Final Report on the 2006 Prairie Creek Monitoring Program

June 5, 2007

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1.0 Introduction

Canada's north is currently experiencing large growth in industrial developments and the potential for continued development is high. There is a significant need to assess the sensitivity of aquatic ecosystems in the north and to develop tools to track changes within these northern ecosystems (Mallory et. al. 2006, Evans 2000, Lockhart et. al. 1992, Halliwell et. al. 2003, Lumb et. al. 2006). Northern ecosystems are considered to be especially sensitive to contaminants due to their high-lattitude geographical location and extreme climate (Schindler et. al 2006, Evans et. al. 2005). Slower reproduction cycles leave northern species at an increased vulnerability to stressors in the environment (Barrie et. al. 1992). Species diversity in northern ecosystems tends to be reduced due to the harsh climate, limited opportunity for species migration from southern ecosystems, and short period of time since the last glaciation (Evans et. al. 2005).

Most northern ecosystems are considered to be oligotrophic, with less productivity and species abundance than southern systems (Schindler et.al. 2006). Reduced primary production most often leads to the overall reduction in organism abundance common in northern mountain rivers (Hill et. al., 2000, Ivorra et. al, 2002). The oligotrophic state of these rivers can put ecosystems at risk for both nutrient enrichment and other stressor effects (Vis et. al, 1998, Kiffney et. al. 1996). Rivers in the South Nahanni watershed have low productivity compared with other rivers located in southern Canada and can be considered oligotrophic (Benke et. al., 1995, Chambers et. al., 2006). The increased pressures on northern ecosystems and species by climate, reduced production and energy stores and lower species diversity, emphasize the importance for effective monitoring programs to detect and identify changes.

The South Nahanni river is a Canadian UNESCO world heritage site and a highly valued national park. Classified as a Canadian Heritage River, South Nahanni river has water quality considered to be nearly pristine (Halliwell et. al., 2003). Its unique landscapes and ecosystems only emphasize the need to ensure that it is protected from potential stresses of development (Environment Canada, 1991, Halliwell et. al, 2003). Both the Flat River and Prairie Creek, tributaries of the South Nahanni River, have historical and current industrial activity that could have effects on this sensitive environment.

Multi-trophic monitoring allows for determination of biological interactions and assessment of aquatic response patterns in these ecosystems. In the summer of 2006, we conducted multi-trophic effects monitoring programs on both the Flat River and Prairie Creek. Sentinel fish populations, macro-invertebrates, algal communities, water quality and sediment quality were sampled at upstream reference areas and compared to high exposure (near-field) and low exposure (far-field) areas exposed to mine effluents. These control-impact monitoring programs allowed for an assessment of changes in downstream physio-chemical and biological conditions relative to upstream conditions. In addition to the control-impact programs, we also conducted sampling at multiple reference sites throughout the South Nahanni River watershed. These data provided an opportunity to evaluate if any changes in exposed communities fell outside a broader watershed characterization of a reference condition. Methodology employed methods described for the Reference Condition Approach. A reference condition approach (RCA) compares multiple reference or control sites to potentially impacted sites. RCA examines habitat, biological (invertebrates, algae, fish), chemical (water and sediment quality) and landscape variables to determine natural habitat or longitudinal variation in aquatic communities (Bailey et. al, 2004).

The overall objectives of this work were to document current aquatic conditions in these rivers, assess current monitoring methods in northern environments and make recommendations to improve future effects monitoring in northern ecosystems.

2.0 Study Sites

The South Nahanni River is located in the southwest corner of the Northwest Territories (Figure 1). The low subarctic climate in the Nahanni Plateau is characterized by cool summers (mean temperature is 9°C) and cold winters (mean winter temperature is -19.5°C) (Environment Canada, 1991). Most areas are less than 1372 m above sea level but mountain ranges reach to over 1800 m (Halliwell, 2003). The terrain is underlain by Palaeozoic carbonates, and is incised by deep and narrow valleys. Vegetation is sparse at higher elevations but open stands of black spruce with an understory of dwarf birch, Labrador tea, lichen, and moss occur in valleys and at lower elevations. The South Nahanni River flows in a southerly direction 540 km from ice fields near the Yukon-NWT border through the Mackenzie Mountains into the Liard River which then converges with the Mackenzie River. The normal range of flows at the flow gauging station upstream of Virginia Falls is 55 to 1500 m^3 per second (Halliwell et. al., 2003). Prairie Creek, a tributary of the South Nahanni River, has both historic and current development activities.

Advanced mining exploration in Prairie Creek is located approximately 18 km upstream from the confluence with the South Nahanni River (Environment Canada, 1991, Halliwell, 2003). The property was initially explored in the 1950's and a mill complex and tailings pond were constructed in the 1980's (Figure 2). Due to financial difficulties, mining and milling did not proceed at the Prairie Creek property and tailing were not generated. Canadian Zinc Corporation took over the property in 1995 and has begun an advanced exploration program for base metals (lead/zinc/copper/silver). A portal was constructed at the site for exploration and potential mining purposes. The portal discharges water to a polishing pond and catchment pond which discharges into Harrison Creek and subsequently Prairie Creek. As a result of mineral deposits in the area, this discharge has potential to be high in several metals (zinc/lead/cadmium). Prairie Creek flows through deposits of dolostones, limestone and shale (Halliwell, 2003) containing mineralized veins of zinc, lead, copper and silver. Prairie Creek originates and continues through upland and steep canyon terrain which leads to reduced levels of suspended sediments (Halliwell, 2003). Due to the underlying geological formations, Prairie Creek precipitates carbonate and other minerals as well as metals from natural mineral deposits (Indian and Northern Affairs, 2001). Flow rates in Prairie Creek are much lower than those in both the Flat River and the South Nahanni River.

Figure 1. Location of the South Nahanni Watershed in the southwest corner of the Northwest Territories

Figure 2. Aerial overview of Prairie Creek exploration property showing portal discharge flowing into the polishing pond then to the catchement pond and into Harrison Creek. Harrison Creek then discharges into Prairie Creek.

For the control-impact monitoring program, selection of upstream reference, high exposure (near-field) and low exposure (far-field) sites in Prairie Creek was done by reviewing existing information for the exploration property, consultation with regulators, First Nations communities and Canadian Zinc personnel, and a reconnaissance site visit. A reference site was selected 3 km upstream from development activities, a high exposure site was selected directly downstream from the catchment pond discharge and a low exposure site was selected 2 km downstream from the discharge (Figure 3).

