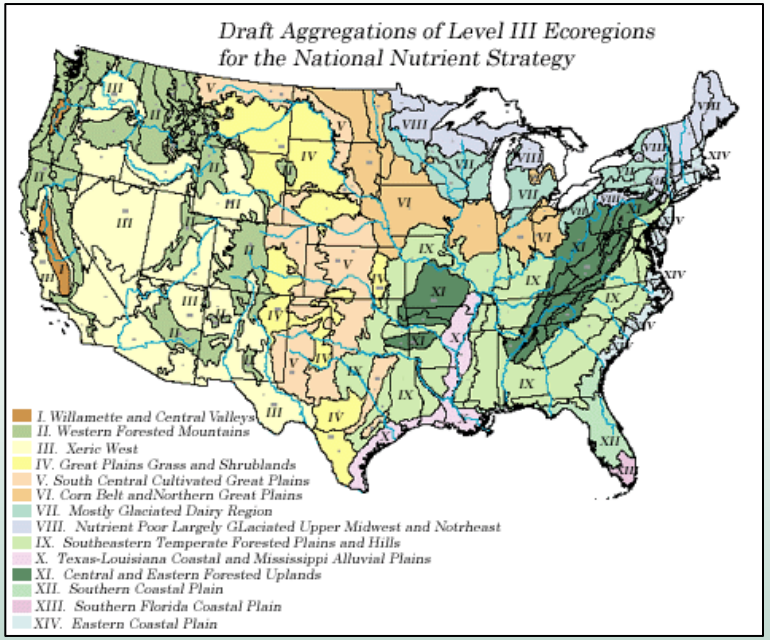
EPA
United States
Environmental Protection
Agency

Ambient Water Quality Criteria to Address Nutrient Pollution in Lakes and Reservoirs

Lester L. Yuan
Office of Water
U.S. Environmental Protection Agency

EPA's Ecoregional Nutrient Criteria

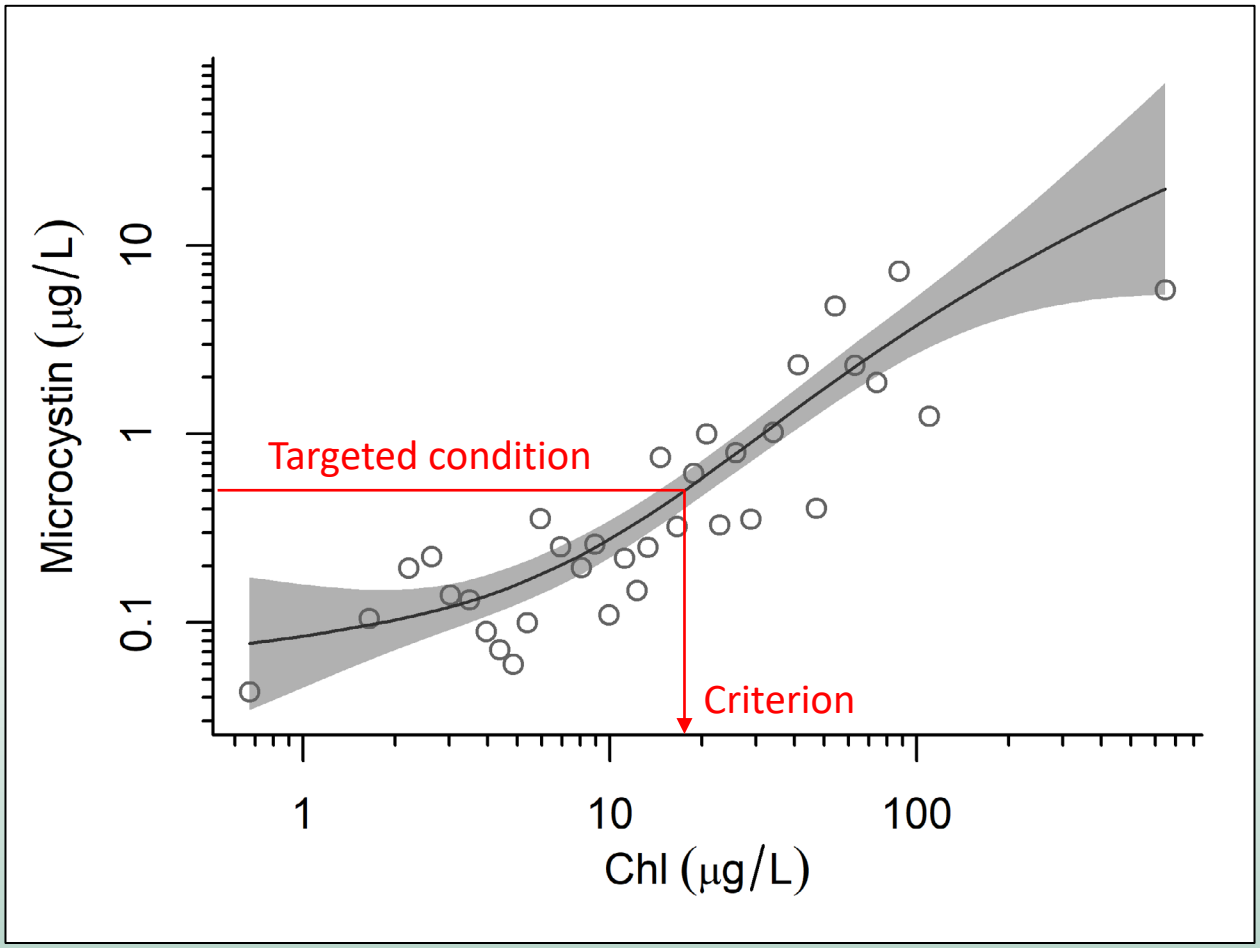
- EPA published numeric nutrient criteria recommendations in 2000 – 2001 for lakes and reservoirs.
- U.S. classified into 14 nutrient ecoregions in which nutrient concentrations were expected to be similar.
- Criteria were derived using a reference distribution approach.
  - Numeric criterion values were the 25th percentile of all available total nitrogen (TN), total phosphorus (TP), chlorophyll *a* (chl *a*), and Secchi depth.
  - Data were sufficient to apply this approach in 12 of 14 ecoregions.
- Criticized for not linking directly to support of designated uses (aquatic life, recreation, and drinking water source).



