ESKAY CREEK MINE ENVIRONMENTAL EFFECTS MONITORING PROGRAM AND ITS IMPLICATIONS FOR CLOSURE PLANNING

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ABSTRACT

Effluent from the Eskay Creek Mine constitutes 6 to 12% of the flow of Ketchum Creek – the immediate receiving environment. Hence, the Metal Mines Effluent Regulations required an Environmental Effects Monitoring Program to determine the effects of effluent of aquatic organisms. Sampling of benthic invertebrates in Ketchum Creek in September 2005 showed significantly higher family richness at an exposed station compared to a reference station, but no significant variation in average benthos density or species diversity. Benthos characteristics may be driven more by variation in physical habitat than by exposure to mine effluent. The naturally high metal concentrations of Ketchum Creek caused bioaccumulation of metals in Western Pearlshell mussels (*Margaritifera falcata*) in two stream-side mesocosms (reference and exposed) run from early August to late September 2005. Metal concentrations were higher in the exposed mussels than in reference mussels. However, survival was slightly higher at the exposed mesocosm and growth was zero for both mesocosms. The conclusion was that the ecological effects of mine effluent are low in magnitude and difficult to distinguish from natural effects. Therefore, current closure planning, which will maintain or lower the existing discharge rates, should be protective of the receiving environment in perpetuity.

INTRODUCTION

The Eskay Creek Mine is an underground gold-silver mine located approximately 80 km north of Stewart, BC. It has been operating since 1995 and is expected to last until 2008. The imminent closure of the mine has raised questions about the potential long-term effects of mine effluent on the receiving aquatic environment. Water will continue to flow from the waste rock impoundment (Albino Lake), the tailings impoundment (Tom MacKay Lake) and the mine site into Ketchum Creek and then into the Unuk River (Figure 1). The results of Eskay Creek's Environmental Effects Monitoring (EEM) Program may provide some preliminary answers.

The Eskay Creek EEM Program has been in operation since 1997. During those 8 years the Program underwent annual review and revision, and different environmental components were monitored (*e.g.*, drift invertebrates, periphyton community, sediment toxicity, *etc*.) and excluded if they failed to consistently show a mining-related effect. The results have shown the following:

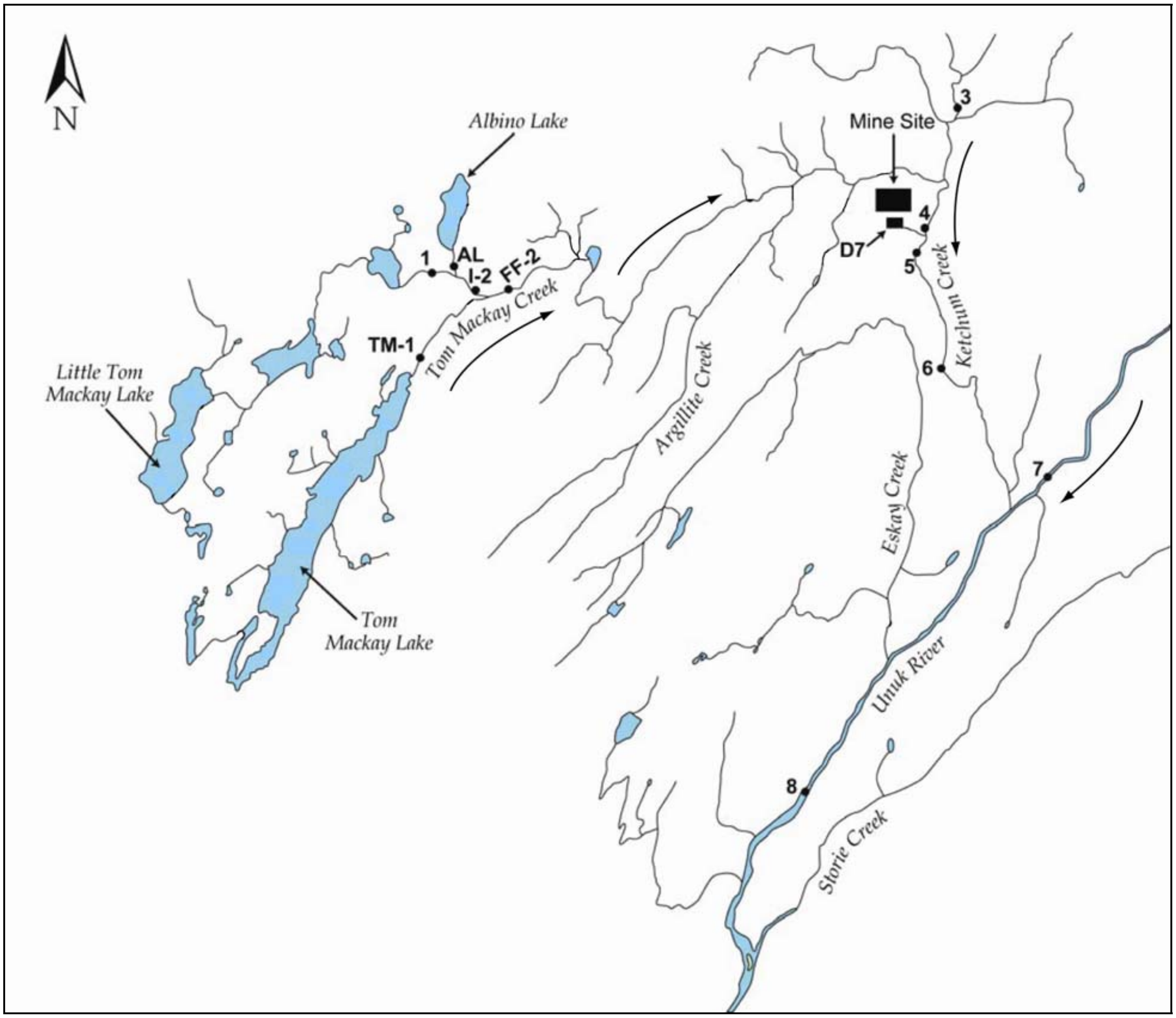

Figure 1. Location of drainages and sampling stations for the Eskay Creek Mine 2005 Environmental Effects Monitoring Program

