Causal Analysis and Probability Surveys: Examples

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EMAP-Surface Waters
EMAP-Coastal

Presentation Outline

- What is causal analysis?
- Hill's elements of causality
- Stressor Identification Guidance
- Examples
- Take home message

What is causal analysis?

Identify what is causing an effect.

Difficult, if not impossible, to prove cause-effect for natural resources.

What most people consider “proof” is really convincing evidence (for them).

Easier to disprove cause-effect

Sir Bradford Hill's Elements of Causality

Hill, 1965, Proc Roy Soc Med, 58:285-300

1, Strength of Association

2, Consistency

3. Specificity of Association

4. Temporality

5. Biological Gradient

6. Plausibility

7. Coherence

8. Experiment

9. Analogy

Stressor Identification Guidance Document

EPA-822-B-00-025)

- Identify alternative candidate causes
- Logically eliminate what you can
- Diagnose when you can
- Use strength of evidence when you can

- Do not claim proof of causation
- Identify the most likely cause
- Use a consistent process
- Document the evidence and inferences

Criteria to Judge Evidence

- Time order SDI
  - Strength SDI
  - Consistency SDI– replication
  - Coherence SDI– agrees with fact & theory
  - Specificity SDI – occurrence of one with other

** Beware of publication bias **

Aquatic Examples

EMAP data

Eutrophication in Northeast Lakes

EMAP sampling of lakes in northeast in 1991-94

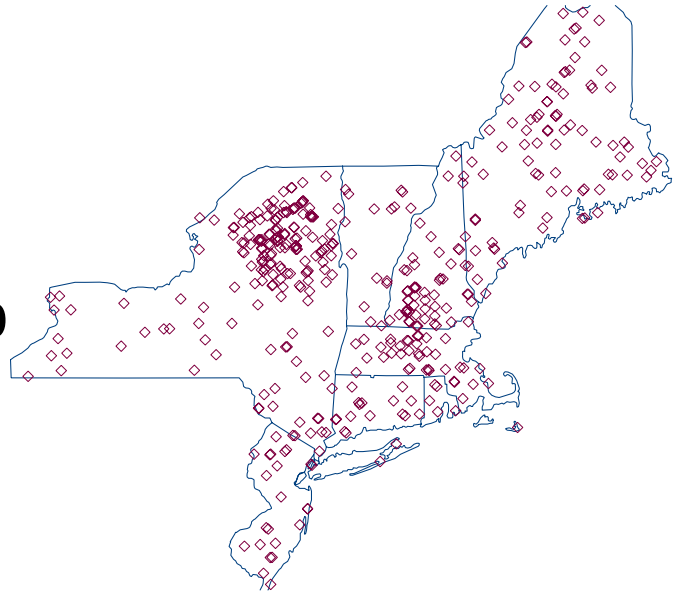
Response variable – chlorophyll a

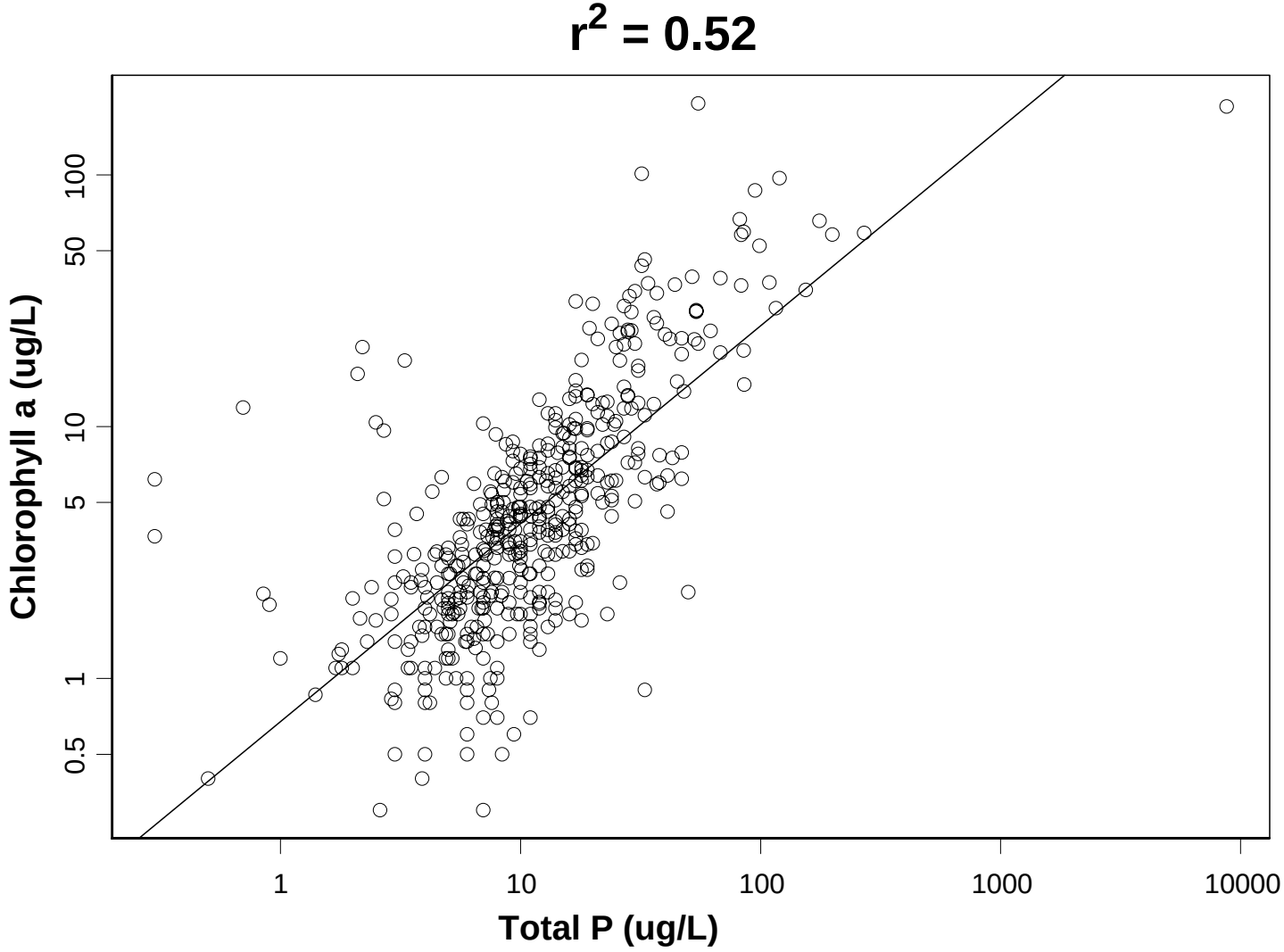
Define eutrophy as chla > 30 ug/L

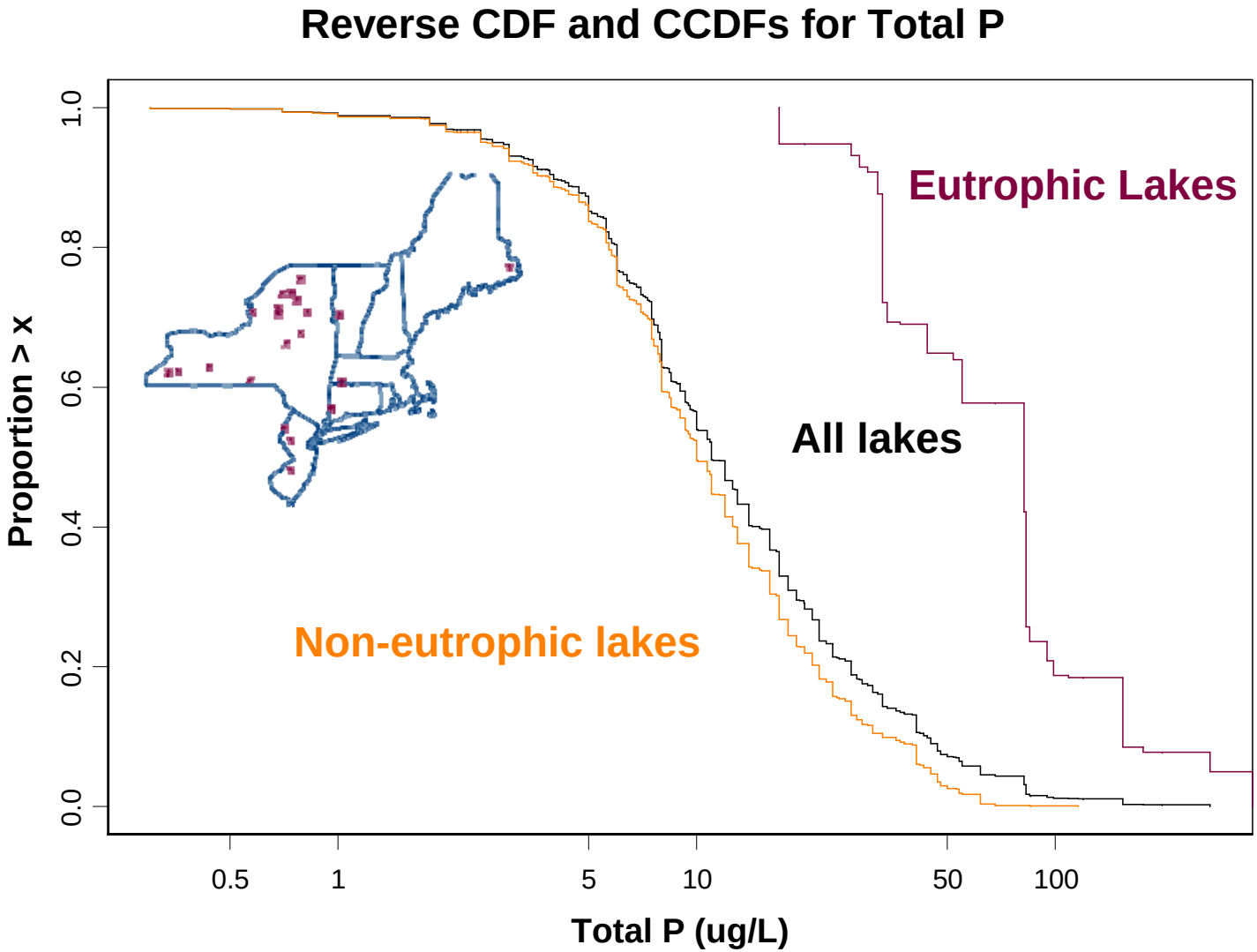
Threshold parameter – phosphorus

333 lakes sampled

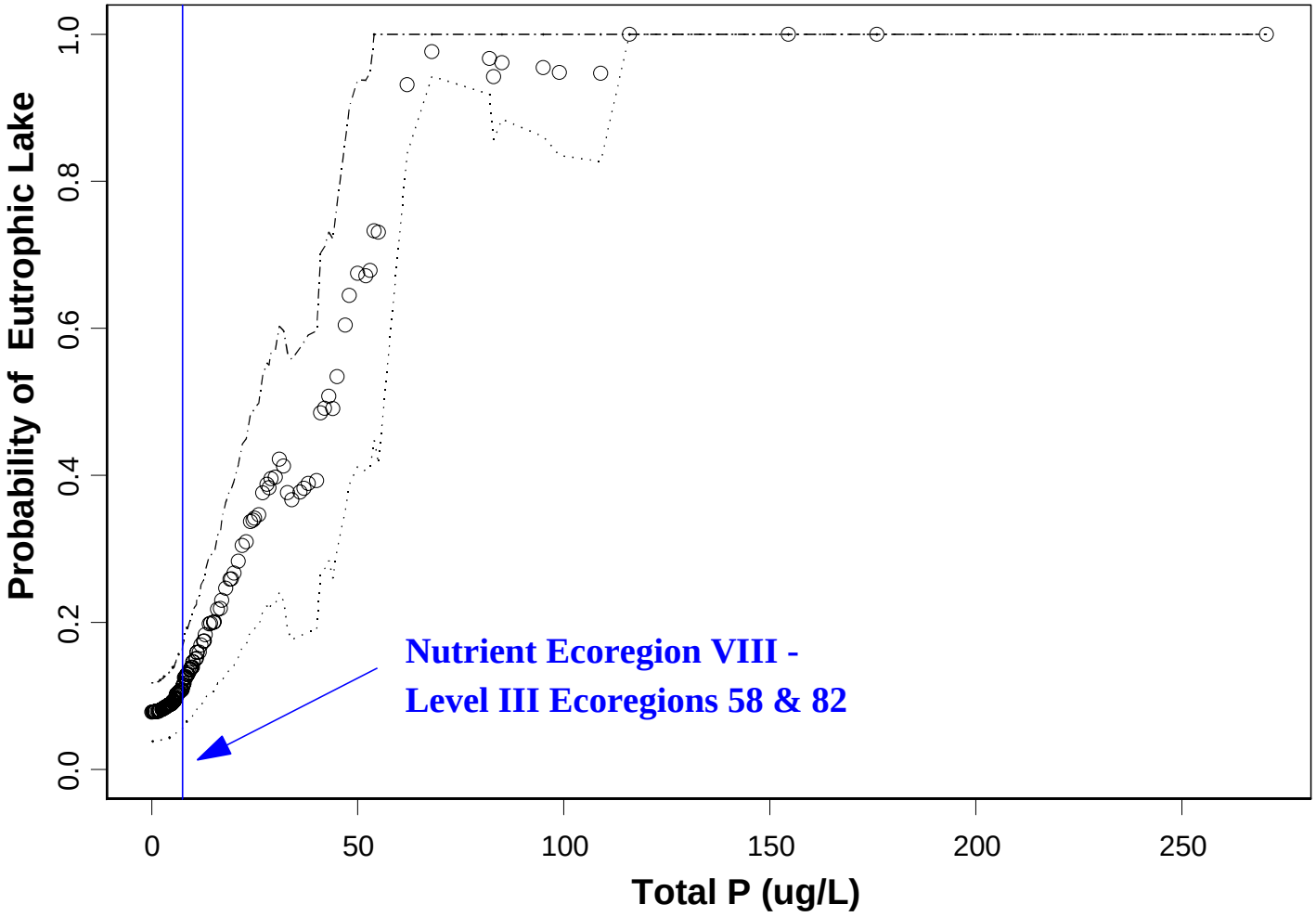
Data available at www.epa.gov/emap




r2 = 0.52
Chlorophyll a (ug/L)
0.5
1
5
10
50
100
1
10
100
1000
10000
Total P (ug/L)


