DELAWARE RIVERKEEPER®

February 12, 2010

Environmental Quality Board
P.O. Box 8477
Harrisburg, PA 17105
Rachel Carson State Office Building, 16th Floor
400 Market Street
Harrisburg, PA 17105-2301
RegComments@state.pa.us

Re: 25 PA Code Ch. 95 Wastewater Treatment Requirements

Dear Environmental Quality Board Members,

Delaware Riverkeeper Network submits this comment on behalf of our members in Pennsylvania and throughout the Delaware River Watershed, numbering 7000, and in furtherance of our mission to protect, defend and restore the Delaware River, its tributaries and habitats. We provided verbal comment on December 17 at the Public Hearing in Allentown, PA and supplement those comments with this document.

General Comments and Interim Policies

Delaware Riverkeeper Network supports action by the Department of Environmental Protection (DEP) to protect our streams, rivers and water supply from high-TDS discharges, especially from the burgeoning flow of gas drilling wastewater. The proposed standards for TDS, sulfate and chloride are a first step that must not be weakened. However, these standards do not go far enough and additional protective measures need to be taken by DEP now to prevent further degradation of the State's waterways and water resources.

DEP should stop issuing gas drilling permits immediately since there are NO discharge standards in place at this time for Total Dissolved Solids, chloride and sulfate. DEP should not allow new gas wells to be drilled, producing millions of gallons of wastewater, when protective standards are not yet in place. DEP has stated in its news releases that approximately 5,200 drilling permits are expected this year, which could produce over 5.8 billion gallons of wastewater, all requiring processing and adequate treatment. It is simply unacceptable that DEP continues to issue permits that will generate billions of gallons wastewater without ensuring the availability of safe treatment.

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According to DEP, “Estimates from the industry indicate that demand for brine water treatment in Pennsylvania will reach approximately nine million gallons per day (MGD) in 2009, 16 MGD in 2010, and 19 MGD in 2011. Estimates from the Susquehanna River Basin Commission are 20 MGD for that same timeframe.”[1] Considering these large numbers and the potential for adverse impact on the streams and rivers of the State, drilling permits should be paused until best technology treatment facilities are in place, tested and proven to be sufficient to remove dangerous pollutants and until DEP adopts protective discharge and water quality standards.

Likewise, no new wastewater plants should be permitted by DEP until protective standards are implemented. The interim policy of DEP, which is permitting new plants with effluent standards well in excess of those being proposed, is damaging our streams, rivers and water supplies. DEP states that “…many of the rivers and streams of Pennsylvania have a very limited ability to assimilate additional TDS, sulfates and chlorides because of elevated levels from historic practices”.[2] In its Permitting Strategy, DEP goes on to discuss the overload of TDS in the Monongahela River: TDS and sulfates reached historic highs in 2008 (this condition recurred in 2009), exceeding water quality standards at the water facilities that supply water to over 325,000 people in the basin, including Pittsburgh. DEP also lists South Fork Tenmile Creek, the Beaver and Conemaugh Rivers and the West Branch of the Susquehanna river as being overloaded with high TDS concentrations. DEP identifies oil and gas drilling wastewater from the Marcellus shale formation as the high-TDS wastewaters they need to focus on to get a handle on the problem.

To prevent further degradation, we advocate that no existing or new plants should be allowed to accept or discharge gas drilling wastewater in the interim period before effluent standards are adopted by DEP, no matter whether the plants would have to meet the new discharge standard by the adoption date or not. This interim period should not be a sacrifice period that will allow high-TDS wastewater and other polluting parameters to be loaded into our streams without adequate regulation of effluent quality.

To address the degraded condition of the State’s streams, DEP states that it plans to “maximize the use of available assimilative capacity of receiving streams where that is feasible” instead of allowing more high-TDS discharges to already compromised waterways.[3] We do not agree that DEP is faithfully implementing that strategy; the proposed construction of a plant by Shallenberger Construction to discharge gas drilling wastewater into the Monongahela River required an appeal by Clean Water Action in November 2009 to stop its progress. Even if the policy were being adequately implemented, this policy itself does not address the need for DEP to restore these degraded waterways in the interim; DEP itself notes that an allocation strategy will be needed to address water quality limitations in streams where multiple discharges are causing water quality standard violations. In spite of this recognition by DEP, this process has not yet begun and, under Clean Water Act requirements, should already be underway to prevent further degradation.

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[1] DEP “Permitting Strategy for High Total Dissolved Solids (TDS) Wastewater Discharges”, April 11, 2009, http://files.dep.state.pa.us/Water/Wastewater%20Management/WastewaterPortalFiles/MarcellusShaleWastewaterPartnership/high_tds_wastewater_strategy_041109.pdf. Last visited February 12, 2010.
[2] Id.
[3] Id.

Further, DEP's policy regarding new discharges will push high-TDS dischargers to the State's good quality waterways, those that are not yet degraded by gas drilling wastewater discharges. This result would be contrary to anti-degradation goals and will lead to adversely impact the state's good and, in some instances, best waterways. We cannot degrade our waterways because of industry interest in drilling. DEP needs to show strong leadership in the face of industry pressure by employing a precautionary approach that prevents in the interim any polluting discharges from these wastewaters. The best way to do this is to place a moratorium on the approval of gas drilling wastewater plants that do not prohibit the discharge of high-TDS effluent and effluent containing other gas drilling pollutants. DEP says their goal is to prohibit new sources of high-TDS wastewaters; DEP can accomplish this goal now, before further degradation, by banning all new discharges of gas drilling wastewater until protective standards are implemented.

As far as existing plants are concerned, we advocate that these must be required to upgrade their treatment systems to the new effluent standards as well in order for the state to gain control of already degraded waterways and protect all streams and rivers and the water supplies they provide. Sewage plants that are simply diluting gas drilling wastewater with their sewage flows must be stopped from discharging immediately and required to modify their permits and systems if they want to accept this waste stream. Until protective discharge and water quality standards are implemented and existing facilities retrofitted to meet those standards, discharges from existing plants must be stopped. This means no "grandfathering" of existing facilities, many of which are major contributors to the water quality limitations in the State's waterways.

Proposed TDS Standard

The proposed standard of 500 mg/L for Total Dissolved Solids and 250 mg/L for sulfate and chloride should not be weakened. There are substantial questions as to whether these standards are protective enough; they certainly should not be relaxed.

Regarding the measurements used, DEP must use real data to set standards, not averages. The proposed TDS, chloride, and sulfate standards all use a monthly average to meet a maximum daily requirement. This means they can discharge more than the level allowed on a given day as long as they don't exceed it on average over a month's time. INSTANTANEOUS measurement must be required to prove compliance so the standards adopted are never exceeded or we will see excursions and a maximum criteria not be exceeded at any time must be set in order to avoid large fluctuations or large spikes of TDS entering the waterway. This is especially important for gas drilling wastewater since the constituents of the wastewater vary greatly depending on the specific geologic properties of the source gas well.

Not only will excursions have the potential to adversely impact the receiving and downstream waters on their own but cumulatively multiple discharges that exceed the standard on a given day can cause substantial adverse impacts for downstream water supplies and for in-stream quality. Further, fluctuations of TDS in a waterway can be damaging or even deadly to aquatic life by affecting the osmoregulation of aquatic animals. (See Appendix A, Environmental Protection Agency Power Point) Further, measurements that dictate treatment levels and standards compliance must be taken at the point of discharge, not at the next withdrawal point.

The background level in a receiving water body of TDS, chloride and sulfate must be considered for individual discharges. If the existing level of these pollutants is already high, then the effluent standard for that discharge must be adjusted to protect in-stream quality and the strictest standard applied (Delaware River Basin Commission (DRBC) uses 133% of background but this may not be strict enough). When existing in-stream levels of TDS are high, the applicability threshold must be removed and all TDS discharges regulated in order to not further impair the receiving waterway. DEP does discuss the need for Chapter 93 Water Quality Standards and states that this will help protect aquatic life uses and water supplies. But that proposal has not been issued so these Chapter 95 proposed standards must be considered in a stand-alone frame; even with water quality standards, background and natural conditions of streams and waterways need to be considered if the TDS effluent standard is to protect aquatic life.

Aquatic Life Protection

PADEP must set standards that are protective of aquatic life. Analysis must be done to set standards that do not harm the living communities of our streams and rivers. To examine why TDS is so important to aquatic life, it is important to understand that organisms in both aquatic and terrestrial environments must maintain the right concentration of solutes and amount of water in their body fluids. This involves excretion or the process of getting rid of (via organs such as the skin and the kidneys) metabolic wastes and other substances such as hormones that would be toxic if allowed to accumulate in the blood. Organisms must keep the amount of water and dissolved solutes in balance; this is referred to as osmoregulation. Even in the absence of other stressors such as pH, organic enrichment, habitat quality, and metals, TDS/conductivity significantly explains impairment of aquatic life use. This is especially true in mayflies. (See Appendix A, Environmental Protection Agency Region 3 Power Point) TDS affects osmoregulation in aquatic animals and high TDS concentration can impair their ability to excrete harmful substances.

The EPA Region 3 study that examined ionic stress impacts to aquatic life reports that most clean streams in the Appalachian region are naturally dilute with a TDS less than 50 ppm. Therefore, the invertebrates that are present are physiologically adapted to low TDS concentrations. When comparing conductivity in streams with biological diversity, EPA scientists found many mayfly taxa were not present at all or found in lower percentages in streams with increasing conductivity. Mayflies, in many clean streams like that of the Appalachia region and the upper Delaware region can represent 25-50% of abundance and about 1/3 the biodiversity in natural, undegraded streams. They form the base of the aquatic food chain, are important for healthy fish populations and help assimilate organic enrichment in streams. The function of osmoregulation in these animals needs to be protected at these naturally adapted levels if they are to survive. A protective TDS standard needs to be in place to accomplish this.

In the Delaware River, DRBC Special Protection Waters data (north of Trenton) for the main stem and 15 tributaries (1028 samples) show that the minimum TDS reading is 10 ppm, the maximum is 618 ppm, the median is 160 ppm, and the average is 183 ppm. Therefore, in the Delaware River Watershed, background levels for these waters are generally low, which means that discharges have the potential to significantly raise the natural background levels, harming or destroying aquatic life, degrading water quality and reducing biological diversity. In the case where there are multiple TDS discharges to a waterway the likelihood of adverse impact is magnified many fold. DEP must adopt discharge standards that take background conditions into account if the standard is to protect naturally adapted aquatic life. Also, DEP must not allow mixing zones that are hazardous to fish and aquatic life and the ecosystems which they are part.

It is not established that 500 mg/L will not harm aquatic life; some aquatic life are more sensitive and show adverse impacts at 350 mg/L or even less. According to a California study, "Spawning fish and juveniles appear to be more sensitive to high TDS levels. For example, it was found that concentrations of 350 mg/l TDS reduced spawning of Striped bass (*Morone saxatilis*) in the San Francisco Bay-Delta region, and that concentrations below 200 mg/l promoted even healthier spawning conditions."[4] In the Truckee River, the EPA found that juvenile Lahonton cutthroat trout were subject to higher mortality when exposed to thermal pollution stress combined with high total dissolved solids concentrations.[5]

Also, the California State Water Resources Control Board's Quality Criteria states:
"…Hart et al, have reported that among United states waters supporting good fish fauna about 5% have a specific conductivity under 50x10-6 mhos (50 micromhos/cm) at 25 degree C: about 50% under 270x10-6 mhos (270 micromhos/cm); and about 95% under 1100x10-6 mhos (1100 micromhos/cm). While in-stream conductivity may be taken into account in future Chapter 93 rulemaking, these numbers should be considered by DEP in setting Chapter 95 effluent standards as well.

Other Considerations regarding Chapter 95 Standards

WET Testing

DEP should require whole effluent toxicity (WET) testing as part of their wastewater treatment strategy. Acute and chronic WET testing is required by DRBC and others as a method of analyzing the toxicity of the effluent from wastewater facilities. Shale gas drilling wastewater in Pennsylvania contains numerous toxic components.[6] WET testing would provide more information about the level of toxicity and its effects on living things.

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[4] Kaiser Engineers, California, *Final Report to the State of California, San Francisco Bay-Delta Water Quality Control Program*, State of California, Sacramento, CA (1969).

[5] (C.M. Hogan, Marc Papineau et al. *Development of a dynamic water quality simulation model for the Truckee River*, Earth Metrics Inc., Environmental Protection Agency Technology Series, Washington D.C. (1987))

[6] New York State Draft Supplemental Generic Environmental Impact Statement, Chapter 5 and appendices.

How WET testing is accomplished is important in order to accurately reflect the effect of toxics in the waste scream on organisms. EPA scientists are questioning the use of *C. dubia* for the 7-day WET tests that are commonly used to set permit discharges. *C.dubia* are not as sensitive to TDS concentrations as other aquatic species that are found in the receiving streams. In one example, EPA compared the genus level GLIMPSS metric (which directly measures aquatic life use impairment [less than 66] to *C.dubia*. While *c.dubia* thrived at 1000 uS specific conductance, the GLIMPSS organisms were affected negatively and were impaired at this same 1000 uS reading. (See Appendix A, Environmental Protection Agency Power Point) Any WET testing that is required should not employ *C dubia* alone.

Other Contaminants

There are many dangerous constituents in gas drilling wastewater that are not addressed by this proposed rulemaking. Natural gas drilling wastewater is loaded with toxics. In fact, the U.S. Department of Energy says that natural gas drilling wastewater is ten times more toxic than oil drilling wastewater.[7] The New York State Department of Environmental Conservation (NYSDEC) reported that at least 260 "unique chemicals" are used in hydraulic fracturing of the Marcellus shale in Pennsylvania and West Virginia, including formaldehyde, methanol, benzene and benzene derivatives and distillates, glutaraldehyde, ethylene oxide and at least 40 compounds with undisclosed chemicals.[8]

And hundreds of chemical hazards are contained in the flowback or "produced water" after the well is hydraulically fractured. Among the known hazardous constituents are bromide, arsenic, and other metals, benzene and other volatile organic compounds, and radionuclides from Naturally Occurring Radioactive Materials (NORMs) in dangerous amounts, according to NYSDEC.[9]

For example, PADEP acknowledges in its rulemaking that bromide is a key parameter of concern in the effluent because it can form brominated disinfection by-products (DBP's) in water supplies. These are a drinking water hazard because of the propensity for the brominated DBP's to "increase[s] overall DBP concentrations, specifically trihalomethanes (THMs)", which can cause cancer.[10] Yet bromide is not being regulated in this rulemaking or in any other rulemaking.

Another example is benzene, a known carcinogen regulated by EPA that is present in both flowback due to its presence in deep geologic formations and in hydraulic fracturing fluid. Yet benzene is not addressed in this rulemaking either. A third example are normally occurring

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[7] U.S. Dept. of Energy, Argonne National Laboratory, "A White Paper Describing Produced Water from Production of Crude Oil, Natural Gas, and Coal Bed Methane", January 2004, p. 4.
[8] New York State Department of Environmental Conservation, Division of Mineral Resources, "Draft Supplemental Generic Environmental Impact Statement on the Oil, Gas, and Solution Mining Regulatory Program", September 2009, 5-35 and 5-45.
[9] NYSDEC Draft Supplemental Generic Environmental Impact Statement on the Oil, Gas, and Solution Mining Regulatory Program (DSGEIS), 2009, Tables 5-8 and 5-9, p. 5-109.
[10] PADEP "Permitting Strategy for High Total Dissolved Solids (TDS) Wastewater Discharges", April 11, 2009.

radioactive materials or NORMs – radium 226, a highly dangerous derivative of uranium, was found by NYSDEC to be in Marcellus wastewater in amounts thousands of times greater than is considered safe in drinking water. Other radionuclides were also found in the water sampled from Pennsylvania and West Virginia.[11] These radioactive materials must be regulated in order to protect water quality, whether in the water column or in solids.

Additionally, we know that many other anions and cations will be present in the gas drilling wastewater in addition to conductivity that can affect aquatic life as well as water supplies. In order to adequately protect fish and aquatic life, these toxic substances must be removed.

These and the hundreds of other pollutants in gas drilling wastewater need to be included in Chapter 95 rulemaking in order to protect our streams, rivers, and water supplies from degradation and pollution.

There is no attempt to regulate the recycling or re-use of flowback and hydraulic fracturing fluids that are produced at the gas well site; some companies are already reusing these fluids and the concentrations and amounts of contaminants in these fluids are not being tracked or regulated—this is a HUGE loophole that must be closed to protect our water quality. Discharge standards should be applied to re-used fluids and consideration of the applicability of Underground Injection Control regulations must be made. The present practice of re-use without DEP regulation should be stopped immediately until the potential impacts of re-use of this chemical-laden water can be made and consistent treatment requirements for all re-used or recycled water implemented state-wide.

Solids

Many pollutants of concern will attach to solids in the wastewater processing facility. NORMs, salts, and other dangerous constituents will contaminate the wast amount of solids that are daily produced at these facilities. DEP must plan now for the safe disposition of these contaminated solids to avoid a repeat of the disgraceful legacy of coal mining and coal fired power plants which have left millions of piles or basins of polluted solids throughout the state, steadily leaching or volatilizing hazardous pollutants to the water and air. To allow this new breed of industrial wastewater treatment to begin without addressing the inevitable contaminated solids that will need special handling and processing is irresponsible and will lead to further environmental degradation in Pennsylvania.

