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The impact of episodic coal mine drainage pollution on benthic macroinvertebrates in streams in the Anthracite region of Pennsylvania

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Episodic coal mine pollution decreases benthic macroinvertebrate richness and density.

Abstract

Episodic coal mine drainage, caused by fluctuations in mine discharges relative to stream flow, has devastating effects on aquatic macroinvertebrate communities. Seven stream reaches in the Anthracite region of Pennsylvania were identified as chronically, episodically or not impaired by mine drainage, and sampled seasonally for 1 year to determine the effect of episodic mine drainage on macroinvertebrates. Specific conductance fluctuated seasonally in episodic sites; it was lower in winter when discharge increased and higher in summer when discharges decreased and mine drainage made up a larger proportion of stream flow. Although we hypothesized that episodic streams would have higher macroinvertebrate richness than chronic streams, comparisons showed no differences in richness between treatments. Episodic pollution may result from undersized or poorly maintained passive treatment systems; therefore, intensive macroinvertebrate monitoring may be needed to identify streams being affected by episodic mine drainage because macroinvertebrate richness may be sensitive to water quality fluctuations.

Keywords: Macroinvertebrates; Coal mine drainage; Episodic pollution; Metal; Water quality

1. Introduction

Low pH and high metal concentrations measured in approximately 2400 miles of streams in Pennsylvania are the result of contamination from coal mines (Earle and Callaghan, 1998). When coal is mined, pyrite is exposed to oxygen and water, setting off a series of reactions that can result in lowered pH (if there is insufficient calcareous material to neutralize acids produced by oxidation and hydrolysis) and high concentrations of metals such as iron, aluminum, and manganese. In addition to causing poor water quality, mine drainage (particularly circum-neutral mine drainage) can affect the substrate of a stream. Ferrous iron (Fe^{2+}) is oxidized to ferric iron (Fe^{3+}) to form a precipitate on the substrate (commonly referred to as ‘‘yellow boy’’) in the presence of water when pH is greater than about 3.5 (Rose and Cravotta, 1998). In many mine drainage streams with relatively high pH, precipitated iron and aluminum may coat the stream substrate and cause unstable habitat for macroinvertebrates (Warner, 1971; Koryak et al., 1972; Hoehn and Sizemore, 1977; Moon and Lucostic, 1979; McKnight and Feder, 1984; Earle and Callaghan, 1998).

The effects of chronic mine drainage on benthic macroinvertebrates, such as decreased density and richness, are well documented in Pennsylvania (Roback and Richardson, 1969; Koryak et al., 1972; Weed and Rutschky, 1972; Letterman and Mitsch, 1978; Moon and Lucostic, 1979) and other states (Parsons, 1968; Warner, 1971; Dills and Rogers, 1974; Hoehn and Sizemore, 1977; Schmidt et al., 2002; Simmons et al.,

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2005). Although most of these studies were done in the 1960s and 1970s, the results are still applicable to studies done on chronic mine drainage today.

Episodic coal mine drainage pollution can enter clean streams, lowering water quality. Metal concentrations and pH in streams can vary significantly due to seasonal or weather-related changes in stream and mine discharge flows. Obviously, the nature of episodic pollution in streams depends on the sources of acidity and metals and hydrology of streams. Dills and Rogers (1974), in a study on a coal mine drainage affected stream in Alabama, found lowest pH and highest metal concentrations in summer (when stream flow and rainfall were lowest), which they attributed to higher relative contribution of mine drainage water to total stream flow. In a study on a coal mine drainage polluted stream in Pennsylvania, Cravotta and Bilger (2001) found that during storms, pH and conductivity decreased and total and dissolved metals increased due to acidification (from rain), dilution, and scouring of the stream bottom. Passive treatment systems installed on discharges and streams with mine drainage may also contribute episodic pollution to downstream remediated reaches of a stream if the system cannot handle excess flow or fails to work properly (Wiseman et al., 2004; Simmons et al., 2005).

These episodic events may have severe effects on benthic macroinvertebrate populations by periodically lowering water quality below what is tolerable for most organisms. Roback and Richardson (1969) and Soucek et al. (2000) showed that streams episodically polluted by coal mine drainage had lower macroinvertebrate taxa richness than reference streams but higher macroinvertebrate density and richness than chronically polluted streams. Parsons' (1968) study showed that macroinvertebrate communities were decimated in receiving streams after episodic coal mine drainage pollution from upstream strip mining operations. Recovery of macroinvertebrate populations in Parsons' study depended on how invertebrate life cycles coincided with the timing, intensity, and duration of rainfall that initiated episodic pollution into the lower basin.

