Field-based Methods for Developing Water Quality

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Why conductivity and Why a new method?

- Biological impairments are known to occur in streams that meet benchmarks derived by the laboratory method.

- In low conductivity waters, more than 50% of genera are affected and streams still meet the laboratory based benchmarks.

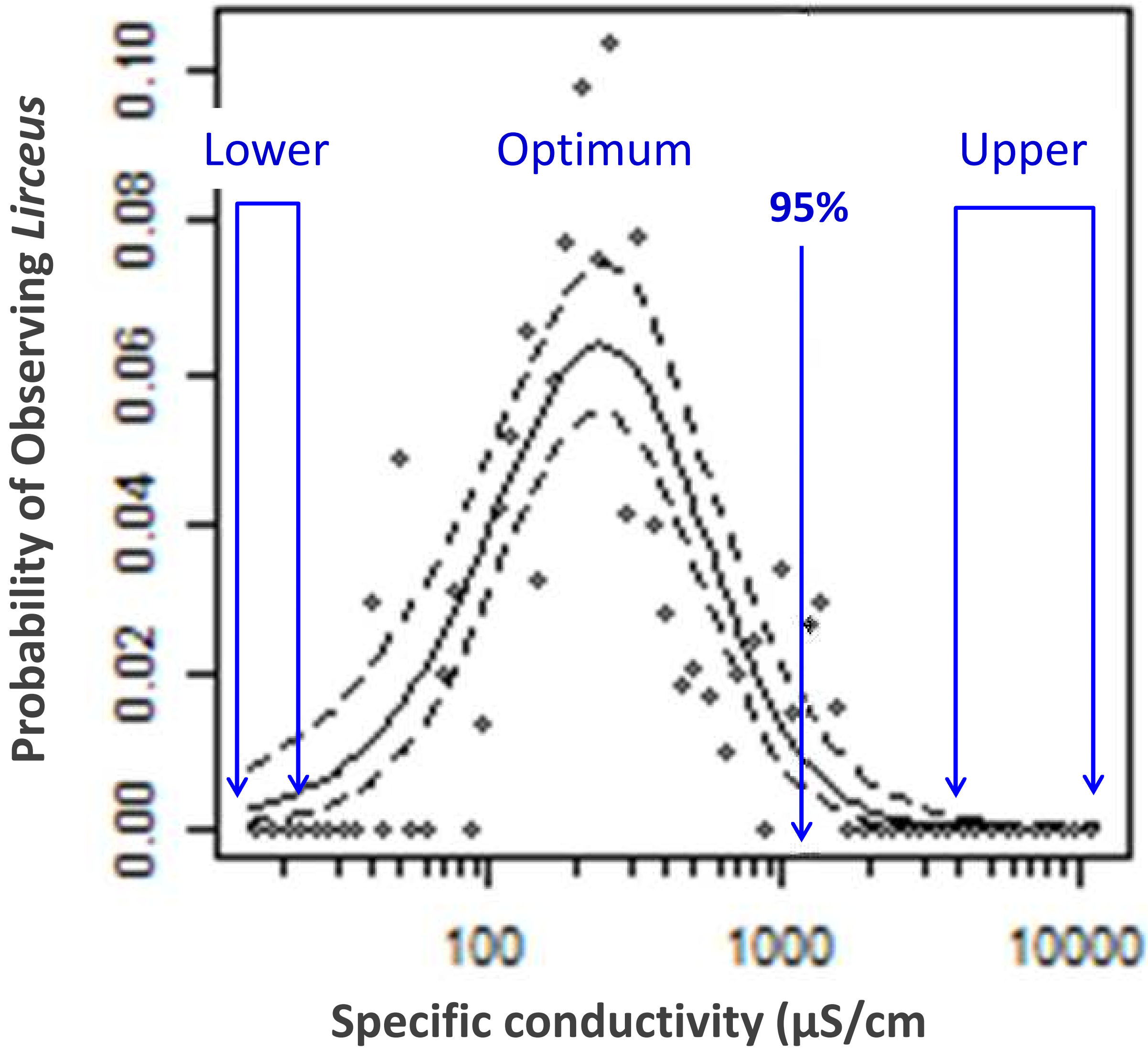
Advantages of Field Method

Advantage	Directly measures actual exposures of resident organisms and includes direct and indirect effects across entire life cycles
Weakness	Exposures and deleterious effects must already have done their damage (i.e., data sets for new and rare pollutants are unlikely)
	Observed effects may be caused or modified by coincidentally occurring agents (i.e., confounders)

Theoretical foundation of field-SD aquatic life benchmarks

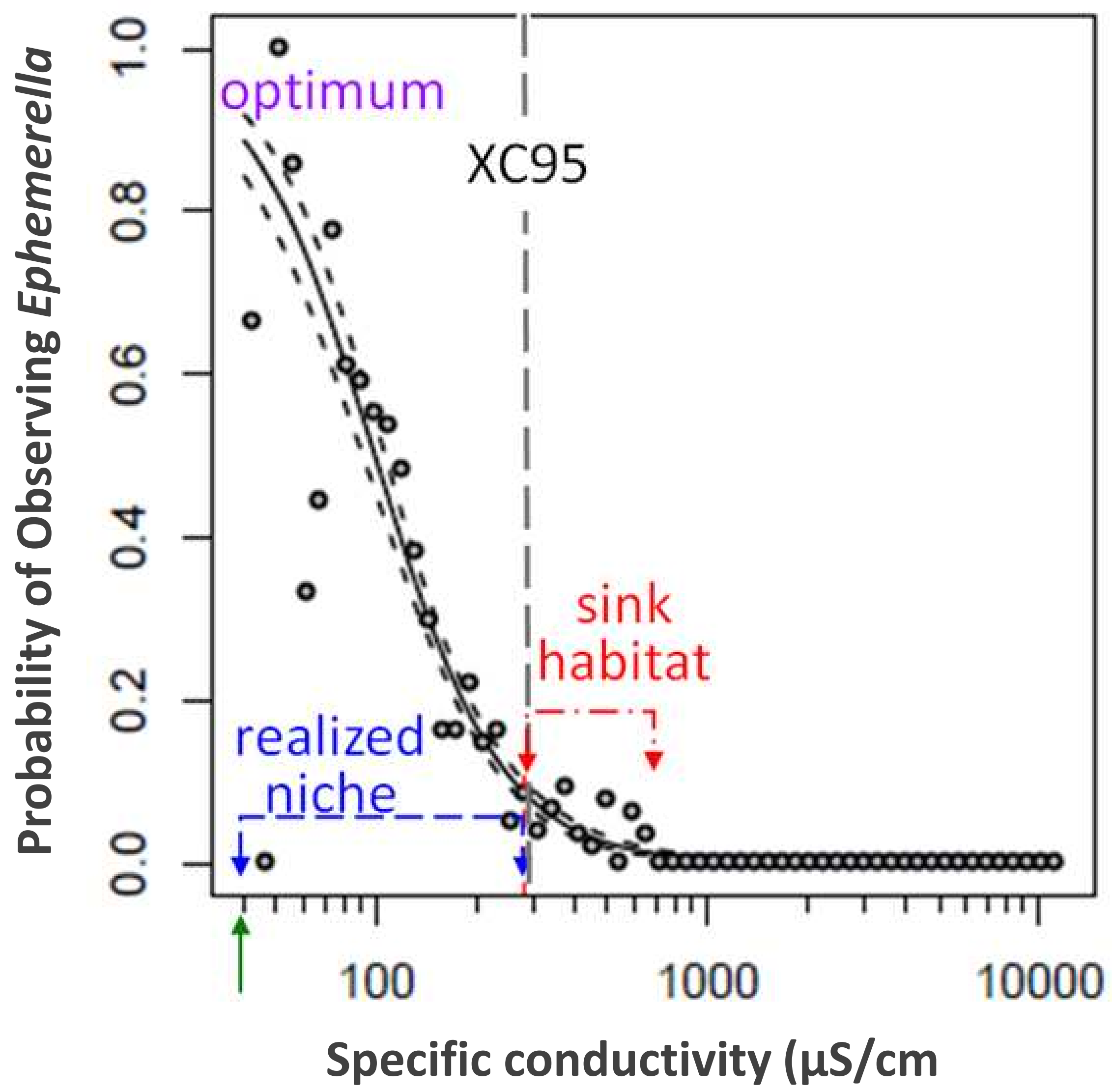
- Organisms have evolved different physiologies and behaviors;
- Variation within and among species results in different tolerance ranges to both natural and xenobiotic challenges;
- Where a physiological tolerance is exceeded, a taxon is not expected to be present;
- Therefore, upper tolerance levels of many taxa can be used to develop models to predict the proportion of extirpation for a given exposure.

