North Carolina Division of Water Resources

Surface Water Quality Monitoring Programs

Overview of Monitoring

PHYSICAL-CHEMICAL

- Ambient Monitoring
- Monitoring Coalition
- Random Ambient Monitoring
- Reservoirs and Lakes

BIOLOGICAL

- Community Assessments
  - Fish
  - Benthic Macroinvertebrates
  - Phytoplankton
- Fish Tissue

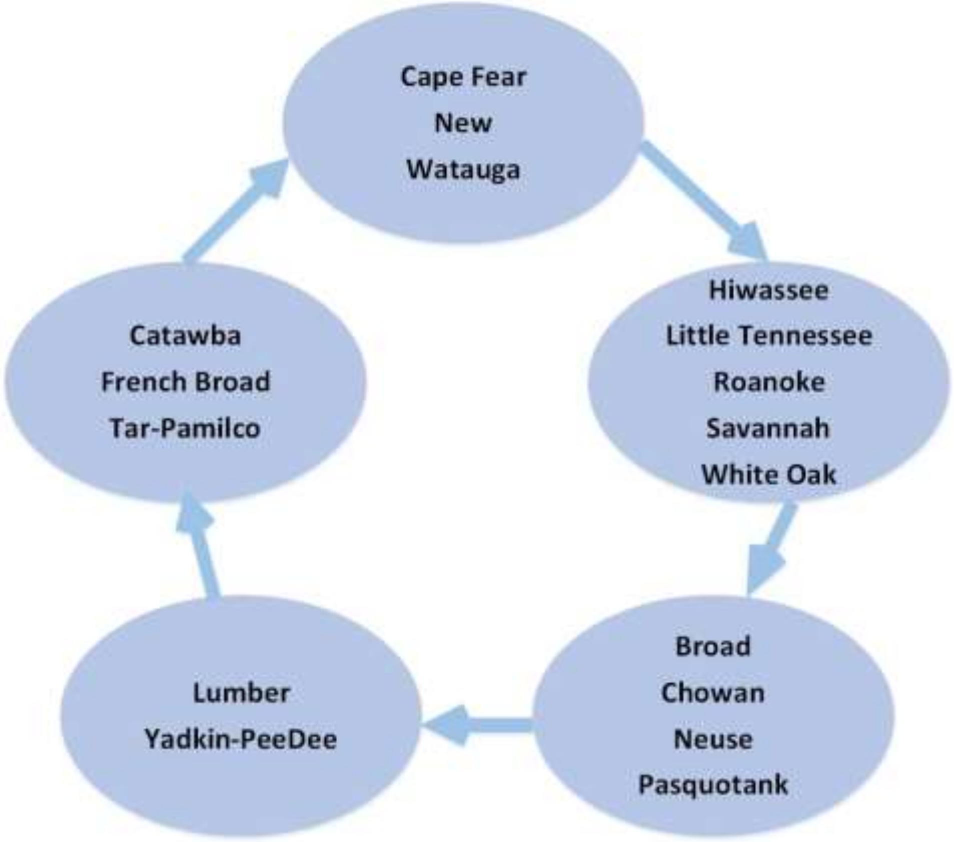
Purposes of Monitoring

- Determine compliance with water quality standards.
- Assess “biological integrity”
- Assess effectiveness of water quality management strategies
- Identify sources of pollution

Frequency of Monitoring

Program	Monthly	Rotating Basin Schedule
Physical/Chemical		
AMS	X	
Coalitions	X	
RAMS	2-years	
Reservoir-Lakes		X
Biological		
Benthos		X
Fish Community		X
Phytoplankton	Estuaries; Jordan, Falls	Reservoirs/Lakes
Fish Tissue		

5-Year Rotating Basin Sampling



Physical-Chemical Monitoring
AMS and Coalition

- Stream, river, and estuary stations.
  - Located statewide (AMS)
  - Long-term monitoring of water quality.
  - Ambient monitoring system - active for 30+ years

- Use of data:
  - Characterize water quality
  - Use support (compliance with standards).

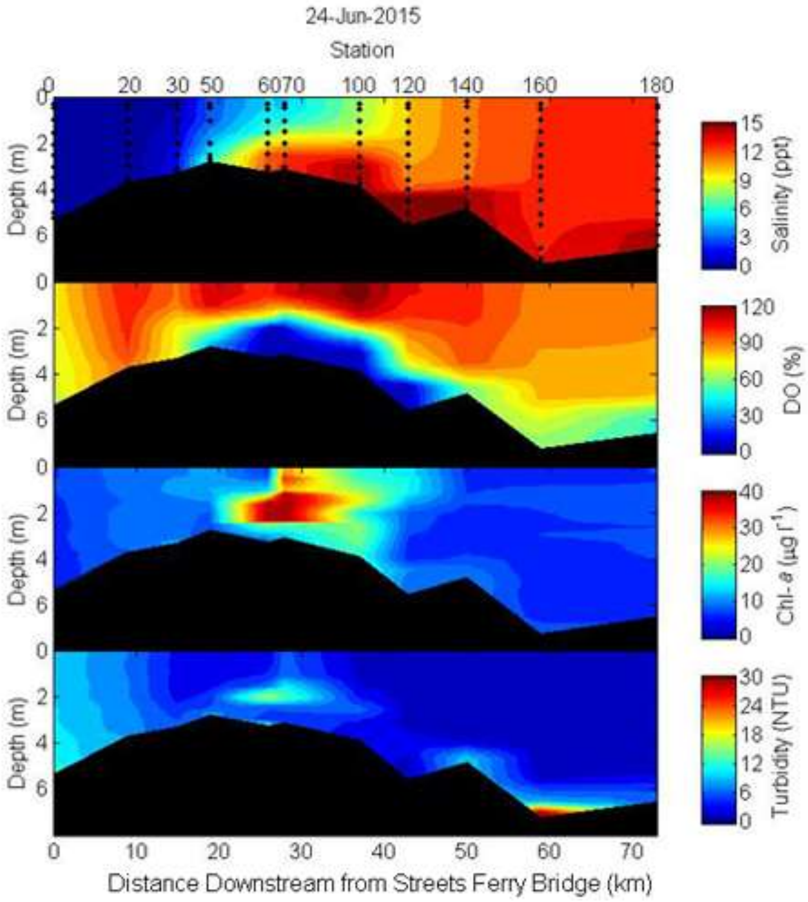
Physical - Chemical Monitoring

Parameters Collected

- Physical (dissolved oxygen, specific conductance, temperature, pH)
- Fecal coliform bacteria
- Turbidity
- Chlorophyll-*a*
- Nutrients
    - Ammonia (NH_3 as N)
    - Total Kjeldahl nitrogen as N (TKN; ammonia + organic-N)
    - Nitrite + Nitrate as N (NO_2 + NO_3)
    - Total Phosphorus
- Metals (dissolved and total)
- Solids (total suspended solids, others as deemed necessary)

Physical - Chemical Monitoring
Other Sources of data

- NPDES Discharge Monitoring Reports
- ModMon (Neuse R. Estuary)
- Environmental Quality Institute (Western NC)
- Upper Neuse River Basin Association



Biological Community Assessments
Fish, Benthos, Phytoplankton

- All three:
    - Identify species
    - Use some measure of abundance or density
- Only fish and benthos are used to assess biological integrity
    - Both use ratings

Biological Integrity

NC Administrative Code, 15A NCAC 02B.0202 (11)

The ability of an aquatic ecosystem to support and maintain a balanced and indigenous community of organisms having species composition, diversity, population densities and functional organization similar to that of reference conditions.

Fish Community
Index of Biotic Integrity

Species Richness and Composition

- Total number of species
- Number of species of darters, sunfish, and suckers
- Number of "clean water" species
- Percentage of pollution indicator fish

Feeding Composition

- Percentage of omnivores + herbivores, insectivores, and piscivores

Abundance and Condition

- Total number of fish
- Percentage of diseased fish
- Percentage of species with multiple age classes

Benthic Community
Bioclassifications

- Mayfly, Stonefly and Caddisfly diversity (EPTs).
  - *EPTs are pollution intolerant*
- EPTs + the Biotic Index (BI)
- The BI is a summary measure of the number and abundance of pollution tolerant/intolerant organisms




Reservoirs and Lakes
Program Goals

- Determine trophic state
- Provide data for use assessment
- Develop or support nutrient management strategies
- Evaluate temporal trends

Reservoirs and Lakes
Lake Selection Criteria

- > 10 Acres
- Accessible to Public
- Water Supplies
- Significant Recreation
- Others as requested

Reservoirs and Lakes
Frequency of Sampling

- Lakes sampled 5 times/basin cycle
- Sampled May - September
- 1-12 stations per lake

Reservoirs and Lakes
Photic Zone

Photic zone =

2 x Secchi depth

Reservoirs and Lakes
Photic Zone Samples

- Nutrients
- Turbidity
- Chlorophyll-*a*
- Total Solids
- Total Suspended Solids

Phytoplankton

Reservoirs and Lakes

Trophic State Index

$$Trophic\ State\ Index = TON_{score} + TP_{score} + SD_{score} + CHL_{score}$$

$$TON_{score} = \frac{log(TON)+0.45}{0.24} \times 0.90)$$

TON = Total organic nitrogen

$$TP_{score} = \frac{log(TP)+1.55}{0.35} \times 0.92)$$

TP = Total phosphorus

$$SD_{score} = \frac{log(SD)-0.1.73}{0.35} \times -.82)$$

SD = Secchi depth

$$CHL_{score} = \frac{log(CHL)-1.00)}{0.43} \times 0.83)$$

CHL = Chlorophyll-*a*

DWR Resources for Monitoring

Physical-Chemical Sampling

- Regional Office Staff / Coalitions

Fish Community Monitoring

- Headquarters staff (Raleigh)

Benthic Macroinvertebrate/

- Headquarters staff (Raleigh)

Reservoir and Lake Monitoring (requires boats)

- Headquarters staff (Raleigh)

High Rock Lake

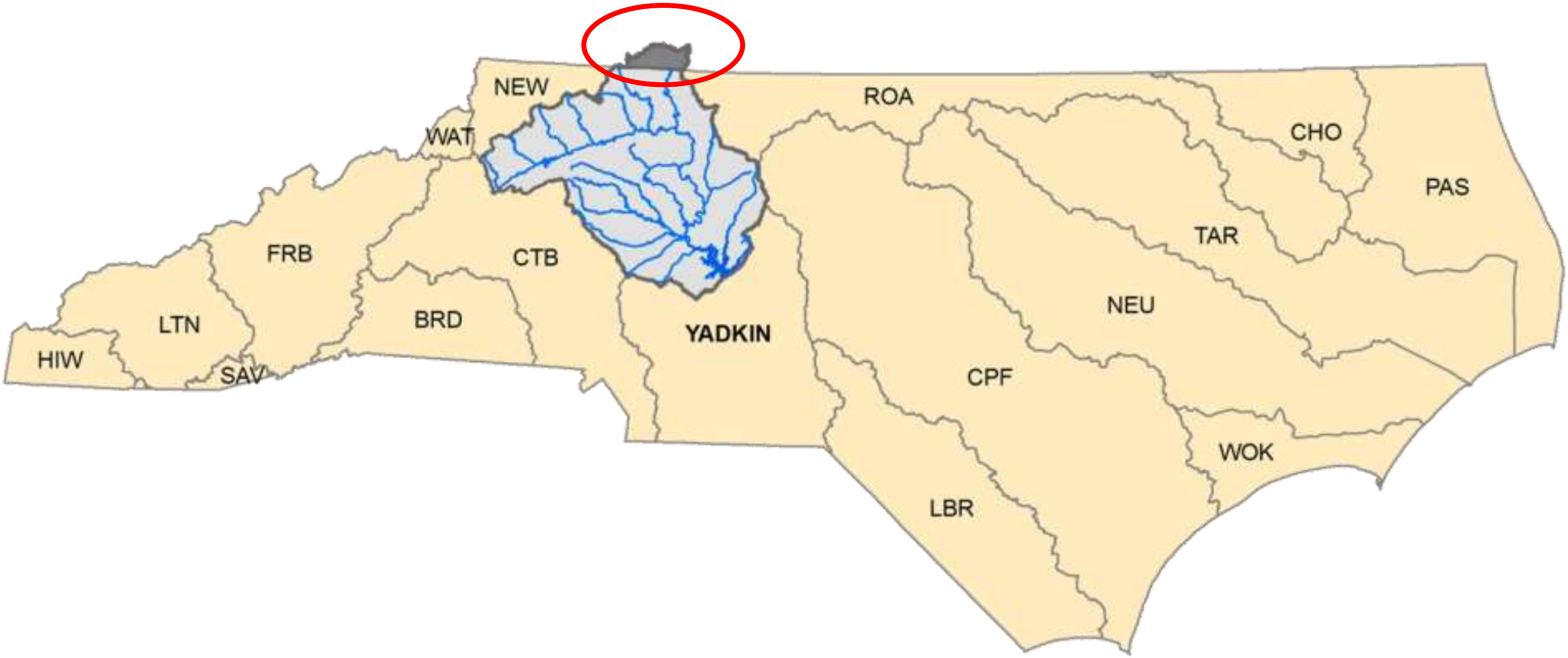
Pam Behm - NC Division of Water Resources

NC NCDP SAC

2nd Meeting

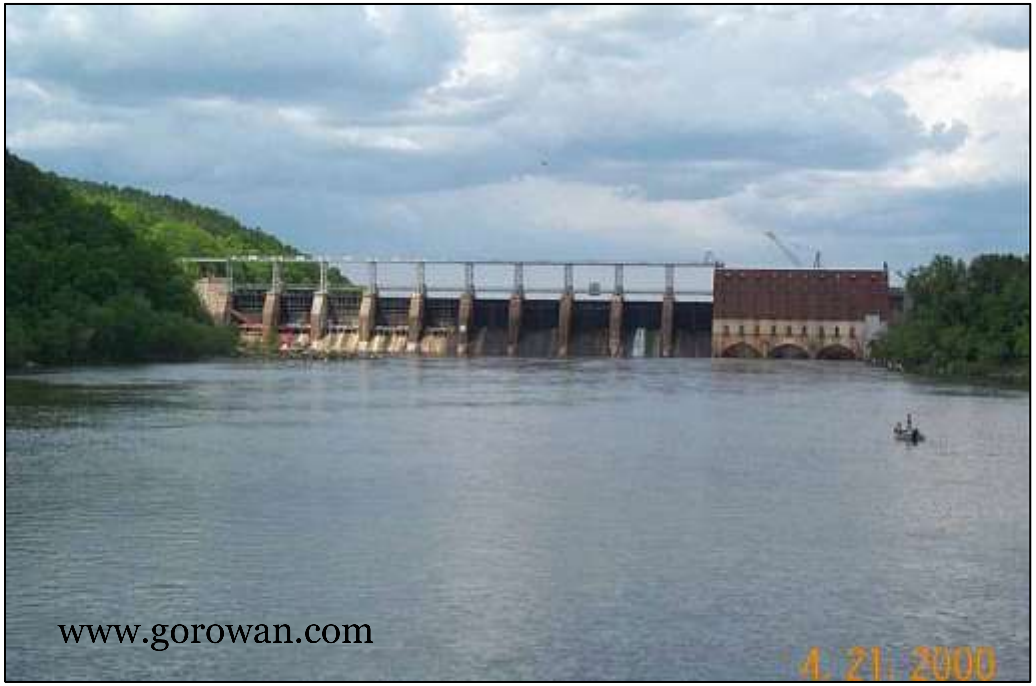
July 21, 2015

High Rock Lake Watershed

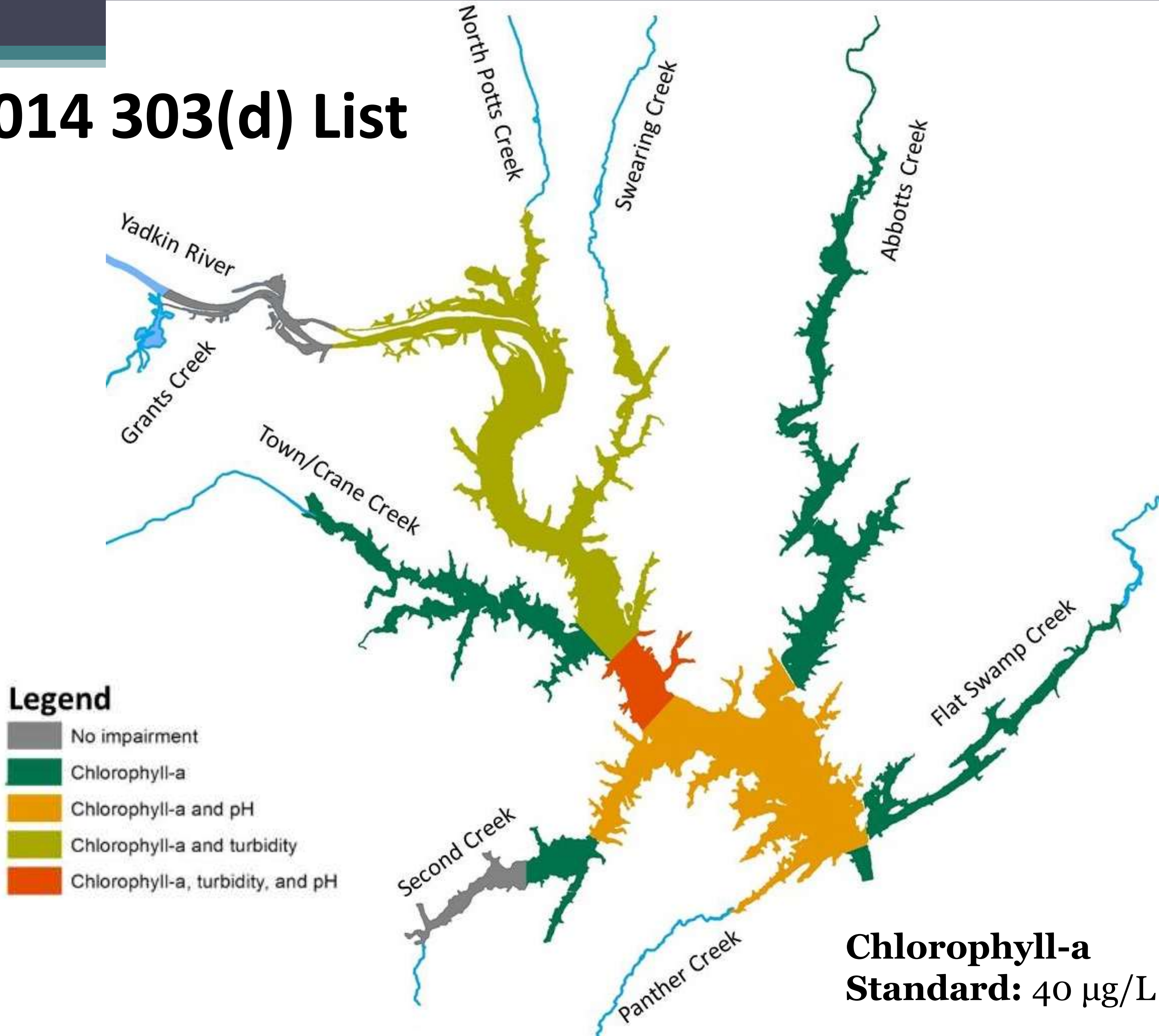


History

- 1928 - Dam construction completed
- Dam owned and operated by Alcoa Power Generating, Inc



2014 303(d) List



Chlorophyll-a Standard: 40 µg/L

Class C Definition

Waters protected for uses such as secondary recreation, fishing, wildlife, fish consumption, **aquatic life including propagation, survival and maintenance of biological integrity**, and agriculture. Secondary recreation includes wading, boating, and other uses involving human body contact with water where such activities take place in an infrequent, unorganized, or incidental manner.

Maintenance of biological integrity

Biological integrity means the ability of an aquatic ecosystem to support and maintain a balanced and indigenous community of organisms having species composition, diversity, population densities and functional organization similar to that of reference conditions.

HRL Questions

Is the current chlorophyll-*a* standard as applied (anywhere in the lake, 90/10 assessment) appropriate to maintain biological integrity? How to determine N/P?

In other words, does the standard of 40 ug/L provide for the ***ability*** of High Rock Lake to support and maintain a balanced and indigenous community of organisms?

e.g. Should blue-green algae NEVER dominate, or is it natural to expect blue-green dominance in summer months, and, if so, what is natural level of dominance/blooms? How much is too much?

Tasks for SAC

1. What concentration/frequency/duration of chlorophyll-*a* is right to protect aquatic life?
2. How to express N&P?
3. Is chlorophyll-*a* standard enough as a response indicator? Are other response indicators appropriate?
4. Is resulting criteria translatable to other lakes?