Monitoring

In addition to accurate sampling and frequent or continuous monitoring of effluent, sampling of the constituents of the incoming wastewater must be required due to the variable nature of the shale gas drilling waste stream. This information should be recorded and made easily available to local communities, downstream water providers, and the public. Also, stream monitoring of the receiving waterway should be required in order to provide real time data to the public and other interested parties, including recreational users of receiving waterways. . This real-time data should be made available on line to the public, should include appropriate water chemistry readings collected by automatic data loggers (and supplemented with lab analysis for specific

[11] NYSDEC Draft Supplemental Generic Environmental Impact Statement on the Oil, Gas, and Solution Mining Regulatory Program (DSGEIS), 2009, Tables 5-8 and 5-9, p. 5-109.

anions and cations found in the wastewater), and should also include annual macroinvertebrate studies and other aquatic life studies to ensure aquatic life are not harmed or degraded due to this industry and the enormous amounts of wastewater being discharged.

There are many systems in place now on streams in the state that make data available to the public; the information should be posted on a website or other readily available location. The discharger and/or the natural gas industry should pay for agency personnel time, monitoring equipment, lab analysis, equipment installation and maintenance, database system development and data entry, and any other costs associated with monitoring - working in partnership with state monitoring agencies to establish a protective network of monitoring stations that will wholly ensure all streams affected by the discharge and the mining activities and footprints themselves are monitored adequately.

The amount of water being consumed at the well bore (lost underground during well development and fracturing), re-used, and carried to each discharge facility, is not being adequately tracked. The depletive loss of fresh water, 2-9 millions of gallons per gas well, will take its toll on our water resources and the discharge of the wastewater will also. We need this data to accomplish effective water resource planning and management. Discharge standards should require an accurate accounting and tracking from beginning to end by industry of the quantities of fresh water, re-used or recycled water and discharged wastewater. This paper trail should be readily available to the public.

Due to the variable nature of gas drilling wastewater, continuous sampling and monitoring of the constituents of the wastewater must be required, and treatment adjusted based on the components present.

In Closing

It is critical that DEP stop issuing all natural gas development permits, including drilling permits and wastewater discharge permits, and that the discharge of gas drilling and other high-TDS wastewater cease until protective effluent standards are adopted by DEP and the waste products/solids associated with treatment are also clearly regulated and minimized that will prevent pollution and degradation of the Commonwealth's waterways, water resources, and water supplies.

Thank you for the opportunity to comment on these proposed revisions to Chapter 95.

Sincerely,

Maya K. van Rossum	Tracy Carluccio	Faith Zerbe
the Delaware Riverkeeper	Deputy Director	Monitoring Director

Attachments: Appendix A: Environmental Protection Agency Region 3 Power Point

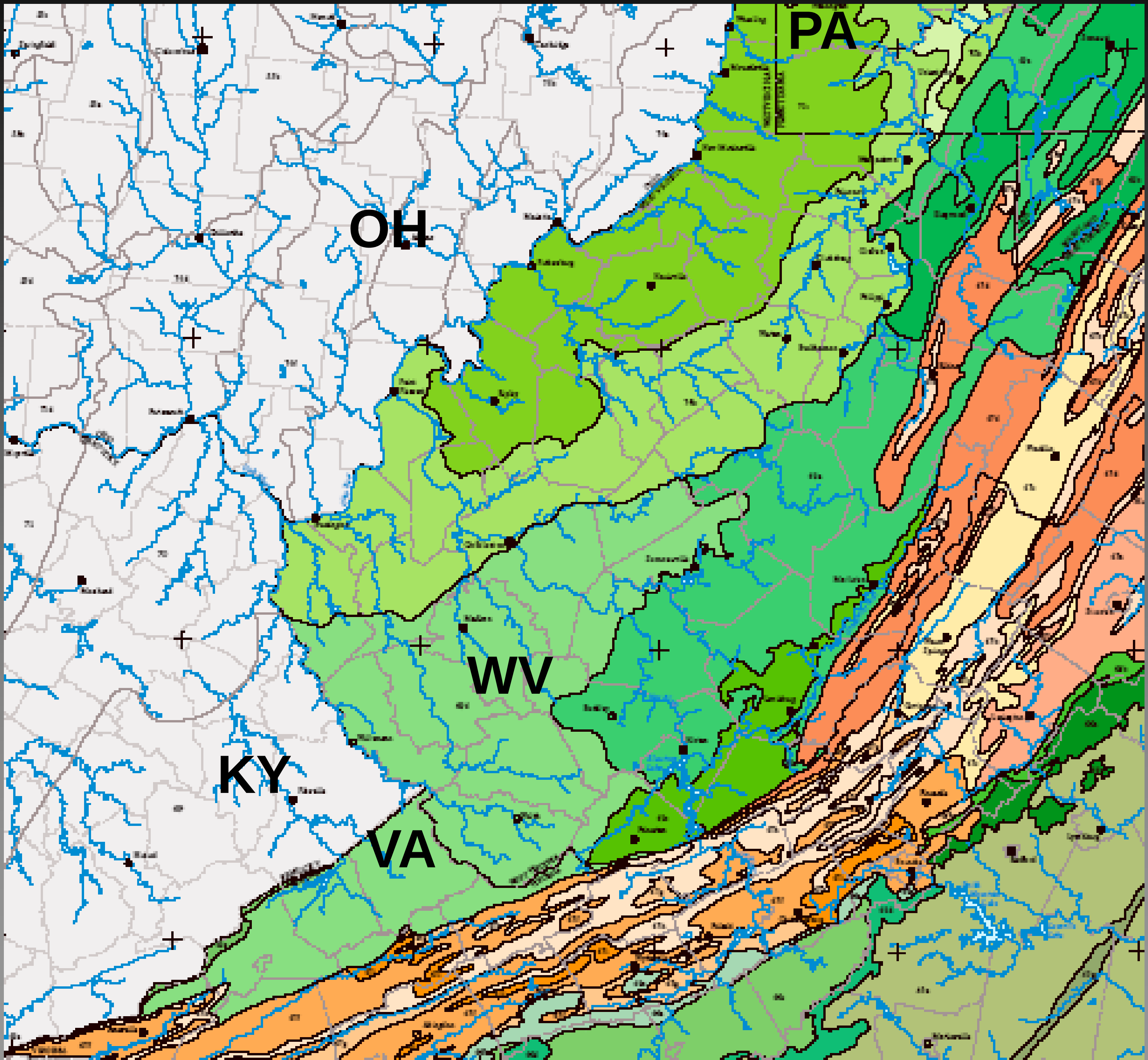
APPENDIX A

U.S. Environmental Protection Agency Region 3 TDS Webinar Power Point
Attached as Adobe file

Water Chemistry associations with benthic macroinvertebrates:

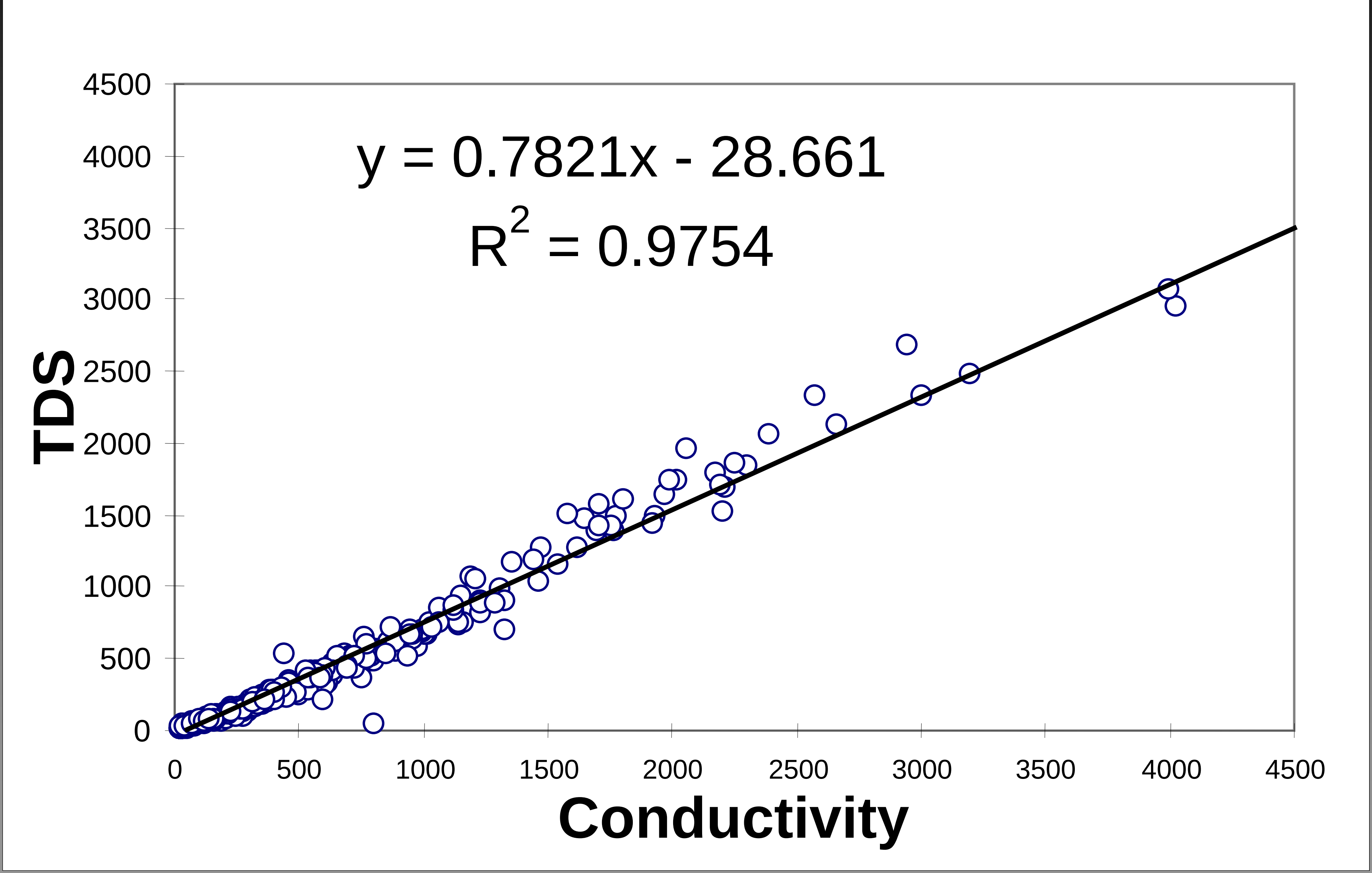
Ionic Stress

US EPA Region 3
Freshwater Biology Team
Wheeling, WV

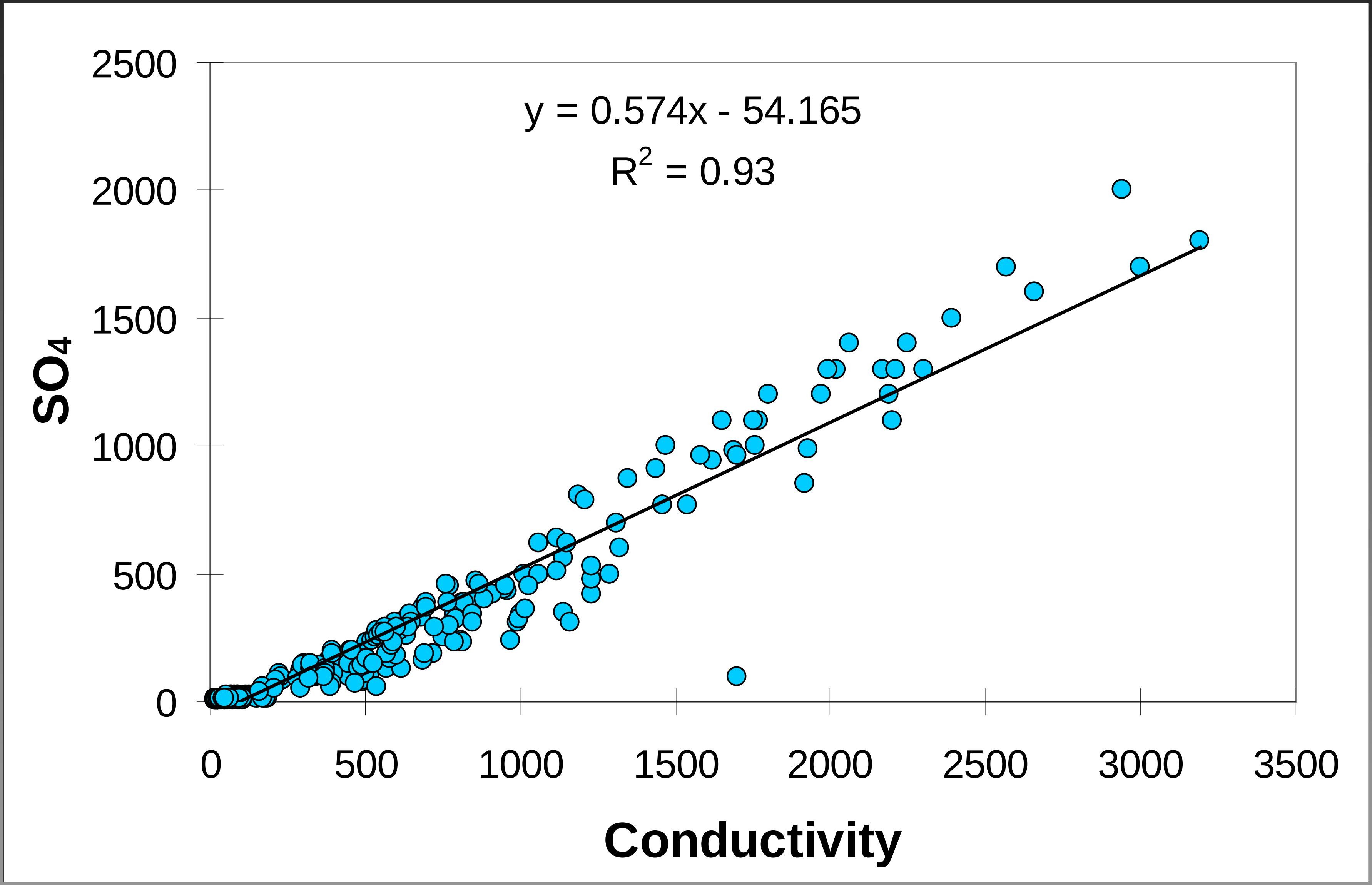

PA
OH
WV
KY
VA

Effluent Dominated Streams

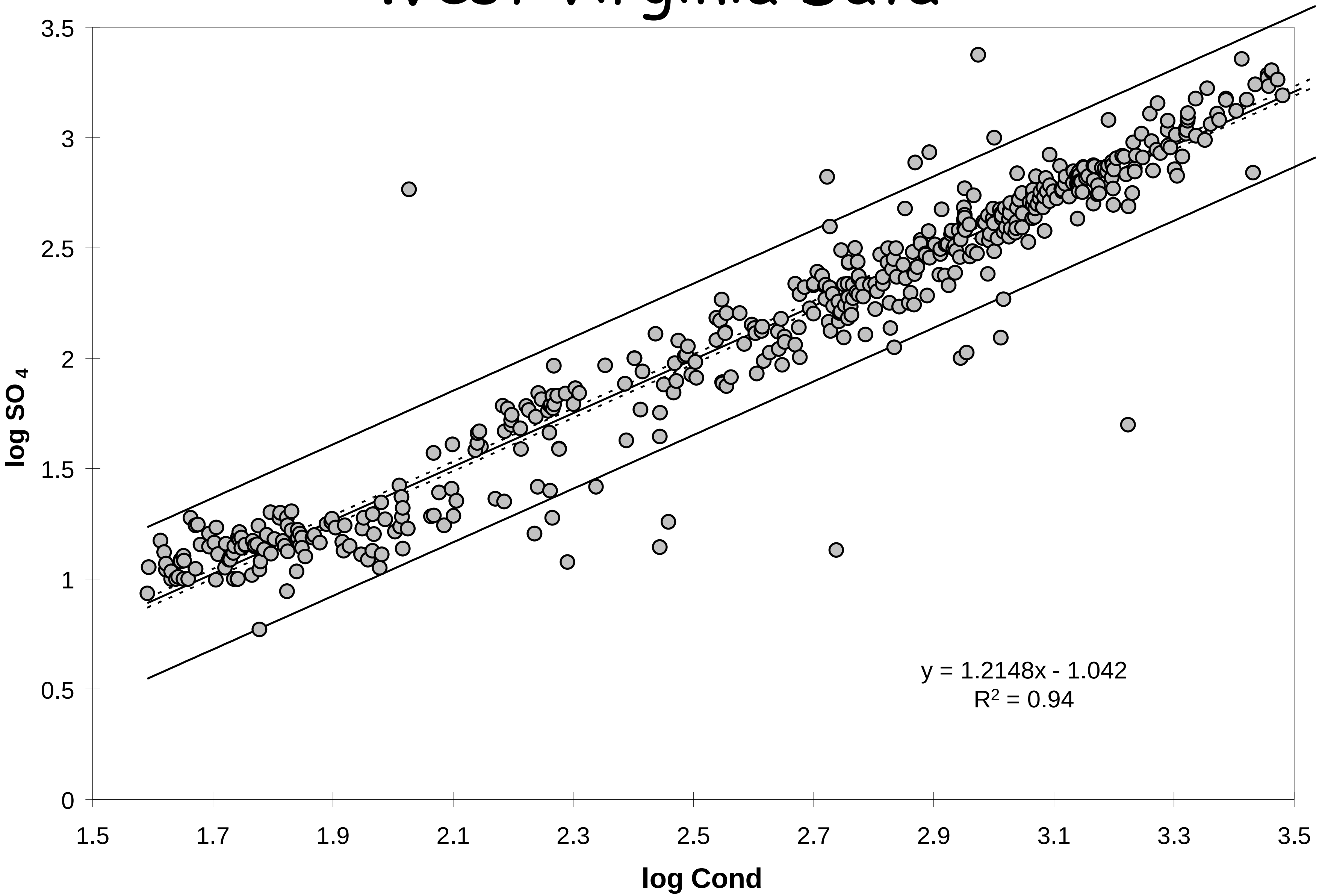
A tight relationship exists

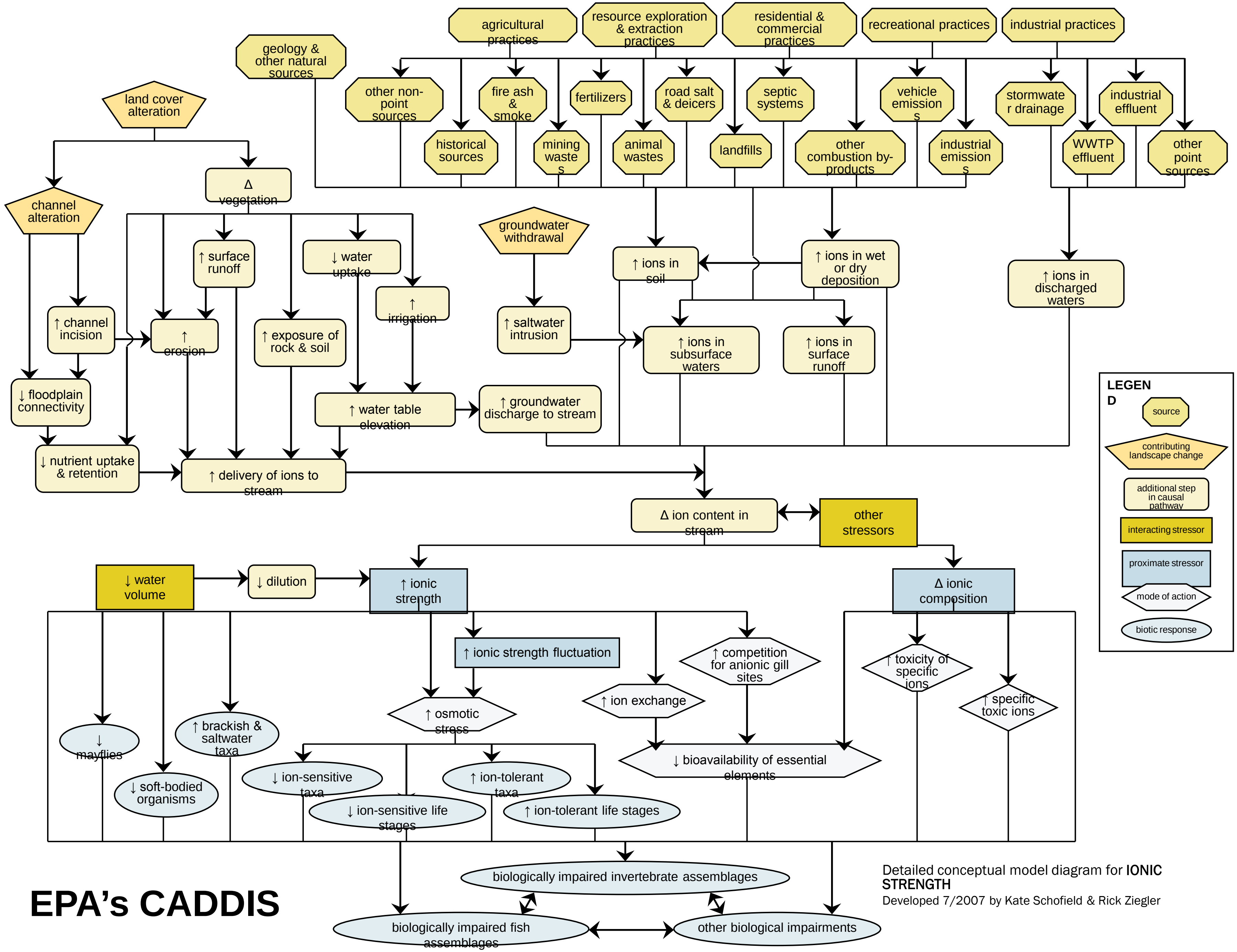


Sulfate vs Conductivity (Kentucky Data)



West Virginia Data



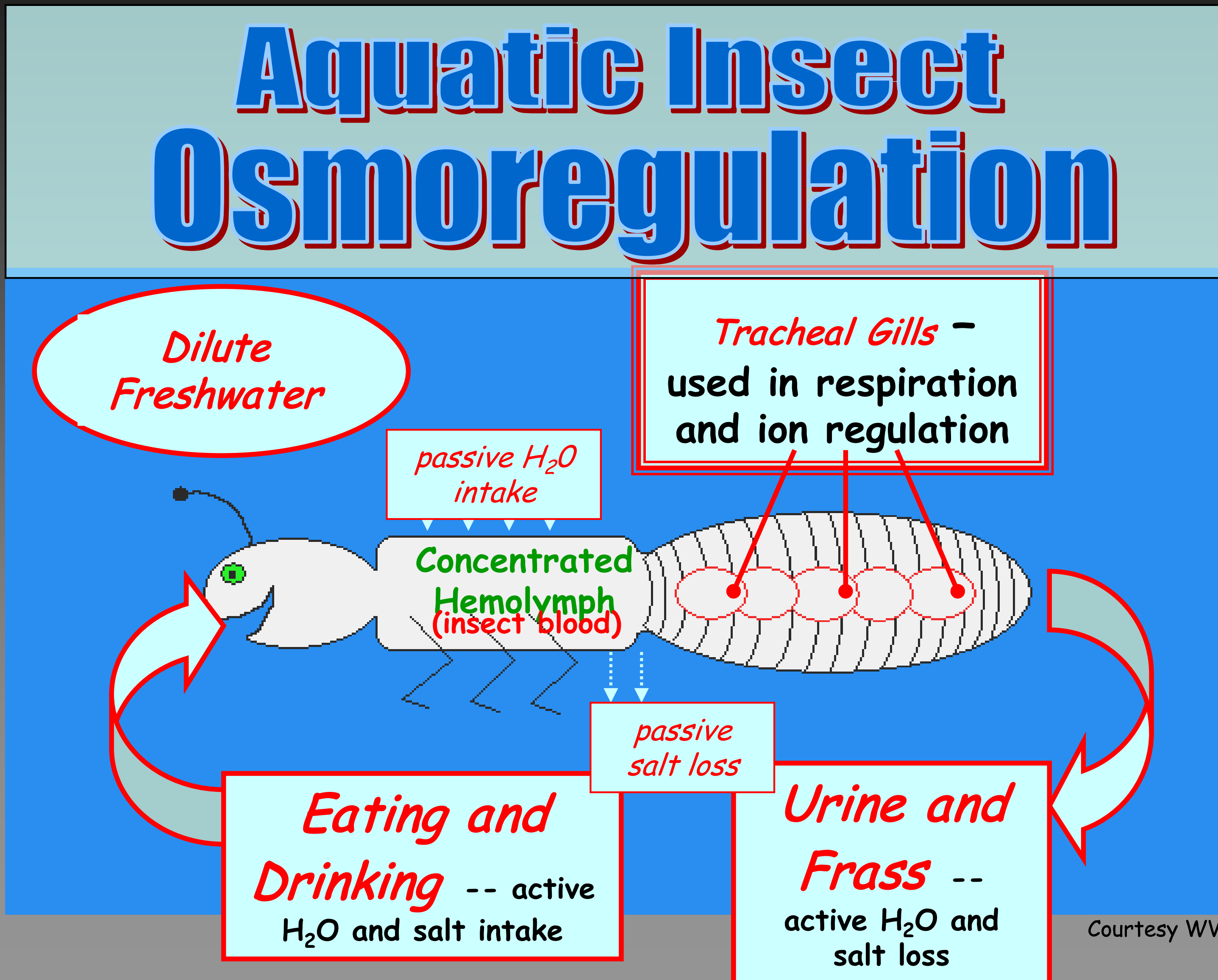


EPA's CADDIS

Detailed conceptual model diagram for **IONIC STRENGTH**

Developed 7/2007 by Kate Schofield & Rick Ziegler

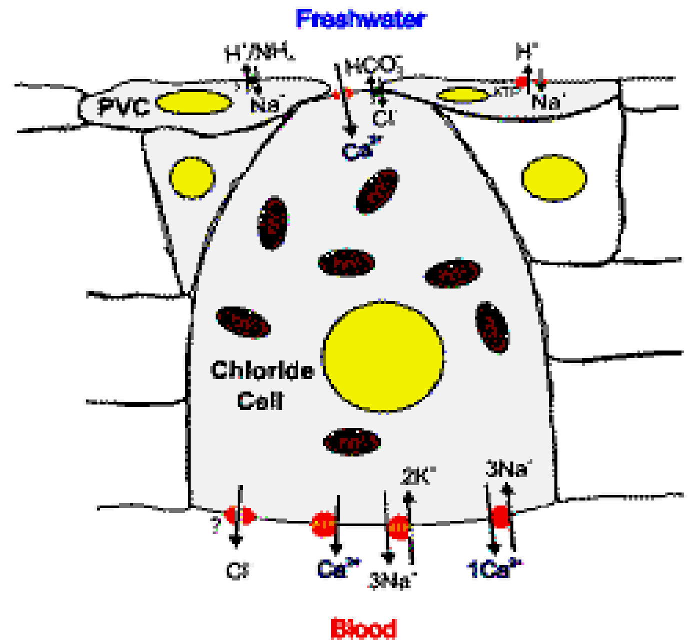
Potential Mechanism



Courtesy WVDEP

Tracheal Gills and Active Ion Uptake

Gill surfaces are covered in chloride cells, the site of ion exchange



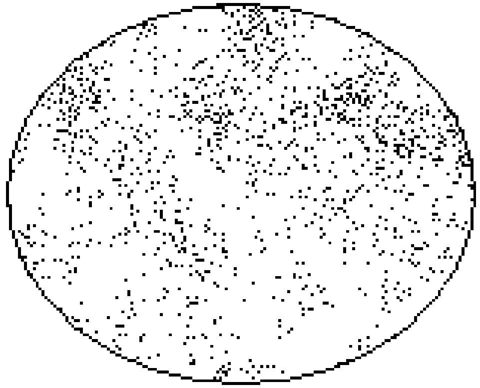
1. Certain species can regulate the number of active cells
2. Within a species, the number of active cells is inversely related to the salinity of the medium
3. Species with abundant chloride cells appear vulnerable due to overexposure to various ions

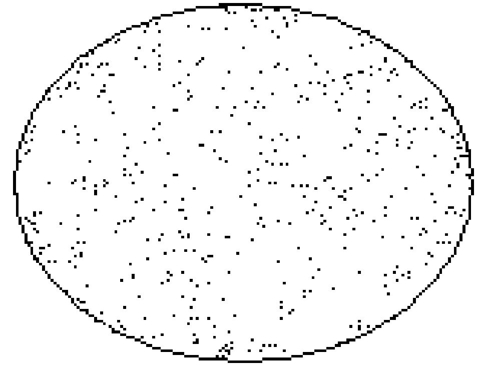
Courtesy WVDEP

Vulnerable/Specialists

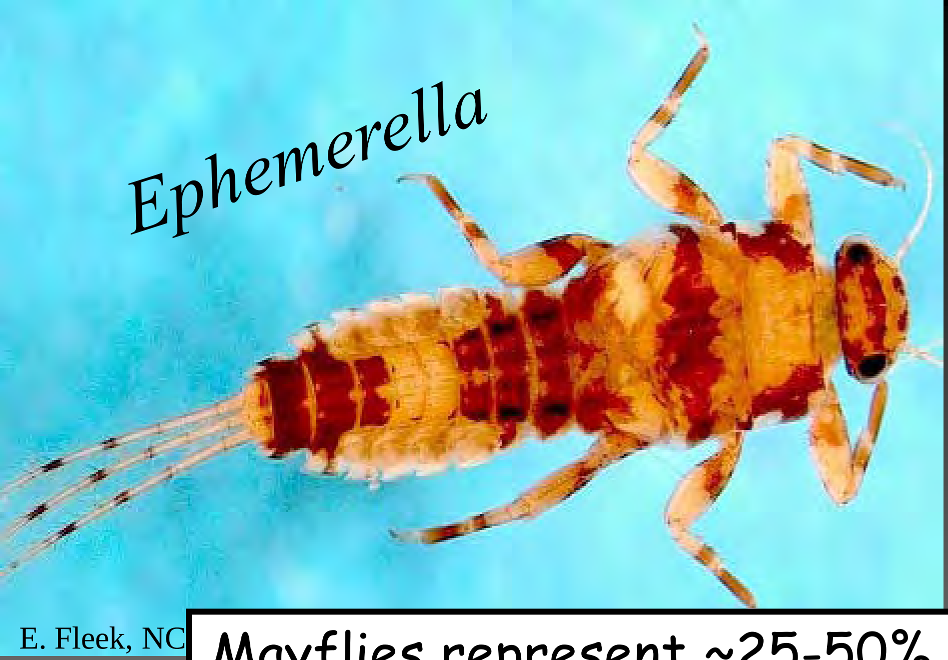
Tolerant/Generalist

High Chloride Cell Density





Low Chloride Cell Density



Mayflies represent ~25-50% of Abundance; ~1/3rd biodiversity
In natural, undegraded Appalachian streams

Some have argued…

Mayflies for Caddisflies

Brookies for Bullheads

Empirical Data are Compelling

- Even in the absence of other stressors (pH, organic enrichment, habitat quality, metals) TDS/conductivity significantly explains impairment of aquatic life use
- Empirical data are being used to develop nutrient and sediment criteria. Why not TDS/conductivity criteria?
- “Total” Dissolved Solids incorporates potential for additive effects from several potentially toxic ions.

EPA EIS data (WV)