Highlights of Updated Criteria

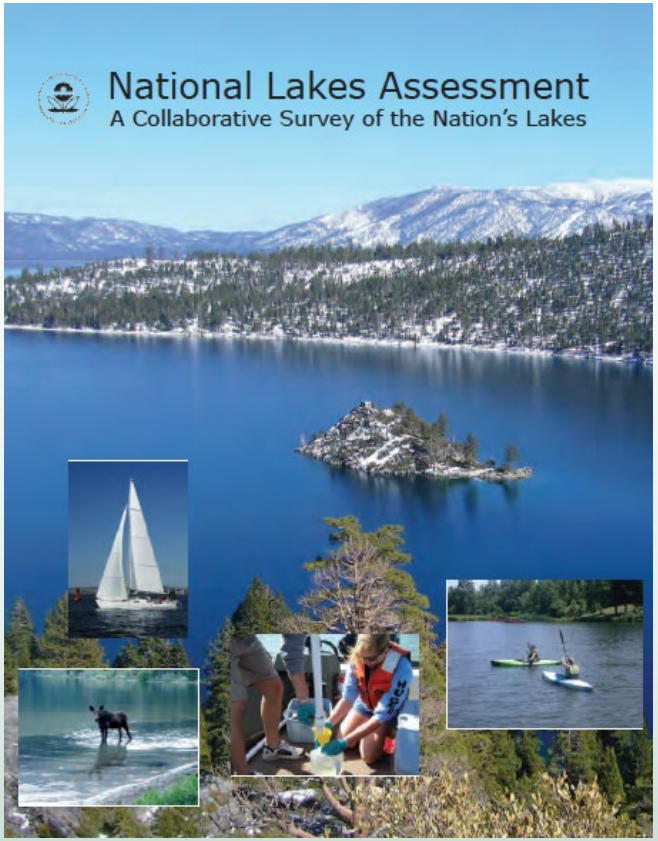
1. Stressor-response relationships are used to link chl *a* concentration to attainment of each of three designated uses (aquatic life, recreation, and drinking water source).
2. When multiple use designations apply to a lake, states and tribes can calculate and compare candidate criteria for each applicable use to ensure protection of the most sensitive use (40 CFR 131.11(a)).
3. Methods are provided to combine state and national data and derive state-specific values that reflect local conditions.
4. Interactive applications provide flexibility for each state to incorporate their own risk management decisions in deriving final criteria.

Stressor – Response Analysis



Nationally Consistent Data for Lakes and Reservoirs

- Lakes assessment data from the EPA's National Aquatic Resource Surveys.
  - Survey data from 2007 and 2012 included.
  - Extensive set of measurements collected at ~ 1800 randomly selected lakes.
  - Consistent protocols used to collect the same measurements from each of the lakes.
  - Data available for the stressors (TN and TP) and the responses (i.e., chl *a*, dissolved oxygen, microcystin, and zooplankton biomass) allow EPA to derive criteria specifically to prevent adverse effects.

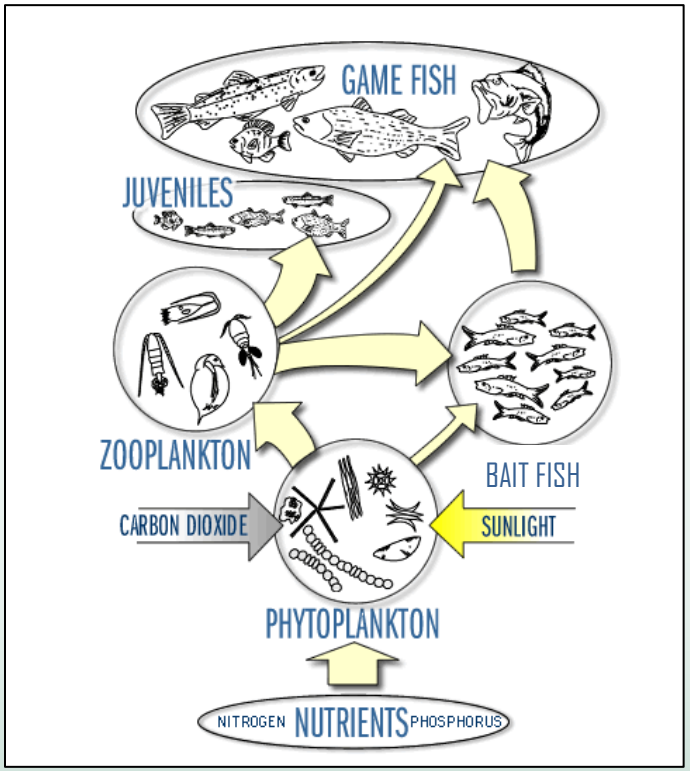


Response Variables and Designated Uses

- Aquatic life use
  - Zooplankton biomass
  - Deepwater dissolved oxygen to protect cold- and cool-water fish
- Recreation
  - Microcystin concentration
- Drinking water source
  - Microcystin concentration
- Separate models link Chl *a* criteria derived for each designated use to total phosphorus (TP) and total nitrogen (TN) concentrations.

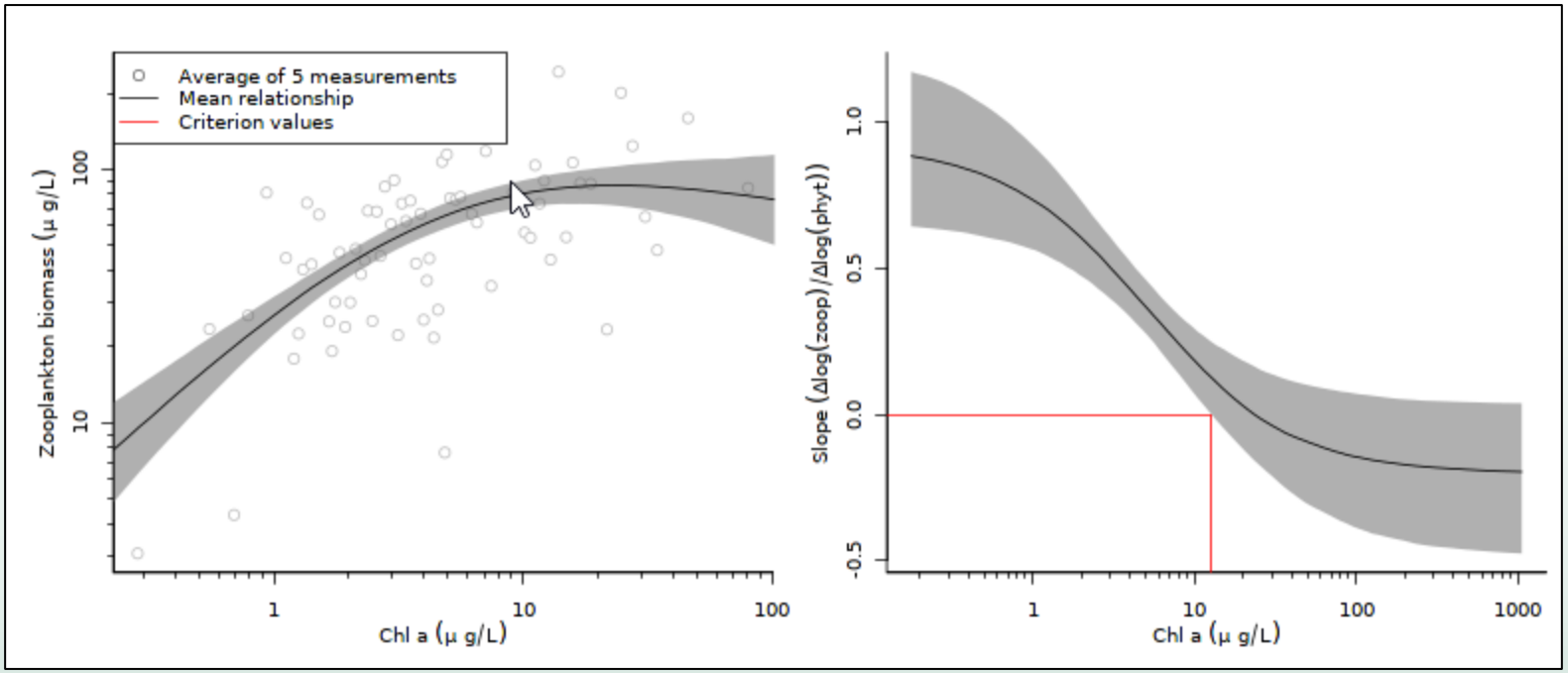
Aquatic Life Assessment Endpoint: Zooplankton

