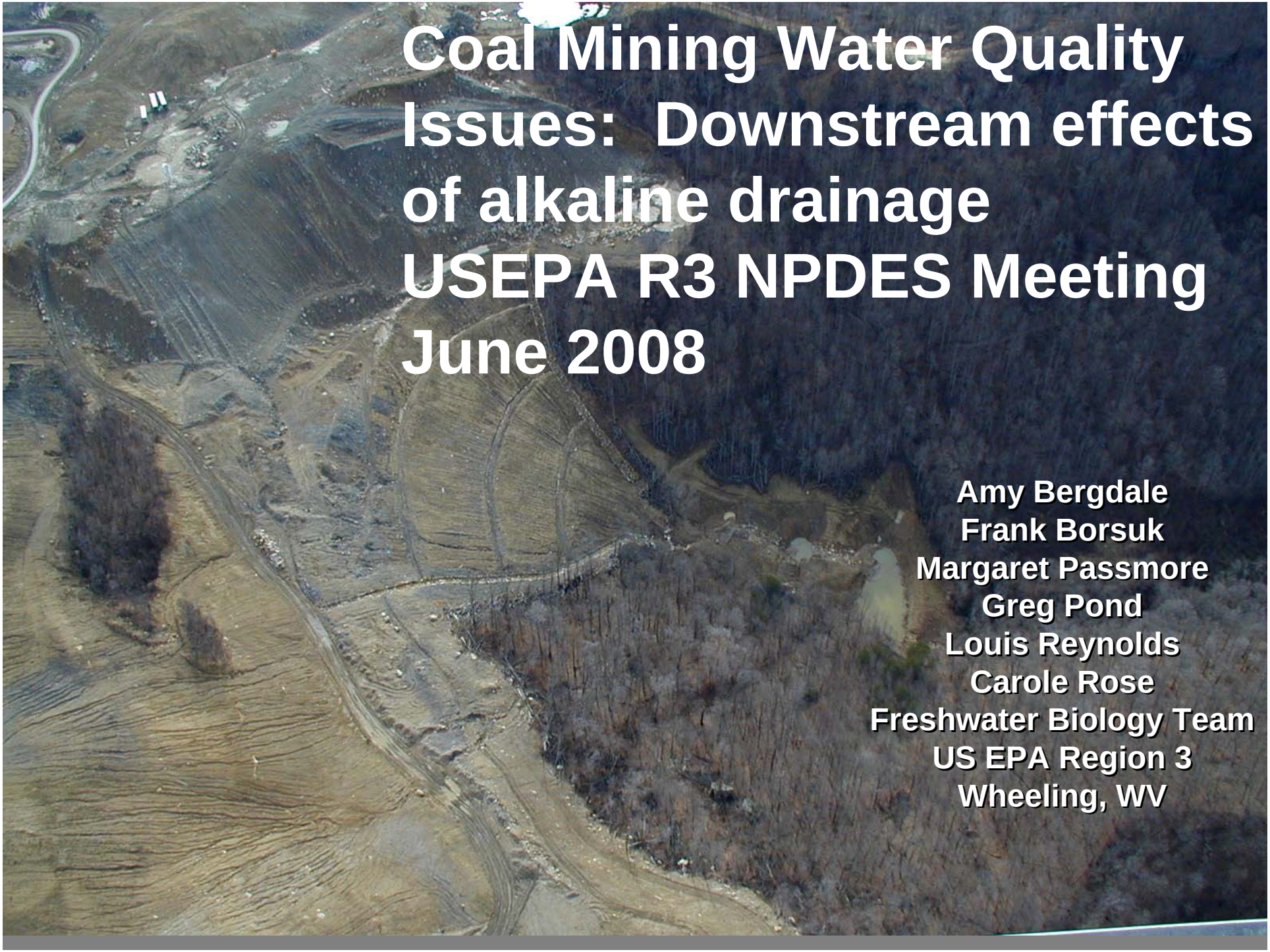


Coal Mining Water Quality Issues: Downstream effects of alkaline drainage
USEPA R3 NPDES Meeting
June 2008

Amy Bergdale
Frank Borsuk
Margaret Passmore
Greg Pond
Louis Reynolds
Carole Rose
Freshwater Biology Team
US EPA Region 3
Wheeling, WV

Outline

- Downstream Effects of Alkaline Coal Mine Drainage
  - Aquatic life uses impaired based on resident biota
  - TDS strongly correlated to impairment
- TDS is a potential pollutant/toxicant
- WET testing as an additional indicator
  - Quantifies toxicity
  - Can be added to NPDES permits
  - Caution - WET surrogates not as sensitive as resident biota

