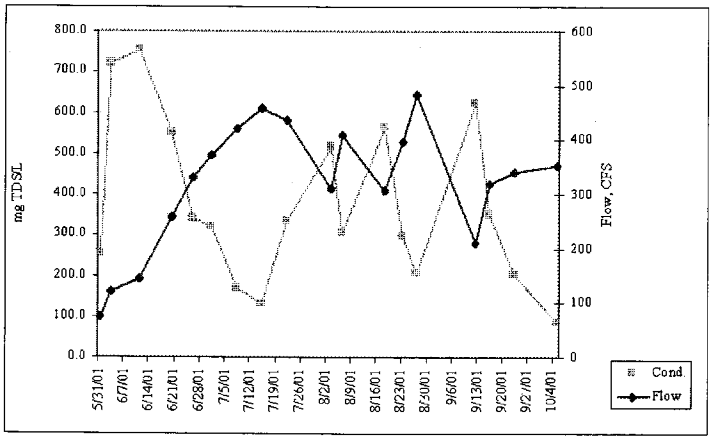
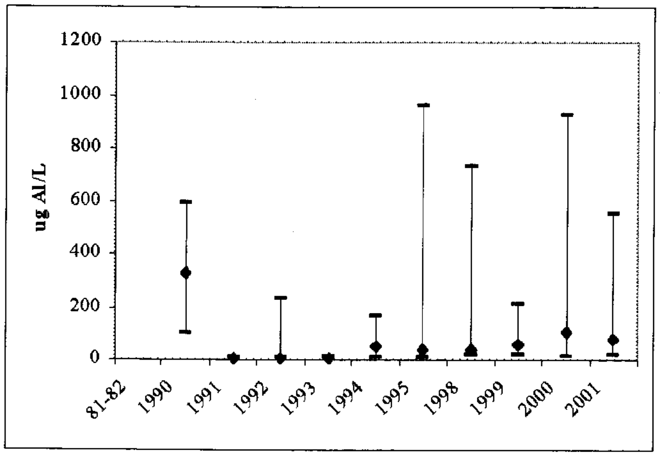


Figure 26. TDS and stream flow at Station 7 (1981-1998) and Station 160 (1999-2001).

CONCENTRATIONS OF HEAVY ELEMENTS

Consistent baseline sampling for heavy elements was limited to Cd, Pb, and Zn. Concentrations of these three elements were low before development of the Red Dog Mine. Concentrations of Cd remained low after 1990 (Figure 27). Median concentrations of Al and Zn have remained below 0.2 mg /L Al and 0.5 mg /L Zn since 1990. The method detection limit for Se in 2000 was 50 μg/L for samples collected early in the summer, these samples cannot be compared with samples of lower (1-2 μg/L) detection limits.



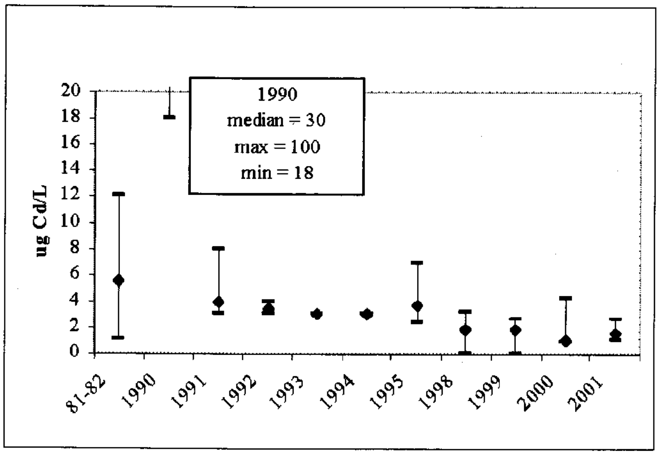


Figure 27. Median, maximum, and minimum concentrations of Al, Cd, Pb, and Zn in Ikalukrok Creek, below Dudd Creek, 1990-1998 at Station 7, 1999-2001 at Station 160. Data from Teck Cominco.

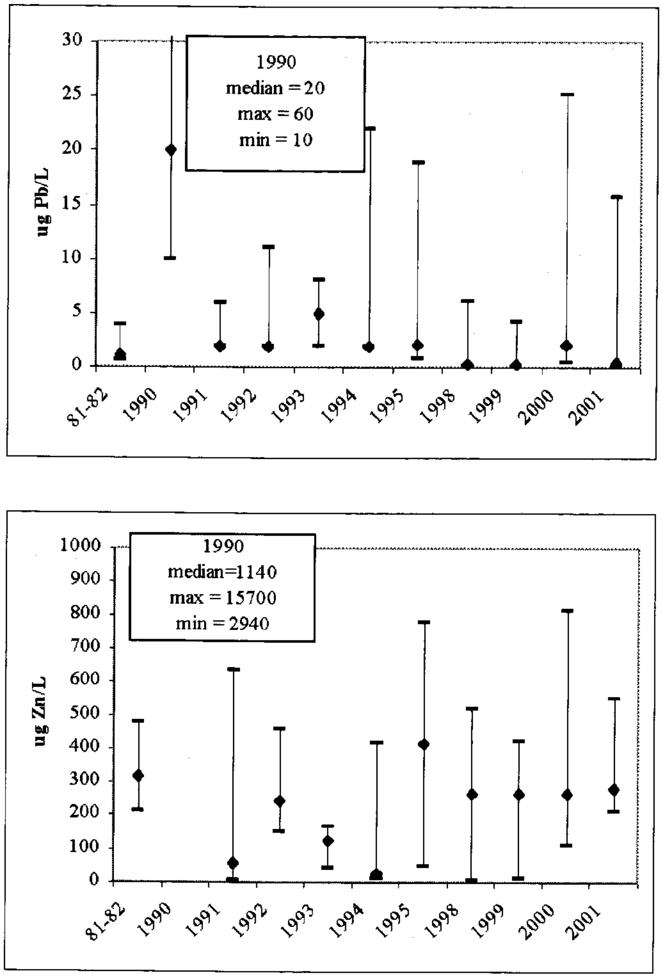


Figure 27, continued.

Invertebrate Community

Abundance, Density, and Taxa Richness

Invertebrate abundance and density were highest in late June 1997 and early July 1998 and lowest in June 1999 (Figures 28 and 29), and then increased in July 2000. In 2001, both invertebrate abundance and density were lower than the previous year.

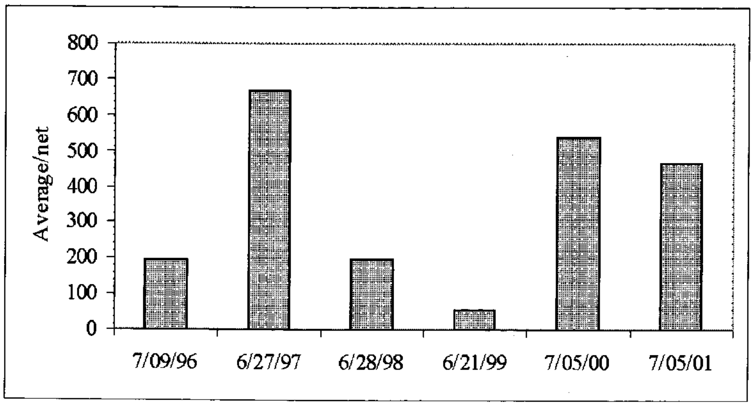


Figure 28. Abundance of aquatic invertebrates collected in Ikalukrok Creek, Station 7.

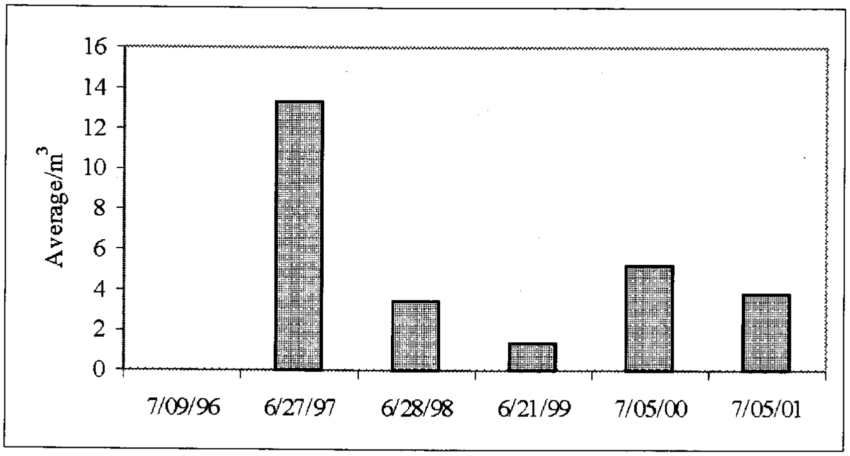


Figure 29. Density of aquatic invertebrates collected in Ikalukrok Creek, Station 7.

We identified 19 different aquatic taxa (usually to genus level) at Station 7 in 2001 (Figure 30). Samples from this year contained the highest taxa richness of any year sampled.

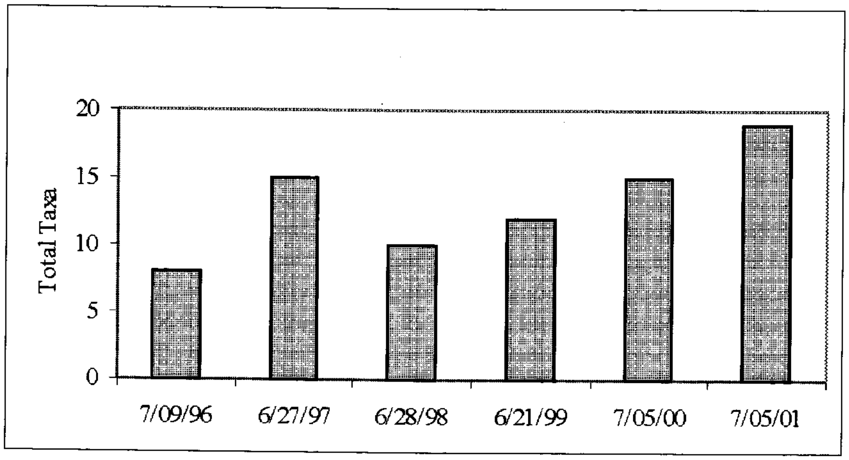


Figure 30. Total aquatic invertebrate taxa collected from Ikalukrok Creek, Station 7.

STRUCTURE OF COMMUNITY

In the 2001 invertebrate samples, 51% were EPT taxa and 39% were larval Chironomidae (Figure 31). The dominant invertebrate family was Chironomidae larvae, as it was in 1997 and 2000. Samples contained numerous Ephemeroptera: Heptageniidae (*Cinygmula*). Common in these samples were Plecoptera Capniidae (*Allocapnia),* Simuliidae (*Simulium),* Acari (Acarina), Collembola: Isotomidae (*Axelsonia),* Onychiuridae (*Lophognathella),* and Sminthuridae (*Sminthurus).* Trichoptera were rare, as in previous years.

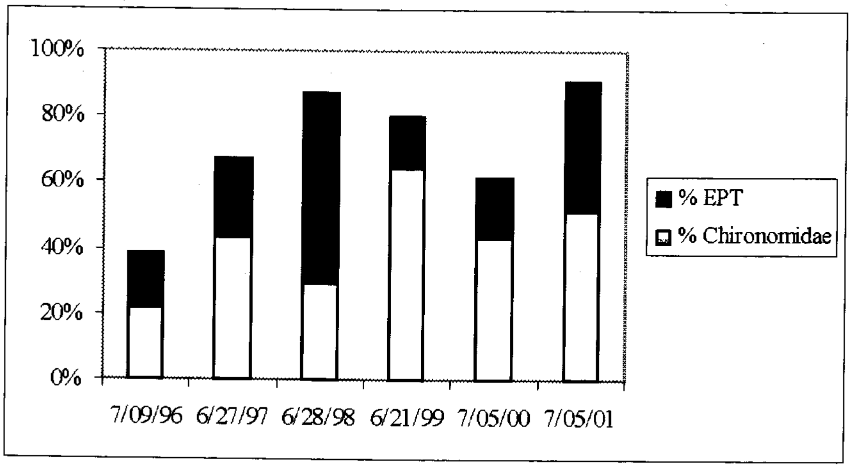


Figure 31. Proportions of EPT and Chironomidae in samples from Station 7, Ikalukrok Creek.

PERIPHYTON STANDING CROP

Stream periphyton has been sampled in Ikalukrok Creek at Station 7 since 1996. Concentrations were highest in 1998 and 2000 (median = 3.4 mg/m^2 in 1998 and 3.7 mg/m^2 in 2000, Figure 32). In 2001, we measured 1.98 mg/m^2 of chlorophyll at Station 7.

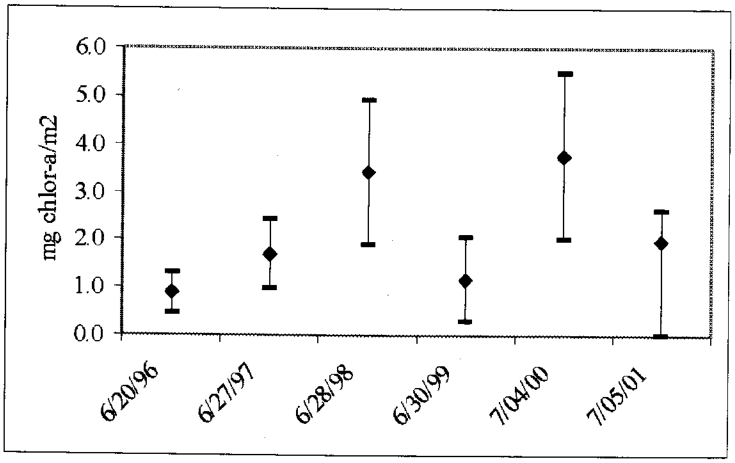


Figure 32. Median, maximum, and minimum concentrations of chlorophyll-a measured in Ikalukrok Creek, Station 7, 1996-2001.

Composition of Algal Communities

In 2001, periphyton samples from this site were mostly chlorophyll-a (84%), with 3% chlorophyll-b and 13% chlorophyll-c. The higher amounts of chlorophyll-c suggest a community dominated by diatoms.

Summary of Biomonitoring, Station 7

Changes in water quality, invertebrate and periphyton communities, and fish populations documented over the biomonitoring period are summarized in Table 17.

Table 17. 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 2001 was similar to 2000. The percent of EPT taxa was greater than 50% in 2001.
Algal Communities	Concentrations of chlorophyll-a in 2001 were lower than the previous year.
Larval Arctic grayling	Found in 2000 only.

Main Stem Red Dog Creek: Station 10

DESCRIPTION OF SITE

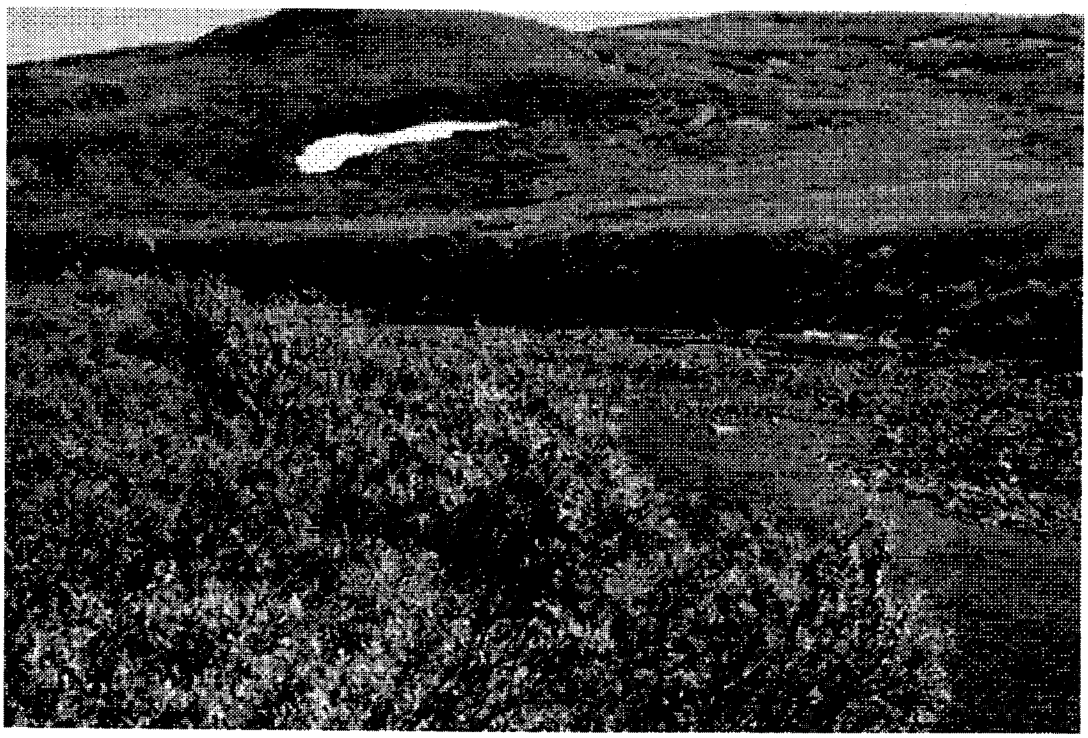


Figure 33. Main Stem Red Dog Creek, Station 10.

The Main Stem Red Dog Creek (Figure 41) 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 (R. Kemnitz, pers. comm., USGS Water Resources Division, Fairbanks). The streambed consists mostly of gravel, small cobble, and small boulders. The creek has some meander and areas where it has shifted locations (Figure 33).

WATER QUALITY

Median pH levels have ranged between 7.0 and 7.8 since 1991 (Figure 34). In 2001, pH ranged from 6.7 (in early June, during break-up flows) to 8.1 (in early August).

The volume of effluent from the mine controls concentrations of TDS in Main Stem Red Dog Creek. In 2001 Teck Cominco limited the volume of discharge of treated water to maintain TDS concentrations below 1500 mg/L in Main Stem Red Dog Creek. During periods of no discharge from the mine, the TDS in the creek quickly reaches background concentrations of 150 mg/L or less (Figure 35).

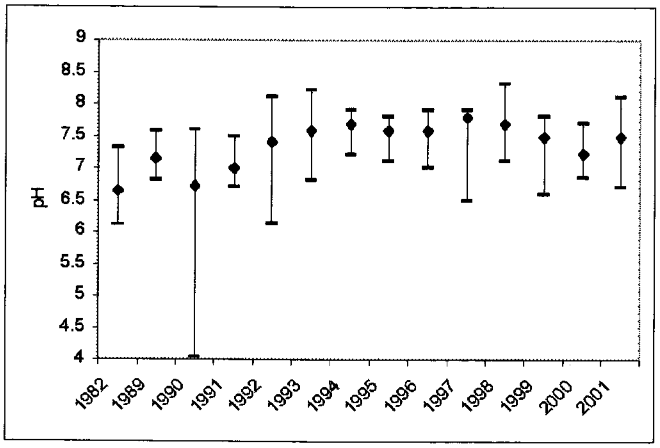


Figure 34. pH levels in Red Dog Creek at Station 10.

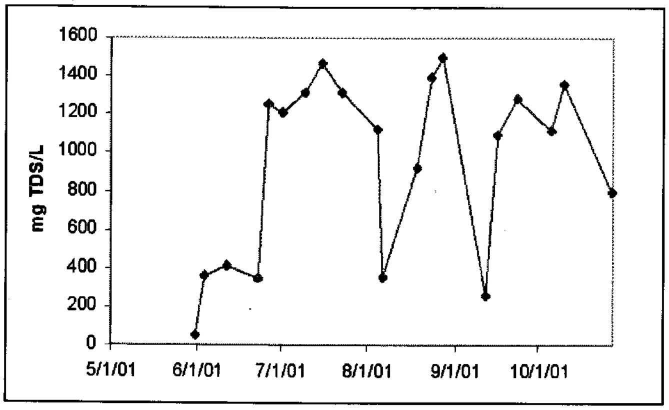
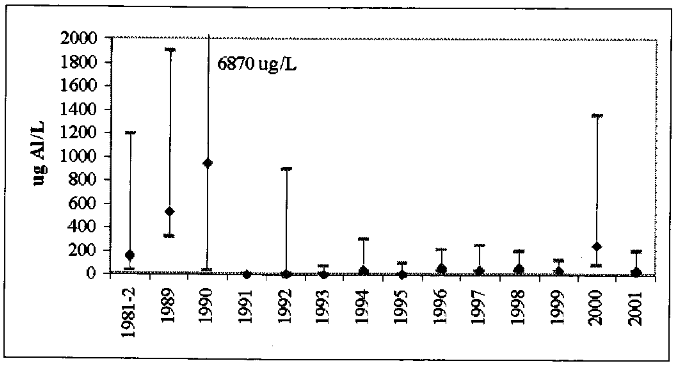


Figure 35. Total dissolved solids (TDS) in Main Stem Red Dog Creek at Station 10, 2001.

CONCENTRATIONS OF HEAVY ELEMENTS

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 2001, concentrations of all metals were among the lowest reported since 1992 (Figure 36).



