Temporal Dynamics of Benthic Macroinvertebrate Communities and Their Response to Elevated TDS in Appalachian Coalfield Streams

Powell River Project Annual Report 2011-2012

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Introduction

Maintaining integrity of benthic macroinvertebrate communities in Appalachian coalfield headwater streams is a key concern. Total dissolved solids (TDS) are ubiquitous as dissolved constituents in surface waters and often occur at elevated levels in streams draining Appalachian coal mines. Most TDS in surface waters originate from the dissolution of rock and mineral materials that are exposed to the natural elements; this process is accelerated in mining regions, as surface mines cause large volumes of fresh, unweathered rock material to be fractured, brought to the surface, and exposed to accelerated weathering processes. The concentration of TDS is closely related to specific conductance (SC), which is the ability for water to conduct a current at 25º C.

We have been conducting research to identify benthic macroinvertebrate community composition relationships with TDS in southwestern Virginia's mining area, where geology and environmental conditions are similar to adjacent coal-mining areas of eastern Kentucky and southern West Virginia. This report summarizes the first year of a two-year study, aimed ***to expand understanding of temporal variability within the benthic macroinvertebrate community in elevated-TDS streams.*** Eleven sets of benthic macroinvertebrate and water quality grab samples have been collected to date and are being analyzed; and continuous conductivity loggers have been installed in all streams. Sampling will conclude in November 2012.

Background

Our past and current research investigates relationships of benthic macroinvertebrate community metrics to TDS concentrations in mining-influenced streams. Macroinvertebrate community composition metrics and TDS/SC vary between and within seasonal sampling (Spring, Fall) periods, suggesting a need for further assessment of these variations.

Furthermore, it is clear that in-stream TDS concentrations and SC are not fixed quantities. Sampling techniques applied in prior studies, including Pond et al. (2008), US EPA (2011), and Timpano et al. (2011) can be described as a "seasonal snapshot," meaning that a TDS/SC sample is comprised of a single point-in-time measurement of water quality combined with a corresponding individual benthic macroinvertebrate sample. The "seasonal snapshot" sampling technique (i.e., simultaneous sampling of benthic macroinvertebrates and water quality) was selected for our initial research effort because it is (1) identical to that used by Virginia DEQ in its probabilistic monitoring program, (2) typical for monitoring benthic macroinvertebrates (Barbour et al. 1999), (3) similar to that applied by Pond et al. (2008) and by US EPA (2011), and (4) economical to administer as both measures can be obtained during a single site visit. However, when viewed from our current perspective, it is limited by a shortcoming: ***The benthic macroinvertebrate community composition at the time of sampling has likely been influenced not only by the water quality measured at the time of sampling, but also by water quality in the days, weeks, and/or months prior.*** (Figure 1).