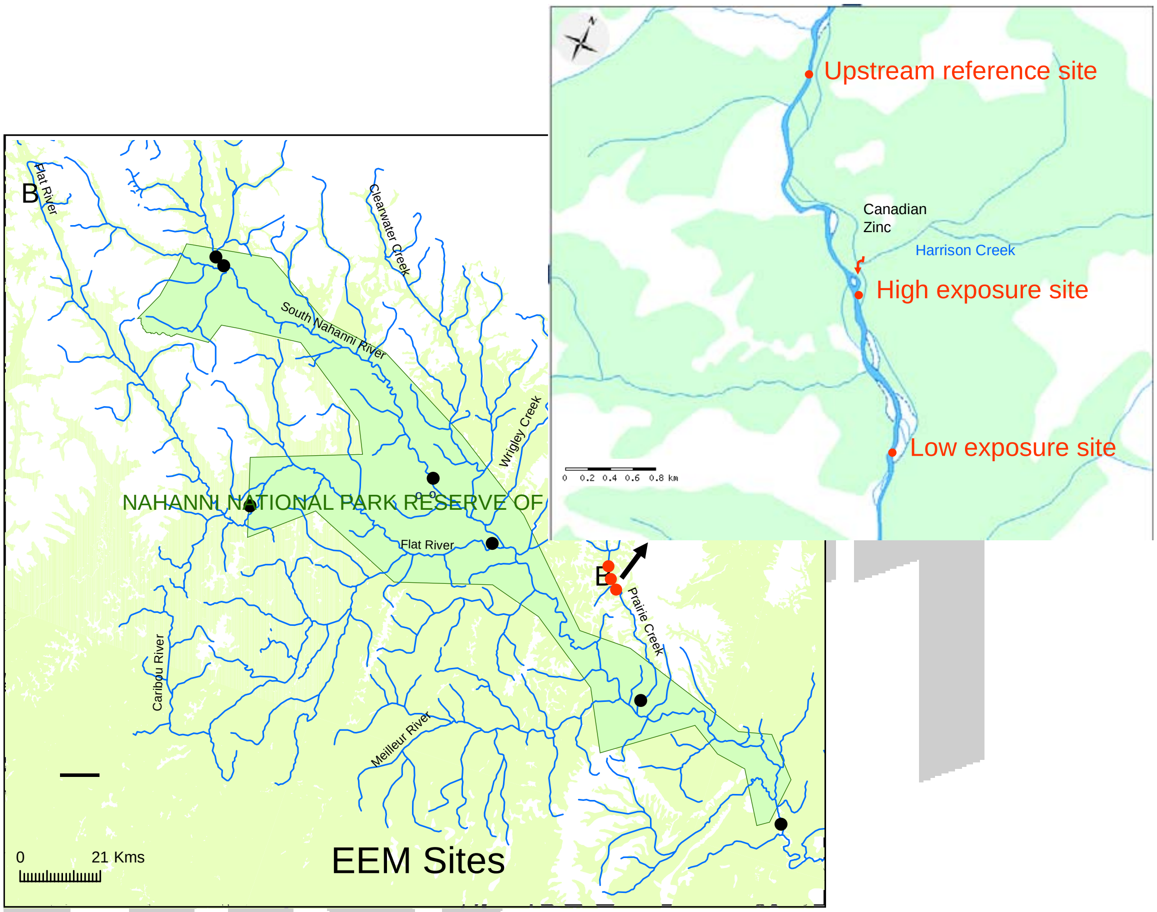

Figure 3. Selected sampling sites on Prairie Creek

For the regional reference sampling program, South Nahanni watershed sites, of similar size to sites selected on Prairie Creek, were selected from examination of geographical information systems and maps. Sites were selected to best reflect the habitat and landscape characteristics of the Prairie Creek sampling locations. In total, 9 Flat River basin and 15 South Nahanni River basin third to fifth order stream sites were sampled (Figure 4). Sampling was conducted from August 21-September 2, 2006. For the purposes of this report, results for the Prairie Creek control-impact monitoring program are emphasized.

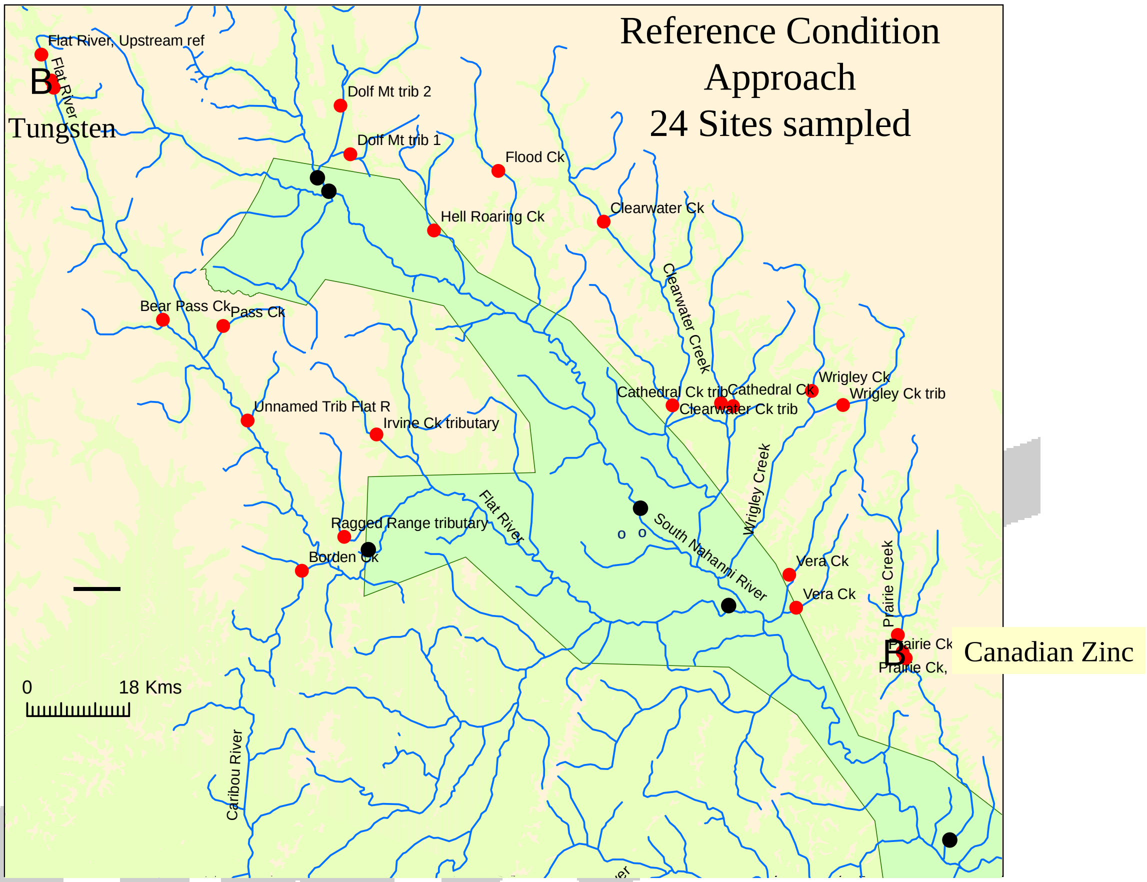

Figure 4. Red circles represent selected as regional reference sites (RCA) and black circles represent current Parks Canada/Environment Canada sampling locations. Control-impact sampling stations on the Flat River and Prairie Creek are also indicated as red circles.

3.0 Methods

A standard Environmental Effects Monitoring control-impact survey was conducted on Prairie Creek utilizing methods outlined in the Metal Mining Effluent Regulations Guidance Document (Environment Canada, 2002). Sampling was conducted to collect information on sentinel fish populations, macro-invertebrates, algal communities, water quality and sediment quality at an upstream reference area and compared to high exposure and low exposure areas based on distance from the discharge point. At Prairie Creek, the catchment pond discharge into Harrison Creek was considered the point source discharge (Figure 2).

3.1 Water chemistry and effluent characterization

Water samples were collected from a location instream at the reference, high exposure, and low exposure sites on Prairie Creek as well as at RCA sites throughout the South Nahanni watershed. Samples were sent Taiga Environmental Laboratory for analysis (Yellowknife, NT) for ICP-MS total metal scan, general water chemistry, nutrients and cyanide. Samples were collected to characterize water being discharged from the catchment pond. Dissolved oxygen, pH, temperature and conductivity were measured at the time of sampling.

3.2 Sediment Samples

A representative sediment sample was collected at each sampling area. Samples were grab samples collected in 500 ml glass jars. Samples were analyzed for total metals, minerals, nutrients, hydrocarbons, particle size and total organic carbon (TOC). Samples were analyzed at Taiga Environmental Laboratory in Yellowknife.