Next SAC Meeting

High Rock Lake:

- Review existing data
- Review existing tools
  - Watershed model
  - Nutrient response model

- Final Model Reports:

http://portal.ncdenr.org/web/wq/ps/mtu/specialstudies#HRL

Contact Information

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High Rock Lake Information:
http://portal.ncdenr.org/web/wq/high-rock-lake

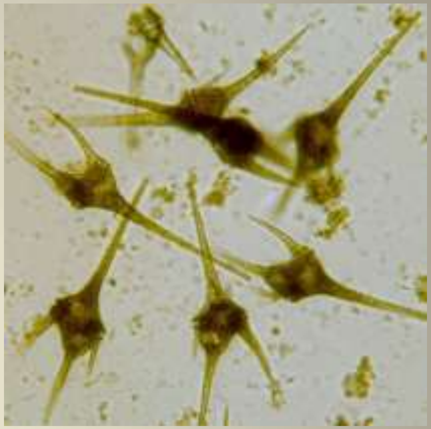
High Rock Lake Algae

Mark Vander Borgh
Division of Water Resources

NCDP SAC mtg July 2015

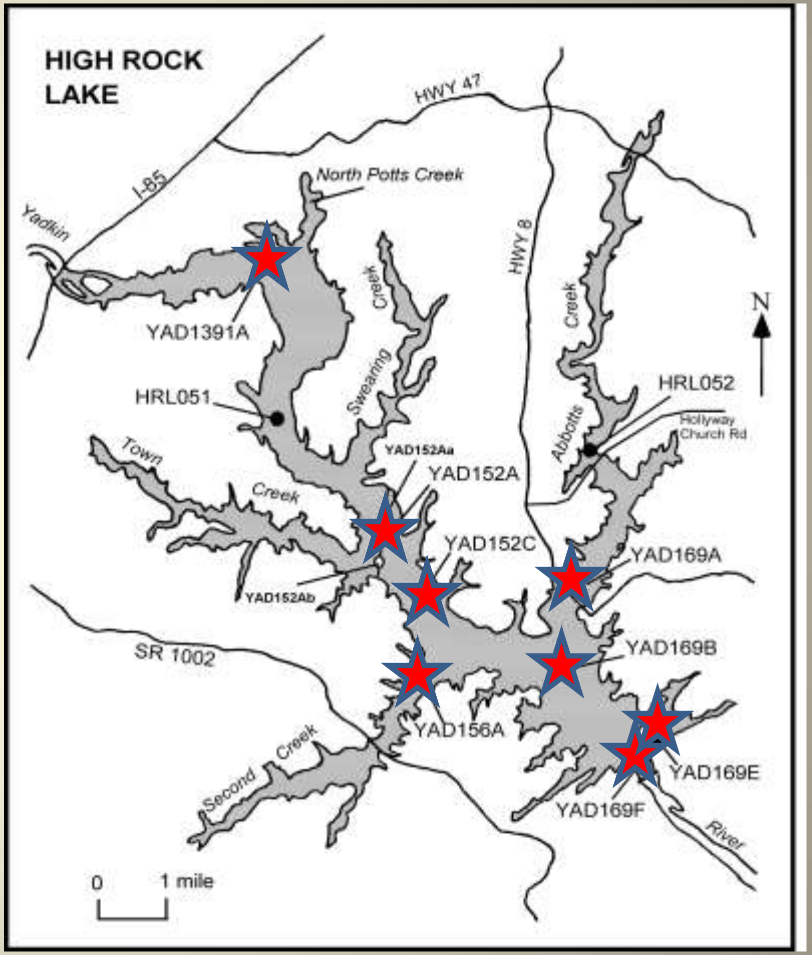
High Rock Lake Algae

- What data do we have
- How did we develop the data set
- What we found
- Algae of concern
- How does the data apply to other reservoirs



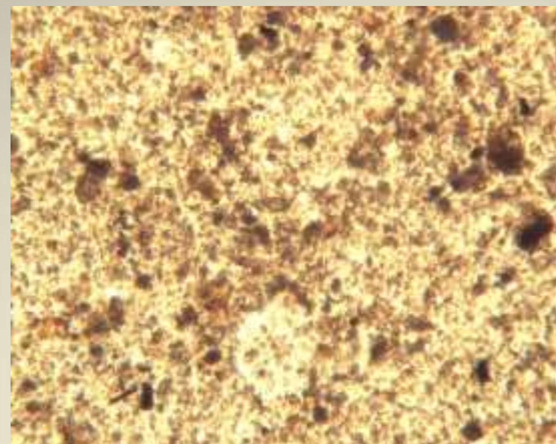
Algal Data: Special Study

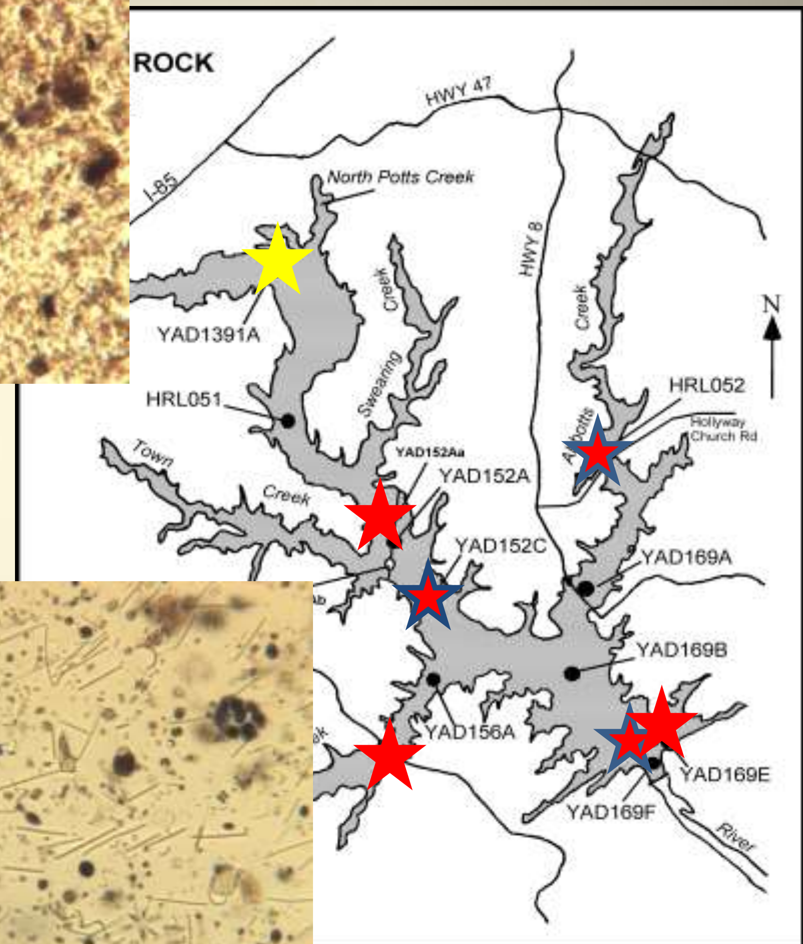
- 2002
  - Drought intensifies
  - fish kills
- 2004
  - 8 stations
  - June-August
    - (N = 15)
    - Some qualitative (N = 9)
  - Consistent blooms in July and August
    - (> 45,000 units/ml)



Algal Data: Scoping Study

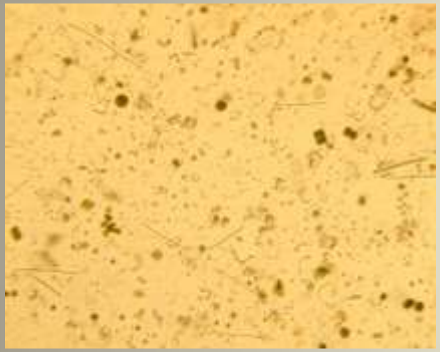
- 2005
  - 4 stations
- 2006
  - 6 stations
- Every other month
  - (N = 48)
- Refined approach
  - Dropped upper
    - sediment
  - Picked up arms

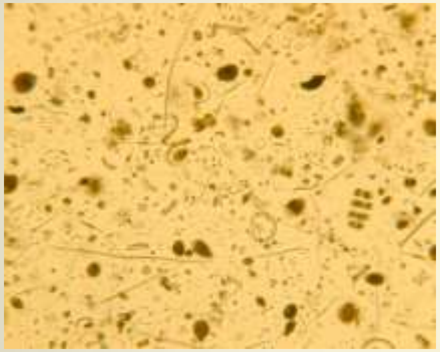


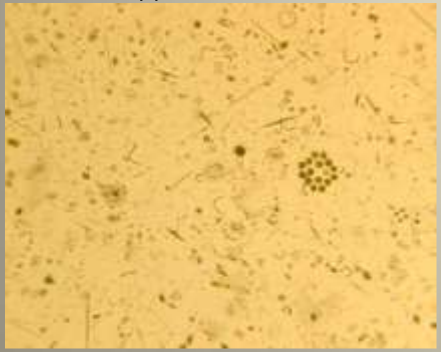


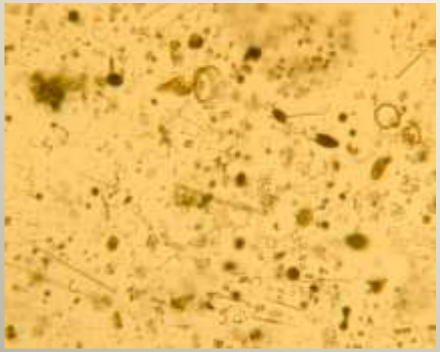
Algal Data: Intensive Monitoring

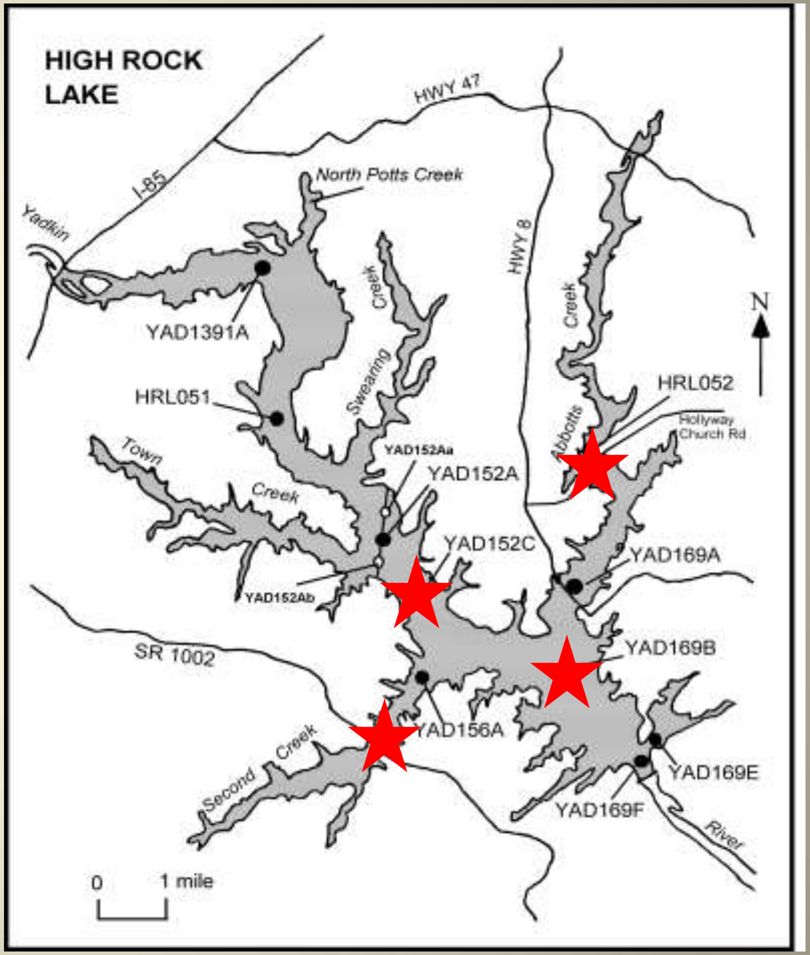
- 2008 – 2010
  - 4 stations: monthly
    - (N = 98)


Upper main stem


Abbotts creek

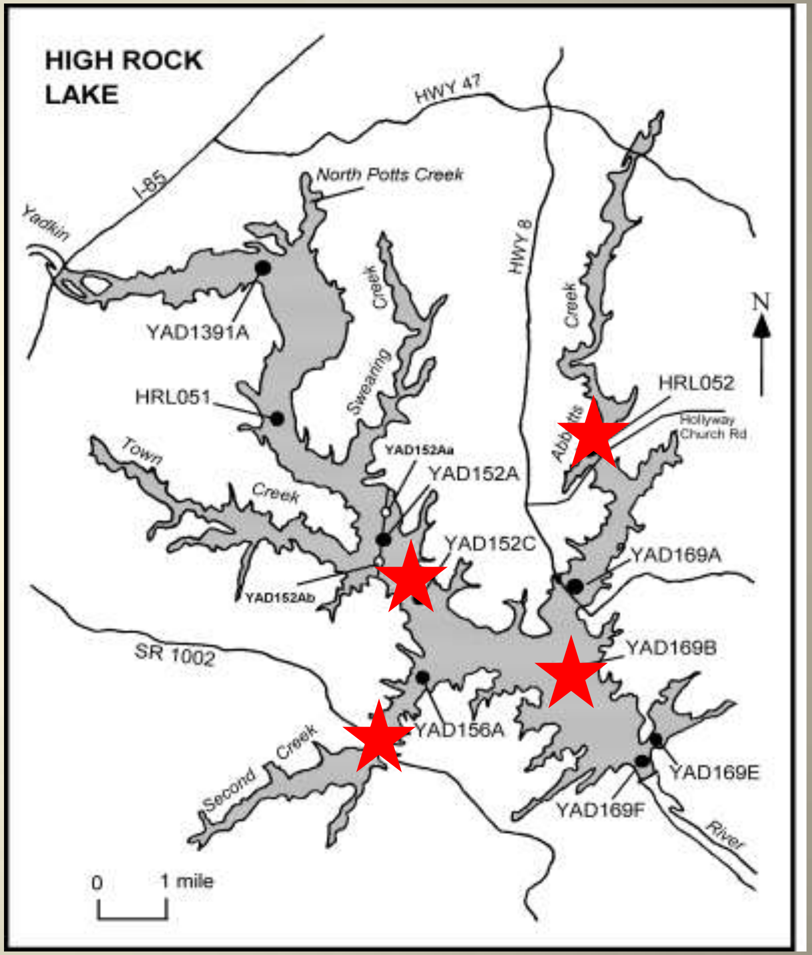

Second Creek


Lower main stem



But Wait! There's more….

- Basinwide 2011
  - 4 stations
  - Repeated 2008-2010
  - May – September
    - (N = 20)
  - NEVER ANALYZED THE DATA!
  - Why?
    - Microcystis blooms in the Cape Fear River



Algal Data Concluded

- Special 2004 (N=15)
- Scoping 2004-2006 (N=48)
- Intensive 2008-2010 (N=98)
- Basinwide 2011 (N=20)

Total # of Assessments = 181

General Conclusions

- Upper end sedimentation issues
- Arms similar in composition and density
  - but act independently
- Elevated algal productivity throughout lake

Sampling and Analysis

- Collected concurrently with chemical/physical parameters
- Are photic-zone composite
- Utermohl chambers and inverted scopes
- Count until 100 units of most dominant found
- Max = 300 units or 40 grids (fields)

Algal Density

- Units and cells estimate density
  - (units/ml or cells/ml)
- “Unit” = single cell, colony or filament
- Cells counted in first 10 units found then averaged
- Avg#cells X #units/ml = cells/ml

Algal Biovolume

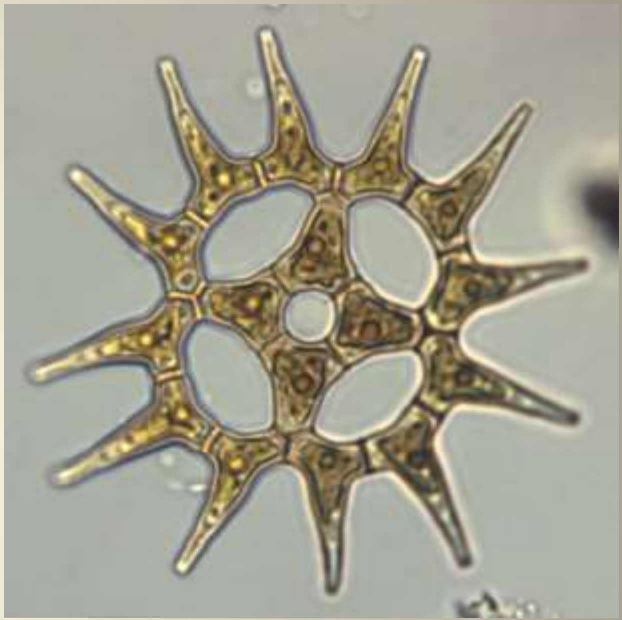
- Biovolume estimate biomass
  - (mm^3/m^3)
- Predetermined biovolume (μm^3/cell)
- Cell # x bv = unit biovolume (BV)

BV Taxa 1 + BV Taxa 2 + BV Taxa 3 = Total BV

Counting in action

Taxa: *Pediastrum simplex*

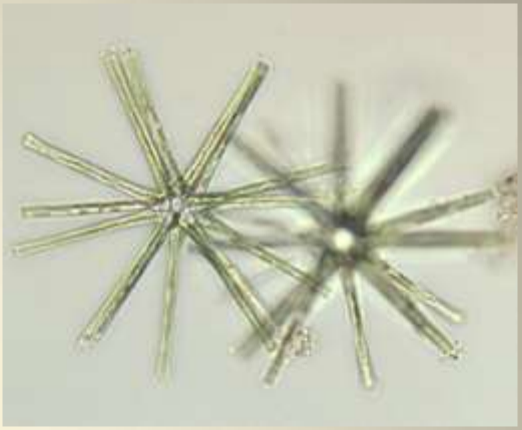
- 1 unit
- 12 cells
- Reference bv/cell = $130\mu m^3$
- 12cells x $130\mu m^3$ = $260\mu m^3$
- Results:



1 unit = 12 cells = $260\ \mu m^3$

Your turn!

What we found in HRL



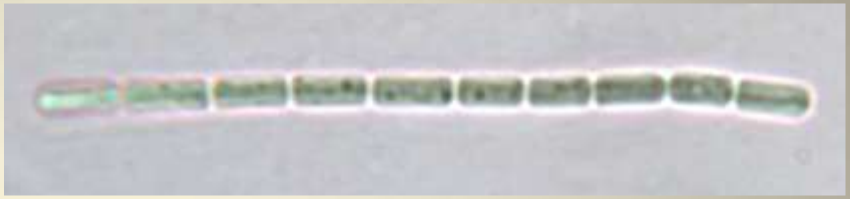
- > 140 algal taxa
  - Identified to genus
    - species when possible
- Most Common
  - Cryptomonads (*Komma*/*Cryptomonas*)
  - Diatoms (Centrics/*Synedra*)
  - *Pseudanabaena* (filamentous blue green)

What we found in HRL

- Seasonal variance
  - January through March
    - Lower densities (< 100 units/ml to 20,000 units/ml)
    - Dominated by
      - Cryptomonads, Chrysophytes, Diatoms or nobody
      - Representing 40% – 50% total density
  - July through September
    - Higher densities (27,000 units/ml to 177,000 units/ml)
    - Dominated by
      - Bluegreens, bluegreens and more bluegreens
      - Representing 69% - 96% total density

What we found in HRL

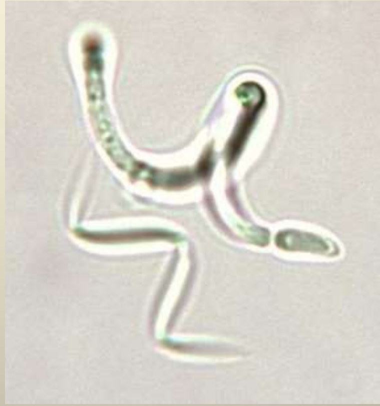
- Most influential:
  - *Pseudanabaena*



    - Present in 83% of the assessments
    - Blooms > 80,000 units/ml
    - Often comprises > 60% total density
    - Grows/blooms throughout water column
    - Ultimately responsible for many DO, pH and Chl-*a* water quality standard violations
    - Toxin producer???

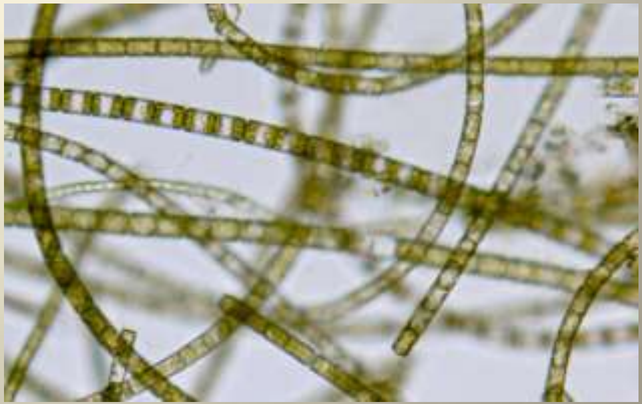
Algae of Interest
Toxigenic bluegreens

- *Planktothrix*?
  - No, no records
- *Microcystis*?
  - Yes, 7 % of samples
- *Aphanizomenon*?
  - Yes, 17 % of samples
- *Anabaena*?
  - Yes, 22 % of samples
- *Cylindrospermopsis*?
  - Yes, 44 % of samples



How does HRL compare to:

- Jordan & Falls of Neuse Reservoir
  - Similar in composition and density
- Norman, Kerr Scott & Gaston
  - Somewhat in composition and density
- Santeetlah, Nantahalah & James
  - Not really



High Rock Lake Algae

- What algal data do we have
  - A lot, 181 data points
- How did we develop the algal data set
  - Trial and error, ultimately selecting best sites
- What we found
  - Seasonal variance
  - Summer dominated by bluegreens at high densities
- Algae of concern
  - Yes, but are they causing toxicity issues?
- How does the algal data apply to other reservoirs
  - Yes, depending on trophic status

Contact Information

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Overview of Approaches for Numeric Nutrient Criteria Development

Tiffany N. Crawford
EPA/OW/OST/HECD
North Carolina SAC Meeting
July 21, 2015

Outline

- Assessment Endpoints
- Tools for Numeric Nutrient Criteria Development
  - Reference Condition Approach
  - Stressor Response Analysis
  - Mechanistic Modeling
- Optional Approaches
  - Combined Criteria

Assessment Endpoints: Background

- What we've learned:
  - Assessment endpoints can be used to link numeric nutrient criteria to protect aquatic life and human health.
- What we need:
  - A clear framework for developing and communicating defensible assessment endpoints and conceptual models of this linkage.

Nutrient Concentrations

link

Terminology

Term	Definition
Management Goal	Narrative criteria or statement reflective of protecting a designated use
Assessment Endpoint	Ecological entity and its attributes to be protected to support designated use
Measure	Measurable attributes of an assessment endpoint
Water Quality Target	Numeric value that indicates attainment of the management goal

Ecological Risk Assessment Framework

1. Planning

– Define the environmental issue of concern

2. Problem Formulation

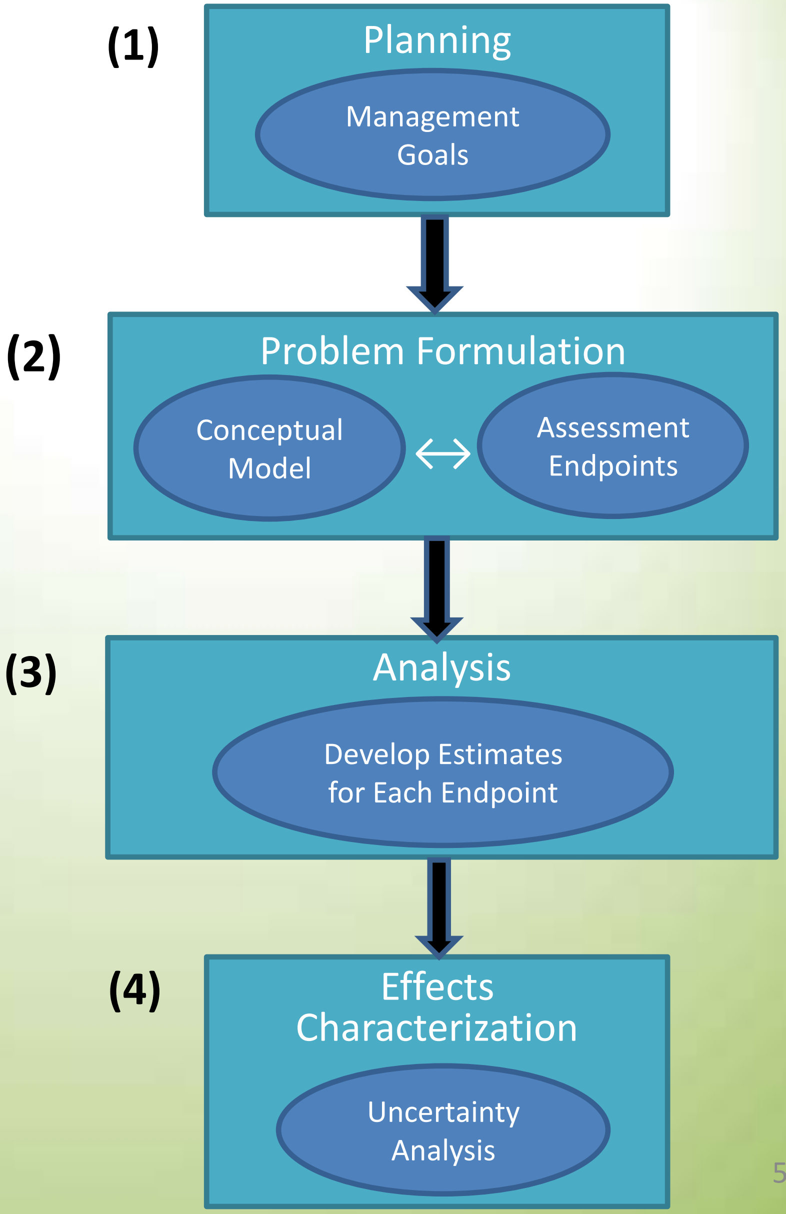
– Identify the ecological conditions representative of environmental improvement