Downstream Impacts

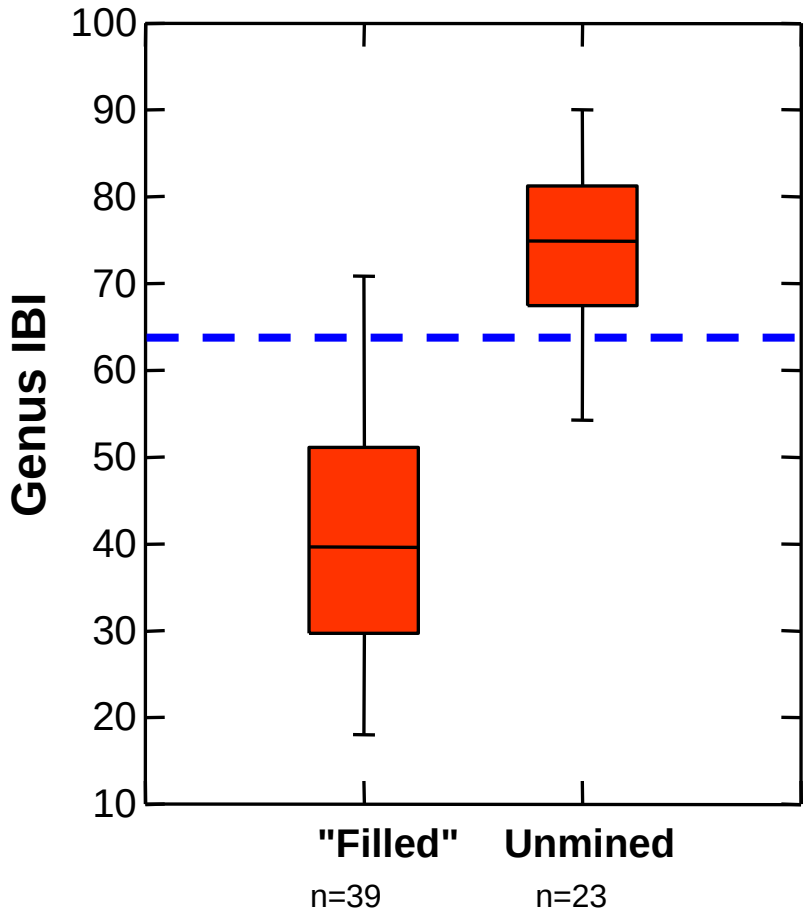
- Appalachian streams are naturally dilute, with high biodiversity
- Coal mining elevates TDS, component anions and cations, some trace metals
- Widespread aquatic life use impairments are found downstream of NPDES outfalls of mines
- Habitat usually plays a minor role as a stressor
- TDS are most strongly correlated to impairment
- WET testing also indicates impairment but is less sensitive indicator than resident aquatic life
- Due to headwater location of many outfalls, limited dilution available

What Constitutes Stream "Impairment"?

- WV **§46-1-3. Conditions Not Allowable In State Waters**.

3.2.i. Any other condition, including radiological exposure, which adversely alters the integrity of the waters of the State including wetlands; no significant adverse impact to the chemical, physical, hydrologic, or biological components of aquatic ecosystems shall be allowed.

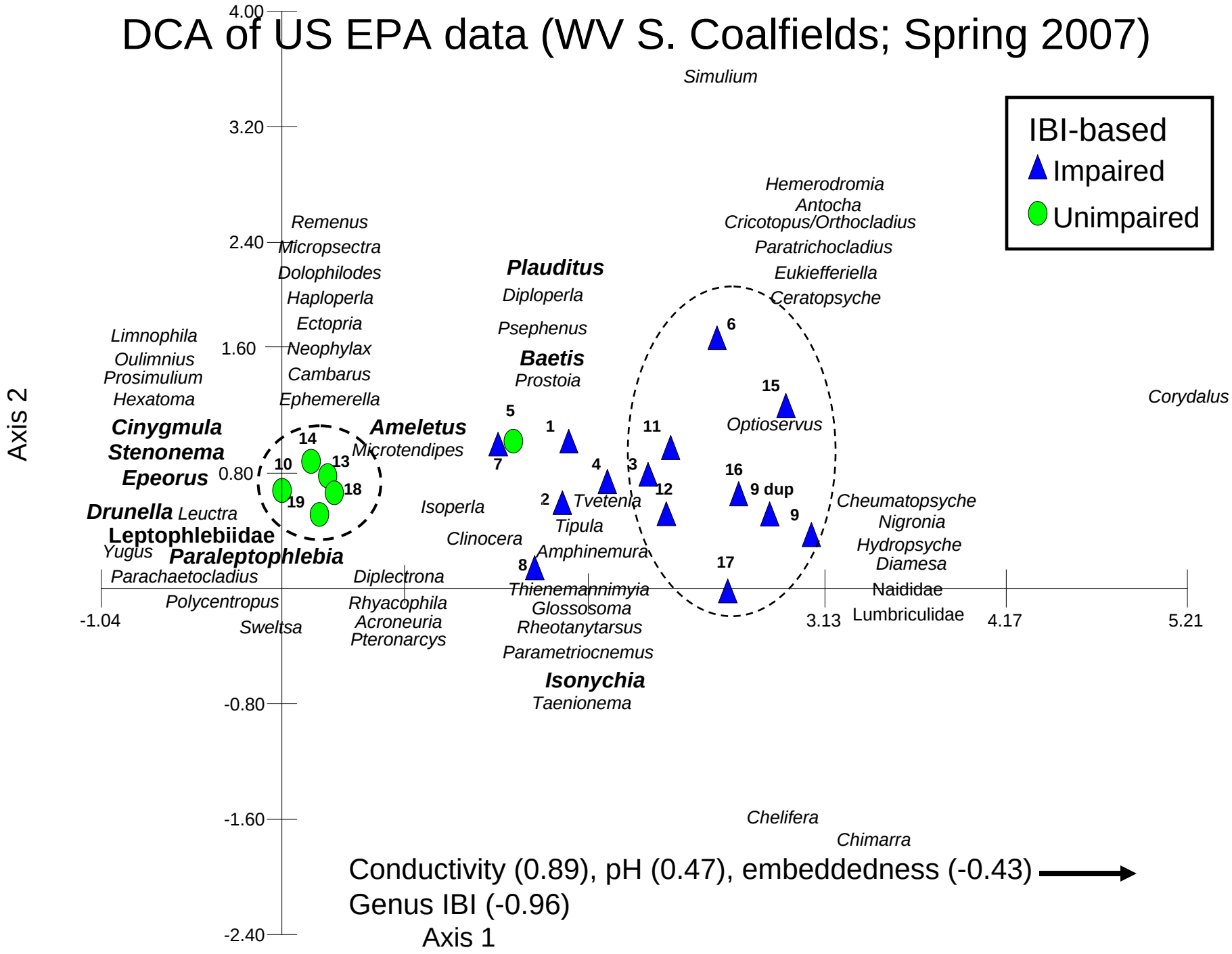
An Example:
Aquatic Life - Macroinvertebrates



