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Overview: Empirical Approaches for Nutrient Criteria Derivation

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Purpose of the document

- Provide guidance on using known and accepted statistical methods to estimate stressor-response relationships from field data and on deriving nutrient criteria from these relationships to support the advancement of environmental protection and achieve water quality goals.

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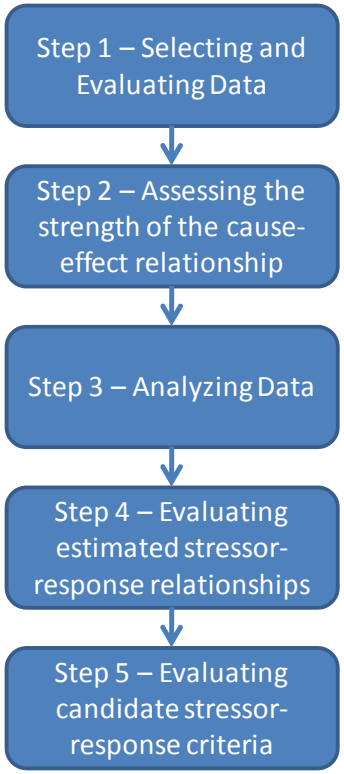
Five step framework for using stressor-response relationships to derive nutrient criteria

1. Select and evaluate data
2. Assess strength of cause-effect relationship
3. Analyze data
4. Evaluate estimated stressor-response relationships
5. Evaluate candidate stressor-response criteria



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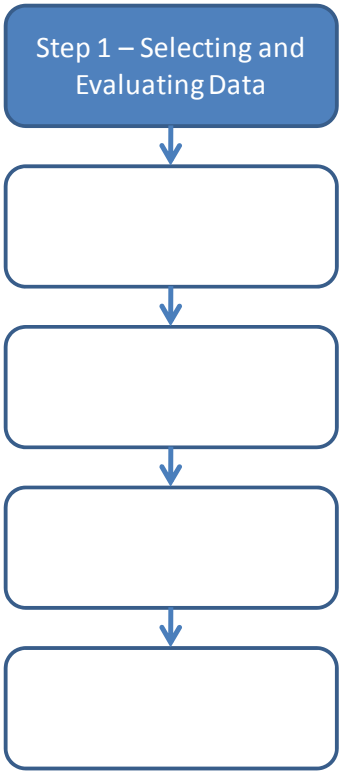
Step 1: Select and evaluate data

- Identify variables that quantify nutrient concentrations and a response variable that relates to a water quality goal.
  - Nutrient concentration variables: (e.g.,TN, TP)
  - Response variables:
    - Relate to water quality goal (e.g., aquatic life protection)
    - Causally relate to changes in nutrient concentrations
- Explore data set to understand relationships between nutrient variables, response variables, and possible confounding variables.



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Identify variables

- Example Dataset: Lakes from the Northeast United States, sampled by the Environmental Monitoring and Assessment Program
- Nutrient variable: total phosphorus (TP)
- Response variable: chlorophyll a (chl-a)
  - *Assume for illustrative purposes that chl-a = 15 µg/L is the threshold to support aquatic life protection in Northeast Lakes.*

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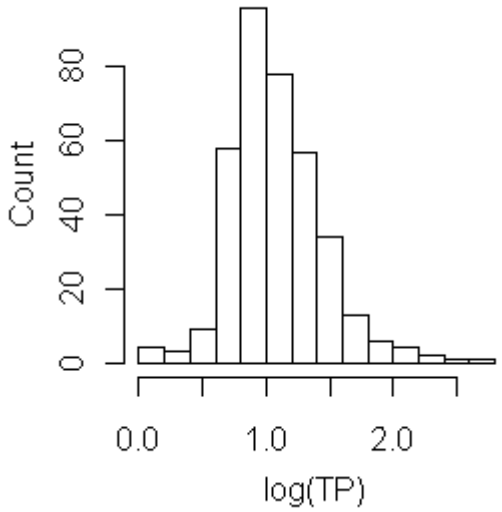
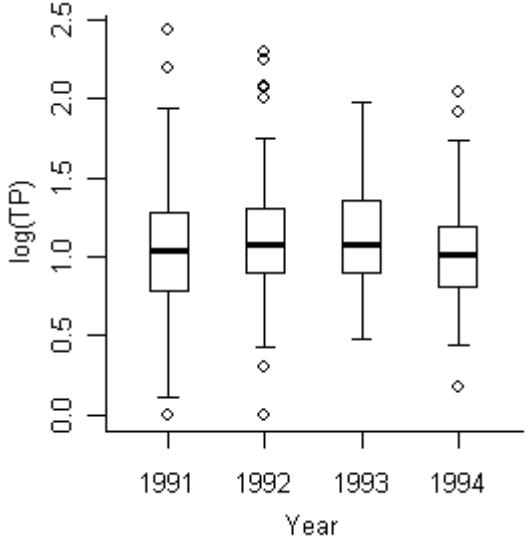
Examine data distributions