Unimodal

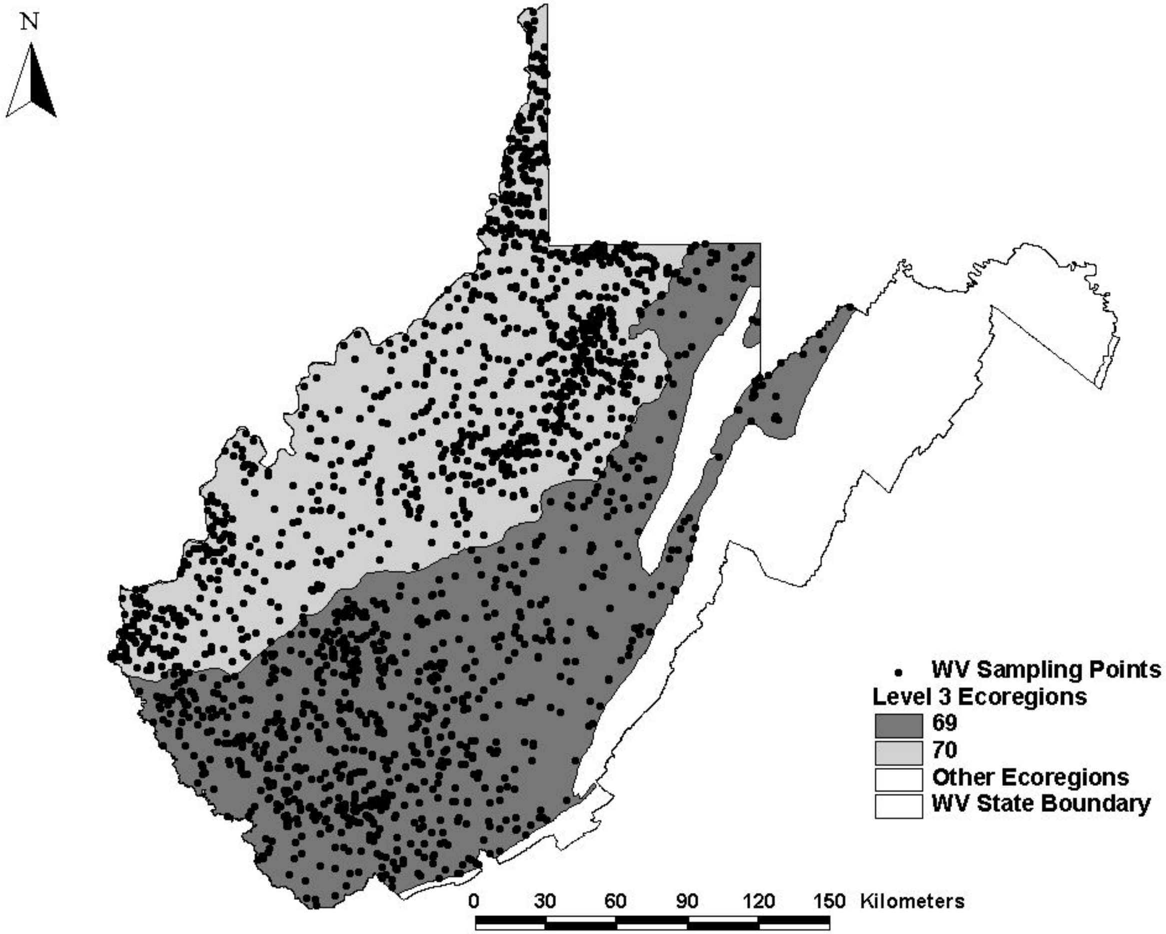


Lower
Optimum
95%
Upper
Probability of Observing *Lirceus*
0.00
0.02
0.04
0.06
0.08
0.10
100
1000
10000
Specific conductivity (µS/cm