91% filled streams Impaired

US EPA EIS on MTM/VF
(Spring 1999-2000; 2006-2007)

DCA of US EPA data (WV S. Coalfields; Spring 2007)

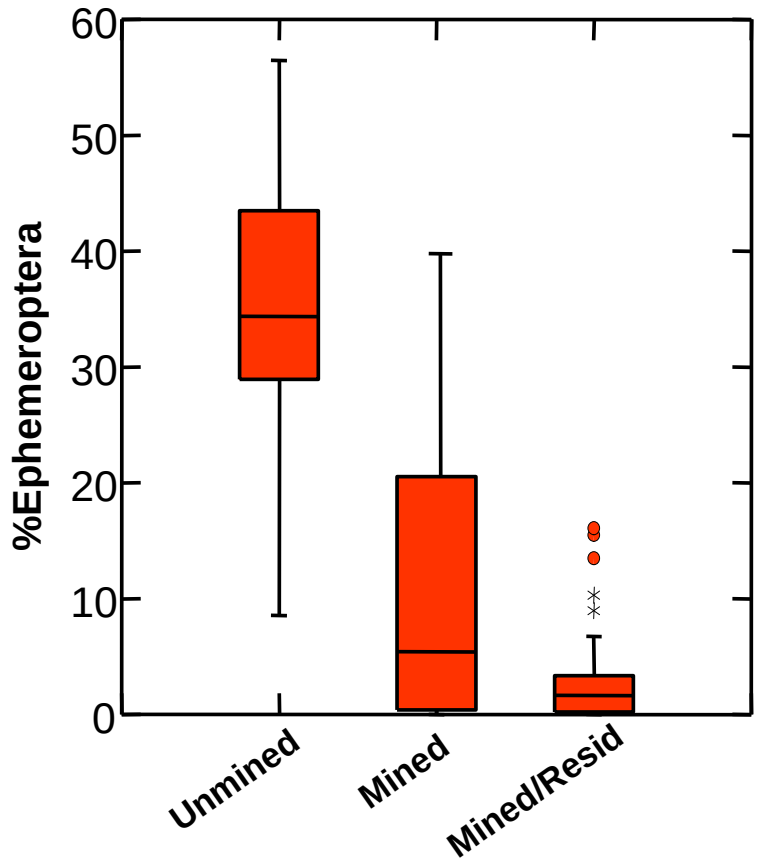


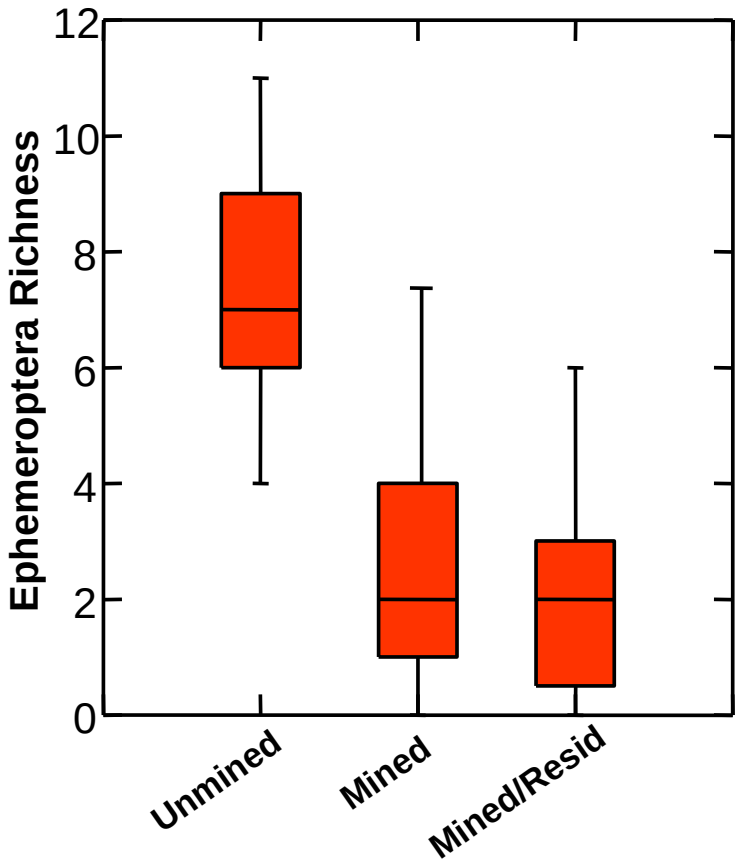
Conductivity (0.89), pH (0.47), embeddedness (-0.43) →

Genus IBI (-0.96)

Axis 1

Mayflies Most Sensitive to Changes





n=89

EPA MTMVF Study (WV)

Spring, Genus Level (200-count riffle subsample)

