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)

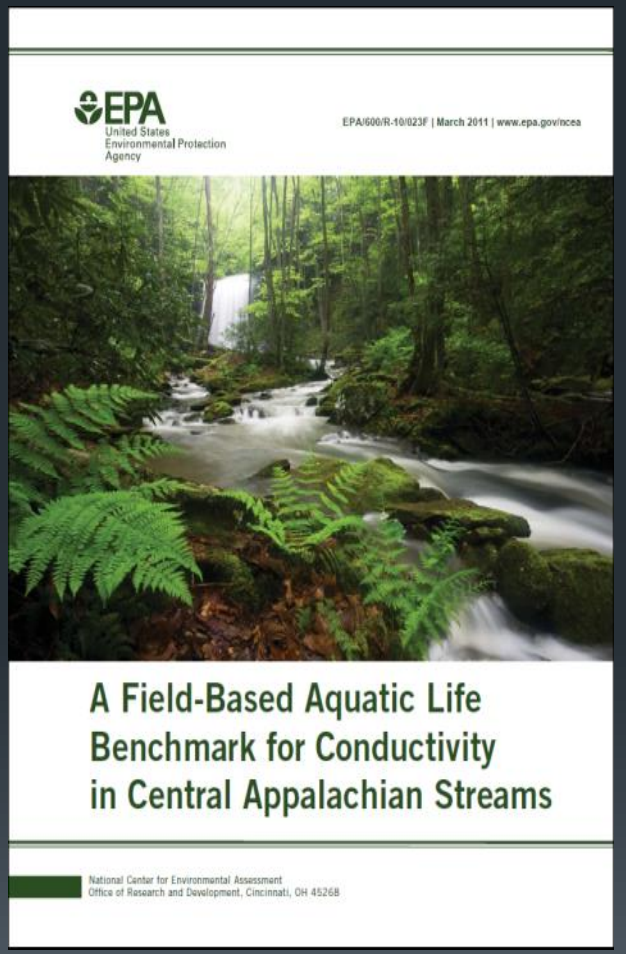
IV. Temporal dynamics of biology (Boehme)

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 ←→ TDS ←→ 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

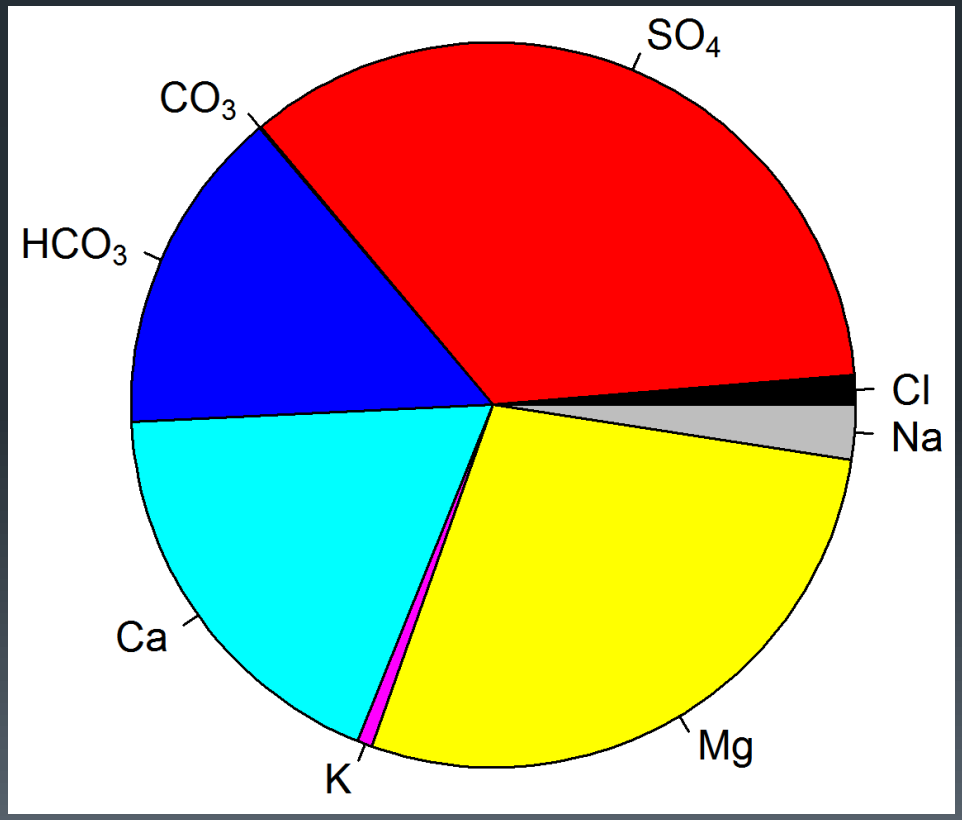
- Two major sources
  - Valley Fill (common; our focus)
  - Underground Mining (less common; not studied here)
- Valley Filled Streams : ~300 – 3,000 μS/cm
- Unmined Streams: 20 – 200 μS/cm

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

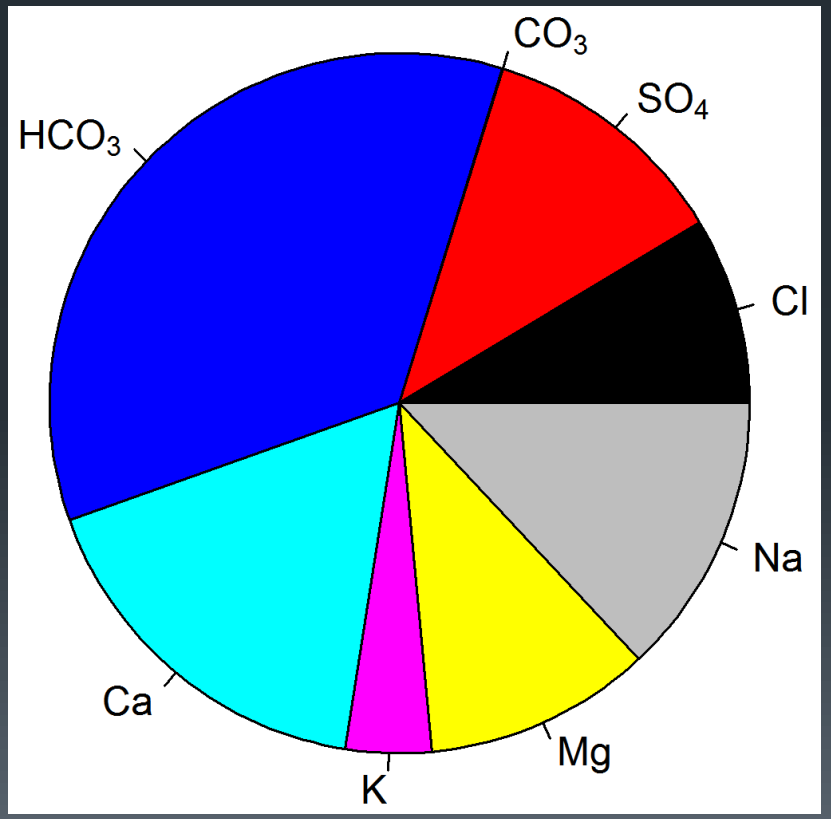
Valley Fill in West Virginia

Ion Matrix (molar proportions)