- water and sediments of the area are elevated in metals because of the highly mineralised geology of the area;

- discharges of waste rock and tailings to Albino Lake and Tom Mackay Lake have resulted in elevated concentrations of some metals (*e.g.*, antimony) in Tom Mackay Creek and Ketchum Creek but not in the Unuk River;

- benthic invertebrate community composition is highly variable between sites and among sampling years at sites, and appears to be driven largely by among-site and among-year variation in habitat quality (*e.g.*, substrate particle size) rather than by mine effects;

- water toxicity tests have indicated a low frequency of toxicity and a spatial pattern of toxicity that is not consistent with mine effects;

- sediment toxicity testing has not shown strong toxicity; and

- caged mussel studies using the Western Pearshell mussel (*Margaritifera falcata*) conducted in 1999 and 2000 showed bioaccumulation of metals at both reference and exposed stations.

In 2005, as part of its obligations under the Metal Mine Effluent Regulations (MMER), Eskay Creek commissioned a mussel mesocosm study in Ketchum Creek. The mesocosm study was supported by sampling of water quality, sediment quality and benthic invertebrates. This report summarizes the results of those studies.

BACKGROUND

Eskay Creek Mine

The Eskay Creek Mine is an underground gold-silver operation. Approximately 750 tonnes of ore are produced each day, most of which is crushed and blended and sold directly to third-party smelters without any further processing. A portion of the ore is processed on site in a small gravity and flotation mill and the flotation concentrate is then shipped off-site for further processing. In 2004, Eskay Creek produced 289,568 ounces of gold and 15,751 million ounces of silver.

Apart from gold and silver, the mine produces waste rock, tailings, precipitated sludge from the polishing ponds and mine water (including treated sewage effluent). Waste rock and tailings are stored under water. Between 1995 and 2001, they were stored in Albino Lake. In September 2001, tailings began to be discharged through a pipeline to Tom Mackay Lake. Water naturally discharges from Albino Lake and Tom MacKay and flows through Tom MacKay Creek into Ketchum Creek and then the Unuk River. Water from the mine itself is treated on site and mixed with treated sewage effluent and surface run-off. It then flows through a series of four settling ponds and is discharged into a drainage channel that flows 500 m downhill to Ketchum Creek. This discharge is monitored at sampling Station D7.

The mine effluent makes up between 6 and 12% of the flows of Ketchum Creek below Station D7, and between 2 and 3% of total flows in the Unuk River below its confluence with Ketchum Creek. The range may be lower during freshet flows and higher during winter low flows.

Environmental Setting

Three streams dominate the hydrology of the area. Tom MacKay Creek has a length of nearly 10 km and an average gradient of 4%. Ketchum Creek has a similar length (~12 km), but an average gradient that is twice as great. A high waterfall in Ketchum Creek near the confluence with the Unuk River is a barrier to upstream fish migration. Ketchum Creek is glacier-fed with high concentrations of suspended solids – particularly during periods of glacier runoff. It flows through a deeply incised canyon with a substrate composed mainly of boulders, cobble and gravel.

The Eskay Creek Mine is located in a highly mineralized area. Hence, concentrations of such metals as cadmium, chromium, copper, iron, mercury, nickel and silver are naturally elevated in water compared to guidelines for the protection of aquatic life (BCMWLAP, 1998a, 1998b; CCME, 1999). In 2001, in recognition of this fact, site-specific water quality objectives were developed using background metal concentrations. Exceedance of metal guidelines is even greater for sediments than for water, but no site-specific sediment quality objectives have been developed.

Lakes in the Tom MacKay Watershed are oligotrophic and no algal or macrophyte growth is visible. The plankton community is typical of alpine lakes and productivity is low, hence there is little drift of plankton from these lakes downstream into the Unuk River.

The benthic invertebrate communities of the Eskay Creek area have been surveyed on an annual basis since 1998. The communities of most stations are dominated by plecopterans (stoneflies) and ephemeropterans (mayflies) with minor numbers of dipteran flies, oligochaete worms, arachnids (spiders) and other taxa. Density of benthic organisms is highly variable within stations and among stations, including reference stations. This indicates the importance of natural environmental factors, particularly substrate size composition and water turbidity, in controlling benthic communities in this area.

There are no fish in the lakes and streams of the area immediately around the mine because of an impassable waterfall in lower Ketchum Creek and because of velocity barriers in the Unuk River near the confluence with Ketchum Creek. Fish first appear in the Unuk River at the confluence with Storie Creek about 10 km downstream of the Eskay Creek Mine.

Regulatory Environment

Discharge of Eskay Creek mine wastes to the receiving environment is currently regulated by Permit PE-10818 issued by the BC Ministry of the Environment. Water quality monitoring is required at three sites: Treatment Ponds Discharge (D7), Albino Lake Outlet Discharge (W20) and Tom MacKay Lake Outlet Discharge (TM-1). These data have been presented in an annual Water Quality Summary Report, which are separate from the annual EEM Interpretive Report. In 2005, the two reports were combined. This report only describes the results of the 2005 EEM study.

The federal MMER requires that metal mines monitor the chemical characteristics and toxicity of mine effluent and conduct an EEM program to determine the effects of effluent on the receiving environment (Environment Canada, 2001, 2005). The EEM program includes water quality monitoring and biological monitoring. The latter usually includes a survey of the benthic invertebrate community and a survey of fish populations. Fish studies are only required if the effluent in the exposure area is >1% within 250 m of the final discharge point. Since the effluent concentration in Ketchum Creek exceeds that criterion, a focused EEM study was conducted in 2005.