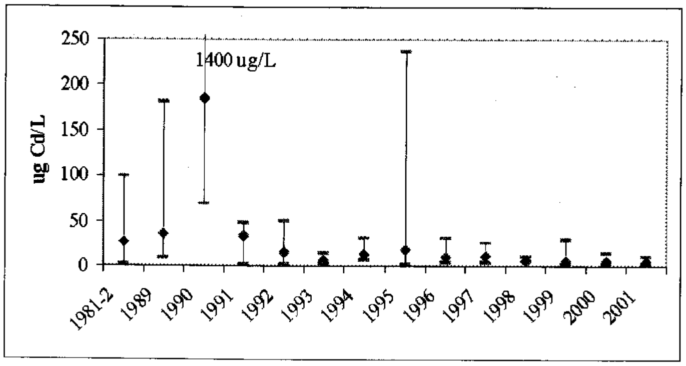
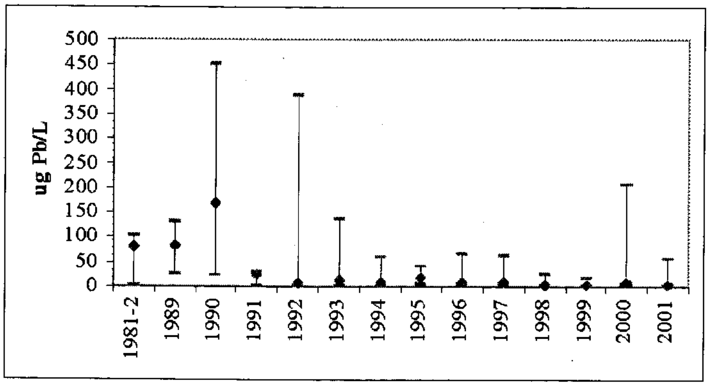
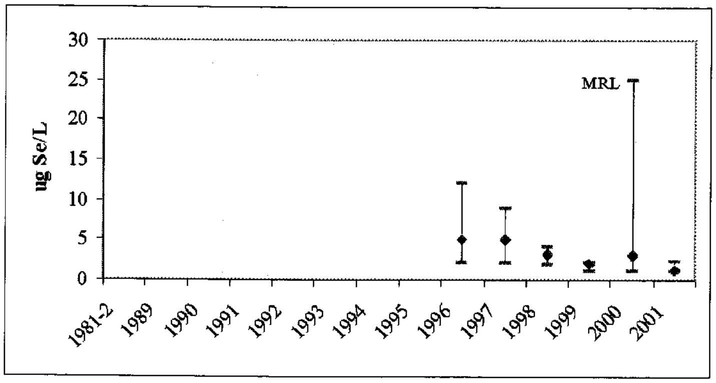


Figure 36. Median, maximum, and minimum concentrations of Al, Cd, Pb, Se, and Zn in Main Stem Red Dog Creek, 1981-2001.





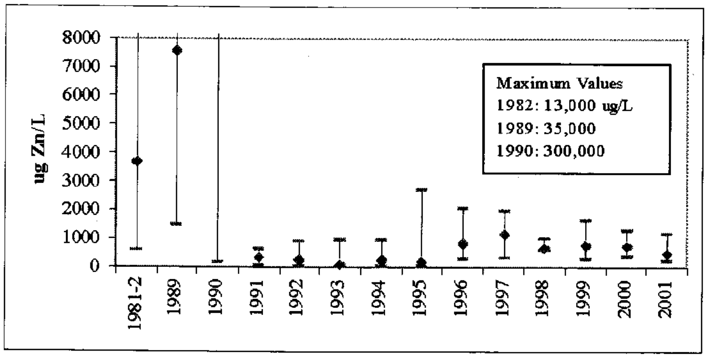


Figure 36, continued.

INVERTEBRATE COMMUNITY

ABUNDANCE, DENSITY, AND TAXA RICHNESS

In 2001, abundance of aquatic invertebrate populations was similar to 1996 and 1997 (Figure 37), both abundance and density (Figure 38) were higher than found in 2000. More taxa were found in 2001 than in any of the other years sampled (Figure 39).

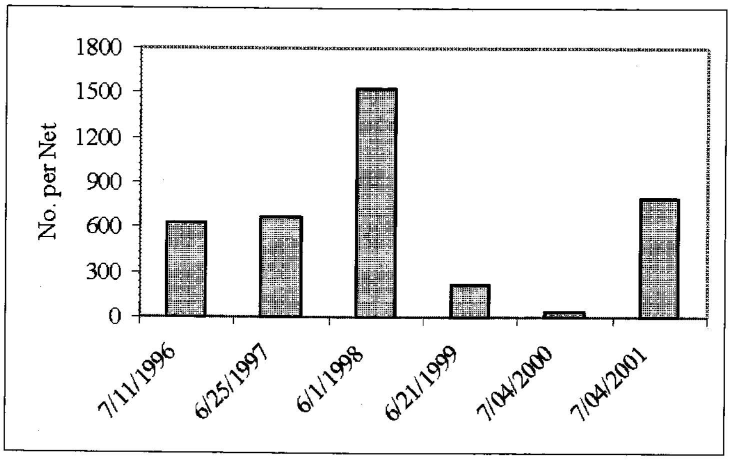


Figure 37. Abundance of aquatic invertebrates collected in Main Stem Red Dog Creek, Station 10.

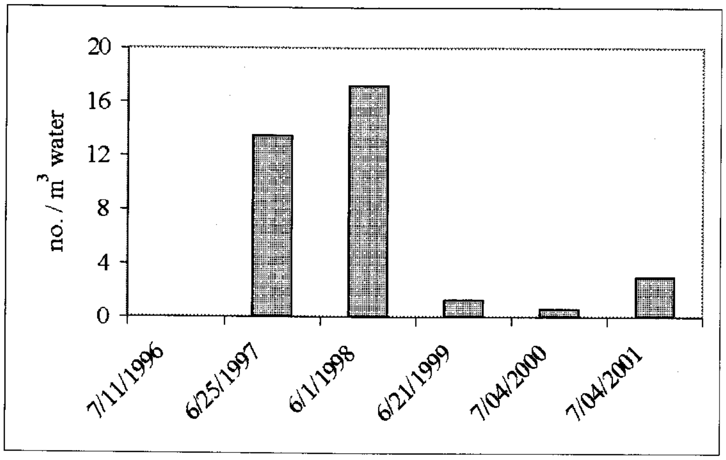


Figure 38. Density of aquatic invertebrates collected in Main Stem Red Dog Creek, Station 10.

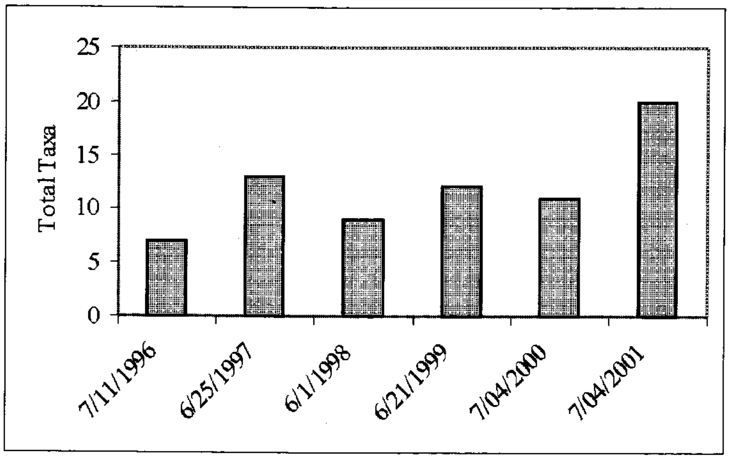


Figure 39. Taxa richness of invertebrate samples collected in Main Stem Red Dog Creek, Station 10.

STRUCTURE OF COMMUNITY

In 2001, only 5% of invertebrate samples were EPT taxa, while 79% were Chironomidae larvae (Figure 40). 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.

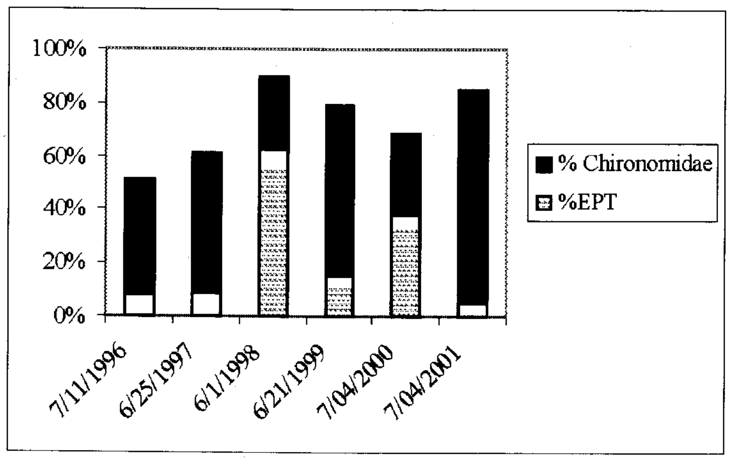


Figure 40. Percent EPT taxa and percent Chironomidae in Main Stem Red Dog Creek.

PERIPHYTON STANDING CROP

In 2001, the abundance of attached algae, estimated by chlorophyll-a concentrations, was the highest measured and substantially higher than amounts found in 2000 (Figure 41). The lowest concentrations were found in samples collected in June 1997 and June 1998, when all replicates were below the detection limit.

COMPOSITION OF ALGAL COMMUNITIES

No measurable amounts of chlorophyll-b or c were found in samples from Station 10 before 2001. In 2001, algal samples contained an average of 0.25 mg/m^2 of chlorophyll-c (22%) and only 0.05 mg/m^2 chlorophyll-b (5% of total pigments), indicating a community dominated by diatoms.

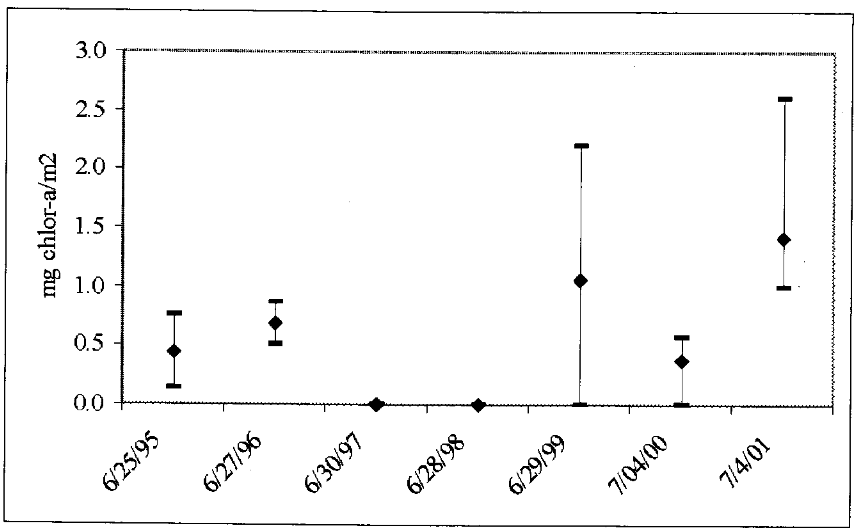


Figure 41. Concentrations of chlorophyll-a measured in Main Stem Red Dog Creek, Station 10.

SUMMARY OF BIOMONITORING, MAIN STEM RED DOG CREEK

Changes in water quality, invertebrate and periphyton communities, and fish populations documented over the biomonitoring period are summarized in Table 18.

Table 18. Summary of Biomonitoring, Main Stem Red Dog Creek, 1995-2000.

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 low in 2001
Invertebrate Community	Abundance high in 2001, number of taxa higher in 2001 than previous years sampled. Community dominated by Diptera during most years sampled
Algal Communities	Chlorophyll-a concentrations high in 2001,abundant diatoms.
Larval Arctic grayling	Found in 1997-2000.

Middle Fork Red Dog Creek, Station 20

DESCRIPTION OF SITE

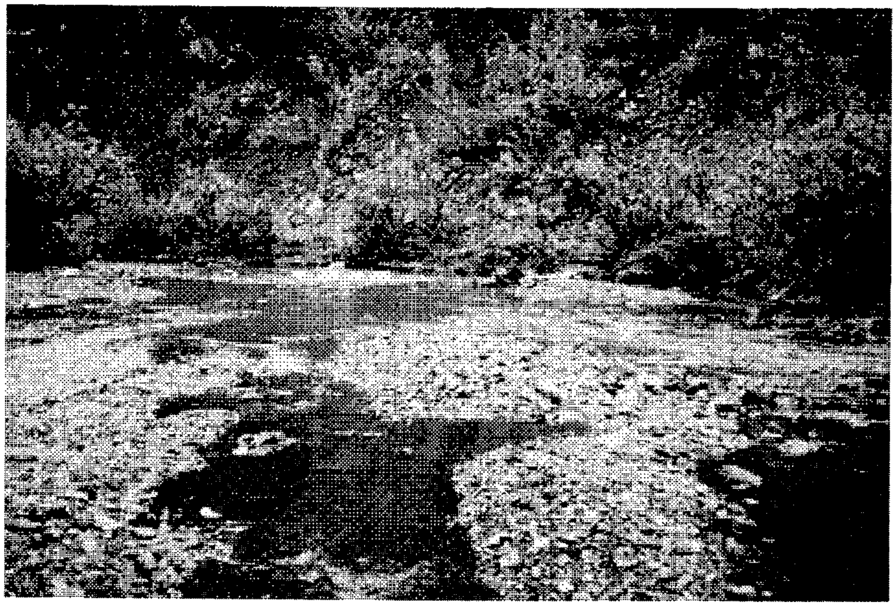


Figure 42. Middle Fork Red Dog Creek, Station 20.

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. The creek has wide meanders with average channel widths from 3 to 10 m (10 to 30 ft), and depths from 0.03 to 0.45 m (0.1 and 1.5 feet) (Figure 42). 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.

WATER QUALITY

Station 20 was not sampled regularly for water quality. The available data suggests that pre-mining pH ranged from 5.7 to 6.9 (Figure 43). In 2001, the pH ranged from a low of 6.8 in mid-August to high of 9.2 in late August. Higher 2001 pH values correspond to periods of higher discharge of treated effluent (treated waste water has pH levels in the 10 to 10.5 range).

Median concentrations of Al, Cd, Pb, and Zn in 2001 were similar to all other years after 1991. However, maximum concentrations of Al and Pb were among the highest reported for the time 1992-2001 (Figure 44).

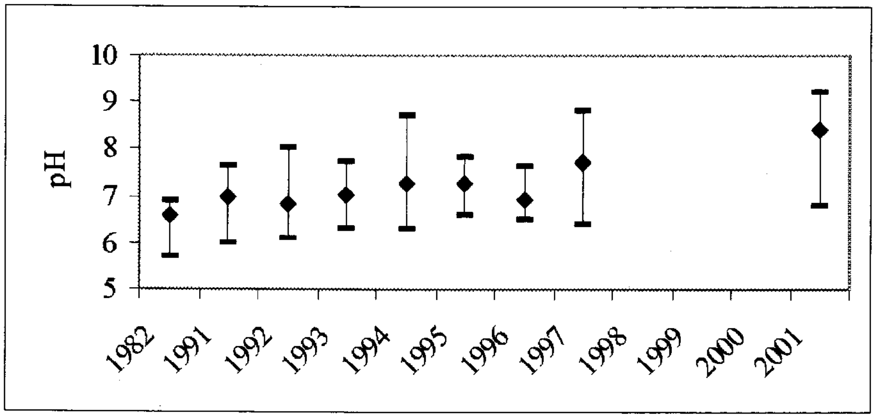


Figure 43. pH levels at Station 20, Middle Fork Red Dog Creek.

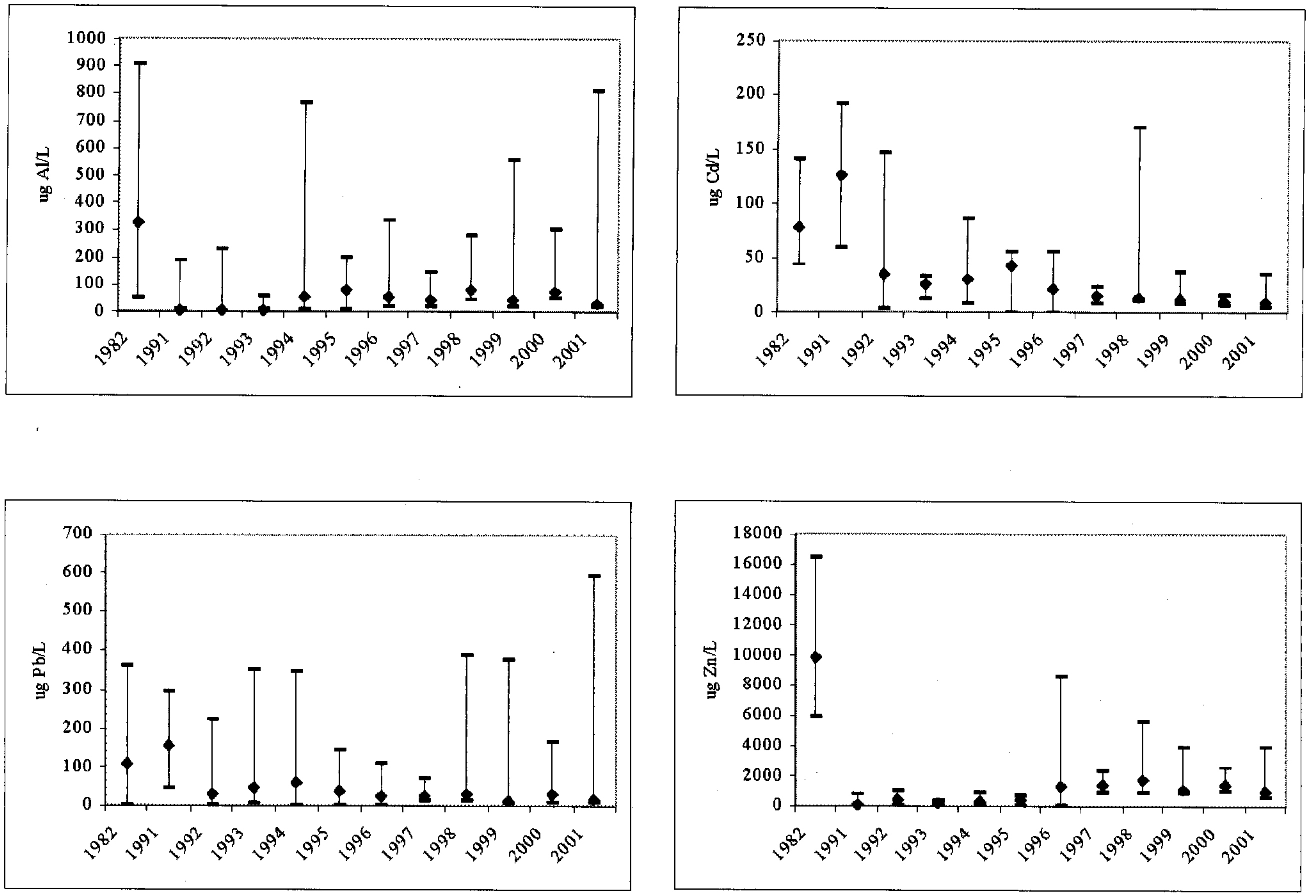


Figure 44. Median, maximum, and minimum concentrations of Al, Cd, Pb, and Zn in Middle Fork Red Dog Creek.

INVERTEBRATE COMMUNITY

ABUNDANCE, DENSITY, AND TAXA RICHNESS

Invertebrate abundance was higher at Station 20 in 2001 than in the previous two years sampled, but lower than 1998 (Figure 45). Samples collected in June 1998 also contained many mature Baetidae (average 52/net) and numerous Chironomidae pupae (average 440/net).

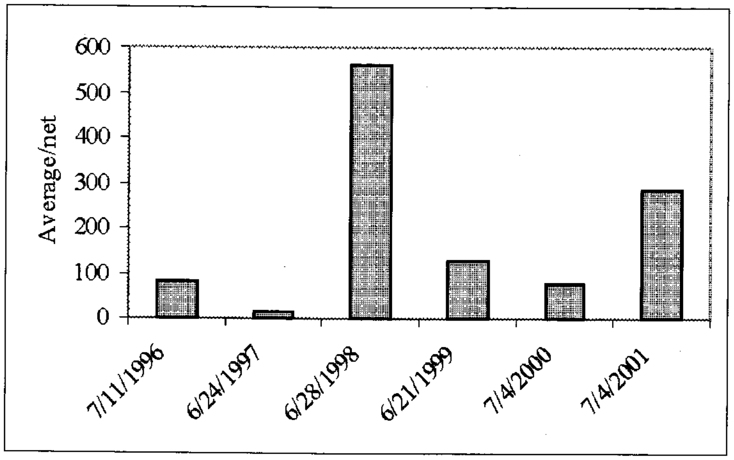


Figure 45. Abundance of aquatic invertebrates (average/net) in Middle Fork Red Dog Creek, Station 20.