3.3 Algal sampling

Nine 15-25 cm diameter cobbles were randomly selected per site. For chlorophyll a analysis, one circular template (13.2 cm^2) was taken from each rock. Three templates were then pooled (representing a total sampled area of 39.6 cm^2 pooled from three rocks) resulting in three replicate chlorophyll a samples per site. For algal taxonomy, one circular template was taken from three rocks and pooled resulting in a single taxonomy sample per site. Samples were placed in scintillation vials and preserved in 5% buffered formalin (taxonomy samples) or frozen in stream water (chlorophyll a samples). Taxonomy samples were made up to a final volume of 21 ml. For taxonomic analysis, two-mL subsamples of epilithon suspension were sonicated for 10-20 s using a Sonifer

Cell Disruptor (model w140) (Findlay et al. 1999) and gravity settled for 24 h in an Ütermohl chamber. Cells were identified, counted and measured from random fields until 100 cells of the dominant species were found. Estimates of cell volume for each species were obtained by measurements of up to 50 cells of an individual species and applying the geometric formula best fitted to the shape of the cell (Rott 1981). Three replicate chlorophyll *a* samples were analysed at the reference, high exposure and low exposure sites on Prairie Creek and one sample at RCA sites. Chlorophyll *a* samples were homogenized in 50 ml of distilled water filtered and prepared for florometric analysis of chlorophyll *a* according to methods of Sartory and Grobbelaar, 1984.

3.4 Benthic Invertebrate Sampling

Five replicate benthic invertebrate samples were collected from the reference, high exposure and low exposure sites consistent with EEM methods. A U-net was used to collect 5 replicate samples per site with each sample consisting of three sub samples. The area of the U-net was $0.101m^2$. Three subsamples were collected and pooled for a total area of $0.303m^2$. The benthic invertebrate community endpoints assessed included total invertebrate density, taxon richness, Simpson's diversity index, and the Bray-Curtis index (Environment Canada 2002). Total invertebrate density is the total number of individuals in all taxonomic categories and expressed in number of individuals per m^2. Taxon richness represents the number of taxonomic families collected at each site based on five replicate samples. Simpson's diversity index is a measure of diversity which takes into account abundance patterns as well as taxonomic richness within benthic invertebrate communities. Calculation of the Simpson's Diversity Index is achieved by calculating the proportion of individuals in each taxonomic group and their relative contributions to the sampling station. The Bray-Curtis Index is a dissimilarity index which is a measure of the percentage of difference between sites.

At RCA sites benthic invertebrates were collected with a 3 minute traveling kicknet sample with 500 µm mesh as per standard RCA methods. Collected material was preserved in 95% ethanol sent to Cordillera Consulting in British Columbia, Canada, where they were sorted, identified to the lowest practical level and counted.

3.5 Fish Collection and Sampling

Fish were collected from upstream, near-field and far-far field sites with backpack electrofishers (Figure 5). Total effort was measured in electrofishing seconds. For the control-impact monitoring program, 20 male and 20 female adult sculpin were targeted for collection at the reference, near-field, and far-field site. Fish were analyzed for the standard EEM fish survey endpoints including for liver size, gonad size, length, weight, age, fecundity, egg size and condition estimates. Fish were also analyzed for flesh tissue metals. For the RCA monitoring program, 20 males and 20 female adult sculpin were also captured for lethal sampling. In addition, fish community composition was determined based on fish captured in 600 electrofishing seconds per site and as per RCA methods.

3.5.1 Fish Morphology:

Fish were collected and held alive on site. Upon completion of electrofishing, captured fish were immediately measured for total length and total weight. Fish used in lethal sampling were transported back to the field lab and euthanized in clove oil prior to dissection. Liver and gonad tissues were removed and weighed. Visual observations of external and internal abnormalities and presence of parasites were noted during dissections.

3.5.2 Fish Tissues:

An increase in tissue concentrations of metals will indicate that environmental contaminants are bioavailable and the data can be used to focus laboratory toxicity testing. Slimy sculpin metal levels were investigated using equal numbers of adult males and females from each site. Samples were analyzed for a suite of 27 total metals which were determined by nitric and hydrochloric acid digestion and inductively coupled plasma–mass spectrometer or inductively coupled plasma–optical emission spectrometer following U.S. Environmental Protection Agency method 200.3, except that HCl was used instead of H^2O^2, at Saskatchewan Research Council Laboratories in Saskatoon.

3.5.3 Fish Community:

Fish community was assessed using the number of species and individuals per species caught during electrofishing at each of the reference, high exposure and low exposure sites.

3.5.4 Egg size and Fecundity:

Ovaries from each female were placed in 10% buffered formalin. For fecundity estimates, 0.02-0.10 g of follicles (42-217 follicles) were removed from the middle of ovaries, separated, and photographed. Image analysis (Image-Pro Plus; Media Cybernetics, Washington, MD, USA) was used to count and measure mean diameter of vitellogenic follicles. Counts of vitellogenic follicles were made and fecundity extrapolated as the number of follicles per gram of carcass weight.

Figure 5. Electrofishing at the low exposure site on Prairie Creek with community members.

4.0 Statistical Analysis

All ANOVA and ANCOVA were performed in Systat 11. One-way Analysis of Variance (ANOVA) was conducted for algal biomass, total benthic invertebrate density, invertebrate taxon richness, Simpson's Diversity Index, Bray-Curtis Index, and each of the fish tissue metals. Assumptions of ANOVA were checked for each variable prior to conducting ANOVA. Normality was confirmed using the Shapiro-Wilkes test and equality of variances were compared using Levene's test. If assumptions of ANOVA were not met, a non-parametric Kruskal-Wallis test was used. For all analyses, $p<0.05$ was determined to be significant. If ANOVA results were significant, post hoc Tukey tests were conducted. Condition, liver weight, gonad weight and age were analyzed by

ANCOVA. Assumptions were confirmed by checking for normality and equality of variances as described above. Assessment of linearity and interactions were also performed prior to ANCOVA. Tukey post-hoc tests were used to define differences between the sites.

5.0 Results

Water quality results and discharge characterization are documented in Table 1. Unfortunately, detection limits for metals measured in the catchment pond were higher than detection limits for water samples collected from reference, high exposure and low exposure areas. Thus, several metals were measured as non detectable in the catchment pond yet detection limits were in general higher than concentrations measured at any riverine sites. This issue of laboratories defaulting to different detection limits confounds comparative based assessments in monitoring programs and is addressed in the discussion of this report. The average zinc concentration in discharge from the catchment pond in August 2006 was 0.472 mg/l. Parameters present in concentrations higher than those in Prairie Creek include manganese, lead, and cadmium. All other parameters in the discharge were present in low amounts. The same detection limits were used for samples collected at reference, high exposure and low exposure sites facilitating comparisons across sites. Water quality results indicate that total zinc increased from 0.0024 mg/l to 0.0123 mg/l (400% increase) from the reference site to high exposure site but levels are below the CCME aquatic quality guidelines for protection life (0.0300 mg/l) (CCME, 2003). Zinc levels decrease again at the low exposure site to 0.0068 mg/l. Total aluminum also increases at the high exposure site (0.0126 mg/l) compared to the reference site (0.0079 mg/l) but also decreases again at the low exposure (0.0073 mg/l).

All total aluminum values fall within the range identified in the guidelines for protection of aquatic life. A slight increase in total copper was seen at the high exposure site but all copper levels were well below aquatic life guideline values (0.002-0.0014). No change was seen in nutrient levels, general water chemistry or cyanide between the sites on Prairie Creek (Table 2).