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

Mayfly Chemical Relationships

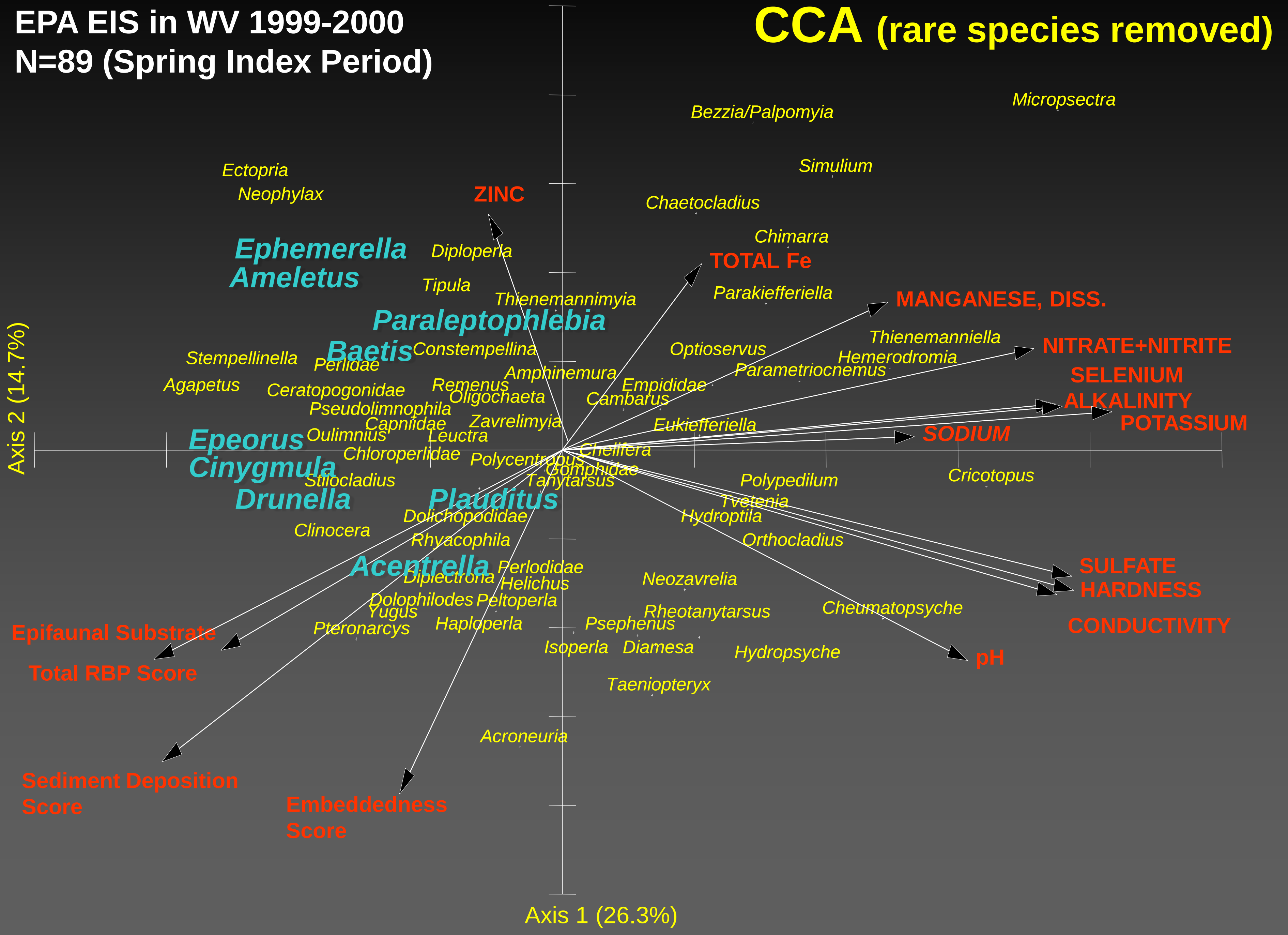
Spearman's Correlation Coefficients

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**

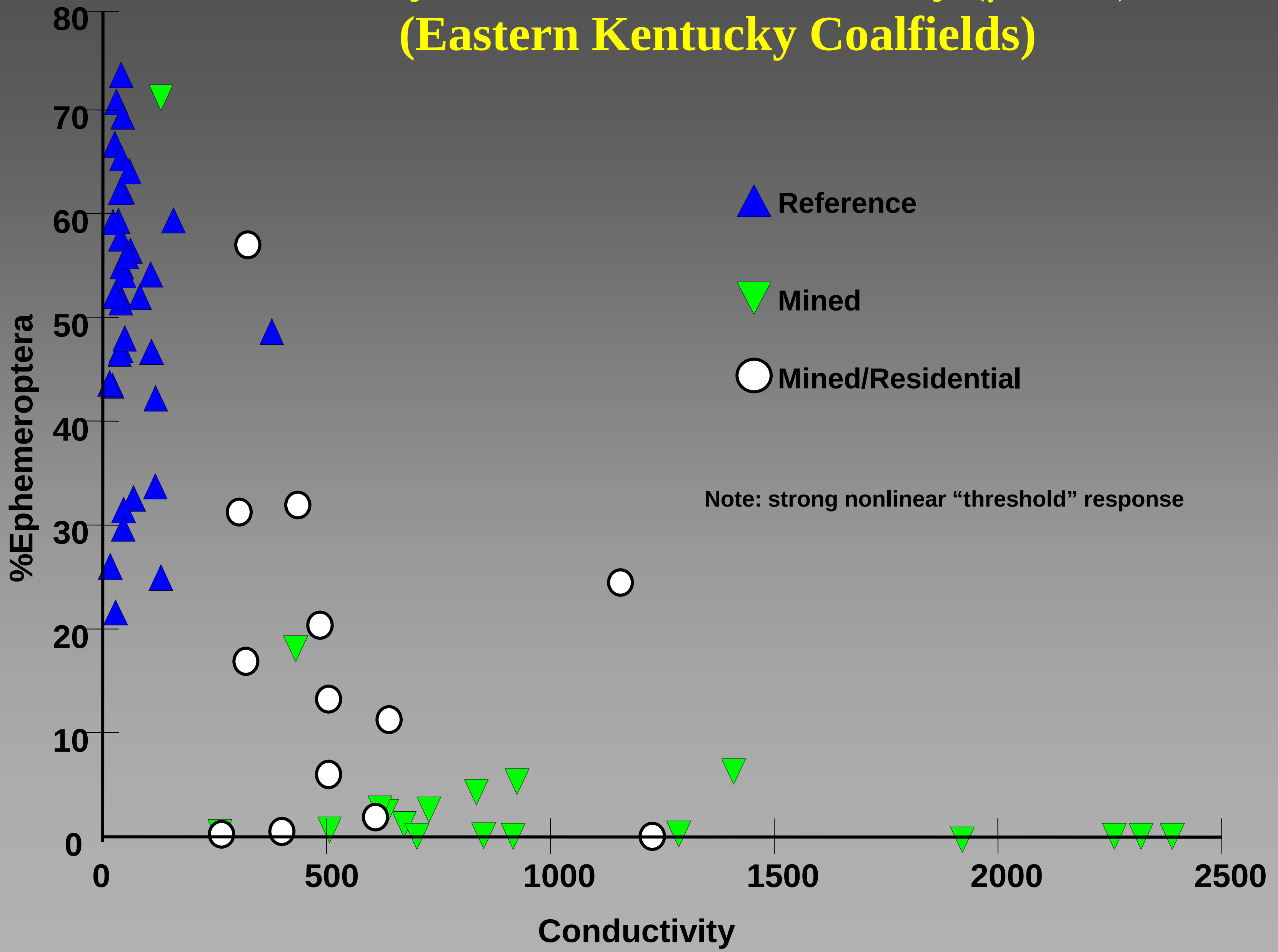
bold values = $p<0.05$

EPA EIS in WV 1999-2000
N=89 (Spring Index Period)

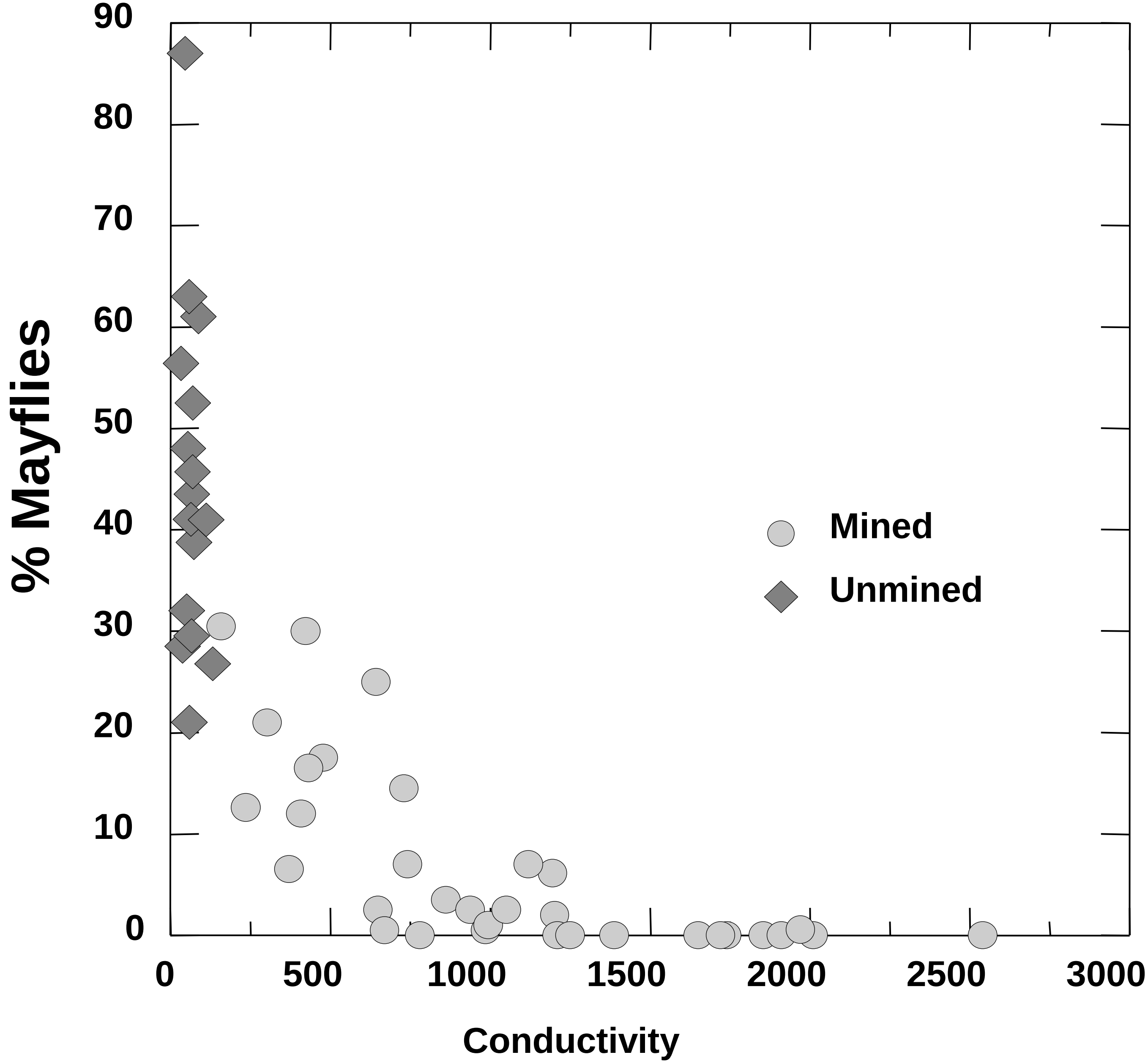
CCA (rare species removed)



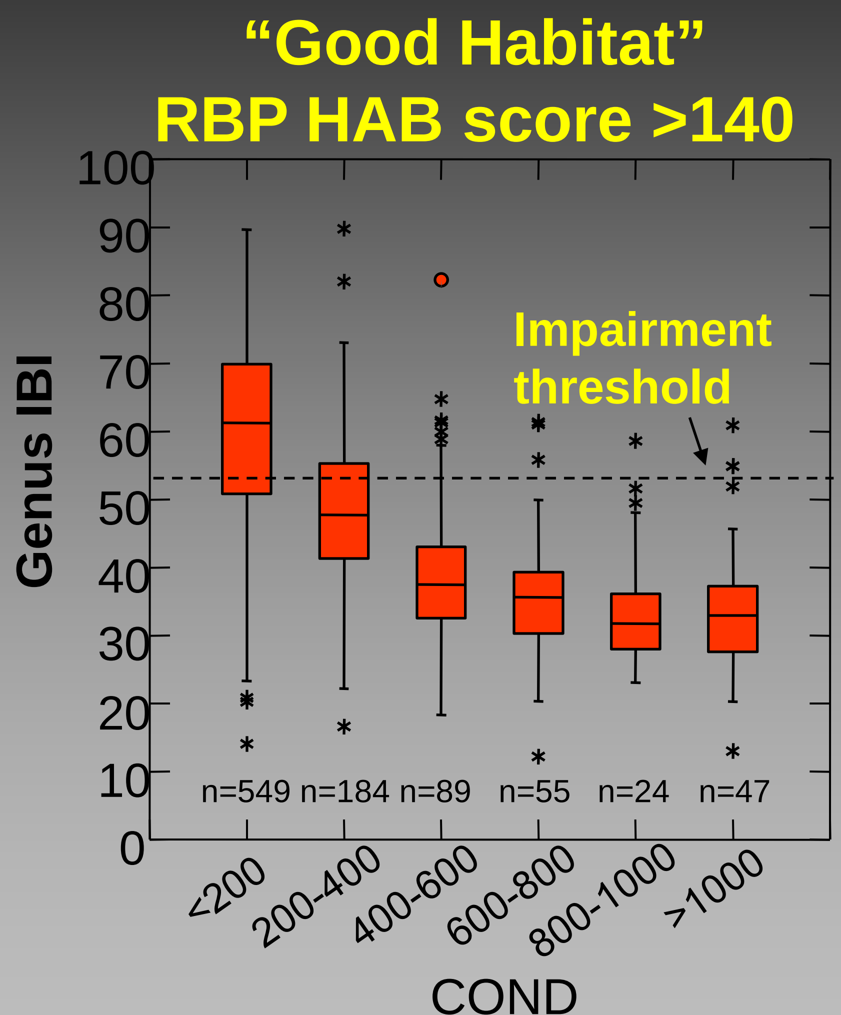
%Mayflies Versus Conductivity (µS/cm) (Eastern Kentucky Coalfields)



EPA Data (West Virginia MTM Region)



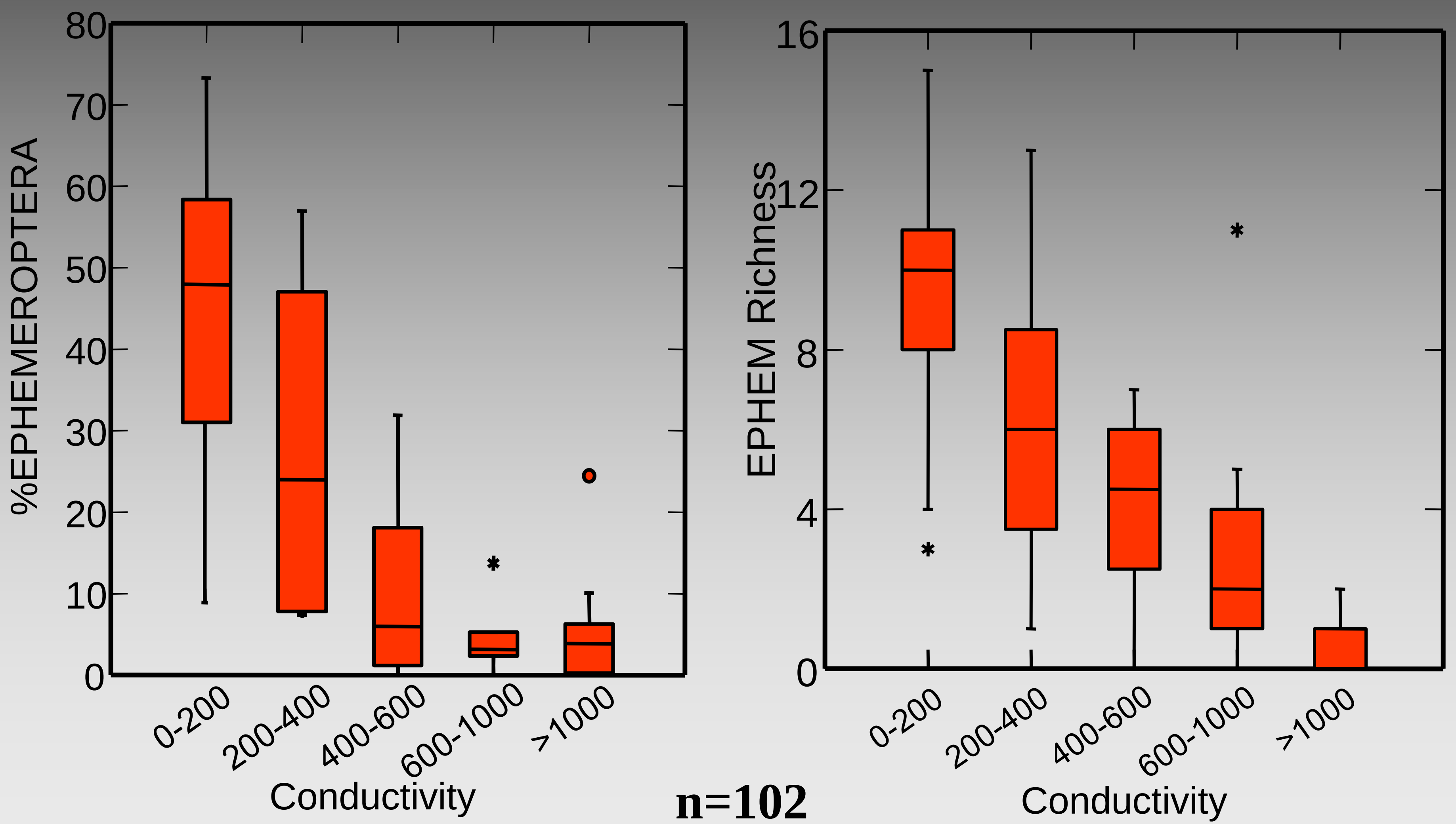
WV DEP Data (Summer; pH>6)
Central Appalachian/Ridge and Valley Bioregion