When the lower tolerance is near zero



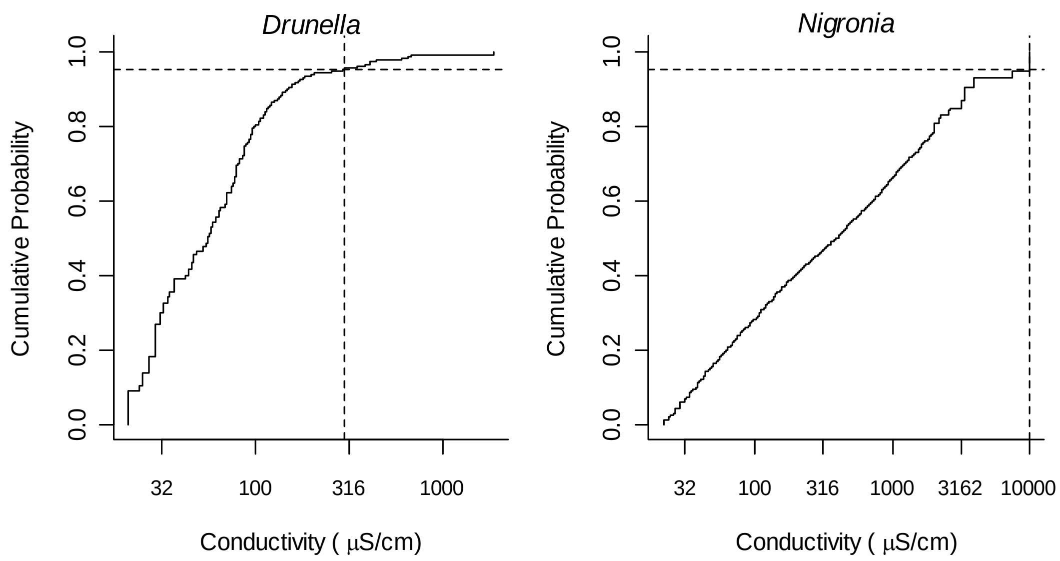
2,210 sampling sites



Example of Field-SD Method

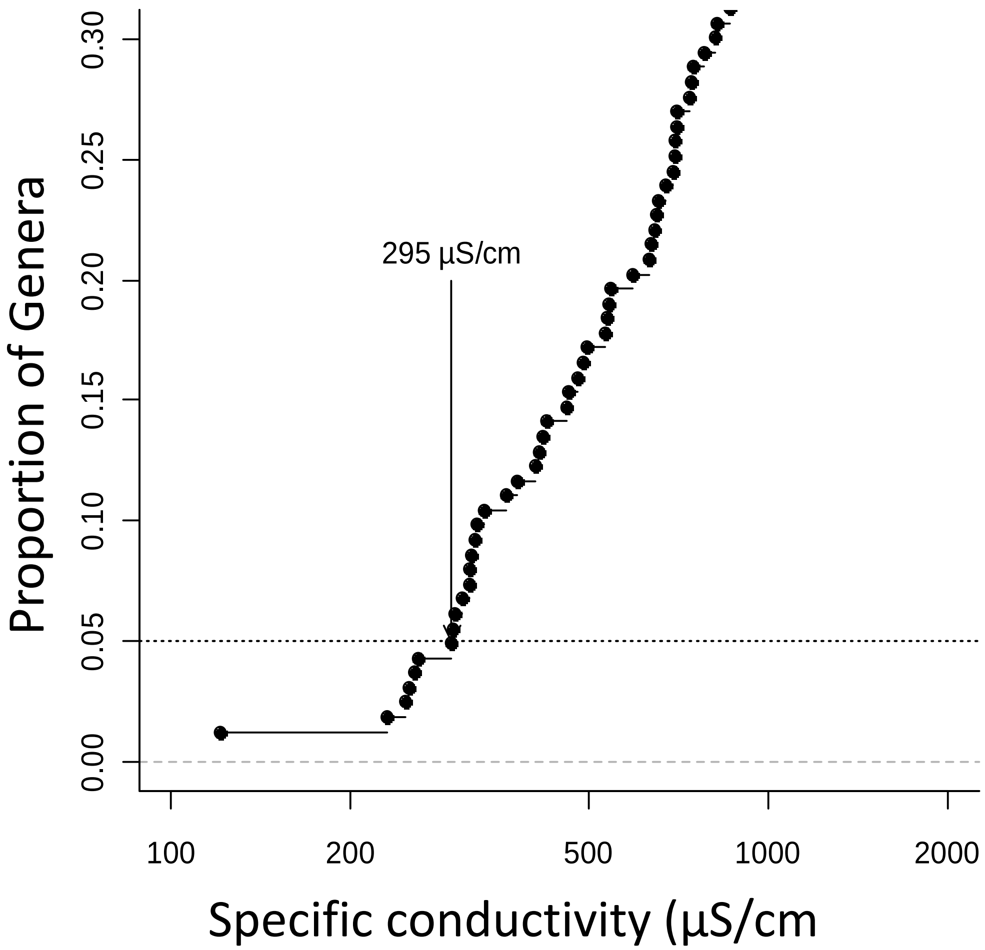
- Exposure endpoint: major ions measured as specific conductivity
- Effect endpoint: extirpation of a taxon, concentration below which 95% of the occurrences of a genus were observed (XC_{95})

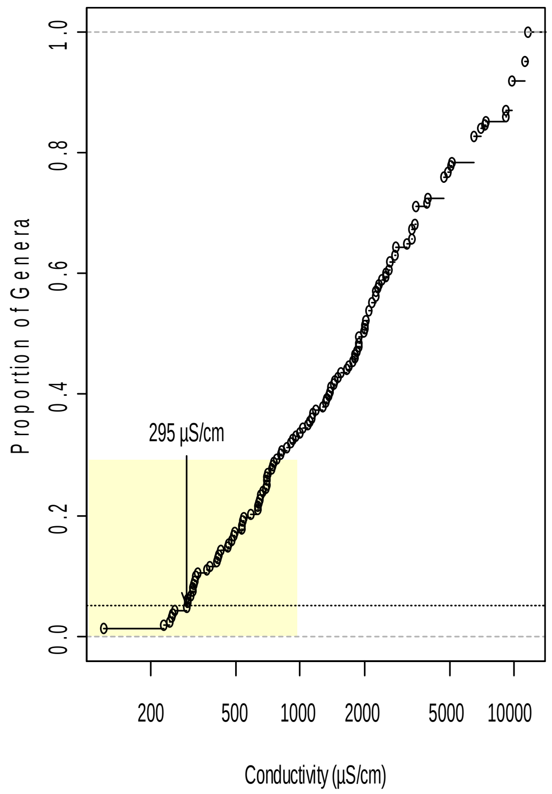
Calculation of XC_{95}



Paired SC and biota data were used to estimate the XC_{95} of > 100 benthic aquatic invertebrate genera

The XC_{95} values plotted in a genus SD and 5th centile (HC_{05}) identified





Characteristics of Causation

- time order
- co-occurrence
- antecedence
- sufficiency
- interaction
- alteration

- **time order**
- co-occurrence
- preceding causation
- sufficiency
- interaction
- alteration

Cause ***then*** **Effect**

No measurements before and after to develop evidence

- time order
- **co-occurrence**
- preceding causation
- sufficiency
- interaction
- alteration

Cause

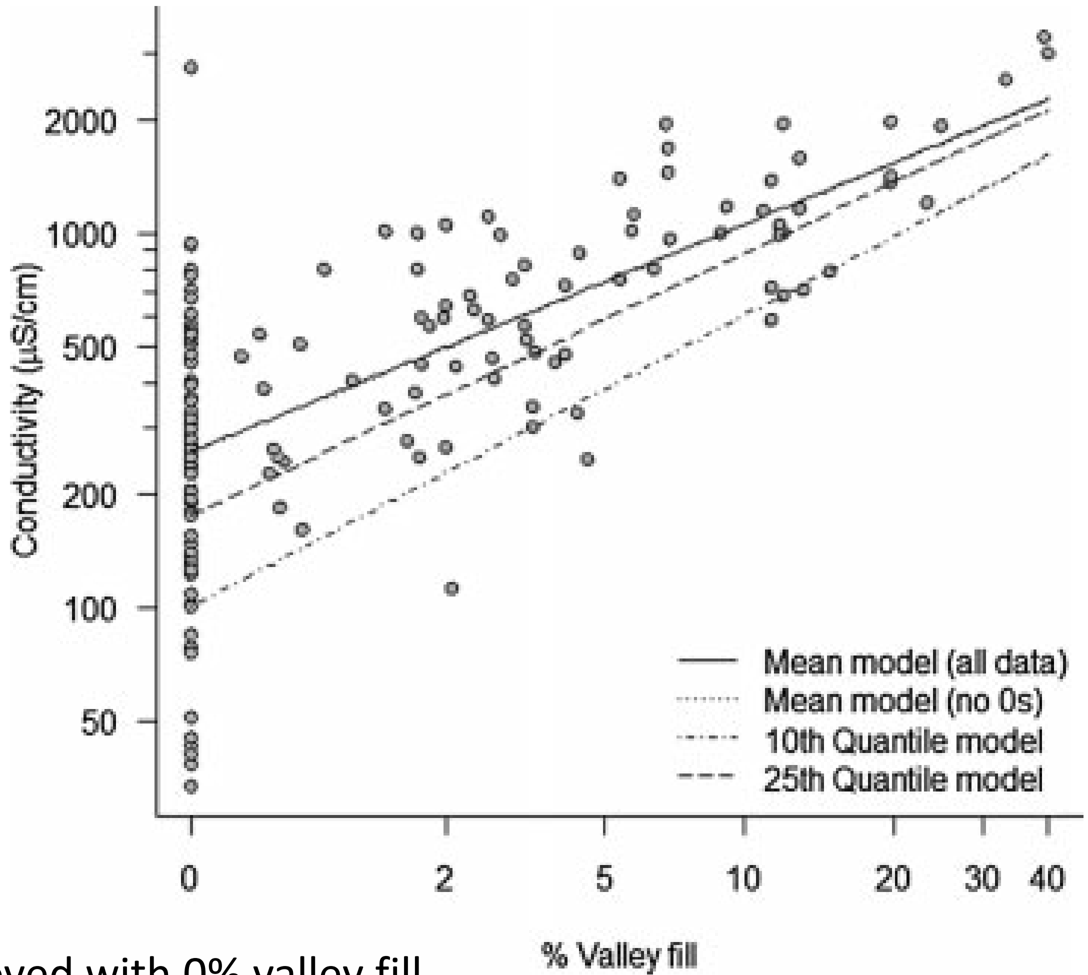
Effect

Example: contingency table

	West Virginia		Kentucky	
	Genera present	Genera absent	Genera present	Genera absent
Near background SC	162	1	104	0
(<150 µS/cm)	(99.9)	(0.01%)	(100%)	(0%)
High SC	123	40	58	46
(1,500 µS/cm)	(75.5%)	(24.5%)	(55.8%)	(44.2%)

