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Numeric nutrient criteria for lakes and reservoirs of the United States

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Objective

- Provide an overview of recent lake nutrient criteria work.
  - Designated uses and response indicators
  - Estimation of stressor-response relationships
  - Derivation of criterion values
  - Incorporating local (state) data

Numeric nutrient criteria

- Tool for effectively managing nutrient pollution
  - Water Quality Standards
  - Assessment
  - Permits
  - TMDLs
- National recommendations for criteria are published and revised from time to time by EPA under Section 304(a) of the Clean Water Act.

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Defining potential assessment endpoints

- Aquatic life use
  - Use problem formulation from ecological risk assessment to select candidate endpoints.
- Recreation
  - Consider proposed EPA criteria.
- Drinking water source
  - Consider existing EPA health advisory.

- Most sensitive use for each lake determines the final criterion value.

Defining assessment endpoints for aquatic life use protection

- Management goal: “…protection and propagation of fish, shellfish and wildlife”
- Assessment endpoints: “…explicit expressions of the actual environmental value that is to be protected…”
  - Selecting several endpoints ensures that aquatic life in different types of lakes is protected.
    - Phytoplankton
    - Fish
    - Macrophytes

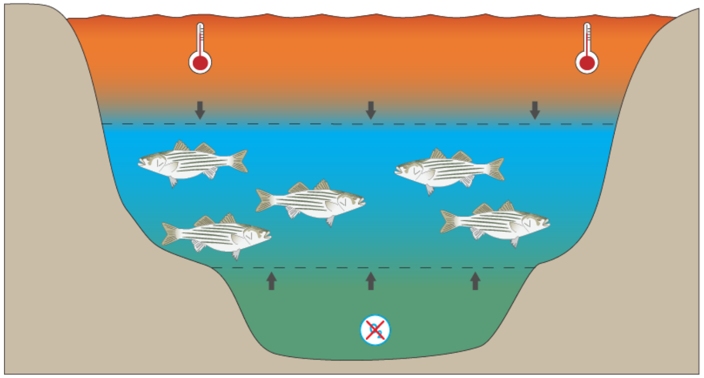
Refining assessment endpoints: Phytoplankton

- Increased nutrient concentrations alter phytoplankton assemblage structure, typically increasing the abundance of cyanobacteria.
- Cyanobacteria are less palatable to grazing zooplankton species (e.g., daphnia).
  - Effects of reduced grazer abundance can cascade through the lake food web.
- Potential endpoint: Cyanobacteria account for no more than 50% of volume of the phytoplankton assemblage (Downing et al. 2001, Poikane et al. 2014)

Photo credit: Sarah Spaulding

Refining assessment endpoints: Fish

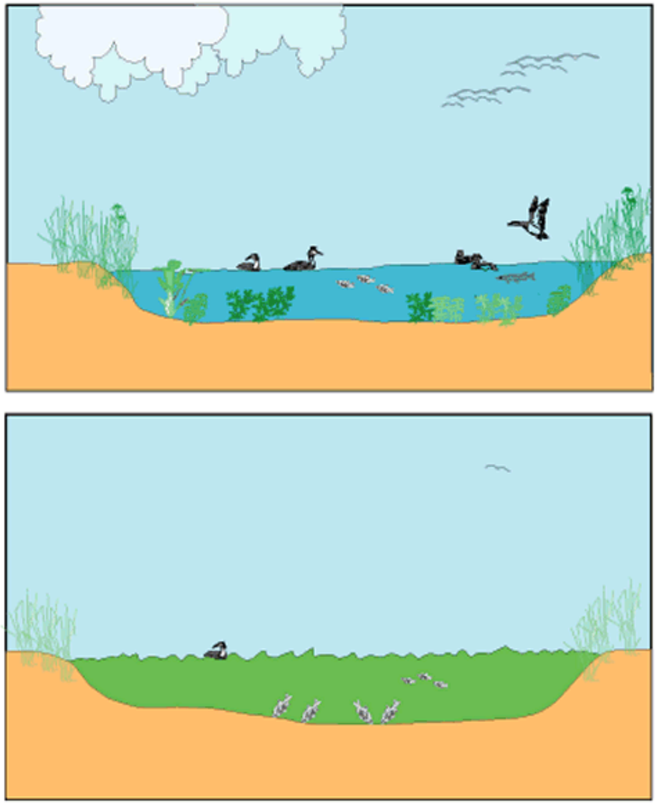
- Distribution of many fish species is limited by water temperature.
- In stratified lakes, depletion of oxygen below the thermocline can eliminate viable habitat for certain fish species.
- Potential endpoint: Sufficient dissolved oxygen in hypolimnion to allow fish to persist through the summer (US EPA 1986).