Valley Fill
SO_4, Mg, Ca, HCO_3



Reference (Unmined)
HCO_3,Ca



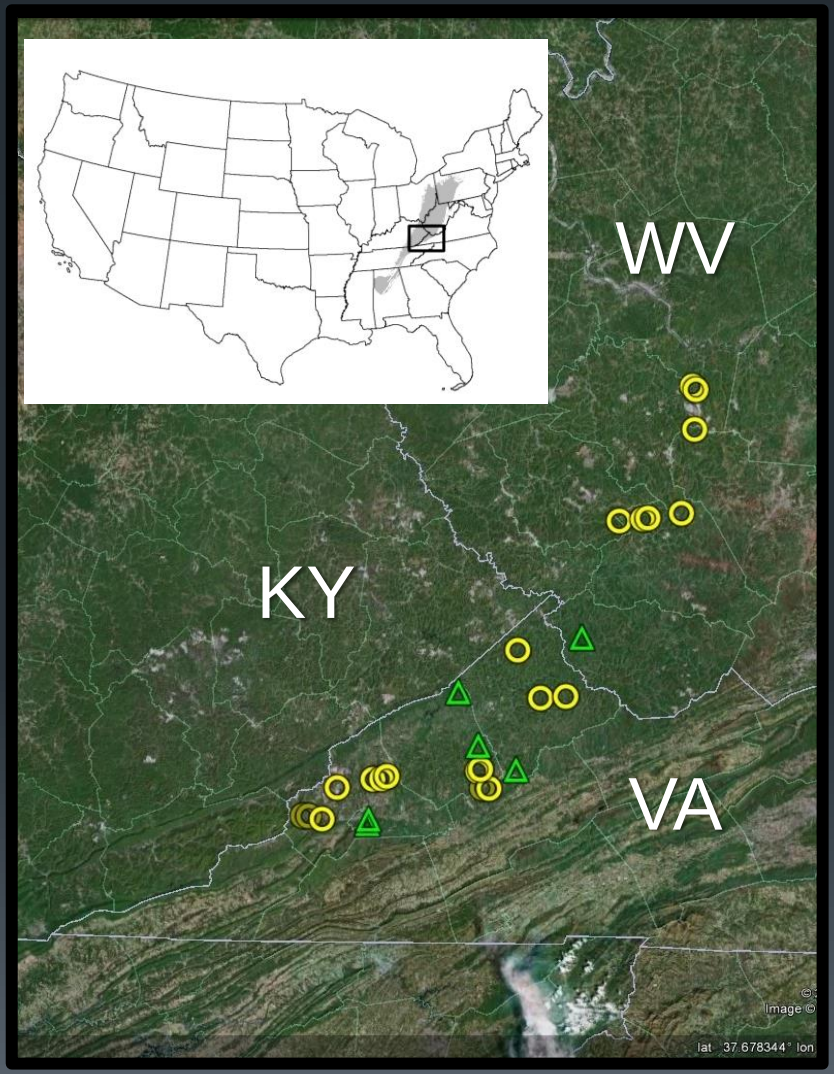
Managing Salinization Effects

- 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



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

Reference (22 µS/cm)

Test (265 µS/cm)

Test (594 µS/cm)

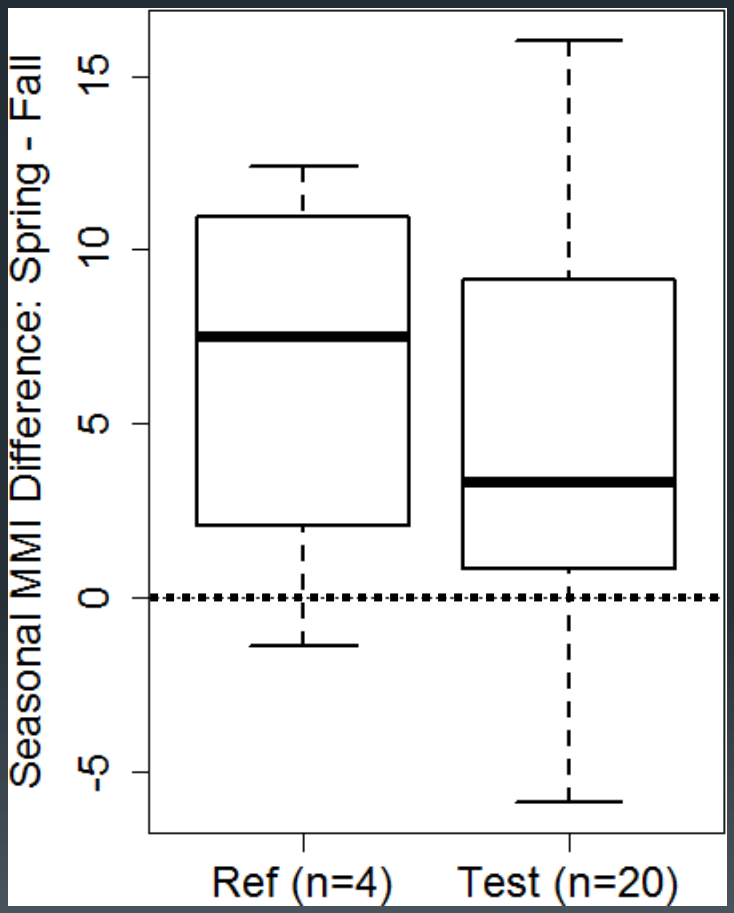
Test (1,670 µS/cm)