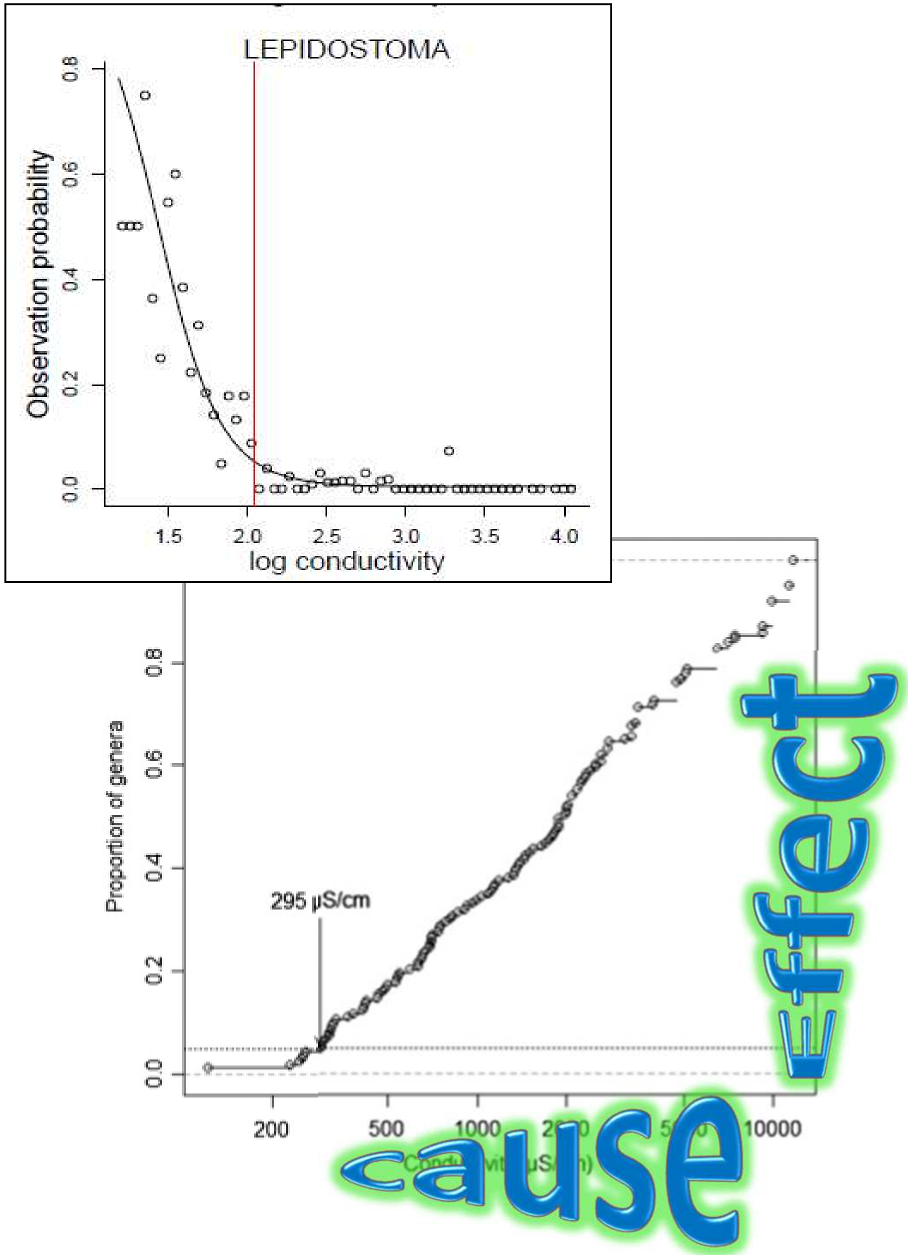
Source → Cause

- time order
- co-occurrence
- **antecedence**
- sufficiency
- interaction
- alteration



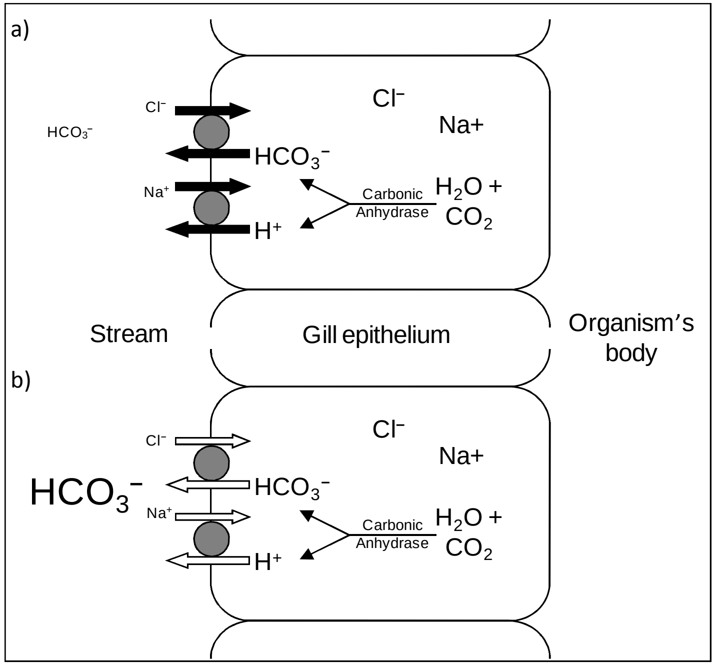
Samples removed with 0% valley fill
(OLS, *n*=78) *r* = 0.75

- time order
- co-occurrence
- antecedence
- **sufficiency**
- interaction
- alteration

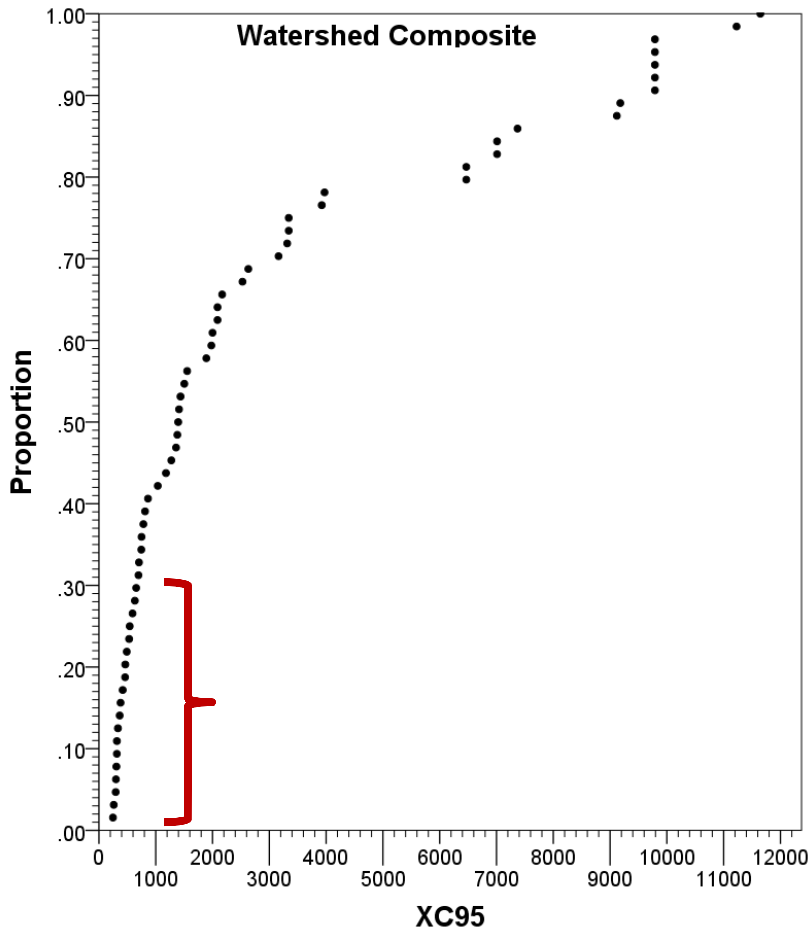


Cause Effect

- time order
- co-occurrence
- antecedence
- Sufficiency
- **interaction**
- alteration

