A BIOLOGICAL ASSESSMENT OF FOUR NORTHERN BLACK HILLS STREAMS

Ryan L. Newman
Department of Wildlife and Fisheries Science
South Dakota State University
Brookings, SD 57007

Charles R. Berry and Walter Duffy
U.S. Geological Survey
South Dakota Cooperative Research Unit
South Dakota State University
Brookings, SD 57007

ABSTRACT

The health of Whitewood Creek, which has a history of degradation from mining activities, was evaluated using a rapid bioassessment technique for benthic macroinvertebrates, and by determining fish and anuran species richness. Data from two reaches of Whitewood Creek were compared with data from two reaches in Bear Butte, Spearfish, and Crow creeks. Macroinvertebrate communities were similar between reaches in each stream and between 1997 and 1998 (P > 0.05), but seasonal differences were found. In August, the macroinvertebrate assessment scores were similar among streams (Whitewood Creek score = 38; reference creek score = 36), but in May, the Whitewood Creek score declined to 16, whereas the score for reference creeks remained 36. Five of seven components of the assessment score for Whitewood Creek declined in May, especially components using counts of ephemeroperans, plecopterans, and trichopterans. Anuran species richness ranged from three to four species depending on stream. There were five fish species in Whitewood Creek, seven in Spearfish Creek, eight in Crow Creek, and 22 in Bear Butte Creek. The invertebrate community may be impacted by contaminants leached from mine tailings by spring floodwaters.

Keywords
Black Hills, invertebrates, streams, bioassessment, mining, anuran, fish.

INTRODUCTION

Past mining practices in the Black Hills of South Dakota often damaged stream habitat and water quality. From 1878 through 1970, about 15 kg of mercury and 140 kg of cyanide were discharged to the Whitewood Creek daily (Hesse et al. 1975, Rahn et al. 1996). In the 1950s, Whitewood Creek was a "legally" polluted stream (Stewart and Thilenius 1964), and was later a "su-
perfund" site (Lineburg and Lawrensen 1993, Homestake Mining Company 1996). Tons of tailings remain in the lower Whitewood Creek basin on the Missouri Plateau, which extends from the foot of the Black Hills to the confluence with the Belle Fourche River (Fox Consultants, Inc. 1984, Marron 1992). Contaminants (e.g. arsenic, mercury) from the tailings may be harmful to the aquatic biota (Brown 1972, Bergeland et al. 1976, Cain et al. 1988, U.S. Geological Survey 1988, 1989), but there has been no assessment of aquatic communities in the Plateau reach of Whitewood Creek.

Fish and benthic macroinvertebrate communities have been studied in Black Hills streams before they leave the Black Hills physiographic province and enter the Missouri Plateau. Analysis of the benthos has been done to evaluate impacts of municipal waste, recreational property development, and mining (Jurgens 1968, Drewes 1984). Lechner (1986) found 71 macroinvertebrate taxa in streams in the central portion of the Black Hills. Fisheries surveys have been conducted routinely to gather data for recreational fisheries management (Meester 1999). The fish community is usually made up of about six species; several salmonids and longnose dace (*Rhinichthys cataractae*), mountain sucker (*Catostomus platyrhynchus*) and white sucker (*C. commersoni*). The amphibians and reptiles of the Black Hills have not been studied recently (Peter-son 1974).

Our study was preceded by a cursory study of the benthic community in Whitewood Creek that suggested the presence of a stressor (Duffy, unpublished data). Our objective was to compare the macroinvertebrate, fish, and anuran communities in the Missouri Plateau portion of Whitewood Creek with those of three near by creeks (Bear Butte, Spearfish, and Crow) where mining has not occurred.

**STUDY REACHES**

Bear Butte, Spearfish, and Crow creeks were chosen as reference streams because they are near Whitewood Creek, and are in the same geologic and climatic setting (Fig. 1). Sampling was done on each reference stream and on Whitewood Creek in spring and fall of 1997 and 1998 at two 200-m-long reaches that were located away from tributaries, bridges and roads. Both reaches were on the Missouri Plateau; reach one was located where the streams enter the prairie
and reach two was downstream near the confluence with the receiving stream (Belle Fourche or Redwater rivers).

Reaches were dominated (50%-80%) by cobble and gravel substrate (Table 1). Each stream had peak flows in April, May and June and lowest flows in the fall and winter. Daily discharge at the time of sampling ranged from 117 cubic feet per second in May on Spearfish Creek to 0.65 cubic feet per second in August on Crow Creek. Dissolved oxygen was higher in May (8.1-9.2 mg/l) than in August (3.4-5.3 mg/l). Specific conductance ranged from 320–1080 μS at upper reaches to 430-2300 μS at downstream reaches. There was evidence of habitat disturbance (i.e. irrigation, grazing, physical channel alterations) at the upstream reach on Crow Creek, but the reach was cautiously included because study reaches were limited by access and landowner cooperation.