Mayflies should make up 30-60% of the macroinvertebrate sample in these streams

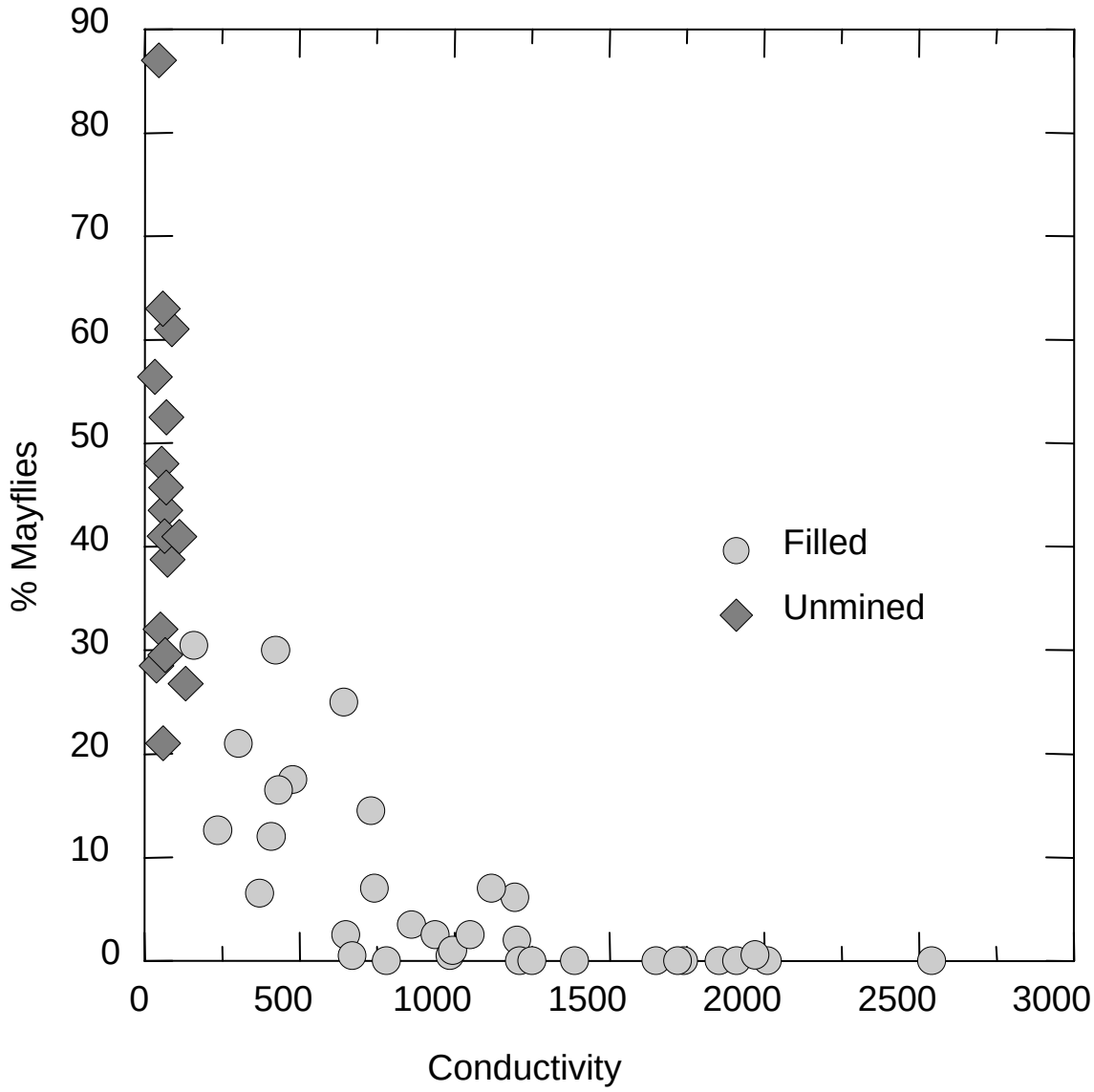
What's causing the aquatic life impairment?

Spearman's Correlation Coefficients

n=89	# Ephem Taxa	% Ephem
TDS	**-0.88**	**-0.86**
Conductivity	**-0.87**	**-0.86**
SULFATE	**-0.87**	**-0.85**
CALCIUM	**-0.87**	**-0.85**
MAGNESIUM	**-0.86**	**-0.83**
POTASSIUM	**-0.85**	**-0.82**
SELENIUM	**-0.74**	**-0.72**
NITRATE/NITRITE NITROGEN	**-0.72**	**-0.69**
pH	**-0.64**	**-0.60**
SODIUM	**-0.60**	**-0.59**
IRON, DISSOLVED	**-0.57**	**-0.61**
CHLORIDE	**-0.39**	**-0.46**
MANGANESE	**-0.34**	**-0.35**
NICKEL	**-0.31**	**-0.31**
TOTAL ORGANIC CARBON	**-0.31**	**-0.35**
COPPER	-0.05	-0.13
TSS	-0.03	0.03
Temperature	-0.02	-0.02
D.O.	0.02	-0.02
ALUMINUM	0.07	0.10
BARIUM	0.10	0.05
ZINC	0.19	0.16
LEAD	**0.25**	**0.23**

bold values = p<0.05

based on mean monthly WQ concentrations (n=13 months)