II. Seasonal Snapshots of Salinity and Biology

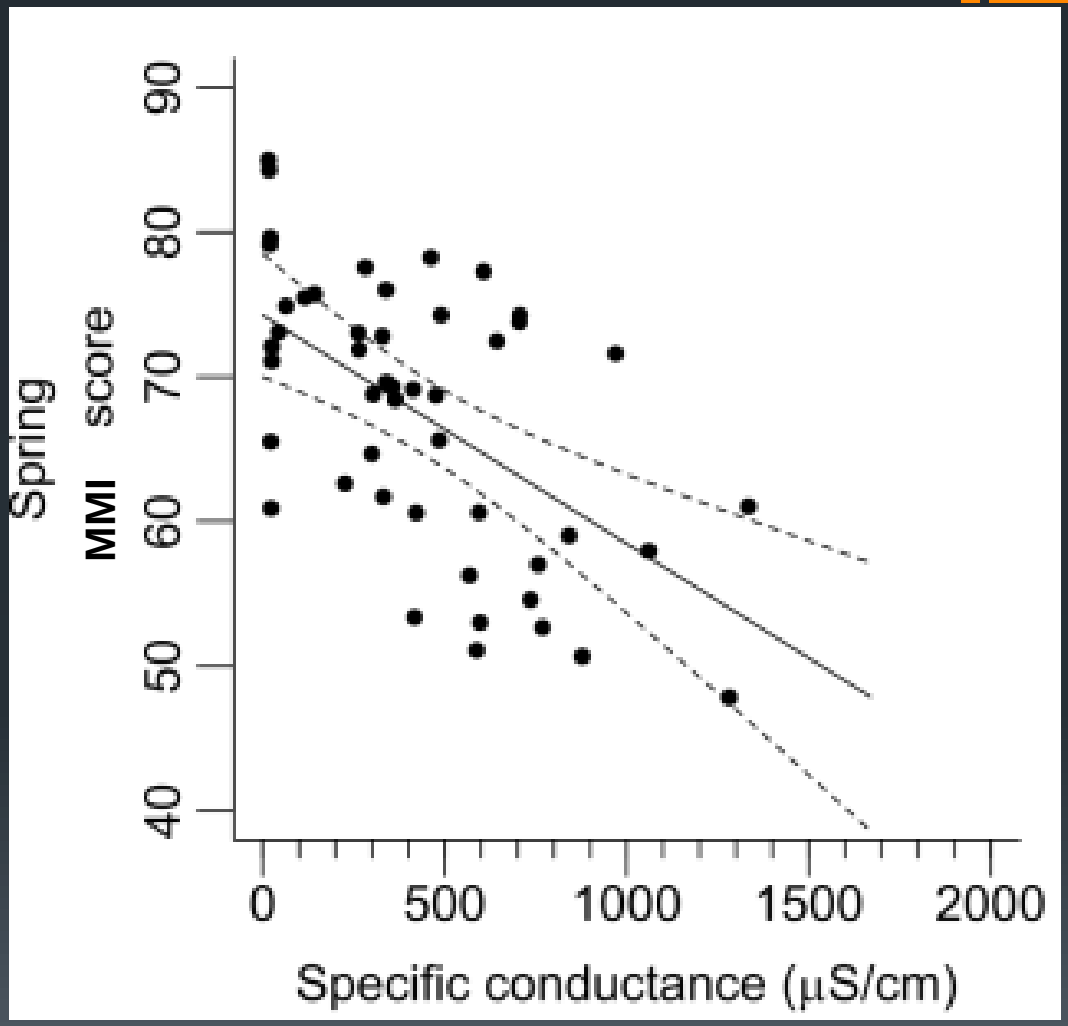
Tony Timpano

2008 - 2010

Snapshot Biology vs. Snapshot SC

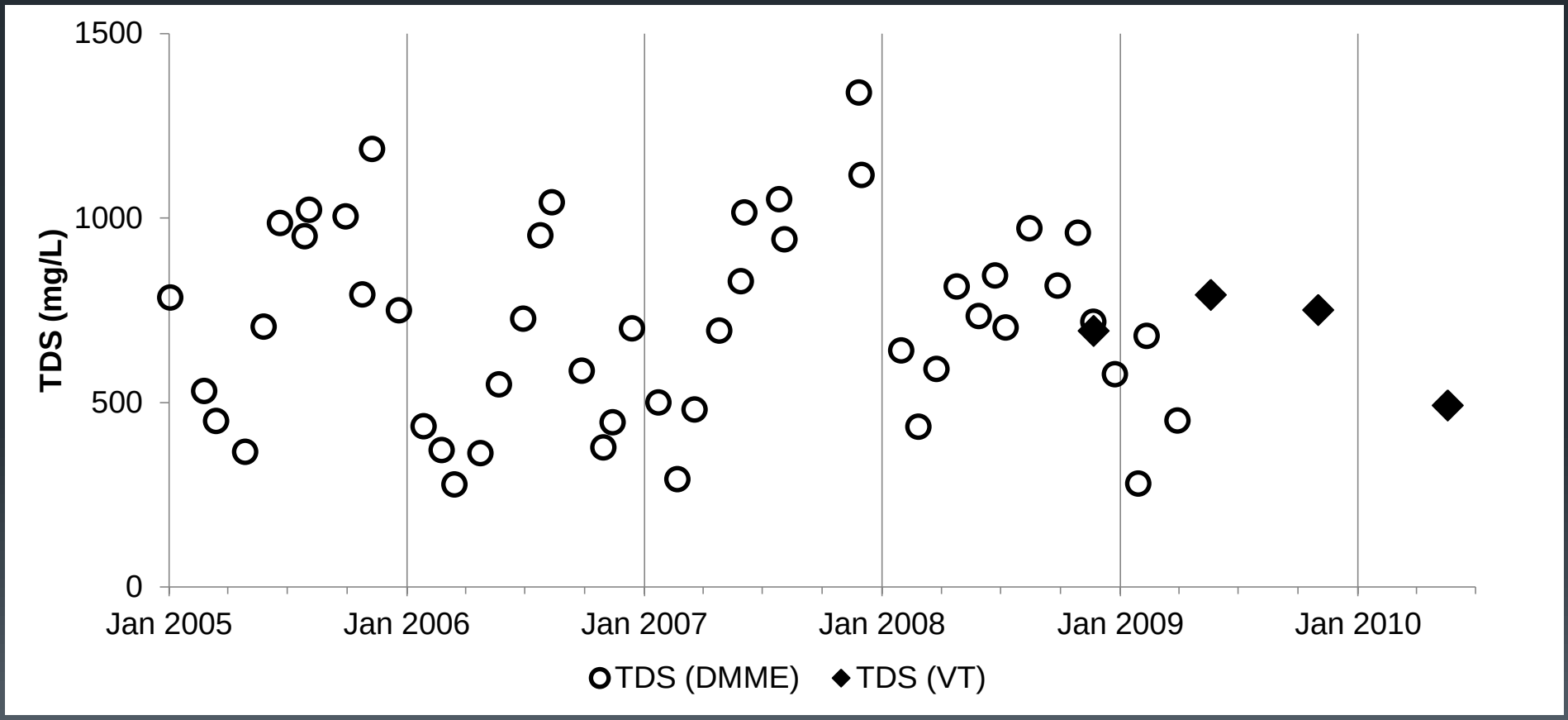


- Seasonality



- Strong Negative Relationship
- High Variability