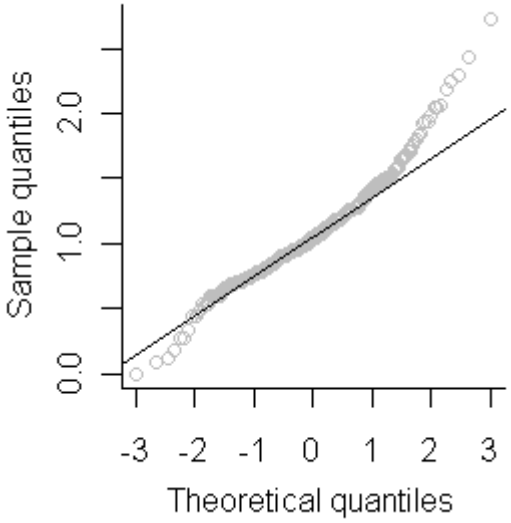
Histograms



Boxplots

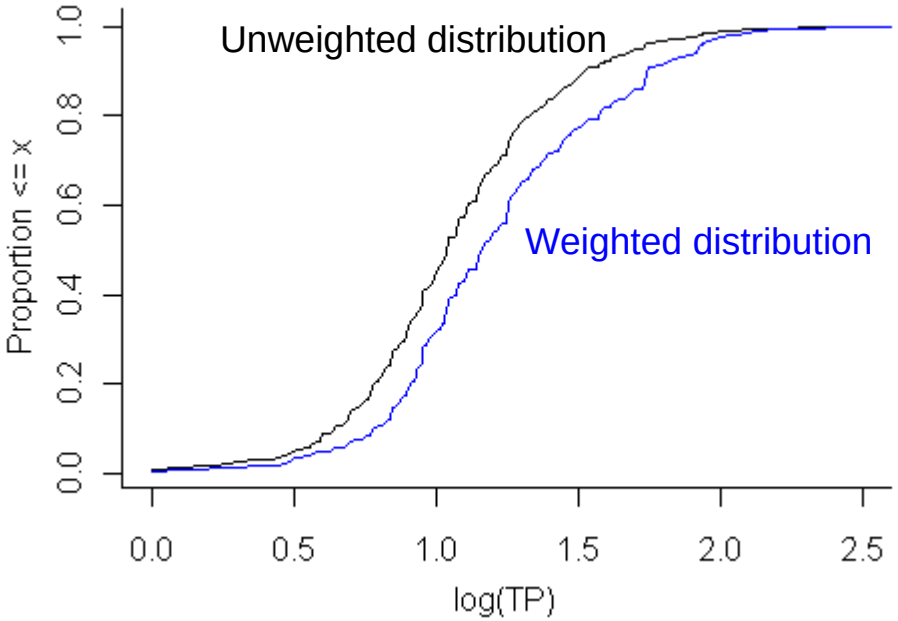


Q-Q plots



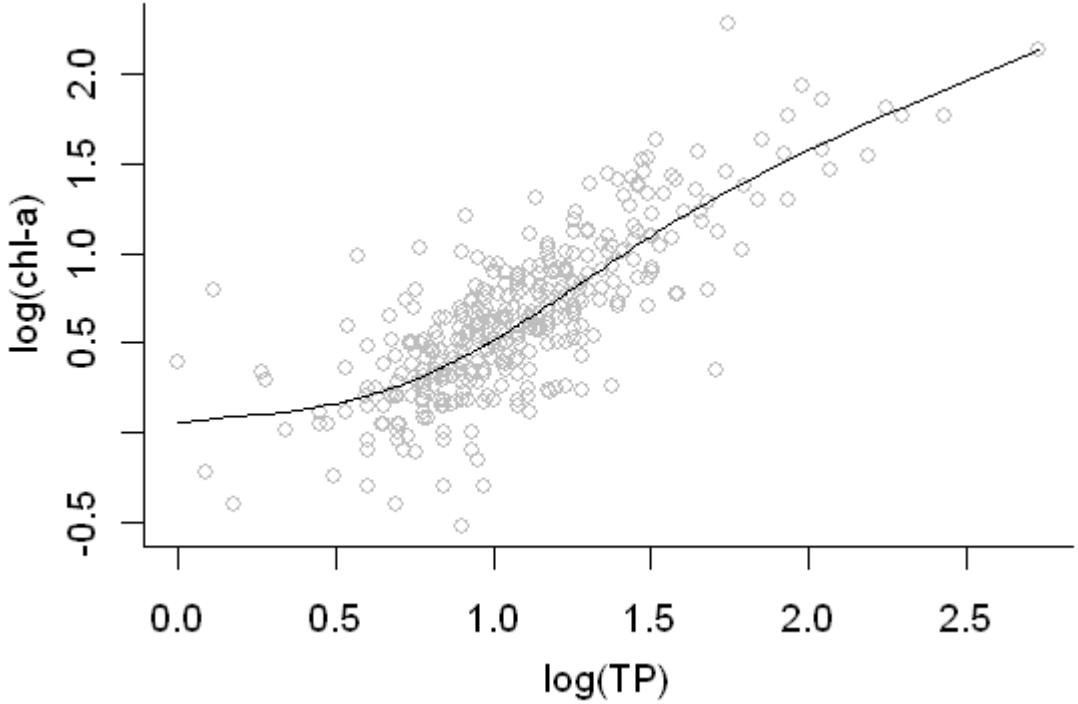
Cumulative distribution functions

- View distribution of data and allows for weighting of data from probability samples.