Invertebrate densities were higher in 2001 than in the previous year, but not among the highest measured (Figure 46). 2001 samples contained the most invertebrate taxa (usually genera, Figure 47).

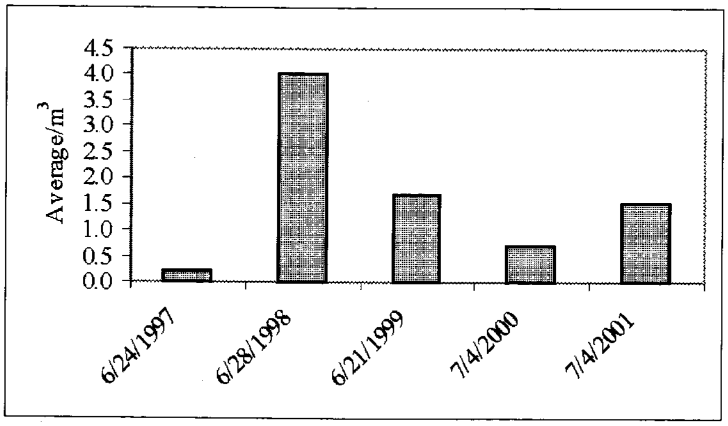


Figure 46. Density of aquatic invertebrates in Middle Fork Red Dog Creek at Station 20.

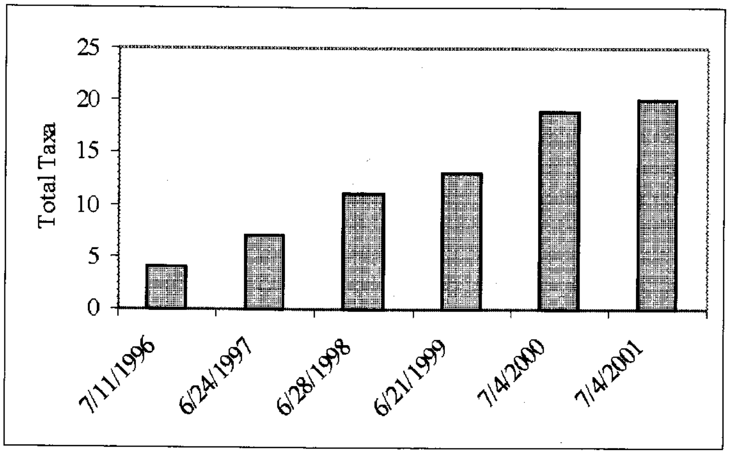


Figure 47. Total aquatic invertebrate taxa collected in Middle Fork Red Dog Creek at Station 20.

STRUCTURE OF COMMUNITY

The invertebrate community at Station 20 contained from 2 to 11% EPT taxa in all years sampled except 2001 (Figure 48). 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.

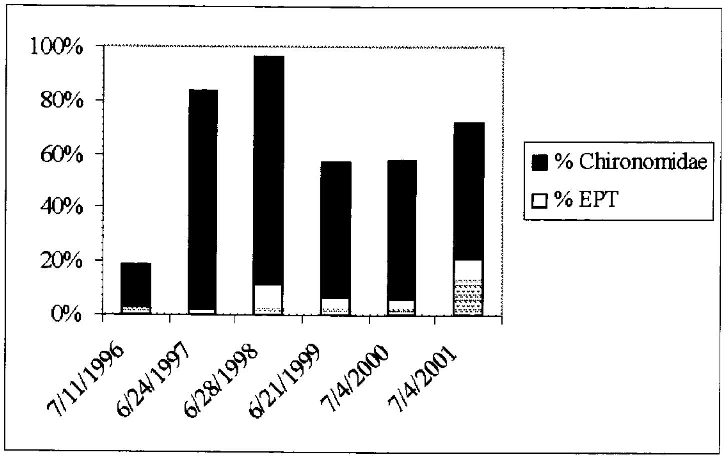


Figure 48. Percent EPT and percent Chironomidae larvae in the invertebrate community in Middle Fork Red Dog Creek at Station 20.

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 49). In 2001, samples did not have sufficient amounts of chlorophyll to distinguish the three major pigments.

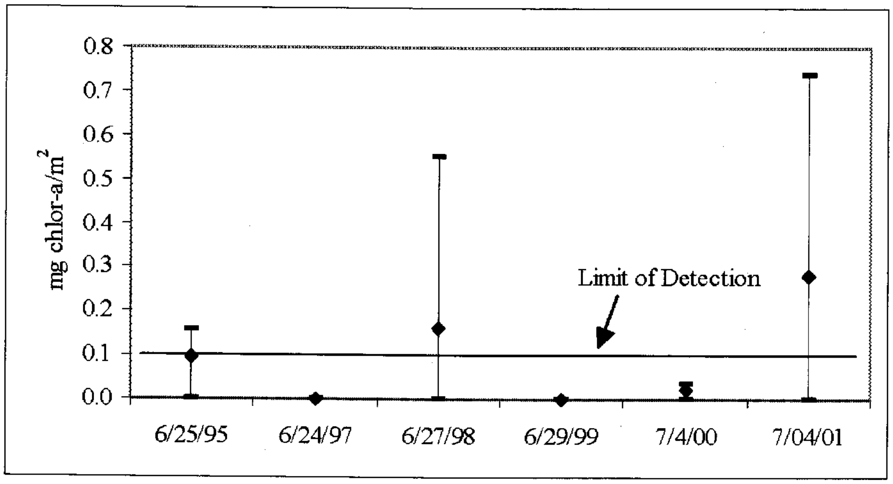


Figure 49. Concentration of chlorophyll-a in Middle Fork Red Dog Creek Station 20, 1995-2001.

Summary of Biomonitoring

The changes observed in the water quality conditions and aquatic communities are summarized in Table 19. 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 19. Summary of Biomonitoring, Station 20, 1995-2000

Factor	Changes Observed
Water Quality	Insufficient baseline data to make comparisons. Median pH somewhat higher than pre-mining.
Concentrations of metallic elements	Decrease in median concentrations of Al, Cd, Pb, and Zn, maximum Al and Pb higher in 2001.
Invertebrate Community	Abundance and density usually low at this site. No consistent pattern of change in abundance, density, or taxa richness . 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, Station 12

Description of Site

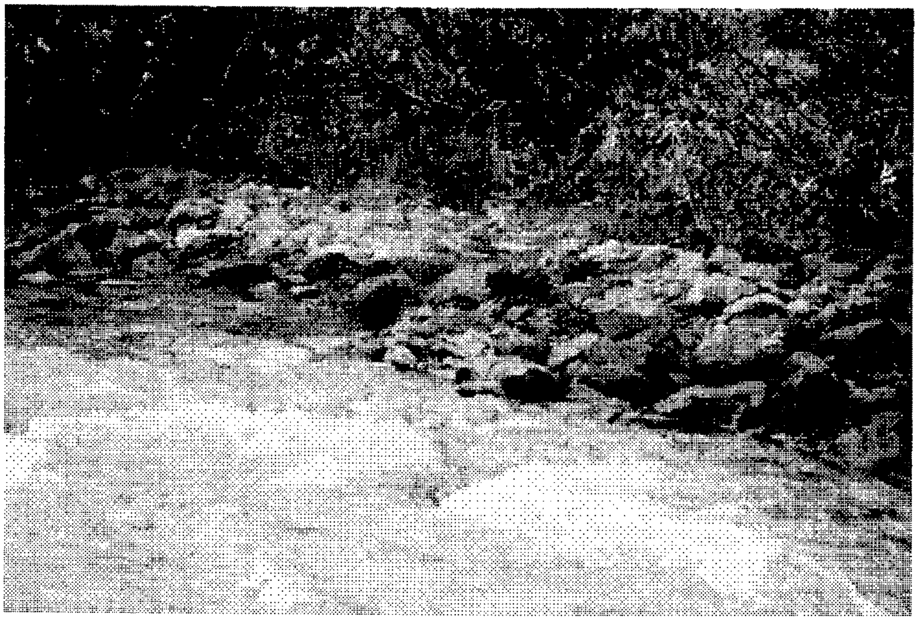


Figure 50. North Fork Red Dog Creek, Station 12

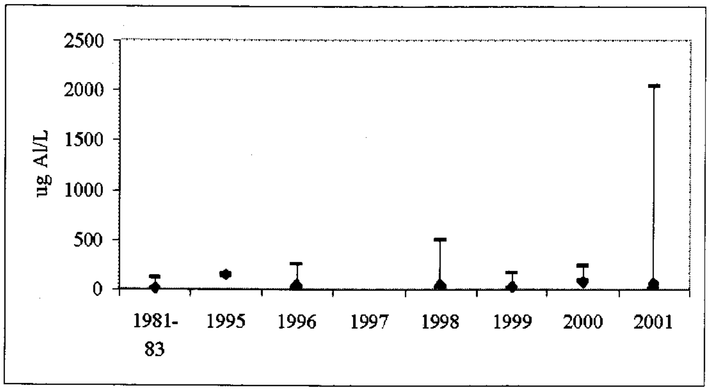
The North Fork Red Dog Creek is a tributary to Main Stem Red Dog Creek. Concentrations of metals at the monitoring site, Station 12, are consistently below the USEPA standard for aquatic life (Weber Scannell and Andersen 1999). The North Fork Red Dog Creek has a drainage area of 41 km^2 (15.9 mi^2), abundant streamside vegetation, deep pools, and wide riffle areas. Widths range from 7 to 15 m (24 to 50 ft) and depths from 0.09 to 2 m (0.3 to 6 ft). Mineral staining is not evident (Figure 50). Arctic grayling spawn in North Fork Red Dog Creek and both Arctic grayling and Dolly Varden juveniles rear in this creek.

Water Quality

The creek is a clear water stream with moderate hardness and total dissolved solids and low sulfate (TeckCominco data files). In 2001, pH ranged from 6.9 to 8.2.

CONCENTRATIONS OF HEAVY ELEMENTS

Median concentrations of metals in the North Fork Red Dog Creek were low, although occasional samples showed elevated concentrations of Al, Cd, Pb, or Zn (Figure 51). In 2001, concentrations of Al, Cd, Pb, and Zn were lower in the North Fork Red Dog Creek than any other creeks sampled.



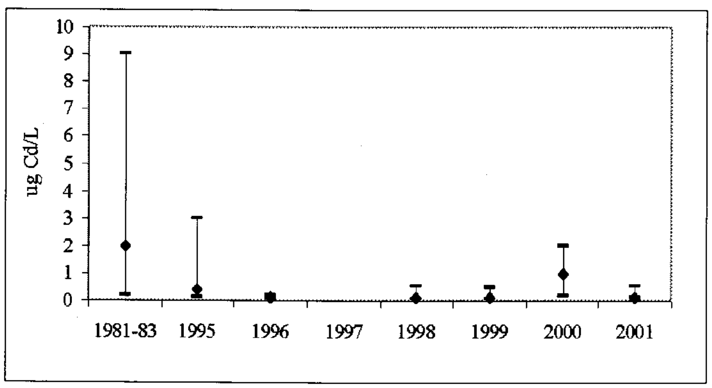
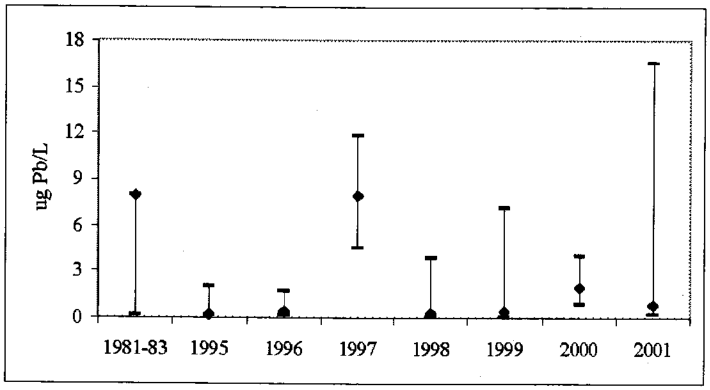


Figure 51. Concentration of select metals in North Fork Red Dog Creek, Station 12, 1981-2001.



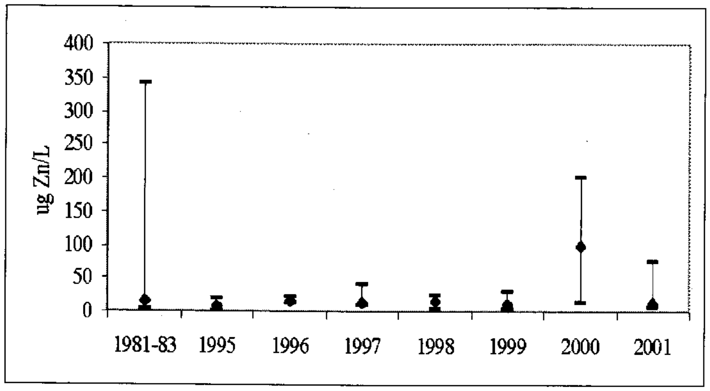


Figure 51, continued.

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 52). 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 lowest in June 1997. In 2001, invertebrate abundance was comparable to the high values reported in 1997. However, invertebrate densities were low (Figure 53).

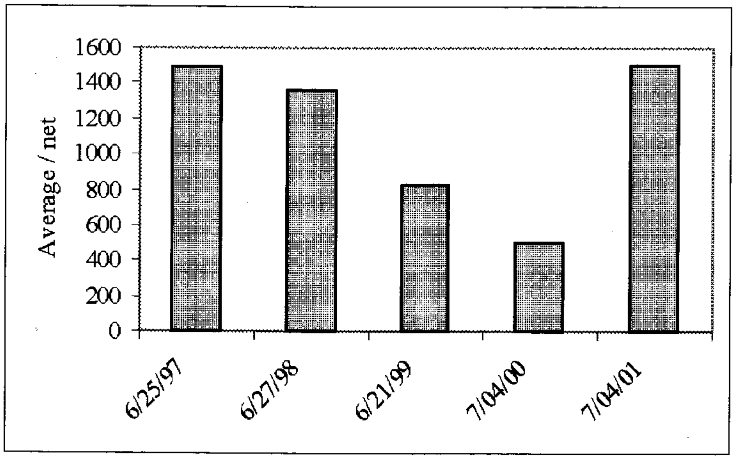


Figure 52. Abundance of aquatic invertebrates (number/net) collected in the North Fork Red Dog Creek, 1997-2001.

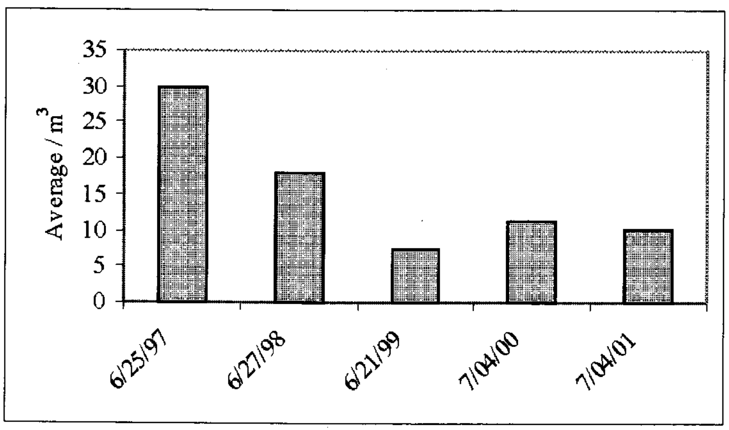


Figure 53. Density of aquatic invertebrates (number/m^3 water) collected in the North Fork Red Dog Creek, 1997-2001.

Taxa richness in aquatic invertebrate samples from the North Fork Red Dog Creek showed little fluctuation among the years sampled (Figure 54). In 2001, we identified a total of 17 genera plus Chironomidae.

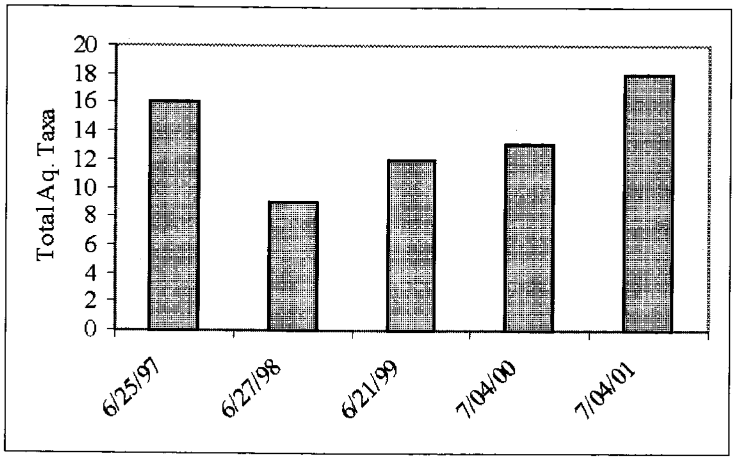


Figure 54. Total aquatic invertebrate taxa from North Fork Red Dog Creek.

STRUCTURE OF COMMUNITY

Invertebrate samples contained low proportions (usually < 20%) EPT taxa in most of the sample events (Figure 55).

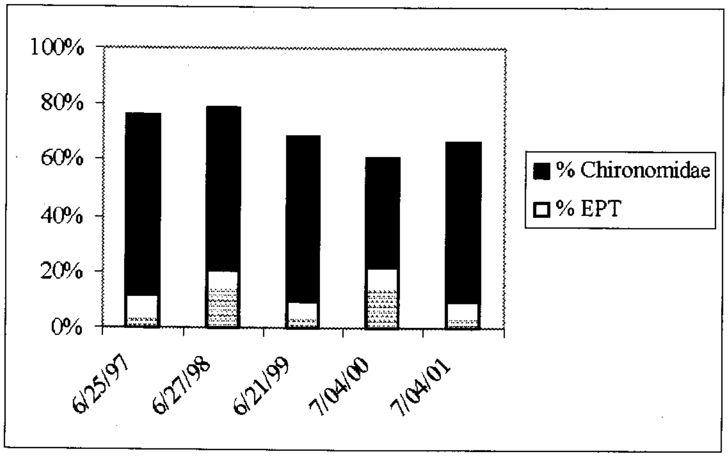


Figure 55. The proportions of EPT taxa and Chironomidae larvae in aquatic invertebrate samples from North Fork Red Dog Creek.

The invertebrate community was dominated by Diptera in all years sampled. Chironomidae larvae were the most abundant taxa in all years with an average 854 Chironomidae larvae/net in 2001. Also common in 2001 samples were Simuliidae: *Simulium,* Ephemeroptera: Baetidae (*Baetis*), Plecoptera: Capniidae (*Allocapnia*), 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 56). Concentrations in 2001 were among the highest measured at this site.

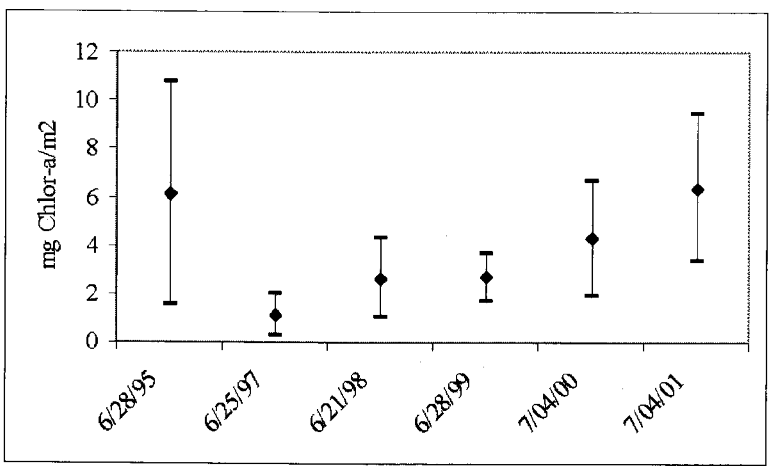


Figure 56. Concentration of chlorophyll-a (mg/m^2) from attached algae collected in North Fork Red Dog Creek.

Composition of Algal Communities

Algal communities in the North Fork Red Dog Creek are a mixture of diatoms and green algae with concentrations consisting of 48% chlorophyll-a, 16% chlorophyll-b, and 16% chlorophyll-c in 2001. The proportions of chlorophyll-b and c are higher at this site in 2001 than in any of the other sites sampled under the NPDES biomonitoring program, indicating a biological diverse community.

Summary of Biomonitoring, North Fork Red Dog Creek

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 20).

Table 20. 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. Higher reported values usually reflect higher method reporting limits.
Invertebrate Community	Abundance is high at this site; however, proportions of EPT taxa are low. 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.

To determine term trends in metals concentrations during the NPDES permit monitoring period (1999-2001), we focused on Al and Cd in kidney tissue, Cu, Pb, and Zn in liver tissue, and Se in kidney, liver, and reproductive tissues. Concentrations of all metals tested are low in muscle tissue (ADF&G data files). Metals concentration data from previous years is presented in Weber Scannell et al. 2001.