Prelude to Temporal Variability of Salinity



III. Temporal Variability of Salinity

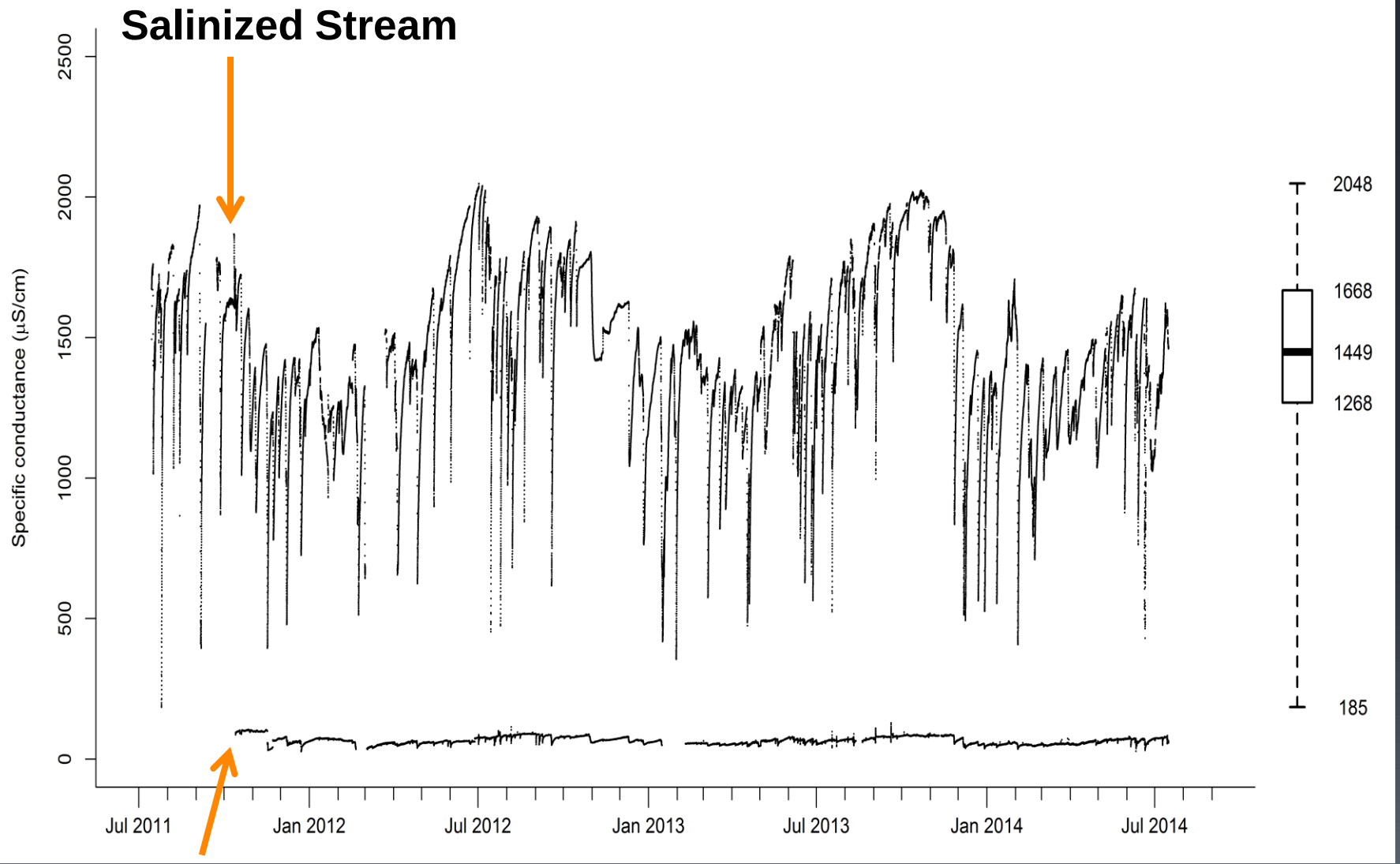
Tony Timpano

2011 – 2014 (initial), and ongoing

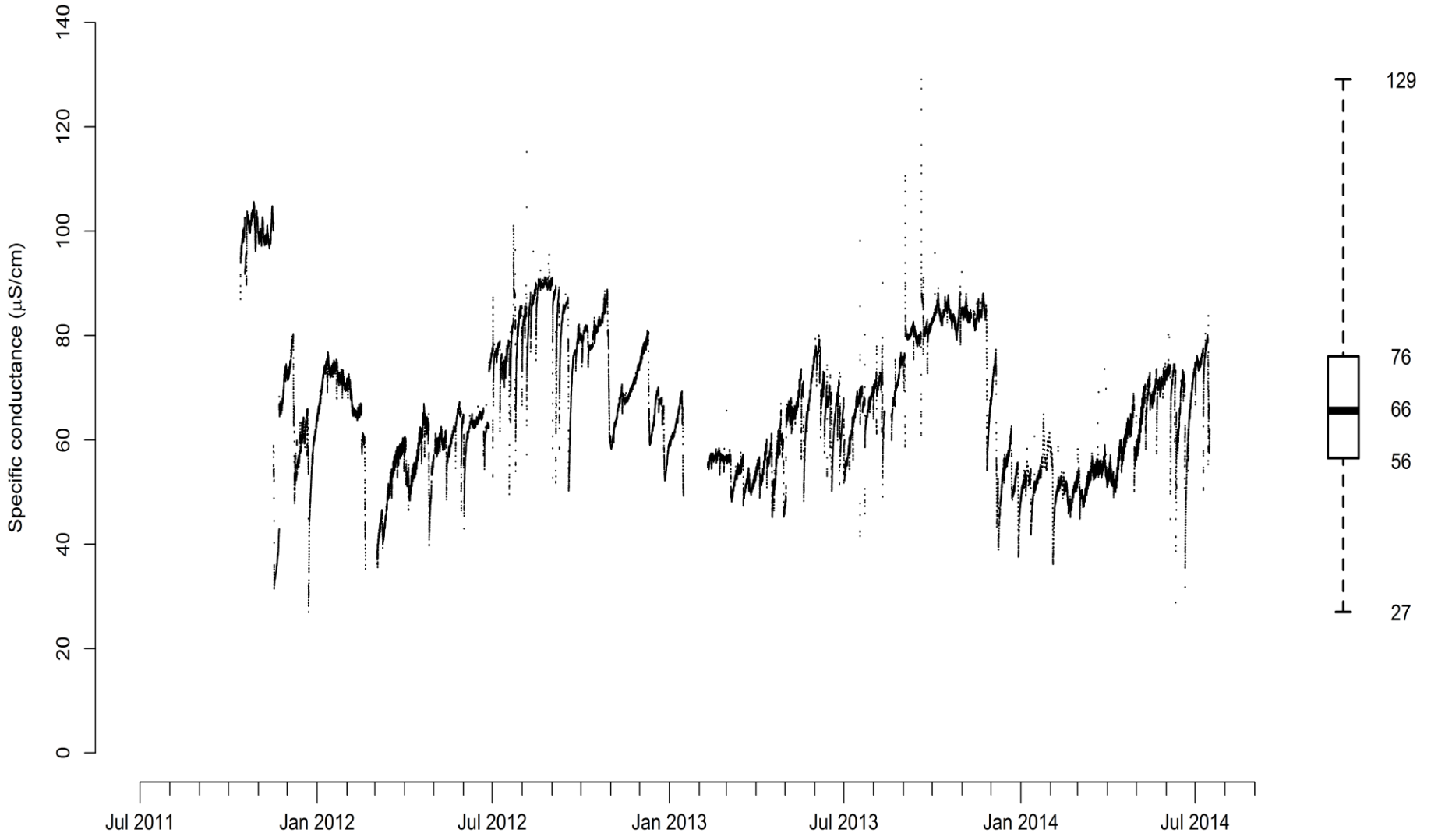
Study Design