Reverse CDF and CCDFs for Total P
Proportion > x
1.0
0.8
0.6
0.4
0.2
0.0
0.5
1
5
10
50
100
Total P (ug/L)
Eutrophic Lakes
All lakes
Non-eutrophic lakes

Conditional Probability for Exceeding Total Phosphorus Level



Mid-Atlantic EMAP Streams

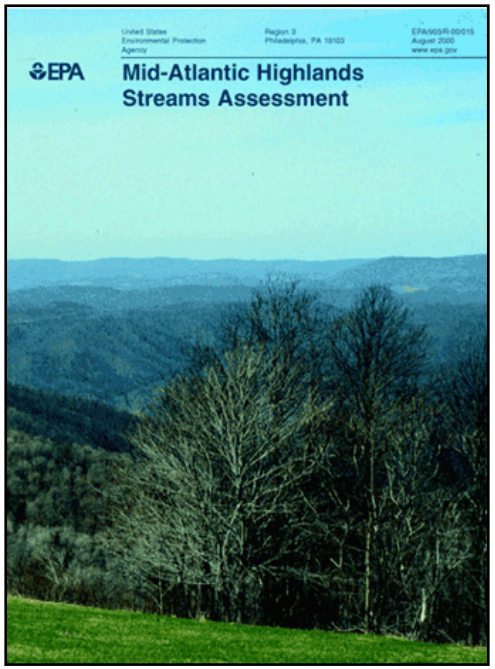
Status of biological resources – EMAP indicators

Sampling with EMAP probability design

380 stream segments sampled in 1993-96

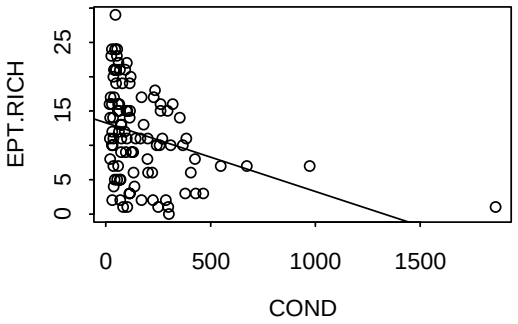
1st to 3rd order wadable streams

Data available at www.epa.gov/emap



Scatter plots (EPT taxa richness vs. stressors) and correlation coefficients

r = -0.341959039872149



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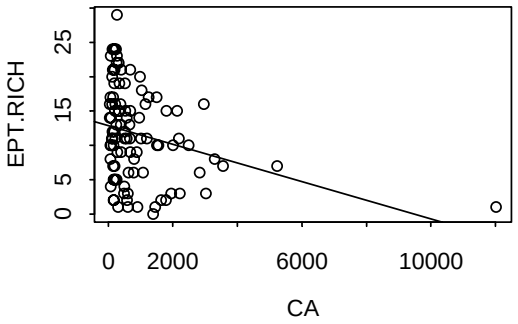

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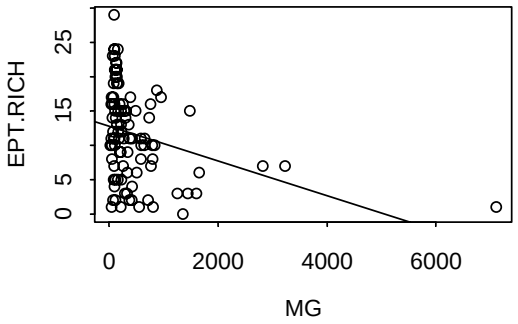
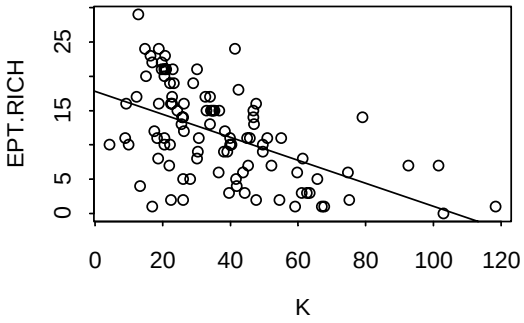


r = -0.535333858269259



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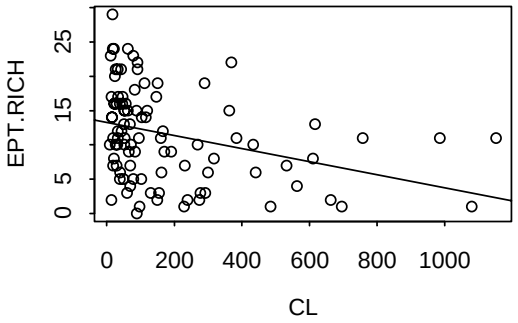

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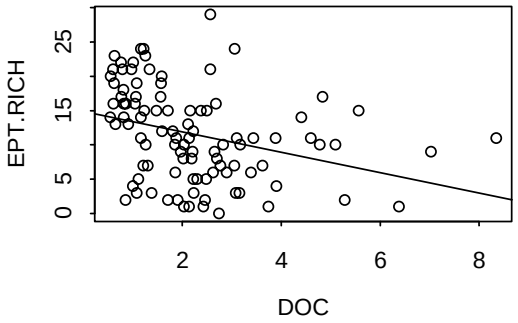

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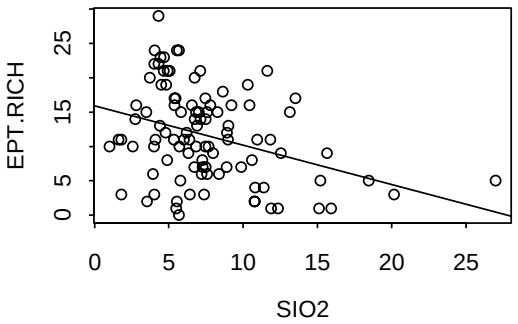

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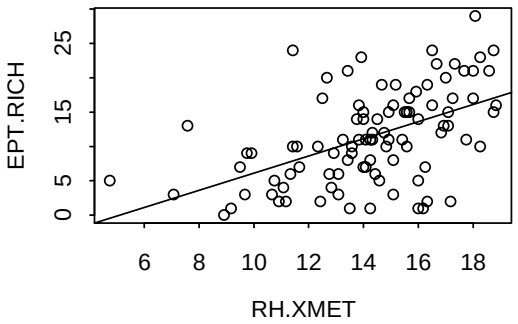