3. Analysis

– Select an approach to quantify the issue of concern

4. Effects Characterization

– Description of uncertainty
– Typically post-criteria development

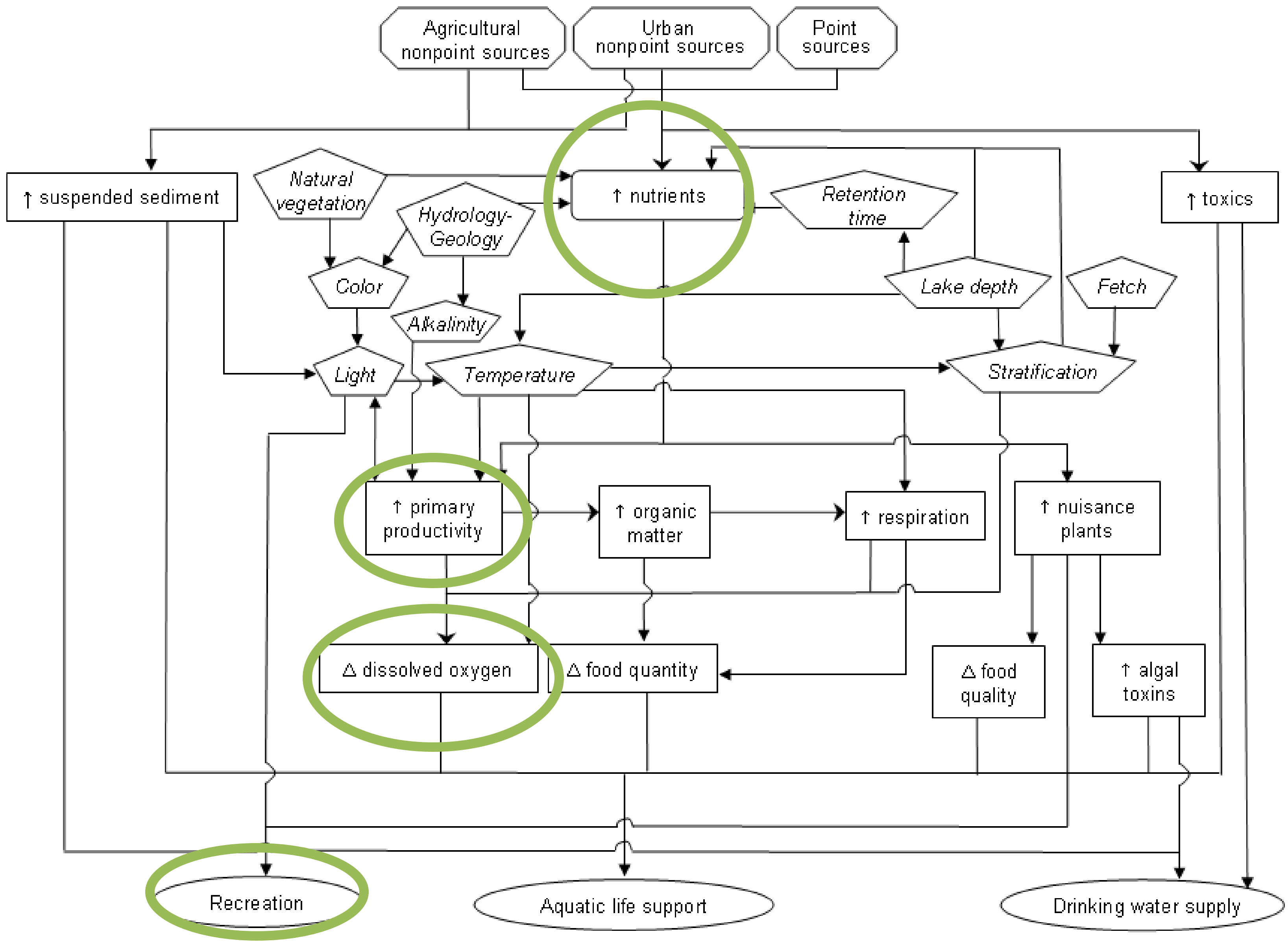


Case Study: Lake Example

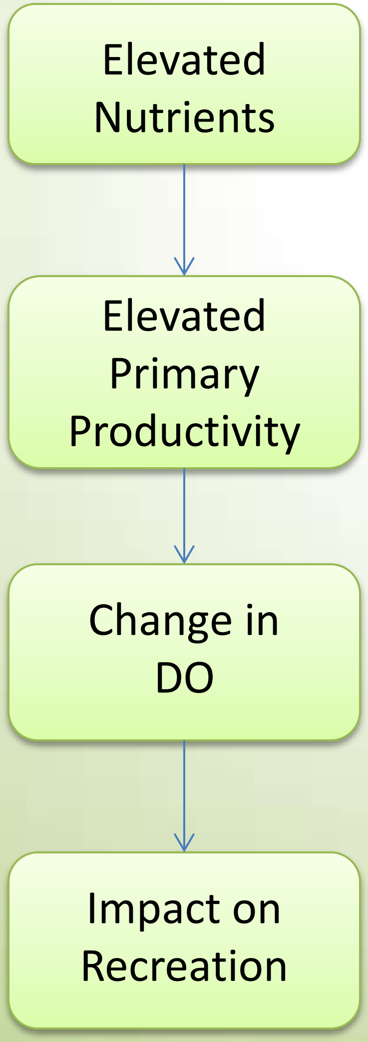
Case Study:
Linking Endpoints to Criteria Derivation

- Management goal:
  - *Surface waters must be free from nutrients which produce a predominance of undesirable aquatic life.*
- Refined management goal: Algal bloom prevention

Case Study: Lake Conceptual Model



Case Study: Lake Conceptual Model



Case Study: Linking Endpoints to Criteria Derivation

Initial Endpoints Considered

- Dissolved oxygen
- Littoral macroinvertebrate structure
- Diatom structure
- Cyanotoxin
- Disinfection byproducts
- Water clarity
- Algal biomass from cyanobacteria bloom frequency

Literature Review →

Selection Factors

- Ecological relevance
- Relevance to goals
- Public importance
- Nutrient sensitivity
- Data availability
- Ability to measure

→

Final Endpoints Selected

- Algal biomass

Case Study: Identifying Assessment Endpoints for Numeric Nutrient Criteria Derivation

Lake Case Study

Management Goal: *Surface waters (except wetlands) must be free from nutrients which:*

- *produce a predominance of undesirable aquatic life.*

Refined Management Goal	Assessment Endpoints	Measure	Water Quality Target
Algal bloom prevention	Algal biomass	Chlorophyll-a concentrations	Warm-water lakes: 8 – 25 ug/L Cold-water lakes: 2.5 –8 ug/L

Case Study:
Refined Lake Conceptual Model

Refined Management Goal	Algal bloom prevention
Biological Assessment Endpoints	Algal biomass
Measure	Chl-a concentrations
Water Quality Target	Warm-water lakes: 8 – 25 ug/L Cold-water lakes: 2.5 –8 ug/L
Response Variable	**Chlorophyll-a Criteria**
Causal Variable	**Proposed Total Nitrogen and Total Phosphorus Criteria**

Lessons Learned

- Ecological risk assessment framework is a valuable tool to derive criteria based on assessment endpoints and conceptual models
- Assessment endpoints clarify what is being protected; conceptual models illustrate the linkages between nutrients and what is being protected
- The most sensitive assessment endpoints should be used to derive the nutrient criteria
- It is possible to identify many assessment endpoints, but there may not be scientific information available to derive numeric criteria for each endpoint

Tools for Nutrient Criteria Development

- Reference condition approach
  - Ability to demonstrate minimally impacted waters
  - Sufficient nutrient data
- Stressor-response analysis
  - Paired stressor-response data
  - Sufficient data across all classes (each cofactor requires more data)
- Mechanistic modeling
  - Any water condition (doesn’t require minimally impacted waters)
  - Ambient trend data (doesn’t require paired data)
  - Models “borrow” information from neighboring segments

Defining "Reference Condition"

- Types of reference conditions (Stoddard et al. 2006, NLA paper):
  - Minimally disturbed condition
  - Historical condition
  - Least disturbed condition

- Working definition: In general, sites should be selected that reflect our management goal.
  - Supporting designated uses

Reference Condition Approach

- Scientifically defensible approach for deriving numeric nutrient criteria
- Spatial and temporal applications:
  - Spatial: Identifying reference waters in a region
  - Temporal: Identifying reference time periods in a site
- Physical, landscape, biological screens used, for example:
  - Land cover
  - Habitat conditions
  - Biological assessment endpoints

Selecting Reference Sites

- Ensure sites selected accurately reflect the desired ecological condition or designated use support.
- Establish site screening requirements to ensure reference site quality.
  - Landscape development intensity index score
  - Biological condition index
  - Impairment status
  - Presence of point source dischargers
- Monitoring data are used to show how each reference site's waters are supporting designated uses.

Considering Data Quantity

The quantity of data should enable:

- Capturing variability across space/time (ideal case)
- Spatial/temporal representativeness
  - Site-specific – Need considerable representation over time
  - Regional – Need considerable representation over space

Considering Data Quality

Elements of data quality important for criteria derivation:

- Ensuring data are verified and validated
- Having associated metadata, so data can be traced to a sampling site, date, and time
- Ensuring sample integrity was maintained
- Using approved EPA/state sample collection and laboratory analysis methods
- Sufficient use of quality control measures in the laboratory
- Records of instrument calibration and verification of performance

Classification of Reference Sites

- Classification of water segments and reference sites ensures water quality expectations are appropriately represented for different types of sites.
- Classification factors (e.g., geological, hydrological, chemical)
- Examples:
  - Streams
  - Estuarine and coastal waters

Selecting a Defensible Percentile

- Also based on statistical reasoning
- For a small data set with greater heterogeneity, choose a lower percentile; for a large data set with greater homogeneity, choose a higher percentile
- Ties into assessment endpoint selection
  - Support your percentile choice with scientific literature and other available information

Reference Period Approach

- Approach to consider for a specific waterbody when:
  - There are insufficient regional reference waters
  - Current conditions might not meet reference criteria
  - Data exists from historic conditions that justifiably met reference criteria
- Need temporal screens:
  - For example:
    - Demonstrated attainment of other criteria during that time period
    - No evidence of adverse nutrient impacts
    - Pre-discharges
    - Trend data available support temporal reference

Case Study: Reference Period Approach in Estuaries

- Coastal lagoon estuary
- Minimally disturbed condition
  - No 303(d) listings for nutrients or dissolved oxygen
- Long-term data set available
  - Spatial and temporal representativeness

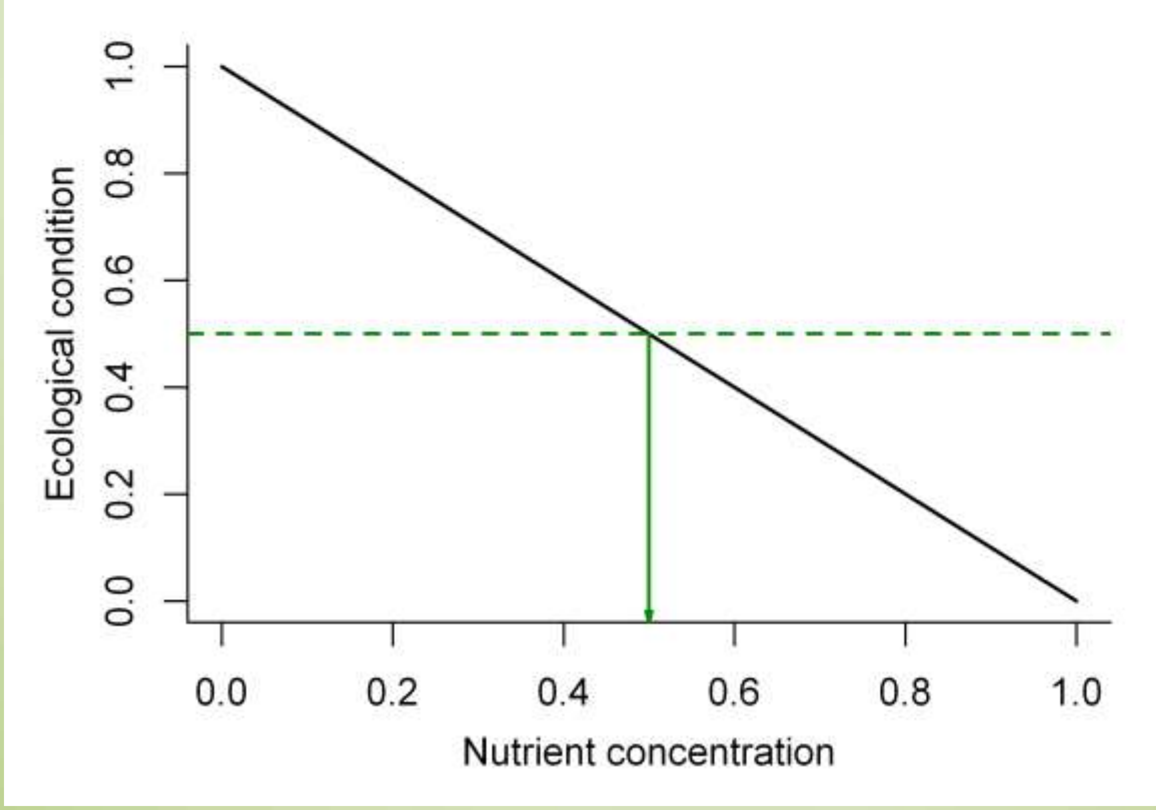
Case Study: Reference Period Approach in Estuaries (continuation)

- All data available from 1974–2009 were reviewed
  - No nutrient-related impairments were identified
  - Nutrient assessment endpoints were evaluated
  - Data screening is not needed
- Numeric nutrient criteria were calculated at the 90th percentile of annual geometric means
  - Water quality from the reference time period is likely protective of the designated uses

Lessons Learned

- Definition of *reference condition* varies; however in all cases:
  - Reference conditions should support designated uses
  - It need not mean pristine
  - High quality data are developed through application of data quality objectives
  - Objective data screens are used to define reference and arrive at a final data set for deriving criteria
- States have concerns with applying the reference condition approach when there are not many uncompromised sites. There are solutions for regions with heavily impacted sites.
- Selecting the percentile of the reference condition data set is dependent upon the data, and the amount of uncertainty one has that it accurately reflects the reference condition.
- The reference condition approach is scientifically defensible when supported with appropriate rationales and data.

What is a Stressor-Response Approach?



Background

- Relationship between total phosphorus and chlorophyll-a used to guide management of lakes (Dillon and Rigler, 1974).
- Stressor-response relationships described as an approach for deriving nutrient criteria for different waterbodies (EPA 2000).
- Guidance on the use of stressor-response for nutrient criteria derivation reviewed by EPA SAB (2010).
- Final guidance document on use of stressor-response released (2010).

Data Requirements

- Data need to be nominally matched in time and space.
  - For example, nutrient measurements should be collected in the same stream reach as biological response data.
  - Matched data become harder to find as the number of other variables used in the model increases.
- Estimating a simple linear regression requires a minimum of 10 independent samples per degree of freedom (e.g., 10 samples per estimated coefficient).
  - Example: chlorophyll-a = $b_0 + b_1 \times TP$.
  - Two coefficients (b_0 and b_1) requires a minimum of 20 samples.
  - More data is always better.

Thresholds for the Response

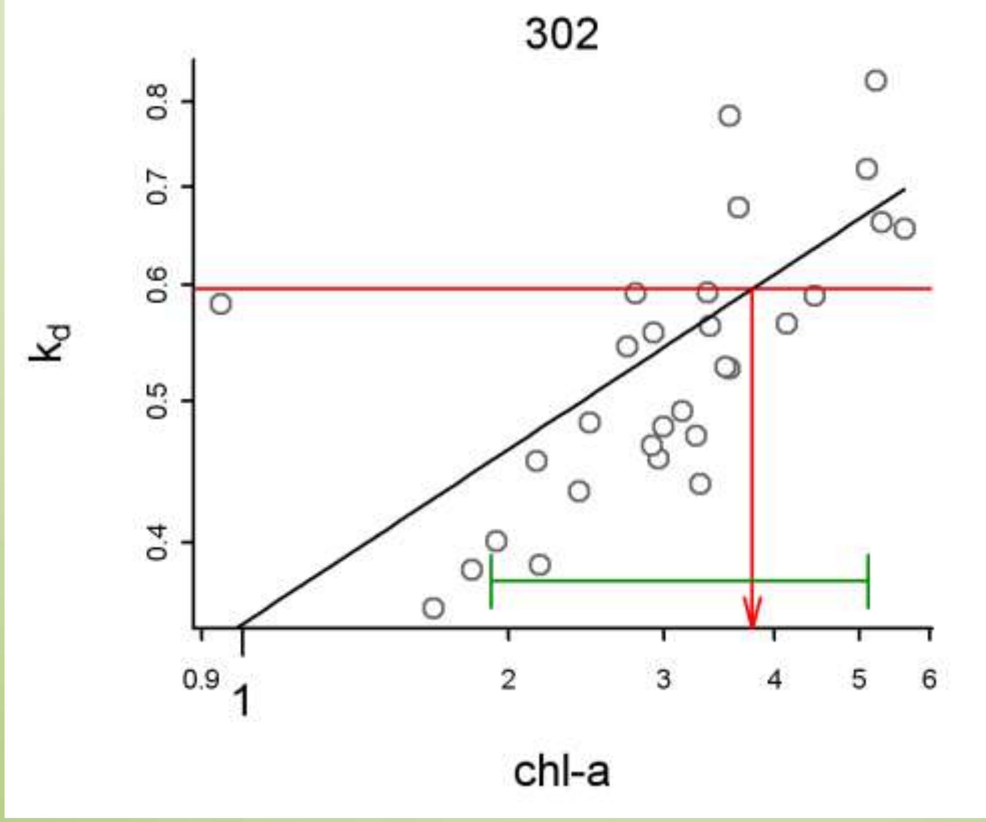
- Thresholds should link directly to an assessment endpoint.
  - Lake examples:
    - Excessive nutrients → higher microcystin → impaired drinking water
    - Excessive nutrients → lower dissolved oxygen → impaired aquatic life
  - Estuary example:
    - Excessive nutrients → increased turbidity → loss of SAV
- Thresholds for aquatic life uses can also be derived from reference conditions approaches.

Threshold Based on Extent of SAV

Estuary Segment	SAV Depth Target (m)	K_d Target (1/m)
0301	None	-
0302	2.7	0.6
0303	3.3	0.5

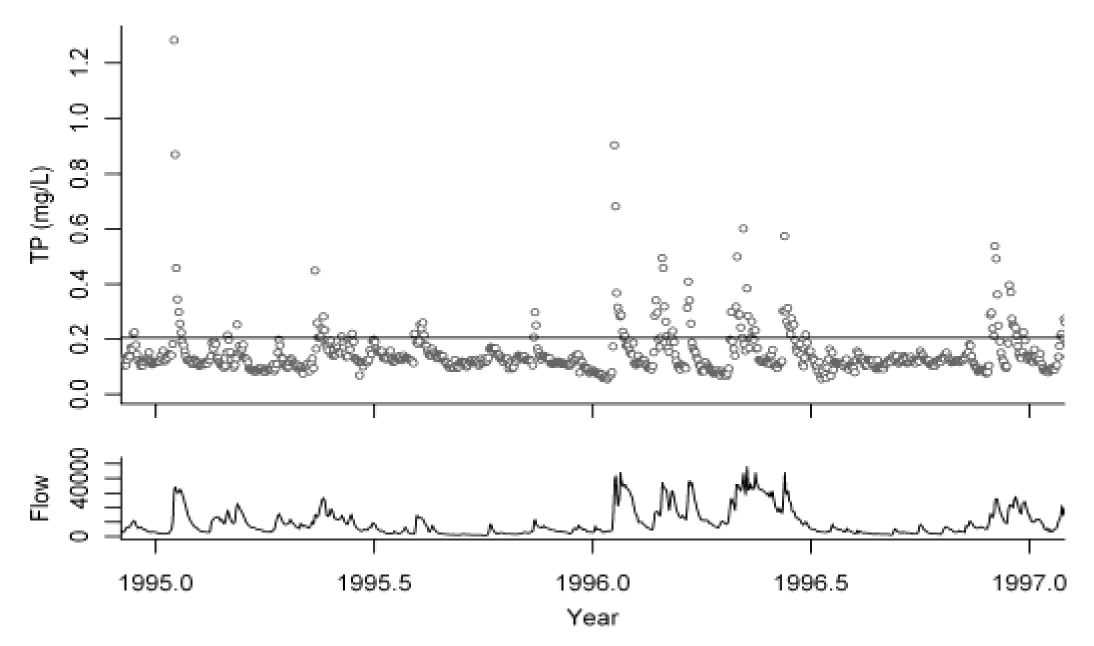
Threshold Based on Extent of SAV

Water clarity provides a threshold from which we estimate a chlorophyll-a criterion.



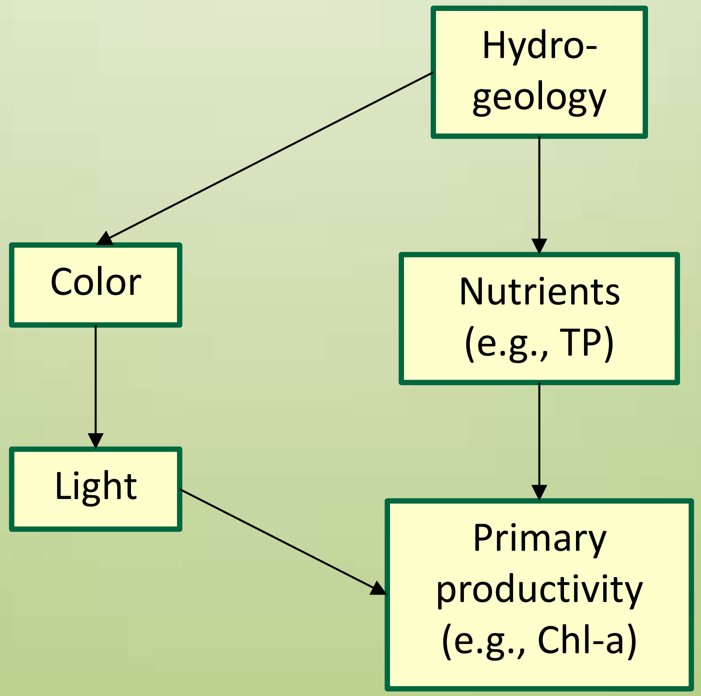
Unexplained Variability in Stressor-Response Relationships

- Measurement error:
  - Nutrient measurements are highly variable, even during baseflow.
- What summary statistic of nutrients should we be calculating?
  - Annual average baseflow concentration?
  - Flow-weighted concentration?



Unexplained Variability in Stressor-Response Relationships

Other unmodeled factors:



Approaches for Addressing Variability in Relationships

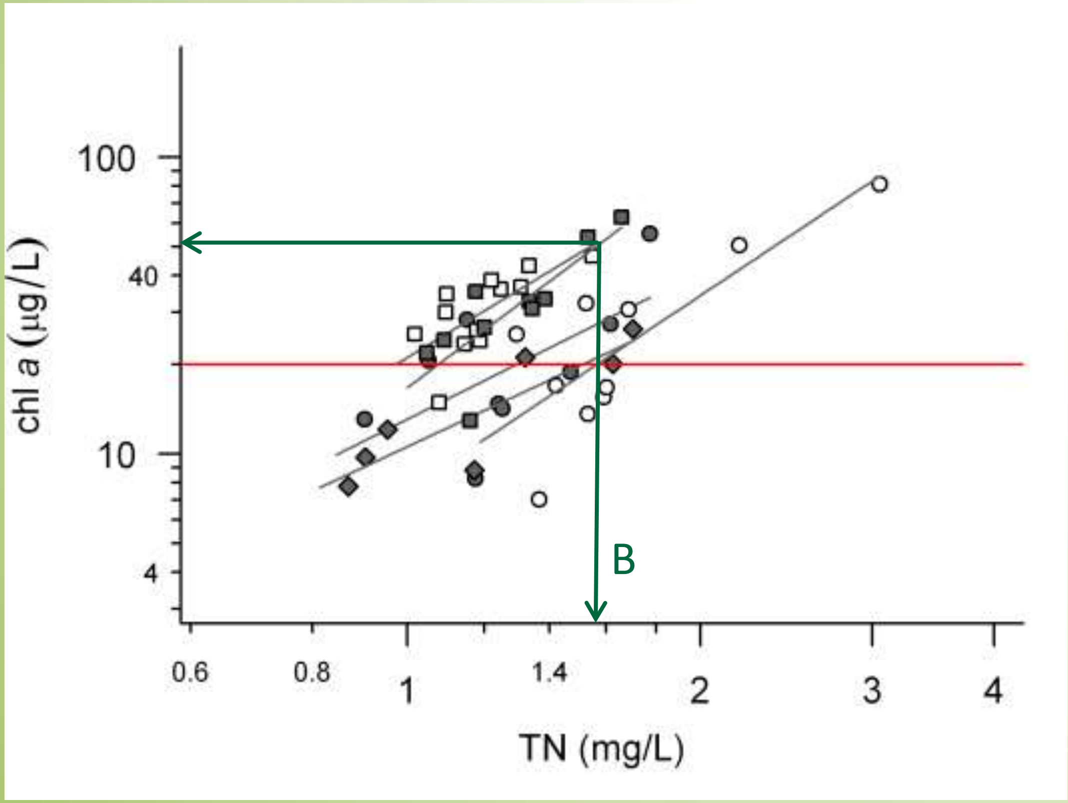
- Classification
  - TREED models
- Hierarchical models

Precision: Is a Stressor-Response Model Precise Enough?