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

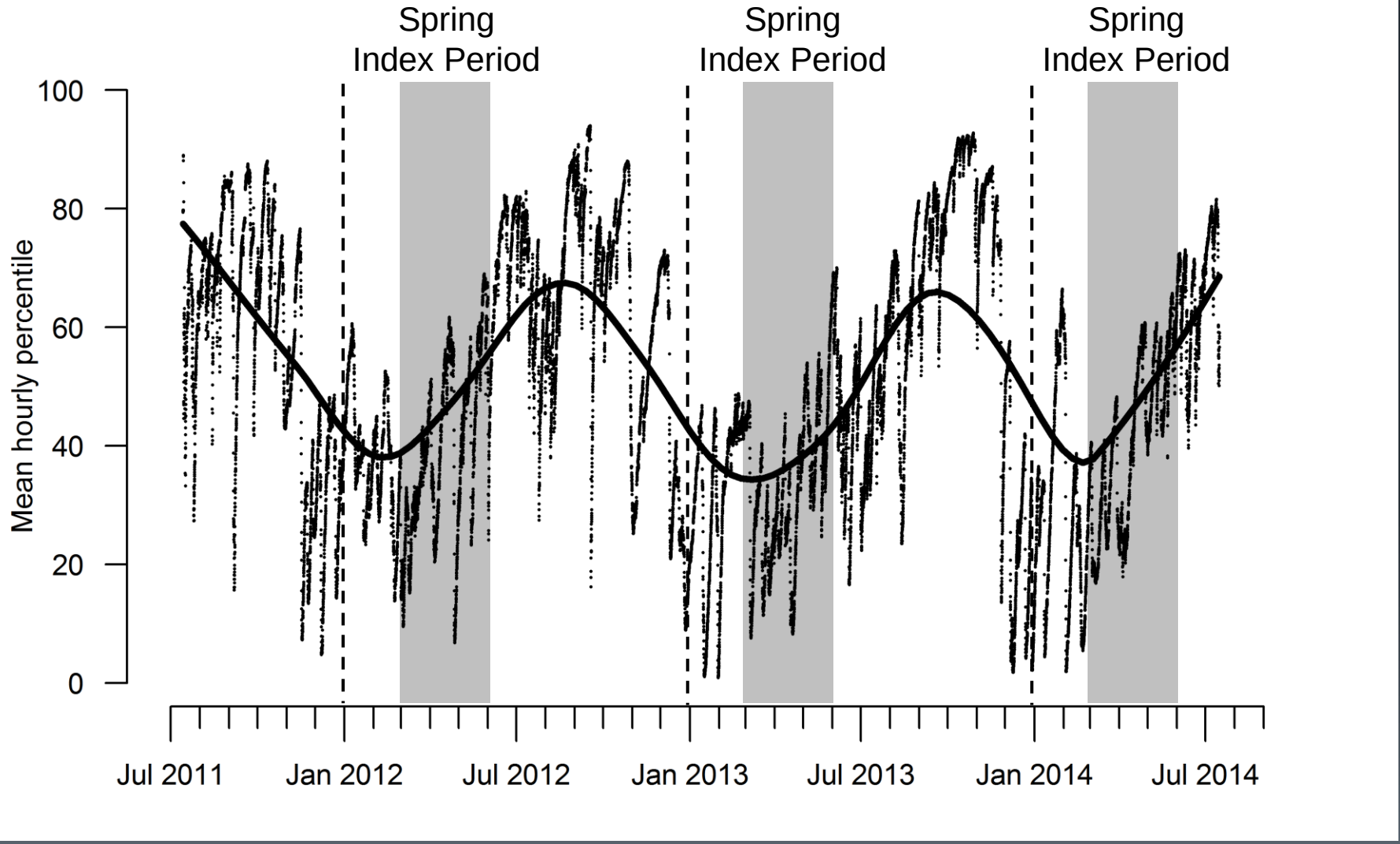
Typical SC Pattern



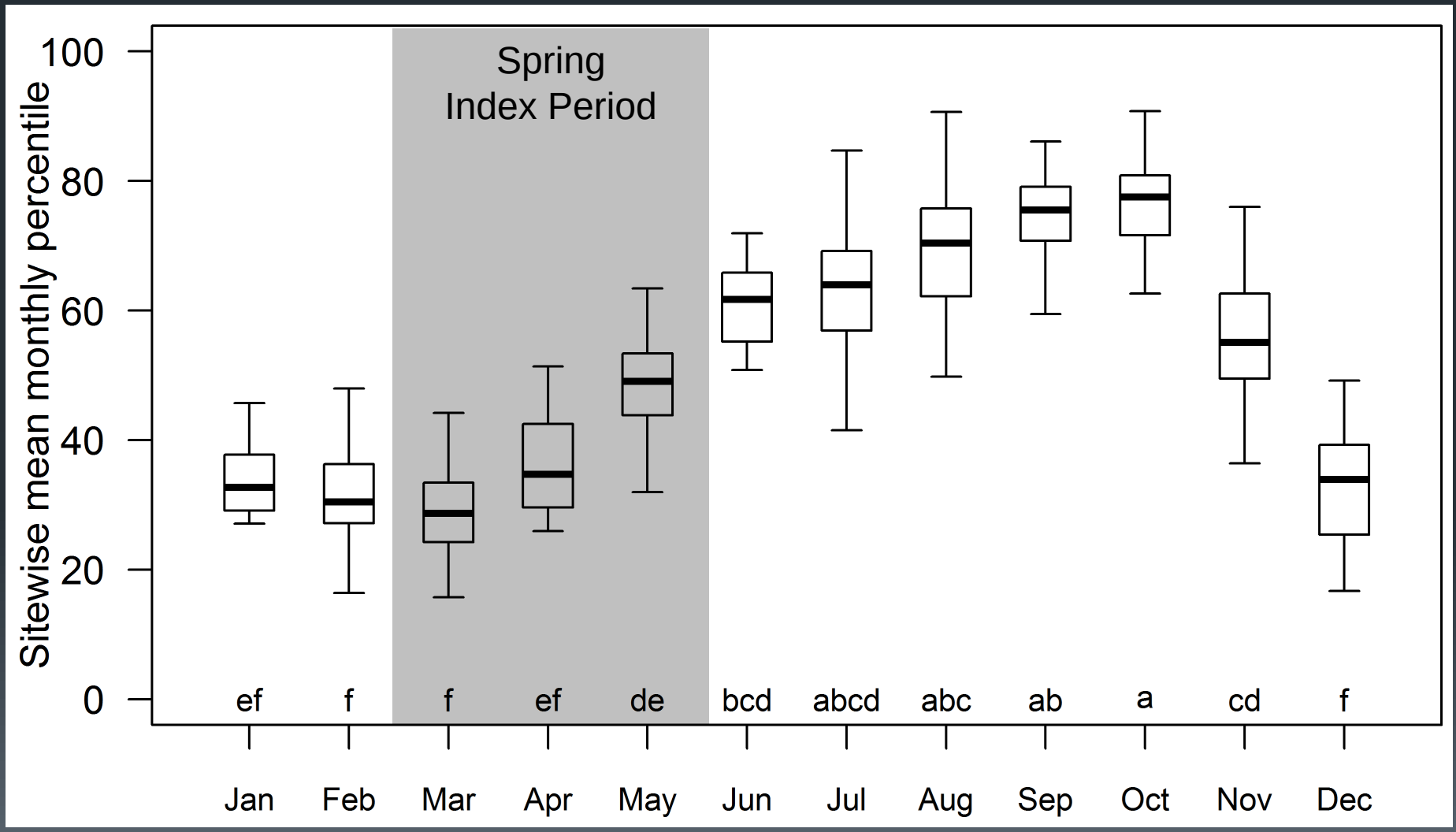
SC Varies at Reference Streams Too



Mean Hourly Percentile of SC



Mean SC Percentile by Month



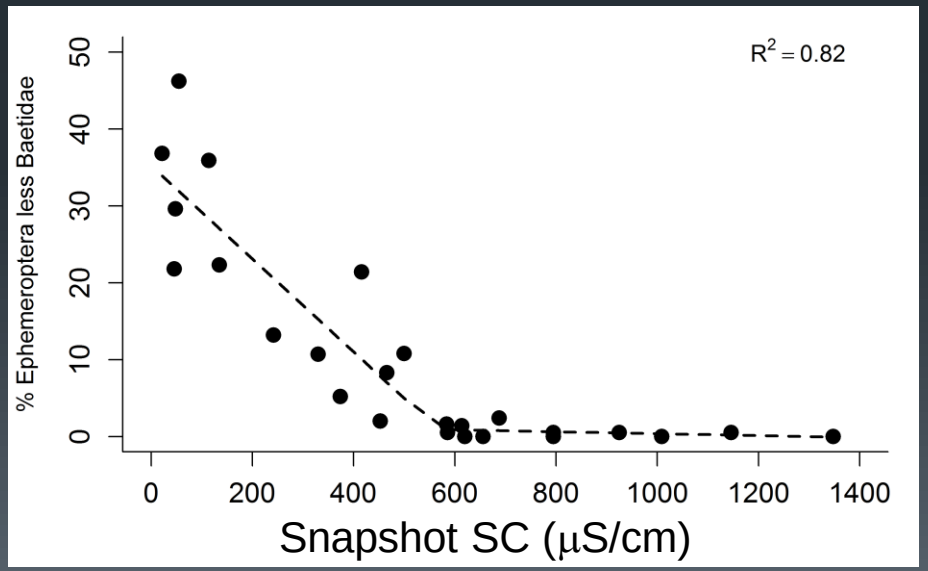
Salinity-Biota Relationships

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

Spring 2014
Spearman Correlations

Biological Metric	Chronic High SC
Total Richness	-0.73
Sensitive Mayfly Richness	-0.89
Sensitive Mayfly Rel. Abundance	-0.91