ALUMINUM

Concentrations of Al in kidney tissues from Dolly Varden collected in spring and fall 2001 were similar to 1999-00 concentrations (Figure 57).

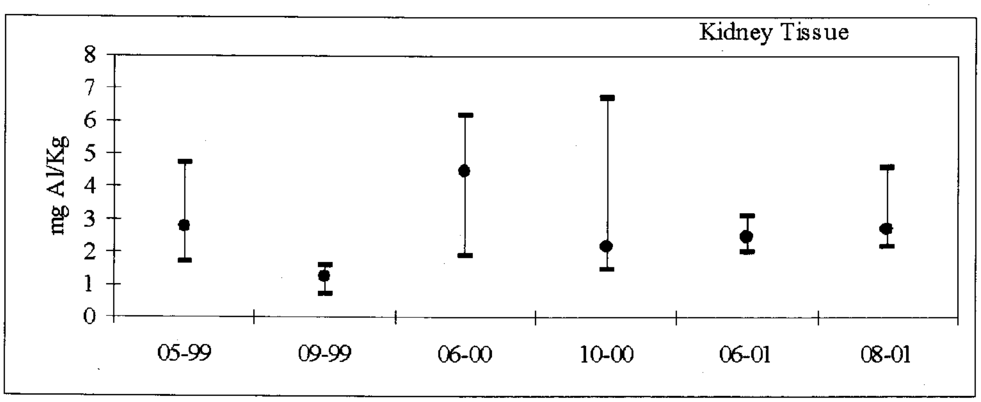


Figure 57. Median, maximum, and minimum concentrations of Al (dry weight basis) in adult Dolly Varden kidney tissue, Wulik River, 1999-01.

CADMIUM

Cadmium concentrations in Dolly Varden kidney tissues in 2001 were within the range found in 1999 and 2000 (Figure 58).

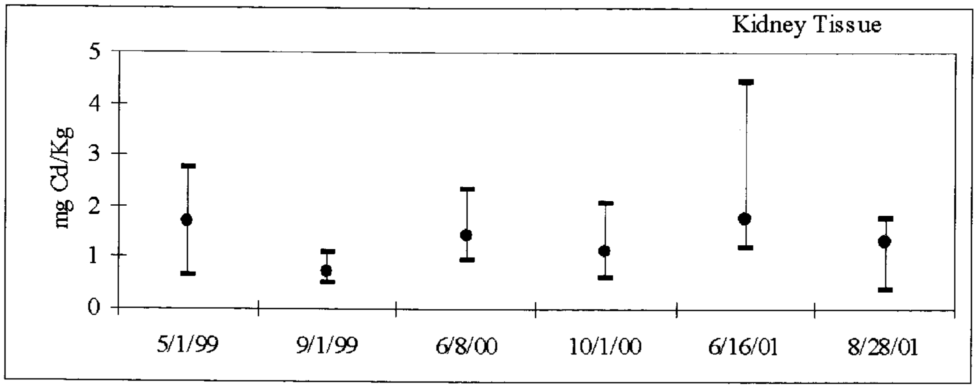


Figure 58. Median, maximum, and minimum concentrations of Cd (dry weight basis) in adult Dolly Varden kidney tissue, Wulik River, 1999-01.

COPPER

Median Cu concentrations reported in spring and fall 2001 were within the ranges found from 1999–00 (Figure 59).

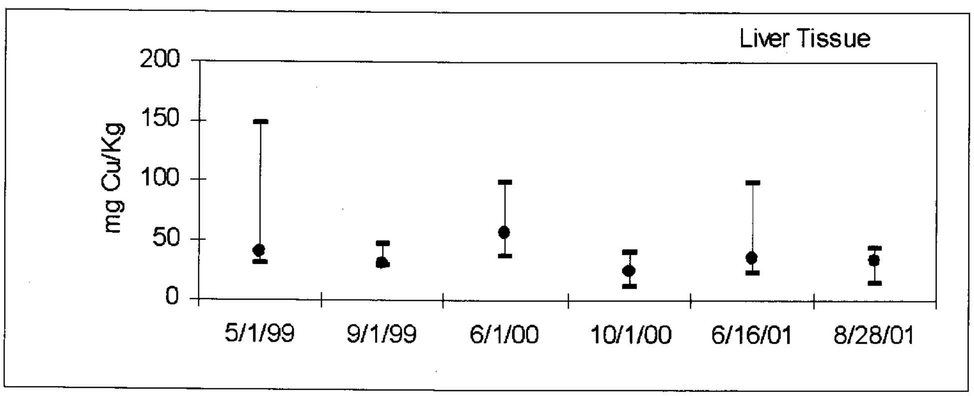


Figure 59. Median, maximum, and minimum concentrations of Cu (dry weight basis) in adult Dolly Varden liver tissue, Wulik River, 1990-01.

LEAD

Median Pb concentrations in liver (Figure 60), muscle (Figure 61), and kidney (Figure 62) were lower in 2001 fish than in the previous year, although maximum concentrations in spring 2001 were higher than the previous year in both liver and muscle.

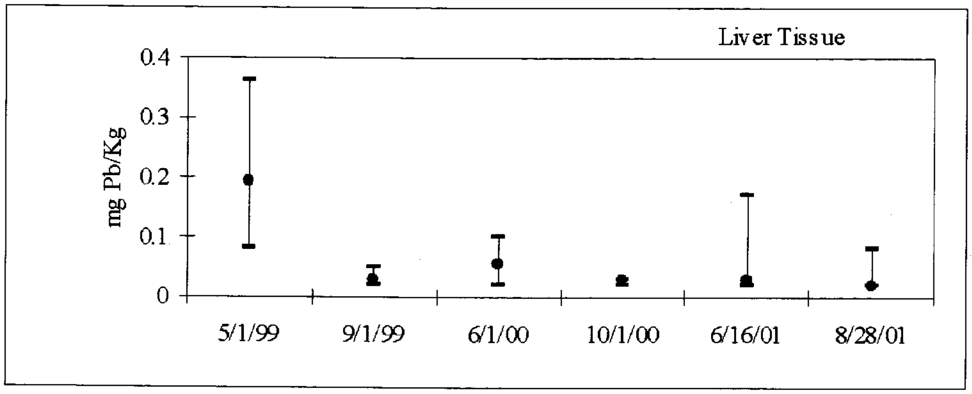


Figure 60. Median, maximum, and minimum concentrations of Pb (dry weight basis) in adult Dolly Varden liver tissues, Wulik River, 1999-01.

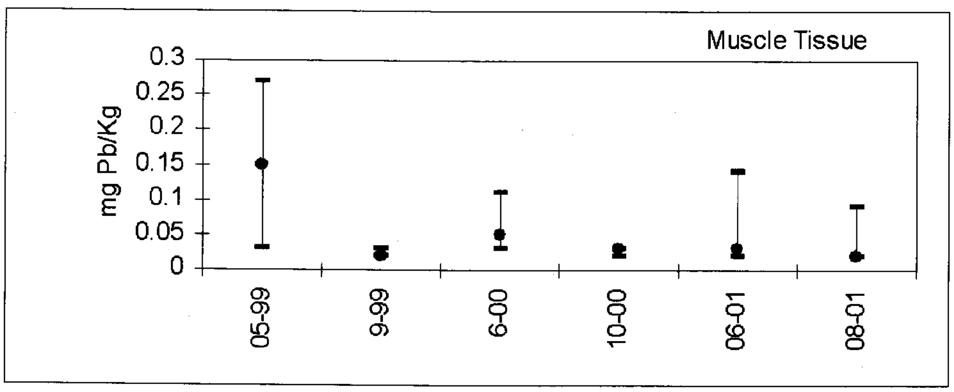


Figure 61. Median, maximum, and minimum concentrations of Pb (dry weight basis) in adult Dolly Varden muscle tissues, Wulik River, 1999-01.

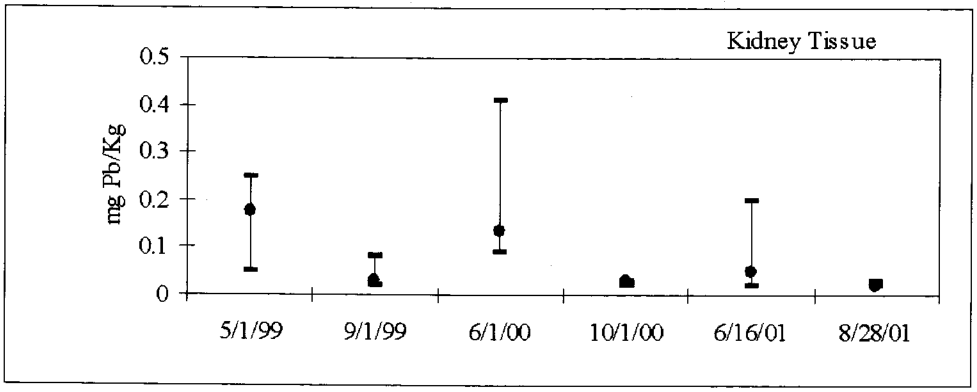


Figure 62. Median, maximum, and minimum concentrations of Pb (dry weight basis) in adult Dolly Varden kidney tissues, Wulik River, 1999-01.

ZINC

Median and maximum Zn concentrations in Dolly Varden liver (Figure 63) were slightly higher in 2001 than samples collected in 2000.

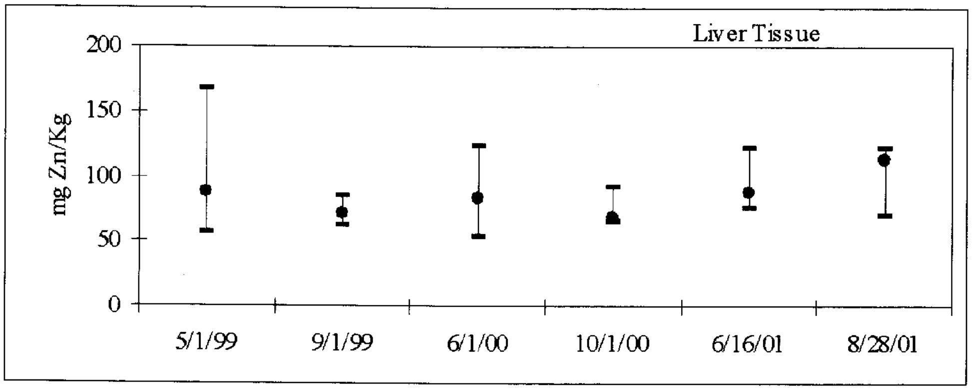


Figure 63. Median, maximum, and minimum concentrations of Zn (dry weight basis) in adult Dolly Varden liver, Wulik River, 1999-01.

SELENIUM

Median Se concentrations in kidney (Figure 64) and liver (Figure 65) tissues were higher in fall 2001 than in the previous two years. Se concentrations in liver tissue were significantly higher in 2001 than in 1999-00 (combined) (Two-tailed T-Test, $p=0.037$), although the differences were not large (mean Se concentration in liver, 1999-00 = 3.39 and mean in 2001 = 3.99). Se concentrations in kidney tissues were not significantly different between 2001 and 1999-00 ($p>0.06$).

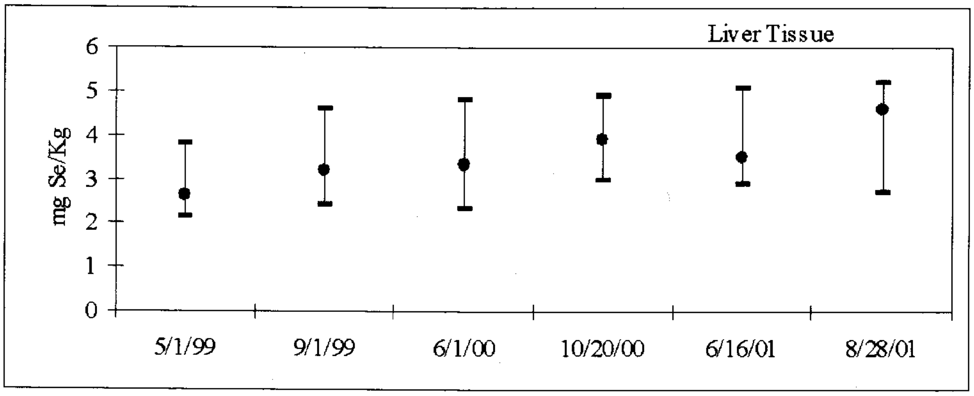


Figure 64. Concentration of Se in adult Dolly Varden liver tissues, Wulik River, 1997-01.

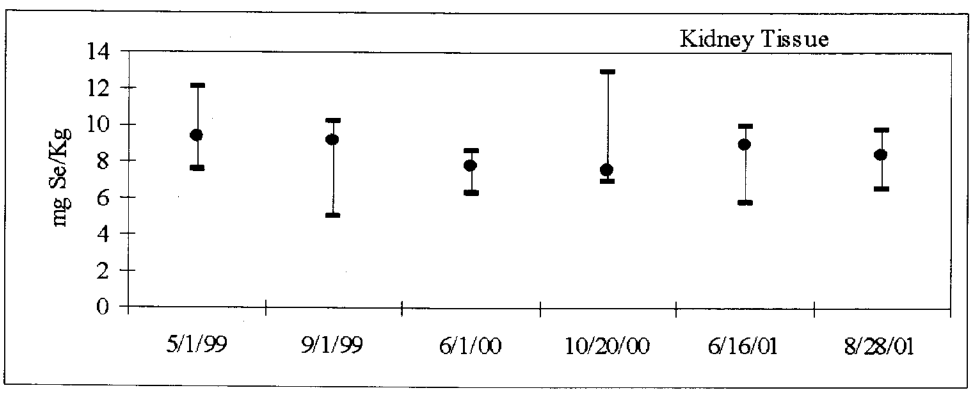


Figure 65. Concentration of Se in adult Dolly Varden kidney tissues, Wulik River, 1999-01.

Median, maximum, and minimum Se concentrations in reproductive tissues were higher in fall-caught fish (returning from the ocean) than in spring-caught fish (after spending the winter in fresh water) (Figure 66). Concentrations observed in 2001 were similar to previous years.

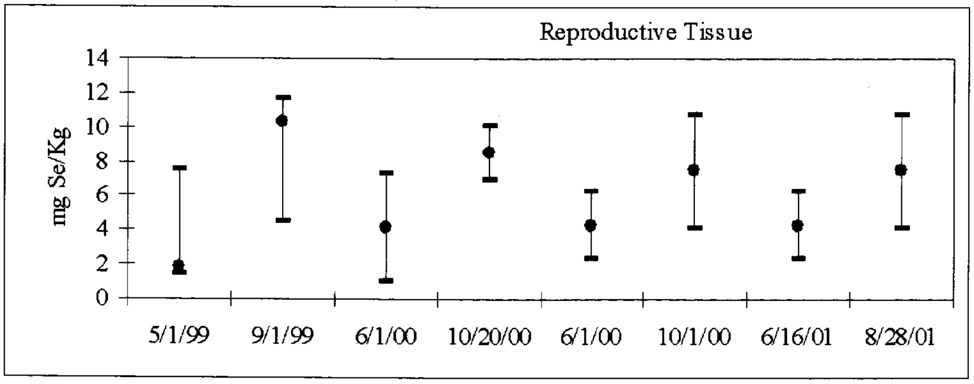


Figure 66. Concentration of Se in adult Dolly Varden reproductive tissues, Wulik River, 1999-01.

Metals Concentrations in Juvenile Dolly Varden

In 2001, we sampled juvenile Dolly Varden for whole body concentrations of Cd, Pb, Se, and Zn concentrations from North Fork Red Dog Creek (upstream of two major forks) and Main Stem Red Dog Creek; we attempted to collect fish at Station 12 and Anxiety Ridge Creek, but were unable to capture any juvenile Dolly Varden. Fish from these two sites were of similar fork length and weight (Figure 67). Concentrations of Cd, Pb, Se, and Zn appear similar between Station 10 and the upstream site in the North Fork; however, statistical comparisons were not made because of small sample size (3 fish from the North Fork and 10 from Main Stem Red Dog Creek (Figure 68).

Fish collected from the Main Stem Red Dog Creek in 2001 contained significantly higher concentrations of Se (Two-tailed T test, $p=0.013$, Figure 69) than fish collected in 1999 and 2000 (combined). Concentrations of Pb were higher (mean for 2001 = 15.12 mg/kg) than in 1999-00 (mean = 8.29 mg/kg); however, the differences were not significant (Figure 70). Concentrations of Cd in fish collected in 2001 were similar to 1999-00 (Figure 71).

Comparisons could not be made for fish collected from the North Fork Red Dog Creek because in 2001 we were unable to collect fish from the same sample location as in 1999 and 2000. We did not successfully collect fish from Anxiety Ridge Creek.

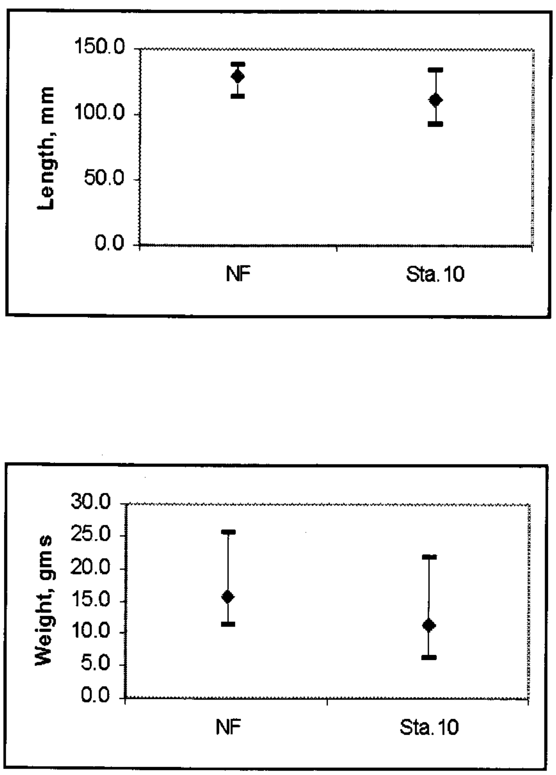


Figure 67. Ranges of length and weight of juvenile Dolly Varden collected for whole body tissue concentrations, 2001.

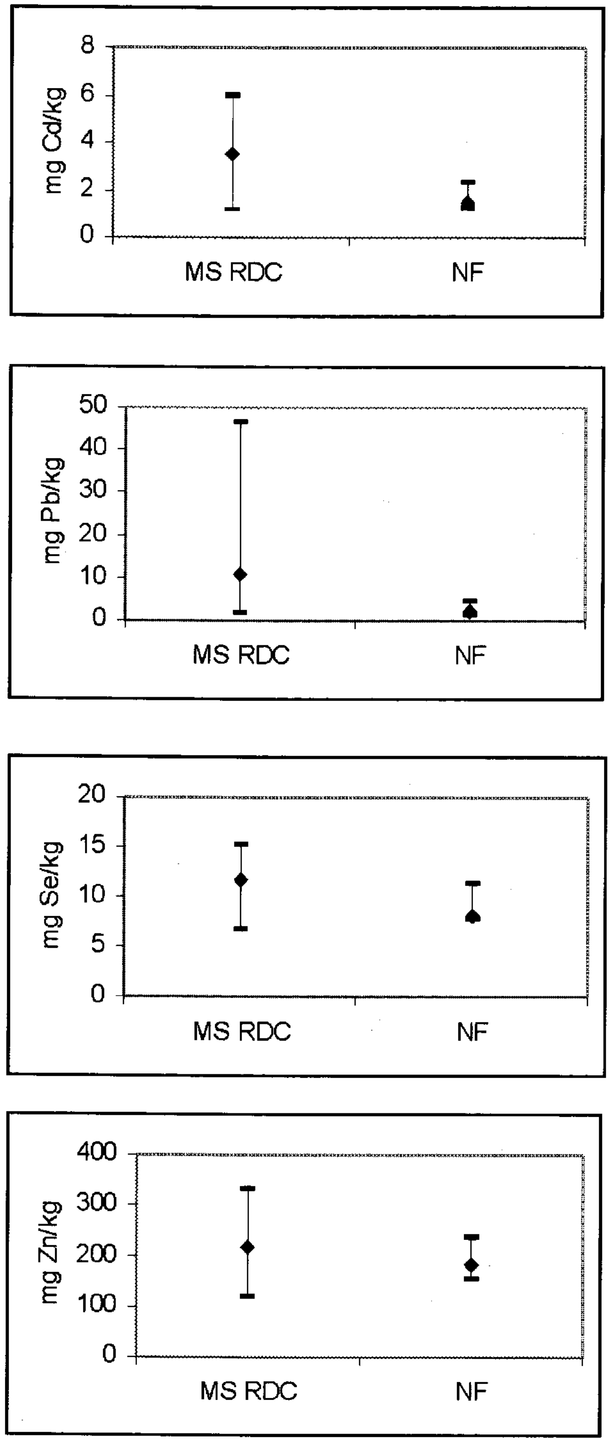


Figure 68. Concentrations of Cd, Pb, Se, and Zn in whole body juvenile Dolly Varden from the North Fork Red Dog Creek (upstream site) and Main Stem Red Dog Creek, 2001.