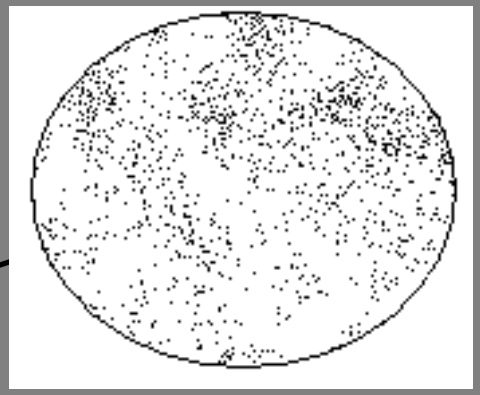


WV Streams

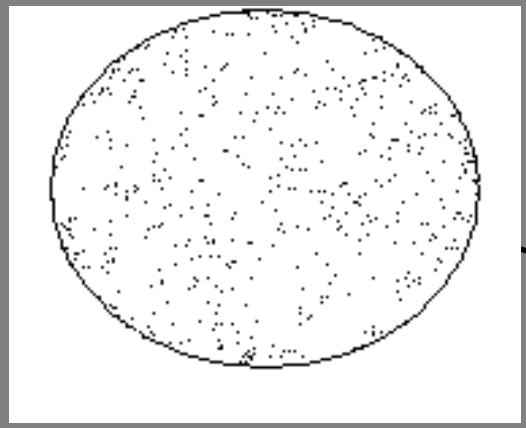
Typical dose response curve indicating a possible threshold for effects between 500-1000 µS/cm.

Vulnerable/Specialists

High Chloride Cell Density



Tolerant/Generalists



Low Chloride Cell Density

Courtesy WVDEP

Impacts to Aquatic Life Based on Relevant Empirical Datasets

- Macroinvertebrates are the most widely used indicator of the aquatic life use.

- Three readily available datasets indicate slightly different (but decidedly inverse and significant) relationships between condition of aquatic life and conductivity.

Conductivity thresholds for protection of aquatic life suggested by these datasets

- Kentucky: <300 uS/cm based on linear regression with KY Headwater MBI scores of 72.
- West Virginia MTM region: 426 – 689 uS/cm based on linear regression with Family WVSCI scores of 70 and 60.
- West Virginia Ecoregion 67/69 Summer: <300 based on linear regression with Genus level WV SCI with stratum-specific index scores.

What does the toxicity testing literature say?

- The toxicity testing literature indicates:
  - increases in the concentrations and types of major ions can be both acutely and chronically toxic to aquatic life, in the absence of any other toxicant.
- Tests are typically conducted using synthetic salt solutions.
  - Some of these tests mimic the makeup of various types of effluents, but lack other toxicants found in the effluents.
- Adverse endpoints include death, and effects on reproduction and growth.

For Example:

- Mount et al (1997) tested acute toxicity (survival) with over 2900 ion solutions and found that for freshwater organisms routinely used in WET testing, the relative ion toxicity was:
- $K^+ > HCO_3^- = Mg^{2+} > Cl^- > SO_4^{2-}$

5x **15x** **32x** **2x** **38x**

- The presence of 2-3 cations tended to decrease the toxicity of the salt solutions to invertebrates.

- These models have successfully predicted toxicity to *C. dubia* in several empirical studies.

However, thresholds suggested by available toxicity literature tend to be higher than empirical data suggest…

Organism/ Author / Toxicant	TDS threshold	Conductivity threshold
Many?/American Petroleum Institute/?		2000
Many?/Hart et al/?	1000	Approx. 1428
Midge/Chapman et al /(mixed synthetic, but sulfate dominated)	1100	Approx. 1570
Mayfly/Leland and Fend/ (ambient waters with wide range of ions)	1000	Appox. 1428
Mayfly/Goetsch and Palmer / (sodium sulfate diluted with river water)		1000

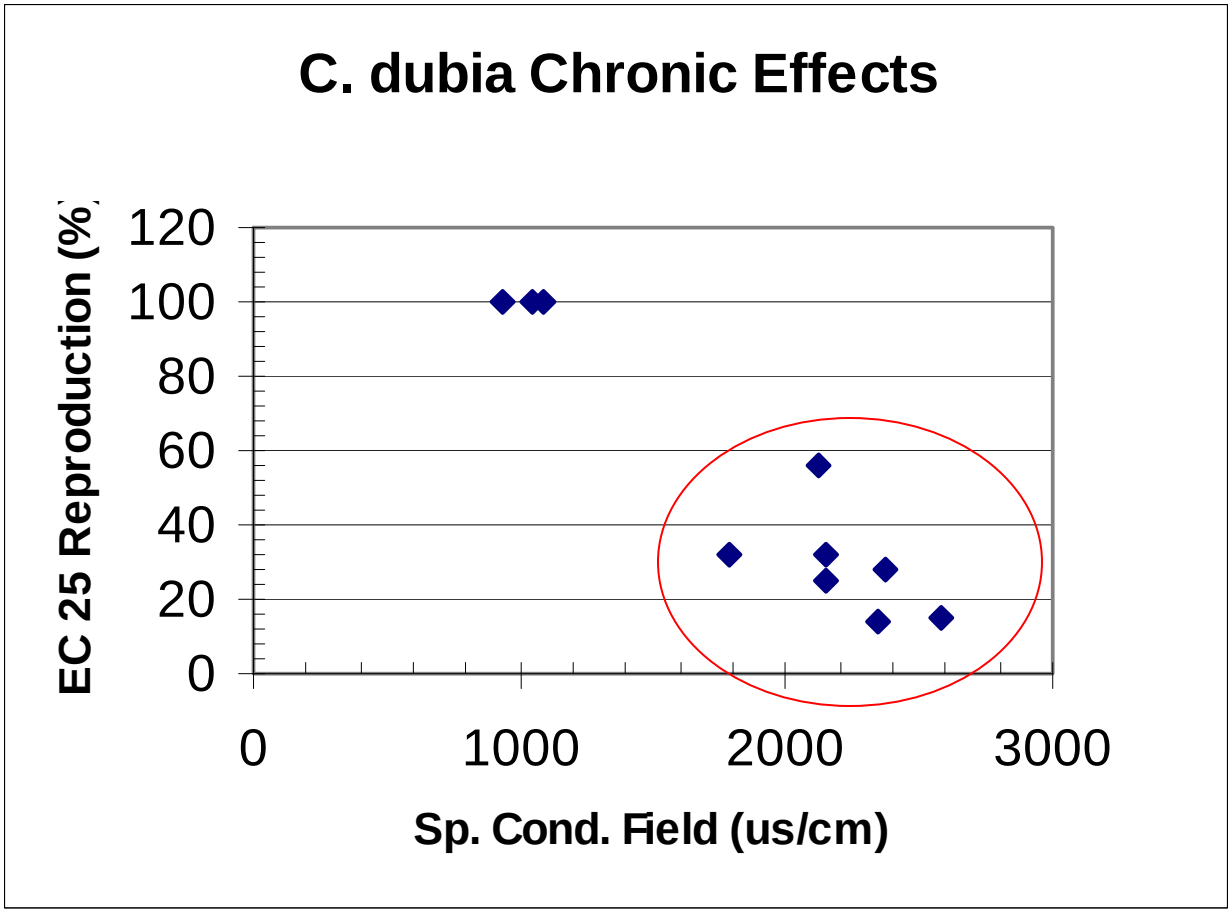
Chronic WET Testing as an Additional Indicator