http://www.teachoceanscience.net/teaching_resources/education_modules/fish_and_physics/explore_trends/oxygen_and_water_temperature/

Refining assessment endpoints: Macrophytes

- In many shallow lakes, two stable states have been observed:
  - Macrophyte dominated: clear water, diverse animal and plant communities
  - Phytoplankton dominated: turbid water, low diversity
- Potential endpoint: At least 65% coverage of submerged macrophytes in littoral zone
  - Analysis suggests an improvement in lake clarity when this threshold is exceeded.



Scheffer, M. 1999. Searching explanations of nature in the mirror world of math. Conservation Ecology **3**(2): 11. [online] URL: http://www.consecol.org/vol3/iss2/art11/

Candidate exposure metrics for drinking water source and recreational uses

- Drinking water source:
  - Microcystin concentration
  - Possible threshold: 0.3 µg/L (US EPA Health Advisory for children, 2015)
  - Based on a variety of health effects
- Recreation:
  - Microcystin concentration
    - Incidental ingestion during recreation

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Estimating stressor-response relationships

1. Data
2. Classify lakes to improve precision of estimate relationship
   - TREED analysis
3. Estimate relationships
   - Hierarchical Bayesian models

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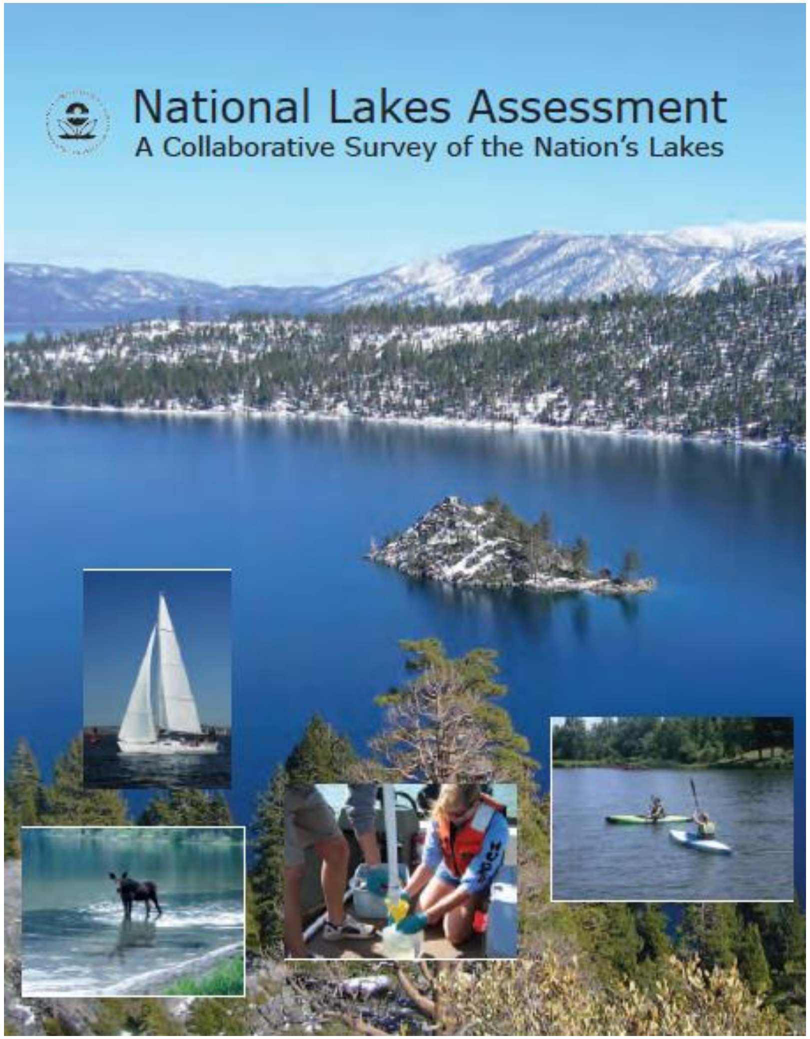
Data