N=949 Sites

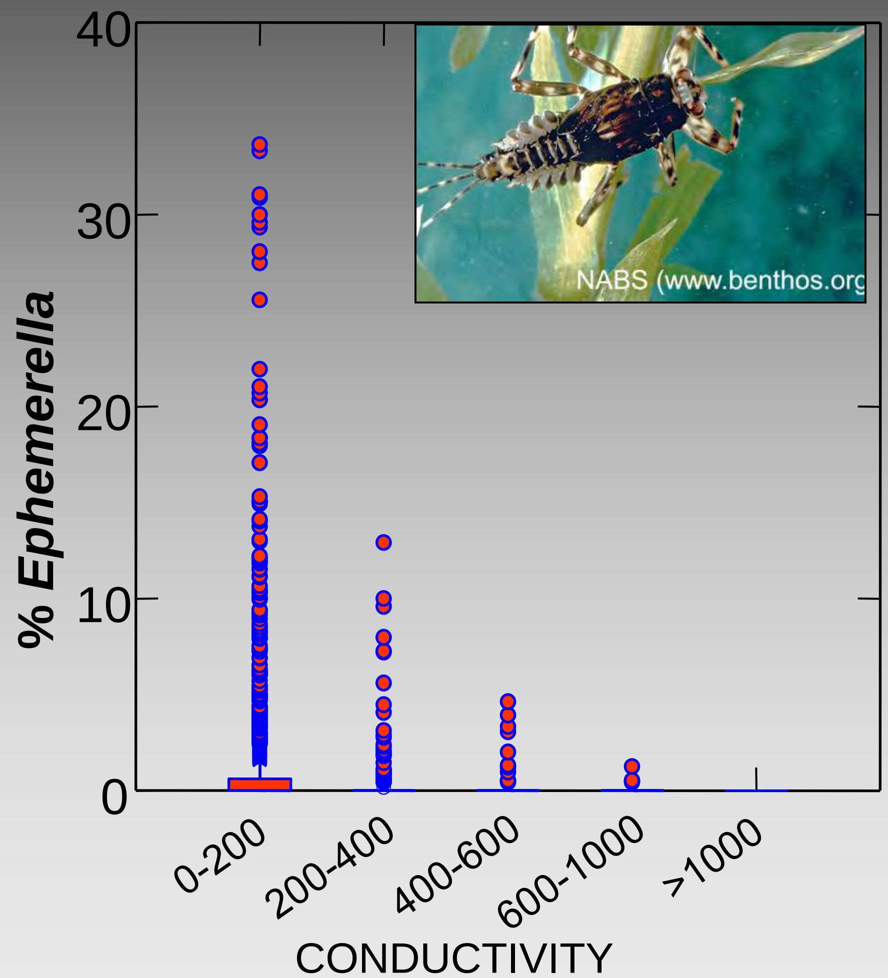
95% of sites >400 µS/cm impaired

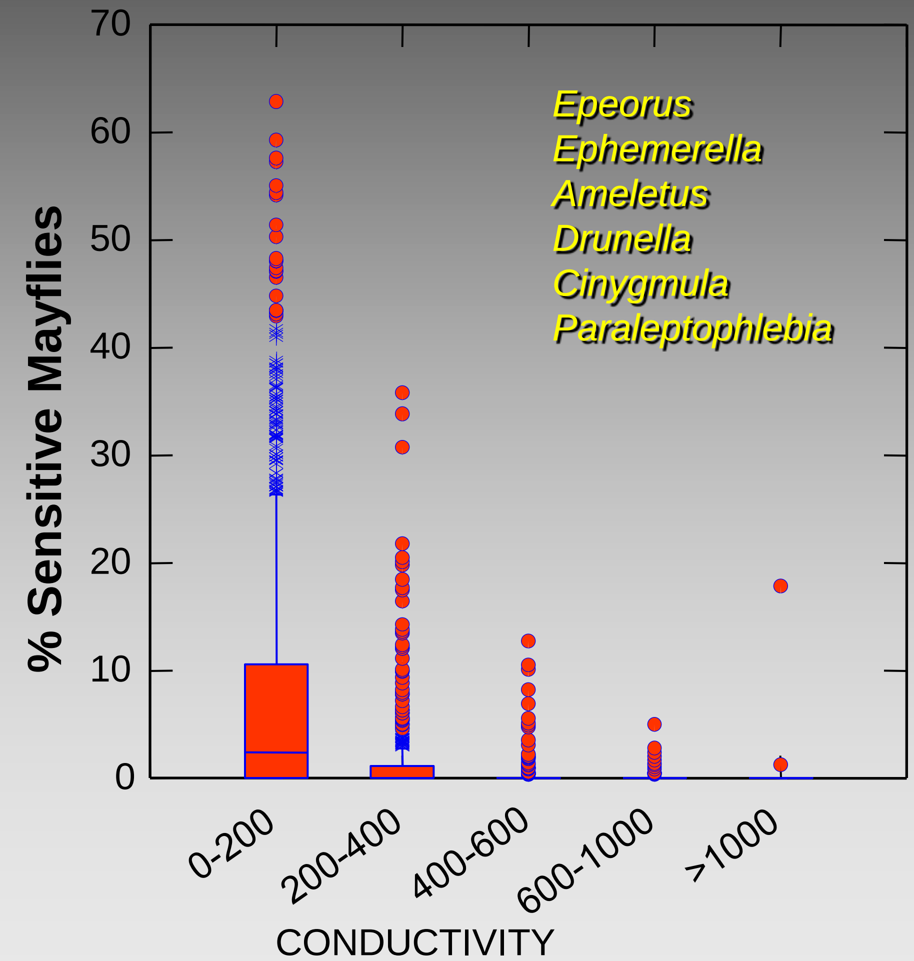
Mayfly Response to Elevated Conductivity in Eastern Kentucky Streams



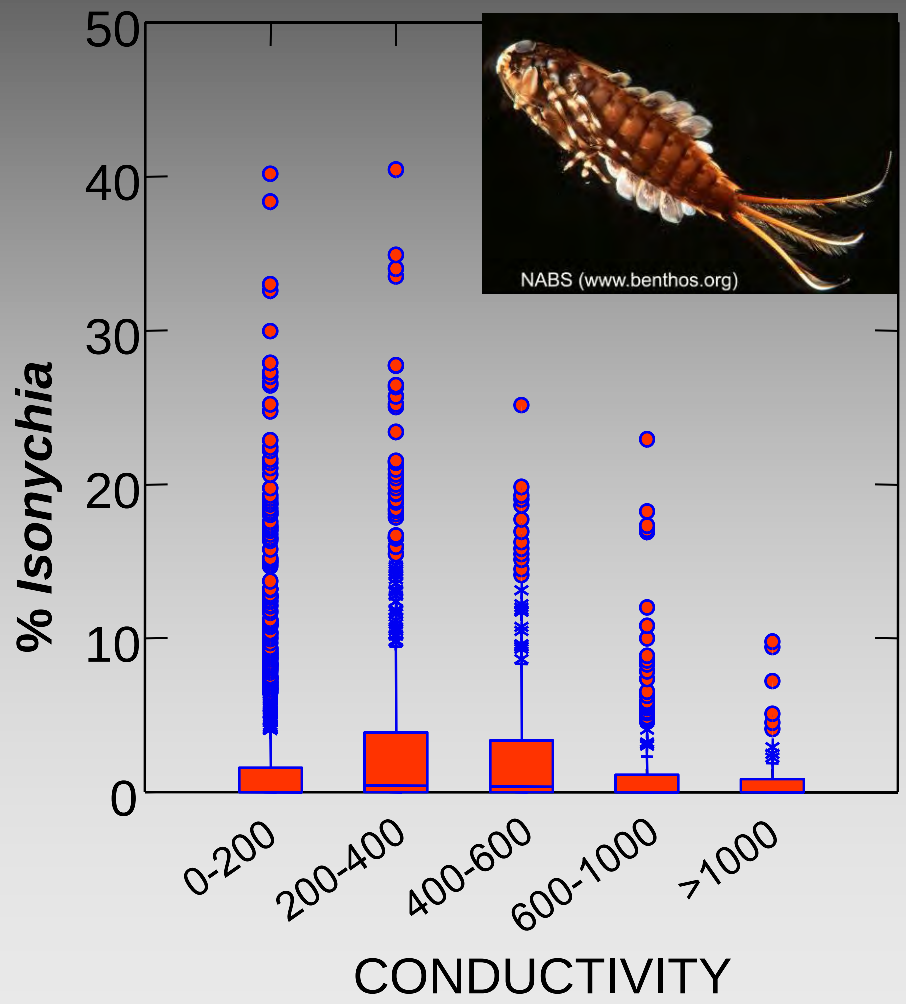
n=102

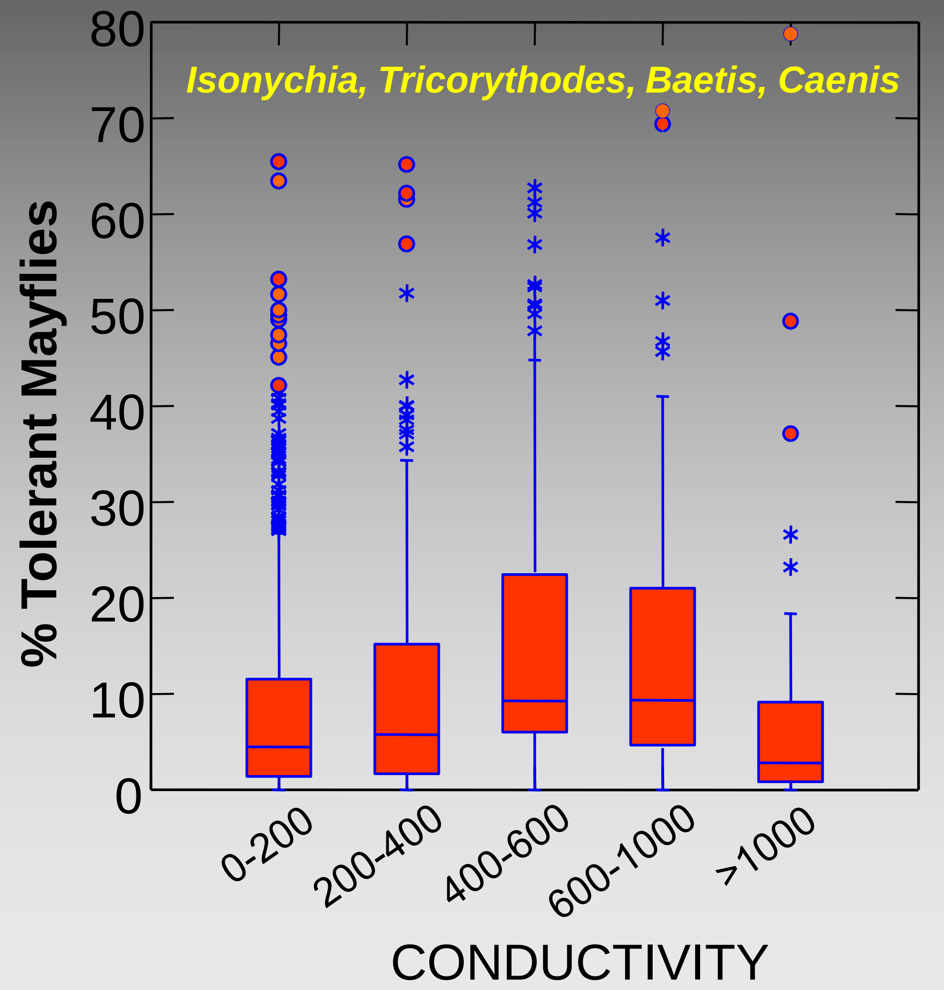
Mayflies and Conductivity (WV data)
Sensitive Types



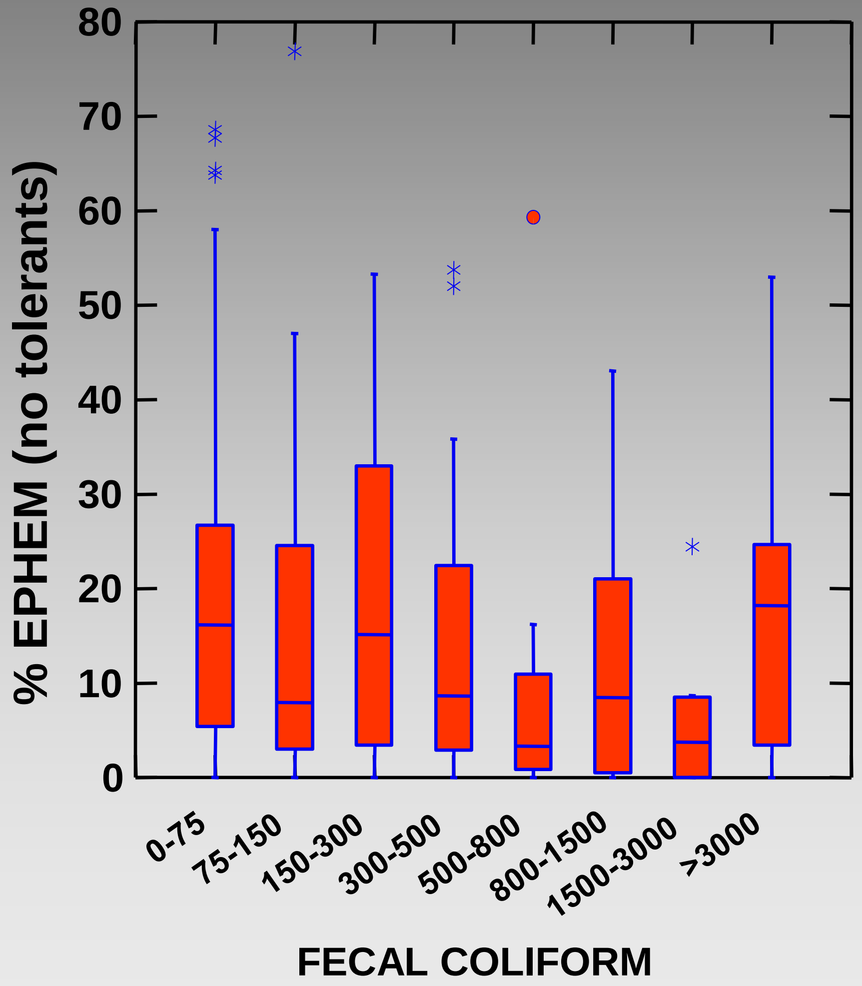


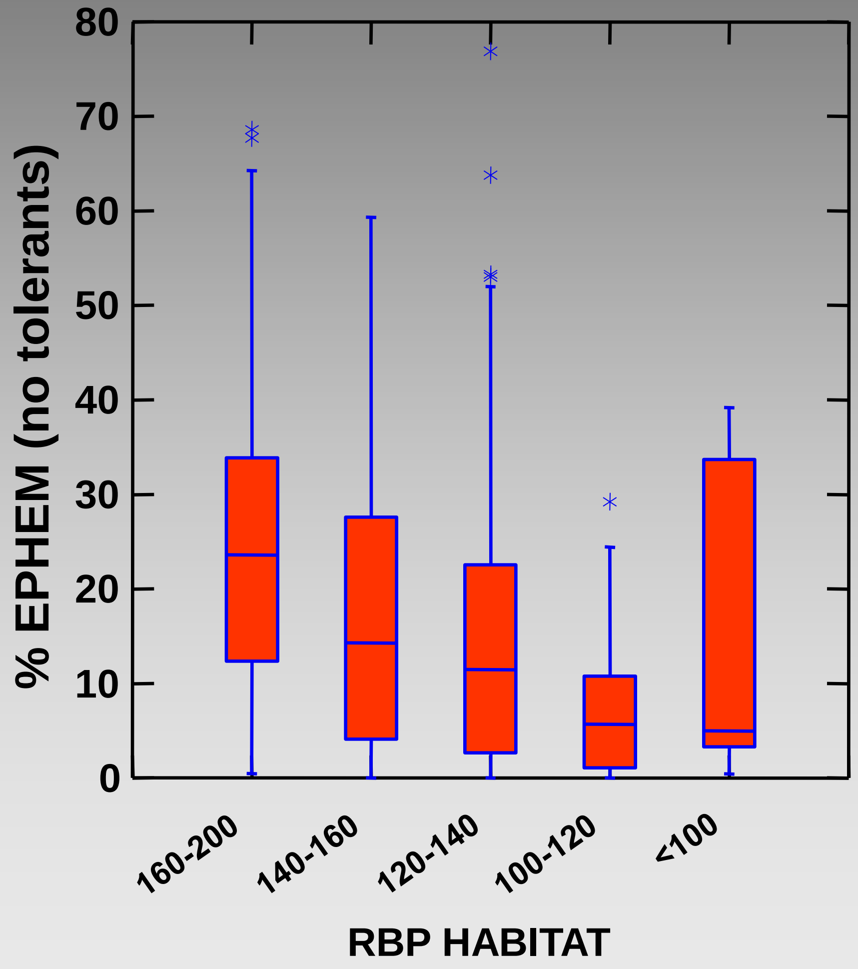
Mayflies and Conductivity (WV data)
Facultative/Tolerant Types





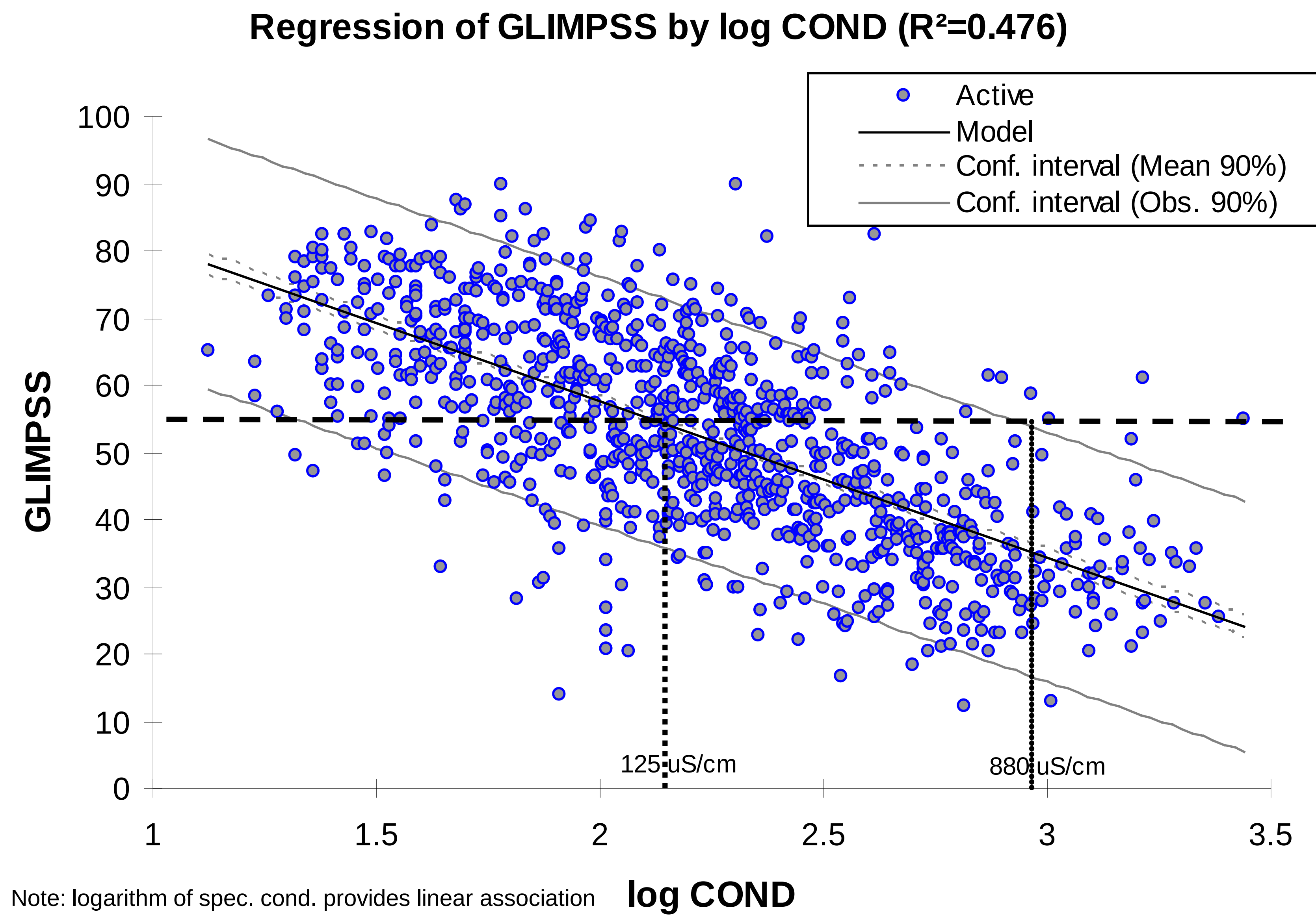
Sensitive Mayfly Responses (or lack thereof): WV data





