Changes in the Benthic Community of Lake Creek, MT, Resulting From Mine Tailings Contamination

Barry S. Hansen
Confederated Salish and Kootenai Tribes
Pablo, MT 59855

Abstract

The benthos of Lake Creek, Lincoln County, Montana were sampled in 1984-85 to determine the effects of a 2.5 years old tailings impoundment located adjacent to the stream. Sampling results were compared spatially in the 1984-85 data set, and temporally with a baseline data set collected three years prior to installation of the impoundment. Lack of replication in the baseline sampling design precluded the use of two-way ANOVA for analysis of temporal changes. Therefore temporal comparisons were made on the basis of changes downstream of the impoundment relative to changes upstream, as measured over time. Spatial comparisons upstream and downstream were made by one-way ANOVA.

Determination of the effects of the tailings impoundment was confounded by a tailings spill that directly contaminated the downstream stations. The spill was assumed to have had a much larger biological effect that did the tailings impoundment itself. *Simuliidae* and *Rhithrogena* spp. increased in abundance after the spill, the former as an opportunist, the latter was a coincidental benefactor since it was in the adult stage during the spill.

The before and after data sets were collected with different sampling gear and had unequal replicate samples within plots. The gradient effect of Bull Lake on Lake Creek was also a concern. These concerns were minimized by utilizing a methodology that analyzed the change in the relationship between control and impact areas over time.

Of 16 taxa analyzed, 10 decreased, two increased, and four showed no significant change in abundance in the impact area relative to the control from 1977-78 to 1984-85. Spatial comparisons above and below the impoundment in 1984-85 showed eight taxa significantly more abundant in the upstream area, five with comparable abundances, and three with greater abundances downstream.

Editor's note: This paper investigates a creek outside the Clark Fork drainage but addresses a problem of much concern in this drainage. Hence the paper is included in this symposium because it provides useful insights on the likely reactions of similar creeks to similar disturbances within the Clark Fork basin.

Introduction

This study was undertaken to measure potential aquatic impacts resulting from a new mining operation. It was inspired by the importance of biological monitoring as a tool to judge the accuracy of pre-development impact predictions, and by the need to provide alarm systems when cumulative impacts approach unacceptable levels.

I collected benthic samples in a northwestern Montana stream three years after the installation of a tailings impoundment adjacent to the stream. An Environment Impact Statement was prepared five years prior to my sampling. The tailings are a fine waste product from milling of copper/silver ore.

My objectives were to document any differences in the macroinvertebrate community between the before and during mining periods, and between the areas upstream and downstream of the impoundment. Significant problems experienced during this field study were: 1) ‘pseudo-replication’ (Hurlbert 1984) in the baseline sample design, 2) the presence of a lake upstream of the study site that may have confounded the results, and 3) the over-whelming influence of a tailings spill between the control and impact stations in June 1984.

Study Area

Lake Creek originates at the outflow from Bull Lake, near Troy, Montana, and flows for 28 km over a gradient of 3.2%, before joining the Kootenai River. Metasedimentary Belt rocks such as quartzite, siltite, and argillite are common in the basin, which was once entirely covered by the Cordilleran ice sheet.

Land use in the basin is predominately for timber production, although about one fifth of the drainage is in wilderness condition. Lake Creek water is calcium-bicarbonate type typically high in oxygen, and low in turbidity and organic matter. Alkalinity measurements range from 10 to 50 mg/l as CaCO and mean annual discharge is 510 cfs.

The tailings impoundment covers about 400 acres along 2000 m of stream channel, and is located 5 km downstream of 1,200 acre Bull Lake. Mining began in 1981, is expected to last until 1997, and results in the annual deposit in the impoundment of about three million tons of tailings.

Methods

Baseline samples were collected with a one square foot Surber sampler, using a 1000 micron mesh capture net, at single sites upstream and downstream of the proposed site of the tailings impoundment. Five samples were collected at each site in April, July, October, and February 1977-78. I used this baseline data for determining temporal changes by 1984.I sampled on the same dates as the baseline, but modified the study design. I used a Hess-type sampler (1000 micron mesh), which seals more effectively to the substrate, increased upstream and downstream stations to two each to eliminate pseudo-replication, and increased replicate sample number at each station from five to eight for greater precision. The changes did not invalidate a comparison between periods, and ensured statistical validity.

Sampling stations were located in riffles that were chosen primarily on the basis of their proximity upstream or downstream of the tailings impoundment. Nearness to the impoundment was of primary importance. Sample sites were further evaluated subjectively for uniformity in stream width, depth, and velocity. The control stations were 1.2 and 0.7 km upstream of the tailings impoundment, and the impact stations were 0.1 and 1.0 km downstream of it.