- Key link in lake food web
- Concurrent increases in phytoplankton and zooplankton biomass are indicative of an efficient transfer of resources up the food web.



http://www.waterontheweb.org/under/lakeecology/11_foodweb.html

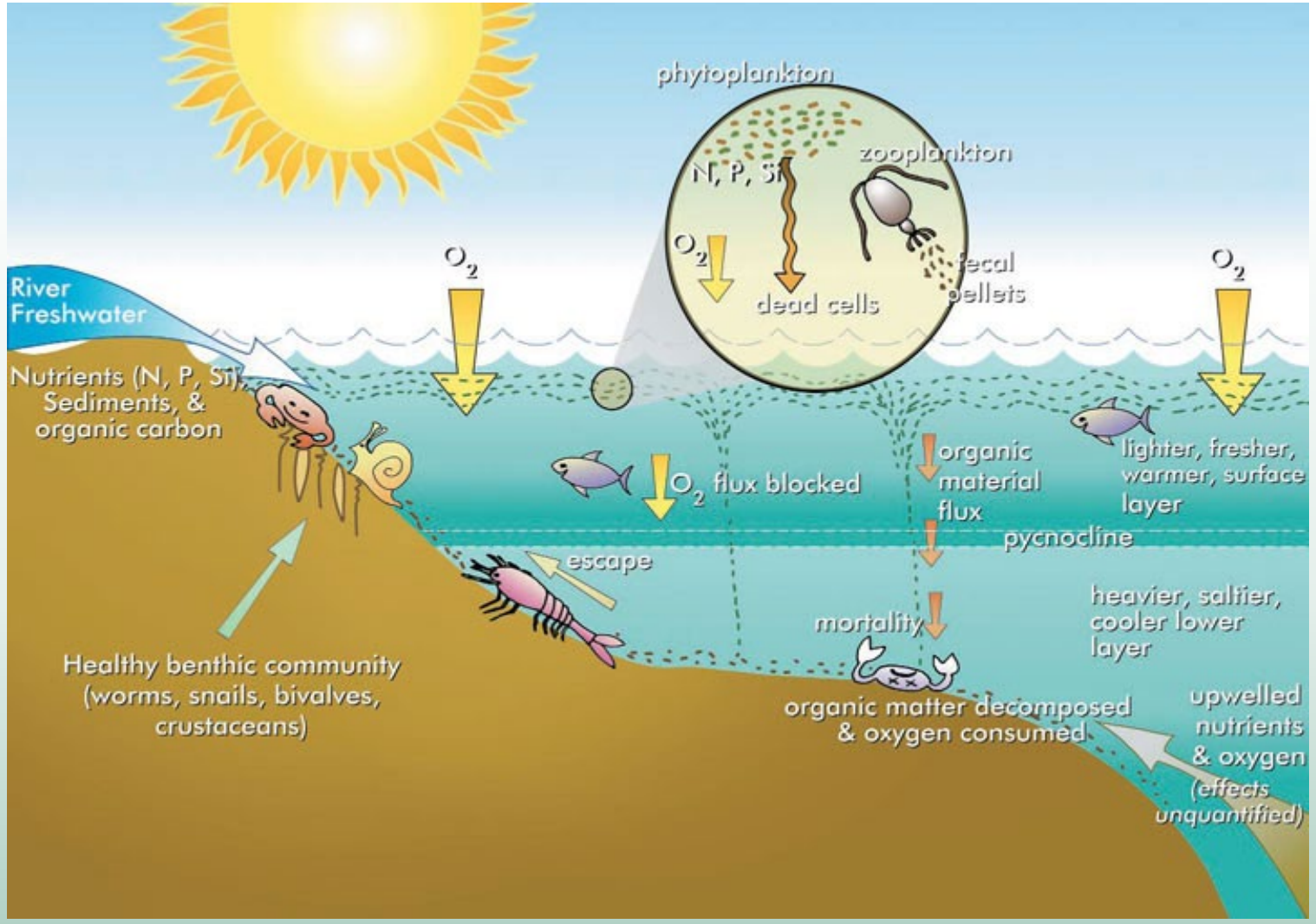
Aquatic Life Assessment Endpoint: Zooplankton



In lakes with high concentrations of phytoplankton and nutrients, transfer of energy from primary productivity to higher trophic levels is less efficient.

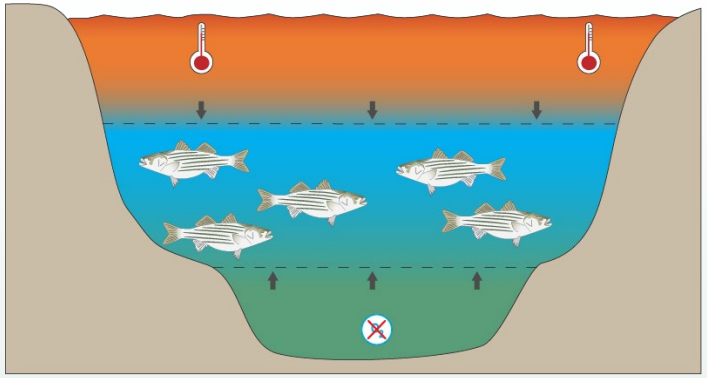
When chlorophyll *a* concentration increases, zooplankton biomass does not increase with phytoplankton.

