Stream Ecosystem Response to Mining-Induced Salinization in Appalachia

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Virginia Tech
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Our Research Team

- Stephen Schoenholtz – Professor, VT FREC Dept., and Director, Virginia Water Resources Research Center
- Carl Zipper – Professor, VT CSES Dept.
- Dave Soucek – Research Program Leader, Aquatic Ecotoxicology, Illinois Natural History Survey
- Beth Boehme – MS graduate
- Damion Drover – PhD student
- Tony Timpano – PhD student
- Kriddie Whitmore – MS student
Outline

I. Background – Mining-induced salinization as aquatic life stressor

II. Seasonal snapshots of salinity and biology (Timpano)

III. Temporal dynamics of salinity (Timpano)

IV. Temporal dynamics of biology (Boehme)

V. Causal links: salinity-biology, non-salinity factors (Drover)

VI. Selenium enrichment & trophic transfer (Whitmore)
I. Salinization as Aquatic Life Stressor

- Salinization = elevated major ions (Ca, Mg, Na, K, Cl, SO$_4$, HCO$_3$)
- Salinity $\leftrightarrow$ TDS $\leftrightarrow$ Conductivity
- Conductivity = specific conductance (SC) = electrical conductivity @ 25 °C
- Aquatic life effects: Benthic macroinvertebrate diversity declines
- CWA requires aquatic life protection = salinity management
Coal-Mining Salinization Sources

- Two major sources
  - Valley Fill (common; our focus)
  - Underground Mining (less common; not studied here)
- Valley Filled Streams: ~300 – 3,000 μS/cm
- Unmined Streams: 20 – 200 μS/cm

- Ionic composition varies by source
- Ionic composition critical if using conductivity as salinity surrogate

Valley Fill in West Virginia
Ion Matrix (molar proportions)

Valley Fill
SO$_4$, Mg, Ca, HCO$_3$

Reference (Unmined)
HCO$_3$, Ca
Managing Salinization Effects

- Relatively new regulatory concern
- Currently, seasonal “snapshot” approach
  - Biology & salinity 1-2x annually

*Questions remain for management*

- Sample timing matters
  - Temporal variability of SC
  - Temporal variability of Biology
- Non-Salinity stressors (often salinity covariates)
  - Physical habitat
  - Toxic trace element (Se) bioaccumulation
Research Sites

- 1<sup>st</sup>-2<sup>nd</sup> order, gradient of salinity
- Reference-quality habitat
- 5 Reference, 20 Test sites

<table>
<thead>
<tr>
<th>Reference (22 µS/cm)</th>
<th>Test (265 µS/cm)</th>
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<tbody>
<tr>
<td>Test (594 µS/cm)</td>
<td>Test (1,670 µS/cm)</td>
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</table>
II. Seasonal Snapshots of Salinity and Biology
Tony Timpano
2008 - 2010
Snapshot Biology vs. Snapshot SC

- Seasonality
- Strong Negative Relationship
- High Variability
Prelude to Temporal Variability of Salinity
III. Temporal Variability of Salinity
Tony Timpano
2011 – 2014 (initial), and ongoing
Study Design

- Continuous conductivity (15-min interval for 36 months)
- Monthly ions & TDS
- Spring & Fall benthic macroinvertebrates
Typical SC Pattern

Salinized Stream

Reference Stream
SC Varies at Reference Streams Too
Mean Hourly Percentile of SC
Mean SC Percentile by Month

Sitewise mean monthly percentile

Spring Index Period

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Salinity-Biota Relationships

- Strong negative correlations
- Mean annual SC < Snapshot SC < Chronic high SC
- Spring > Fall correlations
- Mayflies most sensitive

Spring 2014 Spearman Correlations

<table>
<thead>
<tr>
<th>Biological Metric</th>
<th>Chronic High SC</th>
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</thead>
<tbody>
<tr>
<td>Total Richness</td>
<td>-0.73</td>
</tr>
<tr>
<td>Sensitive Mayfly Richness</td>
<td>-0.89</td>
</tr>
<tr>
<td>Sensitive Mayfly Rel. Abundance</td>
<td>-0.91</td>
</tr>
</tbody>
</table>

Spring 2014 Sensitive Mayfly Rel. Abundance

\[ R^2 = 0.82 \]

% Ephemeroptera less Baetidae

Snapshot SC (µS/cm)
IV. Temporal Dynamics of Biology
Beth Boehme
2011 - 2012
Research Questions

- How does stream community composition vary throughout the year?

- Does biological sample timing influence biotic condition metrics?

- Are community temporal dynamics affected by salinity?
Objectives

1. Quantify how benthic macroinvertebrate community composition varies throughout the year

2. Quantify relationships between community temporal dynamics and mean annual SC
Results

SC level (µS/cm)
- Ref SC (20-102)
- Med SC (311-642)
- High SC (842-1602)
V. Causal Links: Salinity-Biology, Non-Salinity Factors
Damion Drover
2013 – 2015
Rationale

- Observed salinity – biota relationships:
  - Negative
  - Variable

- Are other (non-salinity) factors influencing variability of relationships?

- Measure additional abiotic factors, look for causal links
Approach

Explore potential causal links using evidence from intensive measurements of candidate causes:

- Water Chemistry
  - Salinity – known contributing factor
- Trace Elements
- Hydrology
- Sediment: Substrate Particle Size
- Quantitative Physical Habitat
Causal Pathways

- Sediment
- Hydrology
- Organic Matter/Energy
- pH, Temp
- TDS/SC/Components
- Trace elements/metals
- Total Richness
- Mayflies
- EPT Taxa
- Scrapers
- Stream Condition Index
VI. Selenium Enrichment & Trophic Transfer
Kriddie Whitmore
2015 - 2016
Selenium Enrichment & Trophic Transfer

enrichment → trophic transfer 
(TTF)

Water Column
Periphyton
Sediment
Detritus
Fine Suspended Particulate Matter
Bugs (Primary Consumers, Predators)

Janz (2011)
Summary

II. Snapshot Salinity & Biology (Timpano et al. 2015 JAWRA)
  - Biotic condition declines with increasing salinity
  - Relationship is variable

III. Continuous Conductivity (Timpano; ongoing)
  - Salinity varies Annually & within Index Period
  - Seasonal pattern
  - Spring biological samples most sensitive to salinity
  - Bioassessment implications (sample timing matters)
Summary (cont’d)

IV. Temporal Dynamics of Biology (Boehme et al. in review. *Ecological Indicators*)
- Highest variability in Medium-Salinity streams
- Spring samples = greatest diversity
- Variation within index period
- Bioassessment implications (sample timing matters)

V. Salinity – Biology Causal Links (Drover; concludes 2015)
- Intensive quantitative abiotic survey/quantitative biota

VI. Selenium Enrichment & Trophic Transfer (Whitmore; concludes 2016)
- Quantify Se bioaccumulation; biotic effects?
Acknowledgements

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