**METHODS**

**Benthic macroinvertebrate sampling:** Surber samples were collected at five riffle sites along the midline of the downstream half of the 200-m reach. Five submerged snags were sampled by placing a 500-um-mesh net over a 1-m portion of the snag and removing the enclosed portion with a saw. Samples were preserved in 95% ethanol. Floatation was used to separate organisms from sample residue (Anderson 1959, Mangum 1991). Each sample was separated three times by mixing with 800 ml of distilled water and 120 mg of table salt (specific gravity = 1.12), allowed to settle for 3 min, and filtered through a 500-um-mesh sieve (Brinkman and Duffy 1996, Rosillon 1987, Anderson 1959, Lackey and May 1971). Rose Bengal dye was added to make the organisms more visible. Invertebrates were identified to family. Total invertebrate numbers were compared among reaches, seasons, years, and creeks using analysis of variance (PROC CATMOD, SAS Institute 1989).

**Invertebrate community metrics:** The macroinvertebrate community was analyzed using a modified rapid bioassessment protocol with seven metrics se-

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bear Butte Site 1</th>
<th>Bear Butte Site 2</th>
<th>Whitewood Site 1</th>
<th>Whitewood Site 2</th>
<th>Spearfish Site 1</th>
<th>Spearfish Site 2</th>
<th>Crow Site 1</th>
<th>Crow Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Month</strong></td>
<td>May</td>
<td>May</td>
<td>May</td>
<td>May</td>
<td>May</td>
<td>May</td>
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<td>May</td>
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<tr>
<td><strong>Water Temp. (OC)</strong></td>
<td>19.5</td>
<td>19.5</td>
<td>19.5</td>
<td>19.5</td>
<td>19.5</td>
<td>19.5</td>
<td>19.5</td>
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<tr>
<td><strong>Conductivity (μS)</strong></td>
<td>1080</td>
<td>1100</td>
<td>700</td>
<td>1000</td>
<td>320</td>
<td>1300</td>
<td>490</td>
<td>376</td>
</tr>
<tr>
<td><strong>Dissolved Oxygen(mg/l)</strong></td>
<td>3.4</td>
<td>3.4</td>
<td>3.4</td>
<td>3.4</td>
<td>3.4</td>
<td>3.4</td>
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<tr>
<td><strong>Ph</strong></td>
<td>7.8</td>
<td>7.8</td>
<td>7.8</td>
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<td>7.8</td>
<td>7.8</td>
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<td><strong>Discharge (CFS)</strong></td>
<td>117</td>
<td>117</td>
<td>117</td>
<td>117</td>
<td>117</td>
<td>117</td>
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<td>117</td>
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<tr>
<td><strong>Boulder (%)</strong></td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
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<tr>
<td><strong>Cobble (%)</strong></td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td><strong>Sand (%)</strong></td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td><strong>Silt (%)</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Turbidity (NTU)</strong></td>
<td>3.1</td>
<td>1.5</td>
<td>2.6</td>
<td>0.8</td>
<td>5.4</td>
<td>1.4</td>
<td>2.3</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Table 1. Stream characteristics recorded in 1998 from two Missouri Plateau sites each on Bear Butte, Whitewood, Spearfish, and Crow creeks, South Dakota. Site 1 is upstream from Site 2 on each stream.
lected from Plafkin et al. (1989). We substituted the number of mollusk species for the number of scraper-filter feeding species because we identified organisms only to the family level, and feeding group differences are usually assigned at the genus level. Each metric has a specific value as an indicator of stream water quality:

- **Taxon richness**: the number of taxa in a sample reflects the health of the community, and generally increases with increasing quality of water and habitat.
- **EPT index**: the number of taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera summarizes the presence of orders sensitive to pollution, and usually increases with increasing water quality.
- **Hilsenhoff biotic index (HBI)** is the overall tolerance of the community calculated by by using tolerance values (Plafkin et al. 1989) for each taxon. The HBI is calculated as:  \( HBI = \frac{\sum (x_i t_i)}{n} \)  where \( x_i \) = the number of individuals with a taxon, \( t_i \) = the tolerance value of a taxon and \( n \) = the total number of organisms in the sample. Tolerance values (range = 0 to 10) increase as water quality decreases.
- **EPT/Chironomid ratio**: the ratio of the EPT organisms to midge larvae (family Chironomidae), which are usually more pollution tolerant that EPT organisms, indicates stress if the EPT/Chironomid ratio is low.
- **Percent contribution by dominant taxon**: the total number of organisms in the dominant taxon is an indication of community balance. Communities dominated by few species indicate environmental stress, therefore increases in this percentage indicate stress.
- **Percent shredders**: shredders feed on course particulate organic matter (CPOM). The number of shredders declines when the CPOM is contaminated because of effects on the microbial communities colonizing the CPOM or on the shredders directly (Merritt and Cummins 1996).
- **Mollusk species richness**: number of mollusk species may indicate stress because mollusks are intolerant of metal contaminants.