- This indicator “speaks” to some permit writers
- Toxicity testing can be used in NPDES permit as a monitoring requirement or a limit
- It is a good tool where the pollutant(s) are not known or covered by the effluent limits
- However, species available for culturing and tox testing are much more tolerant of high TDS than resident fauna adapted to live in dilute waters.
- We have tested some ambient waters downstream of mining effluents to determine whether they exhibit toxicity.

EPA Pilot – WET testing of mining impaired streams

- Study Details
  - Chose sites where mining is the only source of pollutants and aquatic life impaired
  - Did not determine if permit in compliance with limits
  - Collected
    - Macroinvertebrates
    - Rapid Habitat Assessment
    - Field and lab chems
  - WET testing of ambient water – Ceriodaphnia dubia 7 day chronic test
  - 10 samples tested to date, all samples collected winter 2007-2008 (not during low flow)

Preliminary Results - WET



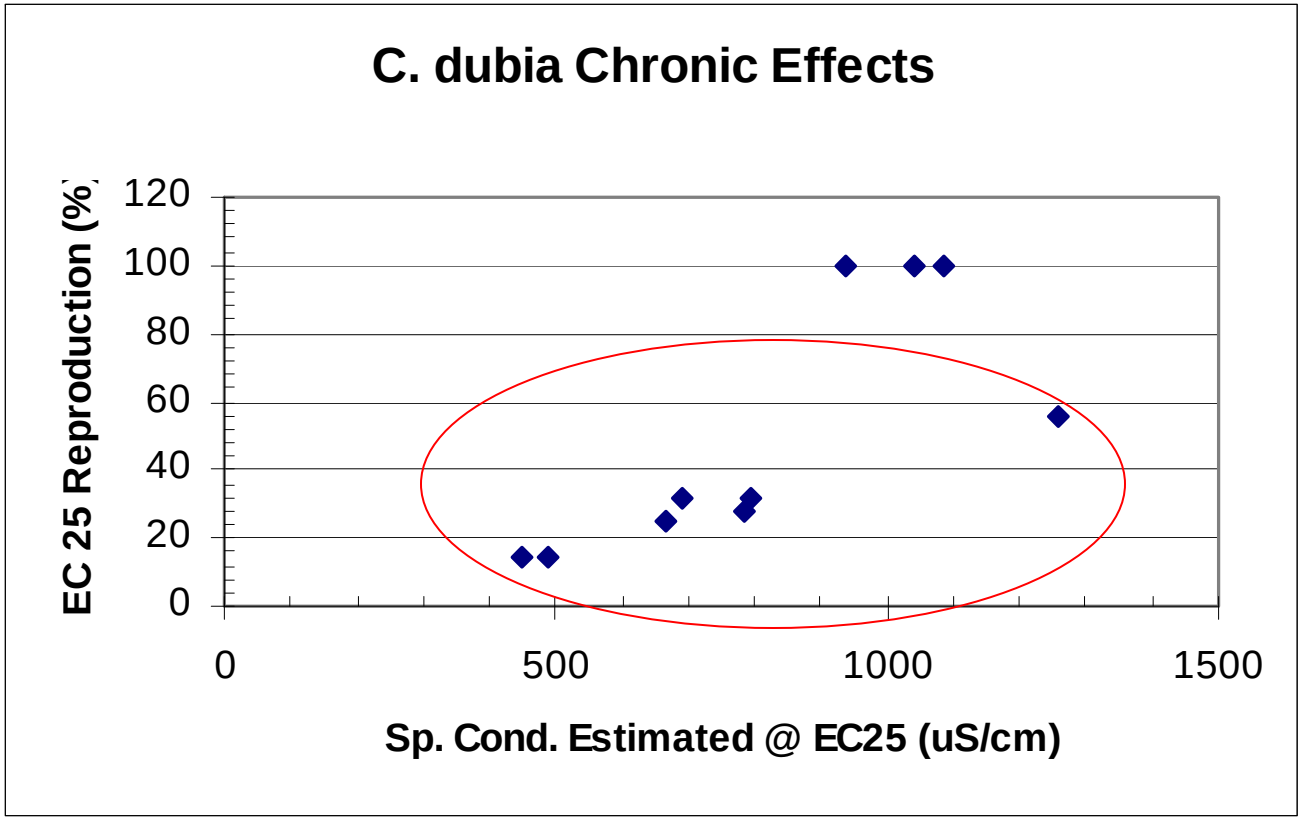
7 of 10 samples exhibited toxicity.