Spring 2014
Sensitive Mayfly Rel. Abundance



IV. Temporal Dynamics of Biology

Beth Boehme

2011 - 2012

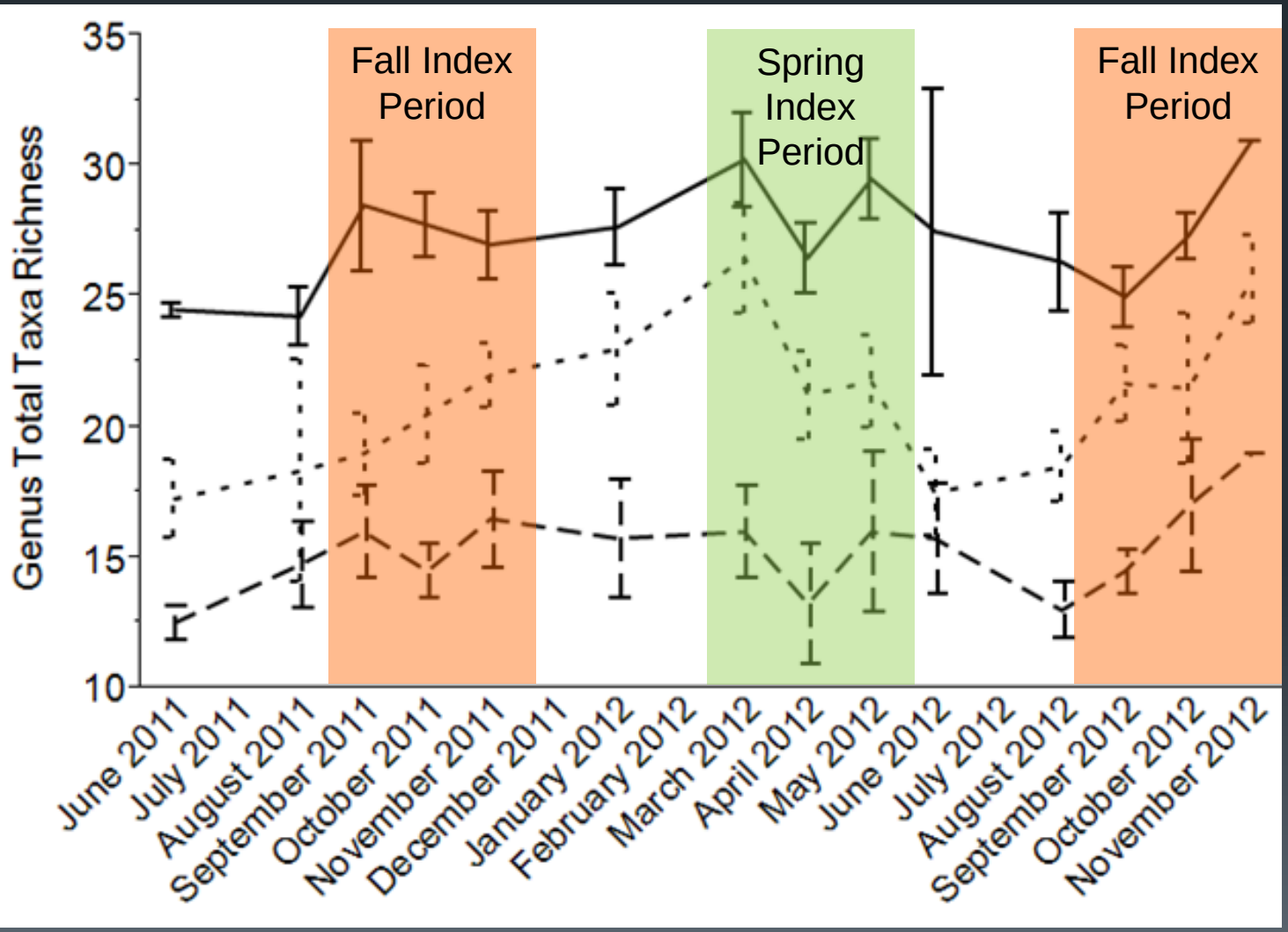
Research Questions

- 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

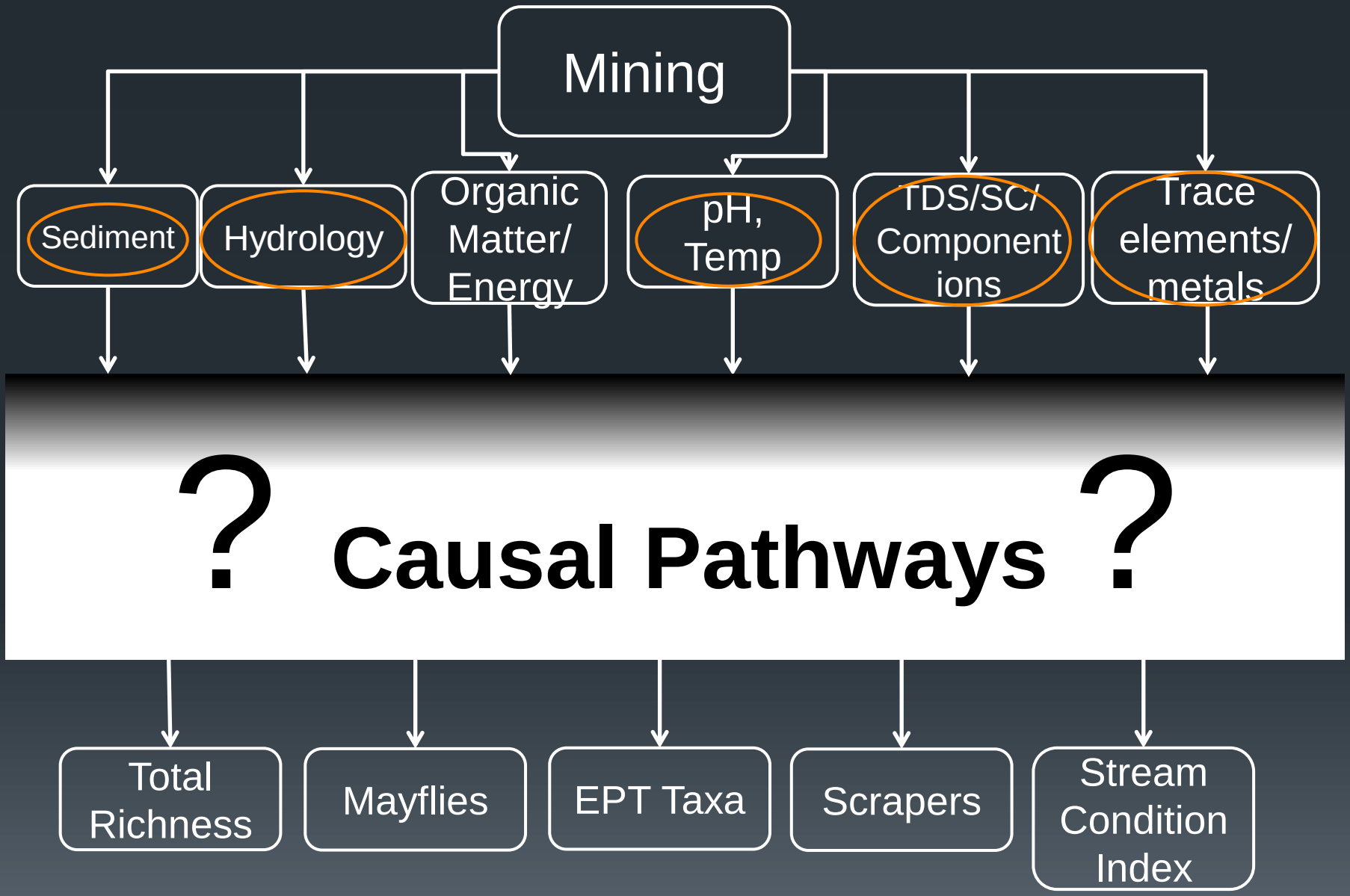
Rationale

- 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

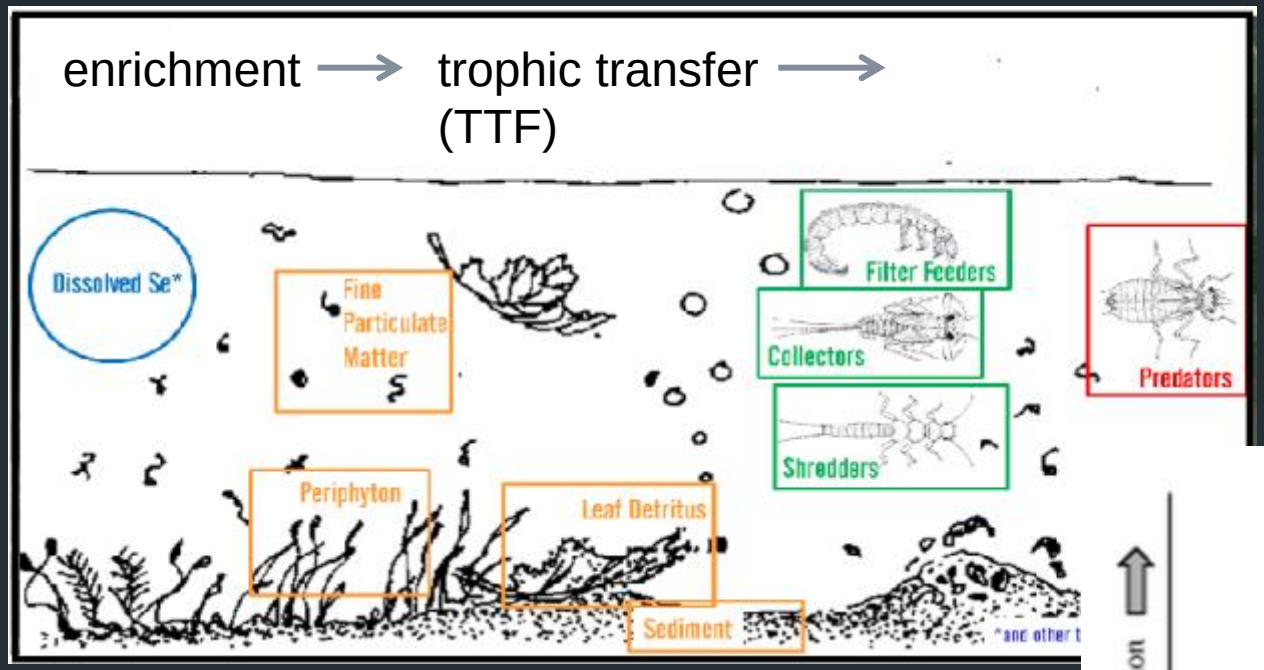

Mining
Sediment
Hydrology
Organic Matter/ Energy
pH, Temp
TDS/SC/ Component ions
Trace elements/ metals
? Causal Pathways ?