Differences in metrics among streams, reaches, months and years were analyzed using analysis of variance (PROC GLM, SAS Institute 1989). Total stream scores were the sum of individual metric scores assigned a value of 0, 2, 4, or 6 according to the degree of impairment (Newman, 1999). Scores for reference creeks were averaged for comparison to the Whitewood Creek score, which allowed us to assign Whitewood Creek to a biological condition category (Table 2).

**Fish sampling**: Fish were collected from the upstream half of each 200-m reach, where riffle, run and pool habitats were present. Block nets (4.7-mm mesh) were placed at the lower and upper ends of the 100-m reach before sampling with pulsed, direct-current, backpack electrofishing. We determined electrofishing time by a timer on the equipment. When flows or conductivity precluded electrofishing, we collected fish with a seine (4.7-mm mesh) that reached from bank to bank. Fish were identified and released. Data were reported as catch-per-unit-effort, which was number of fish collected per hour of electrofishing or number of fish collected per 100-m seine haul.
Amphibian sampling: We searched the riparian zone along both banks of a 100-m section of stream using a hand net to search under rocks, logs, and debris (Bayless 1978). Amphibians were identified to species, and released. Amphibian call surveys were also conducted in each reach in 1998 just after sunset. We sat at each site for 15 min and recorded calls by species.

RESULTS

We found 15 to 17 invertebrate orders representing 46 to 53 families, depending on stream. The most common taxa were Ephemeroptera, Trichoptera, Diptera, Plecoptera, Coleoptera, and Odonata in decreasing order of magnitude. The total number of individuals varied widely among streams, reaches, years, and months. A significant 4-way interaction precluded further statistical analysis for main effects on the total number of individuals. However, a trend was apparent (Figure 2). The number of invertebrates was usually lower in Whitewood Creek than in other creeks, especially in the spring. In May of both years, Whitewood Creek had fewer invertebrates at each reach than did the reference reaches, with the exception of Bear Butte Creek in 1998.

When raw data were converted to metrics for calculating stream assessment scores, six of seven metrics indicated degraded conditions in Whitewood Creek in the May (Table 3). The exception was the percent shredders, which had a higher value in Whitewood Creek compared to reference streams (a low-

<table>
<thead>
<tr>
<th>% Comparison to reference score</th>
<th>Biological condition</th>
<th>Score interpretations</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;83</td>
<td>Not impaired</td>
<td>Comparable to pristine conditions</td>
</tr>
<tr>
<td>54-79</td>
<td>Slightly impaired</td>
<td>Community structure less than expected. Composition lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases</td>
</tr>
<tr>
<td>21-50</td>
<td>Moderately impaired</td>
<td>Fewer species due to loss of most intolerant forms. Reduction in EPT index.</td>
</tr>
<tr>
<td>&lt;17</td>
<td>Severely impaired</td>
<td>Few species. If high densities of organisms, then dominated by one or two taxa.</td>
</tr>
</tbody>
</table>

Table 2. Interpretation of total stream assessment scores developed using benthic macroinvertebrate rapid bioassessment protocols of Plafkin et al. 1989.
Figure 2. Total number of benthic macroinvertebrates collected from two sites on Bear Butte (BB), Whitewood (WW), Spearfish (SF), and Crow (CR) creeks in May and August of both 1997 and 1998.

Table 3. Values of rapid bioassessment protocol metrics for 1997 and 1998 data for Bear Butte, Whitewood, Spearfish and Crow creeks. A "+" or "-" indicate the direction the metric takes when conditions become stressful. Post comparison of means test (lsd) results for the stream by month interaction for each metric are indicated. ** indicates statistical significance (Pr>|T|) between Whitewood Creek and the respective reference stream.
er value for this metric indicates stress). Stream by month interaction was significant (P<0.05) for the HBI index, total species richness, and EPT/Chironomidae ratio. Post-comparison of least-square means showed the same trends found in the metric averages (Table 3). Scores from Spearfish Creek were significantly (P<0.05) better than those from Whitewood Creek in May for percent shredders, HBI, species richness, EPT/chironomid ratio, and EPT index.

The final stream score for Whitewood Creek was similar (38) to the average score for the reference streams (36) in August (Table 4). However, in May the score for the reference streams remained 36, but the score for Whitewood Creek dropped to 16. Important changes were decreases in species richness, EPT index, and EPT/Chironomid ratio, and an increase in percent contribution by dominant taxon.