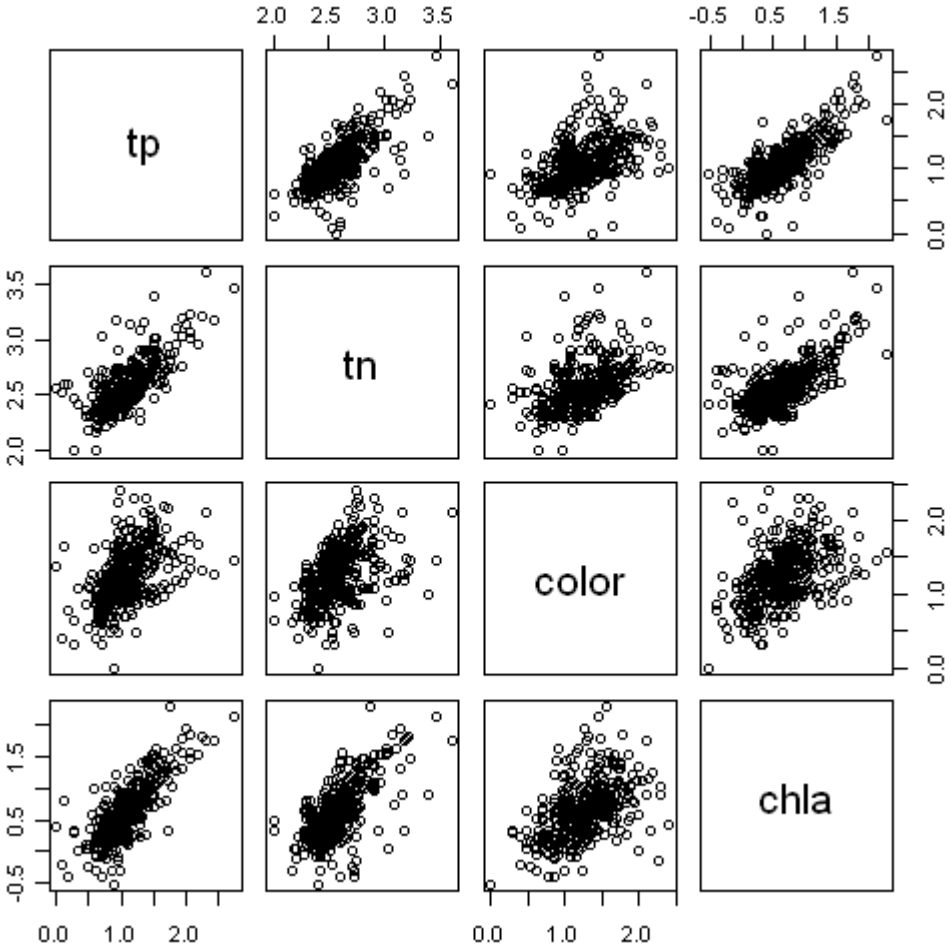


Fit nonparametric curves to data

- Helps visualize relationships between variables

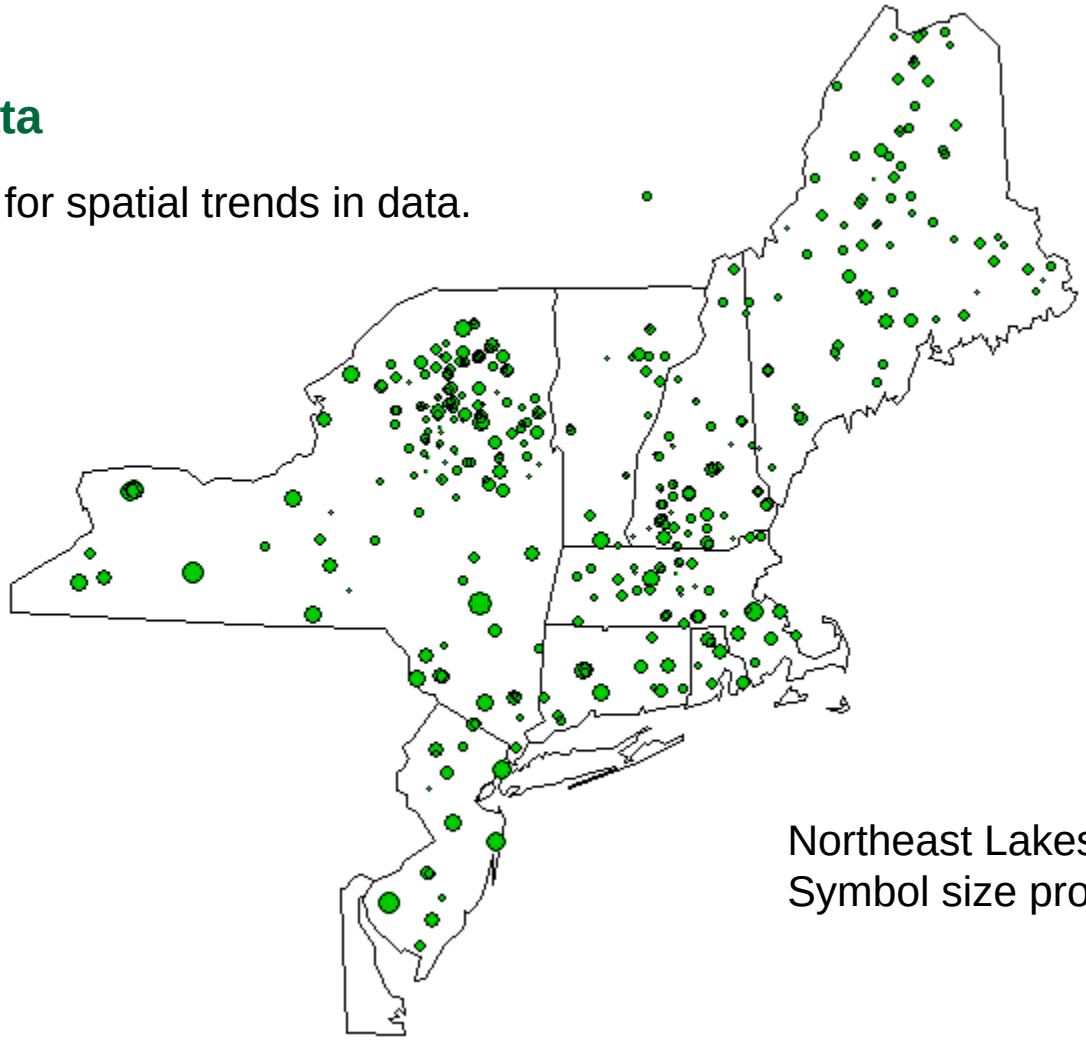


Examine covariance among several different variables



Map data

Look for spatial trends in data.



Northeast Lakes
Symbol size proportional to log(chl-a)

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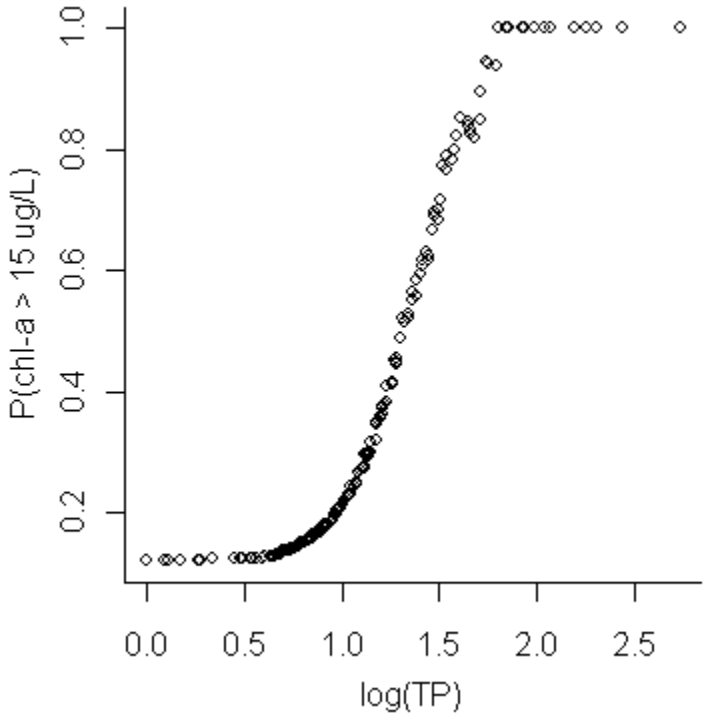
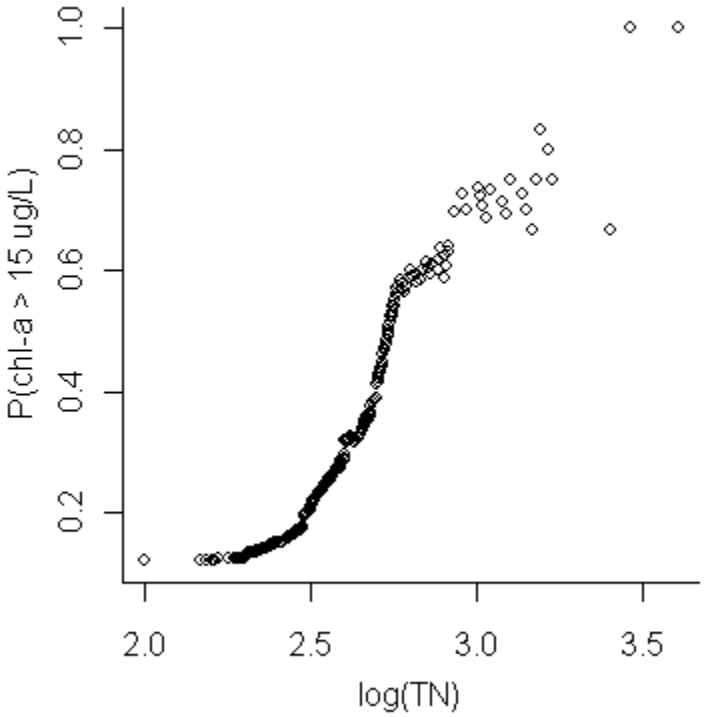
Conditional probability analysis (CPA)

CPA quantifies the probability of not supporting water quality goal, given different nutrient concentrations.





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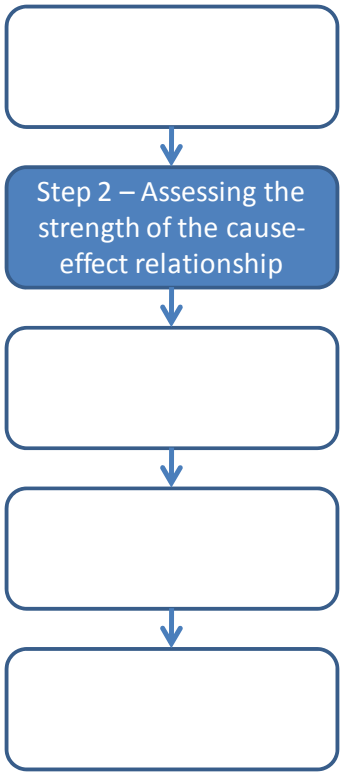
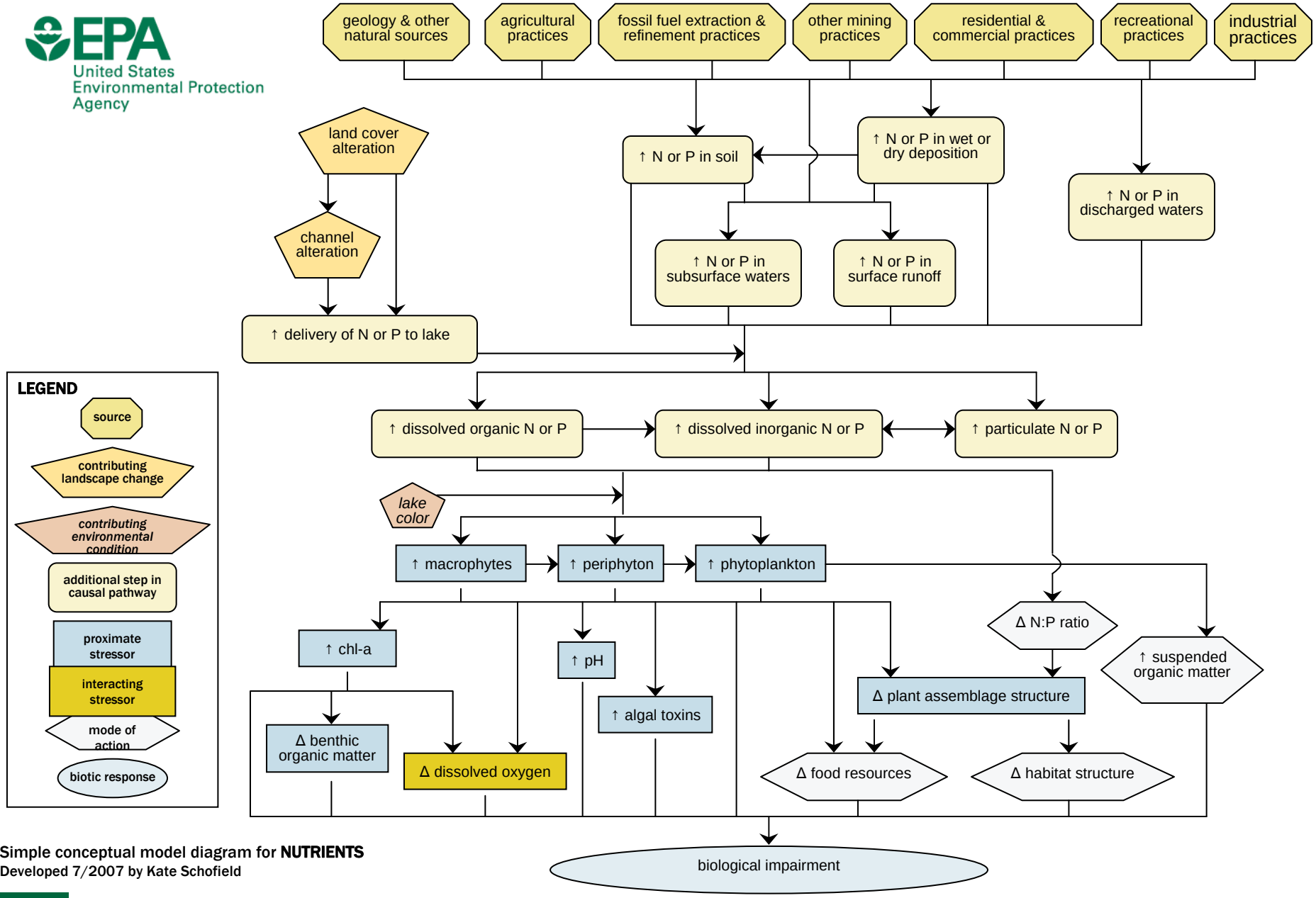
Step 2: Assess strength of the cause-effect relationship