For mines such as Eskay Creek in which studies of native fish are not possible or practical, alternatives are recommended by Environment Canada. In early 2005, a study design based on caged bivalves was prepared for the first cycle of EEM at the mine. A modified version of that study design was the basis of the study plan for 2005.

Caged tests using the Western Pearlshell mussel were conducted in Ketchum Creek in 1999 and 2000, but significant technical problems were encountered: exposure of cages to air because of seasonal variation in stream flows; and loss of cages to flash floods. To avoid those problems, a modified mesocosm approach using bivalves was proposed. This approach involves the construction of flow-through boxes along the stream channel banks. Standard techniques for conducting *in situ* field bioassays would be followed (ASTM, 2001). Mussels of known size and number would be placed in the boxes and allowed to grow for a period of about 8 weeks. Then, they would be retrieved and their survival, growth, condition and tissue metal concentrations would be measured and compared between reference and exposed stations.

METHODS

Study Design

All EEM sampling was conducted during the low-flow period from September 23 to 25, 2005. It included measurement of physical habitat at stations 3, 4, 5 and 6 in Ketchum Creek, water quality sampling at 12 stations in Tom MacKay Creek, Ketchum Creek and the Unuk River, sediment sampling at 10 stations (all except I-2 and D-7), and benthic invertebrate sampling at 4 stations (3, 4 5 and 6 in Ketchum Creek). Stations 3 and 5 were locations for the mussel mesocosm study. Station 3 was a reference station for all components of the study, and stations 1 and 7 were additional reference stations for the water quality and sediment quality components.

Physical Habitat

Habitat characteristics were measured using standard techniques. Each surveyed section was divided into habitat units (riffle, glide, cascade or pool) and then 23 variables were measured including: unit length, stream depth and width (bankfull and wetted), bank height and stability, percent substrate particle size (sand, gravel, cobble, boulder and bedrock), percent instream cover (boulder, instream vegetation, overhanging vegetation, undercut banks, pool, woody debris), and percent riparian cover and canopy cover. To simplify analysis of these data, average stream dimensions and habitat types at each station were calculated from the dimensions recorded for each habitat unit.

Water Quality

Water samples were collected following a strict quality assurance/quality control protocol that included field blanks, travel blanks, equipment blanks and replication of 20% of all samples. All samples were shipped to ALS Environmental of Vancouver, BC, where they were analysed for a total of 86 variables, including physical characteristics (e.g., pH, hardness, total suspended solids, etc.), dissolved anions (e.g., acidity, alkalinity, chloride, sulphate, etc.), nutrients (e.g., nitrate, nitrate, total phosphate, etc.), organics (total organic carbon), total metals and dissolved metals using standard methods (APHA, 2001; ASTM, 2005; US EPA, 1983, 1995).

Water quality values were compared to the provincial and federal water quality guidelines for the protection of freshwater life (BCMWLAP 1998a, 1998b; CCME, 1999) and to the MMER limits. To assess the significance of exceedances, they were expressed as Hazard Quotients (HQ) – the ratio of a metal concentration to the most stringent available water quality guideline. HQ below 3 were considered non-significant, HQ between 3 and 10 indicated potential risk of ecological effect, and HQ greater than 10 indicated moderate to high risk of ecological effects. To remove redundancy from the data set and to identify the central trends of the data, Principal Components Analysis (PCA) was used to extract factors (or artificial variables) that were completely uncorrelated with each other.

Sediment Quality

Two to five sub-samples (depending on availability) of stream sediment were collected at each of 10 stations and then combined and homogenized. All samples were shipped to ALS Environmental where they were analysed using standard methods (SSSA, 1982; US EPA, 1983, 1995). A total of 38 variables were measured, including physical (e.g., moisture, grain size), nutrients (total nitrogen, available phosphorus and total organic carbon), total metals and methyl mercury. Sediment quality variables were compared to provincial and federal standards (BCMWLAP, 1998a, 1998b, 1999, 2002; CCME, 1999), and then they were subjected to PCA.

Benthic Invertebrates

Five replicate samples of benthic invertebrates were collected from each of sampling stations 3, 4, 5 and 6 of Ketchum Creek using a 33 cm diameter Hess sampler with a 250 m mesh cod-end. Organisms were preserved in 10% buffered formalin and shipped to Applied Technical Services in Victoria, BC, where organisms were enumerated and identified to the lowest possible taxonomic level. Four variables were calculated for each station: average density (total number of organisms/m^2); average total number of taxa (*i.e.*, species richness); average Simpson's index of diversity; and average Bray-Curtis index of dissimilarity.

Mussel Mesocosm Study

Two wooden mesocosms were constructed by the Eskay Creek Mine. Each box was made of plywood and was 1 m long, 0.6 m wide and 0.6 m high and had an inlet and an outlet. Mussels were suspended in mesh socks in the mesocosms. The two mesocosms were installed on August 3, 2005, at stations 3 and 5. Temperature dataloggers were installed in each box and in the stream near each box, and water samples were taken from each box and from the adjacent stream. Temperature and water quality data confirmed that the two mesocosms largely replicated the environmental conditions of Ketchum Creek.

On August 3, 2005, approximately 350 wild specimens of Western Pearlshell mussel were collected from Seaskinnish Creek near Terrace and transported to the Eskay Creek Mine. A total of 288 mussels were measured for total length and total weight and then were placed in groups of 12 into 24 polypropylene mesh socks. Eight socks of mussels (total = 96 mussels) were immediately frozen at -20°C to serve as a control group and eight socks were suspended in each of the two mesocosms (total = 192 mussels) on August 4, 2005.

After the mussels were retrieved on September 24, 2005, they were allowed to depurate overnight in distilled water. Then, the mussels were inspected and those that were dead were removed from their mesh tube. Survival was the ratio of the number of live mussels retrieved in late September to the number of live mussels that were placed in the mesocosm on August 4.