Hypoxia and stratification



Aquatic Life Assessment Endpoint: Fish

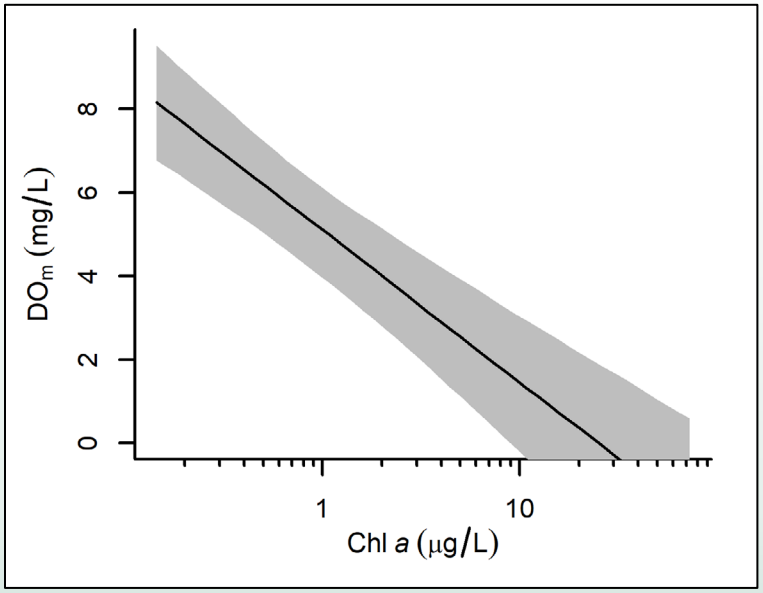
- Distribution of many fish species is limited by water temperature.
- In stratified lakes, depletion of oxygen in deep water below the thermocline can eliminate viable habitat for certain fish species.
- Endpoint: Sufficiently dissolved oxygen below thermocline to allow fish to persist through the summer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



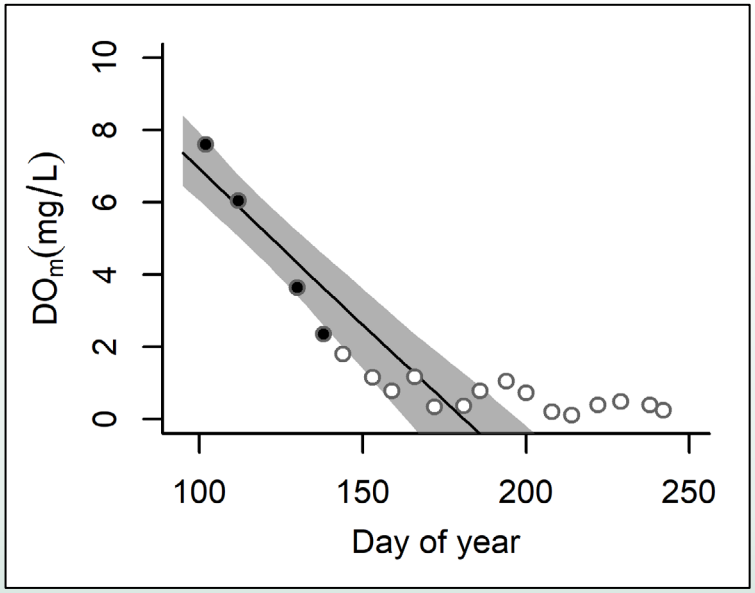
http://www.teachoceanscience.net/teaching_resources/education_modules/fish_and_physics/explore_trends/oxygen_and_water_temperature/

Chl *a* and Dissolved Oxygen

Depth-averaged dissolved oxygen (DO_m) decreases with increased Chl *a*.



Number of days since stratification is also important.



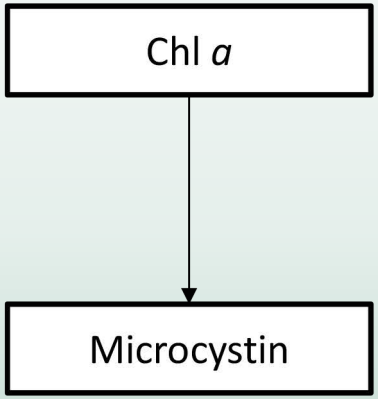
Dissolved organic carbon and lake depth also influence DO_m.

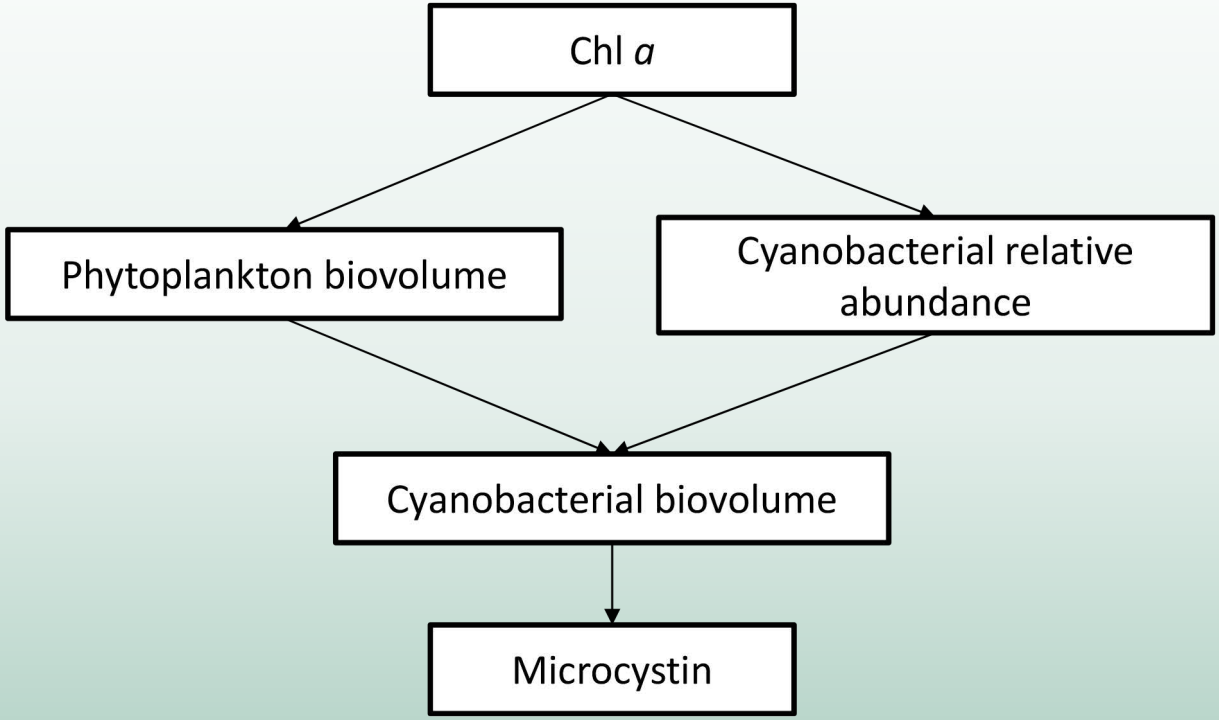
Estimating Stressor-Response Relationships

- Identify known causal relationships and specify models to quantify these relationships.
- Model a set of relationships simultaneously with a Bayesian network, a flexible approach for modeling statistical relationships.