- Conceptual model: Describe sequence of relationships by which nutrients affect response variable
- Existing literature: Document cause-effect relationships observed in other studies.
- Additional analyses:
  - Structural Equation Modeling
  - Propensity Score Analysis





Simple conceptual model diagram for NUTRIENTS
Developed 7/2007 by Kate Schofield

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Cause-effect relationships between TP and chl-a in literature

For example, increased total phosphorus increases chlorophyll a concentration

Supporting evidence includes:

- Whole lake fertilization experiments (Schindler 1974, 1977; Stockner and Shortreed, 1985; Carpenter et al. 1996)
- Consistent relationships estimated from observational data collected from many different locations.

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Step 3: Analyze data

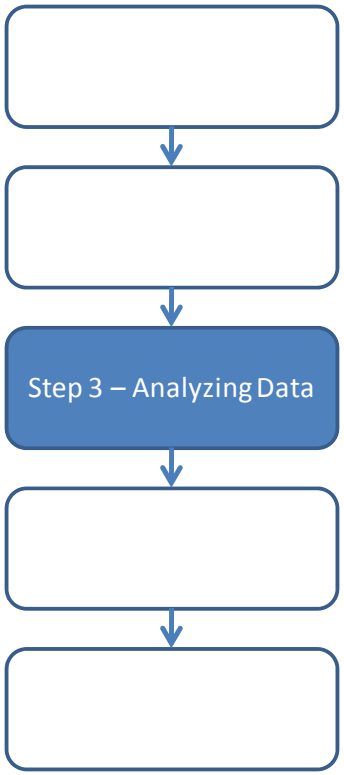
Two distinct approaches for informing criterion derivation from a stressor-response relationship.

1. Threshold is known for response variable

   Stressor-response relationship is used to "translate" response threshold to a protective nutrient concentration.

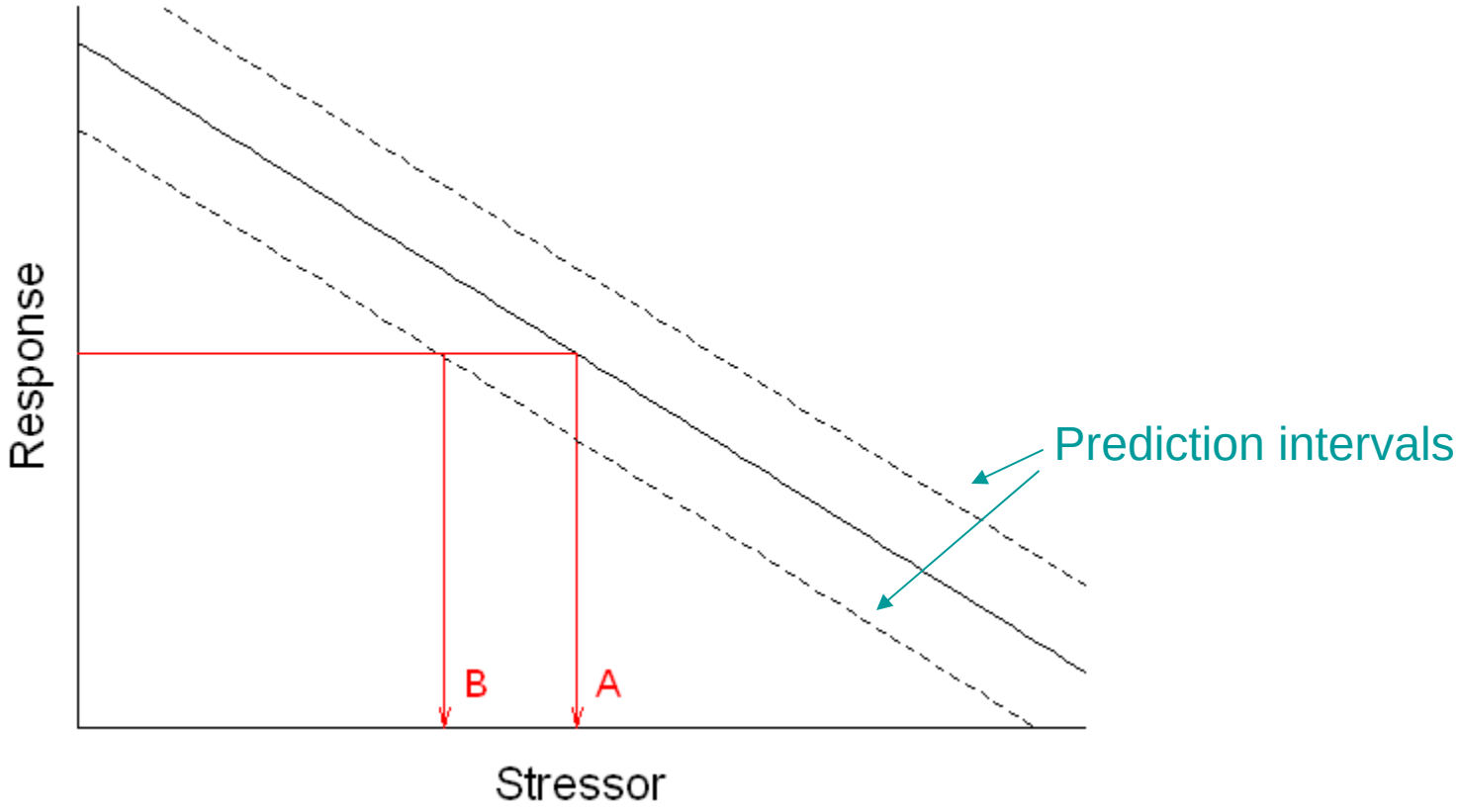
2. No threshold available for response variable

   Use characteristics of the stressor-response relationship to inform the derivation of a criterion.