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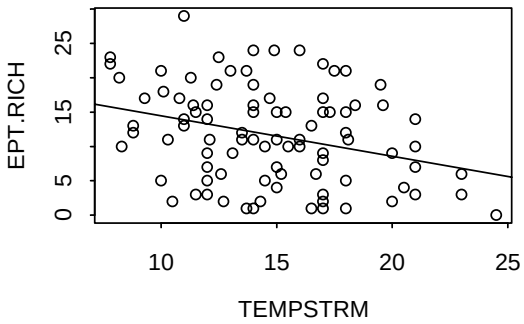
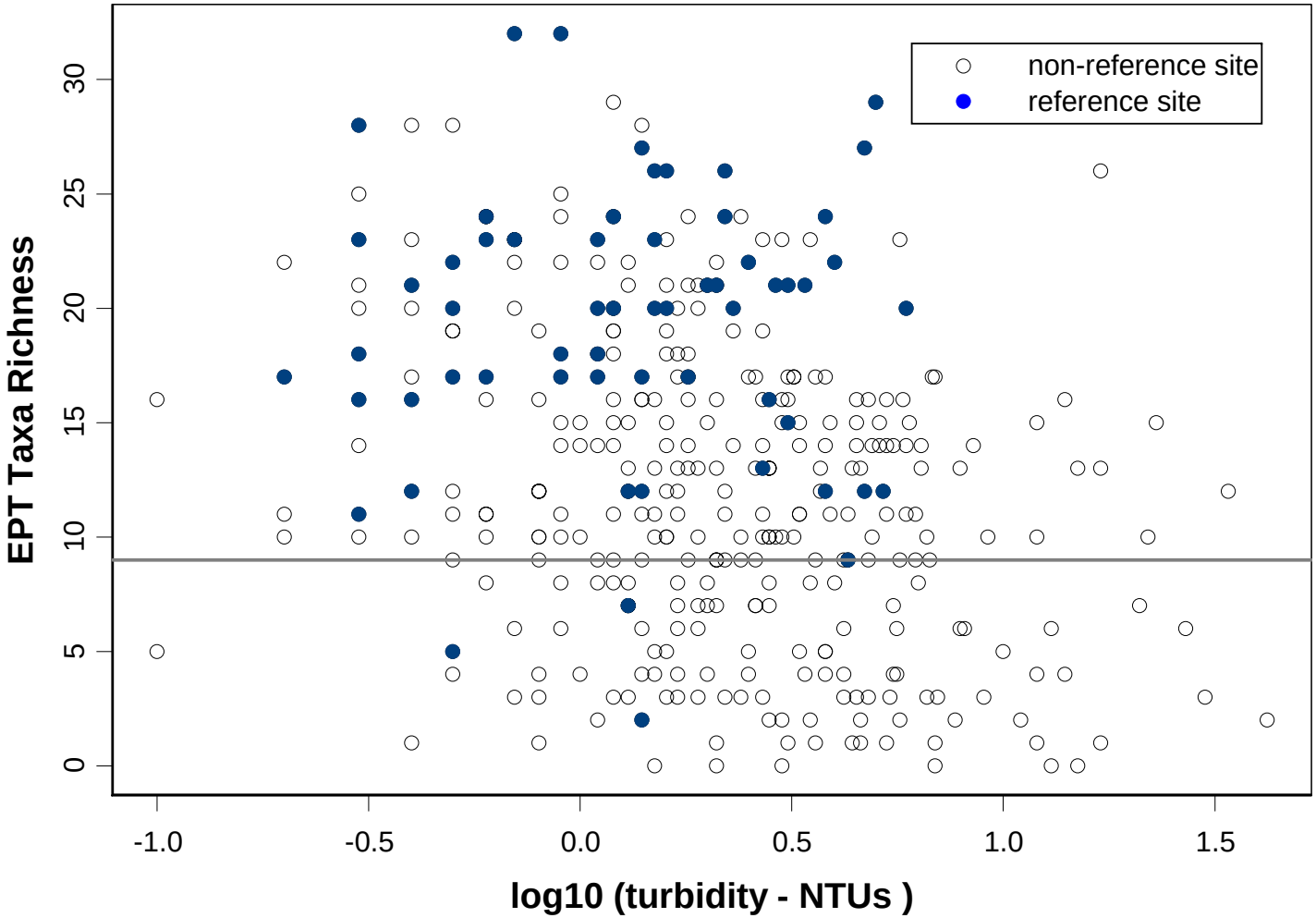


How about log x-scale plots?