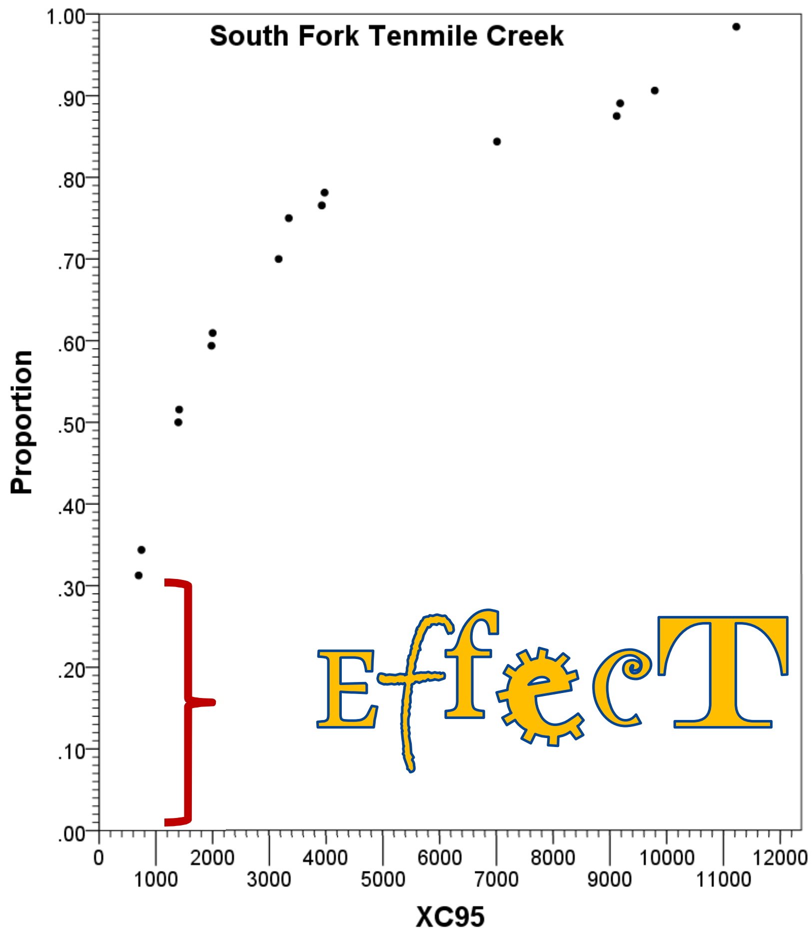


- time order
- co-occurrence
- antecedence
- sufficiency
- interaction
- **alteration**



- time order
- co-occurrence
- antecedence
- sufficiency
- interaction

»**alteration**



Summary of Causal Evidence

Co–occurrence— Loss of genera occurs when conductivity is high but is rare when conductivity is low (+ + +).

Antecedence—Sources of the ionic mixture are present and are shown to increase stream conductivity in the region (+ + +).

Interaction—Aquatic organisms are directly exposed to dissolved ions. Based on first principals of physics, ionic gradients in high conductivity streams would not favor the exchange of ions across gill epithelia. Physiological studies over the last 100 years have documented the many ways that physiological functions of organisms are affected by the relative amounts and concentrations of ions (i.e., combinations of ions that some genera do not have mechanisms or the capacity to regulate (+ +).

Alteration—Some genera and other response metrics and assemblages are affected at sites with higher conductivity, whereas others are not. These differences are characteristic of high conductivity (+ + +).

Sufficiency—Laboratory analyses report results of effects for a tolerant species, but test durations and most ionic compositions are not representative of exposure in streams. However, regular increases in effects on invertebrates with increased exposure to ions, based on field observations, indicate that exposures are sufficient (+ + +).

Time order—Conductivity is high and extirpation has occurred after mining permits are issued, but conductivity and biological data before and after mining began are not available (no evidence).

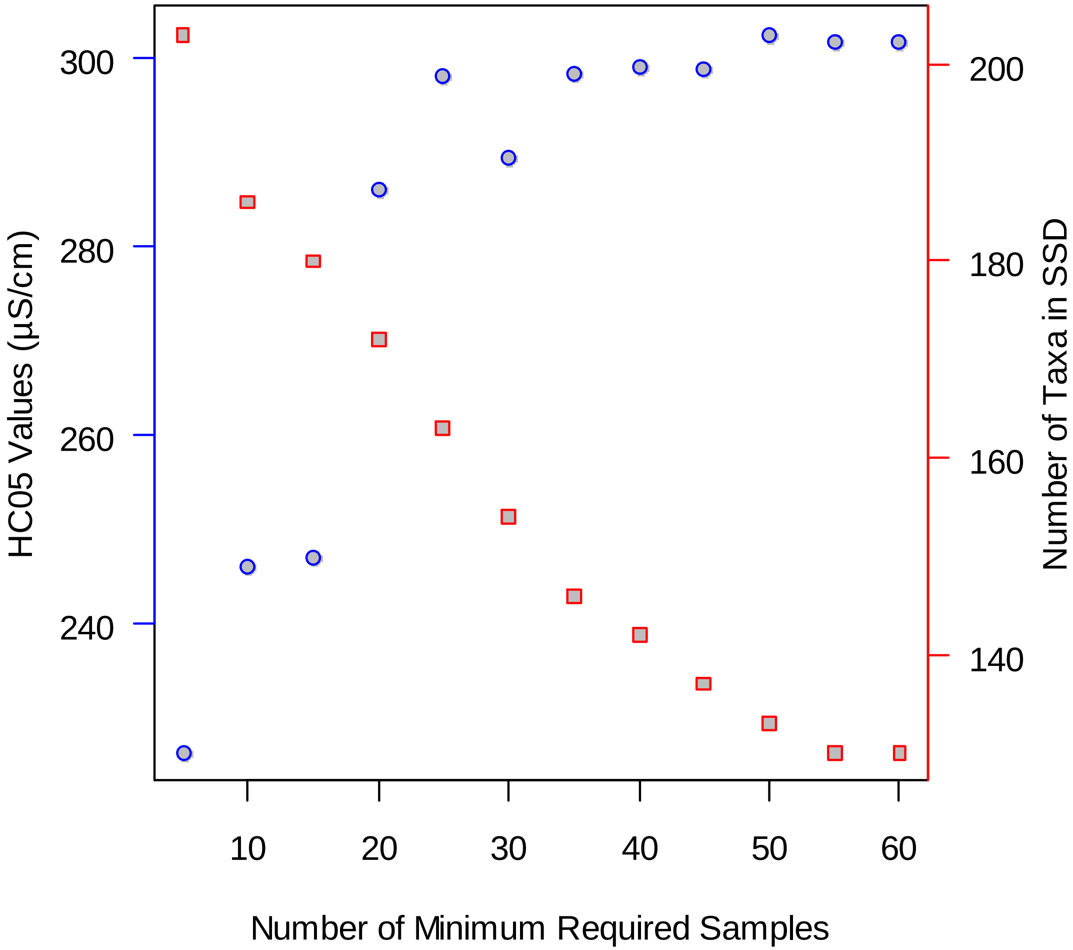
Scoring Body of Evidence

Number of Causal characteristics supported by evidence		Assessment of Causal relationship
Discounted	Supported	
1 refuting		Refuted causation
4, 5, or 6		Unlikely causation
1, 2, or 3	others supporting	Unlikely causation, low confidence
none	strongly 6	Confirmed causation
none	5 or 6	Very probable causation
none	strongly 3 or 4 Including sufficiency or alteration	Probable causation
none	strongly 2 Including sufficiency or alteration	Probable causation but low confidence
	1	Insufficient evidence