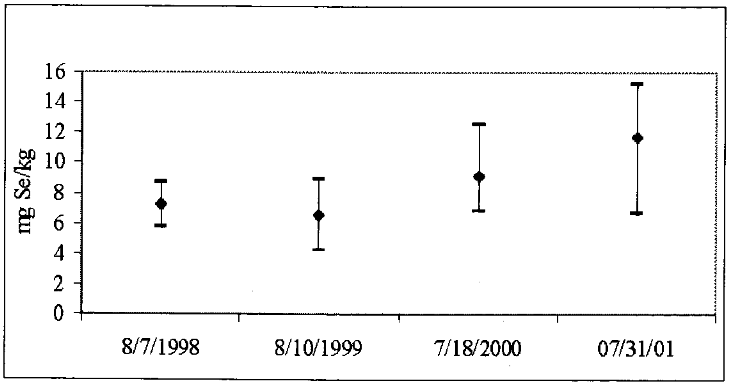


Figure 69. Concentration of Se in juvenile Dolly Varden from Main Stem Red Dog Creek.

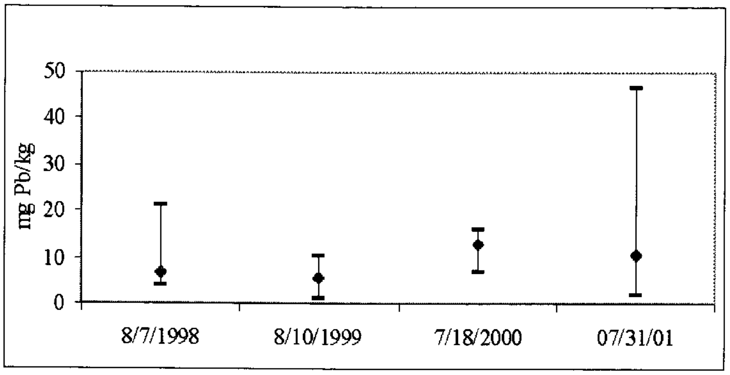


Figure 70. Concentration of Pb in juvenile Dolly Varden from Main Stem Red Dog Creek.

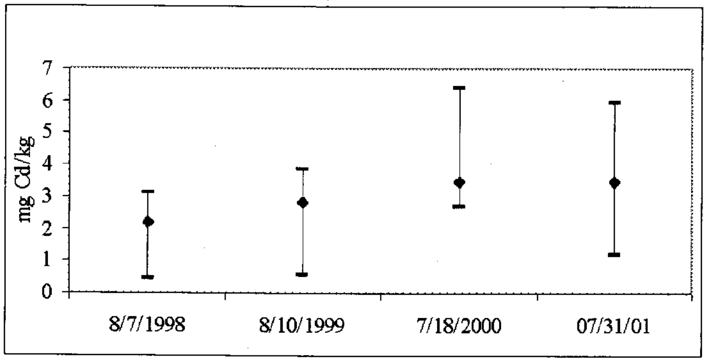


Figure 71. Concentration of Cd in juvenile Dolly Varden from Main Stem Red Dog Creek.

Distribution of Fish throughout Drainage

OVERWINTERING DOLLY VARDEN

The 2001 Dolly Varden fall aerial survey in the Wulik River was made on October 8, in a R-44 helicopter during weather conditions with limited visibility. DeCicco (2001a) estimated 92,614 adult Dolly Varden in the Wulik River from the lagoon to about 3.2 km upstream of Ikalukrok Creek (Appendix 2).

The number of Dolly Varden in 2001 was lower than in six of the previous nine years (Figure 72). Low counts are likely due to limited visibility during the survey. As in previous years, more than 90% of the fish were found in the Wulik River downstream of the confluence with Ikalukrok Creek. Survey areas are shown in Appendix 3.

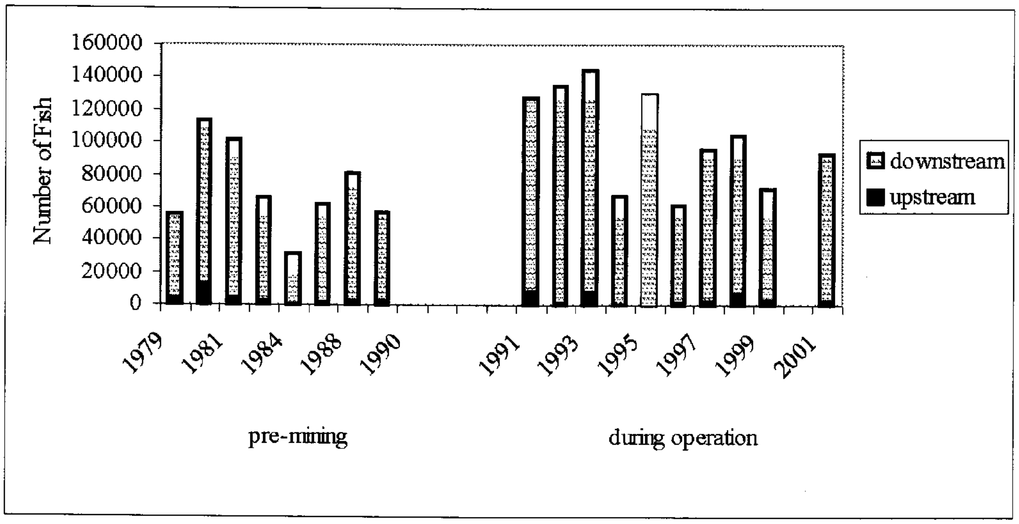


Figure 72. The total number of adult Dolly Varden counted in aerial surveys in the Wulik River, 1979-2001.

CHUM SALMON SPAWNING

In fall 2001, aerial surveys to assess the distribution of adult chum salmon in Ikalukrok Creek downstream of Dudd Creek were done on August 7 (Morris and Ott 2001), August 28 and 29 (DeCicco 2001b), September 23 (DeCicco 2001c), and October 8 (DeCicco 2001a). All surveys were conducted using either a R-44 or an A-Star helicopter. The best survey results were obtained on August 29, 2001, under clear and calm conditions, when DeCicco counted 1,737 live chum salmon and 99 carcasses (Table 21). In 2001, chum salmon began spawning in early August. Although numbers of live fish had dropped to about 232 on October 8, 2001, active spawning was observed(DeCicco 2001a, Morris and Ott 2001). Numbers of chum salmon counted in 2001 were among the highest reported since 1982. A detailed description of chum salmon surveys conducted from 1990 through 1999 is contained in Weber Scannell, Ott, and Morris (2001).

Table 21. Number of adult chum salmon in Ikalukrok Creek downstream of Dudd Creek.

Survey Date	Number of Chum Salmon	Reference
September 1981	3,520 to 6,960	Houghton and Hilgert 1983
August/September 1982	353 and 1,400	Houghton and Hilgert 1983
August 1984	994	DeCicco 1990b
August 1986	1,985	DeCicco 1990b
August 1990	<70	Ott et al. 1992
August 1991	<70	Ott et al. 1992
August 1995	49	Townsend and Lunderstadt 1995
August 1995	300 to 400	DeCicco 1995
August 1996	180	Townsend and Hemming 1996
August 1997	730 to 780	Ott and Simpers 1997
August-September 1998	No survey	
August 1999	75	Ott and Morris 1999
September 1999	145	DeCicco 1999
August 2000	No survey	
August 7, 2001	850	Morris and Ott 2001
August 28, 2001	2,250	DeCicco 2001b
August 29, 2001	1,836	DeCicco 2001b
September 23, 2001	500	DeCicco 2001c
October 8, 2001	232	DeCicco, 2001a

JUVENILE DOLLY VARDEN

Patterns of juvenile Dolly Varden use of Evaingiknuk, Anxiety Ridge, and Ikalukrok Creeks have been studied by ADF&G annually since summer 1990 (Table 22). Weber Scannell, Ott, and Morris (2001) presented detailed descriptions of juvenile Dolly Varden populations from pre-mining (before 1985) and during mine development (1990-2000). Juvenile Dolly Varden sampling areas are shown in Appendix 4.

Table 22. Locations of juvenile fish monitoring and year the site was first sampled. Once established, sampling has continued each year at all the sites.

Site Name	Station No.	Year First Sampled
Evaingiknuk Cr.		1990
Anxiety Ridge Cr.		1990
Ikalukrok Cr. above Dudd Cr.		1990
Ikalukrok Cr. below Dudd Creek	7	1990
North Fork RDC	12	1993
Main Stem RDC, below North Fork	11	1995
Buddy Creek		1996
Main Stem RDC, above Ikalukrok Creek	10	1996
Ikalukrok Cr. Above Main Stem RDC	9	1996
Ikalukrok Cr. Below Main Stem RDC	8	1996

Relative numbers of Dolly Varden were low in 2000 (Weber Scannell, Ott, and Morris 2001), which we attributed to late break-up and cool summer weather. Catches of juvenile Dolly Varden at all sample sites in late summer (late July to early August) 2001 were even lower than in 2000. We caught a total of 79 Dolly Varden in late July – early August, compared with a catch of 945 in early August 1999 (Table 23). Highest use by juvenile Dolly Varden was documented in 1999 at almost all sample sites (Figure 73). Catch data for late summer 1997 through 2001 show that the numbers of fish present in various sample reaches follow a similar pattern. When numbers are high in the reference streams (Anxiety Ridge and Buddy creeks). they also are high in sample reaches downstream of active mining and the effluent outfall.

Table 23. The number of juvenile Dolly Varden caught in minnow traps (10 traps per sample reach) from 1997 through 2001.

Dates Sampled

Sample Location	7/30-8/5/01	7/28-8/1/00	8/9-10/99	8/7-10/98	8/10-13/97
Evaingiknuk Creek	7	2	38	27	54
Anxiety Ridge Creek	6	27	271	94	68
Buddy Creek	34	11	306	154	48
North Fork Red Dog Creek (Station 12)	1	1	17	12	0
Main Stem Red Dog Creek below North Fork	9	13	86	70	14
Main Stem Red Dog Creek (Station 10)	3	1	66	21	10
Ikalukrok Creek below Dudd Creek (Station 7)	6	31	55	51	13
Ikalukrok Creek above Dudd Creek	0	14	37	53	3
Ikalukrok Creek below Main Stem (Station 8)	11	6	28	19	4
Ikalukrok Creek above Main Stem (Station 9)	2	5	41	44	3
Total Catch of Dolly Varden for All Sites	79	111	945	545	217

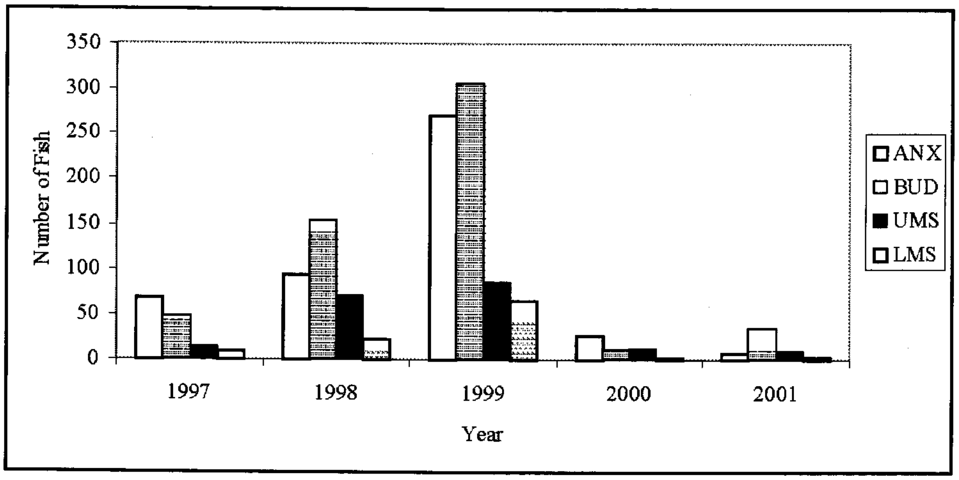


Figure 73. Juvenile Dolly Varden caught in minnow traps in late July – early August 1997-2001. ANX =Anxiety Ridge Cr. BUD = Buddy Cr. UMS = Upper Main Stem Red Dog Cr. And LMS =Lower Main Stem Red Dog Cr.

Higher catches in 1999 are likely due to the abundance of age-0 Dolly Varden found in both 1997 and 1998 (Figure 74). DeCicco (ADF&G Sport Fish Biologist, pers. Comm.

2000) noted that the majority of Dolly Varden collected in 1999 are age 1 and 2. A few older fish and age 0 fish started to appear in the catch. Catches of age-0 Dolly Varden remained low in summers 2000 and 2001 and our catch of juvenile Dolly Varden in late July – early August of 2001 was the lowest recorded in the last five years.

The continued decrease in catch in 2001 likely resulted when larger fish reached smolt size and migrated to marine water in spring 2000. Juvenile Dolly Varden smolt from age 2 to 5; most reach smolt size and migrate to saltwater by age 3 (DeCicco 1990a).

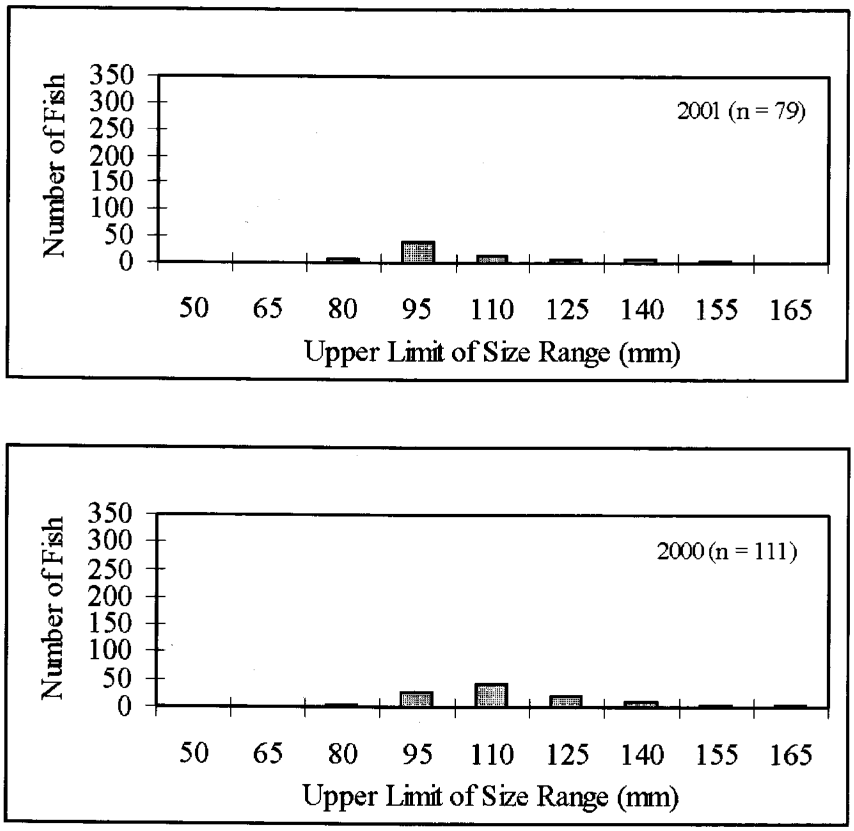
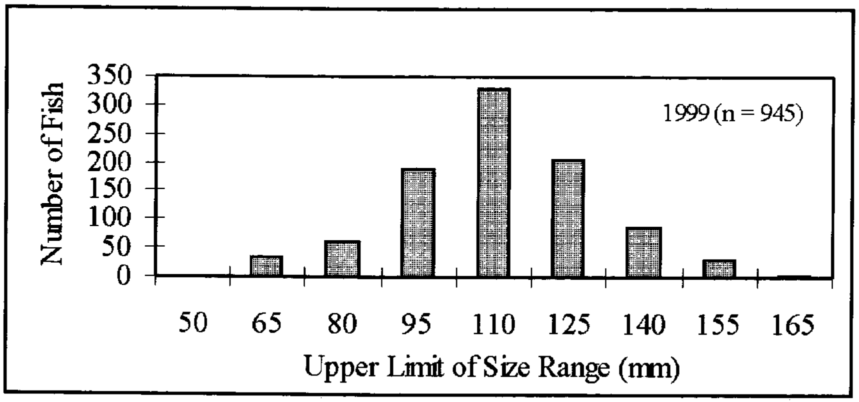
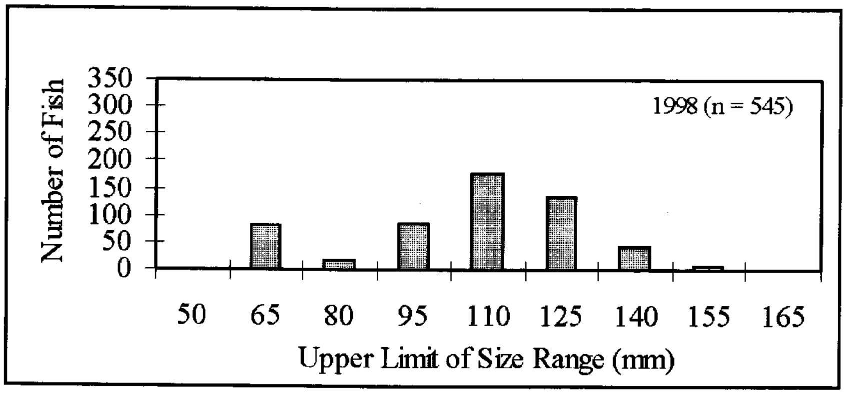


Figure 74. Length frequency of juvenile Dolly Varden captured from 1997 through 2001, all sites combined.





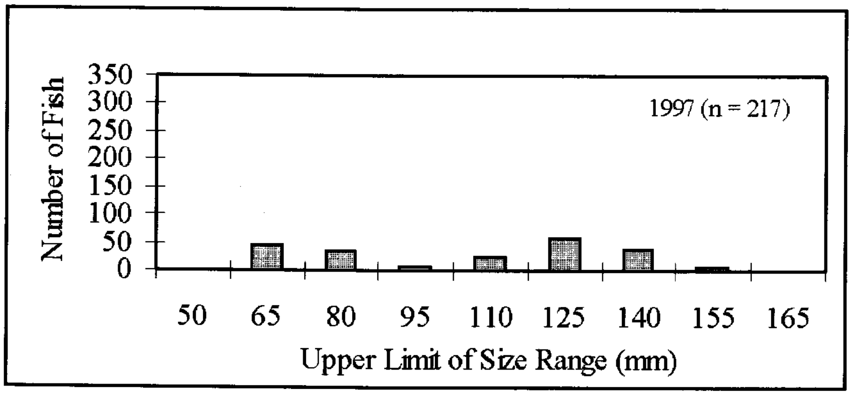


Figure 74, continued.

FYKE-NET SAMPLING FOR DOLLY VARDEN

Fyke-nets were set in the North Fork Red Dog Creek to assess the timing of migration into this creek for summer rearing. Migration of Dolly Varden into North Fork Red Dog Creek in 2001 peaked from June 12 to 15(when we caught 43 juvenile Dolly Varden), following the peak movement of adult Arctic grayling. Fewer fish of the same size range were collected in 2000 (Figure 80). Larger Dolly Varden, with visible parr marks and orange dots along the sides, are likely resident fish moving to North Fork Red Dog Creek for summer rearing. Resident Dolly Varden may preferentially select streams also used by Arctic grayling for spawning, to feed on eggs and age-0 Arctic grayling.

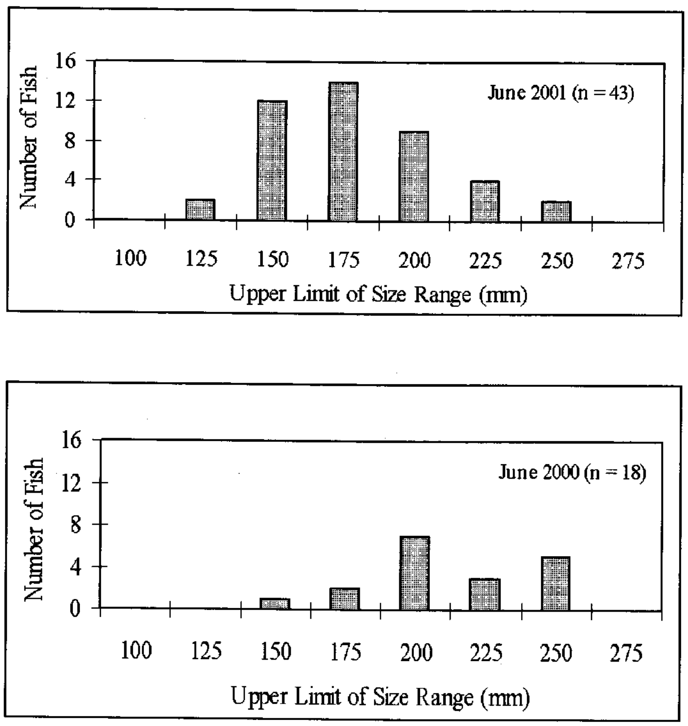


Figure 75. Length-frequency of Dolly Varden captured in North Fork and Main Stem Red Dog Creeks using fyke-nets in June 2000 and 2001.

