The Correlation Between Mine Proximity and Macroinvertebrate Abundance

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The Correlation Between Mine Proximity and Macroinvertebrate Abundance

Submitted in Partial Fulfillment of the Requirements for Graduation

With Honors to the Department of Natural Sciences at

Carroll College, Helena, Montana

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April 9, 2001
This thesis for honors recognition has been approved for the Department of Natural Sciences by:

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ABSTRACT

Before gold was discovered in the 1860's, Montana had a relatively small population. This would quickly change with a steady influx of miners over the next several decades. Men staked hundreds of claims around the state and in some areas every drainage basin saw prospectors. The mining processes left behind large piles of mine tailings and exposed rock which in turn led to both soil and water contamination. I studied the effect of mining contamination on benthic macroinvertebrates. This entailed sampling streams throughout central Montana and looking for a correlation between macroinvertebrate abundance and mine proximity. I found a significant relationship between Ephemeroptera (mayfly) abundance and the number of mines less than one kilometer from the sample site. This indicated a negative environmental impact from the historic mining sites present around the state.
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INTRODUCTION

Known to many as simply “The Treasure State,” Montana has long contained vast landscapes rich in natural resources. American Indians roamed the land for its wildlife and its vegetation; mountain men followed in later years to make a living out of hunting and trapping for the fur trade in the wild country. With all of its natural wealth, Montana gained little notoriety until the entrance of the miner. After the tribal nations native to the area and the mountain men, prospectors were the next men to enter Montana. Many started on a journey for the Idaho gold fields and remained in Montana for the gold that they found it, too, offered (Wolle 1963).

Montana had a relatively small population before gold was discovered in the early 1860's. Established communities included those that the military formed in Fort Benton and Fort Owen along with small missions that persevering missionaries had built in order to introduce Christianity to the American Indians (Malone 1969). This would quickly change with a steady influx of people over the next several decades.

When Francois Finlay, a fur trader by profession, first found gold in the late 1850's, he was told to keep his discovery a secret. Many thought that a gold rush would ruin a more lucrative fur trade and so did not want to risk the loss of fur profit (Malone 1969). However, with more and more people moving into and through the area, gold could not be hidden forever. On July 28, 1862, John White discovered gold at Grasshopper Creek and forever changed the land.

People quickly flooded into the area after White’s discovery. In fact, when
he and his companions went to the nearest town to stake their claim on the land and buy more supplies, suspicions were aroused and close to two hundred people followed them back to the site. This group soon created the bustling town of Bannack. Similar discoveries in Alder Gulch quickly led to Virginia City. Helena came later after a group of men called "the Georgians" found gold at Last Chance Gulch. Each of these towns grew seemingly overnight to contain populations in the thousands. The large group of miners fought for Montana's statehood and won on November 8, 1889. The state motto, *oro y plata*—or gold and silver, will forever remind residents of the legacy of their presence.

The three main discoveries, at Grasshopper Creek, Alder Gulch, and Last Chance Gulch, were the first and most noteworthy. Men staked hundreds of claims around the state and in some areas every drainage basin saw prospectors, if not a city of its own. Once the gold was exhausted from the area, the towns declined or disappeared entirely. Today little evidence can be found of the large population each basin held. The naked eye sees much of the land the same way the miners did, but their presence remains and will for years to come in the damage they caused. The miners gave little thought to the impact they would have on the land and as a result, the techniques used inflicted damage that is still in evidence today.

When prospecting, miners first checked a stream for "colors" or brightly colored rock in the streambed. After locating a stream with "colors," they used a technique called panning to determine if the stream contained gold. Panning made use of the heavy weight of gold in comparison to gravel; when washed with
water, the gravel would wash out of a gold pan while any gold would remain in
the bottom (Wolle 1963.) Once it was decided that the stream contained gold,
the prospectors staked a claim and began mining. They used sluice boxes or
rocker boxes in the first stage of operations.