Stressor – Response Relationships

Modeling a network of relationships allows us to specify relationships between pairs of variables that better represent underlying mechanisms.





Phosphorus – Chlorophyll Models

Model equation:

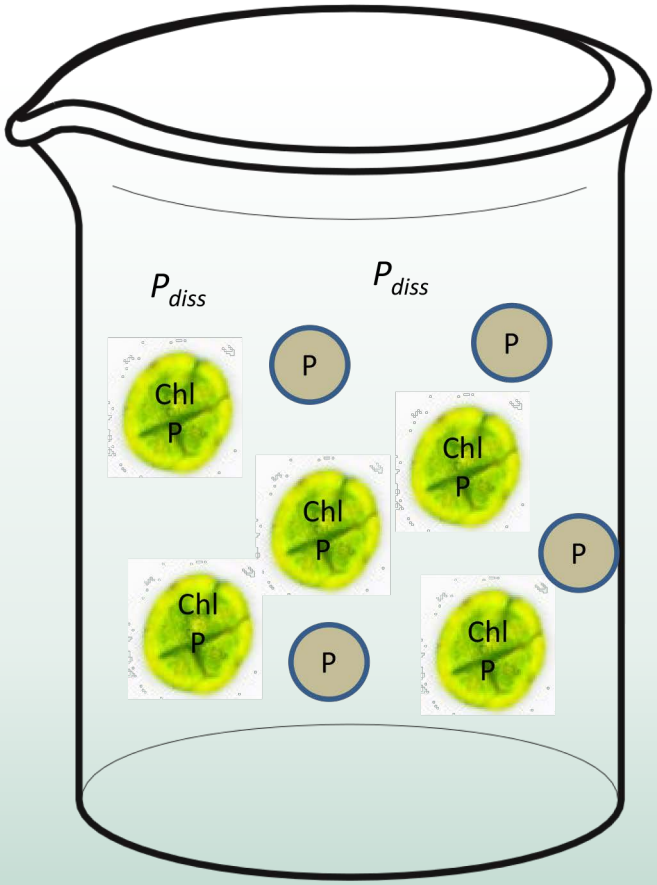
$$TP = d_1 Chl^k + d_2 Sed + P_{diss}$$

When sediment and P_{diss} concentrations are low, we can simplify to the following:

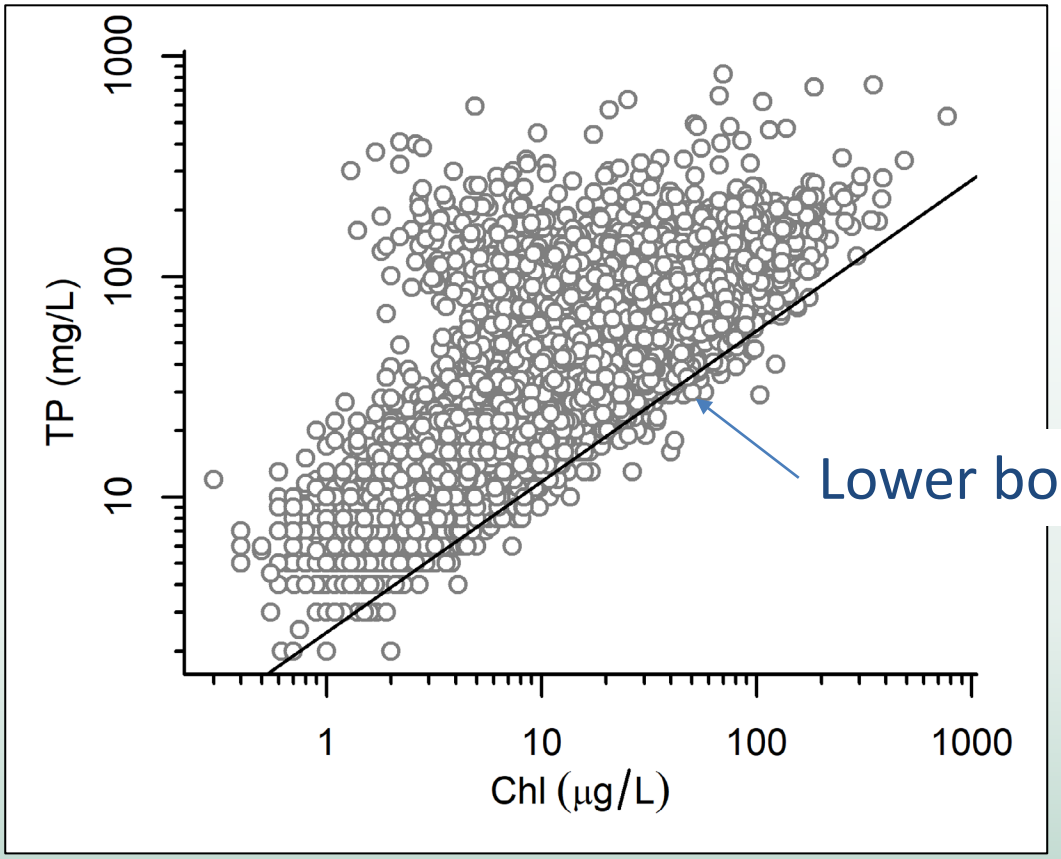
$$TP = d_1 Chl^k$$

$$\log(TP) = \log(d_1) + k\ log(Chl)$$

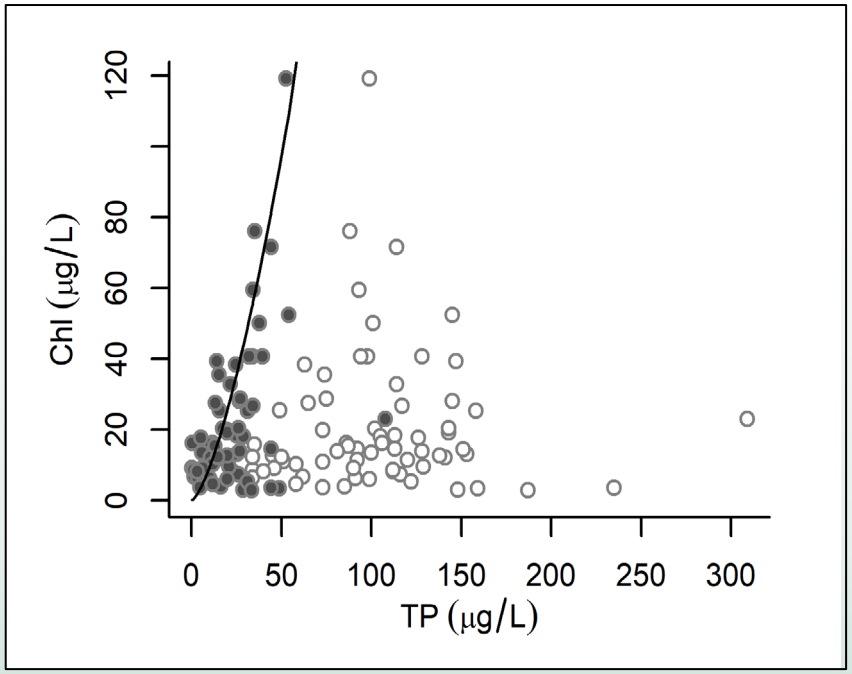
Lower bound between log(TP) and log(Chl) should be a straight line.

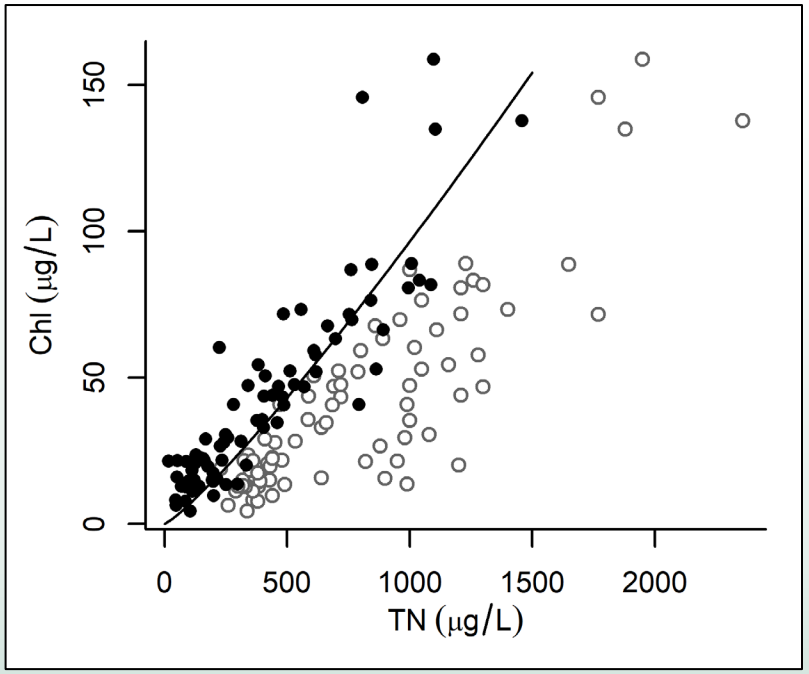


Data from MO Reservoirs



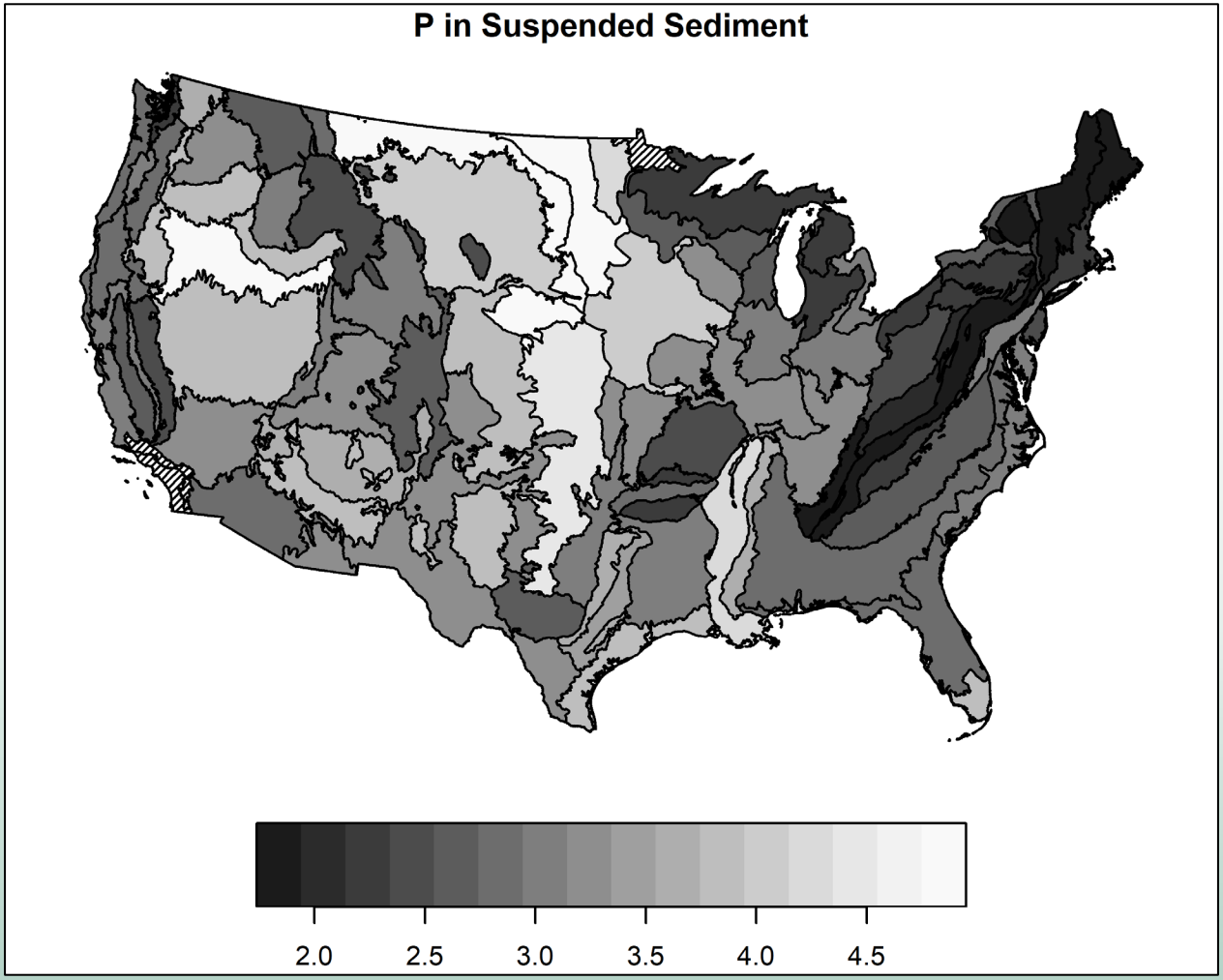
Relationships Between Total Phosphorus, Total Nitrogen, and Chl *a*





Raw measurements of TP and TN (open circles) are weakly associated with Chl. After controlling for the effects of phosphorus bound to sediment and dissolved organic nitrogen (filled circles), more precise relationships can be estimated.