The only metal which showed an increase from sediment samples collected at the high exposure site was arsenic compared to the reference and low exposure sites but values were slightly above the CCME interim sediment quality guideline in all locations (Table 1) (CCME, 2003). All other metals with the exception of zinc and cadmium demonstrated a decreasing trend from the reference site to the low exposure site. There were no changes in concentrations of cadmium and zinc in sediment collected at the 3 sites. Sediment composition differed only slightly between the reference, high and low exposure sites (Table 3), with higher sand at the high exposure site. A decreasing trend was observed for total organic carbon from the reference site to the low exposure site.

Parameter	**Detection Limit**		**Reference**		**High Exposure**		**Low Exposure**		**Catchment Pond**	**CCME Environmental Quality Guidelines**	
ppm	**Water**	**Sediment**	**Water**	**Sediment**	**Water**	**Sediment**	**Water**	**Sediment**	**Water**	**Water**	**Sediment**
Aluminum	**0.0006**	**20**	**0.0079**	**4820**	**0.0126**	**3220**	**0.0073**	**2620**	**<0.020**	**0.005-0.1**	**NA**
Arsenic	**0.0002**	**0.2**	**0.0002**	**6.4**	**0.0003**	**7.6**	**0.0003**	**6.4**	**<0.050**	**0.005**	**5.9**
Cadmium	**5E-05**	**0.01**	**0.00005**	**1.24**	**0.00006**	**1.42**	**5E-05**	**0.88**	**0.003**	**0.000017**	**0.6**
Chromium	**0.0001**	**0.5**	**0.0001**	**9.9**	**0.0001**	**7.7**	**0.0001**	**7.8**	**<0.005**	**0.0099**	**37**
Copper	**0.0003**	**1**	**0.0003**	**12**	**0.0008**	**9**	**0.0005**	**8**	**<0.005**	**0.002-0.004**	**35.7**
Iron	**0.05**	**100**	**0.089**	**12300**	**0.089**	**8900**	**0.091**	**7970**	**0.015**	**0.3**	**NA**
Lead	**0.0001**	**0.1**	**0.0001**	**25.1**	**0.0002**	**22.8**	**0.0001**	**15.2**	**0.03**	**0.001-0.007**	**35**
Manganese	**0.0001**	**10**	**0.0002**	**229**	**0.0004**	**205**	**0.0003**	**179**	**0.234**	**NA**	**NA**
Mercury	**2E-05**	**0.01**	**0.00002**	**0.06**	**0.00002**	**0.03**	**2E-05**	**0.04**	**0.00007**	**0.000026**	**0.17**
Nickel	**0.0001**	**0.5**	**0.0012**	**24.7**	**0.0013**	**20.3**	**0.0012**	**20**	**<0.008**	**0.025-0.150**	**NA**
Selenium	**0.001**	**0.3**	**0.0013**	**0.6**	**0.0012**	**0.6**	**0.0012**	**0.5**	**<0.030**	**0.001**	**NA**
Uranium	**0.0001**	**0.5**	**0.00398**	**1.7**	**0.00411**	**1.7**	**0.0043**	**2.4**	**NA**	**NA**	**NA**
Zinc	**0.0001**	**1**	**0.0024**	**182**	**0.0123**	**179**	**0.0068**	**102**	**0.472**	**0.03**	**123**

*** NA denotes value is not available**
All values are reported in ppm

Table 1. Total metals results for water and sediment sampling compared to the catchment pond discharge and Canadian Environmental Quality Guidelines; Canadian Water Quality Guidelines for the Protection of Aquatic Life and Interim Sediment Quality Guidelines (CCME, 2003)

Prairie Creek Sites

Parameter (ppm)	Detection Limit	Reference	High Exposure	Low Exposure	Catchment Pond
Nitrate	0.01	0.09	0.10	0.08	NM
Total Phosphorous	0.01	<0.01	<0.01	<0.01	0.2
Specific Conductivity @25 C)	0.4	452	459	460	826
pH		8.44	8.46	8.42	8.3
Total cyanide	0.001	0.001	0.001	0.001	0.001
Total Suspended Solids	3000	<3	<3	<3	<3

All values for water chemistry parameters are presented in ppm

Table 2. Water Chemistry Parameters for samples collected at Prairie Creek

Parameter (% by weight)	Prairie Creek Upstream	Prairie Creek Nearfield	Prairie Creek Farfield
Clay-Soil Texture	4.0	2.0	2.4
Sand-Soil Texture	92.4	96.4	93.4
Silt-Soil Texture	3.6	1.6	4.2
Total Organic Carbon	0.33	0.17	0.11

Detection limits were 0.1 for all texture categories, and 0.05 for TOC.

Table 3. Sediment Composition from Prairie Creek.

Prairie Creek Flesh Metals

Parameter	Reference	High Exposure	Low Exposure	Significance (p)
Aluminum	1.790+-0.530 A	2.040+-0.326 A	0.650+-0.272 B	0.024
Arsenic	0.172+-0.013 A	0.142+-0.017 A	0.066+-0.009 B	0.002
Barium	0.285+-0.027 A	0.348+-0.018 B	0.142+-0.018 C	0.000
Cadmium	0.021+-0.002 A	0.028+-0.003 A	0.016+-0.002 B	0.044
Cobalt	0.045+-0.010 A	0.024+-0.002 B	0.015+-0.002 C	0.009
Copper	0.335+-0.014 A	0.340+-0.020 A	0.254+-0.023 B	0.032
Iron	9.525+-0.881 A	11.560+-0.717 A	6.820+-0.635 B	0.018
Lead	0.130±0.025A	0.172±0.047A	0.077±0.034A	0.231
Mercury	0.028±0.018A	0.066±0.024A	0.078±0.021A	0.070
Nickel	0.095+-0.003 A	0.102+-0.030 A	0.024+-0.007 B	0.011
Sodium	1125+-25 A	1140+-24.495 A	966+-14.697 B	0.010
Strontium	1.625+-0.125 A	1.720+-0.080 A	1.004+-0.125 B	0.015
Zinc	43.500±3.279A	64.600±4.273A	49.600±8.244A	0.078

All values are reported in ppm

Table 4. Results of tissue metal analysis on flesh from fish collected at reference, high exposure and low exposure sites on Prairie Creek. ANOVA results are included in the table with n=5. Means with the same letters did not differ between sites.

Analysis for total metals was conducted on the flesh of slimy sculpin captured at the three sampling locations on Prairie Creek (Table 4). Only barium was significantly higher at the high exposure site compared to the reference site at $p<0.05$. All other metals were not significantly different between the reference site and the high exposure site, with the exception of a significant decrease in cobalt from reference to exposure sites. At the low exposure site however, all metals shown in Table 4 were significantly lower when compared to the reference and high exposure sites.

Benthic invertebrate density and diversity were not significantly different between reference, high exposure and low exposure sites although there seemed to be a slight increasing trend from the reference site to the low exposure site. Only richness indicated a statistically significant increase at both exposure sites compared to the reference site. The Bray-Curtis index did not indicate significant dissimilarity between sites. Benthic invertebrate results are illustrated in Figure 5.

Analysis of variance for richness showed a significant difference when EEM exposure sites were compared to the reference site on Prairie Creek. In benthic taxonomy samples mayflies showed an increasing trend in abundance from the reference to the low exposure site, as did the true flies. An increase is seen in stonefly abundance at the high exposure site. Caddisflies showed a slight increasing trend from reference to low exposure site but were generally present in low numbers.