Total Richness
Mayflies
EPT Taxa
Scrapers
Stream Condition Index

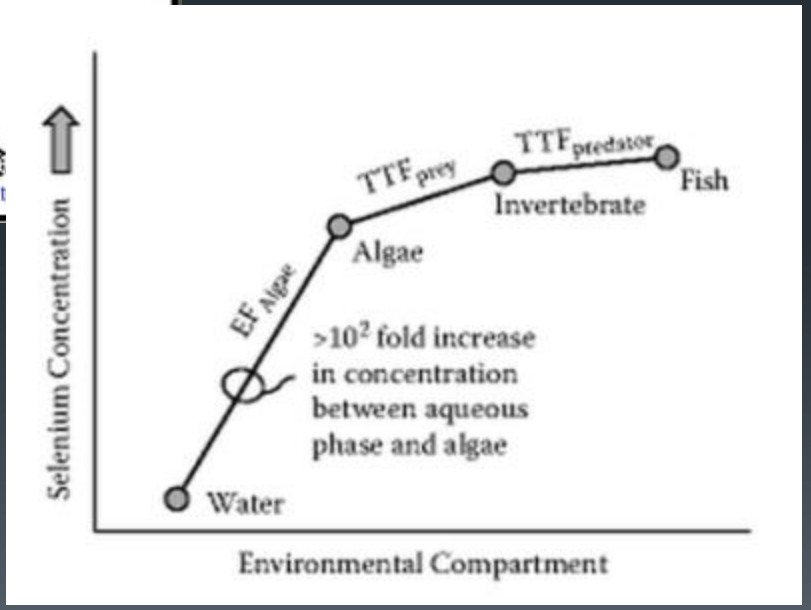
VI. Selenium Enrichment & Trophic Transfer

Kriddie Whitmore

2015 - 2016

Selenium Enrichment & Trophic Transfer





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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ARIES (Appalachian Regional Initiative for Environmental Science)

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US EPA Region 3

West Virginia Dept. Environmental Protection