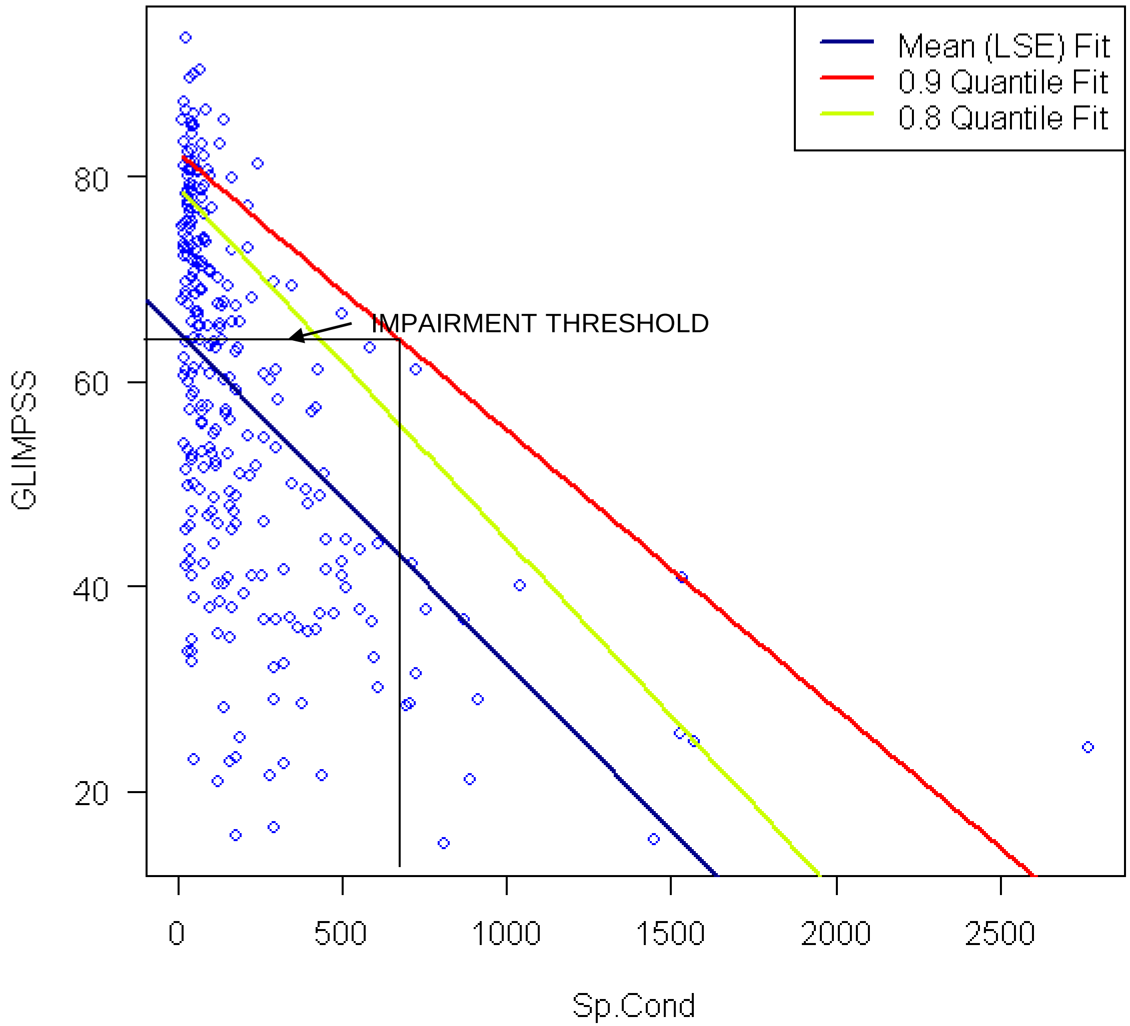
Possible techniques for establishing criteria with empirical datasets

- Regression
- Quantile Regression
- Conditional Probability
- Regression Trees
- Change Point Analysis



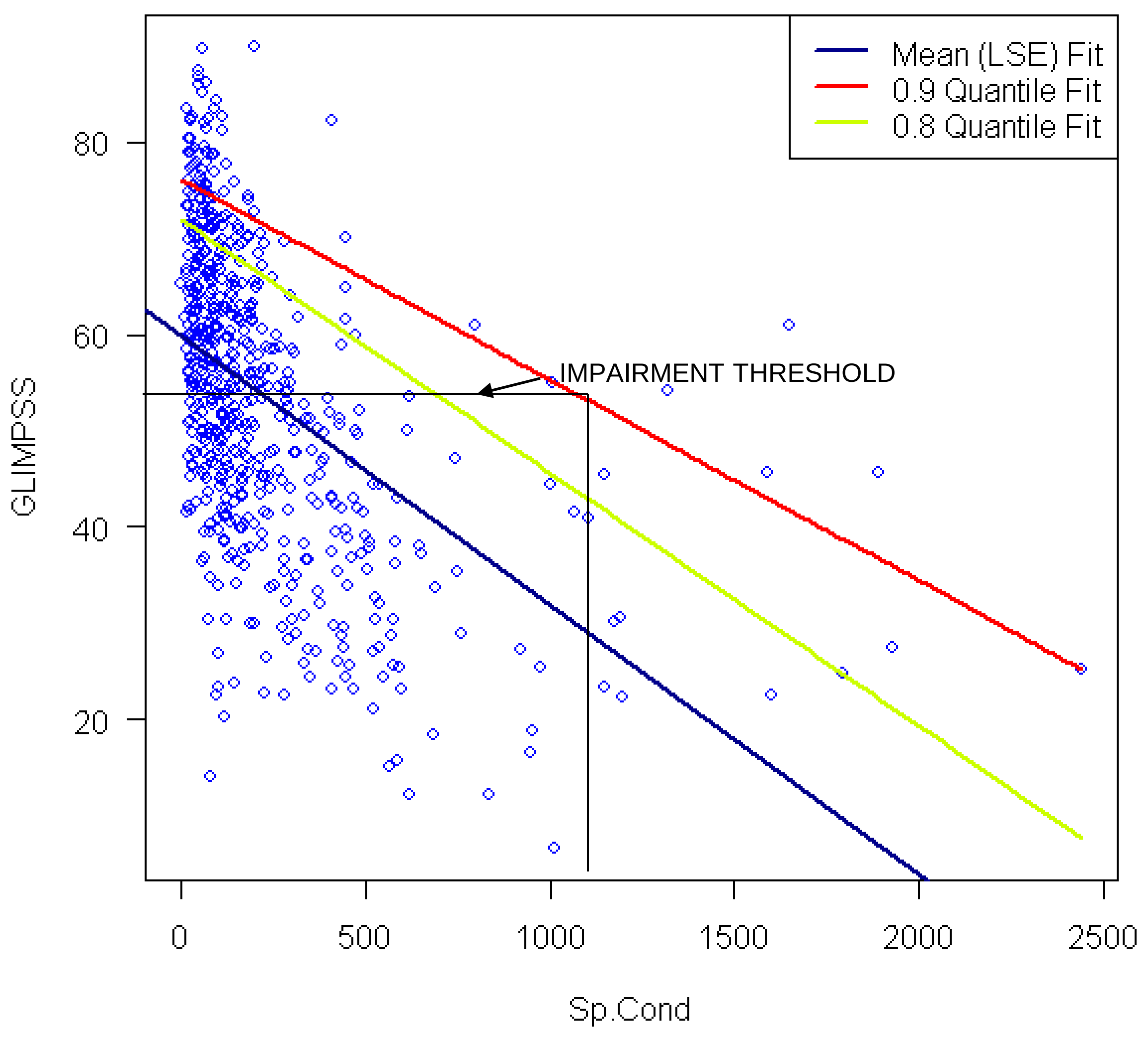
Note: logarithm of spec. cond. provides linear association

WV DEP data: Spring
Quantile Regression Approach



N=276

WV DEP data: Summer
Quantile Regression Approach



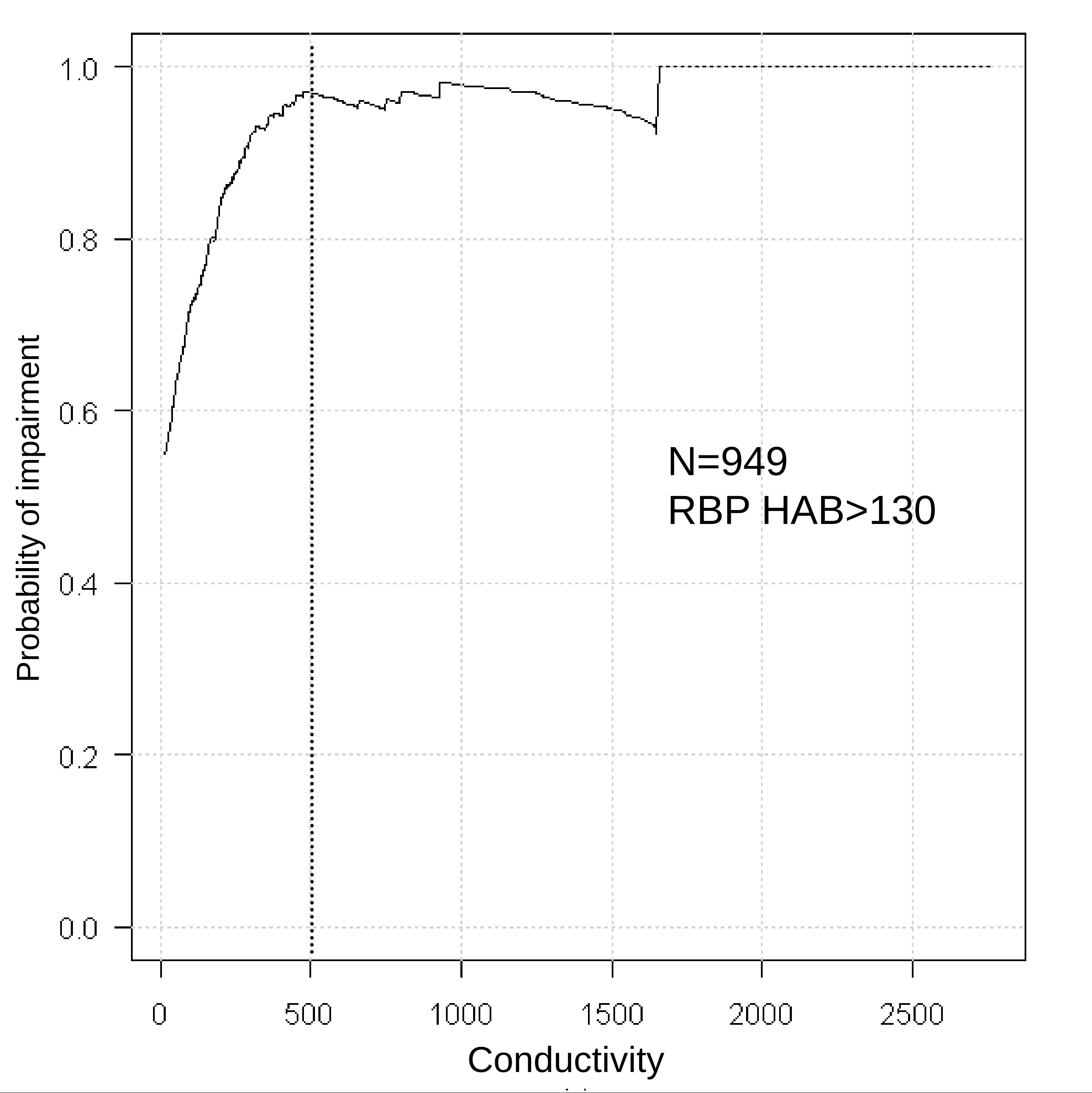
N=535

Conditional Probability Approach

Paul and McDonald (2005)

- CPA relies on a large dataset to develop criteria.
  - Simply asks "what is the probability of event y given exceedence of stressor x"?
    - P(y|x) where y is impairment threshold (IBI), and x is some TDS or conductivity value.
- EPA researcher (J.Paul, RTP, in review) found 100% chance of MAHA sites being impaired with conductivity >575 and 100% chance of Florida streams impaired >750
- Caveat: random sites don't pick up complete gradient of conditions; however, this method doesn't necessarily require random data.