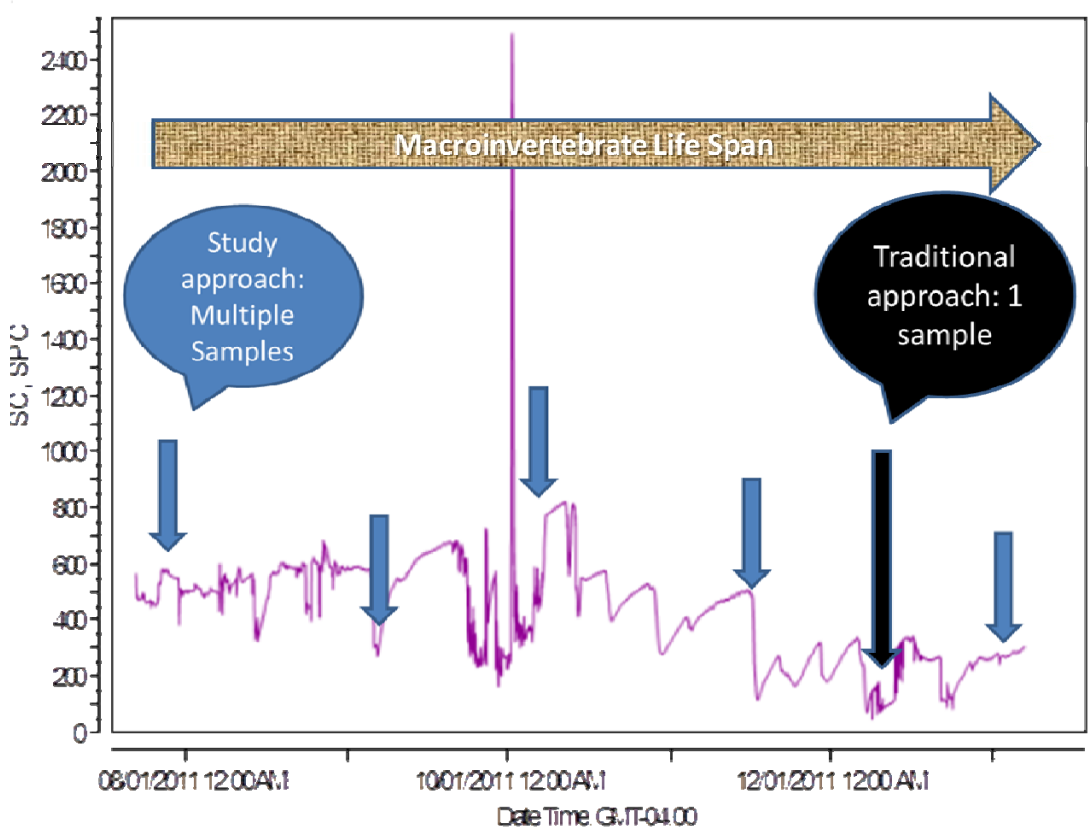

Figure 1: Specific Conductance (µS/cm) recorded every 15 minutes in Spruce Pine Creek, with traditional point-in-time sampling and study approach with multiple samples.

To address point-in-time sampling questions, this study includes multiple macroinvertebrate and water quality grab samples throughout index periods, rather than relying on one sample per season to characterize benthic macroinvertebrate community composition and TDS/SC. Collaborative research on specific conductance variability is being supported by the US Office of Surface Mining (OSM), in which continuous-logging conductivity meters were installed in all 13 study streams. The combination of frequent (~ monthly) macroinvertebrate sampling and continuous conductivity monitoring allows us to address research objectives and questions listed below.

Objectives

1) characterize temporal dynamics of the benthic macroinvertebrate community in reference streams and test streams with elevated TDS

2) determine the association between benthic variability and TDS metrics to be derived from continuous measurements of SC

Research Questions:

1. How do benthic macroinvertebrate communities vary temporally in Virginia Appalachian Coalfield streams (both test and reference)?
2. Do benthic macroinvertebrate community metrics exhibit differences between specific index periods (e.g. fall vs. spring)?
3. Do community composition metrics exhibit predictable patterns within each index period?
4. How do exposure patterns of elevated TDS/ SC affect benthic macroinvertebrate community structure and variation? (ex. Acute, short-term elevation vs. long-term high levels)
5. Will data provide evidence of a "critical period" for TDS/SC exposure, during which the benthic community and/ or sensitive taxonomic groups are more vulnerable to elevated TDS/ SC than other periods?
6. Do benthic macroinvertebrate communities and/ or specific taxonomic groups exhibit evidence of recovery following a peak exposure?

Overview of Methods:

The study includes test streams with habitat and physiochemical conditions as close to reference as possible, excepting the presence of elevated TDS, which is assumed to be acting as the primary stressor. Reference stream data are collected for comparison with the test streams 1) to determine specific biota that are present in reference waters of the Virginia Coalfields that may be absent in test streams and 2) to quantify reference conditions within the Virginia Stream Condition Index (VASCI) and other multimetric indices.