Both sluice and rocker boxes required the removal of large amounts of
gravel that was placed in long boxes. Water continually flowed through the
boxes and carried out the lighter gravel while the gold collected in the bottom of
the boxes. Miners obtained gravel for the sluice boxes from the surrounding area
and did not take into consideration the source of the gravel or the impact its
removal might cause. Often, they would divert a stream channel in order to
easily remove the streambed (Wolle 1963.) The excess gravel from the sluice
boxes, called tailings, was deposited on the surrounding banks or allowed to
wash down the stream. These tailings held the components that caused
pollution in the years to come.

After the small vein of gold in the stream ran out, miners traveled
upstream in an attempt to find the source, or lode. Once they moved away from
water, sluice boxes were no longer effective so they used lode mining. This
required digging deep into the earth and removing large amounts of rock, or ore.
Mills pulverized the ore to release the gold that the rock contained. The earliest
mill, called an arrastre, harnessed horse power to grind the rock and water was
again used to wash away the excess sediment (Wolle 1963.) This also led to a
build up of contaminated tailings.
Towards the end of the gold rush the miners employed a new technique called dredging. Dredges floated on standing water, present due to stream diversion or building dams, and picked up the underlying gravel. The dredge washed the gravel, kept the gold, and spewed the tailings on the banks. Evidence of this process can be found throughout central Montana in large piles of dirt left from the dredges (Wolle 1963.)

Each of the mining processes described left behind large piles of tailings and exposed massive quantities of rock. This allowed pyrite and other sulfide minerals formerly below the soil, and thus protected, to contact both air and water. Exposure to air and water caused an oxidation of the sulfide minerals to form two main products, sulfuric acid and sulfates. Acid mine drainage consists of an acid, such as sulfuric acid, precipitated iron compounds, sulfate ions, and dissolved metals (USDA 1993.) Mixing these components into the natural ground and stream water caused adverse effects. For example, increased sulfuric acid concentrations lower the pH of the water. Acid drainage problems due to rock exposure can hinder a stream’s ability to support life (BM 1982, Robb and Robinson 1995.) Thus aquatic organisms living in the stream die off. The danger of the sulfuric acid does not result from the decrease in pH alone but also the effect acidic environments have on solubility of heavy metals.

Mine tailings also expose a high concentration of heavy metals to the environment (Clements et al. 2000.) These heavy metals released by mining are made available for uptake by organisms in the vicinity of the mine. Coupled with the acidity of nearby water supplies, the metals have a higher solubility and are
readily taken up by aquatic organisms. Metals released by mining include: arsenic, cadmium, copper, lead, and zinc. Farag, et al. (1995) found that fish in the upper Clark Fork River experienced decreased health, survivorship, and reproduction due to elevated concentrations of metals. These effects of mining need to be more thoroughly researched so impacted areas may be restored to their original state and future contamination may be reduced.

Scientists often use benthic macroinvertebrates to study water quality. They provide good indicators of the water quality for several reasons. First, they have prolonged contact with the substrate and are thus influenced by past as well as current contamination (Farag et al. 1995, Wallace et al. 1996, and Clements et al. 2000.) Macroinvertebrates are affected by contaminations in all types of water allowing broad studies to be completed. In addition, they do not have a large range which allows spatial analysis of specific sites. Lastly, they have a long life cycle which allows water to be measured temporally.

My study uses these qualities of macroinvertebrates to study abandoned mine sites. I examined the relationship between macroinvertebrate abundance and mine proximity in order to elucidate the environmental effects of mining. Many of the drainage basins in the Helena area have been impacted by historic mining activity making them good sampling sites. To test whether mining effluent influences macroinvertebrate abundance, I examined the correlation between mine proximity and macroinvertebrate diversity and abundance.
MATERIALS AND METHODS

Study Area

I selected six drainage basins to represent a cross section of mining influence. Samples were taken from randomly chosen streams within each area. Three sites known to have numerous historic mining activity in the surrounding areas were used to gather the experimental data and represent the impacted areas. These locations included the area around Basin, Montana, a small town about 48 kilometers south of Helena and Rimini, Montana, another town about 24 kilometers west of Helena. Additional streams in the area surrounding Park Lake in Jefferson County, Montana (20 kilometers southwest of Helena) were used. Three separate locations were identified as having little or no mining present and made up the control group. This group was comprised of the South Fork of the Sun River in the Bob Marshall Wilderness, the North Fork of the Blackfoot River near Lincoln, Montana, and the region around Gipsy Lake in the Big Belt Mountains east of Helena.