The purpose of this study was to quantify the effects of episodic mine drainage on macroinvertebrate richness and density. We hypothesized that macroinvertebrate richness (e.g., number of families) at episodic sites would be, on average, higher than chronic sites but lower than reference sites and macroinvertebrate richness and density would fluctuate at episodic sites depending on water quality. We also discuss the potential for slow biological recovery downstream of passive treatment systems due to episodic pollution and how monitoring schemes may need to be adjusted to account for this.

2. Study sites

Most of the coal mined in Pennsylvania is bituminous, which is found in the plateaus of western and north-central Pennsylvania, but there is also a small region of anthracite coal in the Ridge and Valley Province of east-central and north-eastern Pennsylvania (Fig. 1a). Large discharges flow from many of the anthracite coal mines because they were mined deep underground, below the water table, due to the extreme deformation of the strata where anthracite coal is found. For this study, seven study sites were located in two stream systems in the Anthracite region: Zerbe Run, a second-order stream in Northumberland County, PA and Lorberry Creek, a second-order stream in Schuylkill County, PA. Each stream system had at least one chronic, one episodic, and one reference site. Stream reaches were categorized as chronically impaired by mine drainage (CHR), episodically impaired (EPI) or not impaired by mine drainage (REF) using previously collected chemical data (Cravotta, 2005; C. Cravotta, USGS, Harrisburg, PA, personal communication, 2005) and on-site observation.

Three sites were used in Zerbe Run, a tributary of Mahanoy Creek, which flows southwest from Trevorton to Hunter (Fig. 1b). ZREF (Zerbe Run, reference reach) was located in the village of Trevorton and was upstream of all mine discharge outputs. An unnamed tributary of Zerbe Run (chronic site, ZCHR) is downstream of ZREF and receives mine drainage from three discharges: North Franklin Drift and Borehole, N. Franklin seepage, and N. Franklin bank seepage (Cravotta, 2005). The Drift and Borehole discharge is the fifth largest source of mine drainage in the Mahanoy Creek watershed (Cravotta, 2005). The rocky substrate of ZCHR is covered with iron precipitate and coal dust. ZEPI (Zerbe Run, episodic reach) was located about 4.7 miles downstream of the confluence of ZREF and ZCHR on Zerbe Run, and therefore received mine drainage from ZCHR but was also diluted by ZREF. Zerbe Run receives one additional mine discharge, the Sunshine Mine Overflow, which discharges intermittently, above ZEPI but below the confluence of ZREF and ZCHR (Fig. 1b; Cravotta, 2005). Substrate at ZEPI is free of metal precipitates.

Four sites were used in Lorberry Creek, which flows southeast from Lorberry to Lorberry Junction in Schuylkill County, PA (Fig. 1c). The upstream Lorberry Creek site (chronic site, LCHR) was located below Rowe Tunnel, which discharges the majority of the flow into Lorberry Creek by releasing mine drainage every 30 h from an active mine (C. Cravotta, USGS, Harrisburg, PA, personal communication, 2005). Substrate at LCHR is covered with flocculent and adhered iron precipitate. Stumps Run (reference site, LREF1) converges with Lorberry Creek below LCHR and is not impaired by mine drainage, but the watershed historically contained abandoned coal siltation basins, which caused extremely high sediment loads in the stream. In 1994, silt was removed, the area was regraded and revegetated, and erosion and sedimentation controls were installed to decrease sediments (NSCWA, 2005). An unnamed tributary to Lorberry Creek (reference site, LREF2) is located in State Game Lands 229 downstream of LCHR and LREF1 and has no mine discharge impairment, but is naturally acidic because its headwaters originate in a high-elevation bog. A reach on Lorberry Creek downstream of the other three sites was characterized as an episodic site (LEPI), because it received both mine drainage from Lorberry Creek and unpolluted water from the tributaries. LEPI has varying amounts of iron precipitate coating the stream substrate, depending on the discharge; during high flow, some of the precipitate was scoured off, while during low flow precipitate accumulated on the stream substrate.