Whole samples were systematically sorted in the lab. Most organisms for which published keys are available were identified to species level. Simuliids and chironomids were identified only to the family level. Approximately 50 taxa were identified in the samples. Abundance data suggested lognormal distributions as histograms of the data were generally skewed to the right and plots on lognormal probability paper produced nearly straight lines. Regressions were run on the 16 most common taxa to determine the dependence of the variance on the mean. According to Anderson (1965) at least three individuals are required per sample before a variance-stabilizing transformation can be found. Log and fourth root transformations were chosen according to which most successfully stabilized the variance.

According to Green (1979), two-way analysis of variance (ANOVA), which determines the interaction of site and time, is the strongest test of mining effects. Two-way ANOVA was inappropriate for this study, since the baseline design was pseudo-replicated, meaning only single control and impact stations were present in 1977-78. Without replicated control and impact sample sites there can be no estimate of among area variance, and only the null hypothesis of "no difference between sites" rather than "no difference between upstream and downstream areas" would be tested. Therefore the spatial and temporal analyses were done separately.

Temporal changes were determined by a procedure described by Stewart-Oaten et al. (1986), who resolve pseudo-replication by evaluating the data as a time series and sampling dates as replicates. The procedure is based on a comparison of the differences between the control and impact areas before and during mining. Impacts are deduced from a consistent change in the comparison of control and impact areas over time between the baseline and 1984-85 period. A t-test with three degrees of freedom (four dates were sampled) determines the level of significance.

Spatial differences (between the upstream and downstream areas) after mining began were determined by one-way ANOVA. Significance differences between control and impact areas support a rejection of the null hypothesis that mean abundance at the control area equals mean abundance at the impact area.

Results

Six taxa were strongly influenced by tailings contamination as demonstrated by greater abundances (a=0.05) at the spatial and temporal controls (Table 1). Heterlimnius corpulentus and *Hydropsyche* are the best examples.

Hydropsyche is a large caddisfly that relies on seston which it filters by means of an intricate silken net. Since all sampling stations were located downstream of Bull Lake, a seston-gradient through the study area may exist, and if so, *Hydropsyche* may not serve as a good indicator of water quality in Lake Creek. Several researchers have shown hydropsychid abundance to decrease with distance from a lake outlet (Valett and Stanford 1987, Sheldon and Oswood 1977). Carlson et al. (1977) observed a rapid reduction in seston in "a few hundred meters" of a lake outlet, and Maciolek and Tunzi (1968) measured a 60% decrease within 400 m of a lake. Since the first control station was located about 2000 m downstream of Bull Lake, I considered it beyond the bounds of lake-outlet community. Furthermore, in the baseline period, *Hydropsyche* was more common at the impact station than the control station on three of four dates sampled. In 1984-85 the situation was changed and *Hydropsyche* was more common in the control area than the impact area on all dates sampled ($p<0.003$). The consistently greater hydropsychid abundance in the downstream area before mining, and the greater abundance upstream of the tailings impoundment during mining, suggests a negative influence at the site of the impoundment.

Riffle beetles, *Heterlimnius corpulentus*, are clingers found in cobble and gravel, that were more common at the control site both before and during mining. *H. corpulentus* presents unusual problems for impact detection, since it was abundant in the control and rare in the impact area even before mining began (Figure 1). This problem is compounded by the fact that *H. corpulentus* increased in the impact area in 1984-85 relative to baseline levels. The conclusion of significant differences between periods is based on the assumption that in the absence of tailings contamination, populations in the control and impact areas should have similar fluctuations in abundance. Therefore downstream abundances should have increased to the same degree as they did upstream, and the fact that they failed to may be due to a stress in the downstream area.

Three taxa increased in abundance downstream of the tailings impoundment (Table 1). *Rhithrogena,* a heptadeniid mayfly, was marginally more abundant at the control station in 1977-78, and substantially more abundance at the impact stations that the control in 1984-85 (Figure 2). The variability in differences between dates accounts for the lack of significance (t=1.8403). In 1984-85 *Rhithrogena* was significantly more abundant at the impact stations than at the control stations on three of four dates. One possible explanation is the coincidental emergence of *Rhithrogena* prior to the tailings spill which may have enabled it to escape the peak of pollution stress and recolonize after competitive pressure was greatly reduced. *Rhithrogena* emerge in nearby Kootenai River during the first two weeks in June (Perry 1983), suggesting they were in the adult stage during the spill. *Rhithrogena* was present in nearly equal abundance at the control and impact sites in April prior to the spill, but much more common in the impact area on all dates after the spill.