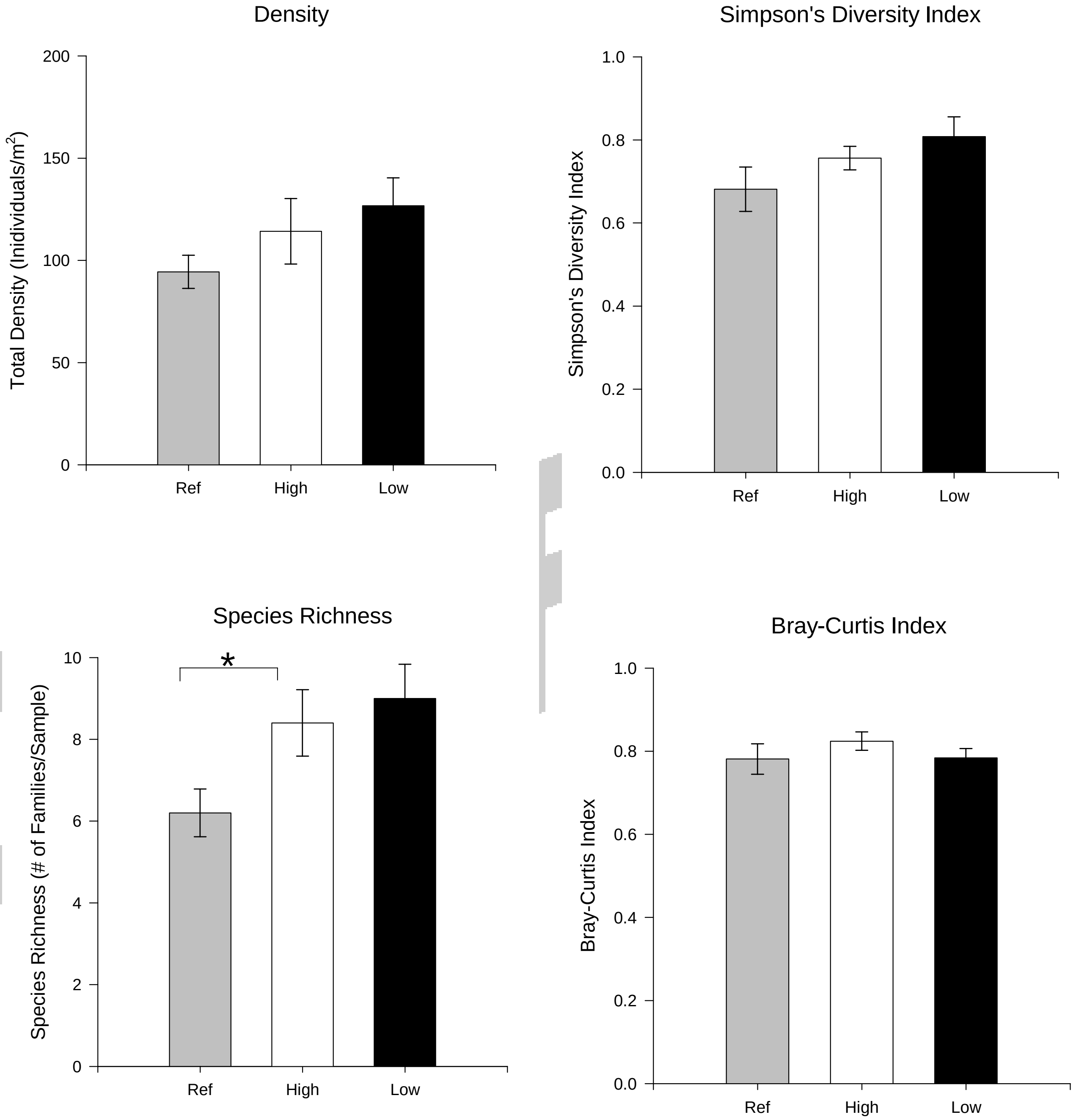

Figure 5. EEM endpoint results for benthic invertebrate sampling at reference, high exposure and low exposure sites. For each endpoint n=5. * denotes a significant difference between sites.

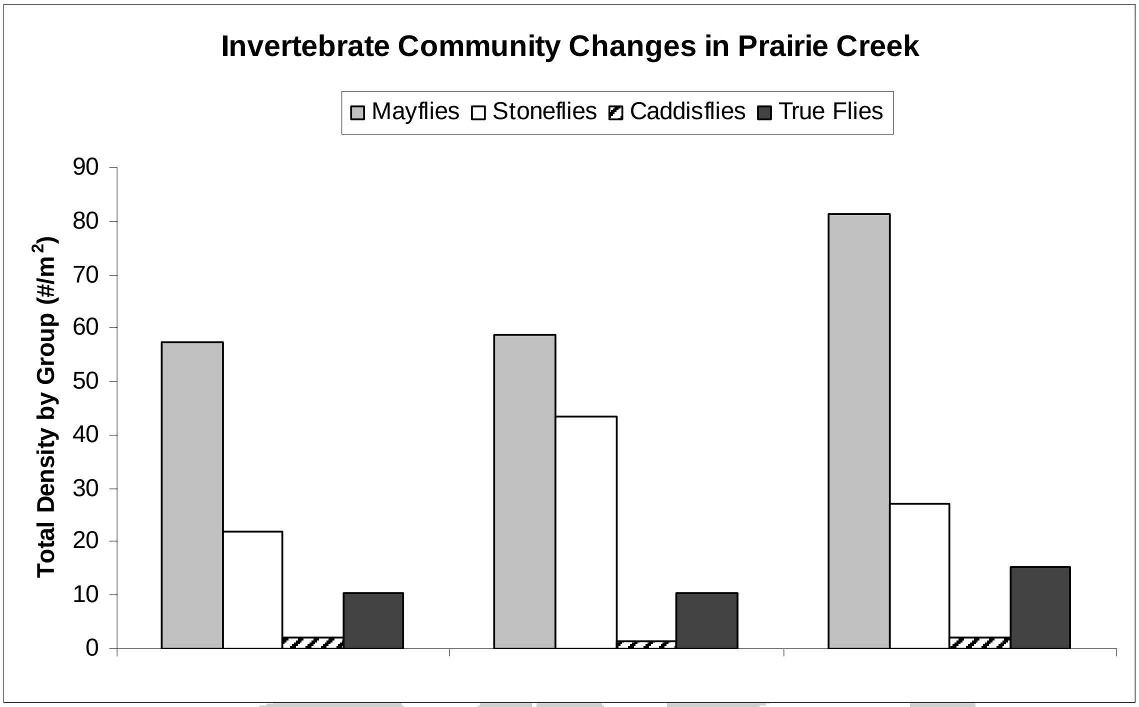

Figure 6. Benthic taxonomy results for samples collected at reference, high exposure and low exposure sites at Prairie Creek

A significant change in chlorophyll a or algal biomass was not observed between the reference, high exposure, and low exposure sites. At the reference site only diatom species were present. Diatom densities decrease at the high exposure site and reappear again in the low exposure site at with densities slightly below those measured at the reference site. Cyanophytes became dominant at the high exposure site and subsequently decreased again at the low exposure site. Limited densities of chlorophytes were present at the high exposure site and disappeared again at the low exposure site