example-MAIA-013.sgr

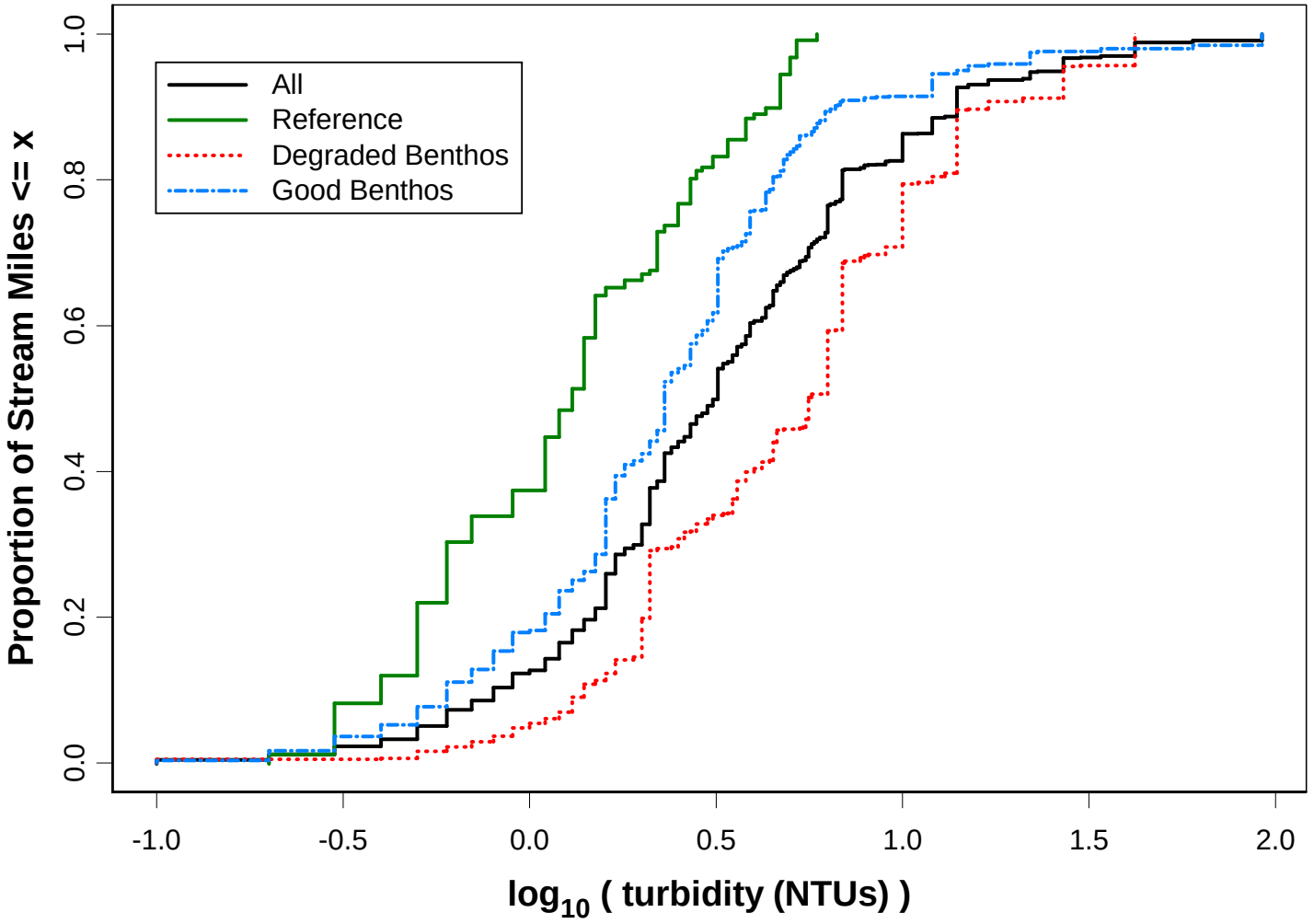


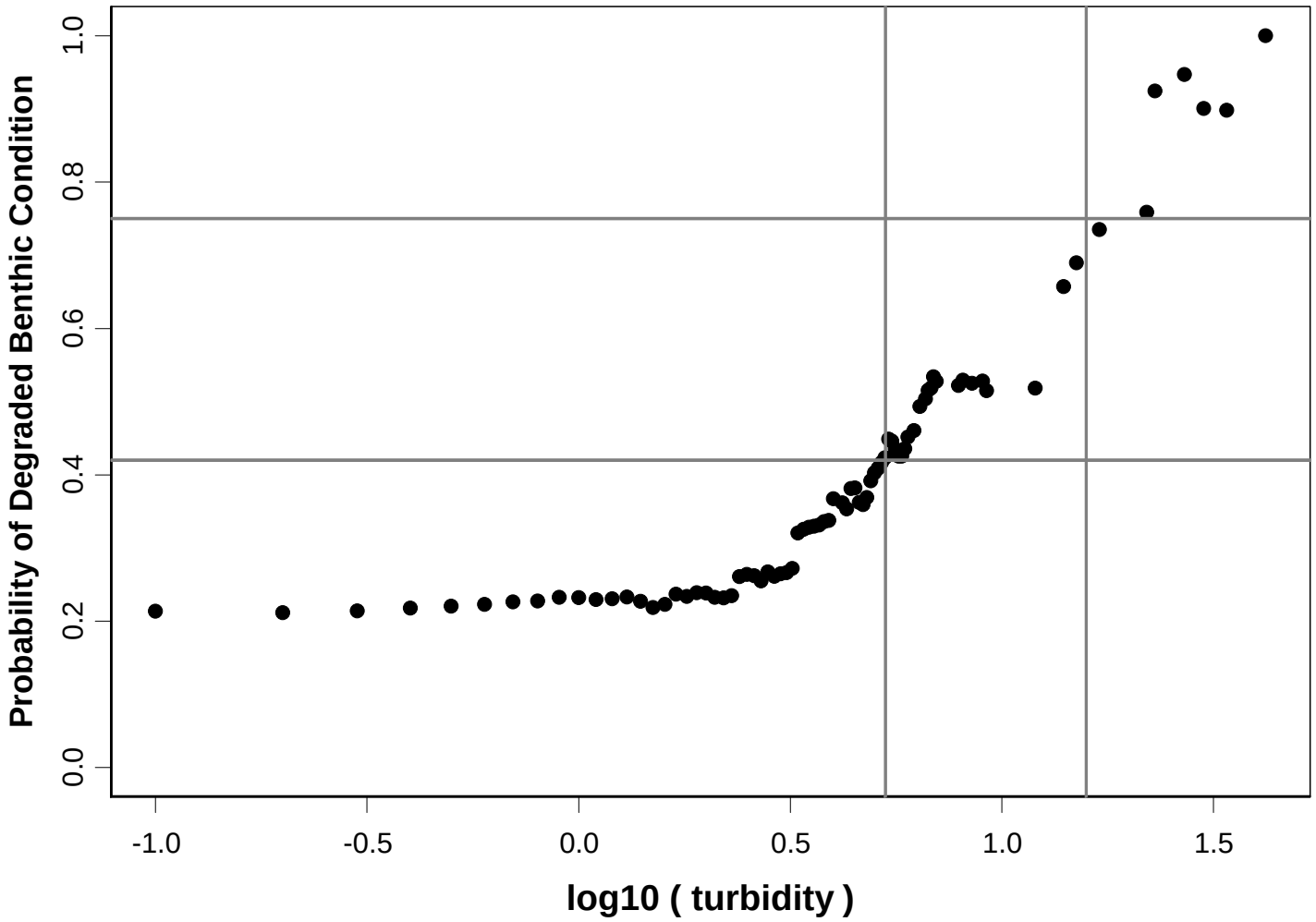
Distribution of Turbidity Values Per Stream Mile

1993-96 data

Cumulative Distribution Functions (CDFs)

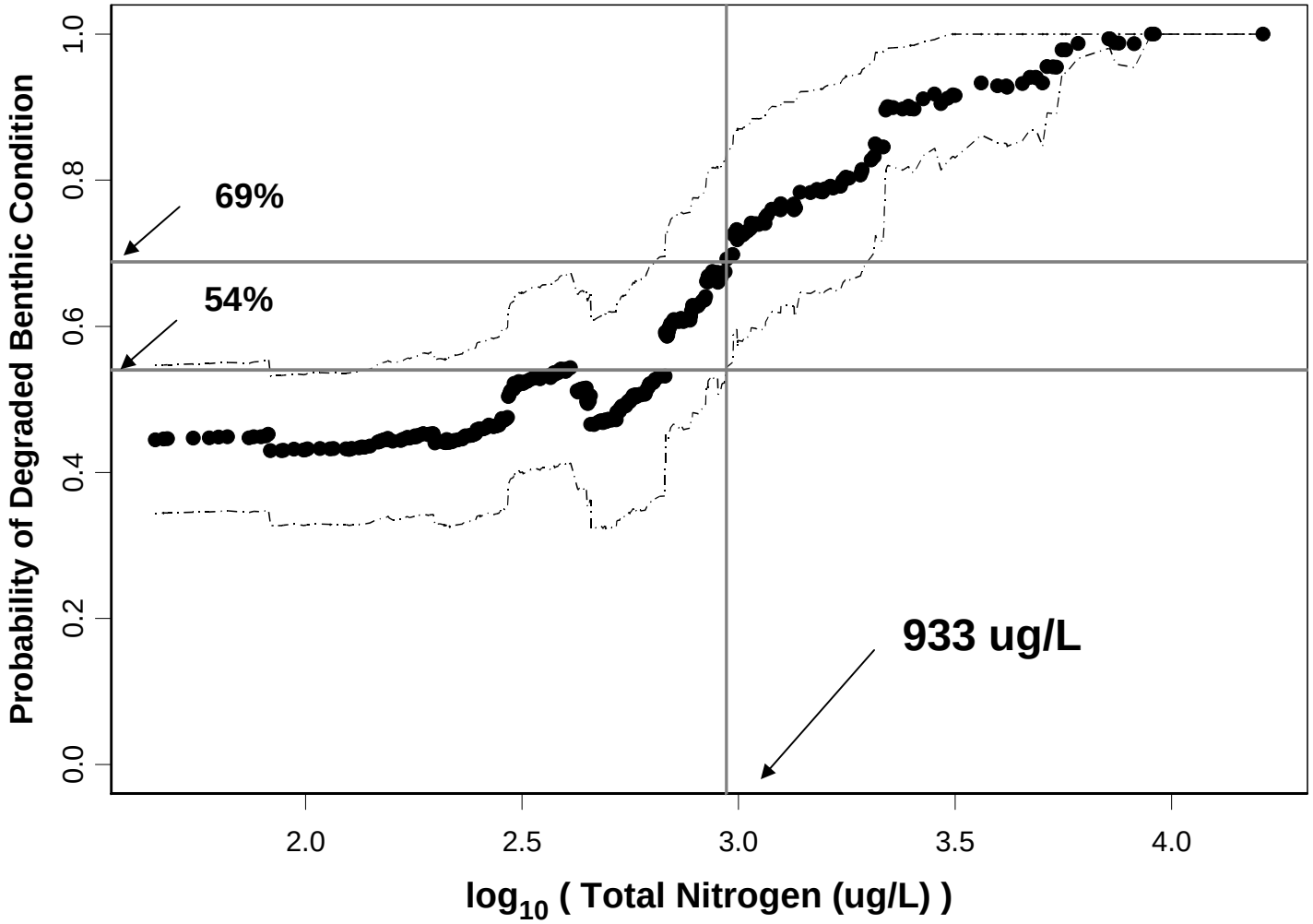
Conditional Cumulative Distribution Functions (CCDFs)