General Approach:

- Nine test and four reference sites were chosen from among those sites studied by Timpano (2011).
- Biological (benthic macroinvertebrate) samples and water quality grab samples are collected from stream sampling locations at approximately 4-6 week increments.
- Continuous conductivity probe data are recorded in collaboration with Timpano.
- Macroinvertebrate, water quality grab samples, and conductivity probe data are being analyzed for statistically significant relationships between variation in TDS/ SC and variation in benthic macroinvertebrate communities. Specific data analysis will be applied as needed to answer research questions.

Sampling dates are weather-dependent, as we endeavor to sample at base flow. We are determining taxonomic composition of benthic macroinvertebrate community samples at both the family and the genus level. We will calculate community composition metrics, VASCI scores, and other multimetric indices for each sample.

Site Selection:

The thirteen research streams chosen for this study (Figure 2) were based on data from previous index periods (Figure 3). Representative samples from a gradient of specific conductance/TDS levels were desired; streams were selected to provide a continuum of TDS levels throughout the range examined by Timpano (2011). The original proposal included only 12 test streams, but a thirteenth was added when July 2011 sampling indicated high variability in two of the streams with previously measured low conductivity (Grape Branch and Spruce Pine Creek). Both test sites with elevated conductivity and reference sites were selected to represent a large geographic area of the Virginia Coalfields including Wise, Dickenson, Russell, and Buchanan Counties (Figure 4). Samples were collected in June, August, September, October, and November 2011 and January, March, April, May, June, and August 2012. Samples will be collected in September and October 2012, with the final study sample collected in November 2012. We are processing benthic macroinvertebrate and water quality grab samples, and continuous conductivity loggers (OSM-funded) have been recording every 15 minutes since December (or earlier) 2011 in all 13 streams.

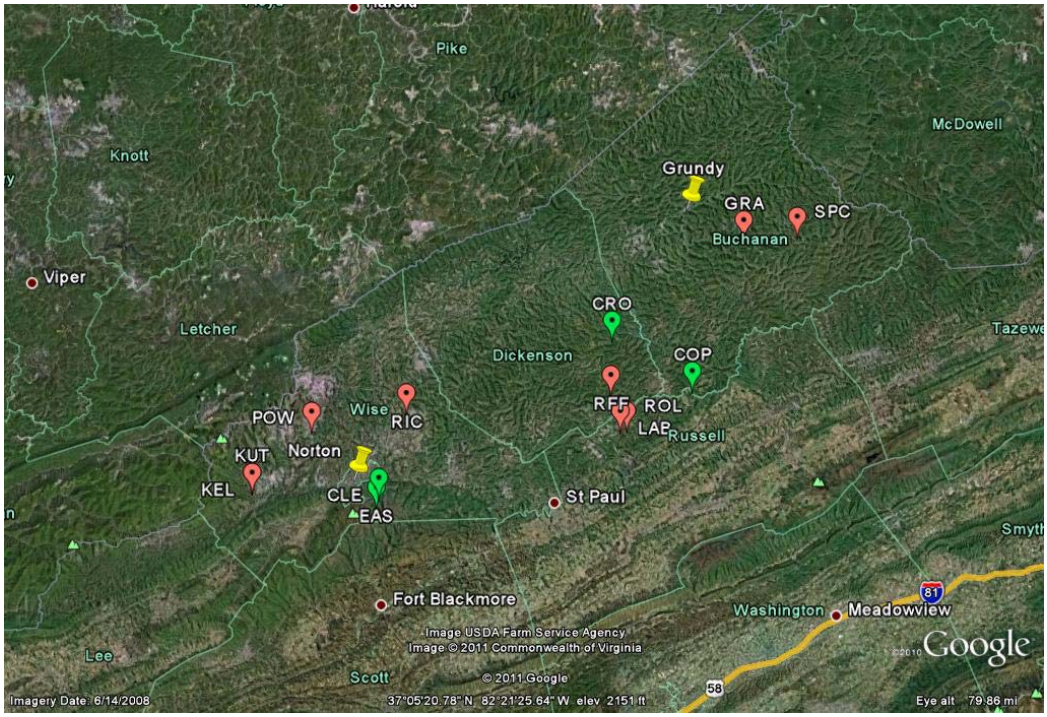

Figure 2: Map of study sites. Test sites are red, reference sites are green, yellow pins are population centers for geographic reference.