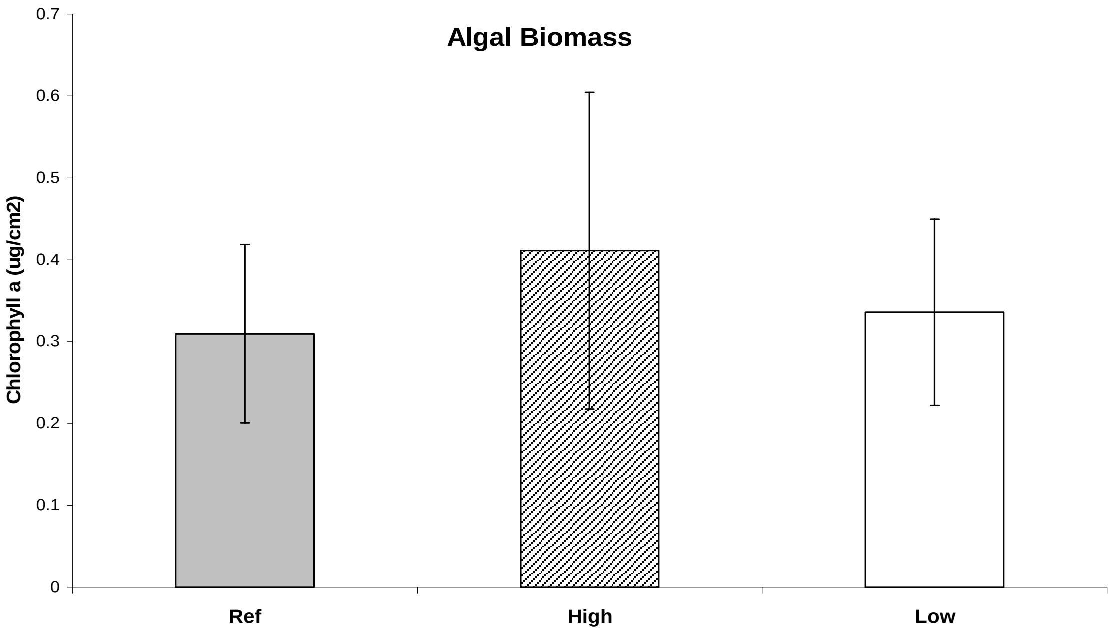

Figure 7. Algal biomass, measured as chlorophyll a, for samples collected at reference, high exposure and low exposure sites on Prairie Creek (n=3). ANOVA results did not indicate significant difference between sites

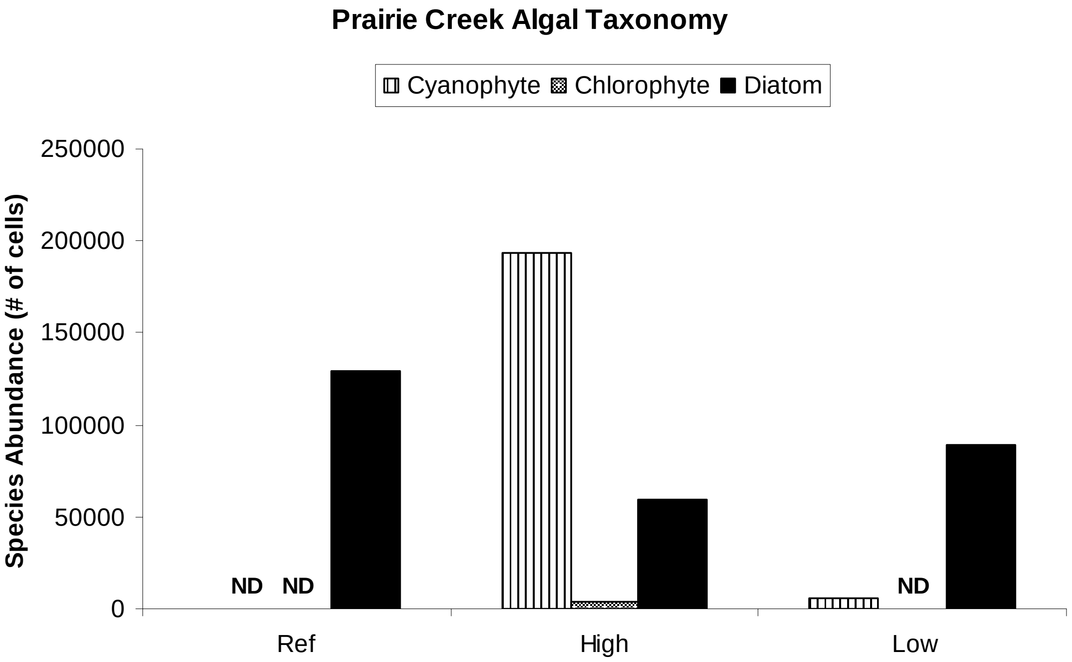

Figure 8. Results of algal taxonomy samples collected from reference, high exposure and low exposure sites at Prairie Creek. ND (non-detect) represents areas where species were not present.

Previous work in the Nahanni National Park have indicated that slimy sculpin are the only possible sentinel species for effects monitoring due to low abundance of other fish species (EBA Engineering 2002, Sigma Resources 1978, Halliwell, 2003).
A summary of fish species captured for Prairie Creek and the watershed reference sites is documented in Table 5. For all sites, slimy scuplin were the only species which were captured in sufficient numbers to justify their use as a sentinel monitoring species and to allow for analysis of fish health based on sampling guidance in the EEM guidance document (Environment Canada, 2002). Although arctic grayling, bull trout and round whitefish were captured in each of the rivers, their presence was sporadic and neither lethal nor non-lethal sampling protocols could be implemented as specified in the EEM guidance document (20 males and 20 females for lethal sampling; approximately 100 fish for non lethal sampling).

Condition, as defined as length against weight, showed a significant increase at both the high exposure and low exposure sites in male and female fish compared to the reference site (Figure 10). Gonad weights and liver weights for male and female fish were not significantly different between the three sites. Size-at-age analyses on male fish indicated that fish had higher growth rates at the low exposure site compared with the high exposure and reference site but a significant difference in growth was not seen in female fish. Fecundity did not differ between the three sites but eggs were significantly larger at the high exposure site.

Prairie Creek Sites	Slimy sculpin	Arctic grayling	Bull trout
Prairie Ck, Upstream	47	-	-
Prairie Ck, High Exposure	72	-	5
Prairie Ck, Low Exposure	32	-	2
Total	**151**	**0**	**7**
RCA Sites			
Stream	**Slimy sculpin**	**Arctic grayling**	**Bull trout**
Wrigley Ck	31	2	2
Cathedral Ck trib	9	-	-
Cathedral Ck	1	2	1
Flood Ck	31	5	-
Hell Roaring Ck	48	-	-
Dolf Mt trib 1	-	4	-
Vera Ck	-	3	-
Vera Ck	37	-	-
Wrigley Ck trib	43	-	-
Clearwater Ck trib	9	2	1
Clearwater Ck	20	-	2
Dolf Mt trib 2	75	-	2
Borden Ck	4	-	-
Flat River	406	14	1
Unnamed Trib Flat R	6	-	-
Total	**314**	**18**	**8**

Table 5. Number of fish caught per species at Prairie Creek sites (reference, high exposure, low exposure) and RCA sites in the South Nahanni Watershed

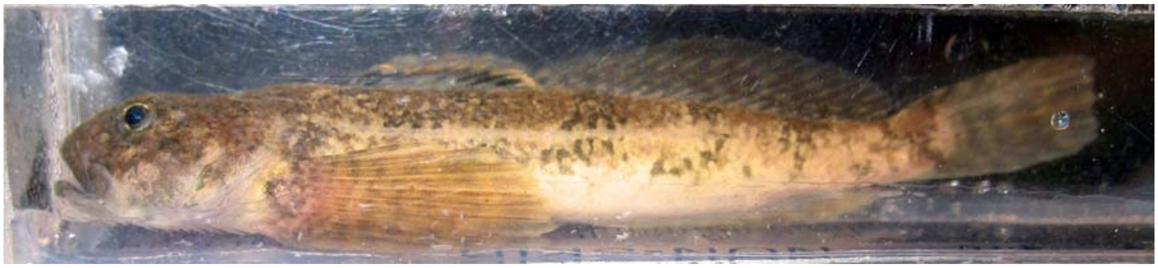

Figure 9. Picture of a slimy sculpin captured at Prairie Creek.