Probability of Degraded Benthic Condition
0.0
0.2
0.4
0.6
0.8
1.0
-1.0
-0.5
0.0
0.5
1.0
1.5
log10 (turbidity)

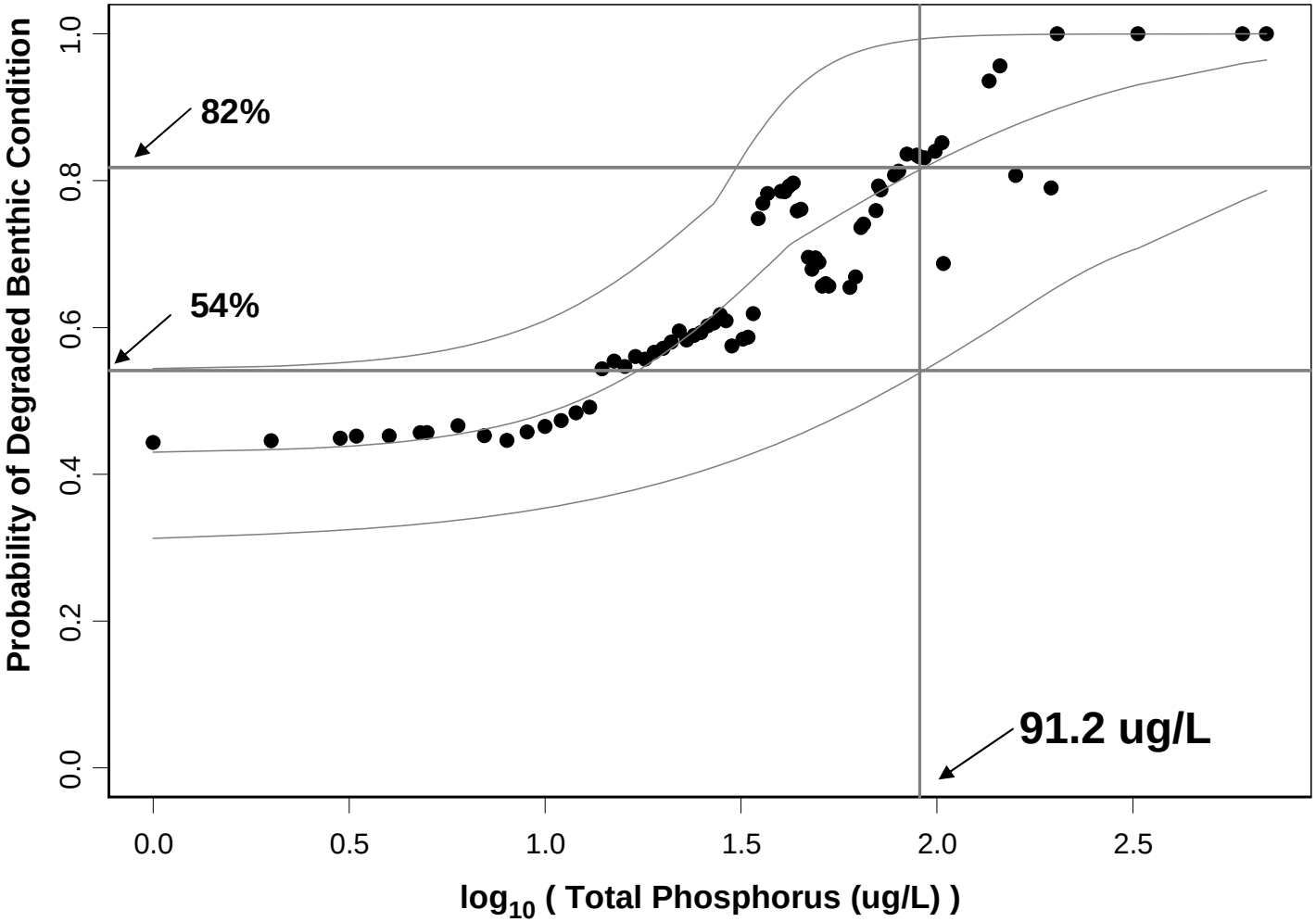
Conditional Probability Analysis for Total Nitrogen

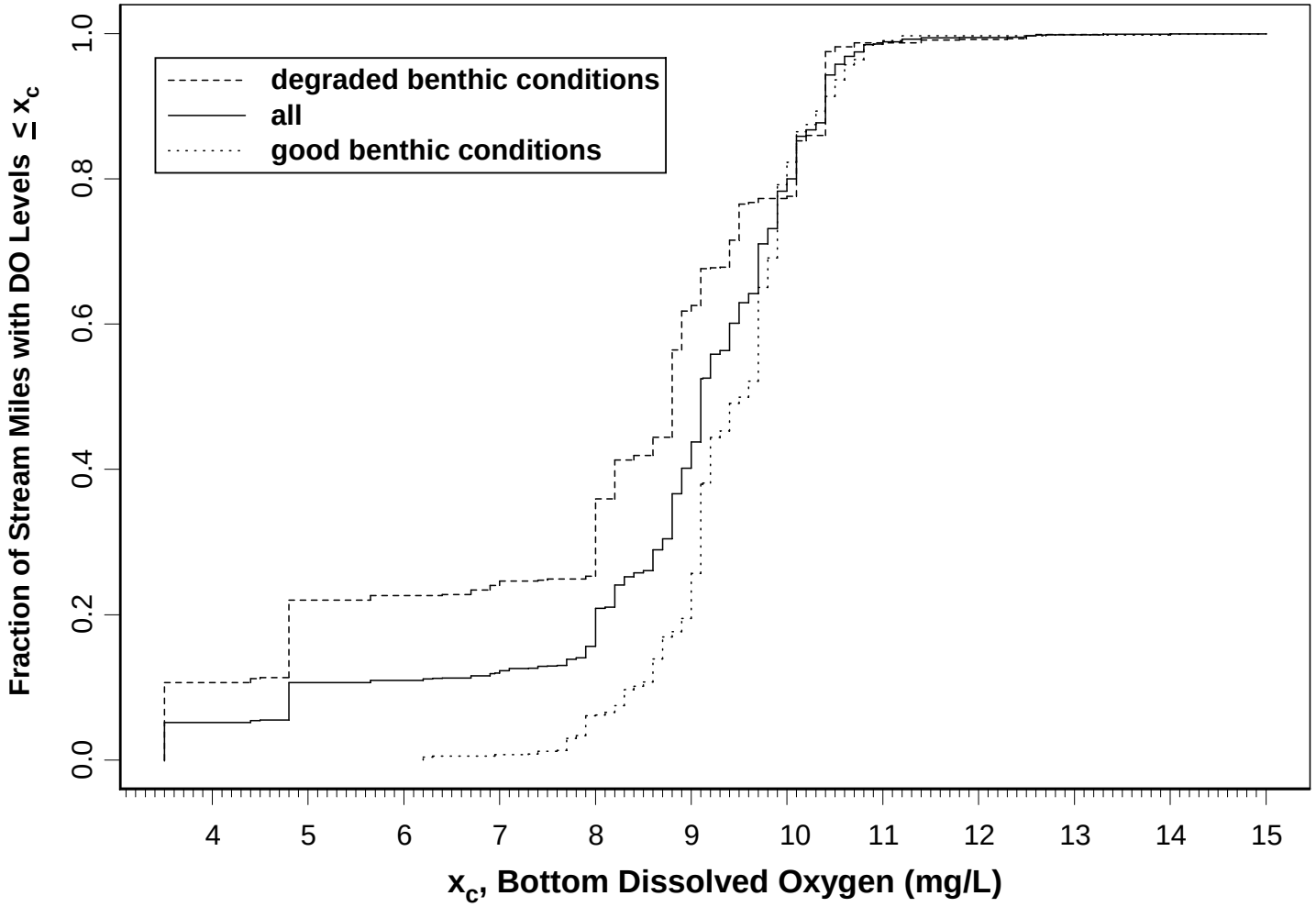
Degraded Benthic Condition for EPT Taxa < 9