The genus *Simulium* was the most common black fly in Lake Creek, and like *Rhithrogena*, it also increased in the impact area. It acts as a filter feeder by utilizing its cephalic fans for removing particles from the current. During the baseline period the control station averaged less than one simuliid per sample, supporting the earlier contention that the control area is not part of a lake-outlet community. During 1984-85 simuliids erupted into large concentrations, in which on particular sample contained 476 larvae and pupae. On all dates in 1984-85 except April, abundance at the control areas was greater than in 1977-78. Increased sampler efficiency and sample size may largely explain that difference, but not why there was a tremendous increase in the impact area in October and February, and only a moderate increase in April and July. The timing and the magnitude of the increases suggest that the tailing spill of June 1984 was primarily responsible. The spill may have caused a large, short term reduction in the population of benthos, in which case organisms best adapted for colonization, like simuliids, would be favored to fill the empty habitat. Short generation times and multivoltine life cycles may have provided simuliids the competitive advantage to exploit the disturbance caused by the spill (Carlson 1977).

Four taxa, *Cinygmula, Rhyacophila,* Perlidae, and Chloroperlidae demonstrated no difference in abundance between areas either spatially or temporally. Notably, all except *Cinygmula* are predacious. The low population density of predators may render them less effective as monitors of biological change.

In the 1984-85 period, taxa richness was greater at the control stations than the impact stations on all dates sampled. The average number of taxa identified in the control area was 39, while only 31 taxa were present in the impact area.

Conclusions

Significant changes in the differences in abundance between control and impact areas from 1977-78 to 1984-85 were measured in nine of the 16 taxa analyzed (Table 1). In all but one (Simuliidae) the change was toward a reduced abundance at the control relative to the impact area.

Significant differences in abundances between areas during the 1984-85 period were measured in 10 taxa. Seven taxa had higher abundances in the control and three had higher abundances in the impact area. All of these differences appear attributable to tailings contamination. It is very unlikely that the significant temporal and spatial differences in so many taxa is a chance occurrence. Furthermore, the changes are generally explainable in terms of the spill event that occurred during the sampling period. It is not possible to separate the effects of the tailings impoundment from those of the tailings spill, although it is assumed that the spill was of much greater influence. None of the biotic changes measured in Lake Creek up to July 1985 appear to be extreme enough to risk local extinction. The absence of extreme changes at this point does not preclude more severe changes later. Lake Creek may be in what Bormann (1982) categorized as Stage 1 or 2, in which an ecosystem serves as a sink for pollutants without exhibiting significant biological changes.

Any discussion of significant impacts involves value judgments concerning the components that are lost. The biotic changes measured in this study do not clearly translate into reduced outputs (i.e. fish, wildlife, water, etc.) to society from Lake Creek, although the link between those changes and the tailings transport and storage facility makes the continued ecological health of Lake Creek a valid concern. I propose that the statistically significant changes measured in this study are also biologically significant, until long term monitoring proves them otherwise.

Literature Cited

Allan, J.D. 1984. Hypothesis testing in ecological studies of aquatic insects. In: Ecology of Aquatic Insects, eds. Resh, V.H. and D.M. Rosenberg.

Bormann, F.H. 1982. New England landscape: air pollution stress and energy policy. Ambio 11:338-346.

Carlson, M., L.M. Nilsson, Bj. Svensson, and S. Ulfstrand. 1977. Lacustrine seston and other factors influencing the blackflies (Diptera: Simuliidae) inhabiting lake outlets in Swedish Lapland. Oikos 29:229-238.

Green, R.H. 1979. Sampling design and statistical methods for environmental biologists. Wiley, New York, New York. USA.

Hurlbert, S.H. 1984. Pseudo-replication and the design of ecological field experiments. Ecological Monographs 54:187-211.

Maciolek, J.A. and M.G. Tunzi. 1968. Microseston dynamics in a simple Sierra Nevada lake-stream system. Ecology 49:60-75.

Sheldon, A.L. and M.W. Oswood. 1977. Blackfly (Diptera: Simuliidae) abundance in a lake outlet: test of a predictive model. Hydrobiologia 56(2):113-120.

Stewart-Oatan, A., W.W. Murdoch, and K.P. Parker. 1986. Environmental impact assessment: “Pseudo-replication” in time? Ecology 67(4):929-940.

Valett, H.M. and J.A. Stanford. 1987. Food quality and hydropsychid caddisfly density in a lake outlet stream in Glacier National Park, Montana, USA. Can. J. Fish. Aquat. 44:77-82.

Table 1. Summary of biological changes in Lake Creek, MT, occurring between 1977-78 and 1984-85.