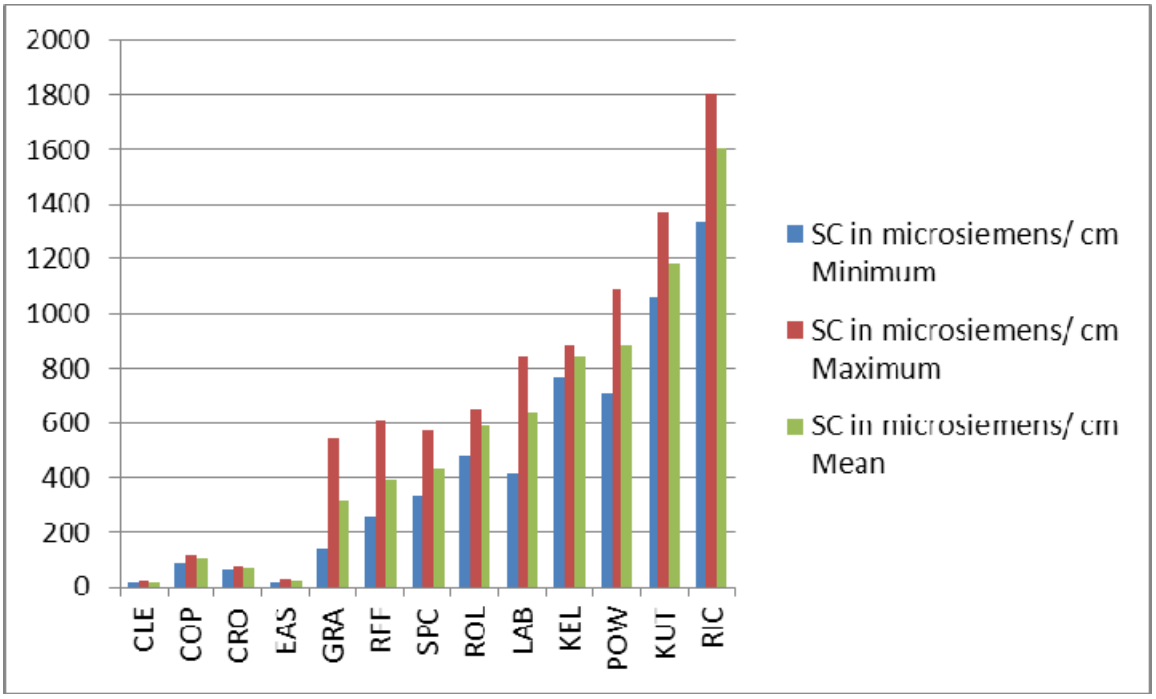

Figure 3: Specific conductance values at study sites, reported by Timpano (2011). Sites were chosen along a gradient of specific conductance. The four streams with mean SC < 200 µS/cm are reference streams.