ARCTIC GRAYLING

Before mine development, Arctic grayling adults were thought to migrate through Main Stem Red Dog Creek in early spring when discharges were high and metals concentrations were low (Weber Scannell, Ott, and Morris 2001 present a detailed description of Arctic grayling population studies before mining and during early years of mine development). Since 1993, we have found adult Arctic grayling and age-0 fish in North Fork Red Dog Creek; the presence of age-0 fish confirms spawning at this site (Table 24). Our observations of stream conditions suggest a strong causal relationship between high numbers of young of the year Arctic grayling and climatic conditions, including warm temperatures, lower flows, and early break-up (Table 14). A few small Arctic grayling were seen in Ikalukrok Creek in early August 2001.

Table 24. Relative number of age-0 Arctic grayling observed in North Fork Red Dog Creek (1992 to 2001).

Year	Relative No. of Age-0 Fish	Comments
1992	high	100's of age-0 fish, late July
1993	low	few age-0 in early August, high water
1994	low	high water after spawning likely 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 followed spawning
1999	high	low flows, low precipitation, warm water after spawning, schools of 50-100 age-0 fish common
2000	low	cold water, late breakup, age-0 fish small (<25 mm) and rare
2001	low	cold-water, late breakup, age-0 fish small (<25 mm) and rare

Water temperatures during, and immediately after, breakup in North Fork Red Dog Creek were highly variable in 1999, 2000, and 2001 (Figure 81). Water temperature is likely a controlling factor in determining spawning time, emergence of age-0 fish, and potential growth during that first summer. In the last three years, only 1999 had a spring breakup that was conducive to early spawning; we found numerous age-0 fish throughout North Fork Red Dog Creek during this year.

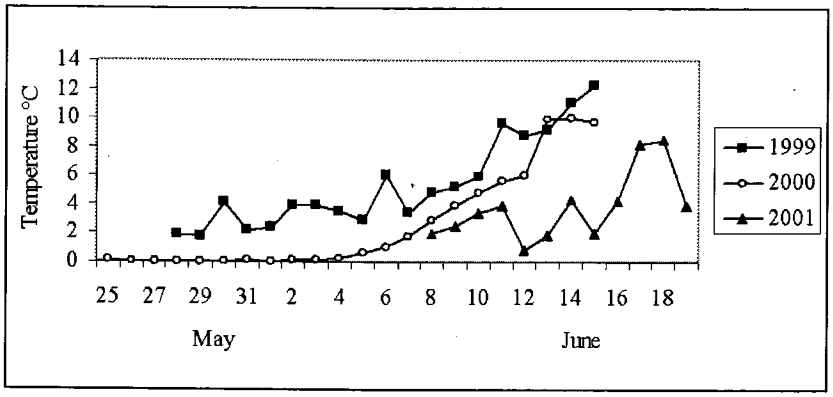


Figure 76. Water temperature (°C) in North Fork Red Dog Creek during spring breakup in 1999, 2000, and 2001.

TIMING OF ARCTIC GRAYLING SPAWNING

In spring 2001, we conducted extensive sampling of Arctic grayling in Main Stem and North Fork Red Dog creeks to correlate physical conditions of temperature, break-up, and stream flow with timing of spawning. Aufeis, ice, and high flows prevented installation of fyke nets in North Fork Red Dog and Main Stem Red Dog creeks until June 8. The fyke-net rolled and no fish were in the net when checked at 1120 hours on June 9. The fyke-net was reset and when checked that evening at 1840 hours we had caught 15 Arctic grayling (13 males and 2 females). Most of these fish were ripe including the two females – water temperature in North Fork Red Dog Creek was 1.3°C.

A second fyke-net was set in North Fork Red Dog Creek about 300 m upstream. Both these fyke-nets were checked at least once a day until the nets were pulled on June 18 and 19, 2001. Highest catches of adult Arctic grayling occurred on June 10 and the first spent female was caught on June 11. Catches of juvenile Arctic grayling peaked on June 15 and 16. All female Arctic grayling caught by fly-fishing in Main Stem Red Dog Creek on June 17 were spent. A number of Arctic grayling were seen spawning in North Fork Red Dog Creek on June 19. Water temperatures were consistently higher in Main Stem Red Dog Creek than North Fork Red Dog Creek during spring 2001 (Figure 82). We believe that these higher water temperatures explain why Arctic grayling spawning was completed in Main Stem Red Dog Creek at least two days before spawning was completed in North Fork Red Dog Creek.

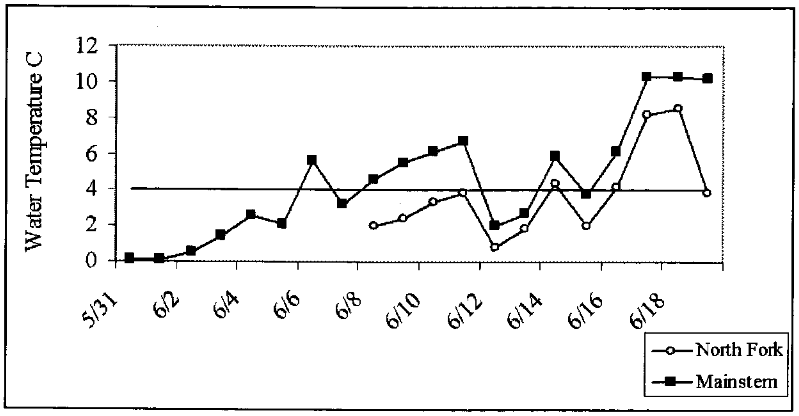


Figure 77. Water temperature (°C) in North Fork Red Dog and Main Stem Red Dog Creeks in spring 2001.

Teck Cominco. was authorized to begin the full discharge from the wastewater treatment plant on June 15, 2001. Total dissolved solids were maintained below 500 mg/L up to the 15th and below 1,500 mg/L after the 15th. Keeping the total dissolved solids concentrations below 500 mg/L was done to ensure protection of Arctic grayling during spawning.

Forty-two Arctic grayling marked in previous years were recaptured (Appendix 5). Three of the Arctic grayling marked in North Fork Red Dog Creek in 1995 were recaptured at the mouth of Grayling Junior Creek in 2001. One fish tagged in East Fork of Ikalukrok Creek in summer 2000 was captured in North Fork Red Dog Creek in early spring 2001 during the spawning run. One Arctic grayling marked in Grayling Junior Creek in summer 2000 was caught in Buddy Creek in early July 2001.

In summer 2001, we marked 234 Arctic grayling in the Ikalukrok Creek drainage (Appendices 6 and 7). Adult Arctic grayling were concentrated at the mouth of Grayling Junior Creek and 73 adults were marked at that site. Aerial surveys conducted during summers 2000 and 2001 indicate that a major portion of the Arctic grayling population spends the summer, post-spawning period, in East Fork Ikalukrok Creek, in Grayling Junior Creek, or in Ikalukrok Creek at the mouths of Grayling Junior, Main Stem Red Dog, and Dudd creeks. Marking a larger number of Arctic grayling in these areas should provide valuable information on movements in subsequent years

Visual surveys of Main Stem Red Dog Creek have been conducted annually since 1994 to document use by Arctic grayling (Appendix 7). Spent female Arctic grayling were present in the lower portion of Main Stem Red Dog Creek on June 17, 2001; we found no indication of spawning in the upstream portion of this creek.

Length frequency distributions for Arctic grayling in North Fork Red Dog Creek for 1995, 2000, and 2001 are presented in Figure 83. Note the presence of several strong age classes of fish < 250 mm in summer 2000. Continued presence of large numbers from these age classes was not observed in summer 2001.

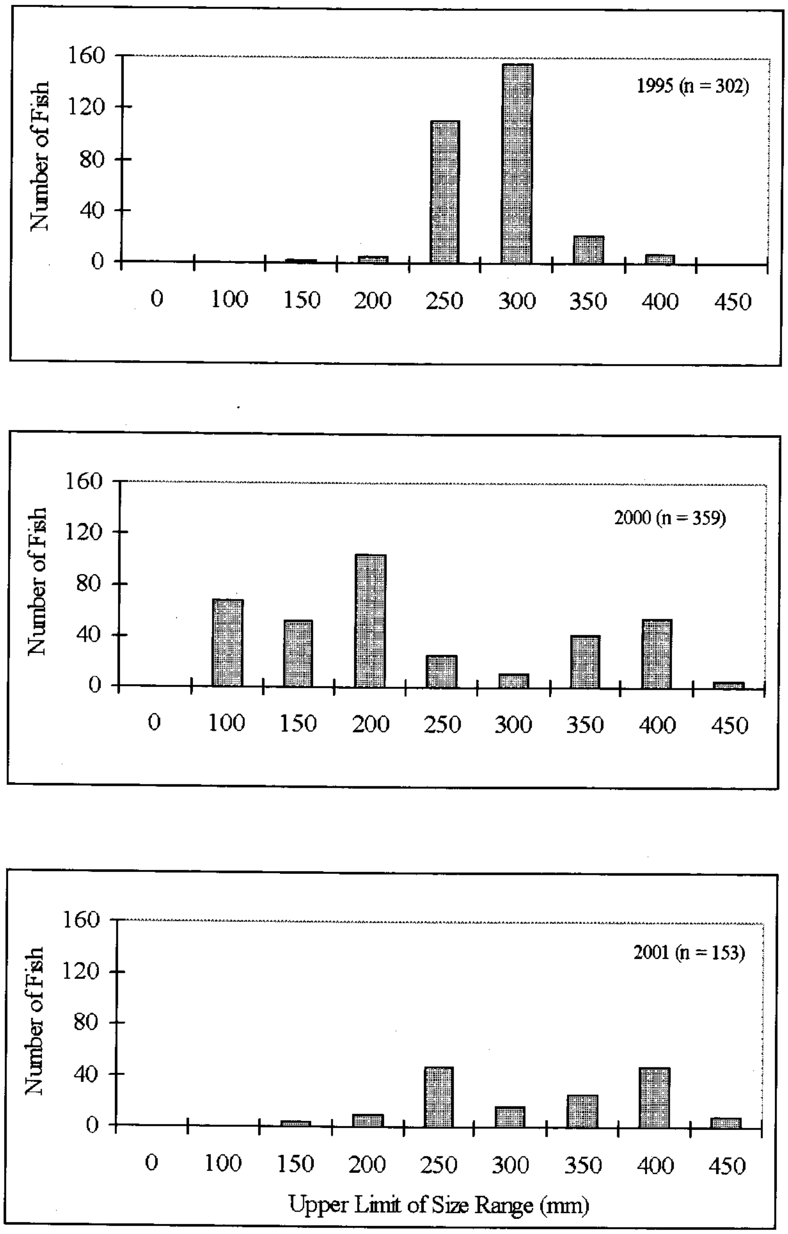


Figure 78. Length frequency distribution of Arctic grayling caught in summer 1995, 2000, and 2001 in North Fork Red Dog Creek.

SLIMY SCULPIN

Houghton and Hilgert (1983) found slimy sculpin in Ikalukrok and Dudd Creeks, but not in the Red Dog Creek drainage. We started sampling with minnow traps in North Fork Red Dog Creek in 1992 and in Middle Fork and Main Stem Red Dog Creeks in 1994. Slimy sculpin were never caught in Middle Fork Red Dog Creek, but were captured in Main Stem and North Fork Red Dog creeks in 1995 (Weber Scannell and Ott 1998). Few slimy sculpin use the Red Dog Creek drainage and the catches are similar to Anxiety Ridge Creek (Weber Scannell and Ott 1998). Most of the slimy sculpin were caught in Ikalukrok Creek near the mouth of Dudd Creek (Figure 84, Appendix 8). We believe slimy sculpin overwinter in lower Ikalukrok Creek and the Wulik River, and probably do not migrate long distances from suitable overwintering habitats to spring spawning or summer rearing areas.

In 2001, we sampled the Omikviorok River upstream and downstream of the Haul Road and caught 14 slimy sculpin in 10 traps; this catch is relatively high compared to catches from sites in the vicinity of the Red Dog Mine. Slimy sculpin populations in Ikalukrok Creek in 1989-1990 may have been depleted by non-point runoff from the Red Dog ore body before construction of the clean-water bypass in late winter 1990. We plan to continue to evaluate catches of slimy sculpin in Ikalukrok Creek.

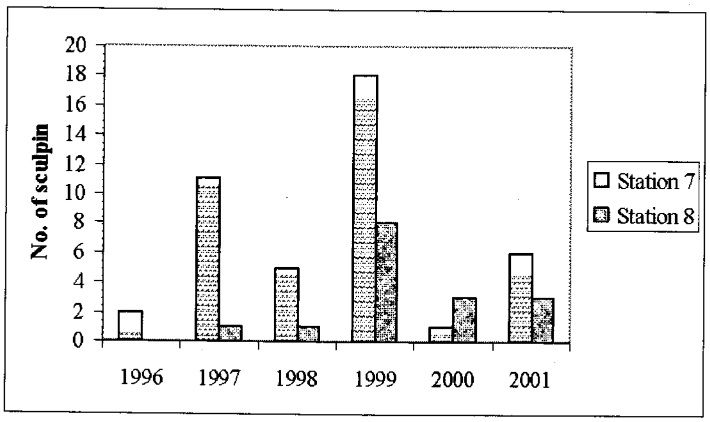


Figure 79. Numbers of slimy sculpin collected in Ikalukrok Creek near Dudd Creek (Station 7) and near Red Dog Creek (Stations 8).

SUMMARY AND CONCLUSIONS

INVERTEBRATE AND PERIPHYTON POPULATIONS

In 2001, invertebrate densities were higher or not significantly changed from 1999-00 at the following sites:

Station 9: Ikalukrok Creek upstream of Red Dog Creek
Ikalukrok Creek upstream of Dudd Creek
Station 10: Main Stem Red Dog Creek
Station 20: Middle Fork Red Dog Creek
Station 12: North Fork Red Dog Creek

Concentrations of chlorophyll-a were higher or not significantly changed at the following sites:

Station 8: Ikalukrok Creek downstream of Red Dog Creek
Station 7: Ikalukrok Creek downstream of Dudd Creek
Station 10: Main Stem Red Dog Creek
Station 20: Middle Fork Red Dog Creek
Station 12: North Fork Red Dog Creek

Both invertebrate abundance and density was highest at Station 9 and Station 12 (North Fork Red Dog Creek) in 2001 and lowest at Station 20 (Figures 80 and 81). Similar amounts of distinct genera were found in all sites (Figure 82). The proportion of EPT taxa was lowest in Stations 10 and 12 and highest in Stations 7, 8, and Ikalukrok Creek upstream (u/s) of Dudd Creek (Figure 83).

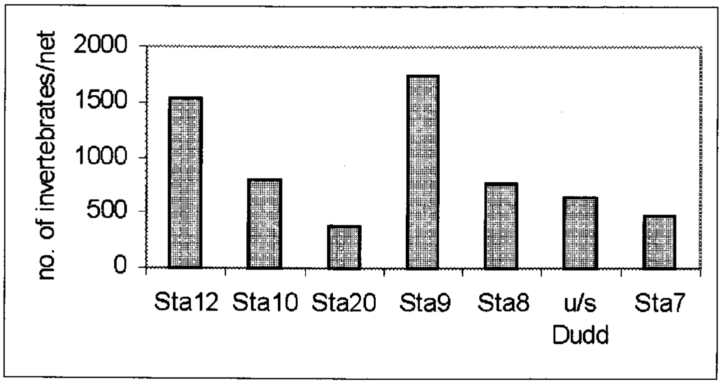


Figure 80. Invertebrate abundance in 2001, all sites.

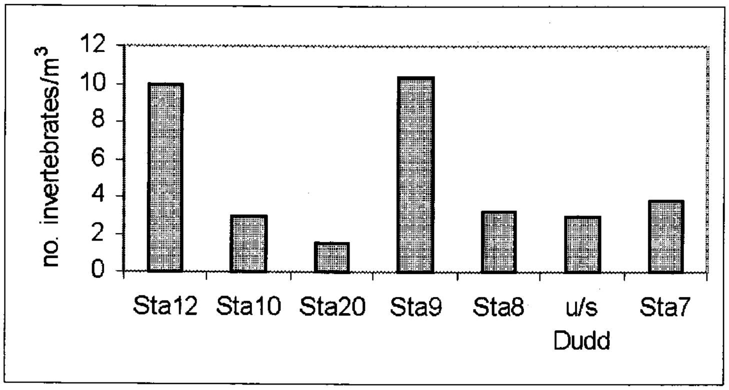


Figure 81. Invertebrate density in 2001, all sites.

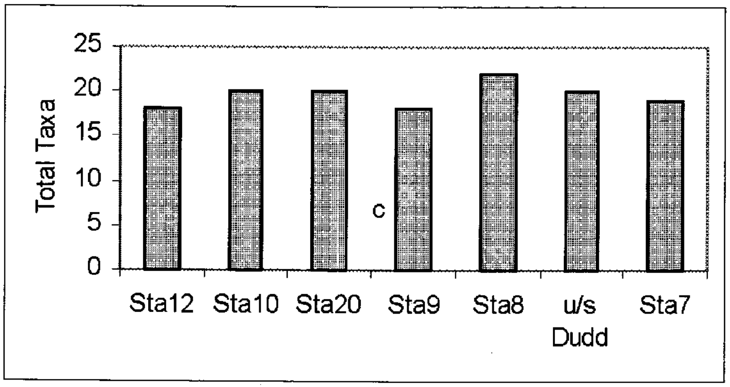


Figure 82. Invertebrate taxonomic richness (total taxa found) in 2001, all sites.

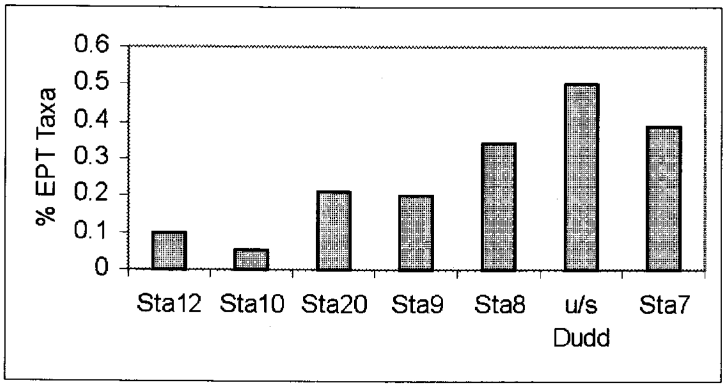


Figure 83. Percent of EPT taxa in 2001, all sites.

ALGAL COMMUNITIES

Concentrations of chlorophyll-a were highest at Station 12, but only slightly higher than found in Ikalukrok Creek upstream of Dudd Creek and at Station 7 Figure 84). To compare relative amounts of chlorophyll b and c among the sites, we only used samples with sufficient chlorophyll to measure all three pigments; samples with values less than the limit of detection for any of the pigments were not used. Concentrations of chlorophylls c and b were substantially higher at Station 12 than any of the other sites sampled.

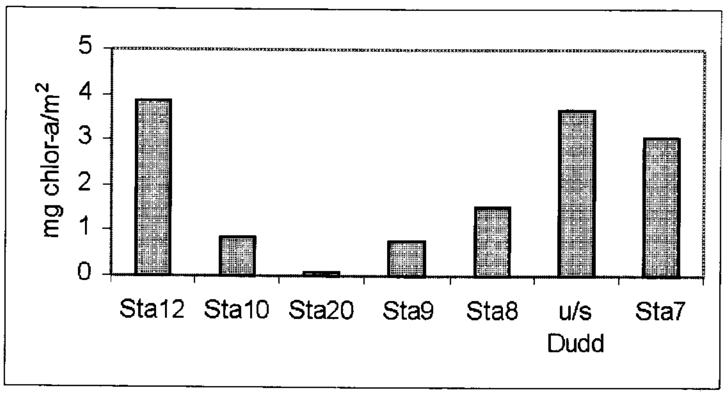


Figure 84. Concentration of chlorophyll-a in 2001, all sites.

LARVAL ARCTIC GRAYLING

Arctic grayling that have recently hatched, but still embryonic (1 to 4 days old) are collected by chance in invertebrate drift nets. Invertebrate samples are not timed to coincide with emergence of embryonic fish. Their presence in the drift nets indicates that spawning has occurred in or upstream of the sample area. The absence of embryonic fish does not define a site as a non-spawning area. At various times, we have found larval fish in all of the sites sampled, except at Station 20. Larval fish most consistently occur at Stations 10 and 12 (Table 25) where we also have observed Arctic grayling on redds actively spawning.

Table 25. Number of larval Arctic grayling found in invertebrate drift nets at each site, 1996-2001.