Live mussels were immediately frozen and shipped to Rescan's Vancouver laboratory. Mussels were thawed and measured for total length and total weight. Each mussel was opened and all tissue was removed, washed in distilled water and weighed. Shell weight was calculated by subtracting tissue weight from total weight. All tissue from each sock (*i.e.*, a sample replicate of 12 mussels) was placed into a pre-labelled plastic bag and frozen. Five samples from station 3, five samples from station 5, and five samples from the control group were shipped to ALS Environmental for analysis of metal concentrations. PCA was used to identify trends in the tissue metals data.

Following convention, the bioaccumulation factor for a metal that is primarily absorbed from water was defined as $BAF_W = C_T/C_{W,}$, where C_T = total concentration of a metal in mussel tissue (mg/kg dry weight) and C_W = total concentration of that same metal in water (mg/L) sampled from the same station. Similarly, the bioaccumulation factor for a metal that is primarily absorbed from ingested sediment was defined as $BAF_S = C_T/C_S$, where C_S = total concentration of that same metal in sediment (mg/kg dry weight) sampled from the same station.

RESULTS AND DISCUSSION

Physical Habitat

The streams of the Eskay Creek area are characterized by steep gradients and high water velocities resulting in abundant riffle and cascade habitat. Within Ketchum Creek, there is a clear difference between reference station 3, which is characterised by narrow width, variable high-velocity flows and boulder-dominated riffles and cascades, and the exposed stations 4, 5 and 6, which are wider, shallower and have substrates with more cobble and gravel (Table 1).

Table 1
Habitat Characteristics of Sampling Stations of the Eskay Creek Area

Variable	Units	Station 3	Station 4	Station 5	Station 6
Total survey length	m	37	45	52	48
Number of habitat units	none	3	6	6	6
Dominant habitat unit	none	riffle	riffle	riffle	cascade
Average unit length	m	12	8	9	8
Wetted width	m	10	11	17	13
Bankfull width	m	14	25	20	24
Total surface area	m^2	360	375	416	436
Water depth	m	0.42	0.53	0.28	0.20
Bankfull depth	m	2.33	0.80	NA	0.40
Percent substrate - sand	%	5	5	7	5
Percent substrate - gravel	%	5	29	9	25
Percent substrate - cobble	%	41	45	43	37
Percent substrate - boulder	%	49	21	41	33
Percent substrate - bedrock	%	0	0	0	0
Bank height - left	m	100	50	100	100
Bank height - right	m	100	100	100	100
Percent instream cover - pool	%	0	0	0	0
Percent instream cover - boulder	%	9	4	40	22
Percent instream cover - instream vegetation	%	0	0	0	0
Percent instream cover - overhanging vegetation	%	0	0	0	0
Percent instream cover - undercut banks	%	0	0	0	0
Percent instream cover - LWD	%	0	0	0	0
Percent instream cover - SWD	%	0	0	0	0

NA = not available

Water Quality

No water quality guidelines were exceeded for any physical variable, anion or nutrient, no permit discharge limits or MMER discharge limits were exceeded at the three discharge stations (*i.e.*, AL, TM-1 and D7), and no BC Provincial guidelines or CCME guidelines were exceeded at reference Stations 1 and 3. However, 25 exceedances were found at the remaining seven stations. Nineteen of the 25 exceedances had HQ less than 3, which are considered non-significant. The remaining 6 exceedances had HQ between 3 and 10, indicating potential risk of ecological effect. These exceedances occurred for total and dissolved antimony, and for total aluminum, lead and iron, and were clearly the result of discharges from the mine. None of the exceedances were greater than ten, which indicates moderate to high risk of ecological effects.

A similar frequency of water quality exceedances and range of hazard quotients have been reported in previous years. These results confirm that mine effluent is present in Ketchum Creek. When combined with the naturally high metal concentrations in streams of this mineralized area, the effluent-derived metals exceed guidelines for the protection of aquatic life. The key issue is whether these elevated metal concentrations produce deleterious biological consequences. The benthic invertebrate survey in Ketchum Creek and the mussel mesocosm study were designed to answer that question.

PCA extracted four components from the water quality data matrix (Figure 2). The first was dominated by the common constituents of treated sewage effluent (e.g., sulphate, total dissolved solids, total organic carbon, nitrogenous compounds, etc.) – a clear signal of the mine effluent sampled at station D-7. The second showed a natural trend of increasing total suspended solids with downstream distance. The third component clearly represented a mine effect because it was highly positively correlated with total antimony, arsenic and lead and negatively correlated with pH. Also, the highest scores of WQPC3 were for the discharge stations AL and TM-1, the lowest scores were for reference stations 1, 3 and 7, and there were gradients of decreasing scores for exposed stations downstream of the three discharge stations. This analysis further confirmed the results of the plume delineation study by showing that substances present in mine effluent are present at all exposed stations.