WV DEP data: Summer pH>6



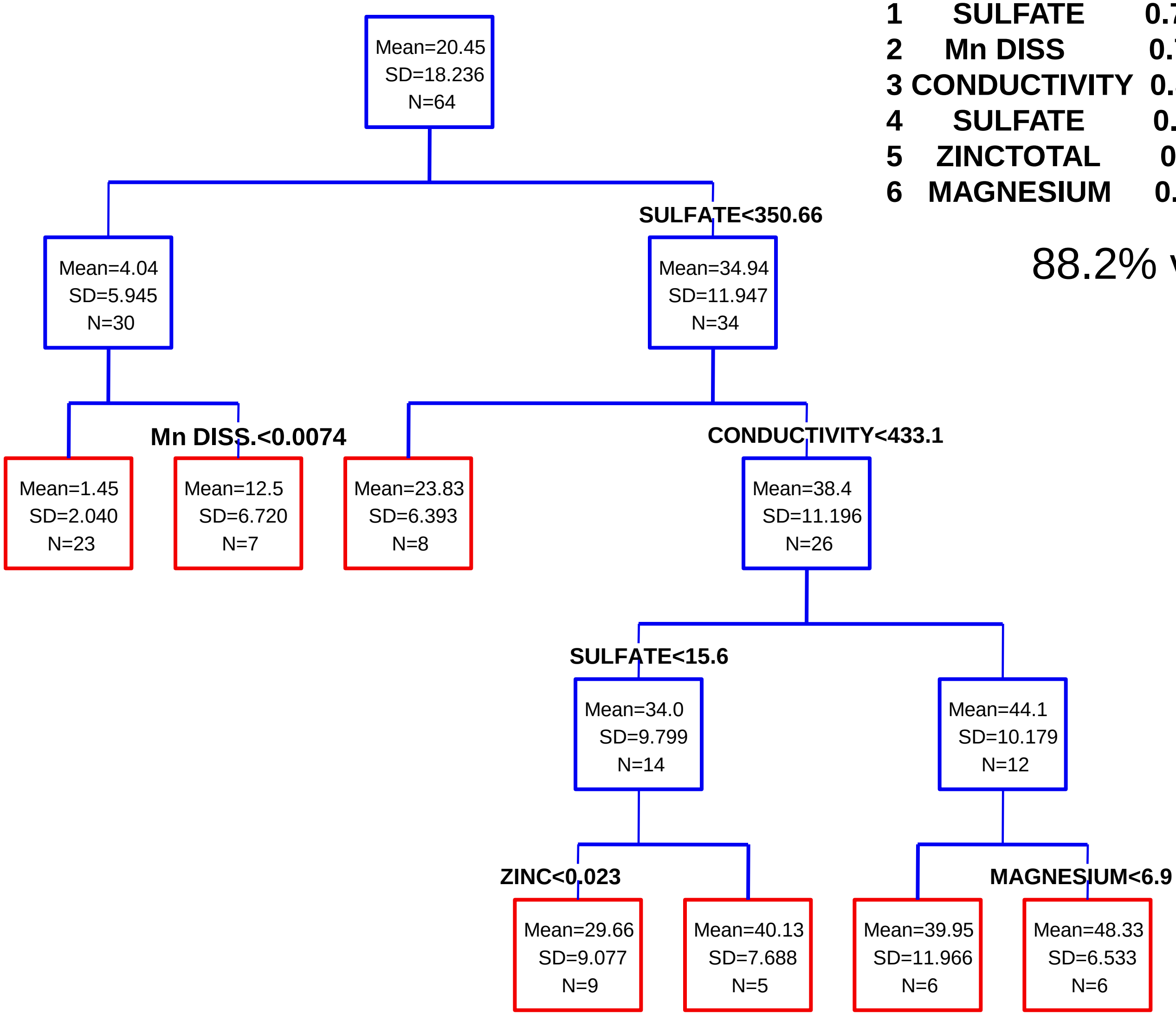
All Ions, Metals, pH, Hardness

Regression Tree from EPA EIS dataset

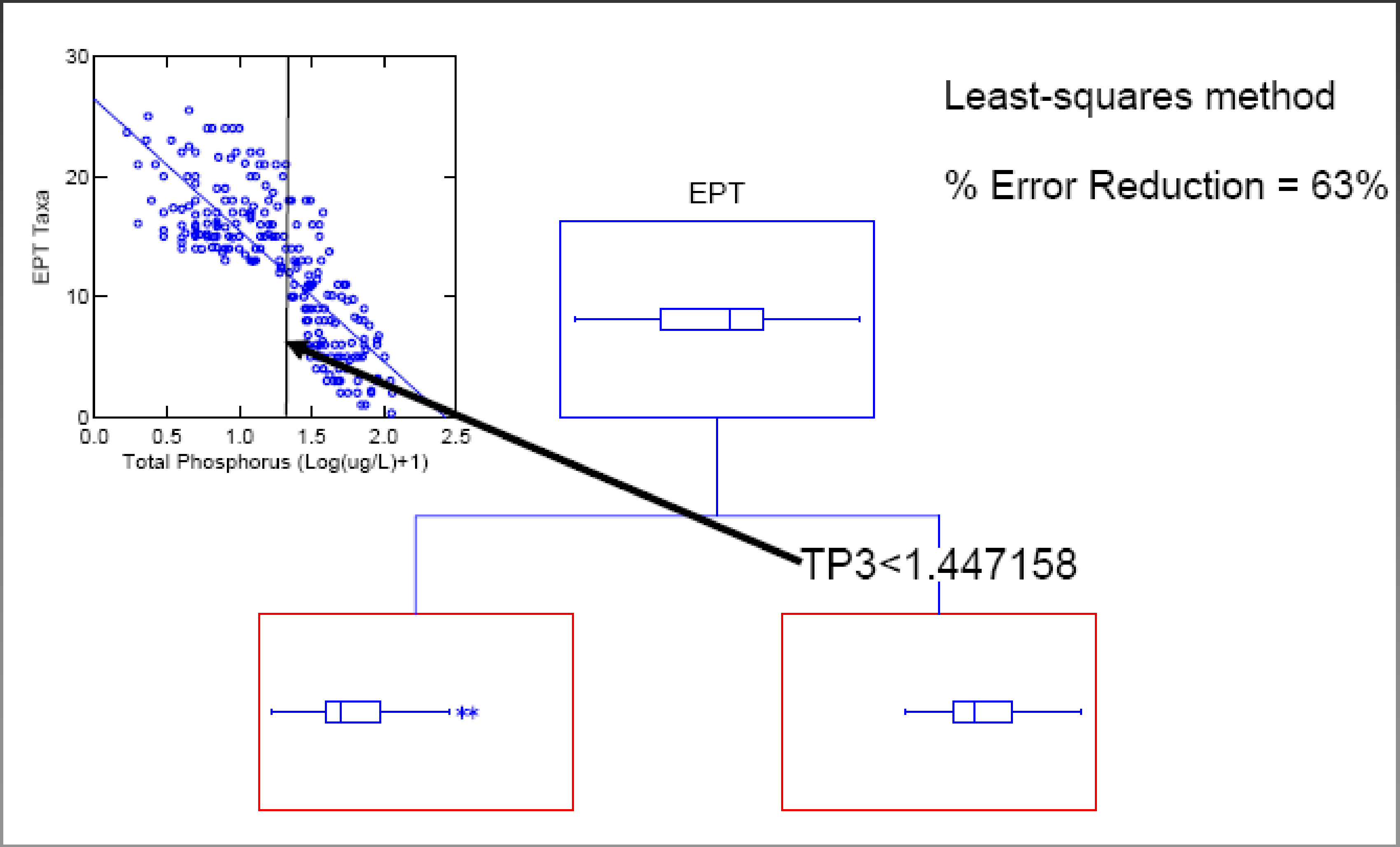
Split	Variable	PRE	Improvement
1	SULFATE	0.726	0.726
2	Mn DISS	0.758	0.032
3	CONDUCTIVITY	0.819	0.062
4	SULFATE	0.855	0.036
5	ZINCTOTAL	0.872	0.017
6	MAGNESIUM	0.882	0.010

88.2% variance

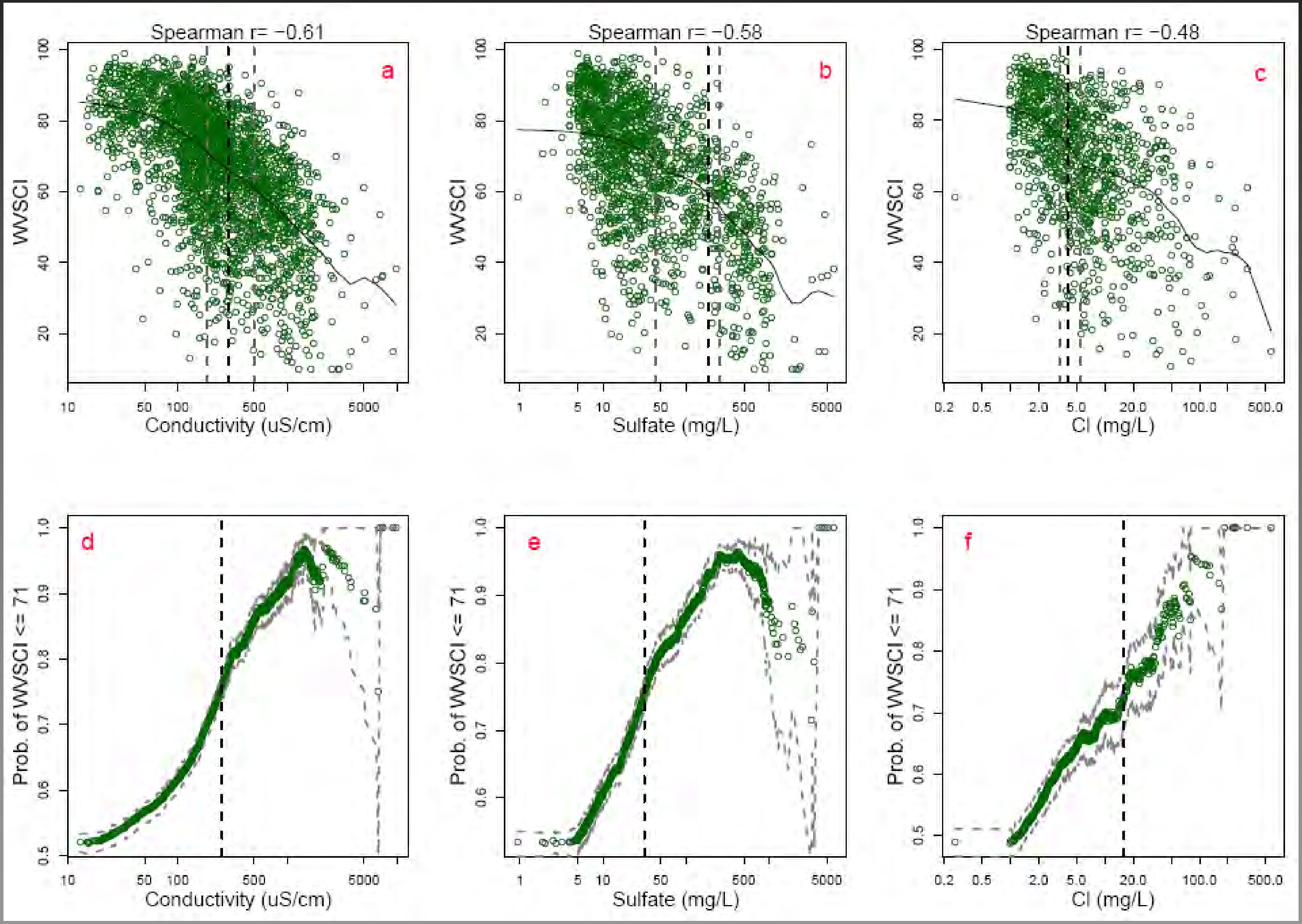
%EPHEM



Change Point Analysis



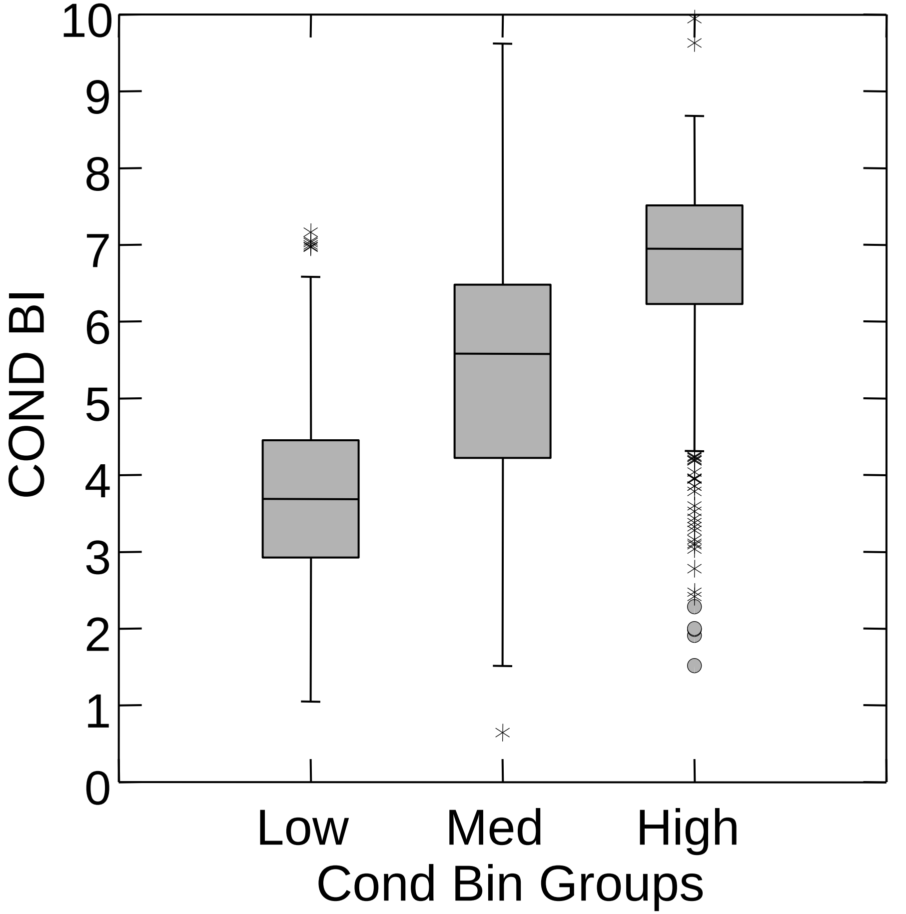
Regression using LOESS and Change Point Analysis



Conductivity Biotic Index

$$= \sum_{i=0}^{10} [(i * n_{indvPTVi})] / N$$

where $n_{indvPTVi}$ = the number of individuals in a sub-sample with pollution tolerance value (PTV) of i and N = the total number of individuals in a sub-sample



What can tox testing tell us about probable impacts to aquatic life?

- Mount et al. (1997) tested acute toxicity (survival) with over 2900 ion solutions
  - for WET organisms, 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.
- Some studies have shown that elevated TDS causes other stressors to be more toxic.

Conductivity/TDS

- Most streams in the region are naturally dilute (TDS<50)
  - invertebrates physiologically adapted to low TDS
- Empirical datasets show TDS is a stressor of concern
  - toxicological literature reveal that elevated TDS is toxic
- However, tox studies traditionally use cultured organisms that are typically more tolerant
- TDS thresholds derived from lab tests generally inadequate to protect aquatic life in Appalachian streams
  - For example (NaCl as toxicant):
    - a NOEC for *Ceriodaphnia* = 1200 μS/cm
    - a LOEC for *Ceriodaphnia* = 2050 μS/cm
- High TDS thought to interfere with normal osmoregulation in aquatic organisms

Evaluation of Toxicity of Streams Receiving Mining Effluents: Whole Effluent Toxicity and Ecophysiology

Chronic WET Testing as an Additional Indicator

- This indicator “speaks” to permit writers
- Can be used in NPDES permit as a monitoring requirement or a limit
- 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 than native fauna
- We have tested some ambient waters downstream of mining effluents to determine whether they exhibit toxicity

What does the toxicity testing literature say?

- The toxicity testing literature indicates:
  - 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.

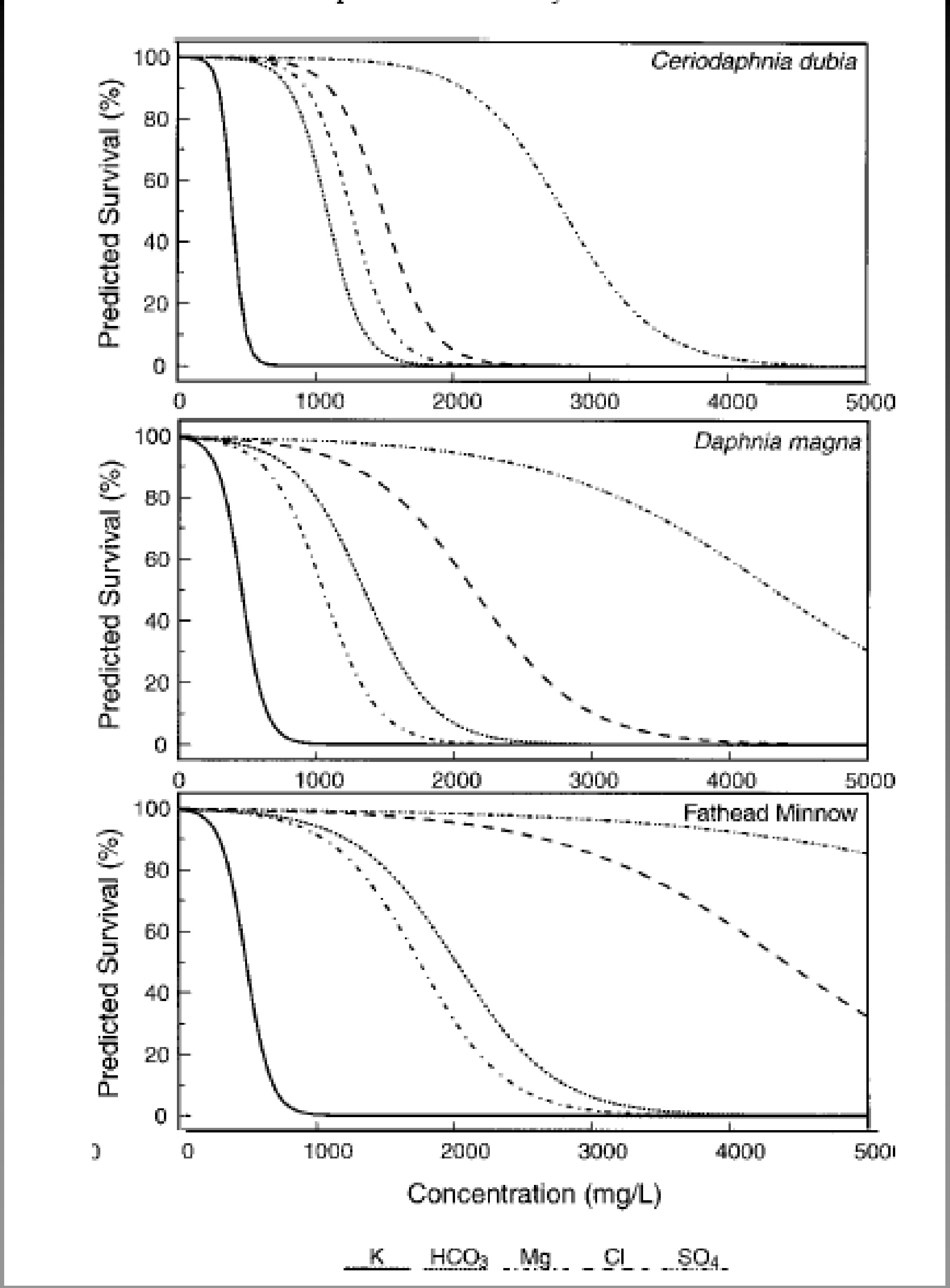
For Example:

- Mount et al (1997) tested acute toxicity (survival) with over 2900 ion solutions and found that 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 acute toxicity to *C. dubia* in several empirical studies.