	Number of Fish for each Year				
Sample Site	1997	1998	1999	2000	2001
Station 7	0	0	0	2	0
IK u/s Dudd	1	0	0	3	0
Station 9	2	0	1		0
Station 8	1	0	0	1	0
Station 10	59	1	0	5	0
Station 12	5	0	1	3	1
Station 20	0	0	0	0	0

CONCENTRATION OF METALS IN ADULT DOLLY VARDEN TISSUES

The following tissues had metals concentrations that were significantly higher in 2001 than in 1999-00:

Gills:	Cd
Muscle:	Al
Liver:	Al and Zn

All other tissues had concentrations of Al, Cd, Cu, Pb, Se, and Zn that were either lower or not significantly changed in 2001.

Concentration of Metals in Juvenile Dolly Varden

Concentrations of Se were significantly higher in juvenile Dolly Varden collected in 2001 from the Main Stem Red Dog Creek than in 1999 and 2000. Concentrations of Cd and Pb were not significantly different among the years 1999 through 2001.

We were unable to collect juvenile fish from the North Fork Red Dog Creek or Anxiety Ridge Creek in 2001.

Fish Populations in the Wulik River

The number of spawning chum salmon counted in the Ikalukrok Creek in 2001 was higher than in previous years. The number of over-wintering (adult) Dolly Varden counted in the Wulik River in 2001 was within the range counted in 1999-00.

Distribution of Fish

We found no changes in fish migration to and use of North Fork Red Dog Creek that could be related to conditions at the mine. We did not observe fish kills in Main Stem Red Dog or Ikalukrok creeks.

Overall, we found that populations of juvenile Dolly Varden were decreased in all tributaries below the mine and in tributaries that were not affected by the mine. We believe the continued low numbers reflect a variety of environmental conditions that were not favorable to spawning success and survival of age-0 fish. Few age-0 Dolly Varden have been caught in the last three years and catches in summer 2001 remained low.

In 2000, recruitment of young of the year Arctic grayling was the highest measured since sampling began in the early 1990s; we believe that late breakup and cold summer temperatures in 2001 caused limited survival of young-of-the-year Arctic grayling.

LITERATURE CITED

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1982

- Baseline studies initiated, Cominco agreement with Nana finalized

1983

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

1984

- Stream surveys conducted along proposed road by private consultant

1985

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

1986

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

1987

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

1988

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

Appendix 1 (continued).

1989

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

1990

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

1991

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

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

Appendix 1 (continued).

1993

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

1994

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

1995

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

1996

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

1997

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

Appendix 1 (continued).

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 Main Stem Red Dog and Ikalukrok Creeks approved by EPA
- Heavy rains cause an unanticipated release of water into Bons Creek from the Kivalina stockpile
- Plans to increase port site capacity for direct loading of ships released to public
- NPDES permit reissued by US EPA
- Two-year aquatic community study completed
- Biomonitoring, including studies of fish and aquatic biota, required under 1998 NPDES permit

1999

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

Appendix 1, continued.

2000

- Effects to Ikalukrok Creek from Alvinella seepage continued; red stain and precipitate observed several km below mouth of Main Stem 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 Cominco
- Biomonitoring study continued
- Baseline fish and aquatic biota studies in streams located in the vicinity of the Anarraaq Prospect begun

2001

- Effects to Ikalukrok Creek from Alvinella seepage continued, red stain and precipitate observed in Ikalukrok Creek to Station 8 below Main Stem 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
- Site-specific criteria for TDS still being worked, data on Arctic grayling spawning/water temperature collected in North Fork Red Dog and Main Stem Red Dog creeks, supplemental data gathered at the Ft. Knox mine
- Studies expanded to include the Delong Mountains Transportation System based on a National Park Service report that metals concentrations adjacent to road were elevated, water sites established upstream and downstream of road and sampled by Teck Cominco, juvenile Dolly Varden samples collected in Omikviorok River and Aufeis Creek, vegetation sampling started by Teck Cominco
- New haul trucks brought on site, hard-covered trucks to minimize loss of Zn and Pb 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 development of a solid waste permit with bonding for the tailing dam. Other issues include site-specific criterion for total dissolved solids, clean-water bypass system, waste rock dumps (acid-rock drainage, and truck wash to minimize metal transport
- Biomonitoring study continued
- Baseline fish and aquatic biota studies in streams located in the vicinity of the Anarraaq Prospect continued for the second field season, four new sites added to study tributaries on west side of Wulik in the area of the Lik Deposit and potential shallow gas development

Appendix 2. Dolly Varden aerial surveys

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

Year	Wulik River upstream of Ikalukrok Creek	Wulik River downstream of Ikalukrok Creek	Total Fish	Percent of Fish downstream of Ikalukrok Creek
Pre-Mining, including Mine Construction				
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	[1]80,144	98
Mine Production				
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	[2]66,752	99
1995	240	128,465	128,705	99
1996	1,010	59,995	61,005	98
1997	2,295	93,117	95,412	98
1998	6,350	97,693	104,043	94
1999	2,750	67,954	70,704	96
2000[3]	-	-	-	
2001	2,020	90,594	92,614	98

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

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

[3]Fall 2000 aerial survey was not made due to weather.

Appendix 3. Adult Dolly Varden survey areas

Appendix 4. Juvenile Dolly Varden sampling areas

Appendix 5. Arctic grayling recaptures during summer 2001.

Tag Number	Color	Date Captured	Site Captured	Length (mm)	Recapture Date	Recapture Site	Length (mm)
1509	W	6/26/95	North Fork	229	7/17/95	North Fork	237
					7/1/98	North Fork	335
					6/15/01	North Fork	364
1520	W	6/26/95	North Fork	223	6/14/00	North Fork	398
					6/9/01	North Fork	395
1537	W	6/29/95	North Fork	230	6/27/97	North Fork	310
					7/11/01	North Fork	373
1548	W	6/29/95	North Fork	236	7/11/01	North Fork	358
1561	W	6/29/95	North Fork	232	7/11/01	Gray Jr. Mouth	370
1599	W	7/17/95	North Fork	377	8/11/95	North Fork	383
					6/27/97	North Fork	385
					7/9/99	North Fork	378
					7/11/01	North Fork	375
1793	W	8/11/95	North Fork	271	6/10/01	North Fork	375
1808	W	8/14/95	North Fork	241	7/11/01	Gray Jr. Mouth	370
1886	W	8/15/95	North Fork	261	7/11/01	Gray Jr. Mouth	410
10646	OR	7/18/96	Dudd Mouth	400	7/10/01	Buddy	410
10939	OR	6/27/97	North Fork	254	6/16/01	North Fork	358
8084	OR	7/8/99	North Fork	215	7/11/01	North Fork	280
8088	OR	7/9/99	North Fork	275	6/16/01	North Fork	340
8034	OR	7/12/99	North Fork	230	6/15/01	North Fork	290
8038	OR	7/12/99	North Fork	345	6/11/01	North Fork	354
10954	OR	7/13/99	North Fork	348	6/11/01	North Fork	356
13008	GRN	6/10/00	North Fork	398	6/9/01	North Fork	408
13010	GRN	6/10/00	Main Stem	362	7/11/00	North Fork	360
					6/10/01	North Fork	367
13012	GRN	6/10/00	Main Stem	370	6/11/01	North Fork	372
13016	GRN	6/11/01	North Fork	362	6/11/01	North Fork	364
13021	GRN	6/12/01	North Fork	392	6/17/01	Main Stem	395
13025	GRN	6/13/01	North Fork	365	6/10/01	North Fork	364
13030	GRN	6/13/01	Main Stem	344	7/11/00	North Fork	344
					6/16/01	North Fork	335
13035	GRN	6/13/00	Main Stem	364	6/16/01	North Fork	375
13047	GRN	7/5/00	North Fork	264	7/11/01	North Fork	295
13048	GRN	7/5/00	North Fork	287	6/16/01	North Fork	309
13050	GRN	7/5/00	North Fork	325	7/11/01	North Fork	355
13051	GRN	7/5/00	North Fork	305	6/17/01	North Fork	315
13052	GRN	7/5/00	North Fork	285	6/17/01	North Fork	300

Appendix 5, continued.

Tag Number	Color	Date Captured	Site Captured	Length (mm)	Recapture Date	Recapture Site	Length (mm)
13062	GRN	7/6/00	North Fork	396	6/10/01	North Fork	392
13063	GRN	7/6/00	North Fork	315	6/16/01	North Fork	330
13070	GRN	7/7/00	North Fork	415	6/10/01	North Fork	420
13076	GRN	7/9/00	North Fork	367	6/10/01	North Fork	374
13088	GRN	7/9/00	North Fork	251	7/11/01	North Fork	
13104	GRN	7/10/00	North Fork	365	6/15/01	North Fork	
13105	GRN	7/10/00	North Fork	325	6/14/01	North Fork	
13116	GRN	7/10/00	Grayling Jr.	410	7/10/01	Buddy	
13126	GRN	7/11/00	North Fork	391	6/11/01	North Fork	
13132	GRN	7/11/00	North Fork	215	6/18/01	North Fork	
13136	GRN	7/11/00	Grayling Jr.	370	7/11/01	Gray Jr. Mouth	
13149	GRN	7/11/00	Grayling Jr.	407	7/11/01	Gray Jr. Mouth	
13173	GRN	7/29/00	EF Ikalukrok	383	6/11/01	North Fork	

Appendix 6. Fyke-net and angling

North Fork Red Dog and Main Stem Red Dog Creeks, June in 2001.

Date	Location	Time	Fish Species	Fork Length (mm)	Tag Number	Tag Color	Water Temp °C	Sex	Condition
6/9/01	Sta. 12	1025		no fish			1.3		
6/9/01	Sta. 12	1840	GR	385	13188	Green	1.3	Male	Ripe
6/9/01	Sta. 12	1840	GR	373	13189	Green	1.3	Male	Ripe
6/9/01	Sta. 12	1840	GR	374	13190	Green	1.3	Female	Ripe
6/9/01	Sta. 12	1840	GR	395	1520	White	1.3	Male	Ripe
6/9/01	Sta. 12	1840	GR	385	13191	Green	1.3	Male	Ripe
6/9/01	Sta. 12	1840	GR	410	13192	Green	1.3	Male	Not Ripe
6/9/01	Sta. 12	1840	GR	384	13193	Green	1.3	Male	Ripe
6/9/01	Sta. 12	1840	GR	405	13194	Green	1.3	Male	Ripe
6/9/01	Sta. 12	1840	GR	415	13195	Green	1.3	Male	Not Ripe
6/9/01	Sta. 12	1840	GR	388	13196	Green	1.3	Male	Not Ripe
6/9/01	Sta. 12	1840	GR	405	13197	Green	1.3	Male	Not Ripe
6/9/01	Sta. 12	1840	GR	380	13198	Green	1.3	Female	Ripe
6/9/01	Sta. 12	1840	GR	408	13008	Green	1.3	Male	Ripe
6/9/01	Sta. 12	1840	GR	395	13199	Green	1.3	Male	Ripe
6/9/01	Sta. 12	1840	GR	363	10824	Orange	1.3	Male	Ripe
6/9/01	Sta. 12	1840	DV	195					
6/9/01	Sta. 12	1840	DV	200					
6/10/01	Net A	1335	GR	385	10823	Orange	1.0	Female	Not Ripe
6/10/01	Net A	1335	GR	396	10822	Orange	1.0	Male	Ripe
6/10/01	Sta. 12	1440	GR	420	13070	Green	NT	Male	Ripe
6/10/01	Sta. 12	1440	GR	385	10821	Orange	NT	Male	Ripe
6/10/01	Sta. 12	1440	GR	392	13062	Green	NT	Male	Ripe
6/10/01	Sta. 12	1440	GR	379	10820	Orange	NT	Female	Ripe
6/10/01	Sta. 12	1440	GR	375	1793	White	NT	Female	Ripe
6/10/01	Sta. 12	1440	GR	379	10819	Orange	NT	Male	Ripe
6/10/01	Sta. 12	1440	GR	408	10818	Orange	NT	Male	Not Ripe
6/10/01	Sta. 12	1440	GR	388	10817	Orange	NT	Male	Not Ripe
6/10/01	Sta. 12	1440	GR	398	10816	Orange	NT	Male	Ripe
6/10/01	Sta. 12	1440	GR	374	13076	Green	NT	Female	Not Ripe
6/10/01	Sta. 12	1440	GR	356	10815	Orange	NT	Female	Not Ripe
6/10/01	Sta. 12	1440	GR	378	10814	Orange	NT	Male	Not Ripe
6/10/01	Sta. 12	1440	GR	352	10813	Orange	NT	Female	Ripe
6/10/01	Sta. 12	1440	GR	380	10812	Orange	NT	Male	Ripe

Appendix 6. Fyke-net and angling, continued.

Date	Location	Time	Fish Species	Fork Length (mm)	Tag Number	Tag Color	Water Temp °C	Sex	Condition
6/10/01	Sta. 12	1440	DV	208					
6/10/01	Sta. 12	1440	DV	206					
6/10/01	Net A	1542	GR	370	10811	Orange	2.0	Female	Not Ripe
6/10/01	Net A	1542	GR	410	10810	Orange	2.0	Female	Not Ripe
6/10/01	Net A	1542	GR	355	10809	Orange	2.0	Female	Not Ripe
6/10/01	Net A	1542	GR	367	13010	Green	2.0	Male	Ripe
6/10/01	Net A	1542	GR	383	10808	Orange	2.0	Male	Ripe
6/10/01	Net A	1542	DV	165					
6/10/01	Sta. 12	2028	GR	389	10807	Orange	1.5	Female	Ripe
6/10/01	Sta. 12	2028	DV	150					
6/10/01	Sta. 12	2028	DV	160					
6/10/01	Sta. 12	2028	DV	155					
6/10/01	Net A	2102	GR	378	10814	Orange	1.2	Male	Ripe
6/10/01	Net A	2102	GR	364	13025	Green	1.2	Female	Not Ripe
6/10/01	Net A	2102	GR	375	10806	Orange	1.2	Female	Ripe
6/10/01	Net A	2102	GR	398	10816	Orange	1.2	Male	Ripe
6/10/01	Net A	2102	GR	383	1793	White	1.2	Female	Ripe
6/10/01	Net A	2102	GR	415	13070	Green	1.2	Male	Ripe
6/10/01	Net A	2102	GR	396	10805	Orange	1.2	Female	Not Ripe
6/11/01	Net A	900		no fish			0.3		
6/11/01	Sta. 12	930	GR	323	10804	Orange	0.7	Male	Not Ripe
6/11/01	Sta. 12	930	GR	331	10803	Orange	0.7	Female	Ripe
6/11/01	Sta. 12	930	GR	349	10802	Orange	0.7	Male	Ripe
6/11/01	Sta. 12	930	DV	230					
6/11/01	Sta. 12	1710	GR	385	10801	Orange	3.1	Female	Ripe
6/11/01	Sta. 12	1710	GR	325	10849	Orange	3.1	Male	Ripe
6/11/01	Sta. 12	1710	GR	390	13126	Green	3.1	Male	Ripe
6/11/01	Sta. 12	1710	GR	385	13173	Green	3.1	Female	Spent
6/11/01	Sta. 12	1710	GR	364	13016	Green	3.1	Female	Ripe
6/11/01	Sta. 12	1710	GR	385	10848	Orange	3.1	Male	Ripe
6/11/01	Sta. 12	1710	GR	347	10847	Orange	3.1	Female	Ripe
6/11/01	Sta. 12	1710	GR	372	13012	Green	3.1	Female	Ripe
6/11/01	Sta. 12	1710	GR	365	10845	Orange	3.1	Female	Ripe
6/11/01	Sta. 12	1710	GR	332	10844	Orange	3.1	Female	Not Ripe
6/11/01	Sta. 12	1710	GR	341	10843	Orange	3.1	Male	Ripe

Appendix 6. Fyke-net and angling, continued.

Date	Location	Time	Fish Species	Fork Length (mm)	Tag Number	Tag Color	Water Temp °C	Sex	Condition
6/11/01	Sta. 12	1710	GR	354	8038	Orange	3.1	Female	Ripe
6/11/01	Sta. 12	1710	DV	200					
6/11/01	Sta. 12	1710	DV	172					
6/11/01	Sta. 12	1710	DV	132					
6/11/01	Net A	1800	GR	354	10842	Orange	2.9	Female	Ripe
6/11/01	Net A	1800	GR	354	10841	Orange	2.9	Male	Ripe
6/11/01	Net A	1800	GR	356	10954	Orange	2.9	Female	Ripe
6/12/01	Net A	910	GR	342	10840	Orange	0.0	Female	Spent
6/12/01	Net A	910	DV	200					
6/12/01	Sta. 12	940	GR	378	10839	Orange	0.0	Female	Ripe
6/12/01	Sta. 12	940	GR	297	10838	Orange	0.0	Female	Ripe
6/12/01	Sta. 12	940	GR	375	10837	Orange	0.0	Female	Ripe
6/12/01	Sta. 12	940	GR	138					
6/12/01	Sta. 12	940	DV	185					
6/12/01	Sta. 12	940	DV	153					
6/12/01	Sta. 12	1310		no fish			0.2		
6/12/01	Net A	1320		no fish			0.2		
6/12/01	Net A	1945		no fish			0.5		
6/12/01	Sta. 12	2020	GR	330	10836	Orange	0.6	Male	Ripe
6/12/01	Sta. 12	2020	GR	297	10835	Orange	0.6	Female	Spent
6/12/01	Sta. 12	2020	DV	196					
6/12/01	Sta. 12	2020	DV	243					
6/12/01	Sta. 12	2020	DV	194					
6/12/01	Sta. 12	2020	DV	184					
6/12/01	Sta. 12	2020	DV	157					
6/13/01	Sta. 12	820	GR	330	10834	Orange	0.2	Female	Part/Spent
6/13/01	Sta. 12	820	GR	225	10833	Orange	0.2	Immature	
6/13/01	Sta. 12	820	GR	224	10832	Orange	0.2	Immature	
6/13/01	Sta. 12	820	DV	160					
6/13/01	Sta. 12	820	DV	178					
6/13/01	Sta. 12	820	DV	171					
6/13/01	Sta. 12	820	DV	156					
6/13/01	Sta. 12	820	DV	133					
6/13/01	Sta. 12	820	DV	168					
6/13/01	Sta. 12	820	DV	134					

Appendix 6. Fyke-net and angling, continued.

Date	Location	Time	Fish Species	Fork Length (mm)	Tag Number	Tag Color	Water Temp °C	Sex	Condition
6/13/01	Sta. 12	820	DV	128					
6/13/01	Net A	900		no fish			0.6		
6/13/01	Sta. 12	1425		no fish			1.0		
6/13/01	Net A	1500		no fish			1.0		
6/13/01	Net A	2025		no fish			1.2		
6/13/01	Sta. 12	2045	GR	342	10831	Orange	1.0	Female	Spent
6/13/01	Sta. 12	2045	DV	165					
6/14/01	Sta. 12	800	GR	250	10830	Orange	0.0	Immature	
6/14/01	Sta. 12	800	DV	116					
6/14/01	Net A	820		no fish			0.0		
6/14/01	Sta. 12	1320	GR	296	10838	Orange	3.0	Female	Spent
6/14/01	Sta. 12	1320	GR	332	10829	Orange	3.0	Male	Part/Spent
6/14/01	Net A	1350	GR	295	10828	Orange	3.0	Male	Part/Spent
6/14/01	Sta. 12	1830	GR	237	10826	Orange	3.9	Immature	
6/14/01	Sta. 12	1830	DV	138					
6/14/01	Sta. 12	1830	DV	165					
6/14/01	Sta. 12	1830	DV	125					
6/14/01	Net A	1840	GR	410	10825	Orange	4.0	Male	Ripe
6/14/01	Net A	1840	GR	350	10874	Orange	4.0	Female	Part/Spent
6/14/01	Net A	1840	GR	340	13105	Green	4.0	Male	Ripe
6/14/01	Net A	1840	GR	405	13197	Green	4.0	Male	Ripe
6/14/01	Net A	1840	GR	330	10873	Orange	4.0	Male	Spent
6/15/01	Net A	750	GR	369	13104	Green	0.4	Male	Ripe
6/15/01	Net A	750	GR	372	10872	Orange	0.4	Female	Ripe
6/15/01	Net A	750	GR	378	10871	Orange	0.4	Female	Part/Spent
6/15/01	Net A	750	GR	364	1509	White	0.4	Male	Ripe
6/15/01	Net A	750	GR	290	8034	Orange	0.4		Spent
6/15/01	Net A	750	GR	346	10869	Orange	0.4	Female	Ripe
6/15/01	Sta. 12	815	GR	212	10868	Orange	0.5	Immature	
6/15/01	Sta. 12	815	GR	218	10867	Orange	0.5	Immature	

Appendix 6. Fyke-net and angling, continued.