Geographic variations in phosphorus associated with suspended sediment



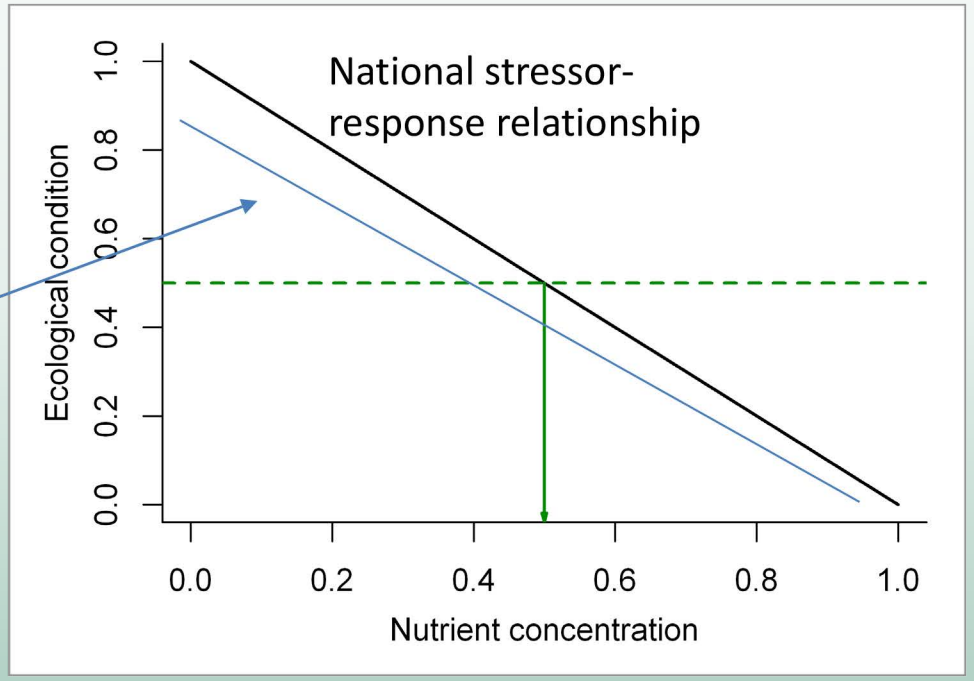
Stressor – Response: Summary

- Chl *a* criteria can be derived for three designated uses.
  - Drinking water and recreation: Chl *a* – microcystin model
  - Aquatic life:
    - Chl *a* – zooplankton model
    - Chl *a* – fish/hypoxia model
  - Final Chl *a* criteria would be based on the most sensitive use.
- TN and TP criteria can be derived from models linking nitrogen, phosphorus, and chl *a.*

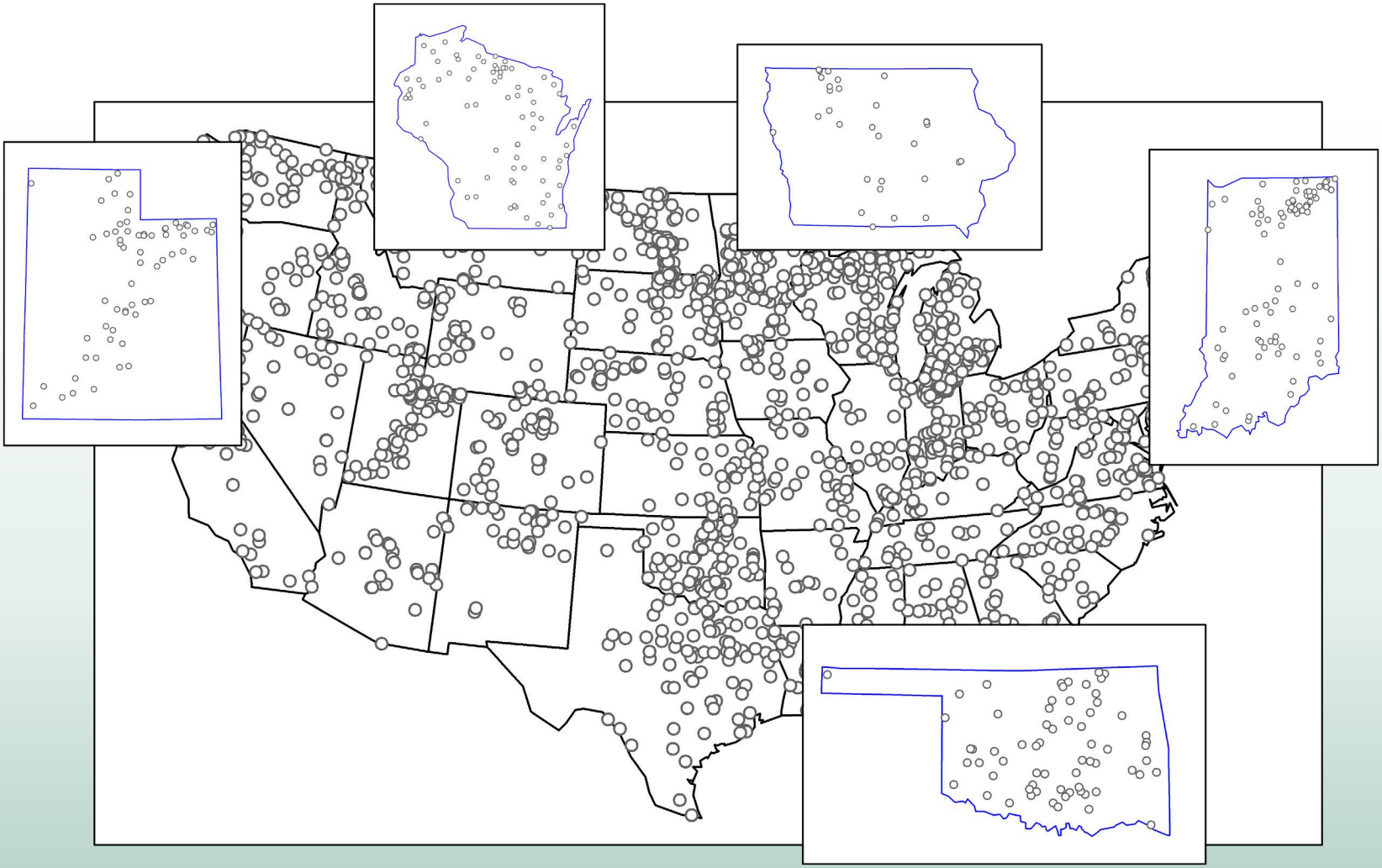
Tools that Combine State and National Data

- We have been working in partnership with states who volunteered to pilot test our tools for combining their state data with national models.
- Analysis results can be used to derive locally-applicable criteria.
- We will continue to work with states to combine state monitoring data with national models.