Step 3: Analyze data

Translate a known response threshold



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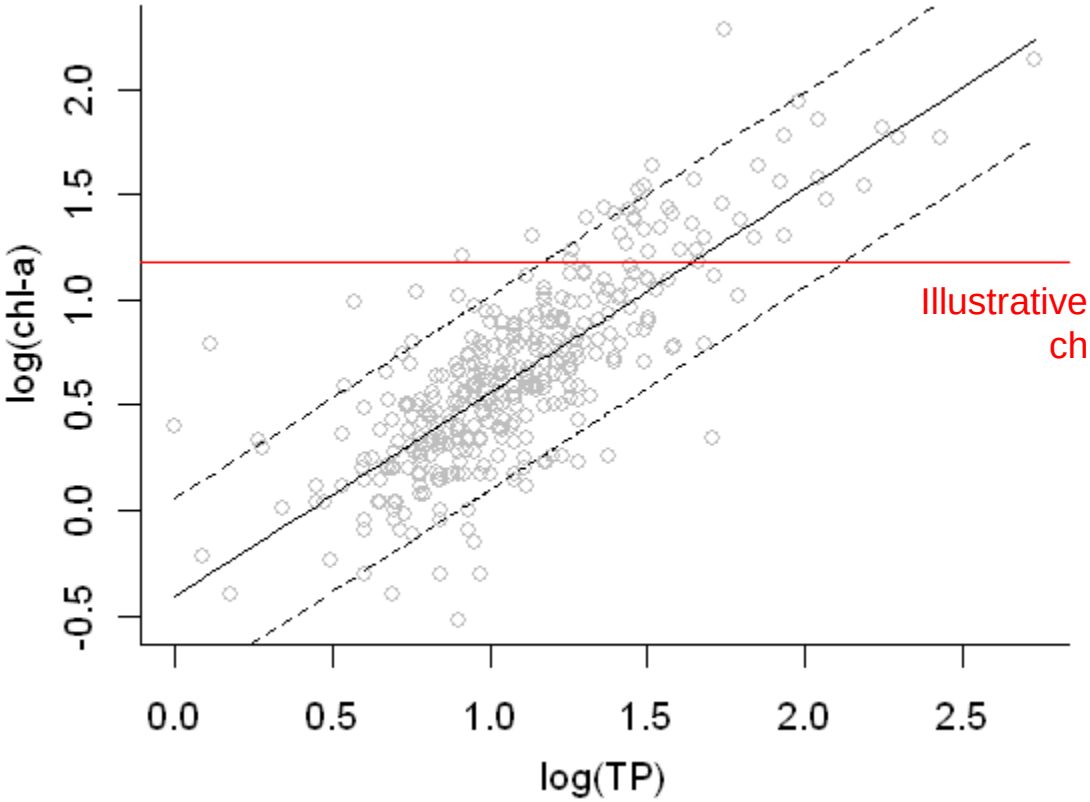
Translate a known response threshold:

Methods for estimating the stressor-response relationship

- Simple linear regression
- Quantile regression
- Logistic regression

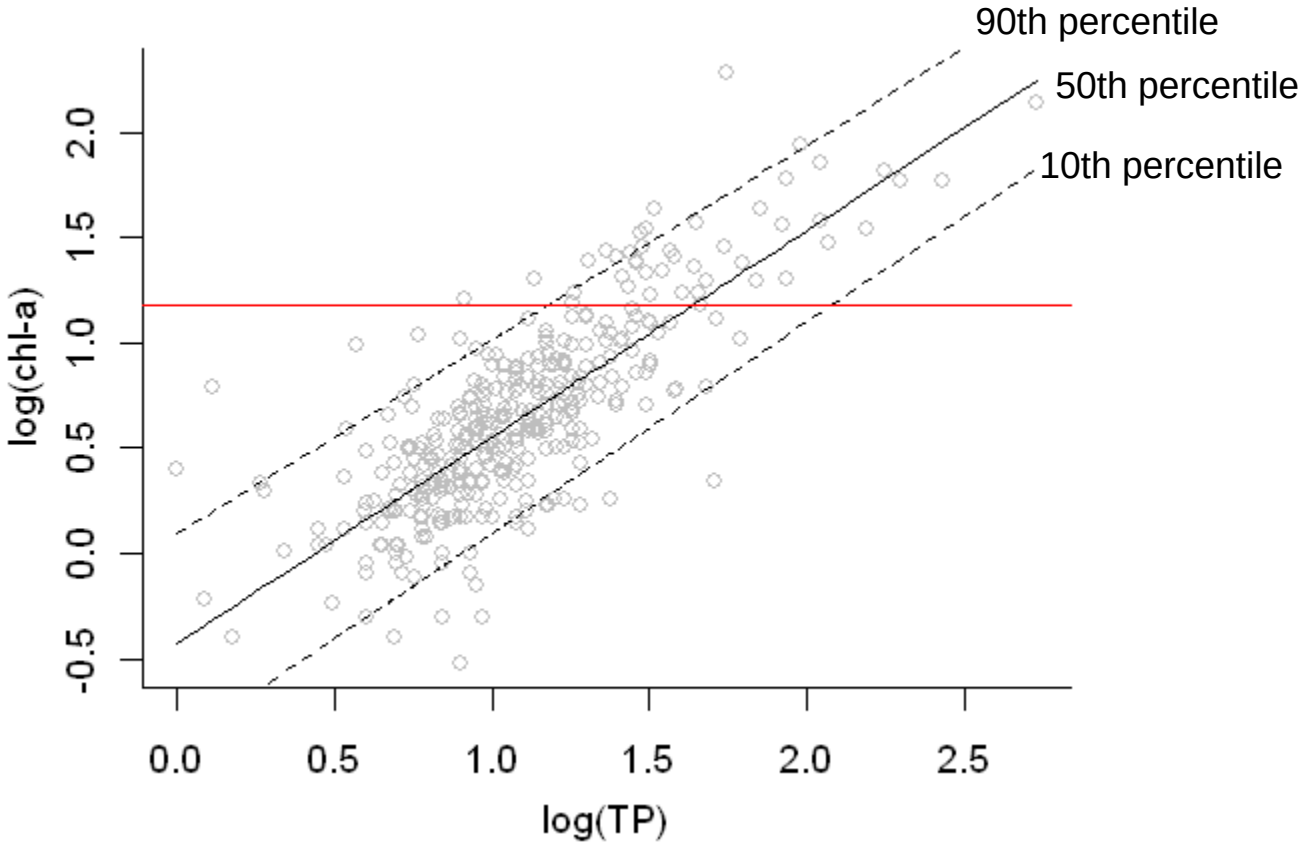
- Multiple linear regression

Simple linear regression



Illustrative response threshold:
chl-a = 15 µg/L

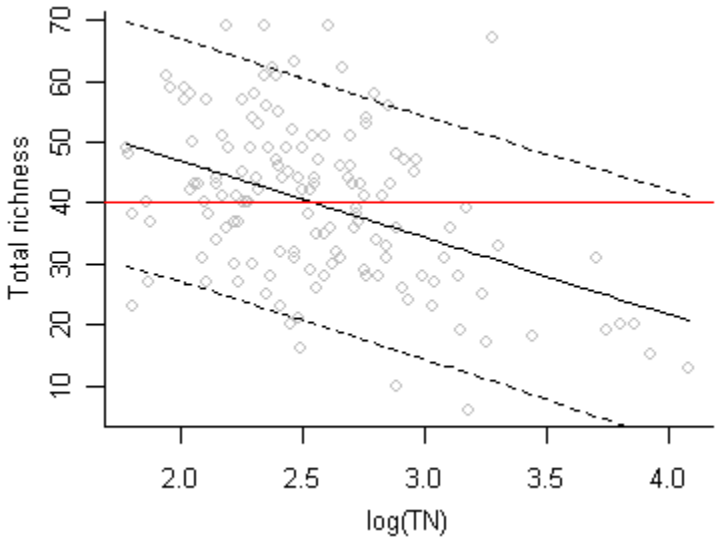
Quantile regression



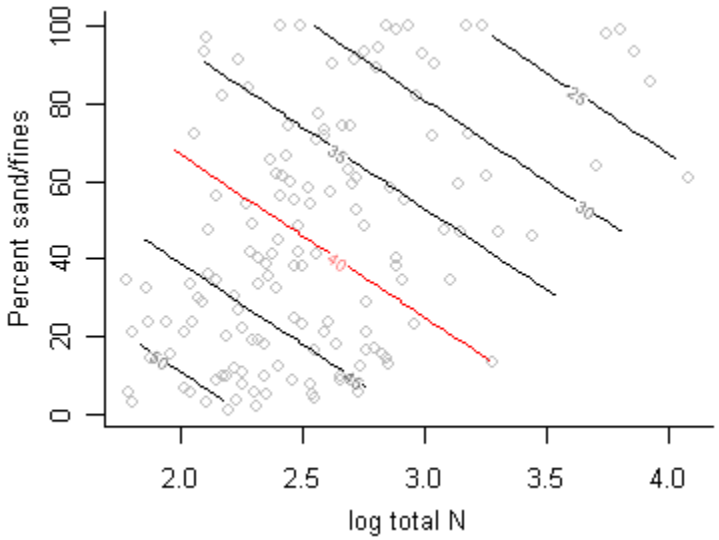
Multiple linear regression

Multiple linear regression models can be useful when nutrients are one of many factors influencing biota.

Many factors, in addition to nutrients, influence macroinvertebrate richness:



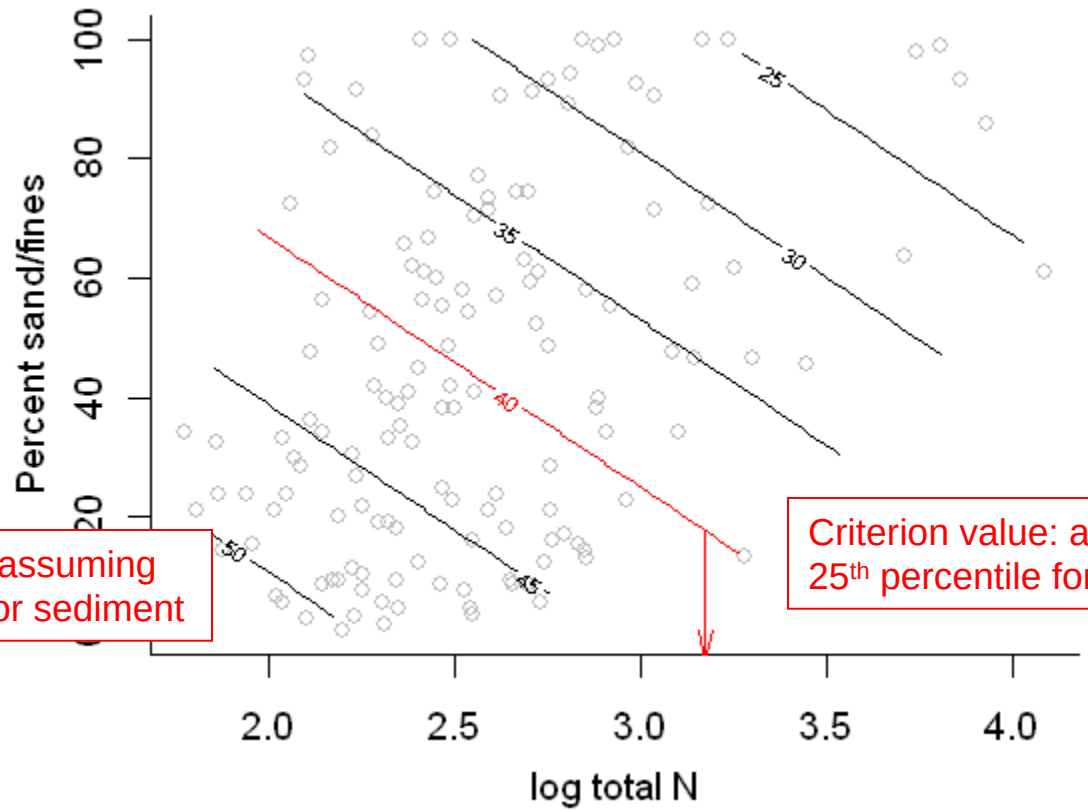
$R^2 = 0.19$



$R^2 = 0.32$

Data from EMAP-West

Use results from multiple linear regression to translate an existing response threshold



Contour lines indicate modeled mean macroinvertebrate richness.

Criterion value: assuming 75th percentile for sediment

Criterion value: assuming 25th percentile for sediment

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Step 3: Analyze data

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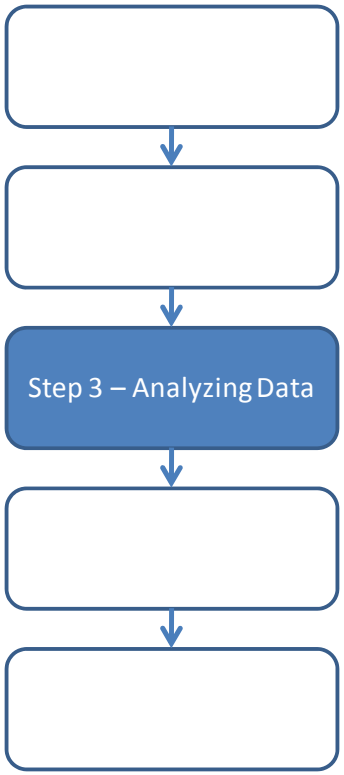

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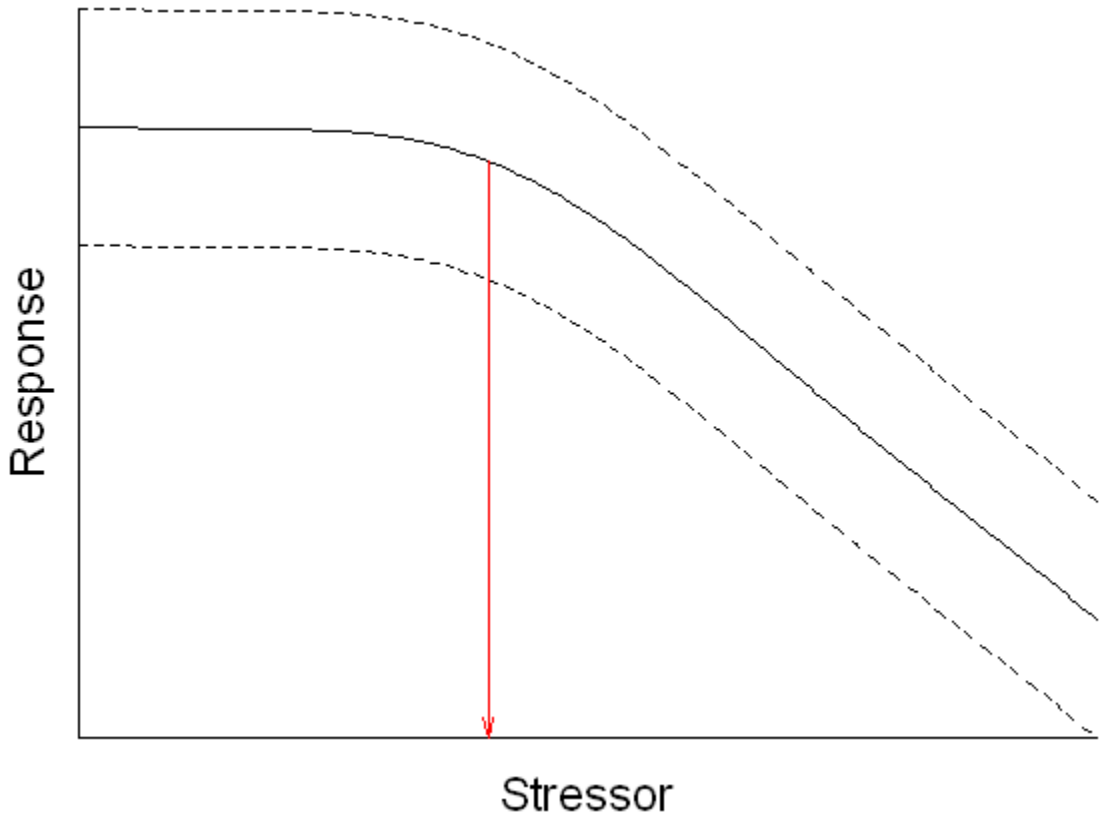
Step 3: Analyze data