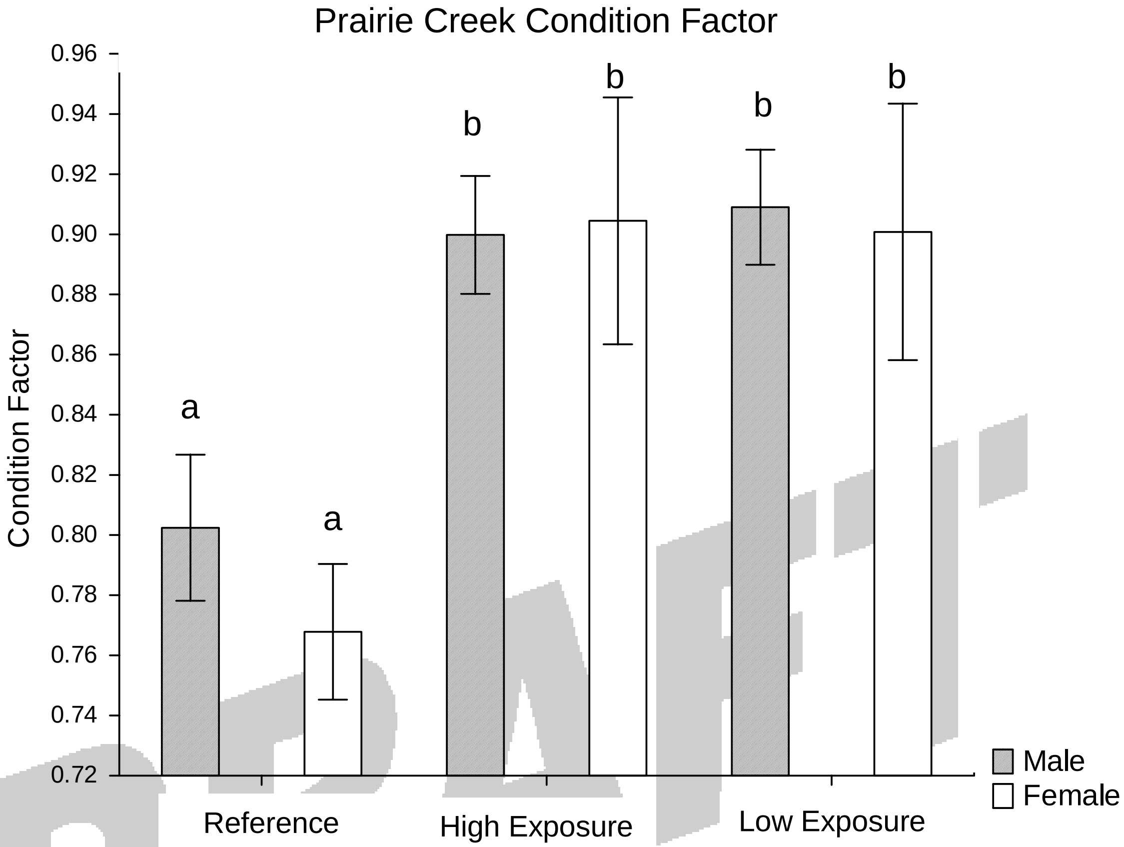

Figure 10. Condition factor calculated as body weight/(length^3) for reference, high exposure and low exposure sites at Prairie Creek. Means with the same letters did not differ between sites.

A high number of parasites were detected in Prairie Creek, and were found to a lesser degree in other rivers. Parasites were identified as Ligula intestinalis (Figure 11). Fish infected with parasites had smaller gonads than uninfected fish. Due to the absence of gonad or very small gonads, statistical analysis was difficult. Parasite body burdens and percent occurrence did not differ between the three sites on Prairie Creek.

Figure 11. Picture of a slimy sculpin collected from the reference site at Prairie Creek with parasite *Ligula Intestinalis* found inside the body.

Site	% Occurence	%Body Burden
Reference	25.5	10.386±1.653
High Exposure	26.4	14.703±1.608
Low Exposure	18.8	12.713±3.451

Table 6. Percent occurrence and percent body burden for fish collected at reference, high exposure and low exposure sites at Prairie Creek

6.0 Discussion and Conclusions

Water and sediment quality results collected from Prairie Creek do not show a conclusive pattern indicative of mine-related changes but given the high degree of mineralization, different landscape features, and highly variable flow rates, natural fluctuations in these rivers would be expected. The discharge contained in the catchment pond at Prairie Creek is of differing chemical composition compared to water samples collected in the river at reference, high exposure, and low exposure sites. However, these differences did not result in changes in riverine water quality at exposure sites. Further sampling to characterize the catchment pond "effluent" using detection limits consistent with riverine sampling should be considered. Although water quality and sediment quality data did not show upstream-downstream changes, these data are often useful to support interpretation of any biological changes should the latter be measured at the mine. In addition, considering the potential for variability in riverine water and sediment chemistry, further sampling should be considered to better understand variability in measures over space and time.

Analysis of fish tissue can serve as indicator of exposure to elevated levels of contaminants (Markert, 2003). An exposure pattern was difficult to detect in fish collected from Prairie Creek. However, Prairie Creek mine does not currently discharge a mine effluent per se, but a minewater portal discharge. Also, there has been no historical discharge of tailings to the Prairie Creek system.

Northern rivers have low productivity compared with other rivers located in southern Canada (Benke et. al., 1995). Nutrient status and productivity was considered low in Prairie Creek. As an example, algal biomass, measured as chlorophyll a, is between 0.8-2.6 ug/cm^2 for rivers of northern Alberta (Chambers et. al., 2006). Proposed guidelines for protection of oligotrophic rivers in Northern Alberta range from 1.9-4.5 ug/cm^2 chlorophyll a (Chambers et. al., 2006). Chlorophyll a in Prairie Creek ranges from 0.3-0.4 ug/cm^2, indicating Prairie Creek was highly oligotrophic at the time and sites sampled during our study.

Benthic invertebrate results from Prairie Creek suggest reduced invertebrate density when compared with southern systems (Benke et. al., 2005). The benthic invertebrate community at Prairie Creek did demonstrate community changes between reference and exposure sites, however these changes are not consistent with typical pollution-dependent responses. Stoneflies have been shown to be pollution sensitive in many previous studies (Hodginson et. al, 2005) while other species such as chironomids are known to be more pollution tolerant. In Prairie Creek, stoneflies increased in density at the high exposure site and chironomids decreased. There is a significant increase in richness at the high exposure site which indicates a slight enrichment may be occurring. In highly oligotrophic ecosystems, very little nutrient input is required to produce a response (Vis et. al, 1998, Hill et. al, 2000). It may be the case at Prairie Creek that a small increase in nutrient or mineral inputs can result in a change to benthic communities. It is important to note that although Prairie Creek has been an industrial development for over 30 years, no mining or tailings deposition has taken place. The property has been in either exploration or care and maintenance phase for the duration of operations.