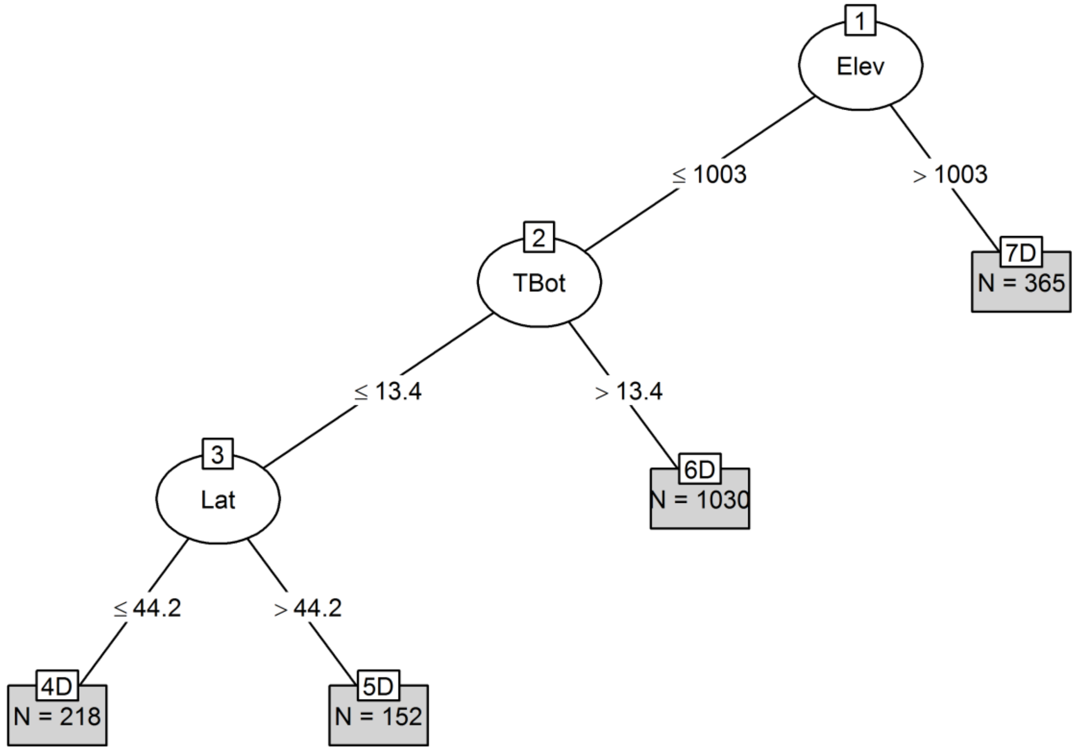
- National Lakes Assessment data
  - Survey data from 2007 and 2012 included
  - Extensive set of measurements collected at ~1800 lakes.
  - Consistent protocols used to collect the same measurements from each of the lakes.



Statistical analysis: Classification

- Define classes of lakes using statistical method that identifies variables that best improve the precision of stressor-response relationship

Example classification: Microcystin



Estimating stressor response relationships

- Hierarchical Bayesian models used to estimate relationship.
  - Model can closely match sampling design of the data (e.g., repeat sampling among-years used to estimate interannual variability)
  - Different components of variability can be estimated:
    - Intra-annual temporal variability
    - Inter-annual temporal variability
    - Sampling variability
    - Spatial variability
  - Simultaneous sets of models can be fit
    - Seasonal TN, TP models
    - TN-TP-chl *a* model
    - Chl *a*-macrophyte model

Deriving criterion values

- Compute TN and TP values that correspond with target values for different endpoints.
- Explicitly account for different sources of variability.