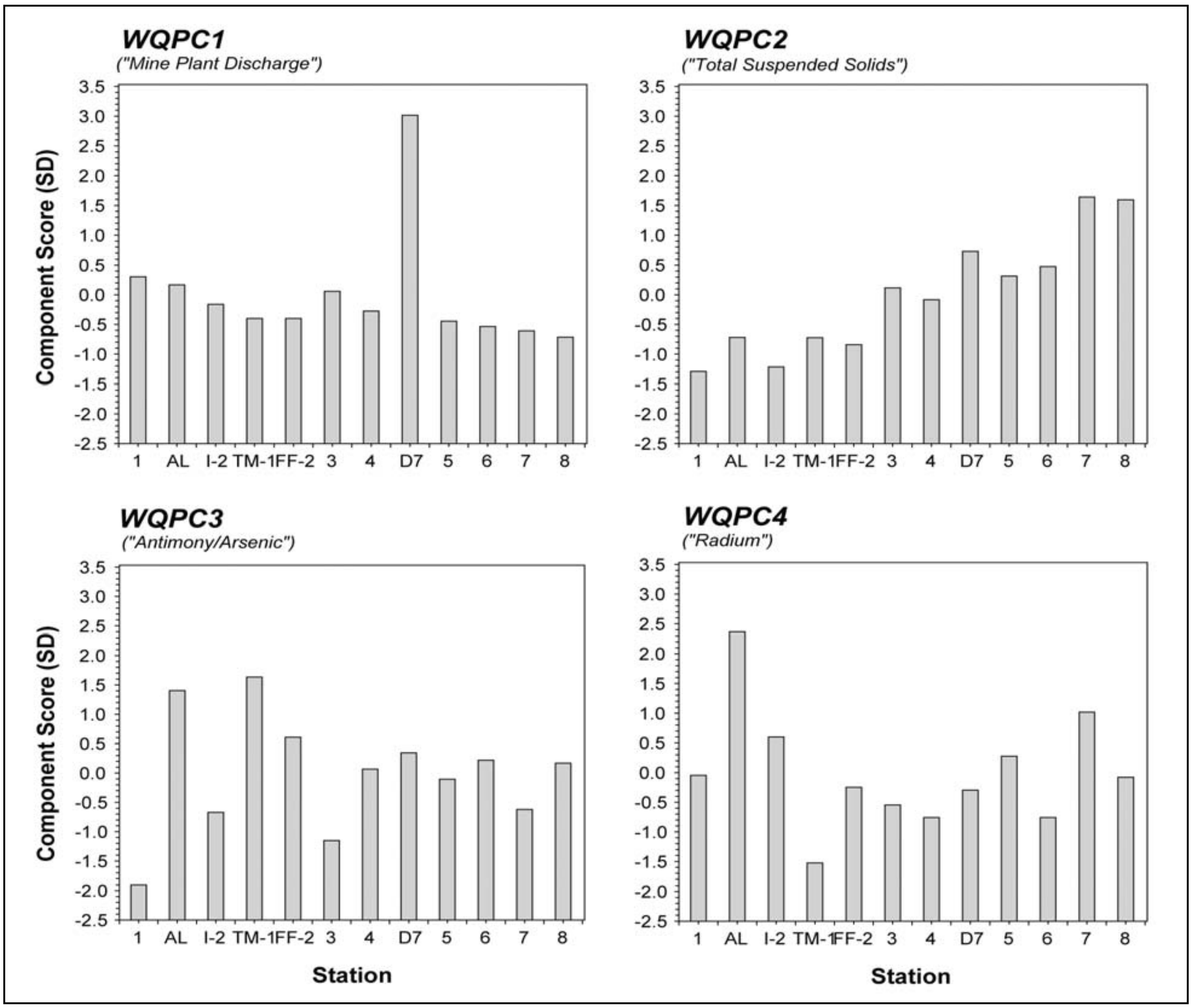

Figure 2. Plots of water quality component scores on sampling station

Sediment Quality

Waste rock and tailings discharge waters both contribute to metal loadings in the sediments of stations of the Tom MacKay Creek system. Sediment collected at station AL downstream of Albino Lake had higher metal concentrations than at any other site. Six metals had an HQ greater than 10 at Station AL, and three of them had HQs greater than 24, including arsenic, titanium, and methyl mercury. Only lead had an HQ exceeding 10 at Station TM-1.

Sediment metal concentrations frequently exceeded sediment guidelines in Ketchum Creek. HQ values indicate that mercury (47), antimony (14) and silver (11) are contaminants of concern at station 4. Downstream at station 5, which also receives mine plant sewage and water, mercury (HQ = 26) and cadmium (HQ = 11) were observed at concentrations at which moderate to high risk of ecological effects are predicted. Mercury was still a major concern further downstream at Station 6 (HQ = 19). Several other metals including lead, titanium and zinc showed moderately high HQ values indicating the potential for ecological effects. However, metals did not show any major exceedance of sediment guidelines at either station in Unuk River.

The frequent exceedance of sediment quality guidelines for metals illustrates the high degree of natural mineralization found in the Eskay Creek area. It also indicates that the mine activities have increased metal concentrations in the sediments of some stations. The key ecological issue in regard to sediment quality is the bioavailability of metals in sediments. Although metal concentrations may be high, they may also be inaccessible to benthic organisms that do not feed directly within the sediment or that do not ingest sediment particles during feeding. The results of both the benthic invertebrate sampling and mussel mesocosm studies support the idea that metals in sediments are not bioavailable.

PCA extracted four sediment quality components of which the third component, SQPC3 (“Mine Effect”), was dominated by seven heavy metals: mercury, silver, zinc, copper, cadmium, antimony and lead (Figure 3). The scores of SQPC3 reflect mine effluent concentrations with the lowest scores at reference stations 1, 3 and 7, and the highest scores at discharge or exposed stations.

Benthic Invertebrate Communities

There was a statistically significant increase in average family richness with downstream distance (ANOVA: $F_{3,16} = 4.989$, $P = 0.012$) that was caused by a significantly greater number of families at station 6 than at station 3 ($P = 0.011$) (Figure 4). However, there were no significant differences in average density among the four stations. Similar non-significant results were obtained for average Simpson’s Diversity index and the average Bray-Curtis index of dissimilarity.

These results do not support the hypothesis of a mine effect. In general, species richness, density and diversity would be expected to decrease with exposure to potentially deleterious substances – not remain the same or increase. Comparison of habitat components with indices of benthos community suggested that the increase in family richness and the apparent increasing trend in density with downstream distance in Ketchum Creek may have been largely due to changes in the stream's physical habitat rather than to changes in water and sediment quality.