Chronic effects were detected in samples with field conductivity >1800 µS/cm.

This range is much higher than where we see effects with resident biota.

Lack of effects in samples 939-1086 µS/cm.
Note lack of samples in between.

Preliminary Results - WET

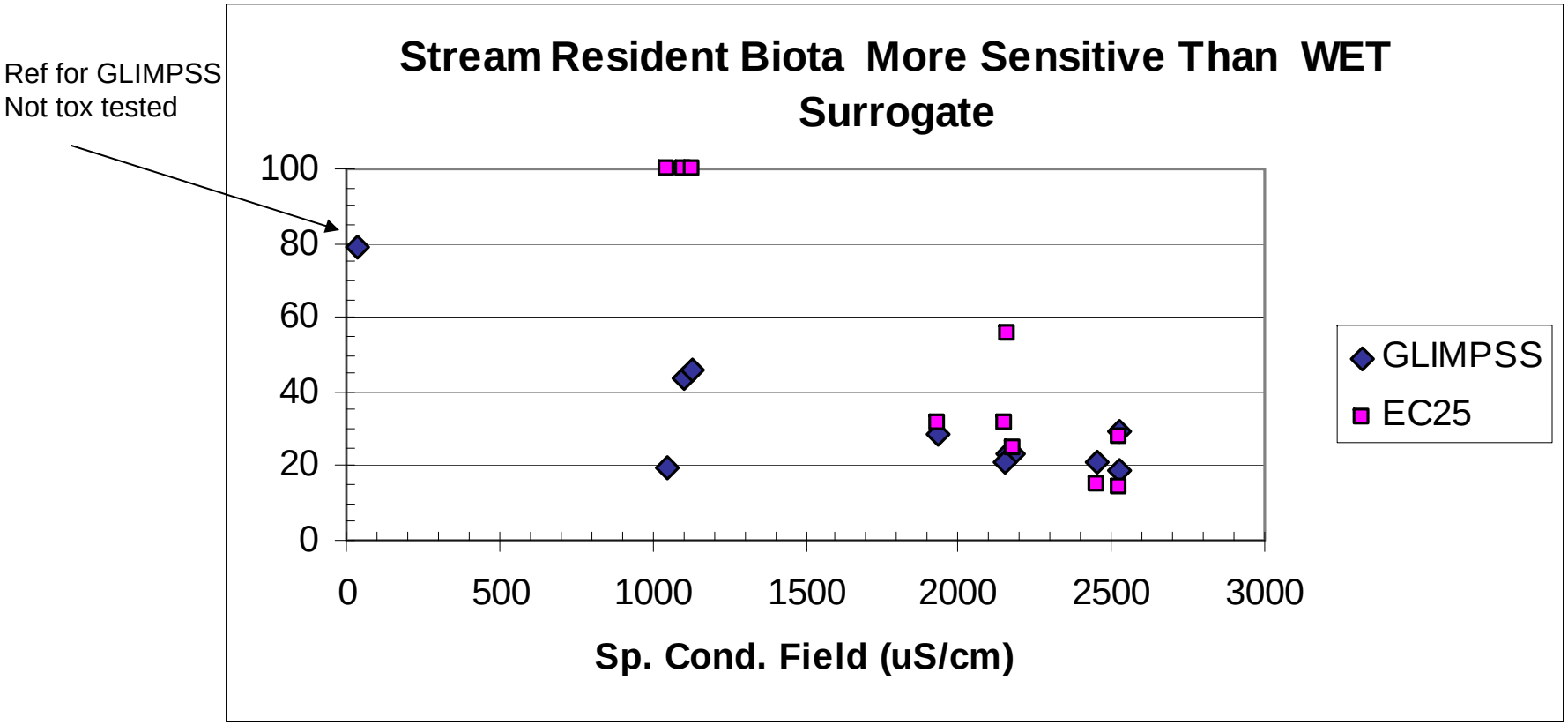


Estimated conductivity at EC25 % ranged from 448-1243 with an average of 820 µS/cm.

This range is slightly higher than where we see effects with resident biota.