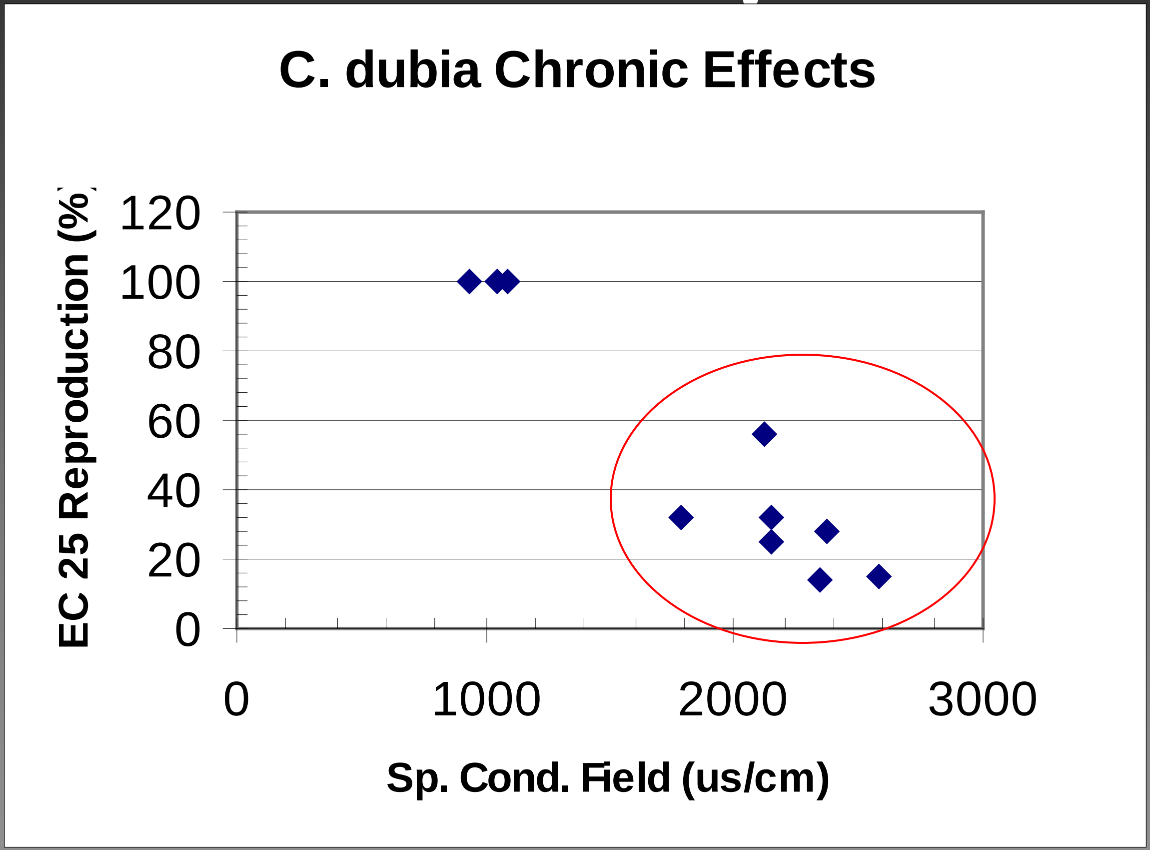


C. Dubia More Sensitive to TDS

EPA Pilot – WET testing of mining impaired streams

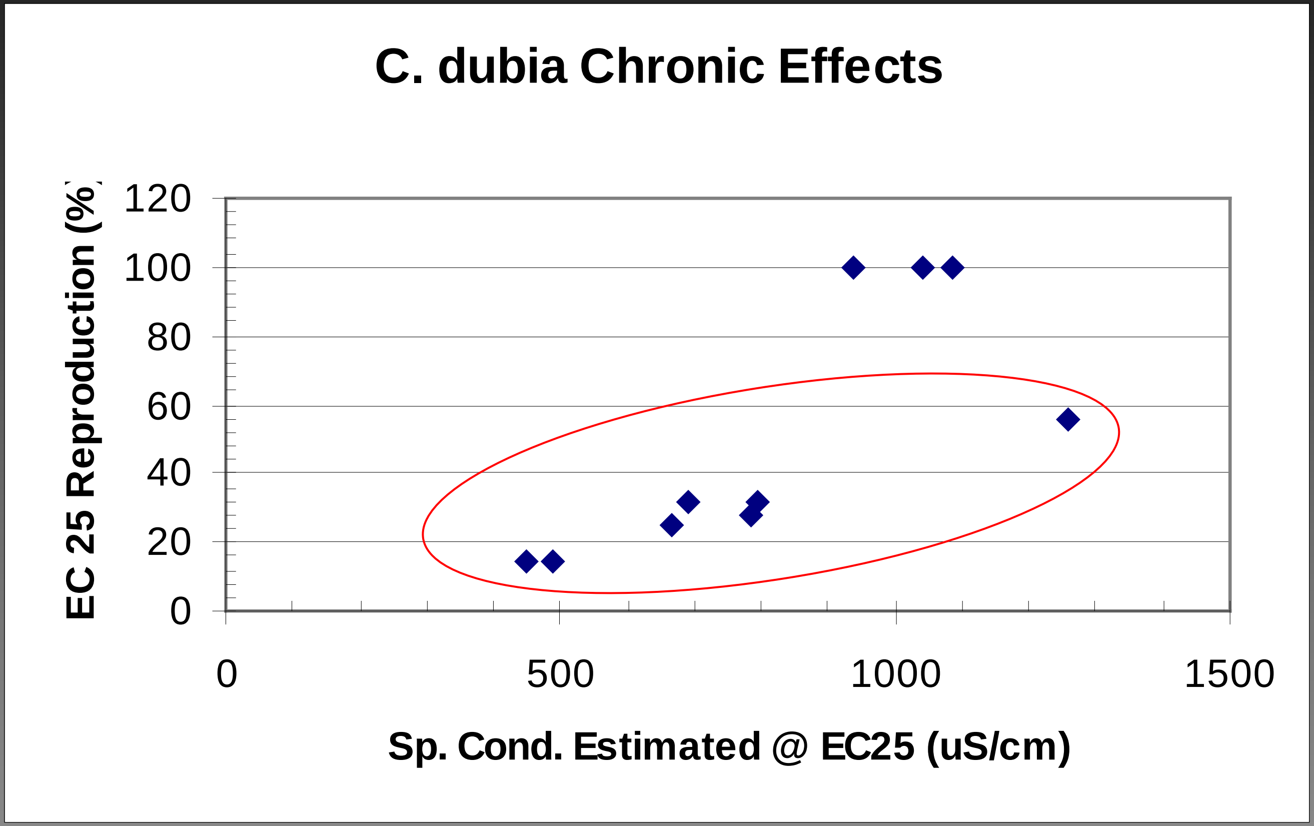
- Study Details
  - Chose sites where mining is the only source of pollutants and aquatic life impaired
  - Did not determine if permit in compliance with limits
  - Collected
    - Macroinvertebrates
    - Rapid Habitat Assessment
    - Field and lab chems
  - WET testing of ambient water – Ceriodaphnia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

Several samples exhibited toxicity



Chronic effects were detected in samples with field conductivity >1800 µS/cm.
There is NO dilution capacity in these streams.

Chronic Effects

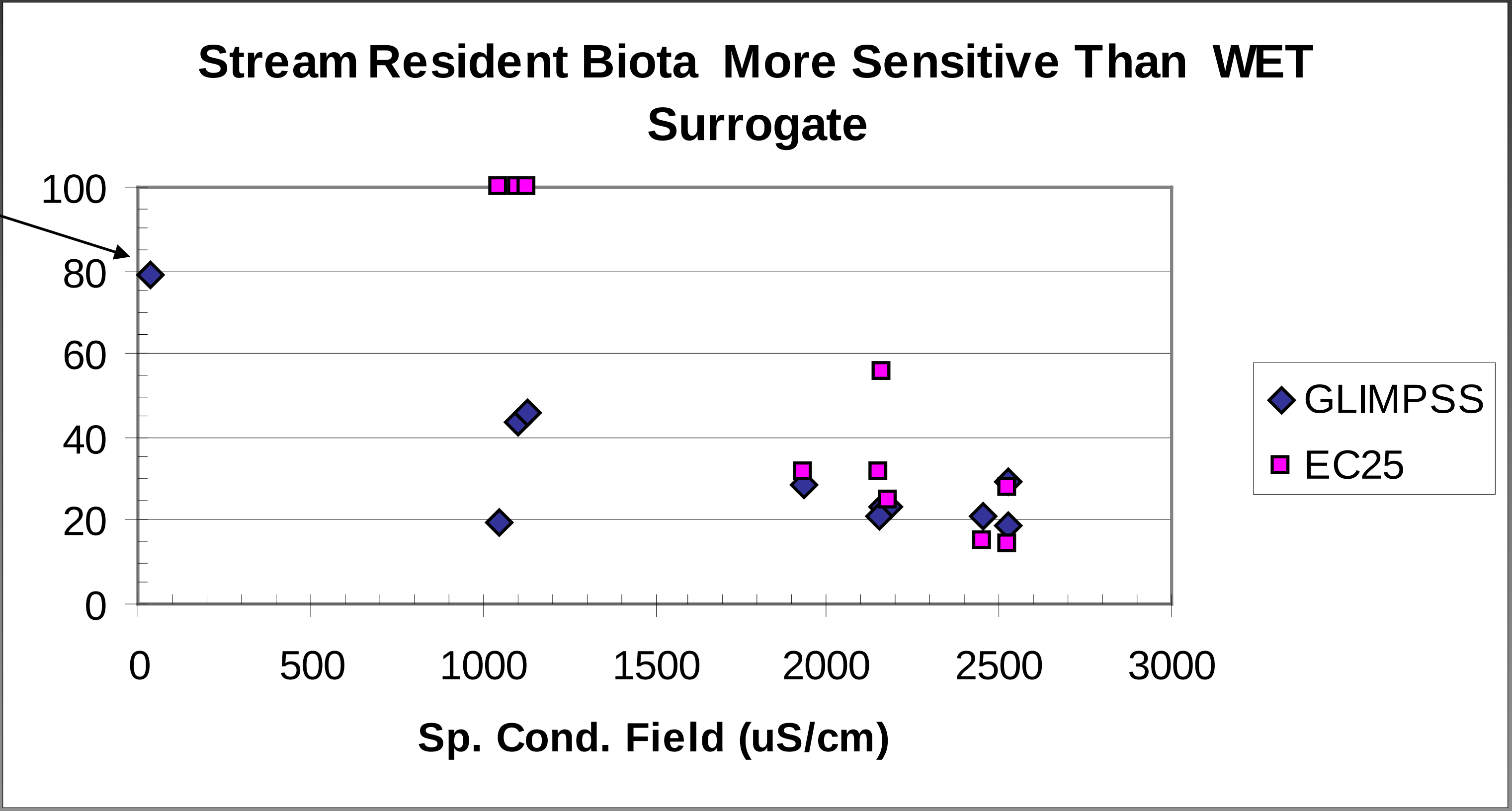


Estimated conductivity at EC25 % ranged from 448-1243 with an average of 820 µS/cm.

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

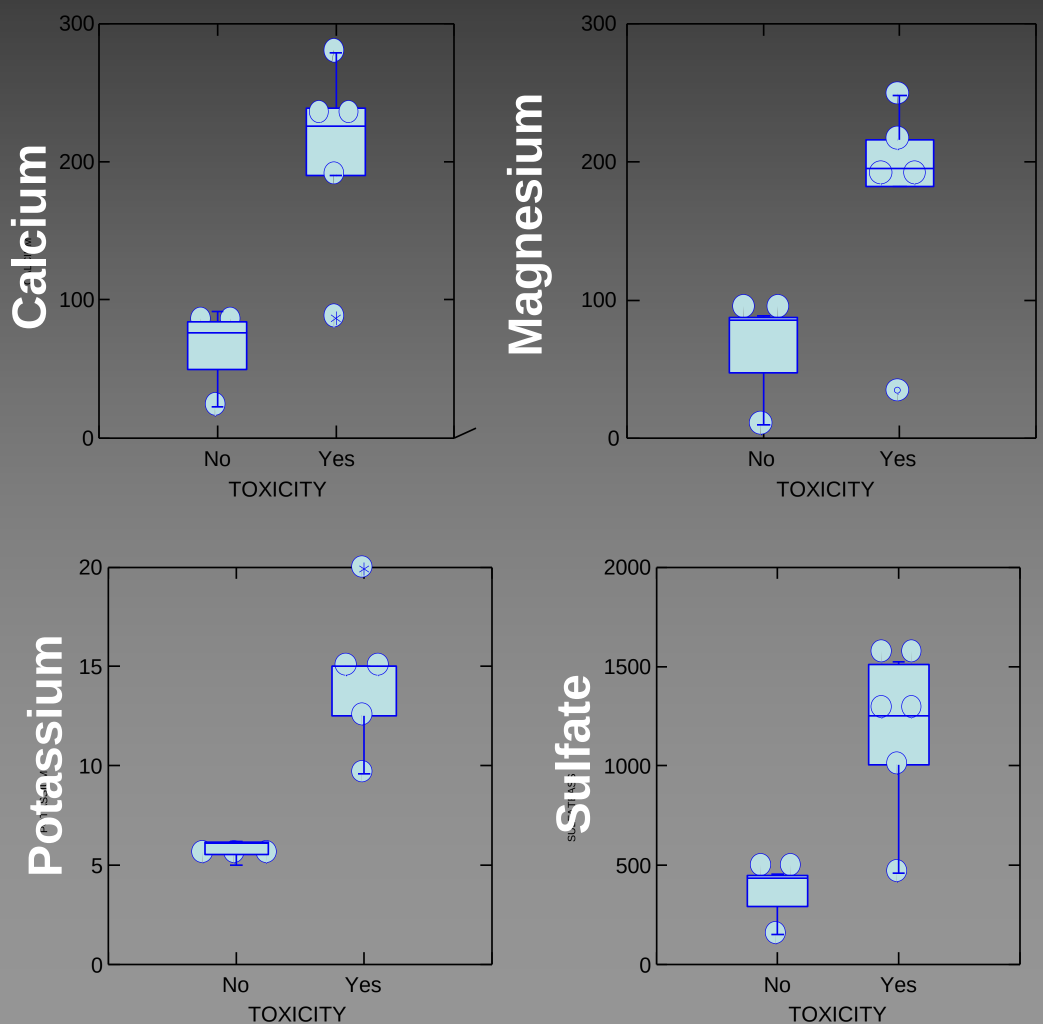
WET compared to Aquatic Life

Ref for GLIMPSS Not tox tested



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 the most toxic discharges.

Toxic vs Non Toxic Samples: TDS

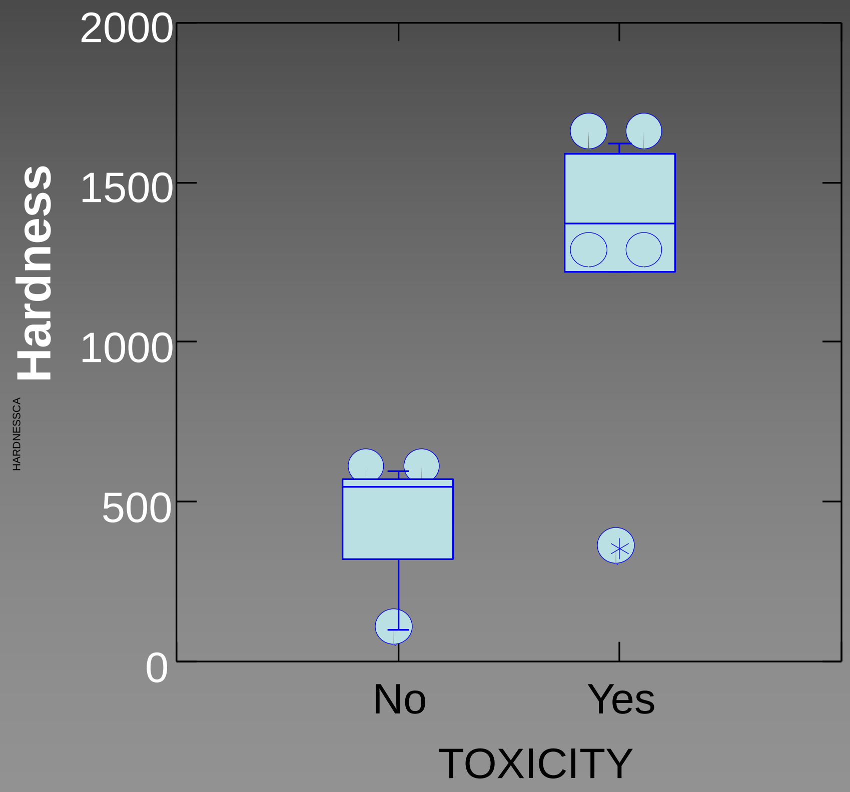


The major cations and ions in the effluent
are calcium, magnesium, bicarbonate and sulfate.

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.

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.

Ongoing Research - Natives

- Metal and osmotic ecophysiology
- Deploy insects in situ – sample individuals in a time course
  - Measure growth, metal and electrolyte content, subcellular compartmentalization of metals
  - Explain any differences in metal tolerance, bioaccumulation and toxicity
- Laboratory Exposures
  - Monitor oxygen consumption, osmoregulatory status and Adenosine triphosphate (ATP) levels
  - Characterize "energetic costs" to living in high conductivity
- Outcome
  - Provide information on whether metal uptake is contributing to impairment
  - Provide information on mechanism for TDS impairment
- North Carolina State

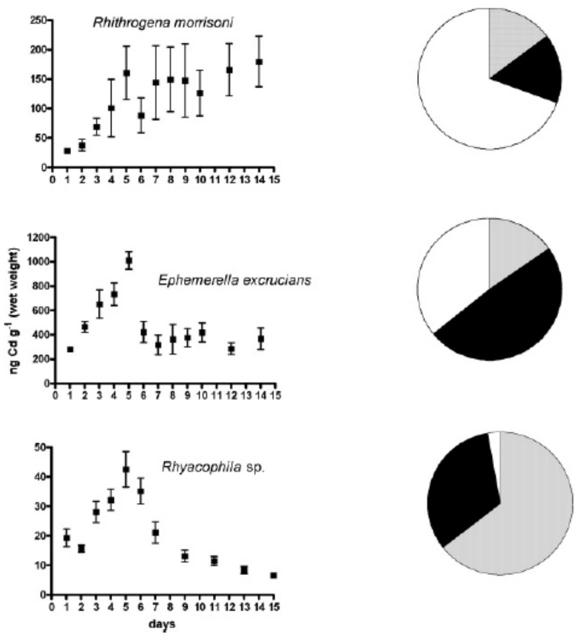


FIGURE 3. Radiotracer experiments show large differences among species in Cd uptake and efflux rates. Pie charts represent the subcellular compartmentalization of Cd into cell debris (hatched), biologically active or potentially toxic sites (black), and detoxified or associated with metallothionein like proteins (white). The combination of these parameters provides estimates of steady-state concentrations in biologically active compartments in addition to providing estimates of times required to reach steady-state concentrations (see Table 2).

Buckwalter et al, 2007