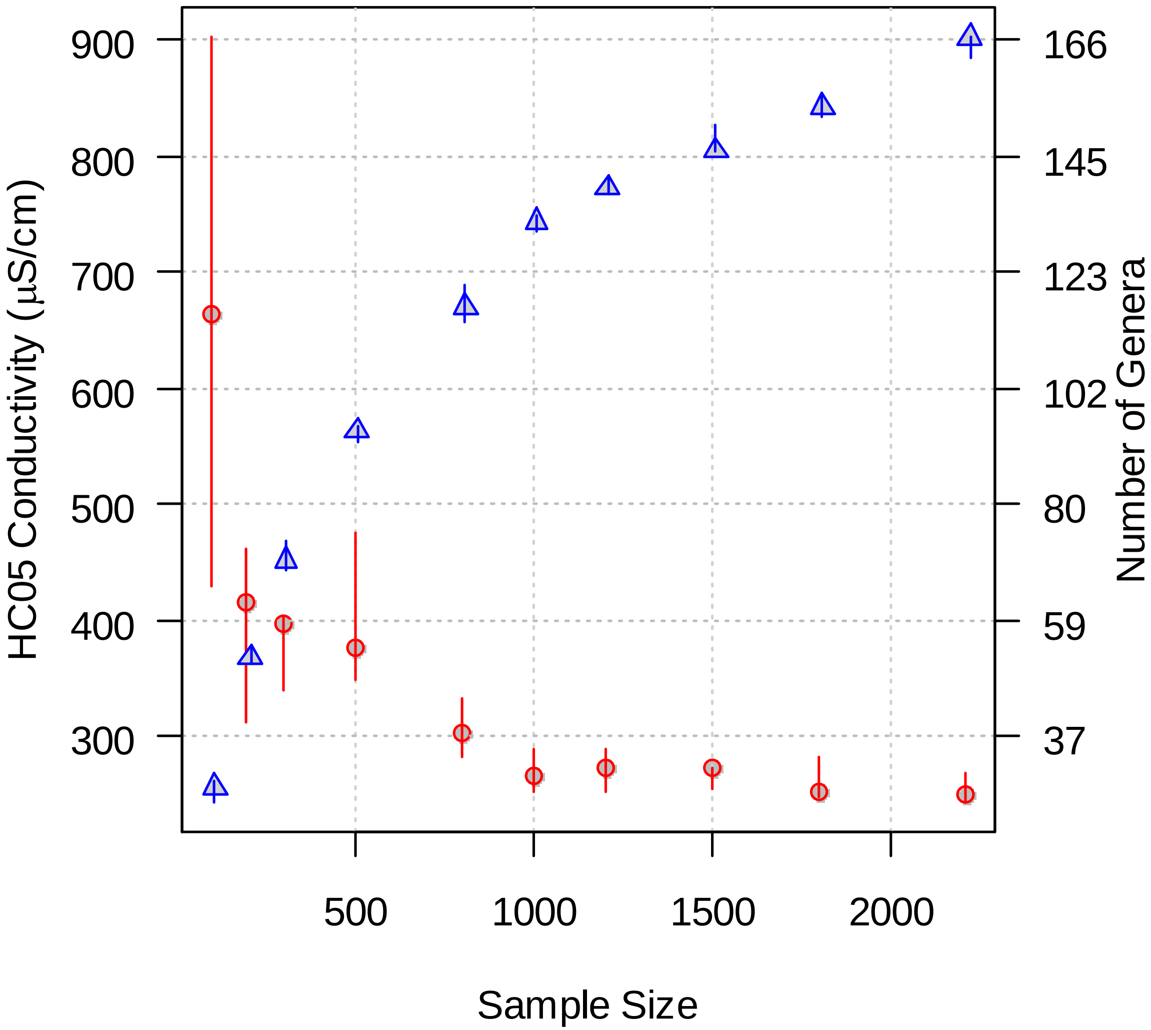
Sensitivities to Modifications the Method

Sensitivities to Modification the Method	
Number of occurrences	---
Total number of sites	---
All genera including non ref	298
Exclude unless 2% of ref	272
Only decliners	248
No removal of low pH	288
Removal of low habitat (<140) & high coliform	326
Season Spring	317
Season Summer	415
Add fish	298
Ecoregion 69	254
Ecoregion 70	345
No weighting	344
XC100	572
Different State (KY)	282
Include large rivers	289