These trends follow those documented for Ketchum Creek over the last 8 years of benthos sampling. The substantial variability among stations and years in stream benthos characteristics makes it difficult to reliably detect mine effects using these communities. The root of the problem appears to lie in the low magnitude of the mine effects combined with unstable stream substrates.

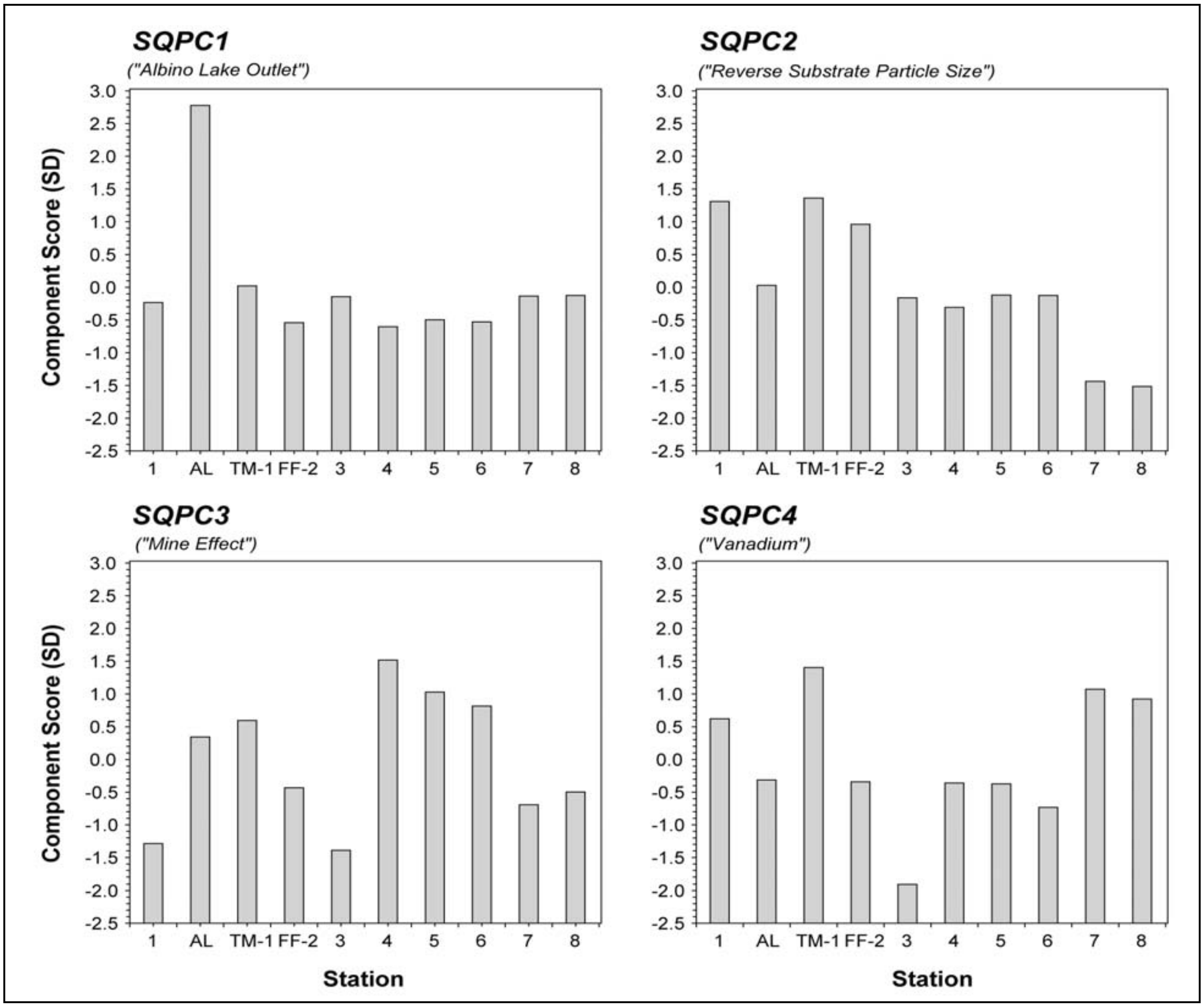

Figure 3. Plots of sediment quality component scores on sampling station

Mussel Mesocosms

Survival of mussels was 95% in the mesocosm at exposed station 5 and 86% in the mesocosm at reference station 3 (Table 2) – the opposite of the trend expected from a mine effect. Those survivals were equivalent to instantaneous mortality rates of 0.0010 and 0.0029 day^{-1}, respectively.

Table 2
Survival of Mussels in Mesocosms, August to September 2005

Mesocosm	Treatment	Number of Mussels		Survival	Duration (t, days)	Mortality Rate (Z, day^{-1})
		Installed	Retrieved			
Station 3	Reference	96	83	0.86	51	0.0029
Station 5	Exposure	96	91	0.95	52	0.0010

Survival = (number retrieved)/(number installed) and Z = -(1/t)ln[survival].