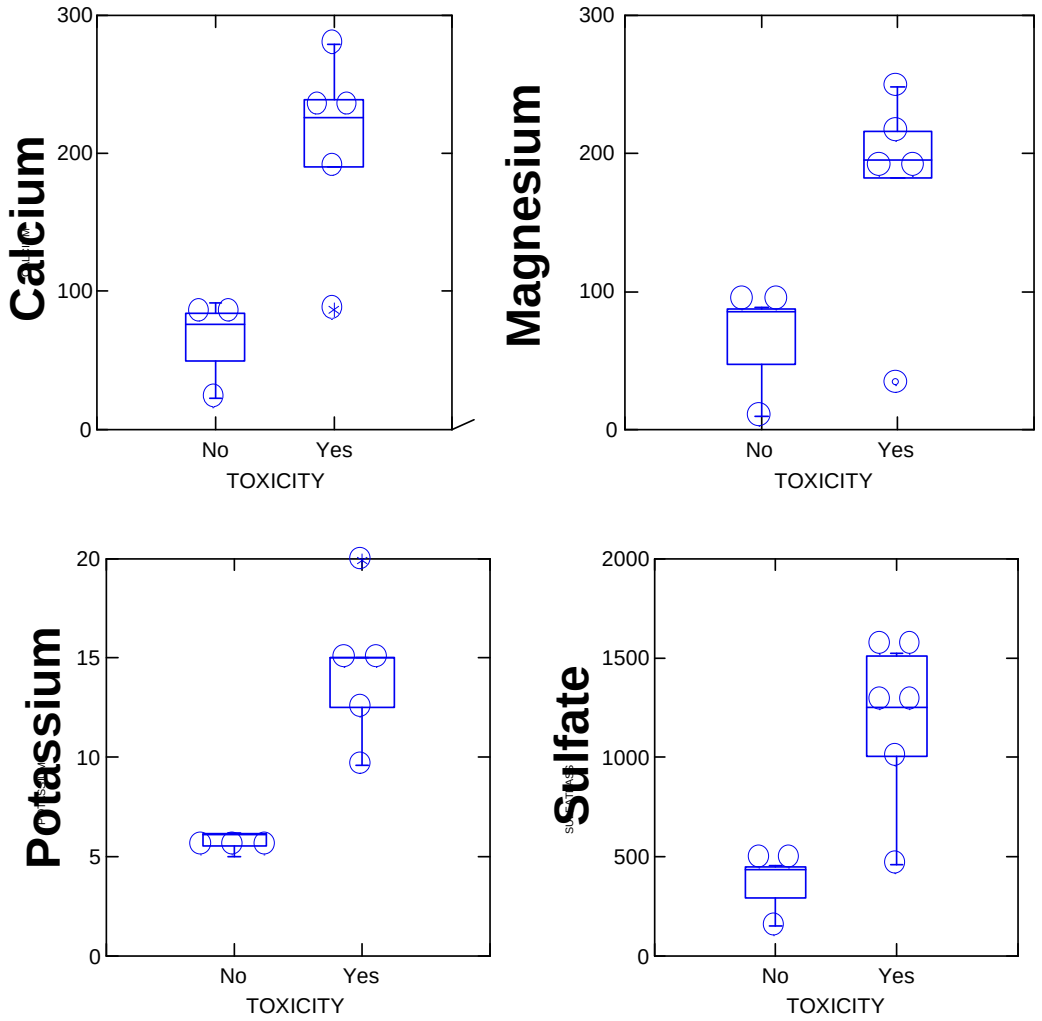
Note: one sample was reconstituted to mimic salt concentrations and tested by an independent lab.

Preliminary Results – WET and Macroinvetebrates



All sites were rated impaired using the genus level GLIMPSS (<66) , which directly measures aquatic life use impairment. The resident biota are more sensitive than the WET surrogate, C. dubia. Can't use C. dubia alone to express "safe" thresholds, but it can be used as an indicator of most toxic discharges.

Preliminary Results – Toxic vs Non Toxic Samples: TDS

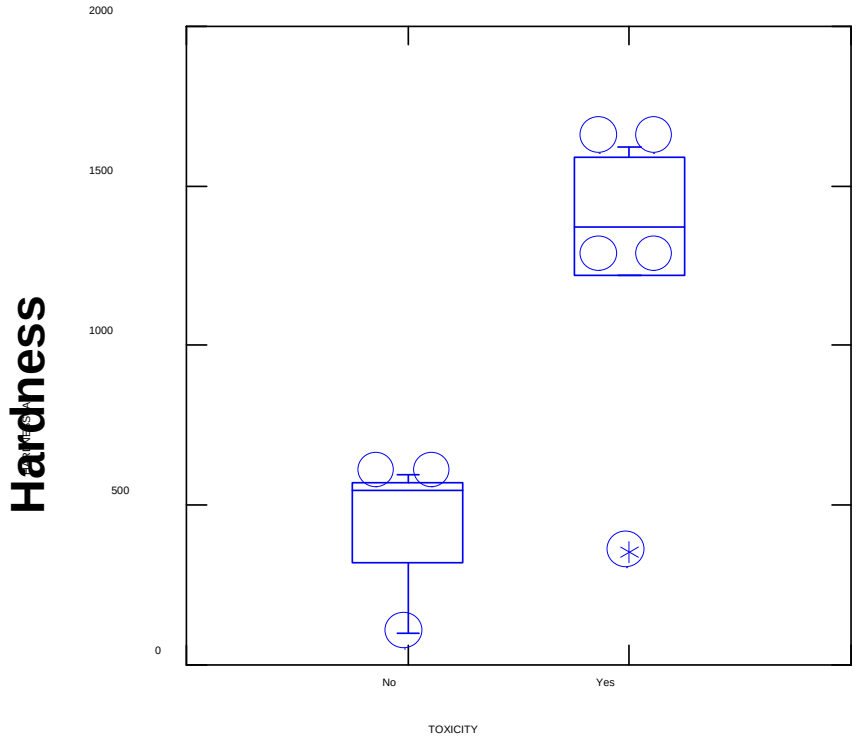


The major cations and ions in the effluent are calcium, magnesium, bicarbonate and sulfate.

Calcium, magnesium, potassium and sulfate were sig different between the samples that were toxic and those that were not.

Mount et al (1997) and others have identified bicarbonate, sulfate, potassium and magnesium as potential toxic ions.

Preliminary Results - Trace Metals



Cobalt, Nickel and Zinc were sig different, but concentrations were less than chronic criteria.

Metals criteria are hardness dependent. All the mining effluents have elevated hardness.

The samples that exhibited toxicity to C. dubia actually had elevated hardness.

Summary

- Downstream Effects of Alkaline Coal Mine Drainage
  - Aquatic life uses impaired based on resident biota
  - TDS strongly correlated to impairment
- TDS is a potential pollutant/toxicant
- WET testing as an additional indicator
  - Quantifies toxicity
  - Can be added to NPDES permits as a monitoring requirement or a limit
  - Caution - WET surrogates not as sensitive as resident biota