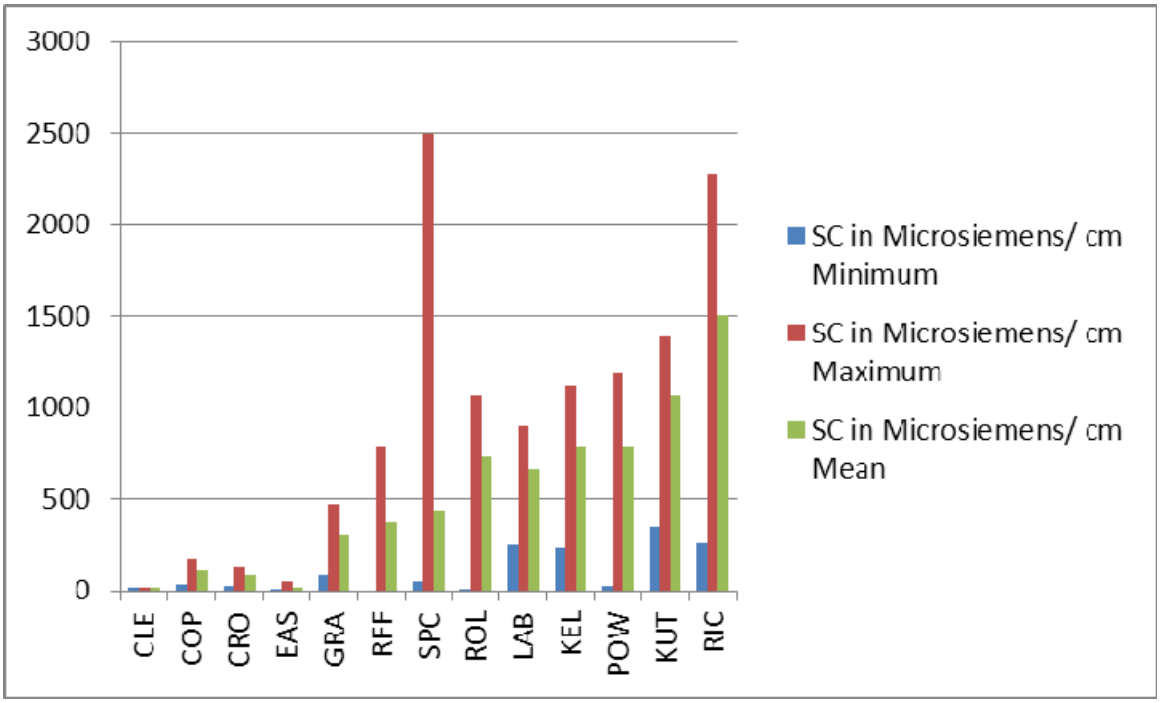

Figure 4. Maximum, minimum, and mean specific conductance levels in study streams June 2011-February 2012. Some streams did not have loggers installed until late November 2011.

Data Analysis:

Associations between benthic macroinvertebrate community metrics and the following TDS/SC metrics are being explored:

1. Maximum TDS/SC level.
2. Mean TDS/SC level
3. Range in TDS/SC level.
4. Timeframe (seasonal) of high level TDS/SC exposure.
5. Duration of high level TDS/SC exposure.
6. Pattern of high level TDS/SC exposure.

In addition, comparison of seasonal dynamics and variation in SCI status between reference and test streams will be evaluated using statistical comparison procedures.

Table 1. Schedule of Major Activities.[1]

Timeframe	Activity	Comments	Status
June 2011-August 2012	Sites selected 11 samples collected	Sample are being processed	Completed and Processing
September-November 2012 VASCI Fall Index period.	3 samples collected	DEQ guidelines allow extension into the first two weeks of December if weather/ flow conditions prevent completion of sampling during September, October, or November.	To be completed
December 2012 – March 2013	Complete sorting and identification of macroinvertebrates		To be completed
March - May 2013	Data analysis	Preparation of final report and thesis	To be completed
June 30, 2013	Final Report due		To be completed

[1]Ongoing: Sorting and identification of specimens, chemical grab sample analysis. Water quality data are also being collected**.**

Deliverables

We will present preliminary findings at the Powell River Project Symposium in September 2012. We will provide a final report that details study methods and findings to study sponsors by 6/30/2013.

Benefits

Better understanding of benthic macroinvertebrate variability will aid development of environmental protection practices and policies concerning assessment of TDS/SC levels in mining-influenced streams, as research questions are directly relevant to water quality management. Understanding how benthic

macroinvertebrate communities vary in such streams can aid refinement of both mining practices and regulatory policies that will protect aquatic communities.

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