- Commonly reported regression statistics include:
  - R^2 : The proportion of variability explained by the model relative to a horizontal line.
  - *p-value* : The probability that observed data would occur if the slope were 0 (i.e., a horizontal line).

✓ **Neither of these statistics directly answer our question.**

Is the Model Precise Enough to Usefully Inform Decisions?



The criterion that protects the least sensitive lake (B) allows chl *a*= 50 µg/L in the most sensitive lake.

Presenting model precision in terms of the effects of a criterion on different classes of waterbodies can be most informative.

Lessons Learned

- Simple linear regression, combined with classification, provides a model that is easily interpreted and communicated.
- Classification is critical for maximizing precision and accuracy of estimated relationships.
- Further research will improve the accuracy and precision of estimated relationships. Some example questions:
  - How can we best quantify nutrient concentrations in streams?
  - How can we best measure primary productivity in streams?

What is a Mechanistic Model?

- Collection of mathematical equations that represent chemical, physical, and biological mechanisms
  - Flow is a key mechanism for the delivery of contaminants and concentrations of contaminants
- Derived from the law of conservation:
  - Momentum
  - Heat energy
  - Water mass
  - Contaminant mass

Types of Mechanistic Models

1. Watershed Models

- Describe hydrologic mechanisms (e.g., flow)
- Describe delivery of contaminants from the watershed to a stream, river, lake, or estuary (e.g., temperature, total nitrogen, total phosphorus, total suspended solids, dissolved oxygen, biochemical oxygen demand)

2. Hydrodynamic Models

- Describe water movement (e.g., volume, velocity, direction); can describe the water movement in one, two, or three dimensions over varying time periods
- Simulate corresponding changes in properties (e.g., temperature and salinity)

3. Water Quality Models

- Describe changes that occur to contaminants (e.g., eutrophication models describe nutrient cycles; growth of algae; and production and consumption of dissolved oxygen)

Why Model?

- Examine the interactions between nutrient loadings and response
- Test if assessment endpoints are sensitive to nutrients
- Predict nutrient condition for which water quality data are either insufficient or unavailable
- Explore candidate nutrient criteria
- Provide a methodology that can be duplicated and is credible and defensible

How to Use Water Quality Models

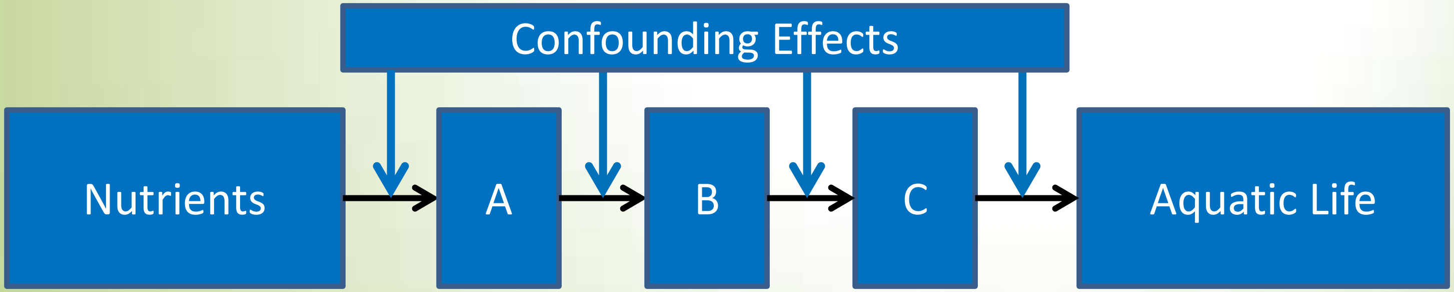
1. **Define** targets
2. **Select** a model that includes processes important to the water quality target
3. **Collect** additional data to inform the model
4. **Configure**
5. **Calibrate**
6. **Run** scenarios
7. **Apply** model results to interpret assessment endpoint targets and calculate nutrient criteria values

Lessons Learned

Mechanistic models:

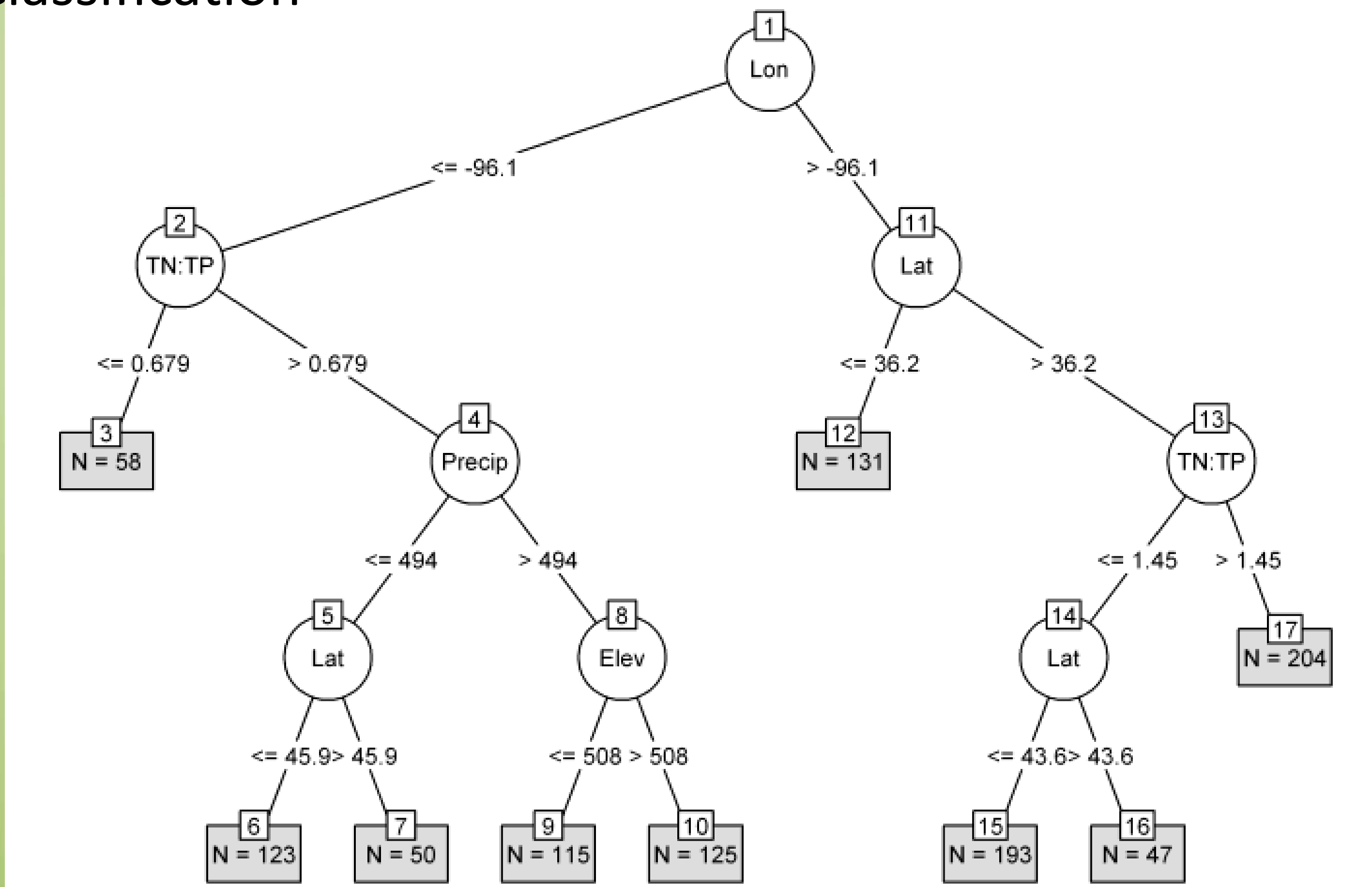
- Describe water movement, better understand water quality dynamics, and link nutrients with their sources
- Test if assessment endpoints are sensitive to nutrients
- Explore candidate nutrient criteria
- Evaluate downstream effects
- Provide a methodology that can be duplicated and is credible and defensible

The Concept of Combined Criteria

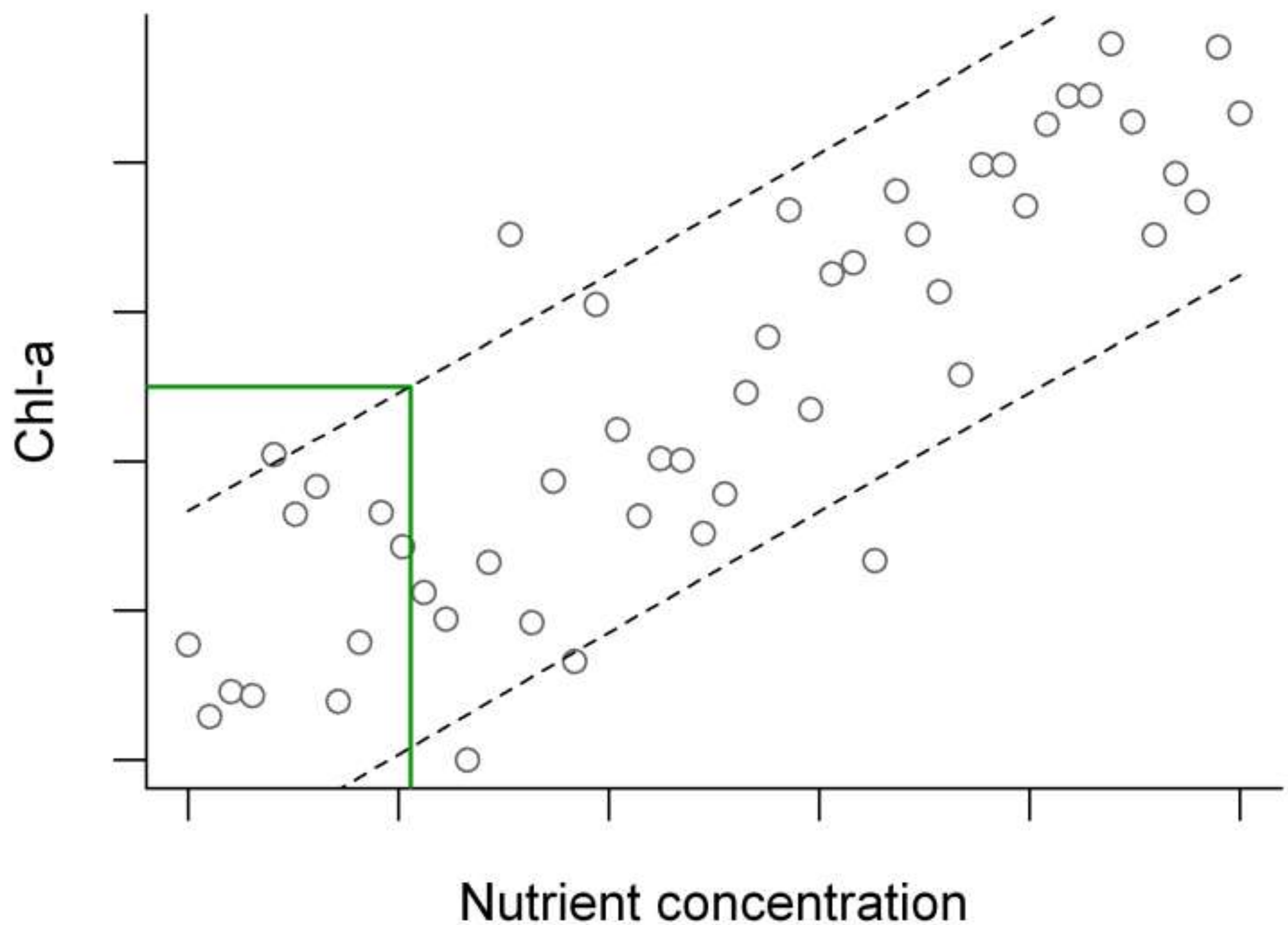


Approaches for Addressing Variability in Relationships

- Classification



Deriving a Protective Criterion



Independent Application

All criteria have traditionally been applied independently.

- Waterbodies are subject to multiple nutrient criteria.
- Exceeding any one water quality standard means that a waterbody must be listed as "impaired."

	Nutrients ≤	**Nutrients >**
Chlorophyll-a ≤	Not impaired	Impaired
Chlorophyll-a >	Impaired	Impaired

Combined Criteria

- Combines multiple nutrient-related thresholds into a single assessment decision (e.g., total nitrogen/phosphorus, chlorophyll-a), which increases assessment accuracy.
  - Exceedance of a suite of causes and responses might be more reliably associated with a high risk of losing a designated use.
- Main considerations:
  - Must protect applicable uses
  - Must be scientifically defensible

Guiding Principles

September 2013 – the Guiding Principles were released to provide a framework for states currently pursuing or considering a combined approach for developing and implementing numeric nutrient criteria that:

- Protect the designated use
  - Exceedance of criteria triggers action before adverse conditions that will require restoration
- Protect downstream waters
  - Ensures attainment and maintenance of water quality standards downstream
- Include numeric nutrient targets
  - Facilitates permitting and total maximum daily loads
- Are scientifically defensible

Expressing a Protective Combined Criterion: Examples

- Simple matrix
- Range approach

Simple Matrix

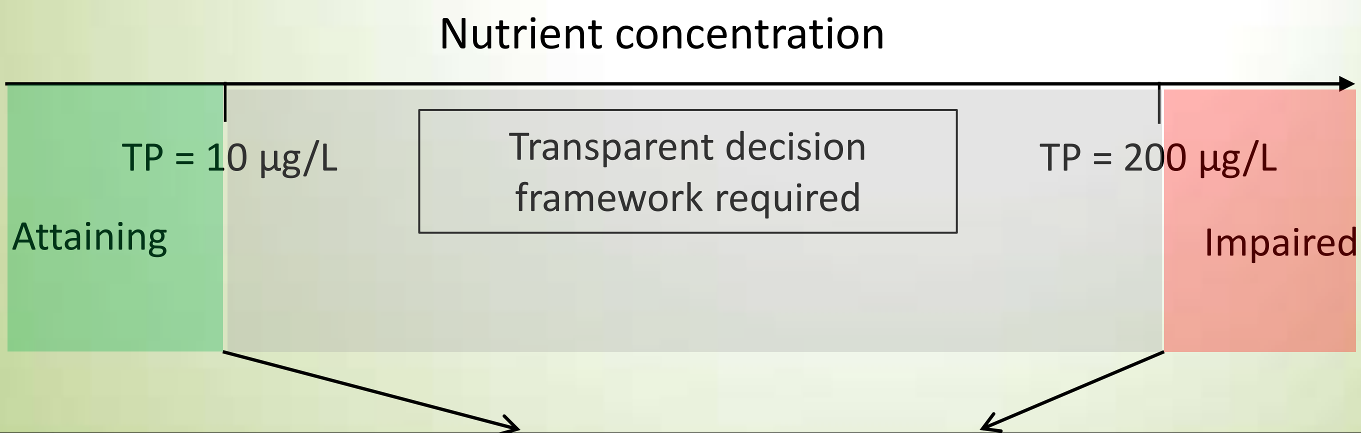
Considers a water "impaired" if causal AND any response parameter are exceeded.

	Nutrients ≤	Nutrients >
All response ≤	Not impaired	Not impaired*
Any response >	Impaired (cause not determined)	Impaired

*Site might be candidate for site-specific criteria.

Range Approach

If causal parameters are within range, response parameters are required to assess attainment.



	Nutrients < lower range	Nutrients in range	Nutrients > upper range
All response ≤	Not impaired for nutrients	Not impaired for nutrients	Impaired for nutrients
Any response >	Not impaired for nutrients*	Impaired for nutrients	Impaired for nutrients

*Site impaired for biological response condition, cause unknown.

Lessons Learned

- Combined criteria provide states with flexibility within the context of quantifiable variability.
  - Combining causal and response variables requires knowing both well and having numeric thresholds for both.
  - Focus on a set of sensitive responses (e.g., algal assemblage, primary productivity).
  - Criteria must protect applicable uses.
- Focus on clear decision frameworks that are transparent and reproducible.

Questions?

For more information:

Nutrient Scientific Technical Exchange Partnership and Support (NSTEPS)

http://nsteps.org/toolbox/toolbox.html

Contact Information: Crawford.Tiffany@epa.gov

NNC Methodologies and Criteria in R4 States

Lauren Petter

July 21, 2015

NC SAC Meeting #2

R4 States Summary – At Present Time

- ALABAMA – chlorophyll *a* only for 40 lakes and reservoirs
- FLORIDA – chlorophyll *a*, TP, and TN for most waters, nitrate-nitrite for springs
- GEORGIA - chlorophyll *a*, TP, TN for 6 lakes
- KENTUCKY – nutrient narrative provisions only
- MISSISSIPPI – nutrient narrative provisions only

R4 States Summary – At Present Time

- NORTH CAROLINA – chlorophyll *a* for trout and non-trout waters statewide and covered in last meeting's presentation
- SOUTH CAROLINA - chlorophyll *a*, TP, TN for lakes/reservoirs greater than 40 acres
- TENNESSEE – chlorophyll *a* for 1 lake, translator for TP and nitrate-nitrite for wadeable streams

Alabama

- Chlorophyll *a* criteria concentrations typically range from 5-20 µg/L (one reservoir is 27 µg/L) and represent growing season averages not to be exceeded.
- Generally measured at dam forebay, main river channel, above deepest point
  - Larger reservoirs tend to have at least one additional criteria location
- Based on samples collected monthly April through October (some are September)
- Criteria were derived using:
  - 1) Historical data
  - 2) Assessment of lakes as fully supporting designated uses (swimming, public water supply, and fish & wildlife) in consideration of nutrients, and
  - 3) ADEM's BPJ in consideration of previous consultations with Auburn University professor, including limnology, aquatic ecology, hydraulic regimes, and flow characteristics
  - Note: Criteria in reservoirs with known nutrient impairments were addressed through modeling and TMDL efforts

Florida – Freshwater Criteria

- Springs
  - Nitrate+nitrite criterion of 0.35 mg/L, as an annual geometric means not to be exceeded more than once in a 3 year period
  - Based on a stressor-response relationship between nitrate-nitrite and the presence of nuisance algal mats, with the criterion established at a concentration that would prevent nuisance mats from occurring.
- Lakes
  - TP, TN, and chlorophyll *a* criteria based on three categories of color/alkalinity conditions
    - TP ranges from 0.01 mg/L to 0.16 mg/L
    - TN ranges from 0.51 mg/L to 2.23 mg/L
    - Chlorophyll *a* of either 6 or 20 µg/L
  - Based on a stressor-response relationship between total nitrogen and total phosphorus (TN and TP) and phytoplankton response (chlorophyll *a*). The lakes chlorophyll criteria were derived using multiple lines of evidence yielding chlorophyll criteria for each of the lake categories.
  - All of the lake TP, TN, or chlorophyll *a* criteria are expressed as annual geometric means not to be exceeded more than once in a 3 year period.

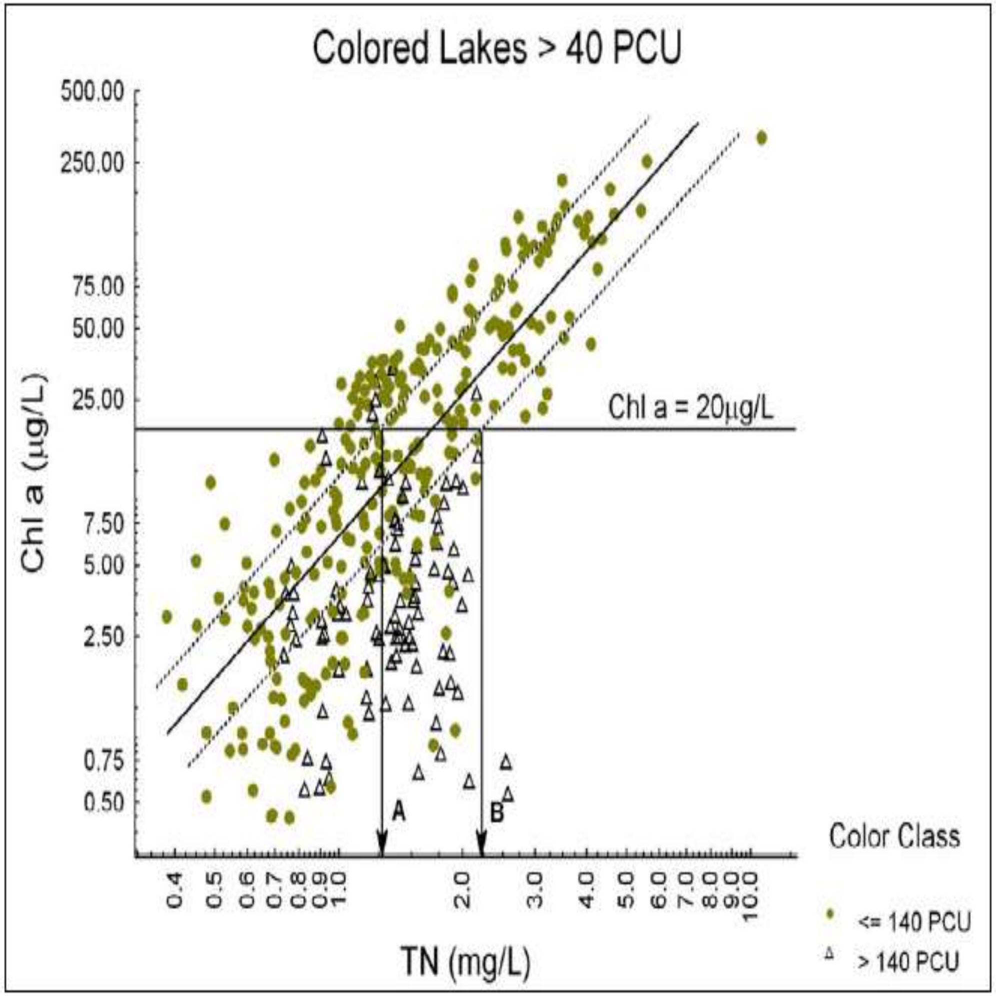


Figure 2-28. Chl-*a* and TN in colored lakes, showing 50% prediction interval (dotted lines) on each side of regression line.

Note that symbols and data as in Figure 2-23. Horizontal line: chl-*a* criterion (20 µg/L). A indicates TN concentration corresponding to 25% probability of chl-*a* exceeding 20 µg/L; B indicates concentration corresponding to 75% probability of exceedance.

