Assessing Ecosystem Health In A Mining-Impacted River

USGS Investigations of the Clark Fork River, MT Superfund Site

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Clark Fork River Basin

• Mining and smelting operations active in the upper drainage from 1860’s to 1980’s

• Downstream transport of mining spoils resulted in metal contamination to more than 250km of Clark Fork River

• Study reaches extend from Silver Bow Creek (below Butte) to the main stem Clark Fork River below Missoula
Mid 1800s: Placer gold discovery

Richest hill on earth, Butte 1900s

Anaconda Smelter: 1918-1980

Silver Bow Creek floodplains

Copper sulfate + cow bone

Slickens (floodplain surface encrusted with metal precipitates)

1908 Flood: Missoula MT

Impacts from floodplain runoff

Silver Bow Creek, 2015

Historic Mining Activities

Legacy mine waste

Remediation / Restoration

Berkeley Pit: 1959

Bank removal and restoration

Declared a Superfund Site: 1989

Removal of contaminated floodplains + soil amendments
• Assessing historic and recent contaminant trends — responses to remediation (20+ years of physical, chemical, biological data)

• Development of field and laboratory models to understand contaminant exposure and uptake kinetics in invertebrate fauna

• Identifying determinants of metal exposure risk in stream invertebrates

• Metal mining impacts on ecosystem processes

• Identifying microbial bioindicators of metal enrichment and toxicity in mining-disturbed systems

Note: results shown are provisional
Assessing historic and present trends in bioavailable metals based on concentrations in *Hydropsyche* larvae (*H. occidentalis* and *H. cockerelli*)

**Trends in relative (total) metal concentrations (As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn) — 1997 vs 2013**

**Cumulative distribution plot of standardized Cu concentrations in *Hydropsyche* larvae — concentration breakpoints identified using piecewise regression**
Laboratory experiments to quantify metal uptake-loss kinetics using enriched stable isotope tracers: $^{65}\text{Cu}$ and $^{106}\text{Cd}$

(M.Hornberger, D.Cain, M.Croteau)

Experiments conducted using different invertebrate fauna to include Hydropsyche and Arctopsyche caddisflies

Contaminant kinetics — laboratory and field based models
Field transplant experiments (caddisflies transplanted from a metal contaminated site to a undisturbed tributary) to test model predictions of metal efflux.
Results for caddisfly larvae indicate that dietary influx contributes approximately 3X metal input compared to dissolved sources.
In this example, the model predicts *Hydropsyche* can reach steady state within 2-3 weeks.

When exposure is “removed” the initial rate of efflux is approximately 20% per day.

**Implications for monitoring**

- Metal uptake by *Hydropsyche* is in part a function of discharge and will likely be at steady state if sampled during base flow.
- Rapid uptake and loss rates may be beneficial in identifying short term effects from episodic events (e.g., remediation).
Factors influencing metal exposure risk

Ecological traits as determinants of metal exposure risk in stream invertebrates

- Development of a trait-based contaminant-exposure model which describes the strength of relationship between species-specific metal uptake and trait expression

1) Determine the extent to which ecological traits influence metal exposure history

2) Identify species at greatest exposure risk based on inherent trait properties

3) Explore potential for using trait-exposure models to explain long-term changes in occurrence and distribution patterns of invertebrate assemblages in a mining-impacted system
Development of trait-based contaminant exposure model —

- Discriminant function analysis (DFA) was used to determine which traits best accounted for differences among taxa in metal bioaccumulation — individual metal concentrations were used as predictor variables for discriminating among trait characteristics.

- A total of 14 traits related to feeding ecology, reproductive strategy, respiration, development, dispersal, habitat preferences, and stressor tolerance.

- Results used to develop scoring metric for species traits based on metal exposure and uptake — and to assess trends in community-level responses.

Radar plot shows contaminant exposure rankings for invertebrate taxa collected along a metal concentration gradient in the Clark Fork River. Results are based on behavioral and physiological attributes that predispose certain species to greater exposure risk.
Mining impacts on ecosystem processes

- Primary productivity in a mining-impacted river — characterizing physical-chemical stressor effects on stream trophy

Objectives of study......

1) Determine effects of dissolved metal exposure on 1° productivity

2) Identify system-level responses to a metal-enriched environment (i.e., spatial and temporal trends in stream trophy (autotrophy ↔ heterotrophy)

3) Examine influence of physical-chemical factors, such as flow velocity and nutrients, on contaminant uptake in periphyton — and if uptake is rate dependent (e.g., is enrichment driving contaminant bioaccumulation dynamics by altering production rate?)

4) Examine contaminant transfer pathways among producers, 1° and 2° consumers “Feeding strategies of stream invertebrates: the importance of resource selectivity to contaminant uptake” (T. Short and M. Hornberger, in prep)
Rates of periphyton biomass accrual and metal uptake were assessed by interval-based sampling using artificial substrate samplers at several locations along a metal contamination gradient.....
Assessing accrual rates as a function of metal enrichment (dissolved <0.2 μm)

*No significant differences in rates of accrual — at concentration levels encountered (Cu = 0.5–10 μg /L)*
Relations between bioaccumulation and productivity

*Plot comparing arsenic and biomass accrual at endpoints of contaminant gradient — showing bioaccumulation is function of productivity

*Plot showing periphyton As and Cu concentrations over time — concentrations reached a steady state within first few days of growth and accrual
Given the importance of dietary exposure......can differences in bioaccumulation patterns be attributed to consumer status?

*Example of 2 dietary sources of metals (Periphyton and Caddisfly larvae)

- Consumer responses were based on comparisons of feeding trait states (50+ species)
- Coded based on affinity scores which show the relative contribution of each type of feeding behavior to the overall food acquisition strategy

0 = no affinity of a species to that state
1 = a species has that trait state exclusively

![Graphs and diagrams showing metal concentrations and affinity scores for different feeding behaviors]
Resource subsidies as contaminant sources — *linkages among hydrology, resource type, and invertebrate consumers*

- SPOM as a contaminant source — contaminant transfer kinetics using suspension feeding invertebrates
- TAPAS “totally awesome particulate acquisition system”
- Wet-dry mass, organic carbon, chlorophyll, metal transport per unit time
Investigation of hyporheic microbial biofilms as indicators of metal toxicity in the Clark Fork River Basin, MT (Elliot Barnhart — Montana WSC, Helena MT)

- Gain a mechanistic understanding of microbial biofilm responses to metal contamination within the Clark Fork River Basin
- Assess temporal variability of microbial biomarkers
- Evaluate the potential use to identify remediation effects
- Develop a standardized microbial metal toxicity assay (next generation risk assessment tools using DNA sequencing)