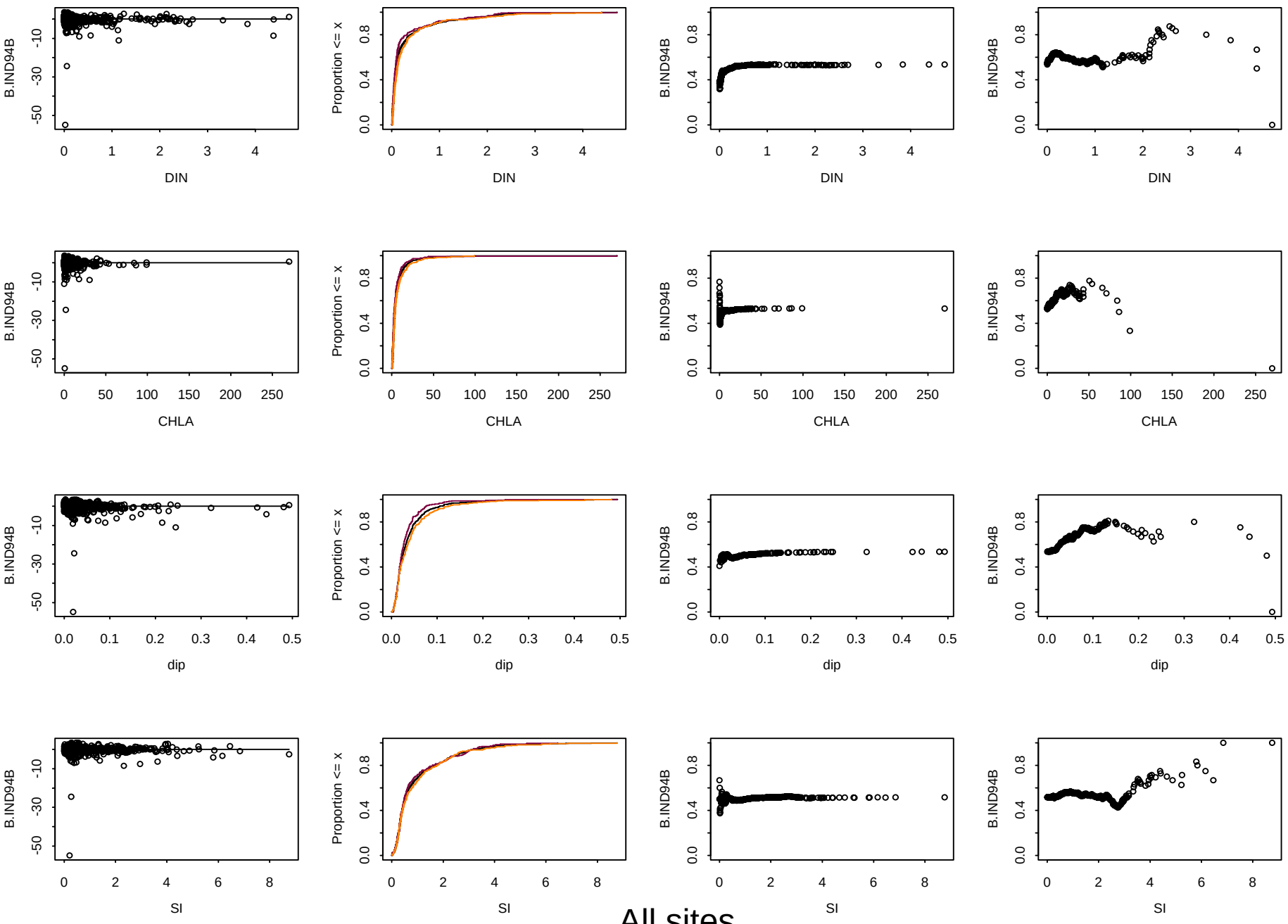
Conditional Probability Analysis for Total Phosphorus