Long Term Geometric Mean Lake Color and Alkalinity	Annual Geometric Mean Chlorophyll a	Minimum calculated numeric interpretation		Maximum calculated numeric interpretation	
		Annual Geometric Mean Total Phosphorus	Annual Geometric Mean Total Nitrogen	Annual Geometric Mean Total Phosphorus	Annual Geometric Mean Total Nitrogen
> 40 Platinum Cobalt Units	20 µg/L	0.05 mg/L	1.27 mg/L	0.16 mg/L[1]	2.23 mg/L
≤ 40 Platinum Cobalt Units and > 20 mg/L $CaCO_3$	20 µg/L	0.03 mg/L	1.05 mg/L	0.09 mg/L	1.91 mg/L
≤ 40 Platinum Cobalt Units and ≤ 20 mg/L $CaCO_3$	6 µg/L	0.01 mg/L	0.51 mg/L	0.03 mg/L	0.93 mg/L

[1] For lakes with color > 40 PCU in the West Central Nutrient Watershed Region, the maximum TP limit shall be the 0.49 mg/L TP streams threshold for the region.

Florida – Freshwater Continued

- Streams
  - Criteria based on reference-based nutrient thresholds, in conjunction with biological information.
  - Therefore, to assess whether a stream attains the stream criterion, an evaluation of water chemistry and biological data, is used to determine if a stream's nutrient concentrations are protective of balanced flora and fauna.
  - The TP and TN values are expressed as annual geometric means not to be exceeded more than once in a 3 year period.
    - TP ranges from 0.06 mg/L to 0.49 mg/L
    - TN ranges from 0.67 mg/L to 1.87 mg/L
  - Biological metrics include:
    - Flora - chlorophyll *a* levels, algal mats or blooms, nuisance macrophyte growth, and changes in algal species composition (most of these have numeric values associated with them)
    - Fauna – Stream Condition Index (macroinvertebrate)
  - EPA described this as an integrated, multimetric criterion in its approval. We can discuss Florida's approach in more detail at a future meeting if needed and earlier we covered "combined criteria".

Nutrient Watershed Region	Total Phosphorus Nutrient Threshold	Total Nitrogen Nutrient Threshold
Panhandle West	0.06 mg/L	0.67 mg/L
Panhandle East	0.18 mg/L	1.03 mg/L
North Central	0.30 mg/L	1.87 mg/L
Peninsular	0.12 mg/L	1.54 mg/L
West Central	0.49 mg/L	1.65 mg/L
South Florida	No numeric nutrient threshold. The narrative criterion in paragraph 62-302.530(47)(b), F.A.C., applies.	No numeric nutrient threshold. The narrative criterion in paragraph 62-302.530(47)(b), F.A.C., applies.

Florida – Streams Continued

- Streams
  - The actual stream criterion itself is adopted as follows:
  - For streams, if a site specific interpretation pursuant to paragraph 62-302.531(2)(a) or (2)(b), F.A.C., has not been established, biological information shall be used to interpret the narrative nutrient criterion in combination with Nutrient Thresholds. The narrative nutrient criterion in paragraph 62-302.530(47)(b), F.A.C., shall be interpreted as being achieved in a stream segment where information on **chlorophyll *a* levels, algal mats or blooms, nuisance macrophyte growth, and changes in algal species composition** indicates there are no imbalances in flora or fauna, and either:

1. the average score of at least two temporally independent SCIs performed at representative locations and times is 40 or higher, with neither of the two most recent SCI scores less than 35,

or

2. the nutrient thresholds set forth in the table [on previous slide] are achieved.

Nuisance macrophyte growth

C of C score of <2.5 and

Frequency of occurrence of FLEPCC exotics is >25% of the total plant occurrences

Presence of algal mats

RPS rank 4-6 percent coverage >25%

Changes in algal species composition

Where thickness rank of 4-6 is 20% or greater, the biologist collects a composite sample of the dominant groups of periphyton in the stream segment for lab identification of the dominant algal taxa. If autecological information is available for the dominant taxa, this is also qualitatively evaluated.

Algal blooms and Chlorophyll a levels

A narrative statement related to “unacceptable phytoplankton bloom” and can consider autecological information for the dominant bloom species, in conjunction with the associated chlorophyll a and the persistence of the bloom, as a line of evidence when assessing imbalances of flora.

Annual geometric mean chlorophyll concentrations > 3.2

Florida – Marine Criteria

- Florida's criteria include chlorophyll *a* criteria for coastal waters and TP, TN, and chlorophyll *a* criteria for estuarine waters. Note: Loading values not shown in this summary.
  - TP: Ranges from 0.019 to 0.86 mg/L
  - TN: Ranges from 0.24 to 1.29 mg/L
  - Chl *a*: Ranges from 1.1 to 15 µg/L
  - Generally annual geometric means, although duration/frequency/forma variable than other waterbody types
- Coastal Waters Methodology:
  - Remote sensing for chl *a* developme
- Estuarine Waters Methodology:
  - Healthy Conditions (based on locati time period) using Distribution Appr
- WQBEL and TMDL Methodologies:
  - Site specific work adopted as WQS, adopted as loading values

Georgia

- Chlorophyll *a* criteria range from 5-24 µg/L, growing season averages, not to be exceed more than 1 out of every 5 years (to account for natural variability, such as extreme weather events).
- TN & TP criteria not to exceed. Loadings for major tributaries derived to be protective of in-lake targets.
  - TN ranges from 3 – 4 mg/L
  - TP ranges from 0.5 to 5.5 lbs/acre-foot (or 12,500 to 2,000,000 lbs/yr)
- Compliance points often include dam forebay, deep points, main river channel, or embayments.
- Derived based on clean lake studies, in response to a state law requiring the criteria, in the 1990's.
  - Initial criteria generally based on a reference approach.

Georgia Lake Nutrient Standards					
	Chl-a (µg/L) *avg monthly photic zone composites Apr-Oct shall not exceed >1:5 yrs*	**TN (mg/L)** *Not to exceed in photic zone*	**TP (lbs / acre-ft)** *Shall not exceed*	**Loadings (TP lbs/yr)** *Shall not exceed*	**Adopt / Revise**
West Point	24 / 22	4.0	2.4	11k, 14k, 1400k	1995 / 2014
Walter F. George	18 / 15	3.0	2.4	2000k	1997
Jackson	20	4.0	5.5	179k, 116k, 55k, 7k	1997
Allatoona	10 / 12 / 10 / 15 / 14	4.0	1.3	340k, 42k, 38k, 12.5k	2000 / 2012
Lanier	5 / 6 / 7 / 10 / 10	4.0	0.25	178k, 118k, 14.4k	2000 / 2014
Carters	10 / 10	4.0	0.46	151.5k, 16k (tribs), 172.5k (whole lake)	2002 / 2014
Oconee & Sinclair	TBD	TBD	TBD	TBD	2015?

Source: http://rules.sos.state.ga.us/docs/391/3/6/03.pdf

South Carolina

- Chlorophyll *a*, TP, and TN criteria concentrations vary by ecoregion and represent instantaneous shall not exceed values.

Blue Ridge Mountains	Piedmont and Southeastern Plains	Middle Atlantic Coastal Plains
Chlorophyll *a* - 10 µg/L	Chlorophyll *a* - 40 µg/L	Chlorophyll *a* - 40 µg/L
TP – 0.02 mg/L	TP – 0.06 mg/L	TP – 0.09 mg/L
TN – 0.35 mg/L	TP – 1.50 mg/L	TP – 1.50 mg/L

- Applicable to all portions of the lake area (lake area means area when measured at full pool elevation).
- Criteria were derived using an all lakes percentile distribution approach.

Tennessee

- Fish and Aquatic Life Use:
  - The waters shall not contain nutrients in concentrations that stimulate aquatic plant and/or algae growth to the extent that aquatic habitat is substantially reduced and/or the biological integrity fails to meet regional goals. Additionally, the quality of downstream waters shall not be detrimentally affected.
    Interpretation of this provision may be made using the document Development of Regionally-based Interpretations of Tennessee's Narrative Nutrient Criterion and/or scientifically defensible methods.
- Similar narrative language is also included within the recreation use.
- Based on TDEC's analysis, the State Methodology recommended the use of the 90th percentiles of the State subecoregion databases for total phosphorus and "nitrate plus nitrite" as the appropriate levels for implementation of the criterion for free-flowing streams in the State.

Tennessee

- The State’s process in developing the methodology can generally be described as follows:
  - (1) analyzed the relationships between other data and nutrients,
  - (2) compared databases from one subecoregion to others,
  - (3) compared biological health and ambient nutrient concentrations using a survey of randomly selected monitoring stations in the Inner Nashville Basin,
  - (4) compared the 75th percentile values of the datasets to the 25th percentile values of EPA ‘s National Nutrient databases, and
  - (5) compared the 75th and 90th percentile values for the database for subecoregion 71i to data randomly collected at sampling sites in this subecoregion in order to compare the accuracy of these two percentiles in projecting use impairment decisions using the nutrient data.

Questions?

A Critical Examination of Nutrient Criteria Development using Weight of Evidence/Stressor-Response Methods

NC Science Advisory Council

William T. Hall, Hall & Associates
Washington, D.C.

WHAT ARE CRITERIA?
NATIONAL GUIDELINES PRINCIPLES

- **Established at Level "Necessary to Protect Uses"**
- Ensure Use Protection with Small Probability of Considerable Over/Under-Protection
- Must Be Consistent With Sound Scientific Evidence-Demonstrated Dose/Response
- Must Account for Major Factors Influencing Pollutant Impact
- Confounded Studies Should Not Be Used for Criteria Derivation (or confounding factors need to be addressed)

Numeric Nutrient Criteria Case Studies

- Use of Weight of Evidence/Stressor-Response Evaluation to Develop Numeric Nutrient Criteria
- Streams
  - Southeast Pennsylvania
  - Jackson River, VA
  - Colorado WQS
  - Alternative Approaches
- Lakes
  - Florida
  - Minnesota
- Estuaries
  - Great Bay

Weight of Evidence/ Stressor-Response

- *Weight of Evidence*
  - *No definition in Office of Water guidance*
  - *EPA Guidelines from Integrated Risk Information System (IRIS)*
    - All information bearing on the subject, whether indicative of potential concern or not, must be evaluated. Whatever evidence may exist from humans must also be factored into the assessment.
- *Stressor-Response*
  - *Regression analysis and verification procedures*
    - USEPA. 2010. Using Stressor-response Relationships to Derive Numeric Nutrient Criteria. United States Environmental Protection Agency, Office of Water, Washington, DC. EPA-820-S-10-001.

SAB Comments on Stressor-Response Guidance (2010)

- Approach Not Scientifically Defensible Without Cause/Effect Demonstration
- Need to Confirm "Impairment" Thresholds Are Biologically Significant
- Need to Account for Factors Influencing Nutrient Dynamics and Invertebrate Metrics
- Loading Approach May Be Better Than Concentration
- Failure to Consider Site-Specific Data May Yield Inappropriate Results

CAUSE AND EFFECT DEMONSTRATION NECESSARY

2010 SAB Report

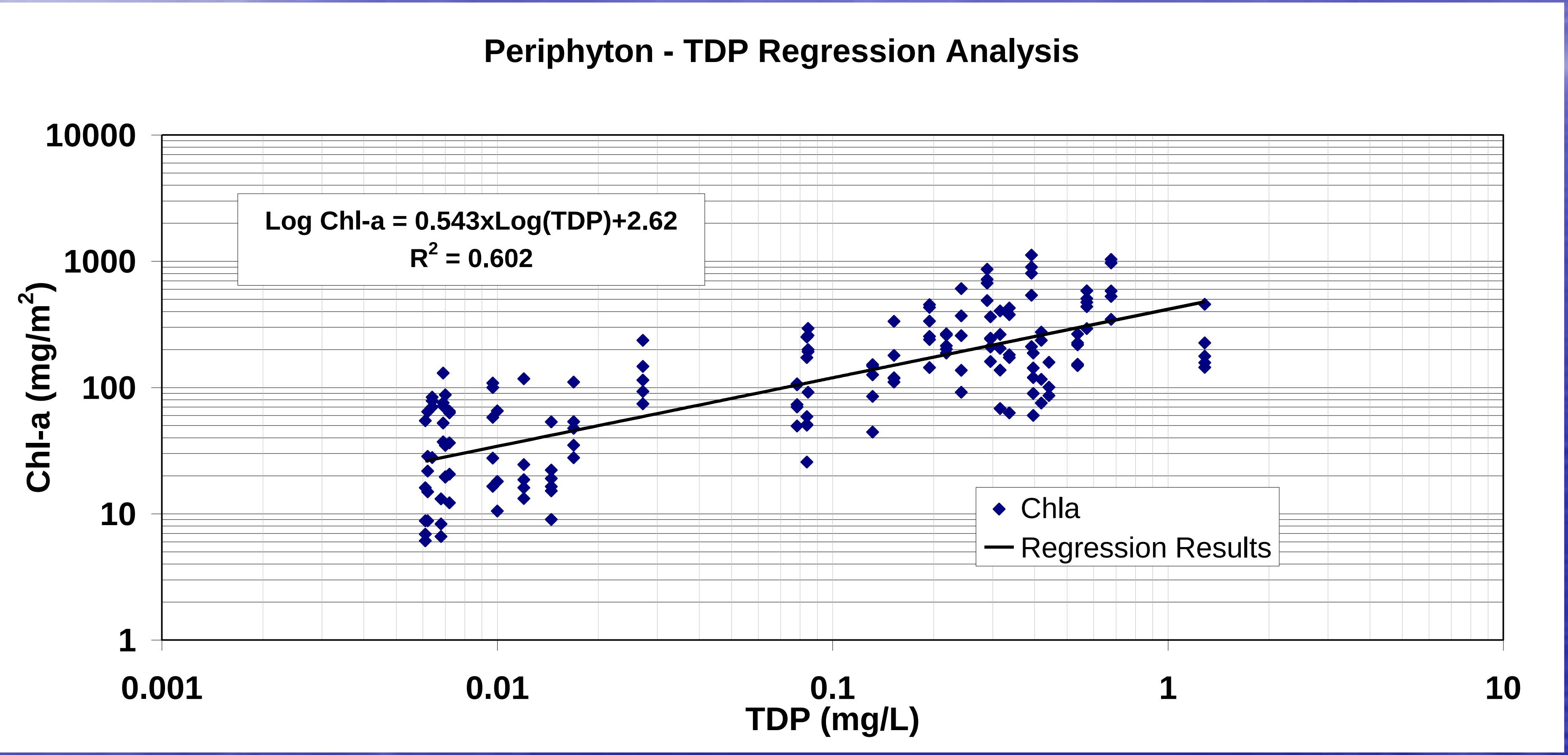
- [T]he final document should clearly state that statistical associations may not be biologically relevant and do not prove cause and effect. (at 2) ***Without a mechanistic understanding and a clear causative link*** between nutrient levels and impairment, there is ***no assurance*** that managing for particular nutrient levels ***will lead to the desired outcome***. (at 4); The Guidance needs to clearly indicate that the empirical stressor-response approach ***does not result in cause-effect relationships***; it only indicates correlations that need to be explored further. (at 39)

- ***Large uncertainties*** in the stressor-response relationship and the fact that causation is neither directly addressed nor documented indicate that the ***stressor-response approach using empirical data cannot be used in isolation to develop technically defensible water quality criteria*** that will "protect against environmental degradation by nutrients." (at 37; see also 22)

Case Studies

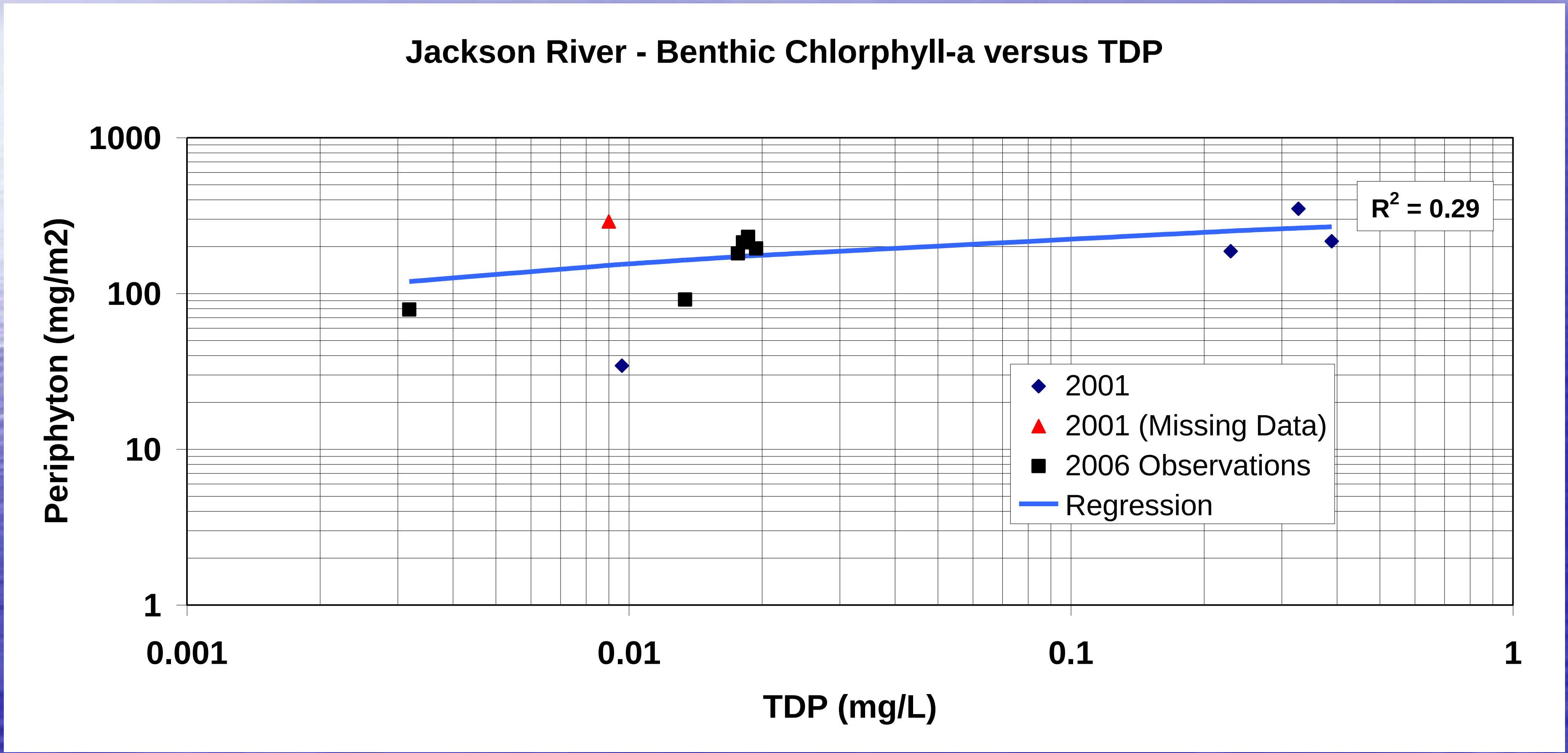
Good and Bad

JACKSON RIVER TMDL (2006)



Impairment: D.O., aquatic life; selected 100 mg Chl-a/m^2 target
TMDL established TDP endpoint of 38 µg/L to meet 80 mg Chl-a/m^2

Jackson River Supplemental Data (2006)



No reduction in periphyton with order of magnitude TDP reduction

User Perception Survey
(2009)

Periphyton growth on the Clark Fork River; TP = 18 µg/L (median) in all locations

PERIPHYTON: NUTRIENT RELATIONSHIP (EPA EXPERTS)

Dodds (2006)

Attached algae might be able to attain impressive bio-mass in nutrient-poor water because periphyton can use the small amounts of nutrients that continuously flow by.

Paul and Zheng (2007)

The highest algal biomass [in PA targeted watersheds] occurred at sites where TP concentrations were relatively low (14 – 35 µg/L). **[Upstream of POTWs]**

Northern Piedmont Ecoregion of Pennsylvania WOE Evaluation (USEPA, 2007)

Table 7 – Summary of candidate endpoints for each of the analytical approaches discussed.

Approach		TP Endpoint (µg/L)
Reference Approach		**2-37**
	Reference Site 75th Percentile	16-17
	All Sites 25th Percentile	17
	Modeled Reference Expectation	2-37
Stressor-Response		**36-64**
	Conditional Probability – EPT taxa	38
	Conditional Probability - % Clingers	39
	Conditional Probability - % Urban Intolerant	64
	Conditional Probability - Diatoms TSI	36
Other Literature		**13-100**
	USEPA Recommended Regional Criteria	37
	USEPA Regional Criteria Approach – Local Data	40-51
	Algal Growth Saturation	25-50
	Nationwide Meta-Study TP-Chlorophyll	21-60
	USGS Regional Reference Study	20
	USGS National Nutrient Criteria Study	13-20
	New England Nutrient Criteria Study	40
	Virginia Nutrient Criteria Study	50
	New Jersey TDI	25-50
	Delaware Criteria	50-100

Is this evidence appropriate? Where is the contrary evidence?

CONDITIONAL PROBABILITY

EPT Taxa; Change Point = 38 ug/L

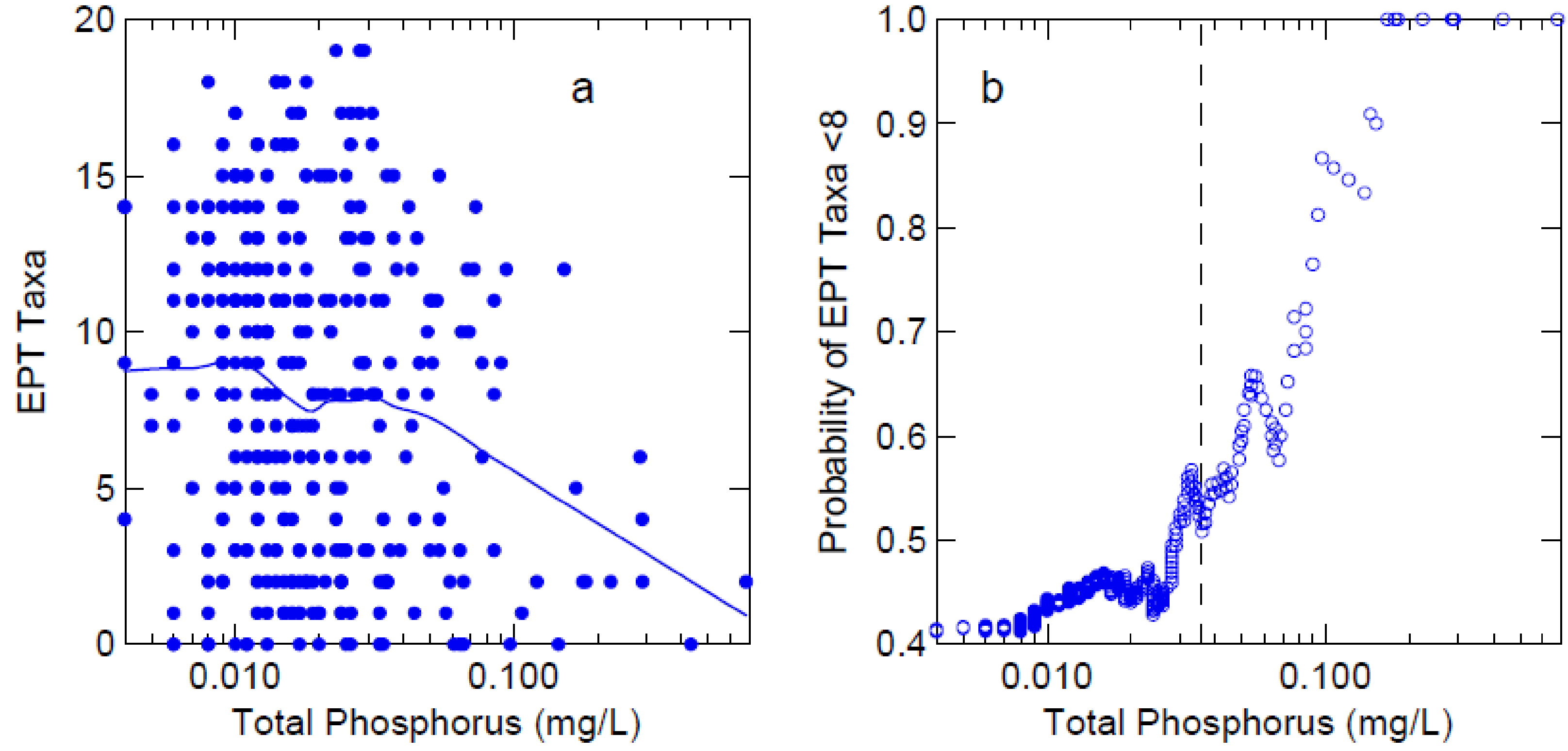


Figure 6 - Response of EPT taxa metric to the phosphorus gradient in the Northern Piedmont Ecoregion. Figure on the right shows the conditional probability of having fewer than 8 EPT taxa as TP concentrations increase.