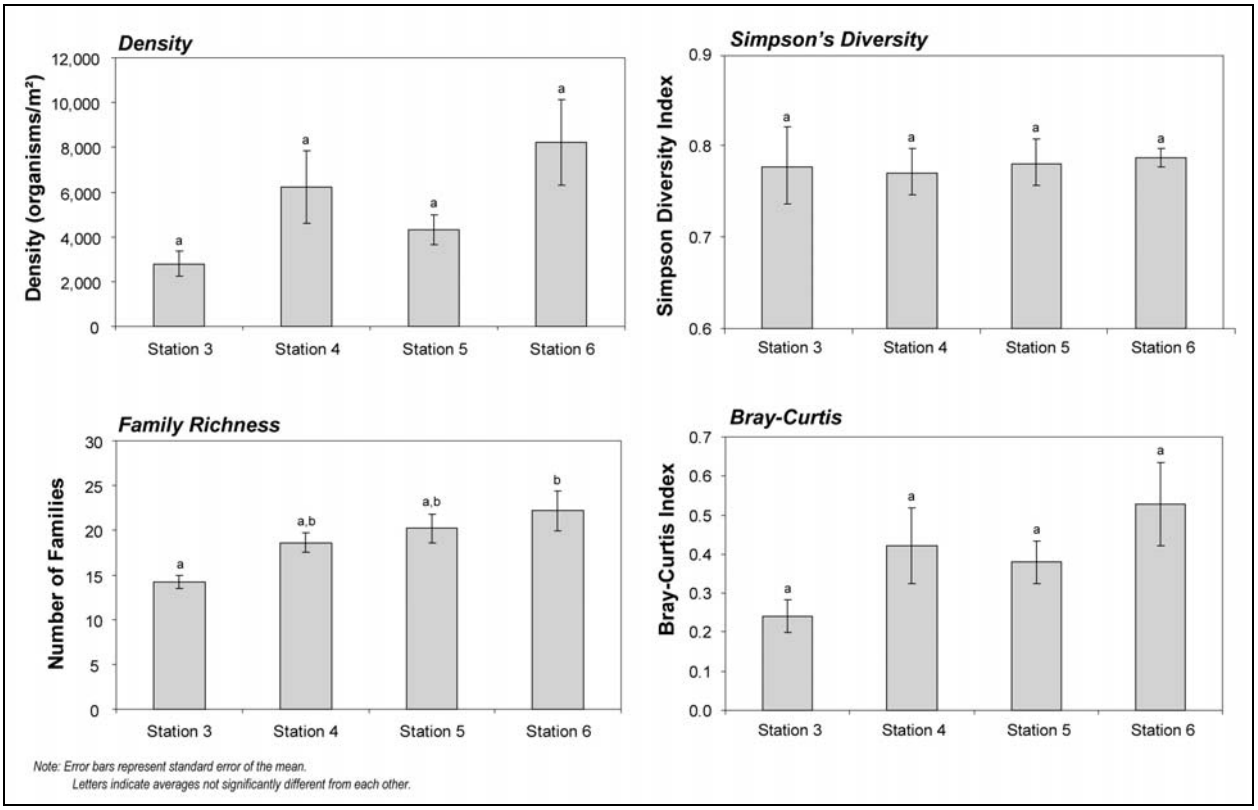

Figure 4. Mean density, family richness and indices of diversity and dissimilarity of benthic invertebrates of Ketchum Creek

Those mortality rates, if extrapolated over 365 days, are equivalent to annual survivals of 69 and 35%, respectively. Both are unusually low annual survivals for a species that can live for over 100 years. This was likely due to reproductive stress and poor rearing conditions in Ketchum Creek. Western Pearlshell mussels prefer clean, oligotrophic water, but Ketchum Creek has naturally high concentrations of suspended solids derived from glacier runoff.

As expected, plots of final shell length on initial shell length fell along the 1:1 line for control, reference and exposed groups with a few outliers indicating errors in identification of mussels and in length measurement. Analysis of Covariance (ANCOVA) showed no differences in average shell length between the three treatments. The plots for total weight showed loss of weight in all three groups due to thawing after freezing. ANCOVA showed no significant difference in average weight between the three groups, indicating no growth during the mesocosm study. The average percent loss of total weight over all three groups was 15%.

Seventeen of the 21 metals in mussel tissue showed significant differences in average concentration among treatments. The trend for all comparisons was increasing average concentration from control to reference (station 3) to exposed (station 5) treatments. PCA extracted three factors from the matrix of ln-transformed metal concentrations (Figure 5). The first factor, MTPC1, contained all of the information on the magnitude of metal concentrations and hence was called “Concentration”. A plot of average MTPC1 scores on treatment showed a continuous increase in average score from control to reference to exposed treatment. This indicates that exposure of mussels to natural Ketchum Creek water at reference Station 3 caused an uptake in metal concentrations greater than that in the control mussels from Seaskinnish Creek. Similarly, exposure to Ketchum Creek water containing mine effluent at exposure Station 5 caused a further increase in tissue metal concentrations.