Use characteristics of the stressor-response relationship



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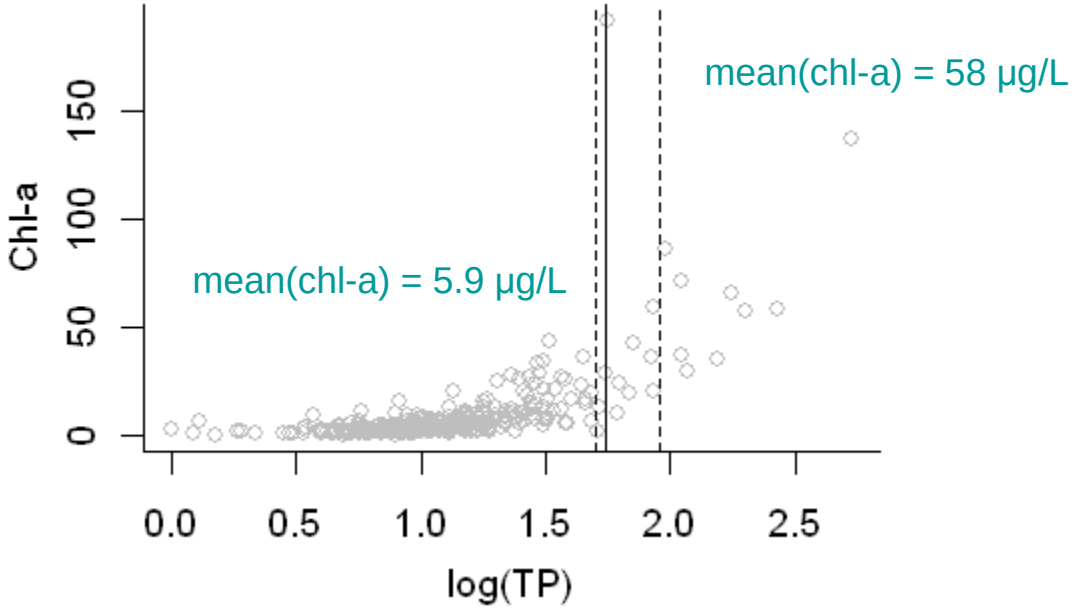
Methods for identifying characteristics of the stressor-response curve

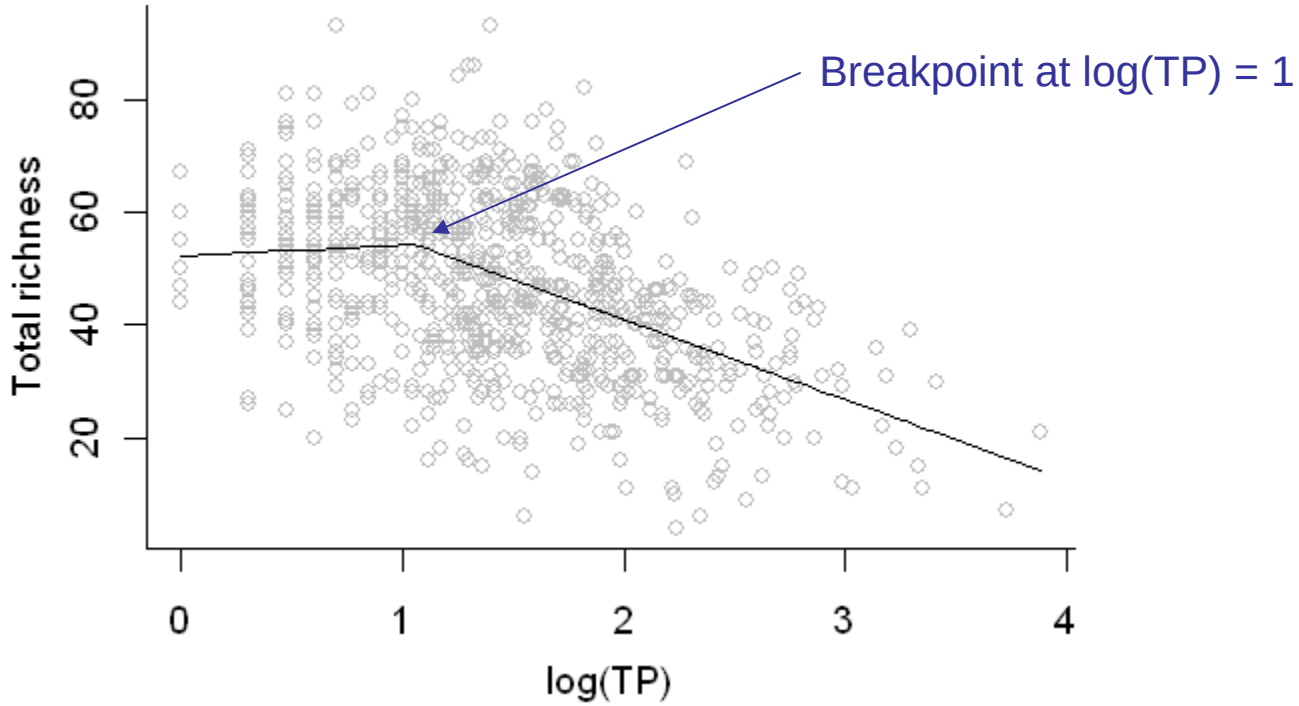
- Nonparametric changepoint analysis
- Discontinuous regression models

Nonparametric changepoint analysis



Data from Northeast Lakes

Discontinuous linear regression



Data from EMAP-West

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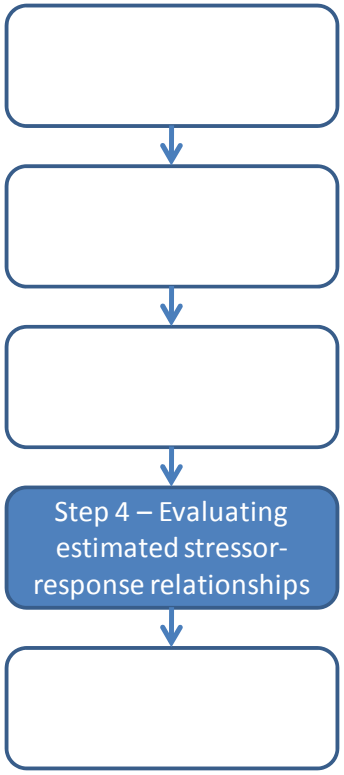
Step 4: Evaluate estimated stressor-response relationships

- Validation:
  - Apply models to independent data to quantify predictive accuracy.
- Assess uncertainty in model
  - Model assumptions (e.g., space-for-time substitution, regression model assumptions)
  - Model structure: included variables and functional form
- Select stressor-response model