Conditional Probability Analysis Based On MBSS (Maryland) Data But Other Data Also Available

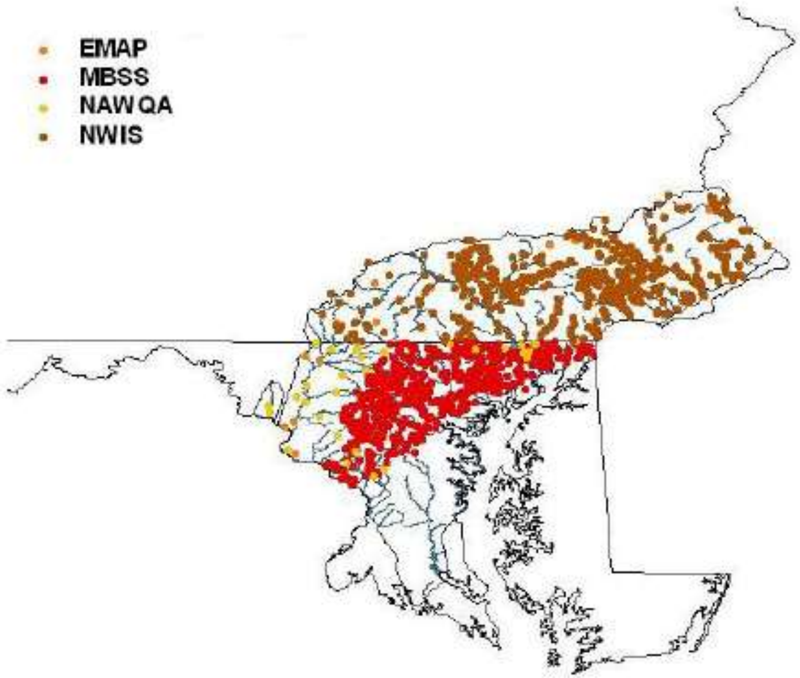


Figure 2 – Map of the sample sites used in the development of nutrient endpoints using the distribution based approach in this study, labeled by agency affiliation.

FOLLOW-UP ANALYSIS
(USEPA, 2012)

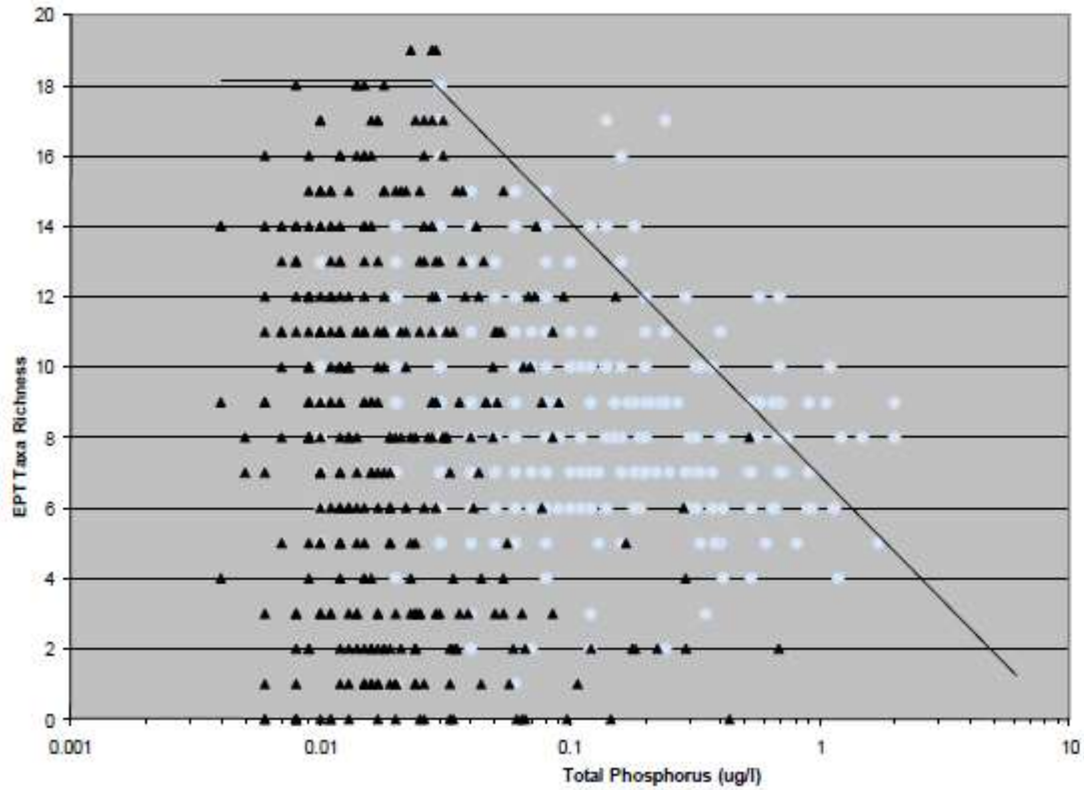
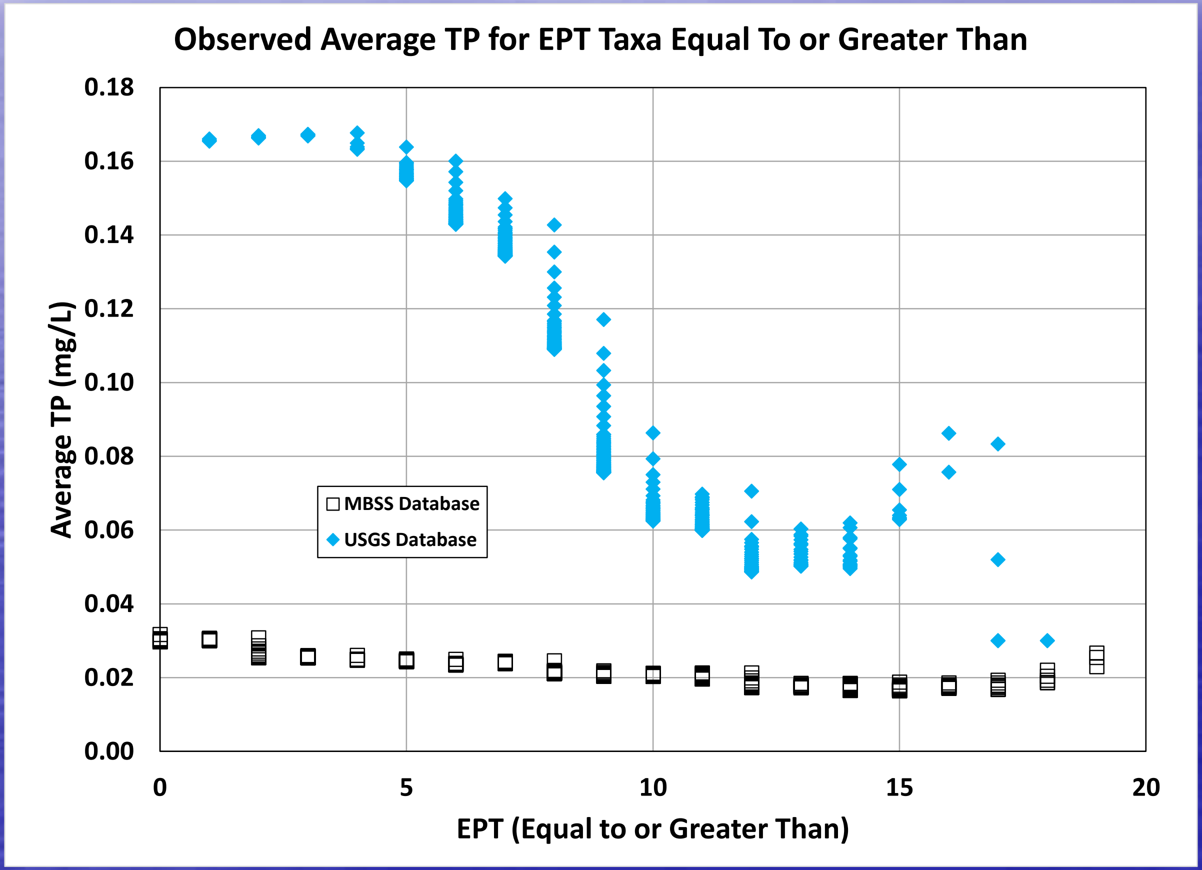


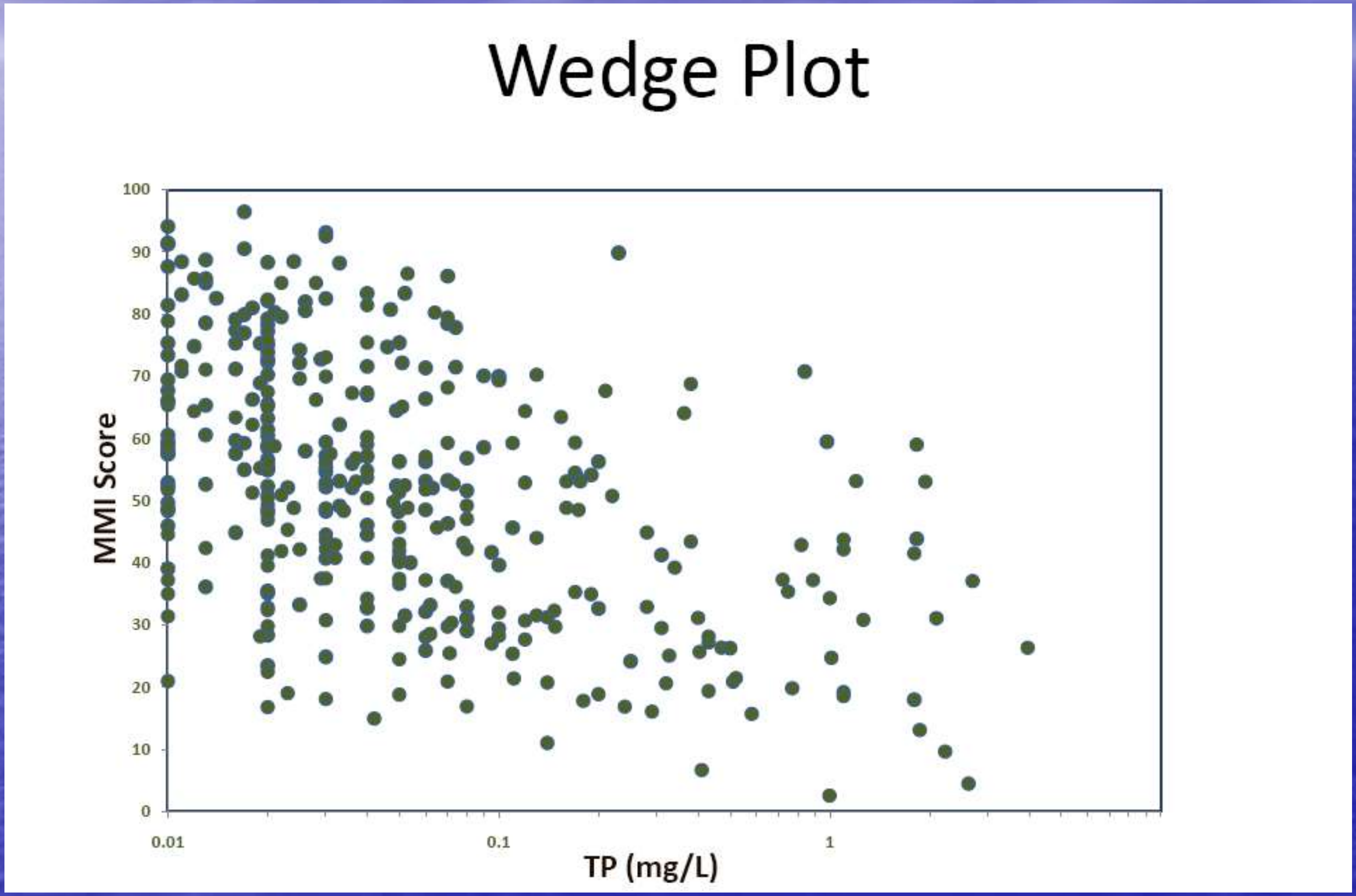
Figure 13 – Plot of TP versus EPT taxa richness for the MBSS (black triangle) and USGS Chester County datasets. The black lines indicate the locations of the approximate wedge shaped relationship between invertebrate response and TP concentration. The outer decline in EPT richness begins at a concentration of approximately 30-40 ug/L TP.

Wedge Plot indicates cause and effect. (Or does it?)

Comparison of MBSS Database to USGS Chester County, PA

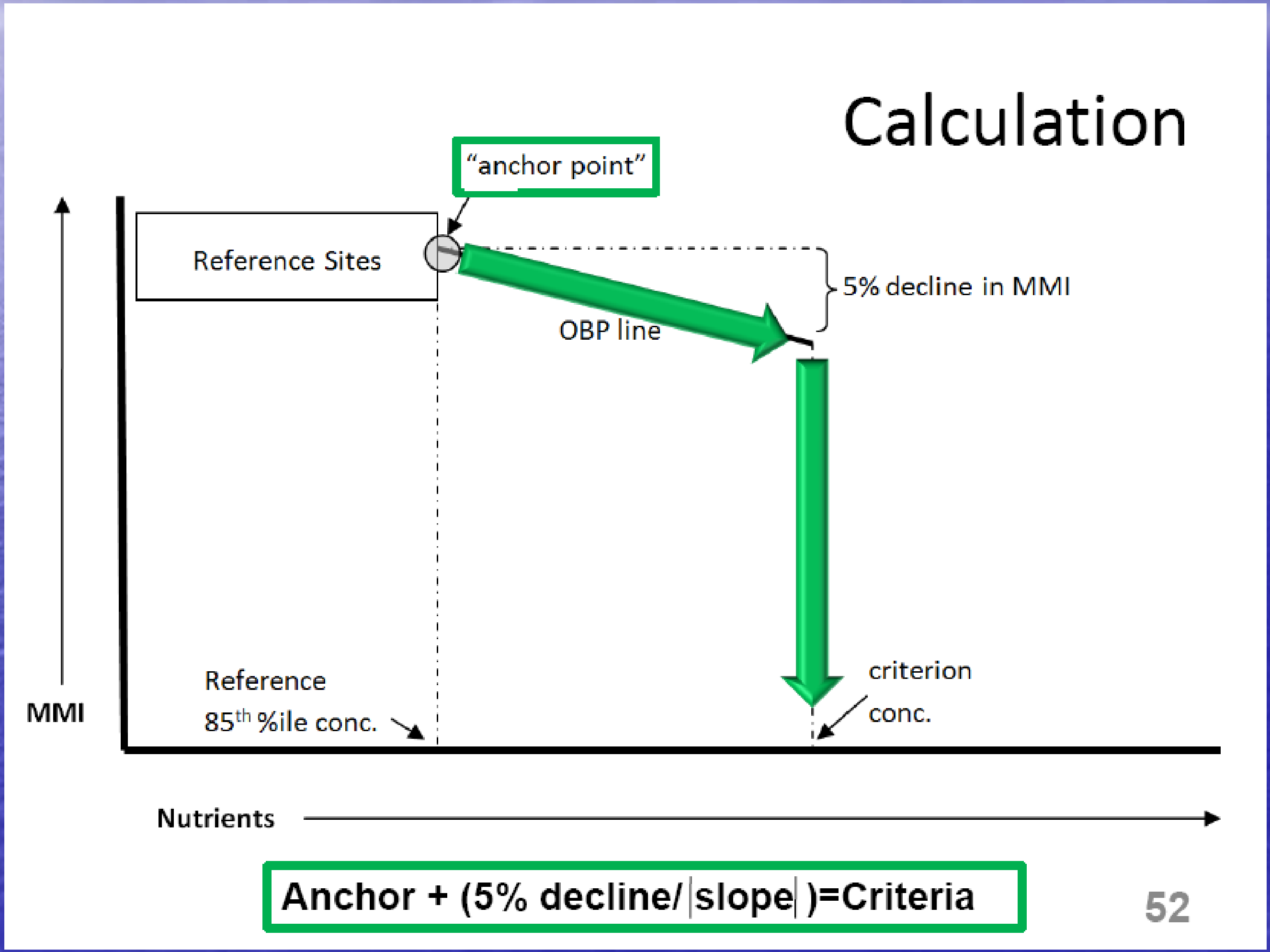


COLORADO STREAM STANDARDS (2011)

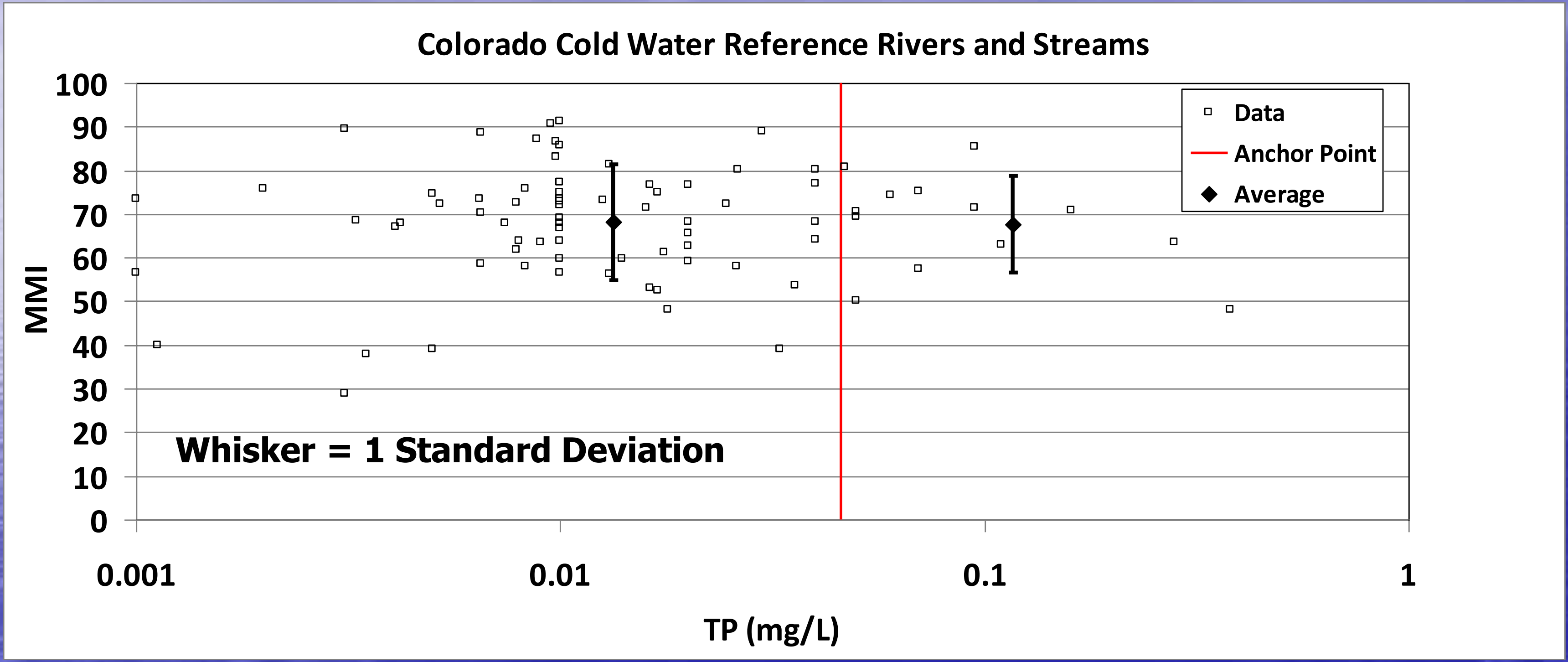


Wedge demonstrates cause and effect?

Colorado Stream NNC Development



REFERENCE STREAMS CONFIRM NO TP IMPACT ON MMI



MMI for reference streams below Anchor Point not significantly different from results for references streams above Anchor Point (P=0.92).

Should conclude that TP is not a stressor for MMI.

General Conclusions for Streams

- Periphyton control is nearly impossible if other conditions are favorable for growth.
- Relationship between macroinvertebrate metric and nutrient concentration difficult to establish.

Alternative Approach to Streams

- Form of Criterion
  - Chlorophyll-a, Transparency, D.O. (causes impairment)
- Florida
  - Response based (no nutrient limits if macro-invertebrates not impaired)
- Ohio TAG
  - Response based
    - Aquatic Life Use Status (Fish, Macroinvertebrates)
    - Algal growth, Dissolved Oxygen swing
  - Adaptive Management before nutrient limits
- Minnesota
  - Treat Periphyton case by case

Numeric Nutrient Criteria for Florida Lakes

Table C–17—EPA's Numeric Criteria for Florida Lakes

Lake color[a] and alkalinity	Chl-a (mg/L)[b] *	TN (mg/L)	TP (mg/L)
Colored Lakes[c]	0.020	1.27 [1.27–2.23]	0.05 [0.05–0.16]
Clear Lakes, High Alkalinity[d]	0.020	1.05 [1.05–1.91]	0.03 [0.03–0.09]
Clear Lakes, Low Alkalinity[e]	0.006	0.51 [0.51–0.93]	0.01 [0.01–0.03]

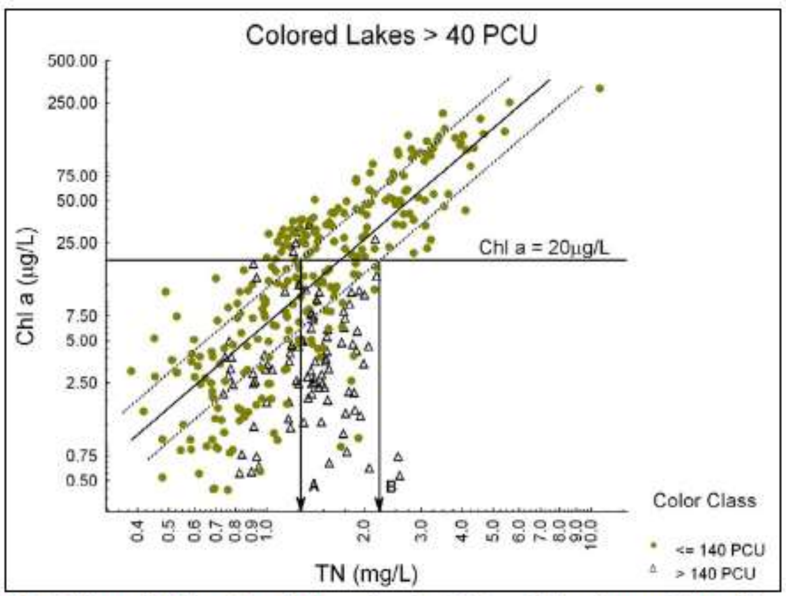


Figure 2-28. Chl-a and TN in colored lakes, showing 50% prediction interval (dotted lines) on each side of regression line.
Note that symbols and data as in Figure 2-23. Horizontal line: chl-a criterion (20 µg/L). A indicates TN concentration corresponding to 25% probability of chl-a exceeding 20 µg/L; B indicates concentration corresponding to 75% probability of exceedance.