State data can reflect local conditions that can differ from national average.

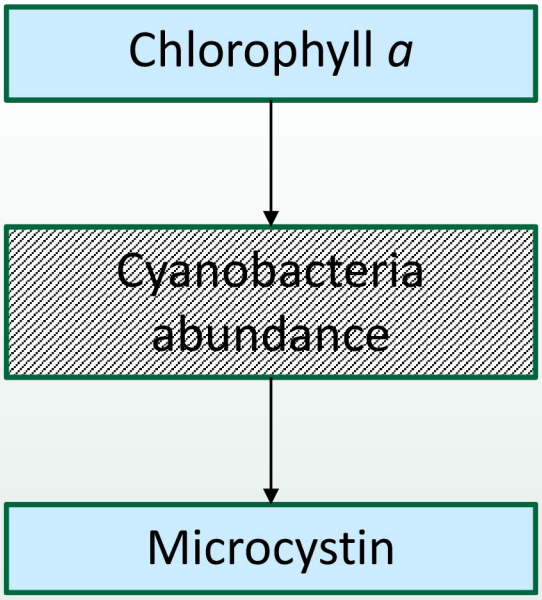


State – Specific Models

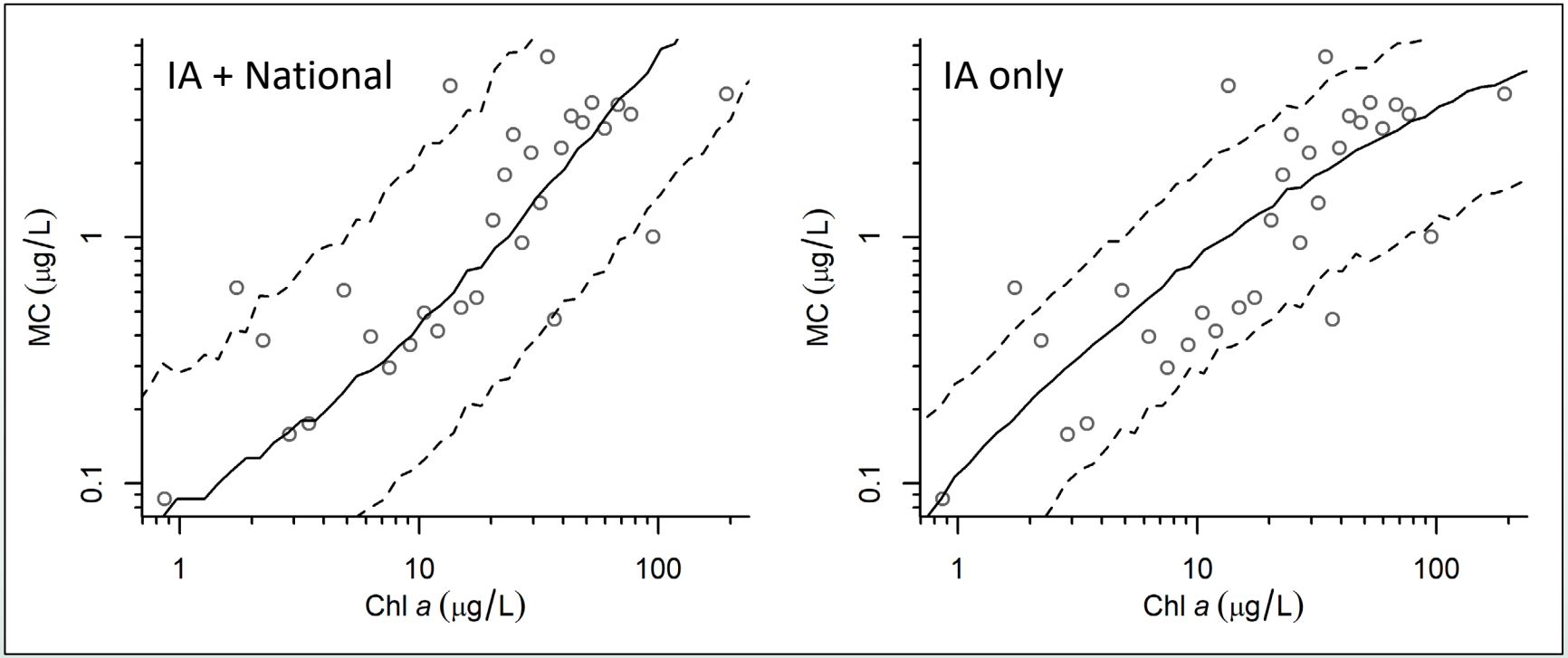


Example: Iowa Case Study

- Chl *a* and microcystin data were available in Iowa.
- National and Iowa data were used to develop a chl *a* - MC relationship.
- The national model sets a range for possible relationships in IA, and "fills in" for missing measurements.



Iowa Case Study



Combining IA data with national models yields a 13% improvement in model accuracy.

Interactive Applications to Derive Nutrient Criteria

Stressor-response models provided online as graphical tools.

- Microcystin model:
  - https://nsteps.epa.gov/apps/chl-microcystin
- Hypoxia model:
  - https://nsteps.epa.gov/apps/chl-hypoxia
- Zooplankton model:
  - https://nsteps.epa.gov/apps/chl-zooplankton
- TP-TN-Chl model:
  - https://nsteps.epa.gov/apps/tp-tn-chl

EPA United States Environmental Protection Agency

Summary

- Revised lake criteria are based on stressor-response models linking protection of designated uses to nutrient concentrations.
- Different endpoints and models are provided for different designated uses, allowing for protection of the most sensitive use.
- Models can incorporate local monitoring data to reflect local conditions.
- Interactive applications provide easy access to models.

Questions?

Contact: Lester Yuan (yuan.lester@epa.gov)