<table>
<thead>
<tr>
<th>Metric value</th>
<th>% Comparison</th>
<th>Assigned score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species Richness</td>
<td>40</td>
<td>41 (38-44)</td>
</tr>
<tr>
<td>EPT/Chironomid Ratio</td>
<td>3.3</td>
<td>1.8 (0.9-2.9)</td>
</tr>
<tr>
<td>HBI</td>
<td>4.9</td>
<td>5.5 (4.9-5.7)</td>
</tr>
<tr>
<td>% Contrib. Dom. Taxon</td>
<td>35</td>
<td>43 (35-48)</td>
</tr>
<tr>
<td>Shredders/Total (%)</td>
<td>26</td>
<td>45 (26-52)</td>
</tr>
<tr>
<td>Mollusk Richness</td>
<td>1.8</td>
<td>1.6 (2-5)</td>
</tr>
<tr>
<td>EPT Index</td>
<td>9.8</td>
<td>8.7 (7.5-9.8)</td>
</tr>
<tr>
<td>Total -</td>
<td></td>
<td>38</td>
</tr>
</tbody>
</table>

Table 4. Metric values, percent comparison, and bioassessment scores for Whitewood Creek and three reference streams (Spearfish, Bear Butte and Crow Creeks) for August and May 1997 and 1998. The reference scores are means (range).

Whitewood Creek had the lowest fish species richness (five) compared to seven in Spearfish, eight in Crow, and 22 species in Bear Butte creeks (Table 5). Fish communities were similar between seasons and years but downstream reaches in each creek had more species than did upstream reaches. Brown trout and white sucker were found in all four creeks, but catch-per-unit-effort was always lower in Whitewood Creek than in reference creeks (Table 5). However, the same trend was not apparent for the other three fish species that Whitewood Creek had in common with some reference streams.
All five anuran species known to the region were encountered (Fischer et al. 1999). Three species were found in all creeks: western chorus frog (*Pseudacris triseriata*), northern leopard frogs (*Rana pipiens*), and Woodhouse's toad (*B. woodhousei*). The Great plains toad (*Bufo cognatus*) was found only in Whitewood Creek, and the plains spadefoot toad (*Scaphiopus bombifrons*) was found only in Bear Butte Creek.

**DISCUSSION**

The low number of invertebrates, brown trout, and white suckers in Whitewood Creek, and the low stream assessment score for Whitewood Creek indicate stressful conditions compared to reference streams, especially in May. The assessment score for Whitewood Creek in the spring was 44% of the average for the reference streams, thus placing Whitewood Creek in the biological condition category of "moderately impaired" (Table 2). The most likely stressors are toxins (e.g. arsenic, copper, mercury) from mine tailings in the riparian zone (Marron 1989, Isom 1978). Arsenic has been detected in surface water, ground water, vegetation, and wildlife in the Whitewood Creek basin (Bergeland et al. 1976, Stach et al. 1978, Cain et al. 1988, Callender and Robbins 1993, U.S. E.P.A. 1971, 1973, 1989, U.S. Geological Survey 1995).

The EPT index and the EPT/Chironomid ratio suggested impairment in Whitewood Creek during spring flooding. The EPT components of the index may be good indicators of mine waste impacts. Horn (1993) found the EPT index and the EPT/Chironomidae ratio to be good indicators of water quality in Chalk Creek, Colorado where mine tailings were present. Chironomidae tend to become increasingly dominant in the benthic community as heavy metal contaminants increase.
concentration increases (Ferrington 1987) perhaps because they are more resistant to metal toxicity than mayflies. The data also suggest some impairment at reach one of Crow Creek, where we suspected impacts from irrigation activities and grazing.

We assumed that the seasonal changes in the invertebrate community would be similar among creeks. Seasonal fluctuations occur because of life cycle dynamics and scouring flows (Somer and Hassler 1992, Merritt and Cummins 1996). However, communities recover quickly from disturbance (Barton and Wallace 1978), which may explain why there were no differences among creeks in August after contaminants were flushed or resettle.

The paucity of fish in Whitewood Creek also indicates degraded habitat or water quality. The longnose sucker, which is on the state’s threatened fishes list, was found in reference streams, but not in Whitewood Creek. Fish species richness in each stream was higher at the second reach than the first because the streams change from cold-water to warm-water prairie streams. The community at the lower reach includes species usually found in either the Belle Fourche or Redwater rivers (Doorenbos 1998).

Schooner and Sate (1984) found that some arsenic in Whitewood Creek was derived from eroding banks, bed, and alluvium, and found transport of particulate arsenic at scouring flows. We suggest that flooding may inundate mine tailings on the flood plain and carry toxins into the creek in the spring. The contaminants markedly change invertebrate communities in the spring, and probably have subtle long-term negative impacts on both invertebrate and fish communities.

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