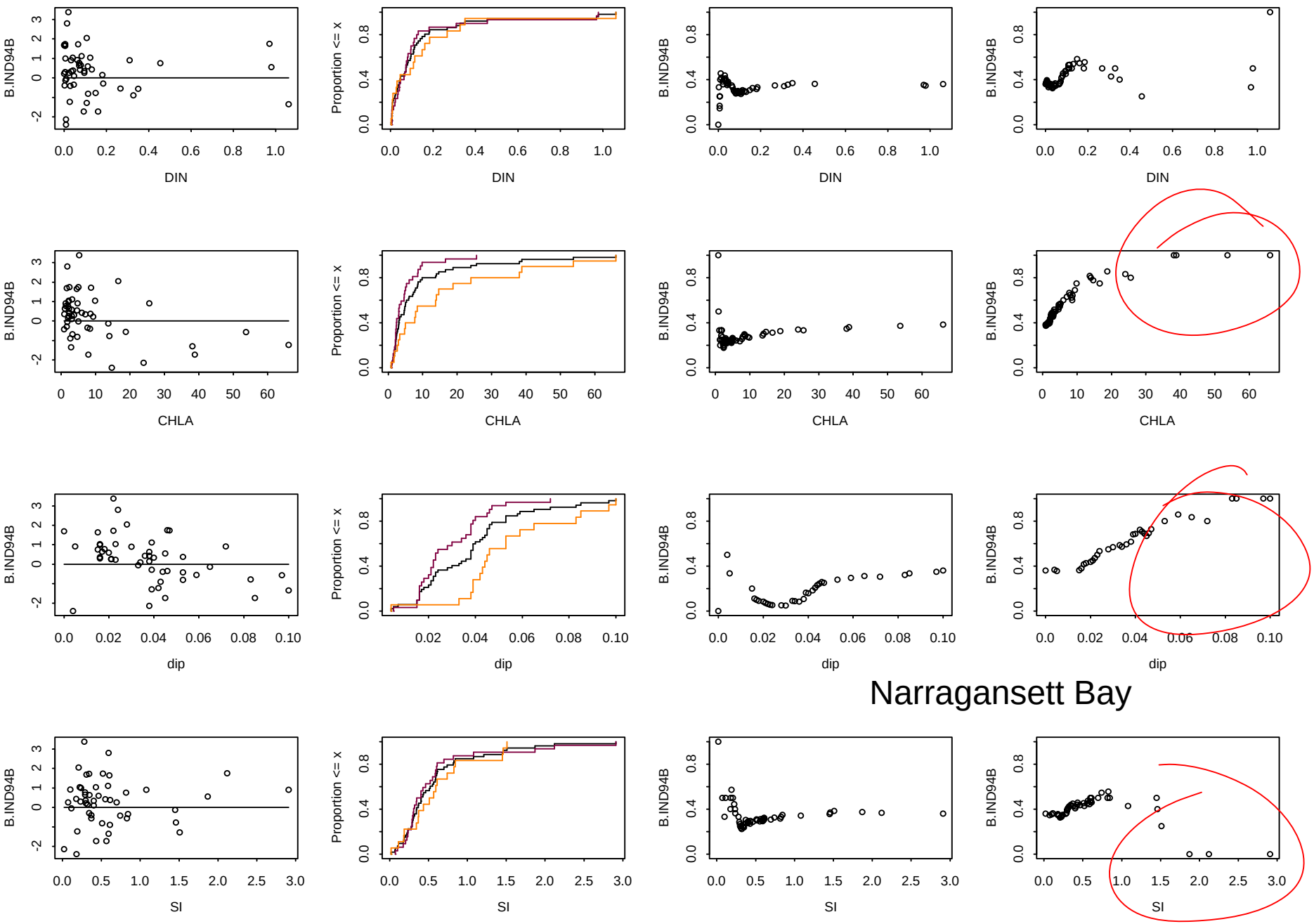
Degraded Benthic Condition for EPT Taxa < 9

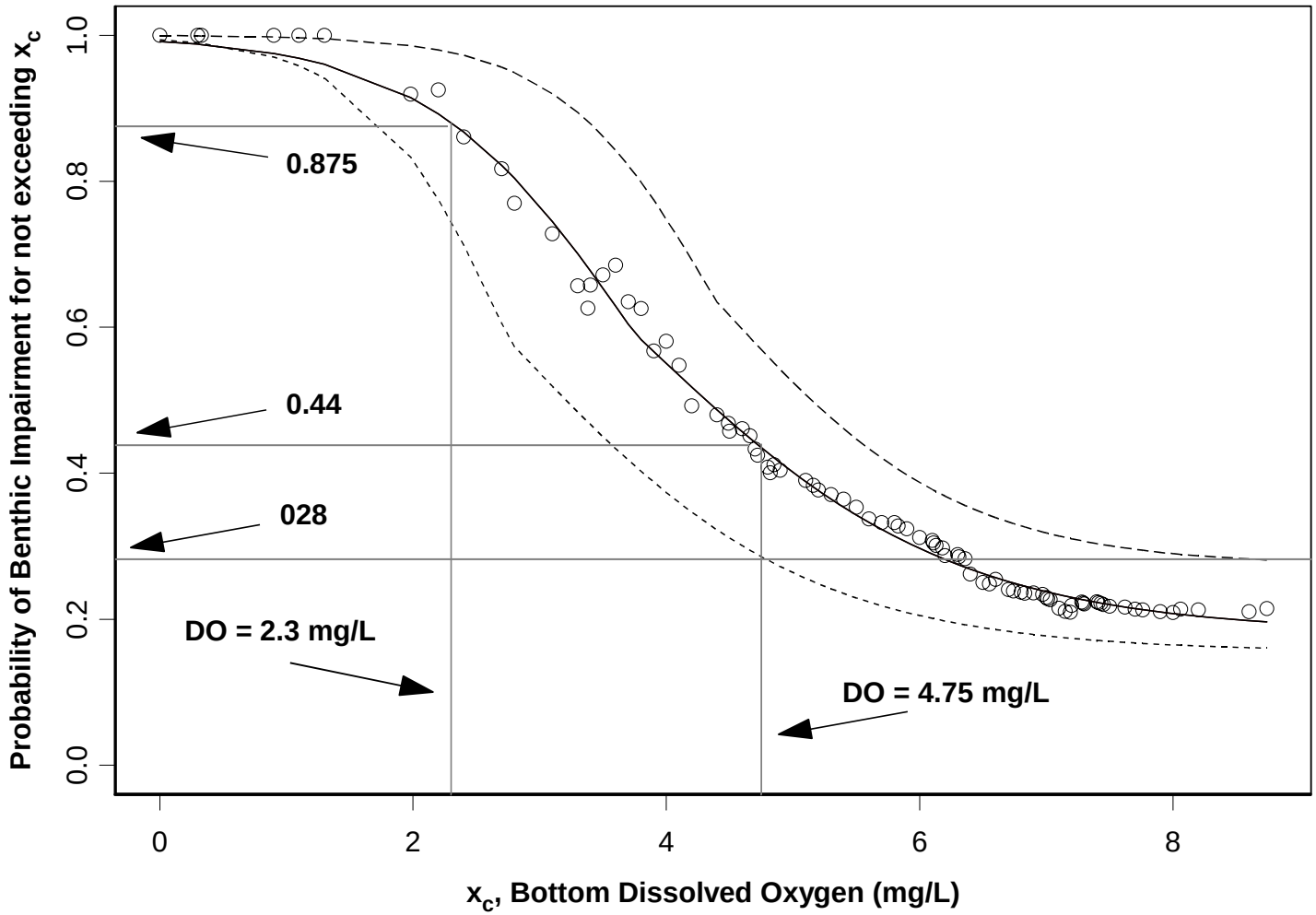



degraded benthic conditions
all
good benthic conditions
Fraction of Stream Miles with DO Levels ≤ x_c
0.0
0.2
0.4
0.6
0.8
1.0
4
5
6
7
8
9
10
11
12
13
14
15
x_c, Bottom Dissolved Oxygen (mg/L)

Estuarine example


B.IND94B
Proportion <= x
DIN
CHLA
dip
SI
All sites


B.IND94B
DIN
Proportion <= x
CHLA
dip
SI
Narragansett Bay


Probability of Benthic Impairment for not exceeding x_c
1.0
0.8
0.6
0.4
0.2
0.0
0.875
0.44
028
DO = 2.3 mg/L
DO = 4.75 mg/L
0
2
4
6
8
x_c, Bottom Dissolved Oxygen (mg/L)

But……

What value do probability surveys add?

Instead of results being applicable only to sites of observations, now they can be extrapolated to entire statsitical population

Things to Remember

- Use a consistent process
- Identify possible candidate causes
- Document, document, document
- Stressor Identification Guidance
- WWW. EPA.GOV/CADDIS

Take Home Message

Probability surveys

- Unbiased estimates
- Candidate criteria thresholds
  - Paul & McDonald, 2005, JAWRA
  - SABS WQC Document EPA-822-R-06-001
- Quantitative probabilistic ERA
  - Poster
  - Paul & Munns in review.
- Diagnostics

Cost-effectiveness of probability survey as backbone of monitoring program