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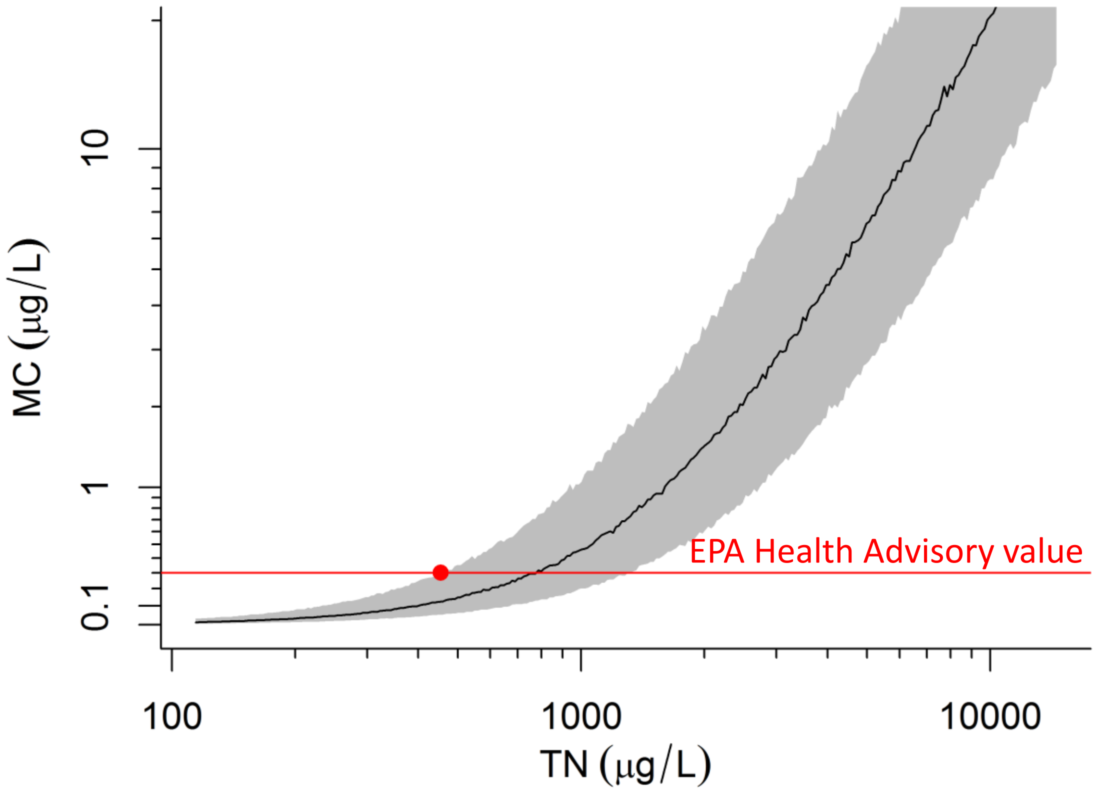
Deriving criterion values example: Drinking water source



Dashed line: mean relationship
Grey: 50% credible intervals

Account for temporal variability
Solid line: 90th percentile of temporal distribution
Grey: 50% credible intervals

Account for spatial variability
Solid line: 90th percentile of temporal distribution
Grey: 50th credible intervals including differences among lakes

Incorporating local data

- Bayesian model allows us to specify elements of state data and national data that are similar and different.
  - Different sampling designs for selecting sites suggests that spatial variability may be different.
  - Different field methods might suggest that sampling variability is different.