Number of Occurrences



Samples in Data Set



Potential Confounders: Remove Poor Habitat and High Coliform

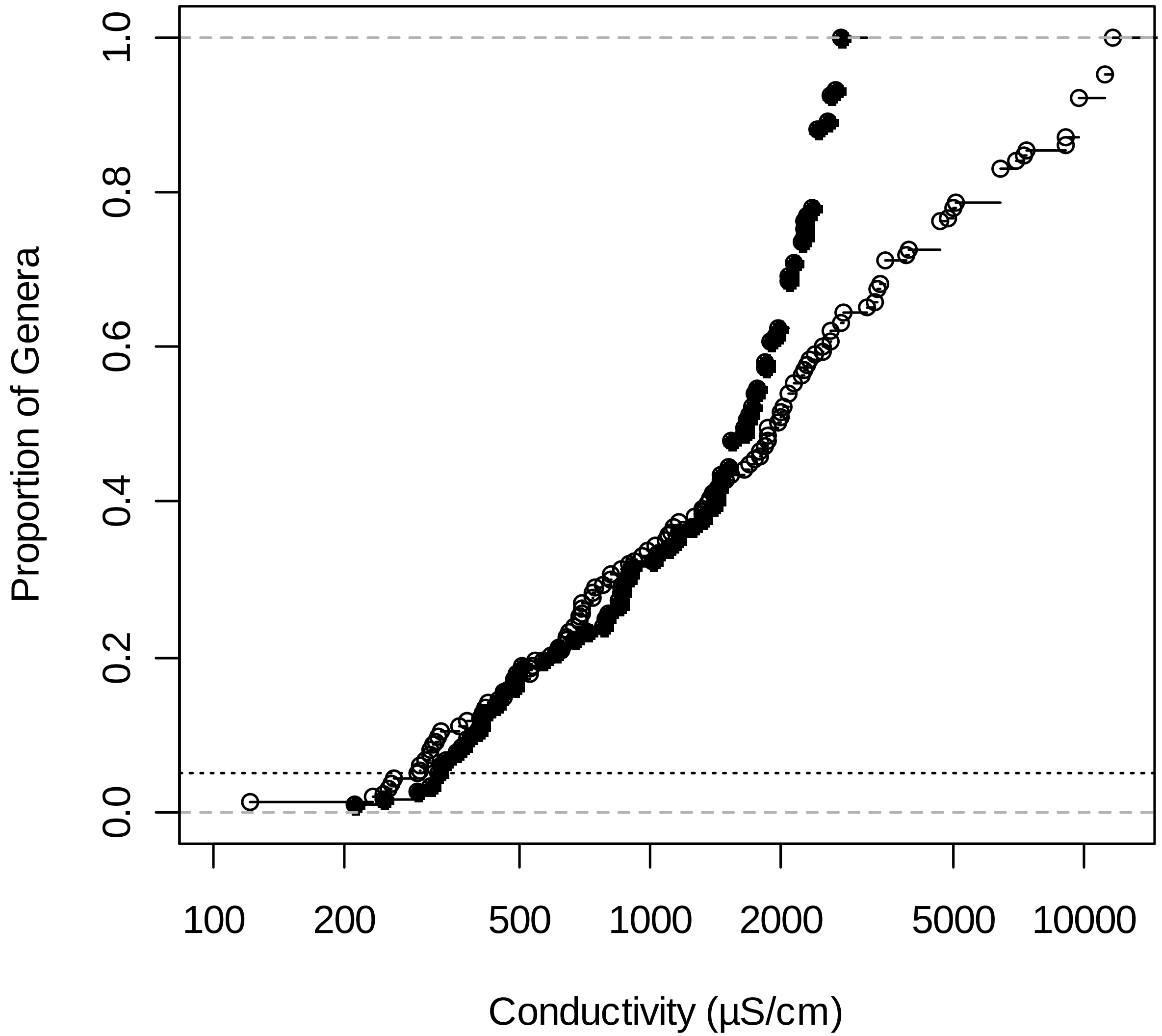
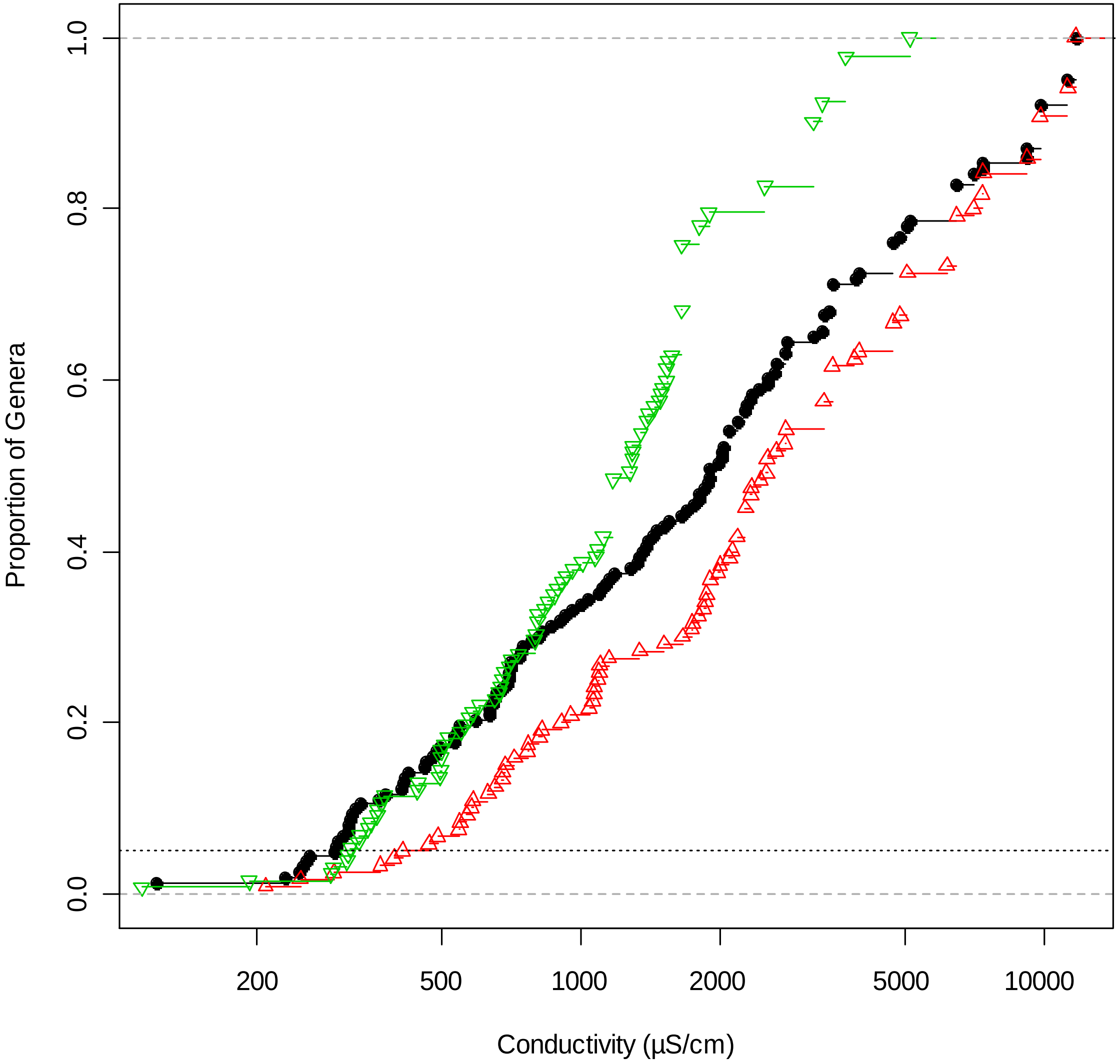
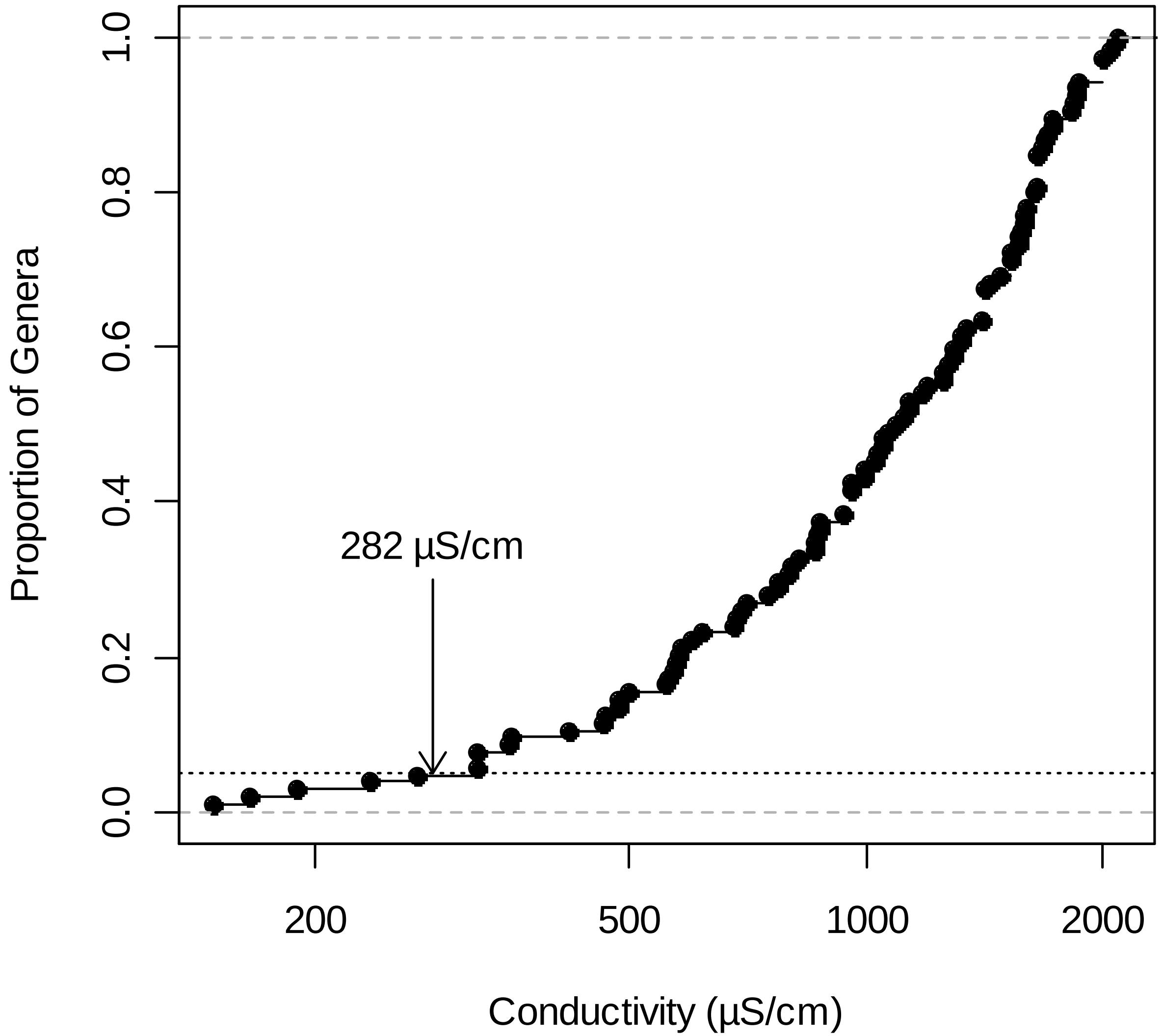