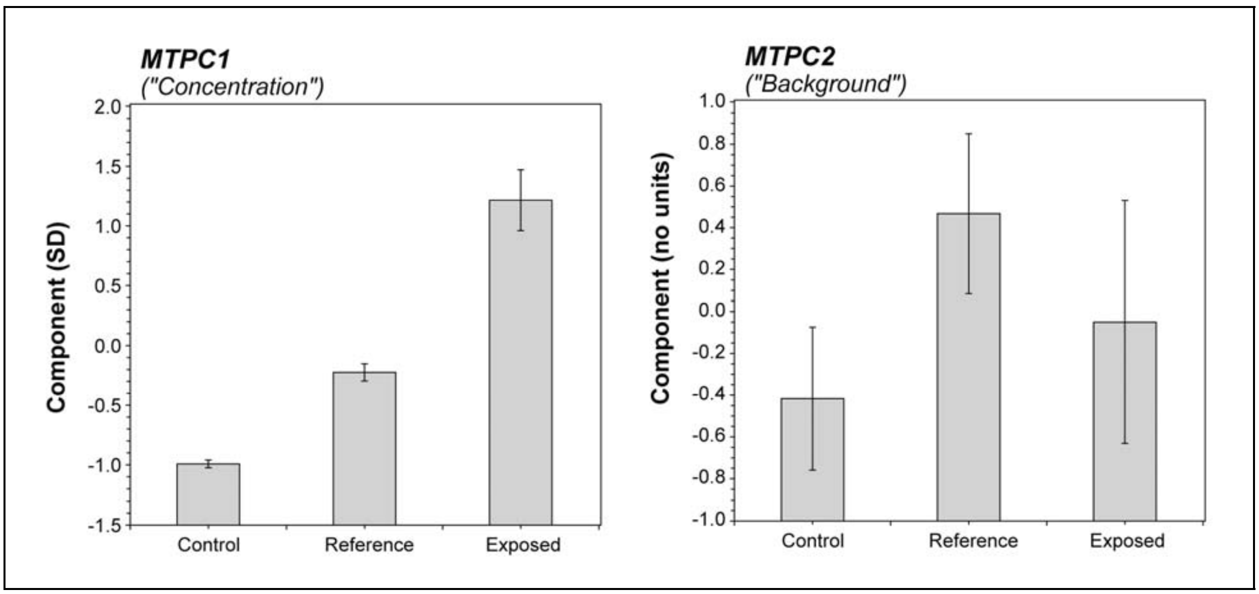

Figure 5. Plots of mussel tissue metal components on treatment

The second component, MTPC2, was highly correlated with the five metals that showed no significant differences among treatments (barium, manganese, selenium and strontium). In the absence of any other information, this component was called the “Background” component. The third component, MTPC3 (not shown here), was correlated only with methyl mercury.

One possible explanation for the higher tissue metal concentrations in the mussels at station 5 compared to station 3 was higher bioaccumulation at station 5 than at station 3 (as opposed to higher metal environmental concentrations at station 5 than at station 3). To test this explanation, bioaccumulation factors for water and sediment were calculated for both stations and then were plotted. They both fell along the 1:1 line, indicating no significant differences in factors between the two stations.

To separate the effect of exposure to the naturally metal-rich waters of Ketchum Creek from exposure to mine effluent, residual metal concentrations were calculated by subtracting the average metal concentrations of the control treatment from station 3 and the average metal concentrations of station 3 from station 5 (Figure 6). The residuals for the first comparison showed that Station 3 tissue was enriched in lead, nickel, chromium, vanadium, aluminum, lithium, cobalt, antimony and cadmium as a result of exposure to natural Ketchum Creek water. The residuals for the second comparison showed that Station 5 tissue was enriched in all metals but particularly antimony, lead, mercury, vanadium and aluminum as a result of exposure to Ketchum Creek water and mine effluent.

In summary, there was clear evidence of metal uptake by mussels, but it occurred in both mesocosms not just the one exposed to mine effluent. Despite the increased metal body burden, there was no clear effect of mine effluent on mussel population parameters.

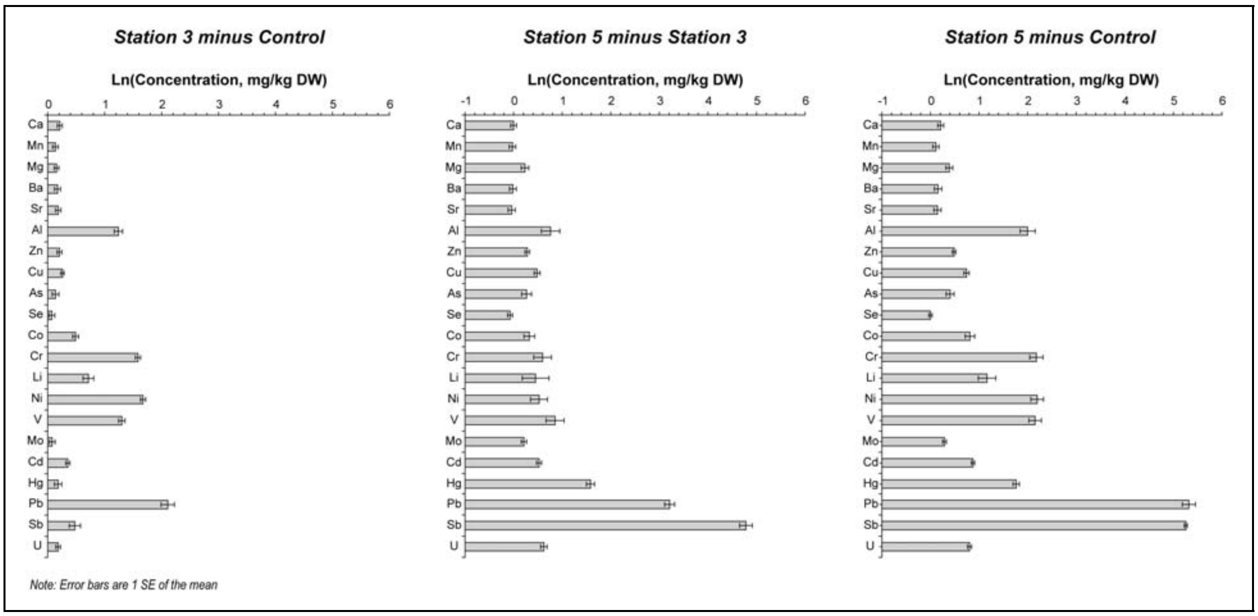

Figure 6. Residual average mussel tissue metal concentrations

CONCLUSION

Eskay Creek Mine effluent is present in Ketchum Creek in concentrations between 6 and 12%. This effluent affects aquatic biota, but the effects are low enough in magnitude that they are difficult to distinguish from natural effects. The consequences of this situation for aquatic ecosystems downstream of the mine are assumed to be negligible for the following reasons. The lakes and creeks of the Eskay Creek area are cold and oligotrophic and do not produce many drifting organisms that could be used as food by downstream consumers. Hence the loss of this source of drift prey would have no significant impact on downstream consumers. There are no fish in the Eskay Creek area, hence there are no commercial, recreational or subsistence fisheries that may be affected by mine effluent. The absence of fish means there are no mobile consumers that can transfer the elevated metal concentrations of the area as body burdens to downstream consumers.

The consequences of these findings for closure planning is that maintenance or reduction in current levels of mine effluent discharge will result in negligible long-term harm to aquatic organisms of Ketchum Creek or the Unuk River.

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