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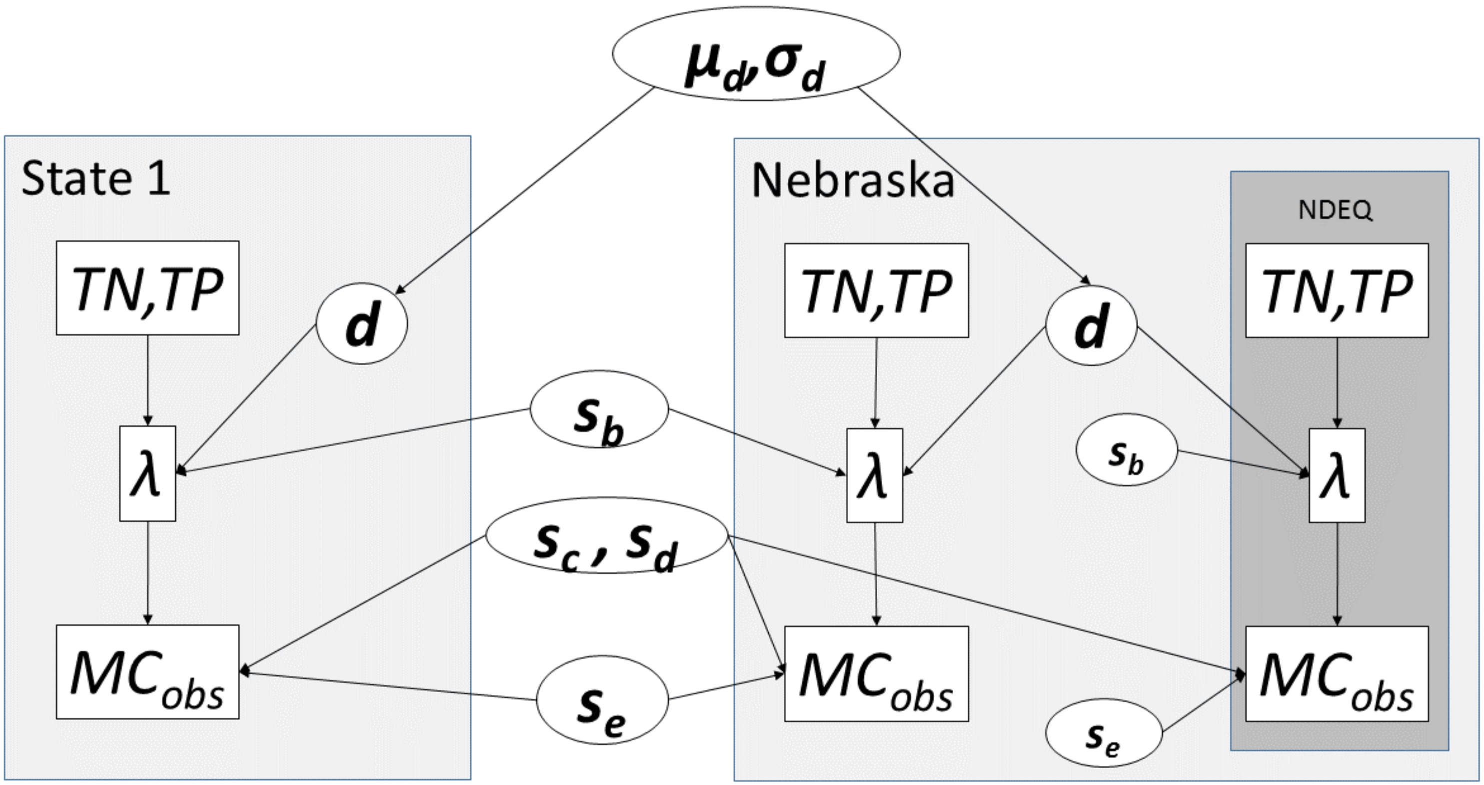
Schematic for combining state and national data



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Summary

- Candidate assessment endpoints and exposure metrics were selected to link nutrient pollution to designated use protection in lakes and reservoirs.
- National Lakes Assessment data analyzed to estimate relationships between nutrient concentrations and different endpoints.
  - New classes of lakes defined by statistical analyses.
  - Stressor-response relationships estimated using Bayesian models
  - Approach developed for interpreting state data in the context of national models.
- Currently, we are starting several case studies combining national and state data to derive state-specific nutrient criteria.