Figure 14

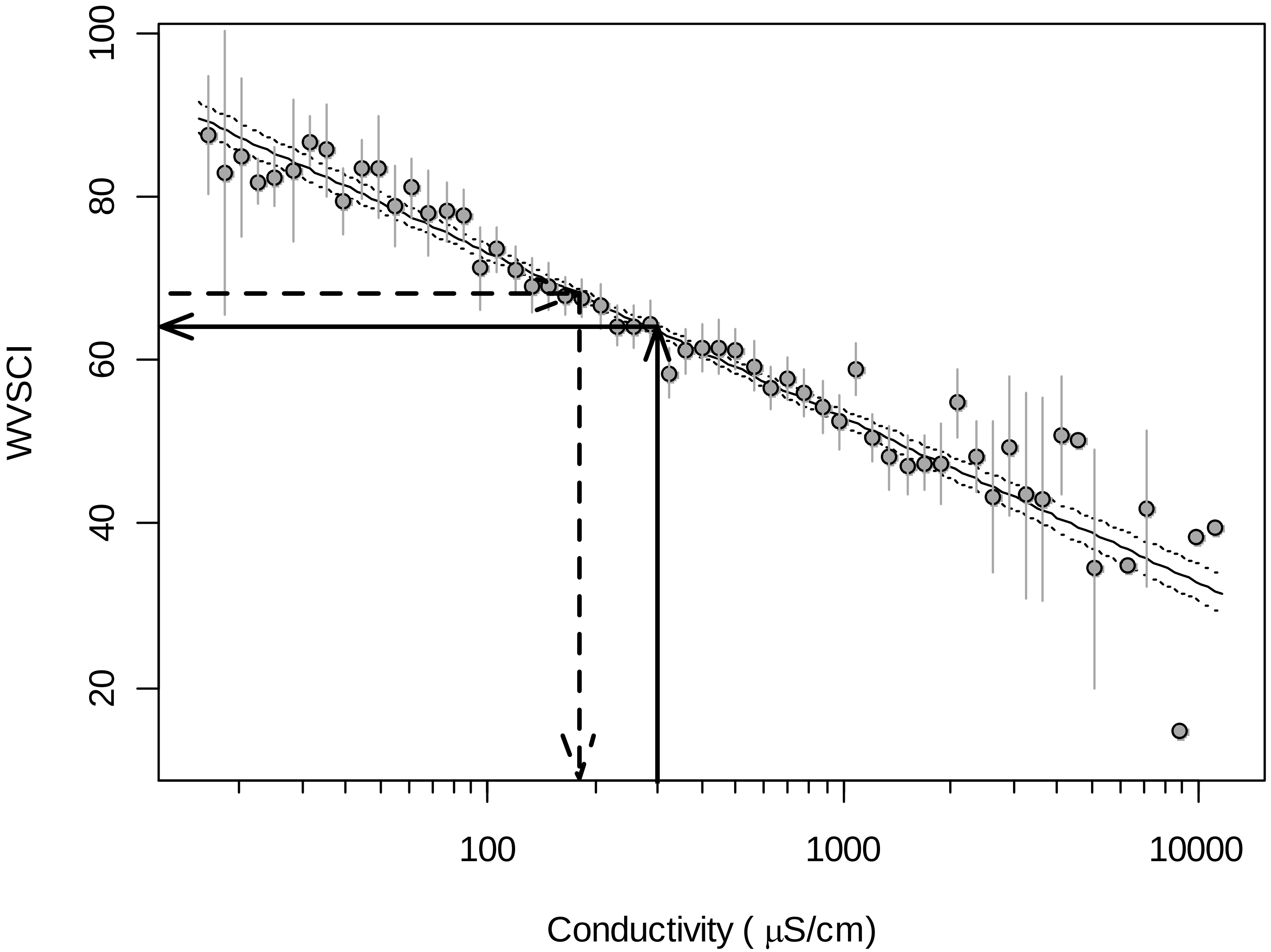
Seasons:
All year vs. Spring vs. Summer



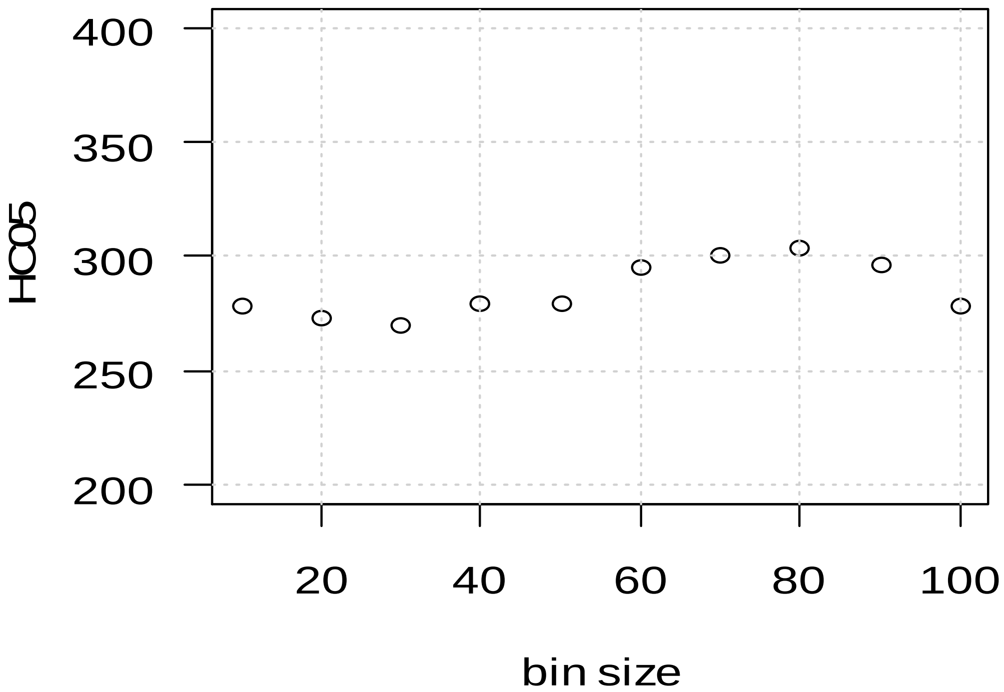
Geographic Source of Data with Different Sampling Methods: KY vs. WV



Index vs. SSD



Number of bins used to set weights



	µS/cm
1/3 fewer bins	280
1/3 more bins	303

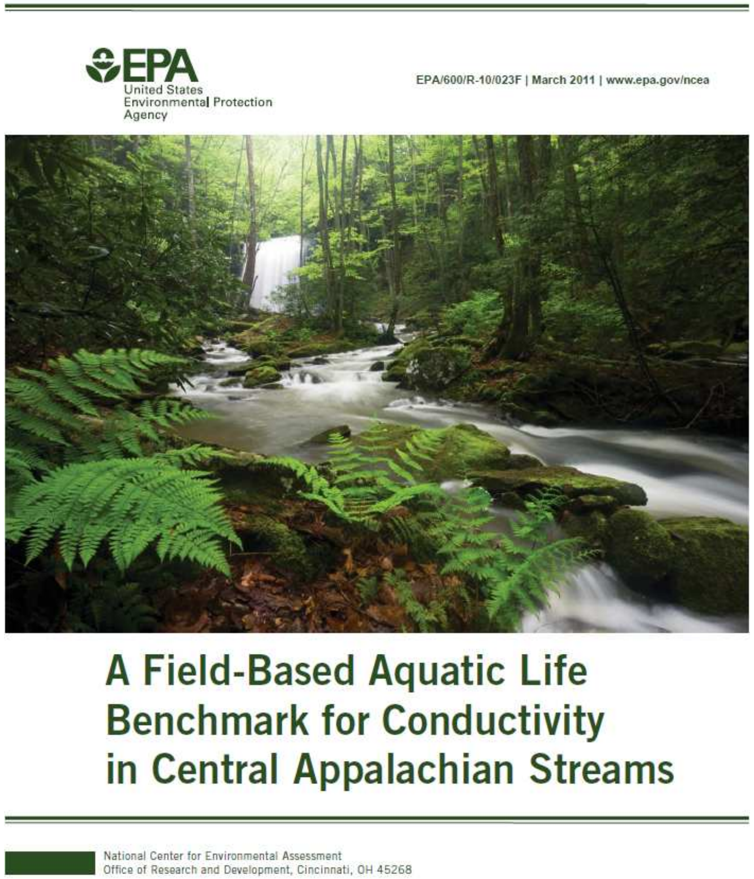
Other Analytical Methods

Method	**µS/cm**
GAM derived XC95s	270
Quadratic logistic XC95s	275
Titan change point	277
J. Paul change point	292
J. Gerritsen change point	267
C. dubia mortality D. Mount mixture model	1,023
C. dubia LC50 ambient water	2,500

Endpoint: Alternative Levels of Protection

HC Level **(% species loss)**	**Point Estimate** (µS/cm)	**95% Confidence Interval** (µS/cm)
HC_{02}	224	137-253
HC_{05}	297	225-305
HC_{10}	335	295-400
HC_{15}	461	375-521

The model was validated with an independent data set and met the criteria of probable causation and minimal confounding



EPA-approved method for developing Water Quality (WQ) benchmarks.

- Provides methods for
  - Deriving the HC_{05}
  - Assessing Causation
  - Assessing Potential Confounding
  - Model Evaluation