Control > Treatment	Treatment > Control
Both Temporal (1977-78 to 1984-85) and Spatial Changes (upstream vs. downstream 1984-85) are Significantly Different	
Hydropsyche	Simuliidae
Agraylea	
Antocha	
Heterlimnius corpulentus	
Total Abundance	
Only Spatial Changes (upstream vs. downstream 1984-85) are Significantly Different	
Brachycentrus	*Rhithrogena*
	Baetidae
Only Temporal Changes (1977-78 to 1984-85) are Significantly Different	
Ephemerella	none
Chironomidae	
No Significant Differences Exist Spatially or Temporally	
Cinygmula	
Rhyacophila	
Perlidae	
Chloroperlidae	

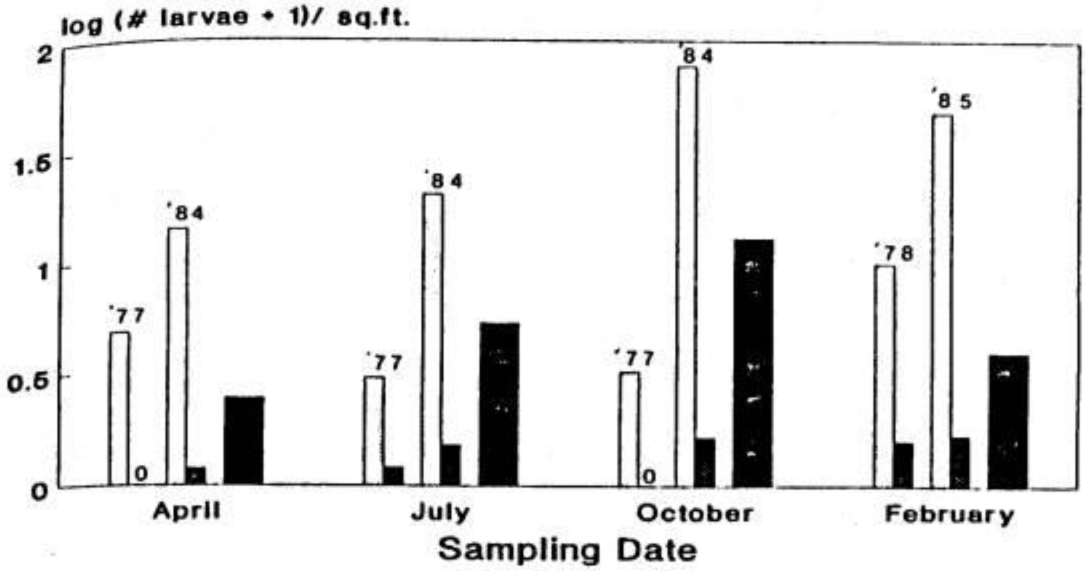

Figure 1. Log abundance of <u>Heterlimnius</u> <u>corpulentus</u> at control ░ and impact ▓ areas, and the change █ in the difference between control and impact areas from 1977-78 to 1984-85, Lake Creek, Montana.

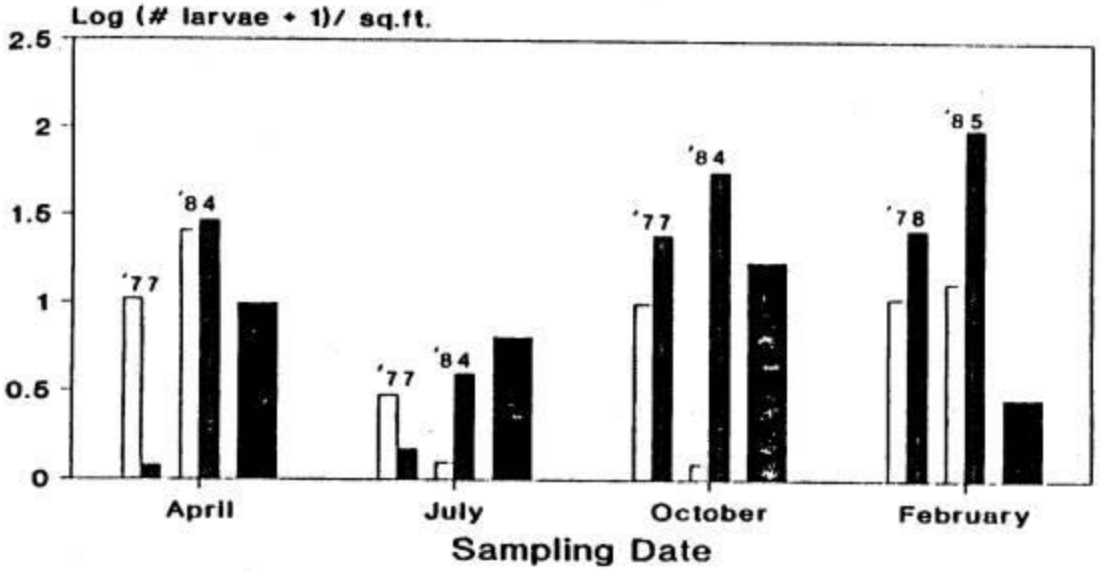

Figure 2. Log abundance of <u>Rhithrogena</u> at control ░ and impact ▓ areas, and the change █ in the difference between control and impact areas from 1977-78 to 1984-85, Lake Creek, Montana.