Collection Methods

Collection techniques of Resh et al. (1996) were used to gather data in the field. Mean stream width and depth were taken to calculate a mean stream area for each sample site. Air temperature, water temperature, and pH were also measured to gather information on the water quality of the stream. I used a Garmin Global Positioning System (GPS) unit to record each site’s Universal Transverse Mercator (UTM) coordinates. UTM is a system that uses north and east distance measurements from specified reference points to obtain a site’s
specific position; it is the primary coordinate system used on U.S. Geological Survey topographic maps. After gathering the preliminary data, I used a stream bottom sampler called a Surber Sampler to collect macroinvertebrates from each site. The device acts as a net, capturing macroinvertebrates that are dislodged by scraping the rocks and substrate upstream from it. I removed debris from the samples and stored them in 75% ethanol until lab analysis could be completed. In the lab, the macroinvertebrates were sorted by order and counted according to a classification system outlined by Hauer and Resh (1996).

**Mapping Sample and Mining Sites**

The UTM coordinates taken at each sample site were plotted on quadrangle maps to measure their proximity to known mines. A listing of all mines in Montana was obtained from the Heritage Foundation. Each mine had its own UTM coordinates that I plotted simultaneously with the sample sites. I counted the number of mines within one kilometer of each sample site and all additional mines upstream of the site and over one kilometer away. Thus I had two different classification criteria for the mining impact at each site: the number of mines within one kilometer and the total number of mines upstream.

**Statistical Analysis**

I first used univariate regression analysis (1984) to test for relationships between the macroinvertebrate parameters (total abundance, total diversity, Plecoptera (stonefly) abundance, Ephemeroptera (mayfly) abundance, and Trichoptera (caddis fly) abundance) and the environmental parameters (number of mines within one kilometer, number of mines further than one kilometer, and
stream area.) All data parameters were log transformed to meet assumptions of normality. Because total macroinvertebrate abundance could be positively associated with stream size, significant univariant results may have been due to the effect of stream size and not due to mine proximity. To control for the effect of stream size, I used stepwise multiple regression analysis to account for the effect of stream area before testing for the effect of mine proximity.
RESULTS

Univariant regression analysis revealed a significant relationship between stream size and total macroinvertebrate abundance (figure 1.) In addition, stream size was positively associated with Ephemeroptera abundance (table 1) as indicated by a p-value of less than 0.05. According to these data, there is a two percent chance that the strong correlation between the stream size and Ephemeroptera abundance could be due to random chance. More likely, one variable is affecting the other. The number of Ephemeroptera was positively associated with an increase in stream size shown by a positive B-value representing a linear slope of the relationship. Analysis also determined a significant relationship between the number of mines within one kilometer of a sample site and Ephemeroptera abundance (table 1.) The two variables were negatively associated; the more mines in the area of a sample site resulted in fewer Ephemeroptera in the stream. There were no other significant relationships between mining and other macroinvertebrate parameters (table 1.)

The negative association between Ephemeroptera abundance and number of mines may be the result of stream size effects; this had to be factored in. Multiple regression analysis revealed a significant relationship between number of mines and Ephemeroptera abundance even after accounting for stream size by systematically removing its effects (table 2.) Ephemeroptera abundance remained negatively associated with the number of mines within one kilometer after removing variation due to stream area (figure 2) depicted by a negative B-value.
DISCUSSION

I found that the proximity of mine sites to stream sample areas significantly reduced the abundance of Ephemeroptera. Clearly, contamination due to mining has a negative effect on mayflies as their survivorship declines in areas with historic mine damage within one kilometer of a sample site. Other types of macroinvertebrates seem to be more resistant to the effects of mining effluent.