With lower productivity in Prairie Creek, fewer algal species were present at the reference site and low exposure site, with diatoms the most prevalent. At the high exposure site, however, proliferation of cyanophytes (blue-green algae) occurs, with an associated decrease in diatoms. Cyanophytes are most commonly associated with enrichment but can occur naturally (Canter-Lund et. al. ,1995). However, the absence of cyanophytes at the reference or low exposure sites provides further evidence for localized enrichment around the Prairie Creek discharge. These results for algal biomass and taxonomy suggest that algae is a useful monitoring tool for detecting changes in these sensitive environments. Previous research has indicated that algae accumulates metals and can therefore be used to determine metal bioavailability and accumulation in aquatic ecosystems (Meylan, 2003, Ivorra, 2002, Gurrieri,1998). In the future, monitoring of metals in algae and benthic invertebrates may provide an alternative to monitoring metal burdens in fish tissue.

Due to low species abundances and decreased diversity when compared to southern rivers, slimy sculpin were the only sentinel species to be identified for monitoring in the South Nahanni watershed based on EEM criteria for sentinel species selection and confirmed by fish community assessments (Environment Canada, 2002). Slimy sculpins are found throughout watersheds in the Northwest Territories (Burr et. al. 1998) and are present downstream of most, if not all, major development in the Northwest Territories and Nunavut (Golder Associates 2005a, Golder Associates 2005b, Jacques Whitford 2006, Golder Associates 2006, Azimuth Consulting 2005, DDMI 2005, DBCM 2005, DBCM 2006). They are a small species of fish with a short life span and limited mobility due to the absence of a swim bladder (Gray et. al. 2004), which allows comparison of effects and exposure to contaminants (Munkittrick et. al. 2000). Sculpin have been shown to be a good sentinel species in several monitoring studies (Gibbons et. al. 1998, Gray et. al. 2005, Tetreault et. al. 2003, Galloway et. al. 2005).

Therefore, of all the fish collected during our study, slimy sculpin were the obvious sentinel for monitoring. However, due to their low abundance in the South Nahanni watershed, and particularily Prairie Creek, relative to southern river systems, on-going lethal monitoring programs involving slimy sculpins could affect populations. Thus, if sculpin are to be used as a sentinel for monitoring, non lethal monitoring methods should be considered. At the very least, if lethal sampling cannot be avoided, then power analysis should be considered to determine optimal sample sizes for collection. Although an increase was noted in fish condition at exposures sites in Prairie Creek, other fish parameters do not indicate changes due to discharge from the catchment pond. An increase in fish condition may support our hypothesis of localized enrichment at the exposure sites and would be consistent with increased benthic invertebrate richness and increased presence of cyanophytes. It is likely that early signs of nutrient-related change will be better detected using benthic or algal sampling, especially during exploration activities.

A high number of parasites, identified as Ligula intestinalis, were found in Prairie Creek fish compared to other rivers in the South Nahanni watershed. Slimy sculpin with parasites had little or no gonads. The consistent presence of parasites at the reference and exposure sites indicates that parasitic infection is not a mine-influenced effect but rather due to other ecological processes. However, parasite infestation should be assessed if fish are monitored in future monitoring programs especially if infestation holds some relationship with the level of gonadal development as changes in gonad size are currently an effects-based indicator in Canadian EEM programs.

In conclusion, the results of multi-trophic monitoring conducted in the South Nahanni watershed and Prairie Creek allowed for characterization of benthic, algal and fish communities. Benthos and algae showed the most consistent response patterns and demonstrate importance for detecting changes in community structure. Variable water quality and sediment quality results are best analyzed in conjunction with biological changes. The most consistent response pattern appears to be a mild nutrient enrichment as indicated by increased benthic invertebrate richness and a change in taxonomic composition for benthic invertebrates and periphytic algae. These changes are supported by elevated nutrients (total phosphorus) in the catchment pond. The focus of further monitoring programs in sensitive pristine areas should include a multi-trophic approach, including adequately replicated benthic and algal community samples combined with water and sediment quality. Water and effluent sampling must ensure laboratories understand the importance of maintaining consistent detection limits across samples to facilitate comparative based assessments. In addition, variables measured in effluent monitoring programs should be consistent with those measured in receiving water monitoring. Given the low abundance of fish species in these ecosystems, the effects of monitoring programs on fish populations should be seriously considered. Results from this study indicate that benthic and algal parameters proved to be more sensitive in detecting changes than fish parameters and should be incorporated into future monitoring programs. Analysis of metal concentrations in algal and/or benthic invertebrate tissue should also be considered.

7.0 Recommended monitoring

Water Quality

Canadian Zinc currently holds a water licence (MV2001L2-0003) requiring samples to be collected at sampling stations 3-10 (Prairie Creek Upstream of Airstrip) and 3-11 (Downstream of the confluence of Prairie Creek and Harrison Creek). These sites are located within the reference and high exposure sites in the August 2006 sampling programs. Canadian Zinc is required to collect samples monthly during decline development and pilot plant operations and 2 times during summer months when operations are not occurring. It is recommended that these sites be sampled monthly during periods of open water or discharge from the catchment pond and statistically analysed to determine if water quality changes are significant between the two sites. Sampling at two sites is the absolute minimum for comparative assessments. Delineation of response patterns is typically facilitated by two or more exposure sites (high exposure and low exposure for example). It is important to ensure laboratories understand the importance of maintaining consistent detection limits across water and effluent samples to facilitate comparative based assessments. Variables measured in effluent monitoring programs should be consistent with those measured in receiving water monitoring for comparative purposes.

Benthic invertebrate and sediment sampling

Benthic invertebrates are an important indicator for detecting changes. It is recommended that samples be collected at the reference and high exposure site every two years and analysed for EEM endpoints (density, richness, diversity, and bray-curtis index), as well as taxonomical changes. As mentioned previously, two sites is the minimum for comparative assessments. The addition of a site further downstream of the high exposure site (ie. far-field or low exposure) should be considered. Collection should follow EEM guidelines and include 5 replicate samples collected at each site with 3 subsamples per replicate sample. At each benthic invertebrate station it is recommended that a sediment sample be collected and analysed for total metals, particle size analysis, and total organic carbon. Results should be analysed according to EEM guidelines.

Algal Sampling

Algal sampling should be conducted for biomass (chlorophyll a) and algal taxonomy every 2 years to monitor for both productivity and algal community changes. Algal samples should be collected following the protocol outlined in the methods section of this report.

Fish

It is not recommended that fish be sampled at this time due to low abundance in the Prairie Creek system. Benthic invertebrates and algae have been used in the past to provide an early indication of change in order to protect fish populations.

Tissue Metals

Tissue metals are useful to support the interpretation of biological changes and to assess bioavailability. It is recommended the consideration be given to analysis of metal levels in benthos and/or algae. Metal variables should be consistent with those measured in water and sediment to facilitate comparison. This sampling should be conducted at the same time as the recommended sampling outlined above.

Comparisons of Prairie Creek samples to the broader regional reference condition is pending.

8.0 Acknowledgements

Funding from Indian and Northern Affairs Canada, Canadian Zinc Corporation, North American Tungsten, Dr. Dube’s Canada Research Chair Funding and the Northern Ecosystem Initiative of Environment Canada allowed us to collect and analyze a wide range of samples from unique and remote areas within the South Nahanni watershed. The provision of logistic support from Canadian Zinc’s Prairie Creek staff and North American Tungsten staff allowed us to focus our efforts on sampling. Troy Searson (INAC) and Stu Merrit (Great Slave Helicopters) were pivotal in our sampling and processing of samples from remote and difficult to access streams. Tim Ambercrombie from EBA Consultants helped with Flat River sampling. Doug Tate (Parks Canada) gave us the full benefit of his knowledge of the Nahanni. John Babaluk from DFO provided valuable advice on sampling in the Nahanni and aging slimy sculpin. This work is dedicated to the memory of Doug Halliwell a man of truth, scientific excellence, and dedication to the conservation and management of northern waters.

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