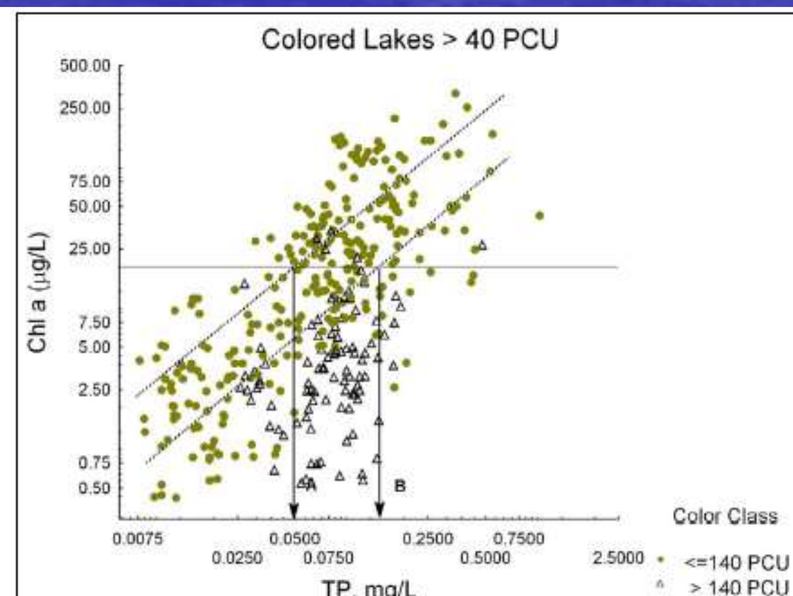


Figure 2-29. Chl-a and TP in colored lakes, showing 50% prediction interval (dotted lines).
Note that symbols and data as in Figure 2-23. Horizontal line: chl-a criterion (20 µg/L). A indicates TN concentration corresponding to 25% probability of chl a exceeding 20 µg/L; B indicates concentration corresponding to 75% probability of exceedance.

TN OR NOT TN, THAT IS THE QUESTION

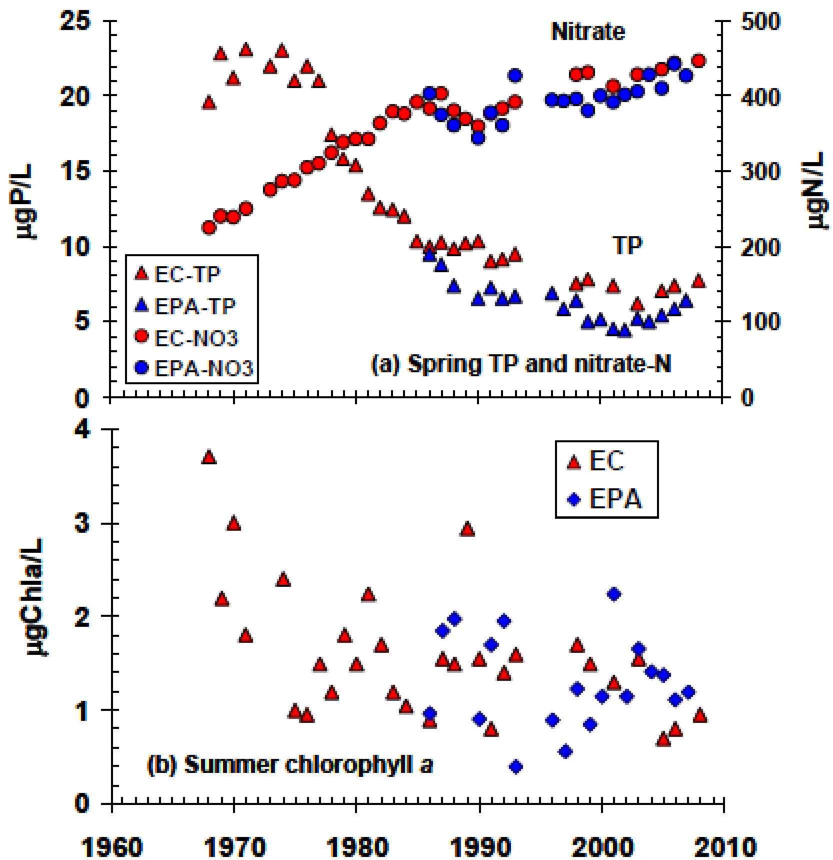


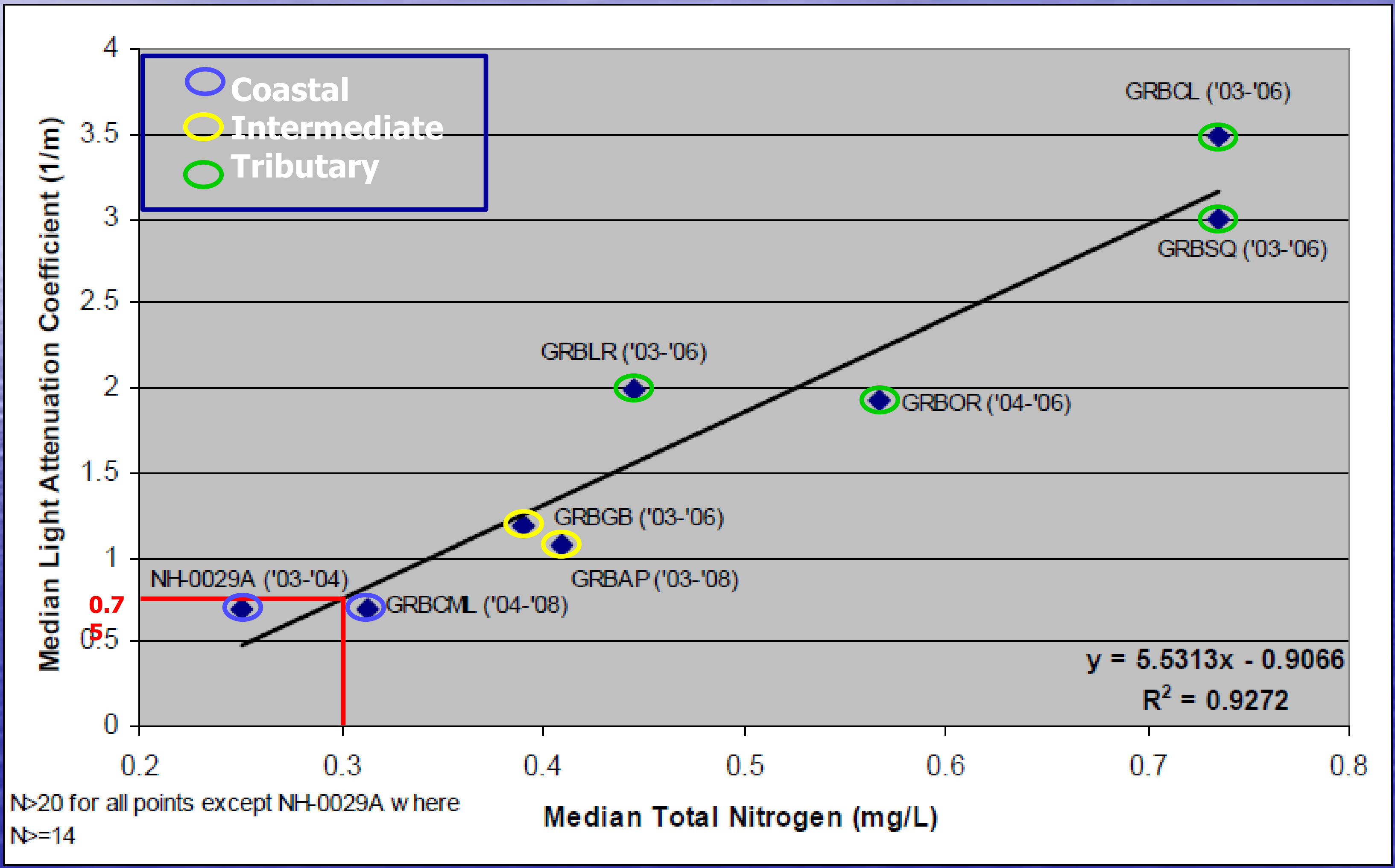
Figure 2 (a) Plot of total phosphorus (TP in µgP/L) and nitrate nitrogen (TN in µgN/L) and (b) summer chlorophyll a (µgChla/L) versus time for the offshore waters of Lake Ontario. Data collected by EPA and Environment Canada are represented by blue and red points, respectively.

MINNESOTA LAKE STANDARDS

- Adopted lake WQS in 2006 (chl a; TP; secchi)
- Multiple ecoregions; multiple lake types
  - Reservoirs vs. natural lakes
  - Shallow vs. deep lakes
- Nutrient criteria apply ONLY IF response variable is exceeded

Relationship between Light Attenuation Coefficient and TN at Trend Stations

(New Hampshire DES, 2009)



RECAP

- Weight of Evidence requires real evidence on both sides
- Simplistic (Stressor-Response) Methods have limited applicability
- Complex Systems (streams, lakes, estuaries) likely benefit from response-based approach

FOR MORE INFORMATION

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North Carolina Nutrient Science Advisory Council

Case Studies on Water-Body Specific Numeric Nutrient Criteria

July 21 | 2015

Outline

- Briefly touch on drivers
- Identify the major variations of approaches
- Describe three case studies
  - Lake/reservoir
  - River/stream
  - Estuary

Tension between simplicity and accuracy

Default concentration-based NNC

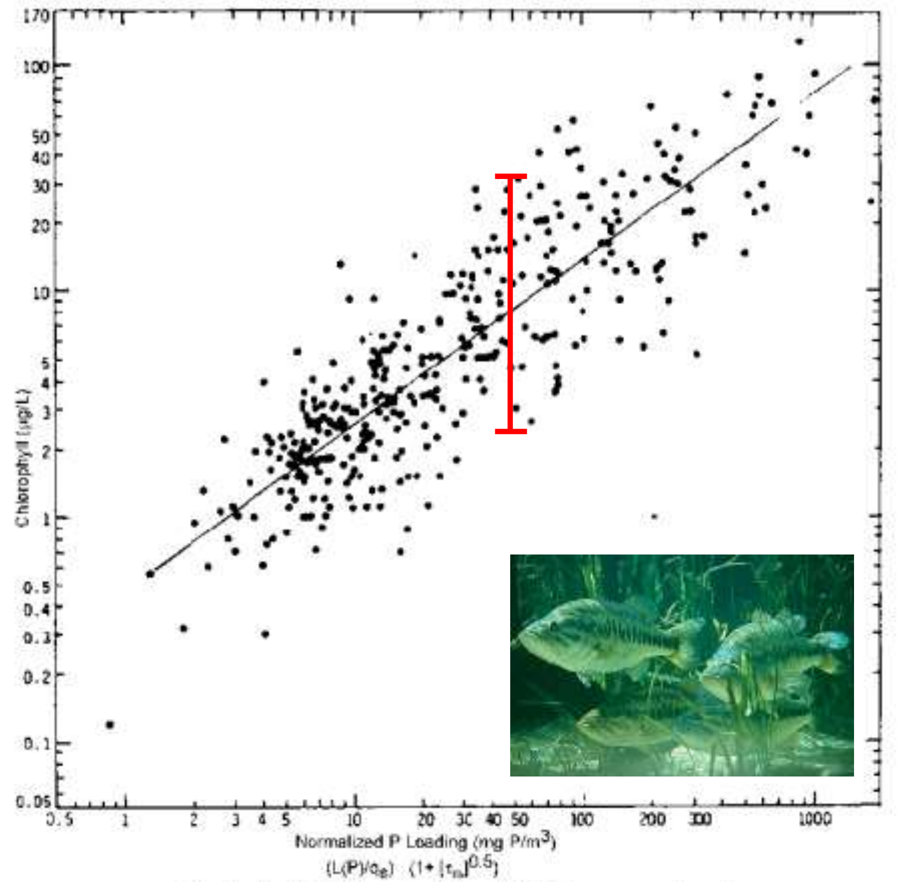
Regulatory Simplicity

Technical Accuracy

More predictive, water-body specific approaches

Major drivers of water-body specific approaches

- Variability between water bodies.
  - Nutrient-response linkages
  - Response-use linkages
- Attainability and diminishing returns.
- All underlain by the high costs of nutrient controls.



Updated Vollenweider-OECD normalized P loading/chlorophyll response relationship

Recall the broad definition of nutrient criteria

North Carolina Nutrient Criteria Development Plan

June 2014

Submitted to the

United States Environmental Protection Agency - Region 4

by the

North Carolina Department of Environment and Natural Resources

Division of Water Resources

Raleigh, North Carolina

- Concentrations
  - Nutrients
  - Response variables

  OR
- Loads **OR**
- Translator mechanisms

Common elements of successful water body-specific approaches

- Response variables that indicate use attainment for the water body.
  - Human health
  - Ecological
  - Aesthetic
- Some way to relate nutrients to those response variables

Variable elements of water body-specific approaches (not mutually exclusive)

- Bioconfirmation / weight of evidence
- Empirical modeling
- Mechanistic modeling
- Technology-based considerations for management
- Attainability / cost-benefit considerations
- Adaptive management

Case Study #1: Integrated Criteria for Arizona Lakes/Reservoirs

- Arizona's "old" nutrient criteria for lakes reservoirs:
  - Narrative criteria
  - NNC based on historical conditions
- In 2004-05, Arizona embarked on process to revise nutrient criteria
- Goals
  - Strengthen criteria use-linkages
  - Consider differences between lake/reservoir types

Literature review of nutrient, CHLa, and secchi depth targets by use

- Recreation/aesthetics
- Coldwater fisheries
- Coolwater fisheries
- Warmwater fisheries
- Drinking water

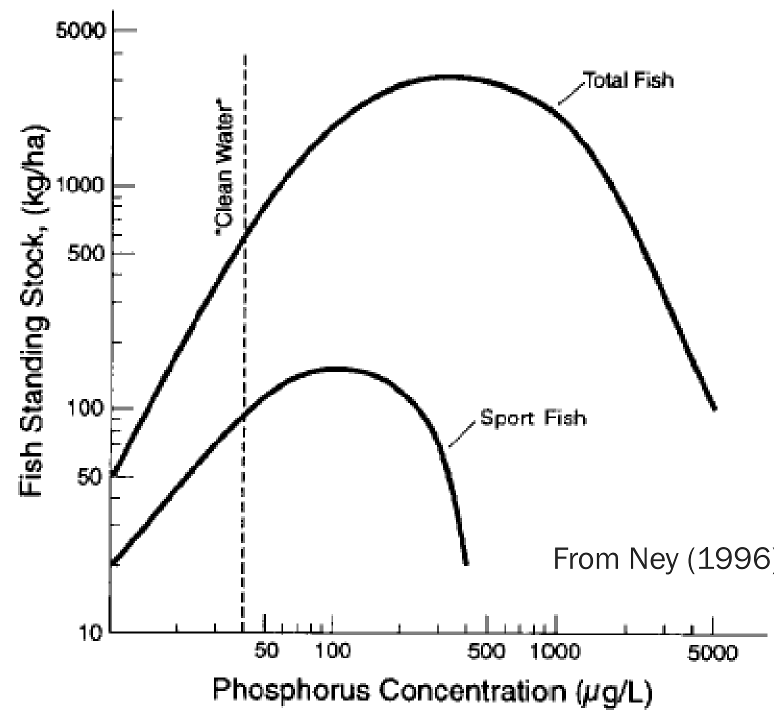
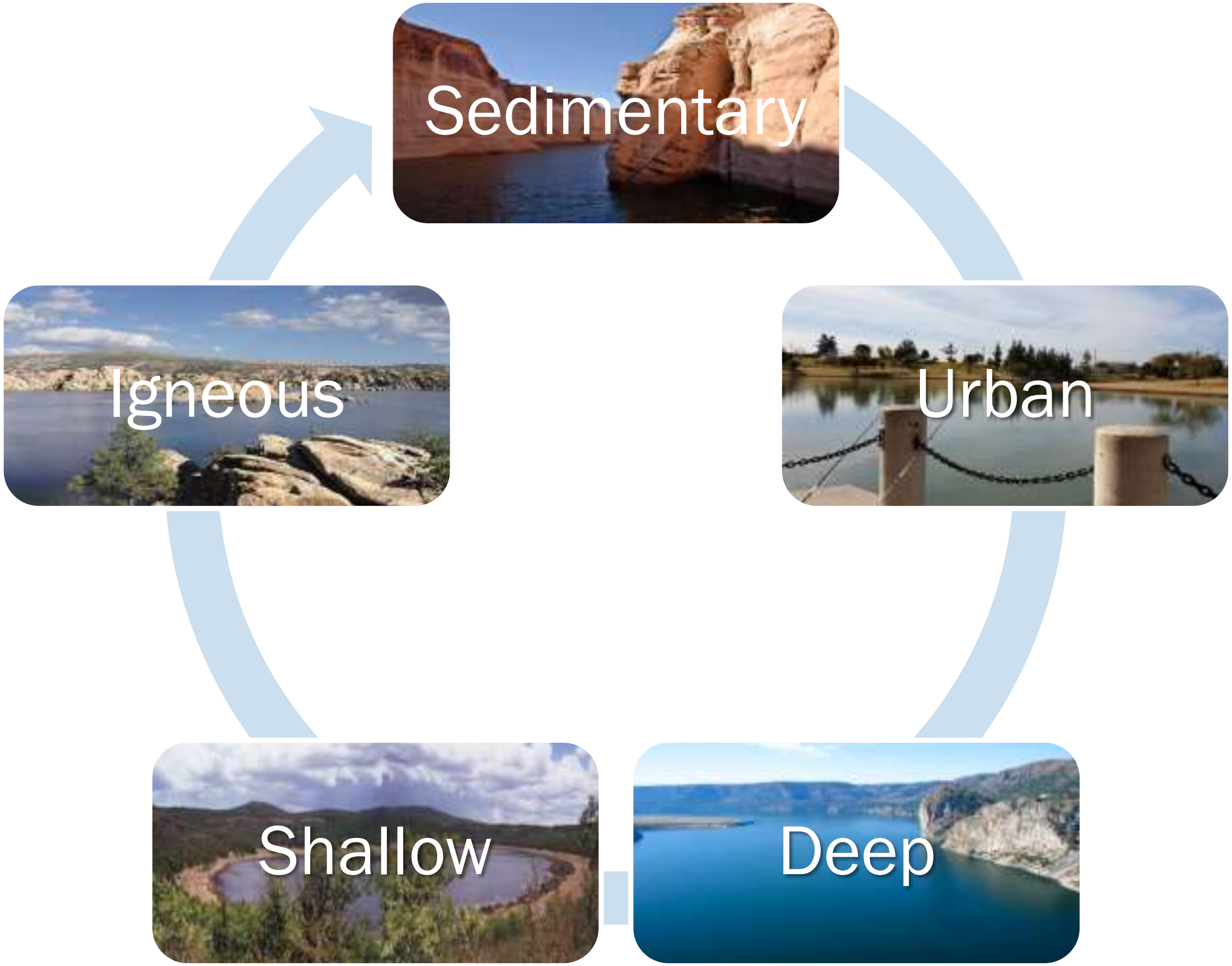


FIGURE 3.—Generalized relation of total and sport fish standing stock to total phosphorus concentration and trophic status in temperate-latitude reservoirs. Standing stock values are representative of southeastern U.S. reservoirs to 100 µg/L total phosphorus. Standing stocks at higher phosphorus concentrations are hypothetical.

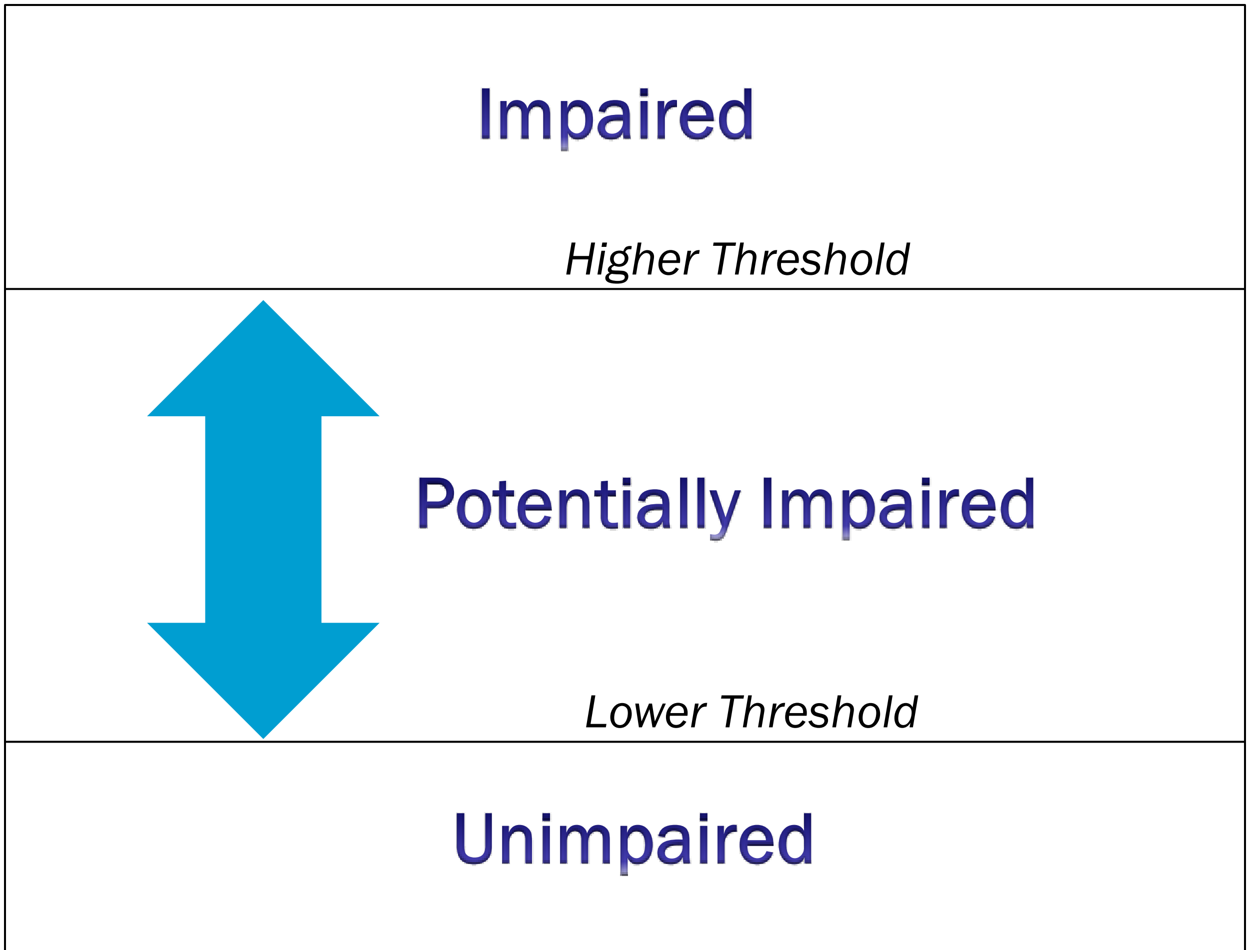
Arizona Trophic Index

Trophic State	TSI	Chlor-*a* (*u*g/L)	Secchi (m)	Total-P mg/L)	TKN (mg/L)
Oligotrophy	**0**	0.3	5.2	0.013	0.3
	10	0.6	4.0	0.019	0.3
	20	1.2	3.1	0.027	0.4
Mesotrophy	**30**	2.5	2.4	0.037	0.6
	40	5.0	1.8	0.052	0.7
Eutrophy	**50**	10	1.4	0.074	1.0
	60	20	1.1	0.103	1.2
	70	40	0.8	0.145	1.6
Hypereutrophy	**80**	81	0.6	0.203	2.1
	90	161	0.5	0.285	2.7
	100	323	0.4	0.400	3.5