Clements et al. (2000) found results which support my data. They found that mayflies experienced significantly lower abundance and species richness than either stoneflies or caddis flies in areas impacted by mining. Specifically, Ephemeroptera numbers showed a significant decline in areas with heavy metal contamination indicating they were more sensitive to this mining impact than other macroinvertebrates. The impact on macroinvertebrate abundance and diversity illustrates the larger problem of mining contamination. If they, as bio-indicator species, experience adverse effects so too will other organisms.

Other researchers have documented this problem with studies on different organisms. Farag et al. (1995) reported impaired health of brown trout in water contaminated by heavy metals. In a different study, acid drainage caused ferric hydroxide to precipitate which polluted streams and killed resident flora (Robb 1995.) In an area near by sample sites, mining contamination decreased survivorship of amphibians (Meis 1999, Wicher 2000.) Acid drainage and heavy metal contamination due to historical mining techniques significantly impact the organisms within the polluted area.
Unfortunately, most of the damage has already been done making prevention no longer an option. The vast majority of mine tailings and contamination stems from a gold rush over 100 years ago. Those miners left behind a legacy greater than *oro y plata*. They left miles of contaminated streams and rivers many of which remain so polluted that the organisms they support experience a reduced survivorship even today.

This holds true for the Ephemeroptera in contaminated Central Montana streams. With this knowledge, future researchers can move forward to locate all of the mine contaminated streams in Montana and then work to contain the damage done. Work has already started in some areas — such as Rimini, which is currently undergoing clean up procedures — to control the effects of acid drainage and metal contamination. But, this chapter of Montana history cannot be closed until all streams return to the natural state.
LITERATURE CITED


Regression analysis of macroinvertebrate and environmental parameters. $R^2$ refers to the correlation between variables; a high value indicates a stronger correlation. $B$ represents the linear slope of a line formed between the two variables. Both $t$ and $p$ are indicators of the validity of $B$.

### Table 1. Univariant regression analysis

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>$R^2$</th>
<th>Independent Variable</th>
<th>B</th>
<th>$t$</th>
<th>p</th>
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</thead>
<tbody>
<tr>
<td><strong>Abundance</strong></td>
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<td>0.13</td>
<td>Mines &lt; 1km</td>
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<tr>
<td></td>
<td>0.01</td>
<td>Mines &gt; 1km</td>
<td>-0.01</td>
<td>-0.42</td>
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<td>2.43</td>
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<td><strong>Number of Orders</strong></td>
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<td>0.77</td>
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<tr>
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<td>Stream area</td>
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<td>0.67</td>
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<tr>
<td><strong>Plecoptera</strong></td>
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<td>0.05</td>
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<td>-1.14</td>
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<td>Stream area</td>
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<td>0.40</td>
<td>0.69</td>
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<td><strong>Ephemeroptera</strong></td>
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<td>-2.47</td>
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<td></td>
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<td>-1.44</td>
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<td><strong>Trichoptera</strong></td>
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<td>-1.65</td>
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<td>Mines &gt; 1km</td>
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<td>Stream area</td>
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Table 2. Multivariate regression analysis

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<th>Independent Variable</th>
<th>B</th>
<th>t</th>
<th>p</th>
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</thead>
<tbody>
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<td>Ephemeroptera abundance</td>
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<td>Mines &lt; 1km</td>
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<td></td>
<td></td>
<td>Stream area</td>
<td>1.02</td>
<td>2.37</td>
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Regression analysis of Ephemeroptera abundance with mines within one kilometer and stream area. $R^2$ refers to the correlation between variables; a high value indicates a stronger correlation. B represents the linear slope of a line formed between the two variables. Both t and p are indicators of the validity of B.
Figure 1. Regression analysis of stream size versus macroinvertebrate abundance.
Figure 2. Multiple regression results for Ephemeroptera abundance versus stream size and number of mines within 1 km.