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Evaluating models for Northeast Lakes

- Quantile regression and simple linear regression provide similar results.
  - *Regression assumptions are reasonably supported*
- Multiple regression model does not substantially increase explanatory power of the model.
  - *Simple linear regression provides representative model*.
- Select simple linear regression model of log(chl-a) vs. log(TP)

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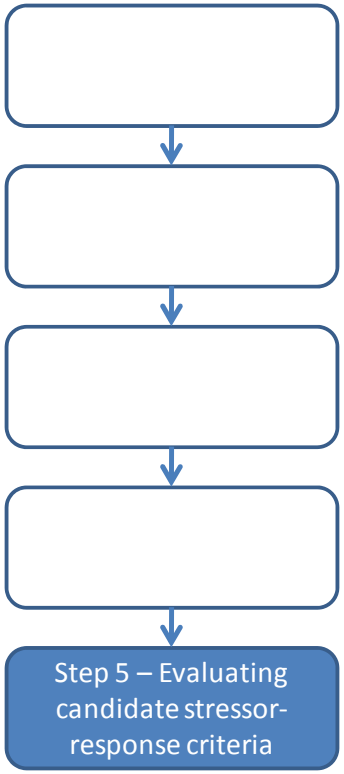
Step 5: Evaluate candidate stressor-response criteria

- Estimate the predicted effects of different candidate criteria to achieve water quality goals.



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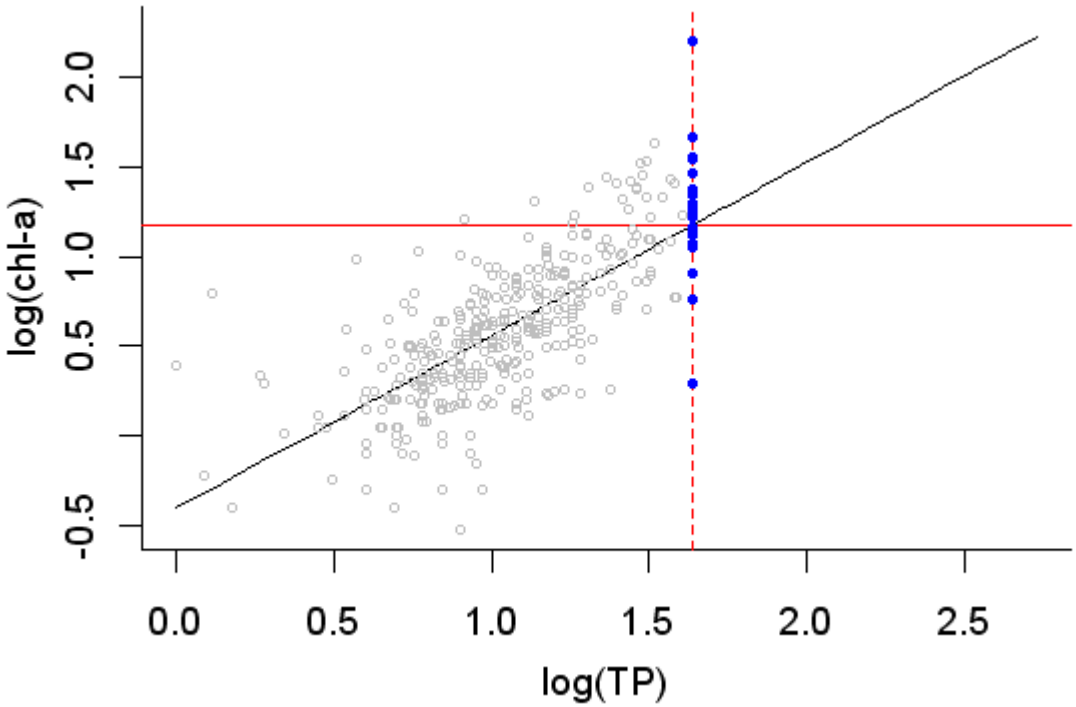
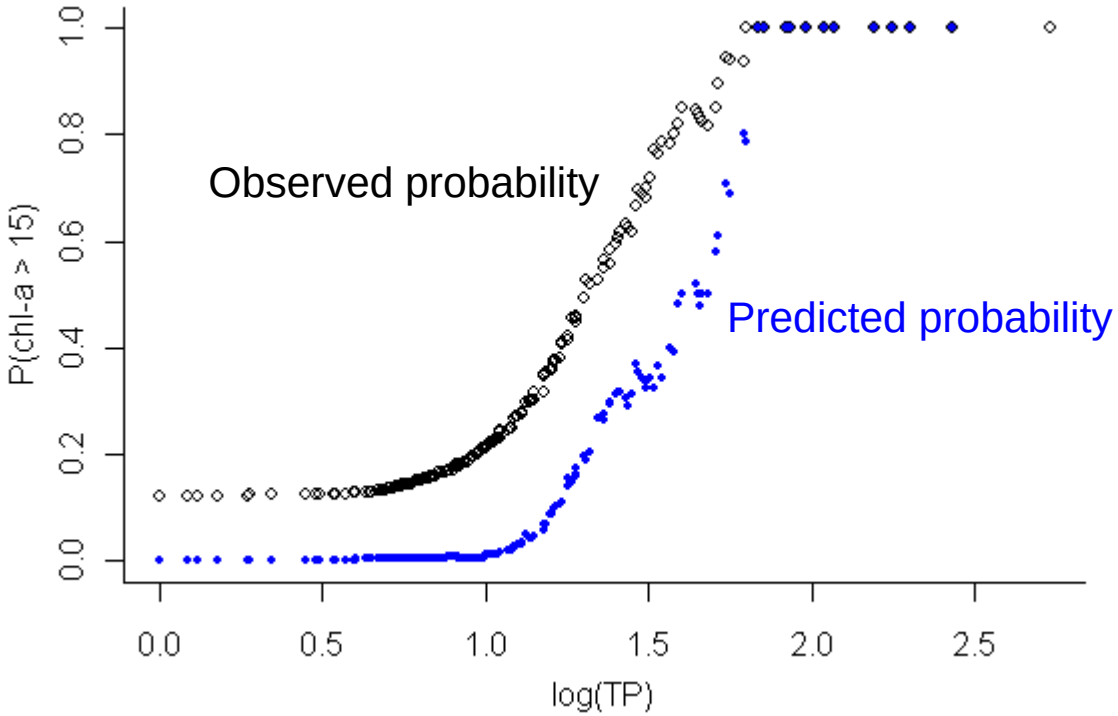
Predicting the effects of a criterion value on achieving water quality goals



Assess effects of different candidate criteria

Compare *observed* probabilities of not achieving water quality goals with *predicted* probabilities, assuming that nutrient concentrations are reduced to a specified criterion value.



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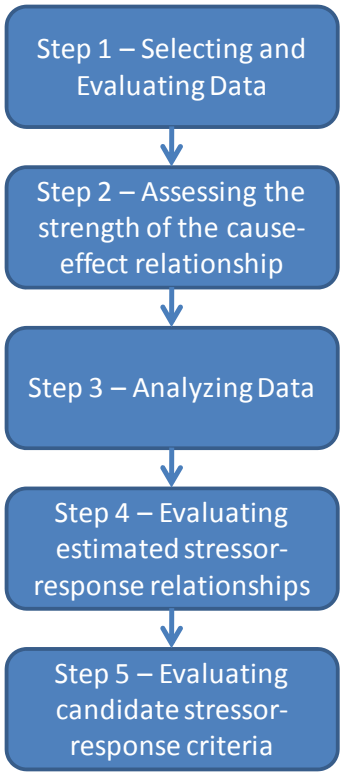
Conclusions

- Statistical methods presented within a five-step framework for deriving nutrient criteria.
- Resulting analyses provide information useful for decisions regarding final nutrient criteria.