Date	Location	Time	Fish Species	Fork Length (mm)	Tag Number	Tag Color	Water Temp °C	Sex	Condition
6/15/01	Sta. 12	815	GR	208	10866	Orange	0.5	Immature	
6/15/01	Sta. 12	815	GR	235	10864	Orange	0.5	Immature	
6/15/01	Sta. 12	815	GR	195			0.5	Immature	
6/15/01	Sta. 12	815	DV	141					
6/15/01	Sta. 12	815	DV	137					
6/15/01	Sta. 12	815	DV	135					
6/15/01	Sta. 12	815	DV	132					
6/15/01	Sta. 12	815	DV	152					
6/15/01	Sta. 12	815	DV	208					
6/15/01	Sta. 12	1430	GR	360	10863	Orange	1.5	Female	Spent
6/15/01	Sta. 12	1430	GR	385	10862	Orange	1.5	Male	Part/Spent
6/15/01	Sta. 12	1430	GR	215	10861	Orange	1.5	Immature	
6/15/01	Sta. 12	1430	GR	203	10860	Orange	1.5	Immature	
6/15/01	Sta. 12	1430	GR	204	10858	Orange	1.5	Immature	
6/15/01	Sta. 12	1430	GR	230	10857	Orange	1.5	Immature	
6/15/01	Sta. 12	1430	GR	205	10855	Orange	1.5	Immature	
6/15/01	Sta. 12	1430	GR	205	10854	Orange	1.5	Immature	
6/15/01	Net A	1450	GR	395	10816	Orange	1.3	Male	Ripe
6/15/01	Sta. 12	2020	GR	215	10852	Orange	1.9	Immature	
6/15/01	Sta. 12	2020	GR	205	10851	Orange	1.9	Immature	
6/15/01	Sta. 12	2020	GR	209	10850	Orange	1.9	Immature	
6/15/01	Sta. 12	2020	GR	202	10846	Orange	1.9	Immature	
6/15/01	Sta. 12	2020	GR	215	10856	Orange	1.9	Immature	
6/15/01	Sta. 12	2020	GR	200	10859	Orange	1.9	Immature	
6/15/01	Sta. 12	2020	GR	205	10865	Orange	1.9	Immature	
6/15/01	Sta. 12	2020	GR	204	10899	Orange	1.9	Immature	
6/15/01	Sta. 12	2020	GR	215	10898	Orange	1.9	Immature	
6/15/01	Sta. 12	2020	GR	204	10896	Orange	1.9	Immature	
6/15/01	Sta. 12	2020	GR	190			1.9	Immature	
6/15/01	Sta. 12	2020	GR	182			1.9	Immature	
6/15/01	Sta. 12	2020	GR	208	10895	Orange	1.9	Immature	
6/15/01	Sta. 12	2020	GR	253	10894	Orange	1.9	Immature	
6/15/01	Net A	2030	GR	218	10853	Orange	1.9	Immature	
6/16/01	Sta. 12	820	GR	215	10893	Orange	0.8	Immature	
6/16/01	Sta. 12	820	GR	218	10892	Orange	0.8	Immature	
6/16/01	Sta. 12	820	GR	212	10891	Orange	0.8	Immature	
6/16/01	Sta. 12	820	GR	258	10889	Orange	0.8	Immature	
6/16/01	Sta. 12	820	GR	288	10888	Orange	0.8	?	Spent

Appendix 6. Fyke-net and angling, continued.

Date	Location	Time	Fish Species	Fork Length (mm)	Tag Number	Tag Color	Water Temp °C	Sex	Condition
6/16/01	Sta. 12	820	GR	340	8088	Orange	0.8	Male	Spent
6/16/01	Sta. 12	820	GR	223	10887	Orange	0.8	Immature	
6/16/01	Sta. 12	820	GR	247	10886	Orange	0.8	Immature	
6/16/01	Sta. 12	820	GR	375	10885	Orange	0.8	Male	Part/Spent
6/16/01	Sta. 12	820	GR	218	10884	Orange	0.8	Immature	
6/16/01	Sta. 12	820	GR	224	10882	Orange	0.8	Immature	
6/16/01	Sta. 12	820	GR	247	10880	Orange	0.8	Immature	
6/16/01	Sta. 12	820	GR	212	10890	Orange	0.8	Immature	
6/16/01	Sta. 12	820	GR	228	10881	Orange	0.8	Immature	
6/16/01	Sta. 12	820	GR	208	10883	Orange	0.8	Immature	
6/16/01	Sta. 12	820	GR	137			0.8	Immature	
6/16/01	Sta. 12	820	GR	207	10897	Orange	0.8	Immature	
6/16/01	Sta. 12	820	GR	204	10900	Orange	0.8	Immature	
6/16/01	Net A	845	GR	260	10879	Orange	0.8	Immature	
6/16/01	Net A	845	GR	200	10878	Orange	0.8	Immature	
6/16/01	Net A	845	GR	220	10877	Orange	0.8	Immature	
6/16/01	Net A	845	GR	230	10876	Orange	0.8	Immature	
6/16/01	Net A	845	GR	184			0.8	Immature	
6/16/01	Net A	845	DV	208					
6/16/01	Sta. 12	1700	GR	358	10939	Orange	2.2	Male	Part/Spent
6/16/01	Sta. 12	1700	GR	210	10884	Orange	2.2	Immature	Immature
6/16/01	Sta. 12	1700	GR	295	10779	Orange	2.2	? Female	Spent
6/16/01	Sta. 12	1700	GR	290	10797	Orange	2.2	? Female	Spent
6/16/01	Sta. 12	1700	GR	210	10796	Orange	2.2	Immature	
6/16/01	Sta. 12	1700	GR	309	13048	Green	2.2	? Female	Spent
6/16/01	Sta. 12	1700	GR	204	10795	Orange	2.2	Immature	
6/16/01	Sta. 12	1700	GR	288	10794	Orange	2.2	? Female	Spent
6/16/01	Sta. 12	1700	GR	155			2.2		
6/16/01	Sta. 12	1700	GR	342	10793	Orange	2.2	? Female	Spent
6/16/01	Sta. 12	1700	GR	330	13063	Green	2.2	? Female	Spent
6/16/01	Sta. 12	1700	GR	302	10792	Orange	2.2	? Female	Spent
6/16/01	Sta. 12	1700	GR	375	13035	Green	2.2	Male	Part/Spent
6/16/01	Sta. 12	1700	GR	210	10791	Orange	2.2	Immature	
6/16/01	Sta. 12	1700	GR	328	10790	Orange	2.2	Male	Spent
6/16/01	Sta. 12	1700	GR	255	10789	Orange	2.2	Immature	
6/16/01	Sta. 12	1700	GR	200	10788	Orange	2.2	Immature	
6/16/01	Sta. 12	1700	GR	335	13030	Green	2.2	Male	Part/Spent
6/16/01	Sta. 12	1700	GR	230	10787	Orange	2.2	Immature	
6/16/01	Sta. 12	1700	GR	285	10786	Orange	2.2	Immature	
6/16/01	Sta. 12	1700	GR	284	10785	Orange	2.2	Immature	

Appendix 6. Fyke-net and angling, continued.

Date	Location	Time	Fish Species	Fork Length (mm)	Tag Number	Tag Color	Water Temp °C	Sex	Condition
6/16/01	Net A	1735	GR	212	10875	Orange	2.2	Immature	
6/16/01	Net A	1735	GR	208	10850	Orange	2.2	Immature	
6/17/01	Net A	835		no fish			0.6		
6/17/01	Sta. 12	837	GR	355	10674	Orange	0.6	Male	Spent
6/17/01	Sta. 12	837	GR	300	13052	Green	0.6	?	Spent
6/17/01	Sta. 12	837	GR	200	10673	Orange	0.6	Immature	
6/17/01	Sta. 12	837	GR	300	10672	Orange	0.6	?	Spent
6/17/01	Sta. 12	837	GR	315	13051	Green	0.6	?	Spent
6/17/01	Main Stem	1500	GR	420	10671	Orange		Male	Ripe
6/17/01	Main Stem	1500	GR	390	10807	Orange		Female	Spent
6/17/01	Main Stem	1500	GR	378	10670	Orange		Female	Spent
6/17/01	Main Stem	1500	GR	385	10669	Orange		Female	Spent
6/17/01	Main Stem	1500	GR	415	10668	Orange		Male	Ripe
6/17/01	Main Stem	1500	GR	374	10667	Orange		Female	Spent
6/17/01	Main Stem	1500	GR	365	10666	Orange		Male	Ripe
6/17/01	Main Stem	1500	GR	425	10665	Orange		Male	Ripe
6/17/01	Main Stem	1500	GR	400	10662	Orange		Male	Ripe
6/17/01	Main Stem	1500	GR	395	13021	Green		Female	Spent
6/17/01	Main Stem	1500	GR	430	10661	Orange		Male	Spent
6/17/01	Sta. 12	1745	GR	205	10851	Orange	7.8	Immature	
6/17/01	Sta. 12A	1750		no fish					
6/18/01	Sta. 12A	805	GR	234	10864	Orange	1.2	Immature	
6/18/01	Sta. 12A	805	GR	246	13132	Green	1.2	Immature	
6/18/01	Sta. 12A	805	DV	163					
6/18/01	Sta. 12	820	GR	342	10660	Orange	1.2	Female	Spent
6/18/01	Sta. 12	820	GR	203	10851	Orange	1.2	Immature	
6/18/01	Sta. 12	820	GR	200	10659	Orange	1.2	Immature	
6/18/01	Sta. 12	820	GR	112					
6/18/01	North Fork	1500	GR	285	10792	Orange	8.2	?	Spent
6/18/01	North Fork	1500	GR	290	10658	Orange	8.2	?	Spent
6/18/01	Net A	1800	DV	133					

Appendix 6. Fyke-net and angling, continued.

Date	Location	Time	Fish Species	Fork Length (mm)	Tag Number	Tag Color	Water Temp °C	Sex	Condition
6/18/01	Sta. 12	1810	GR	387	10657	Orange	8.2	Male	Ripe
6/18/01	Sta. 12	1810	GR	293	10799	Orange	8.2	?	Spent
6/18/01	Sta. 12	1810	DV	140					
6/19/01	Sta. 12	745		no fish			0.9		

Appendix 7. Arctic grayling captures in July 2001.

Summary of fish tagged in 2001	
Site	Total Fish Tagged
Buddy Creek	5
Grayling Jr.	73
Main Stem	10
North Fork	146

Date	Location	Fork Length (mm)	New Tag Number	Tag Color	Recapture Tag Number	Tag Color
7/10/01	Buddy	420			13116	Green
7/10/01	Buddy	310	10656	Orange		
7/10/01	Buddy	235	10655	Orange		
7/10/01	Buddy	410			10646	Orange
7/10/01	Buddy	380	10654	Orange		
7/10/01	Buddy	420	10653	Orange		
7/10/01	Buddy	298	10652	Orange		
7/11/01	Gray Jr. Mouth	268	10651	Orange		
7/11/01	Gray Jr. Mouth	374			13136	Green
7/11/01	Gray Jr. Mouth	245	10650	Orange		
7/11/01	Gray Jr. Mouth	362	8024	Orange		
7/11/01	Gray Jr. Mouth	395	8023	Orange		
7/11/01	Gray Jr. Mouth	435	8022	Orange		
7/11/01	Gray Jr. Mouth	395	8021	Orange		
7/11/01	Gray Jr. Mouth	295	8020	Orange		
7/11/01	Gray Jr. Mouth	410	8019	Orange		
7/11/01	Gray Jr. Mouth	380	8018	Orange		
7/11/01	Gray Jr. Mouth	400	8017	Orange		
7/11/01	Gray Jr. Mouth	310	8016	Orange		
7/11/01	Gray Jr. Mouth	235	8015	Orange		
7/11/01	Gray Jr. Mouth	290	8014	Orange		
7/11/01	Gray Jr. Mouth	374	8013	Orange		
7/11/01	Gray Jr. Mouth	360	8012	Orange		
7/11/01	Gray Jr. Mouth	405	8011	Orange		
7/11/01	Gray Jr. Mouth	420	8010	Orange		
7/11/01	Gray Jr. Mouth	272	8009	Orange		
7/11/01	Gray Jr. Mouth	425	8008	Orange		

Appendix 7. Arctic grayling, continued.

Date	Location	Fork Length (mm)	New Tag Number	Tag Color	Recapture Tag Number	Tag Color
7/11/01	Gray Jr. Mouth	375	8007	Orange		
7/11/01	Gray Jr. Mouth	398	8006	Orange		
7/11/01	Gray Jr. Mouth	370			1561	White
7/11/01	Gray Jr. Mouth	300	8005	Orange		
7/11/01	Gray Jr. Mouth	380	8004	Orange		
7/11/01	Gray Jr. Mouth	388	8003	Orange		
7/11/01	Gray Jr. Mouth	398	8002	Orange		
7/11/01	Gray Jr. Mouth	360	8001	Orange		
7/11/01	Gray Jr. Mouth	410	8000	Orange		
7/11/01	Gray Jr. Mouth	385	8074	Orange		
7/11/01	Gray Jr. Mouth	390	8073	Orange		
7/11/01	Gray Jr. Mouth	375	8072	Orange		
7/11/01	Gray Jr. Mouth	380	8071	Orange		
7/11/01	Gray Jr. Mouth	390	8070	Orange		
7/11/01	Gray Jr. Mouth	410	8069	Orange		
7/11/01	Gray Jr. Mouth	385	8068	Orange		
7/11/01	Gray Jr. Mouth	388	8067	Orange		
7/11/01	Gray Jr. Mouth	415	8066	Orange		
7/11/01	Gray Jr. Mouth	410	8065	Orange		
7/11/01	Gray Jr. Mouth	400	8064	Orange		
7/11/01	Gray Jr. Mouth	430	8063	Orange		
7/11/01	Gray Jr. Mouth	370	8062	Orange		
7/11/01	Gray Jr. Mouth	384	8061	Orange		
7/11/01	Gray Jr. Mouth	388	8060	Orange		
7/11/01	Gray Jr. Mouth	265	8059	Orange		
7/11/01	Gray Jr. Mouth	298	8058	Orange		
7/11/01	Gray Jr. Mouth	420	8057	Orange		
7/11/01	Gray Jr. Mouth	430	8056	Orange		
7/11/01	Gray Jr. Mouth	415	8055	Orange		
7/11/01	Gray Jr. Mouth	385	8054	Orange		
7/11/01	Gray Jr. Mouth	335	8053	Orange		
7/11/01	Gray Jr. Mouth	397	8052	Orange		
7/11/01	Gray Jr. Mouth	405	8051	Orange		
7/11/01	Gray Jr. Mouth	440	8050	Orange		
7/11/01	Gray Jr. Mouth	405			13149	Green
7/11/01	Gray Jr. Mouth	410			1866	White
7/11/01	Gray Jr. Mouth	395	10798	Orange		
7/11/01	Gray Jr. Mouth	400	7849	Orange		
7/11/01	Gray Jr. Mouth	430	7848	Orange		
7/11/01	Gray Jr. Mouth	370			1808	White
7/11/01	Gray Jr. Mouth	390	7847	Orange		
7/11/01	Gray Jr. Mouth	420	7846	Orange		

Appendix 7. Arctic grayling, concluded.

		Fork	New		Recapture	
		Length	Tag	Tag	Tag	Tag
Date	Location	(mm)	Number	Color	Number	Color
7/11/01	Gray Jr. Mouth	390	7845	Orange		
7/11/01	Gray Jr. Mouth	390	7844	Orange		
7/11/01	Gray Jr. Mouth	400	7843	Orange		
7/11/01	Gray Jr. Mouth	420	7842	Orange		
7/11/01	Gray Jr. Mouth	400	7841	Orange		
7/11/01	Gray Jr. Mouth	385	7840	Orange		
7/11/01	Gray Jr. Mouth	350	7839	Orange		
7/11/01	Gray Jr. Mouth	395	7838	Orange		
7/11/01	Gray Jr. Mouth	410	7837	Orange		
7/11/01	Gray Jr. Mouth	410	7836	Orange		
7/11/01	Gray Jr. Mouth	415	7835	Orange		
7/11/01	Gray Jr. Mouth	420	7834	Orange		
7/11/01	Gray Jr. Mouth	374	7833	Orange		
7/11/01	Gray Jr. Mouth	365	7832	Orange		
7/11/01	Gray Jr. Mouth	425	10663	Orange		
7/11/01	Gray Jr. Mouth	430	10664	Orange		
7/11/01	North Fork	280			13088	Green
7/11/01	North Fork	370	13224	Green		
7/11/01	North Fork	256	13222	Green		
7/11/01	North Fork	355			13050	Green
7/11/01	North Fork	305	13221	Green		
7/11/01	North Fork	230	13220	Green		
7/11/01	North Fork	370	13219	Green		
7/11/01	North Fork	360	13218	Green		
7/11/01	North Fork	373			1537	White
7/11/01	North Fork	358	13216	Green		
7/11/01	North Fork	280			8084	Orange
7/11/01	North Fork	320			1599	White
7/11/01	North Fork	295			13047	Green
7/11/01	North Fork	250	13215	Green		
7/11/01	North Fork	328	13214	Green		
7/11/01	North Fork	338	13213	Green		
7/11/01	North Fork	365	10592	Orange		
7/11/01	North Fork	362	13212	Green		
7/11/01	North Fork	343	13211	Green		
7/11/01	North Fork	370	13210	Green		
7/11/01	North Fork	358			1548	White
7/11/01	North Fork	330	13209	Green		
7/11/01	North Fork	350	13208	Green		
7/11/01	North Fork	410	10593	Orange		
7/11/01	North Fork	390	13206	Green		

Appendix 8. Arctic grayling visual observations

Observations and captures in Main Stem Red Dog Creek below confluence of North Fork and Middle Fork Red Dog Creeks since 1994.

Sample Date	Sample Method	Comments on Arctic grayling (YOY = young-of-the-year Arctic grayling)
7/29-31/01	visual	very few YOY seen (about 20 mm), late breakup, cold temperatures resulted in late spawning
6/17/01	angling	11 adults captured, marked, and released in lower 1.6 km of creek, all females spent, two of the fish were recaptures
6/15-18/01	visual	walked Main Stem Red Dog to check for spawning in proposed mixing zone, none observed, one adult seen feeding at rock bluff (0.8 km below North Fork)
6/11-12/00	fyke net	adults captured, marked, and released
7/5/00	visual	two adults feeding at rock bluff (0.8 km below North Fork), juvenile observed
7/6/00	visual	walked most of Main Stem Red Dog Creek, tagged three adults just above dog-leg airstrip, most pools held one to three adults
7/28/00	visual	several age-0 in backwaters and along stream margins in Main Stem Red Dog Creek, not numerous
5/29/99	angling	three adult Arctic grayling caught just below North Fork Main Stem Red Dog Creek mouth
5/30/99	fyke-net	32 adult grayling, about 100 m below North Fork mouth
7/8-9/99	angling	two Arctic grayling marked in lower Main Stem Red Dog
7/8-9/99	visual	12 grayling and some fry in lower Main Stem
7/8-9/99	visual	two adult grayling at rock bluff (0.8 km below North Fork)
7/8-9/99	visual	two adult grayling at rock bluff (0.1 km below North Fork)
8/9-10/99	visual	numerous YOY in backwaters and along stream margins in Main Stem Red Dog Creek
6/10/98	visual	no fish seen in Main Stem, North Fork mouth to rock bluff
6/28/98	visual	one adult feeding (rock bluff 0.8 km below North Fork)
6/25/97	drift net	YOY present near Station 10, 13-15 mm long
6/25/97	visual	two adults near rock bluff about 0.8 km below North Fork
6/26/97	angling	15 tagged fish (range 300-416 mm, average 364 mm) in scour pool at mouth of Main Stem, eight were spawned out

Appendix 8, Arctic grayling visual observations, concluded.

Sample Date	Sample Method	Comments on Arctic grayling (YOY = young-of-the year Arctic grayling)
8/10/97	visual	YOY present in backwater areas
9/29/97	traps	seven YOY caught near Station 10
6/27/97	visual	YOY numerous near Station 10
6/19/96	visual	one adult near Station 10
7/15/96	angling	seven tagged fish (range 274-382 mm, average 330 mm), 2 km above mouth
8/11/96	visual	YOY in shallow eddies at mouth
8/12/96	visual	YOY near rock bluff about 0.8 km below North Fork
6/29/95	angling	one adult (368 mm) just below North Fork
7/17/95	angling	two adults (296, 323 mm) near rock bluff about 0.8 km below North Fork
7/20/95	visual	one adult near rock bluff about 0.8 km below North Fork
8/11/95	visual	YOY (about 30) below North Fork
8/11/95	visual	one adult near rock bluff about 0.8 km below North Fork
8/14/95	angling	11 tagged/recaptured (range 290-340 mm, average 319 mm), near rock bluff about 0.8 km below North Fork
7/27/94	visual	two adults just below North Fork

Appendix 9. Slimy sculpin

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

Creek	Year	No. Sample Periods	No. Traps Used	No. Slimy Sculpin
Ikalukrok	2001	2	20	6
(at Dudd Cr.)	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	2001	2	20	3
(at Red Dog)	2000	2	20	3
	1999	2	20	8
	1998	2	20	1
	1997	2	20	1
	1996	2	20	0