Categorizing Reservoirs by Characteristics that Affect Nutrient Loading & Responses



DEQ concluded that target ranges were more scientifically defensible than single values



Ultimately created a matrix of numeric targets

<table>
<tr><th colspan="11">NUMERIC TARGETS FOR LAKES AND RESERVOIRS</th></tr>
<tr><th>Designated Use</th><th>Lake Category</th><th>Chl-*a* (µg/L)</th><th>Secchi Depth (m)</th><th>Total Phosphorus (µg/L)</th><th>Total Nitrogen (mg/L)</th><th>Total Kjehldal Nitrogen (TKN) (mg/L)</th><th>Blue-Green Algae (per ml)</th><th>Blue-Green Algae (% of total count)</th><th>Dissolved Oxygen (mg/L)</th><th>pH (SU)</th></tr>
<tr><td rowspan="5">FBC and PBC</td><td>Deep</td><td>10-15</td><td>1.5-2.5</td><td>70-90</td><td>1.2-1.4</td><td>1.0-1.1</td><td rowspan="5">20,000</td><td></td><td></td><td rowspan="5">6.5-9.0</td></tr>
<tr><td>Shallow</td><td>10-15</td><td>1.5-2.0</td><td>70-90</td><td>1.2-1.4</td><td>1.0-1.1</td><td></td><td></td></tr>
<tr><td>Igneous</td><td>20-30</td><td>0.5-1.0</td><td>100-125</td><td>1.5-1.7</td><td>1.2-1.4</td><td></td><td></td></tr>
<tr><td>Sedimentary</td><td>20-30</td><td>1.5-2.0</td><td>100-125</td><td>1.5-1.7</td><td>1.2-1.4</td><td></td><td></td></tr>
<tr><td>Urban</td><td>20-30</td><td>0.5-1.0</td><td>100-125</td><td>1.5-1.7</td><td>1.2-1.4</td><td></td><td></td></tr>
<tr><td>A&Wc</td><td>All</td><td>5-15</td><td>1.5-2.0</td><td>50-90</td><td>1.0-1.4</td><td>0.7-1.1</td><td></td><td rowspan="4"><50</td><td>7
(top m)</td><td rowspan="3">6.5-9.0</td></tr>
<tr><td rowspan="2">A&Ww</td><td>All (except urban lakes)</td><td>25-40</td><td>0.8-1.0</td><td>115-140</td><td>1.6-1.8</td><td>1.3-1.6</td><td></td><td rowspan="3">6
(top m)</td></tr>
<tr><td>Urban</td><td>30-50</td><td>0.7-1.0</td><td>125-160</td><td>1.7-1.9</td><td>1.4-1.7</td><td></td></tr>
<tr><td>A&Wedw</td><td>All</td><td>30-50</td><td>0.7-1.0</td><td>125-160</td><td>1.7-1.9</td><td>1.4-1.7</td><td></td><td>6.5-9.0</td></tr>
<tr><td>DWS</td><td>All</td><td>10-20</td><td>0.5-1.5</td><td>70-100</td><td>1.2-1.5</td><td>1.0-1.2</td><td>20,000</td><td></td><td></td><td>5.0-9.0</td></tr>
</table>

Reservoir deemed in attainment if…

1. The mean chlorophyll-*a* concentration is less than the lower value in the target range chlorophyll-*a* for the lake and reservoir category; or

2. The mean chlorophyll-*a* concentration is within the target range for the lake and reservoir category and:
   a. The mean blue green algae count is at or below 20,000 per milliliter, and
   b. The blue green algae count is less than 50 percent of the total algae count, and
   c. There is no evidence of nutrient-related impairments such as:
      i. An exceedance of dissolved oxygen or pH standards;
      ii. A fish kill coincident with a dissolved oxygen or pH exceedance;
      iii. A fish kill or other aquatic organism mortality coincident with algal toxicity;
      iv. Secchi depth is less than the lower value prescribed for the lake and reservoir category;
      v. A nuisance algal bloom is present in the limnetic portion of the lake or reservoir; or
      vi. The concentration of total phosphorous, total nitrogen, or total Kjehldal nitrogen (TKN) is greater than the upper value in the range prescribed for the lake and reservoir category; or

Biggest Differences between Arizona approach and USEPA "Guiding Principles" for Integrated Criteria

"Guiding Principle"

- All parameters should be expressed numerically
- Clear decision framework for waters with mid-range values

Still pressure to derive default NNC for permitting

Arizona Approach

- Includes numeric and narrative components
- Guidance pending...

Other options

- Translators
- Water body-specific targets
- Technology-based considerations
- *Etc.*

Integrated criteria are powerful for assessment, but need guidance for implementation

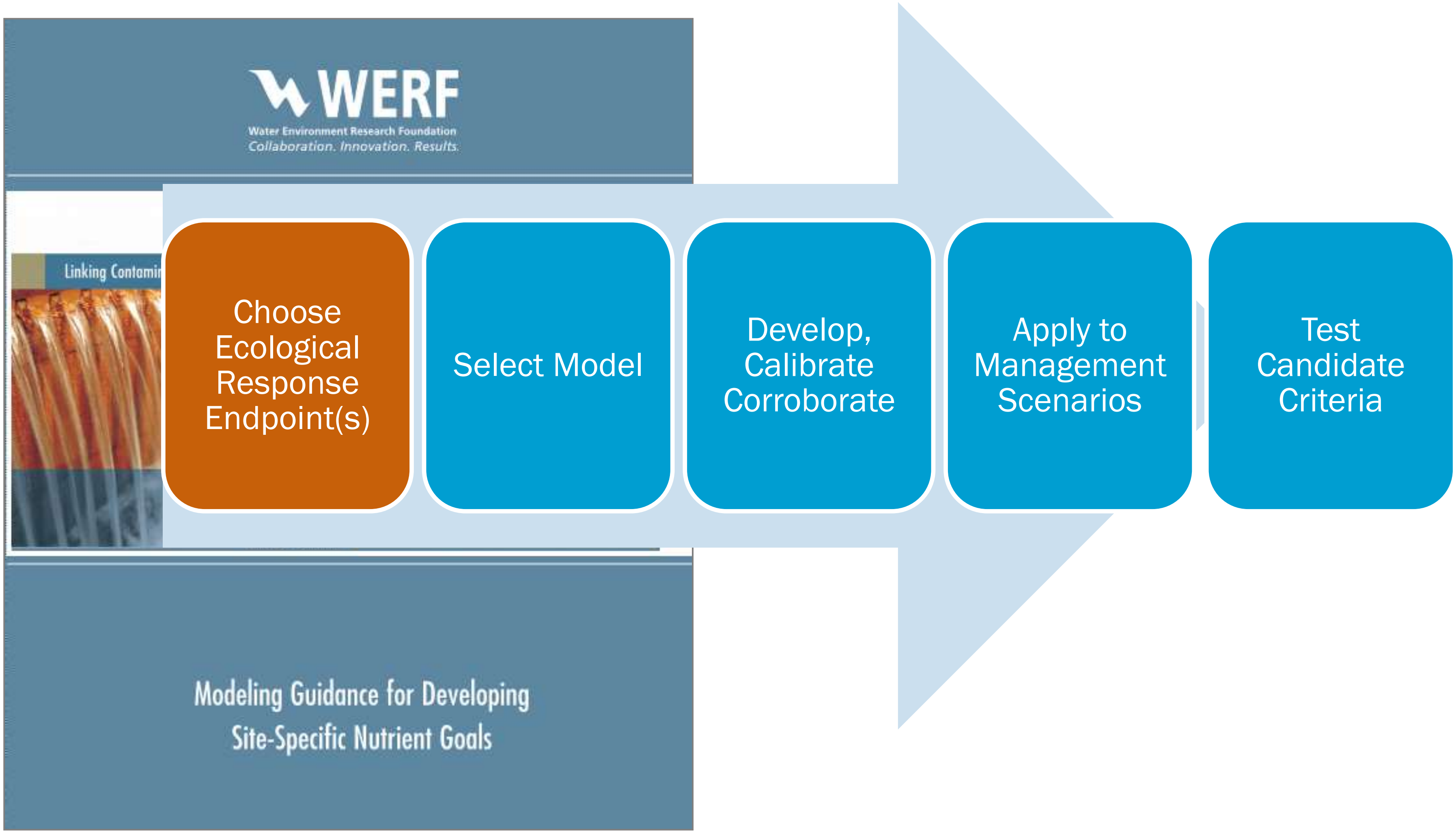
Assessment

- Is the water body attaining designated uses?

Implementation

- To what level should we control nutrients?

Case Study #2: Using a Model to Set Nutrient Goals for a Wadeable Stream



Affected by urban, wastewater, & ag

- Low algae
- Benthics attain

- High algae
- Benthics attain

- High algae
- Benthics attain

- High algae
- Benthics impaired

Default regulatory nutrient targets

Reg. 85 End-of-Pipe Limits

- TP: 1.0 mg/L TP
- TIN 15 mg/L

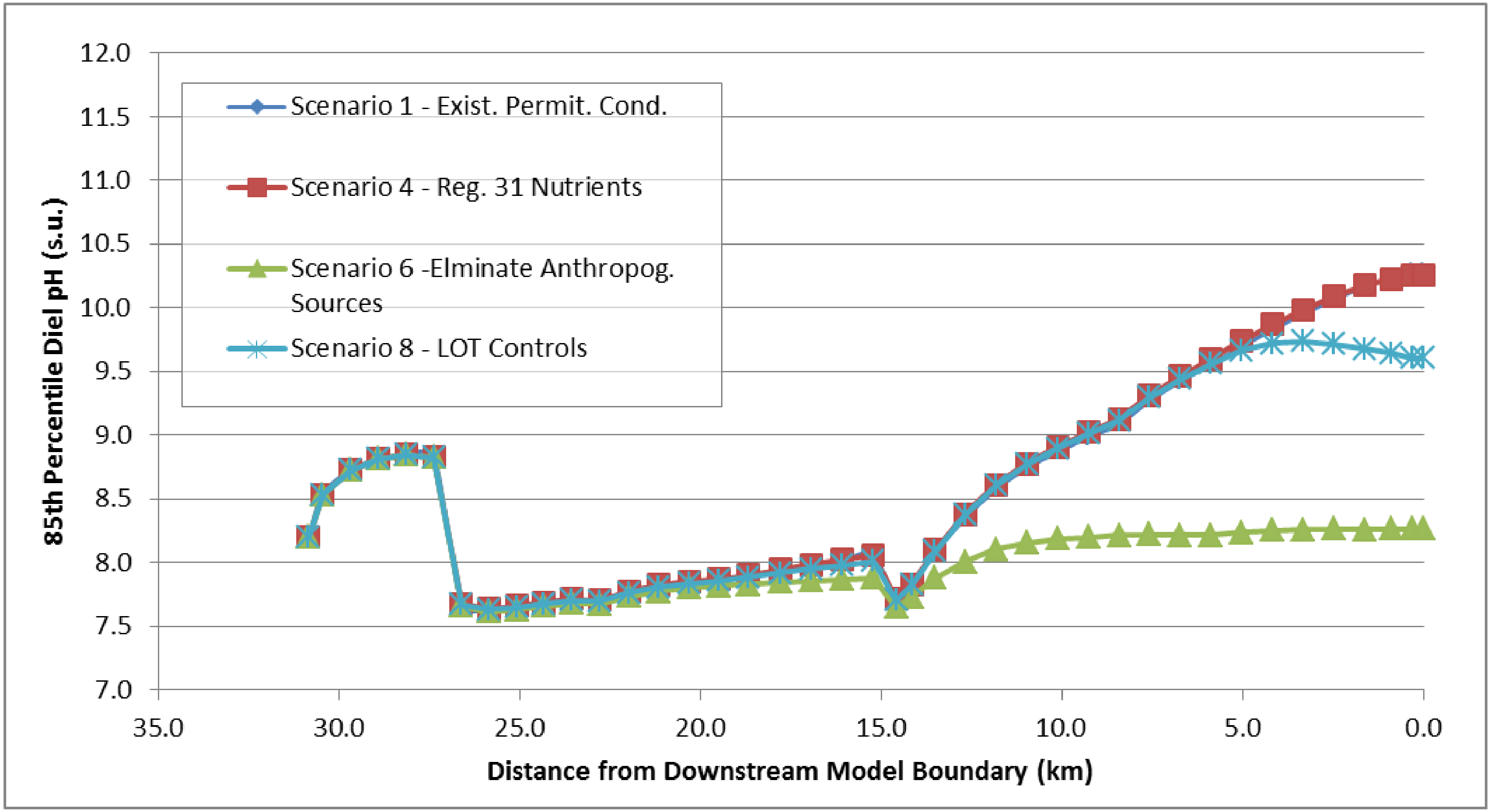
Reg. 31 In-Stream Targets

- TP 0.11 mg/L
- TN 2 mg/L
- CHLA 150 mg/m^2

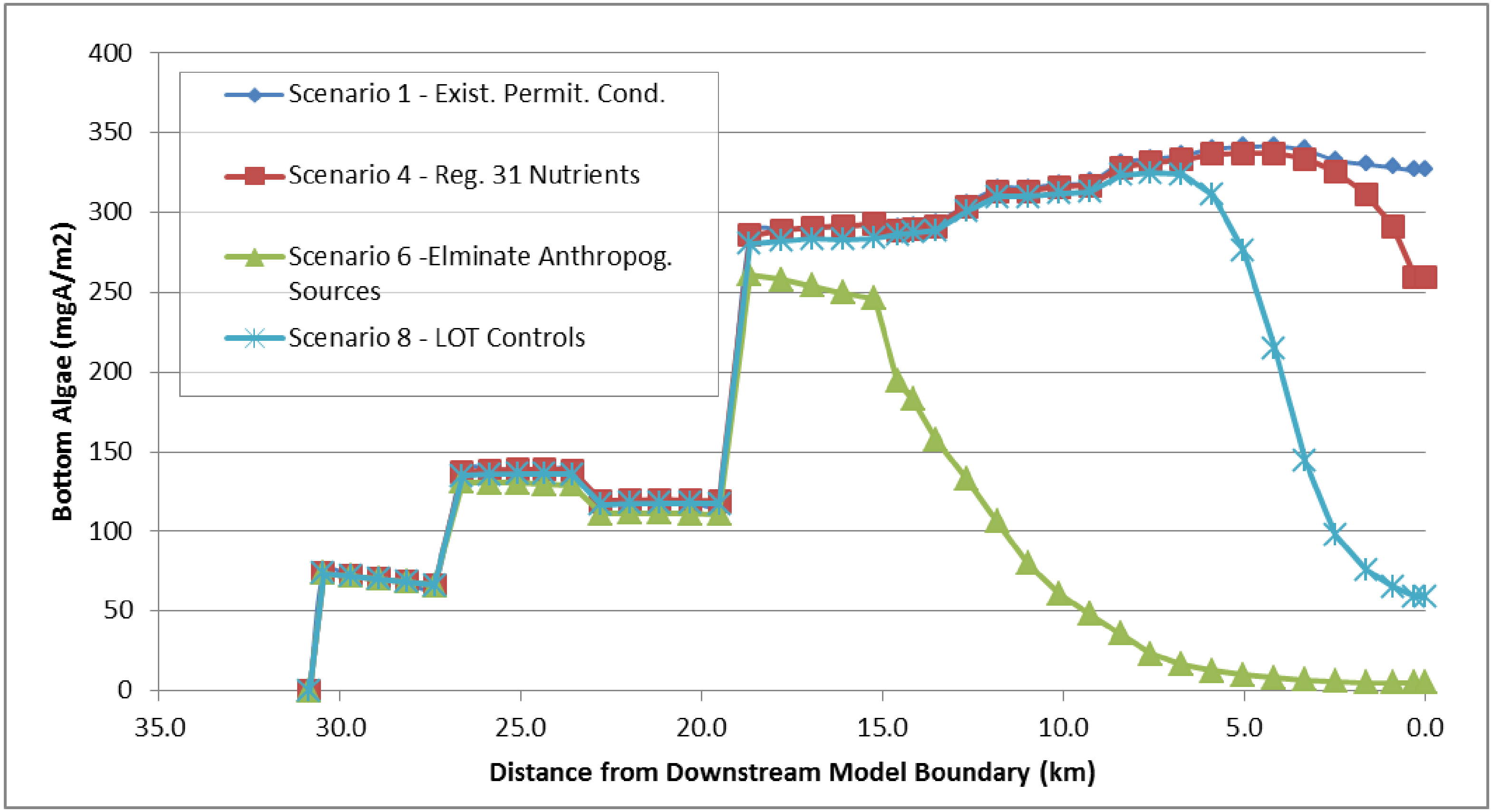
Examples of questions to be addressed for Boulder Creek

- Are these numbers attainable?
- Are these numbers adequate or necessary to protect aquatic life?
- Would alternative goals provide equal or superior protection of aquatic life?

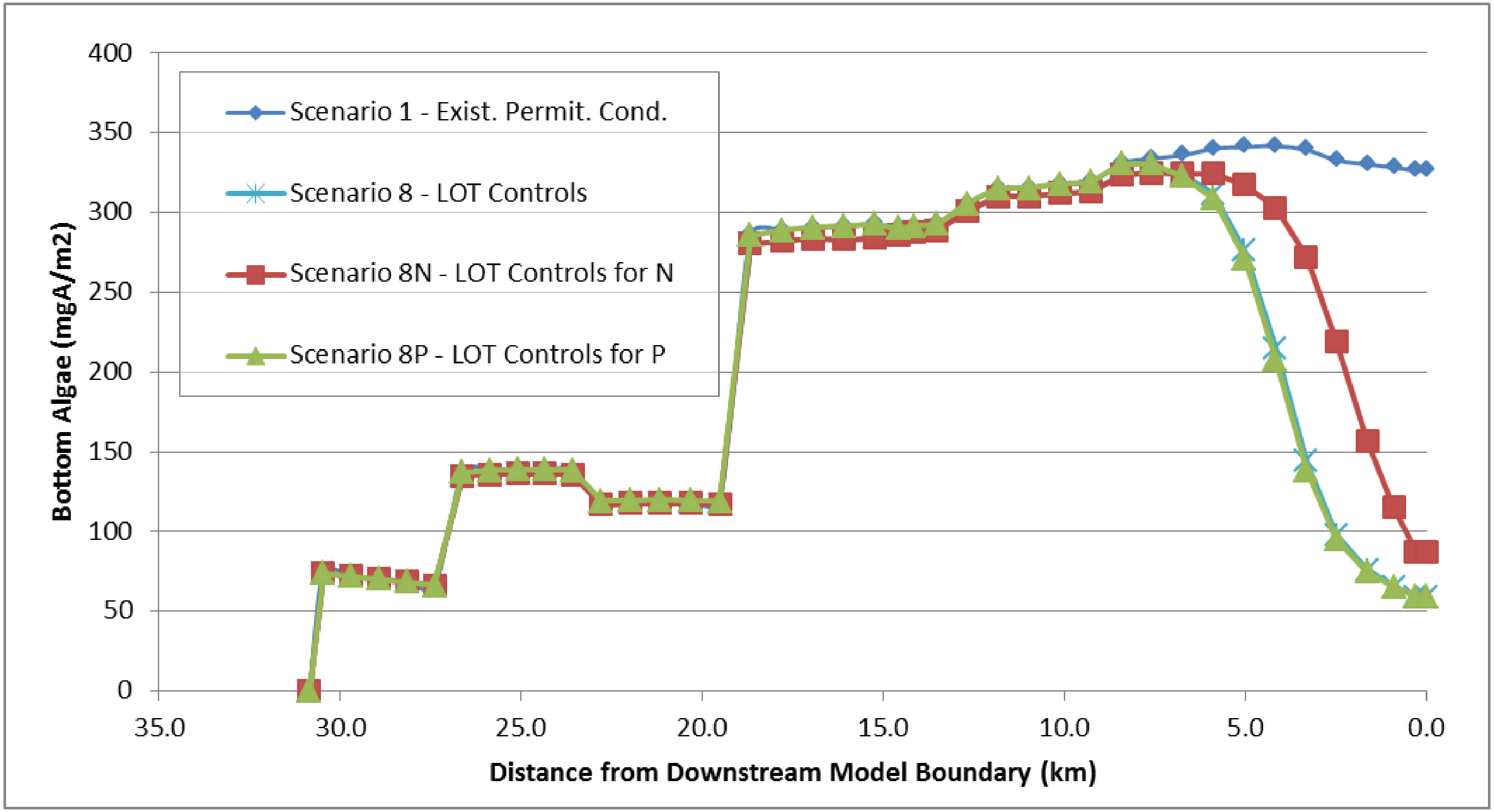
High pH predicted to be stressor to aquatic life



150 mg/m2 predicted to be unattainable even with elimination of all anthropogenic sources

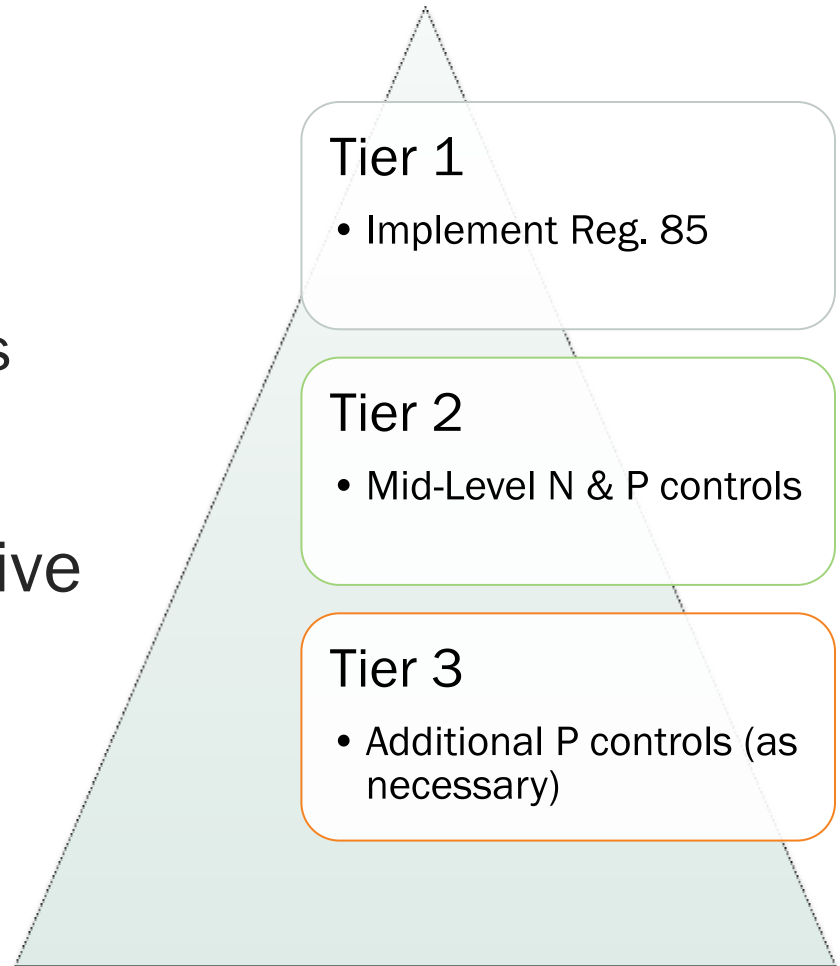


Easier to control algae with P controls

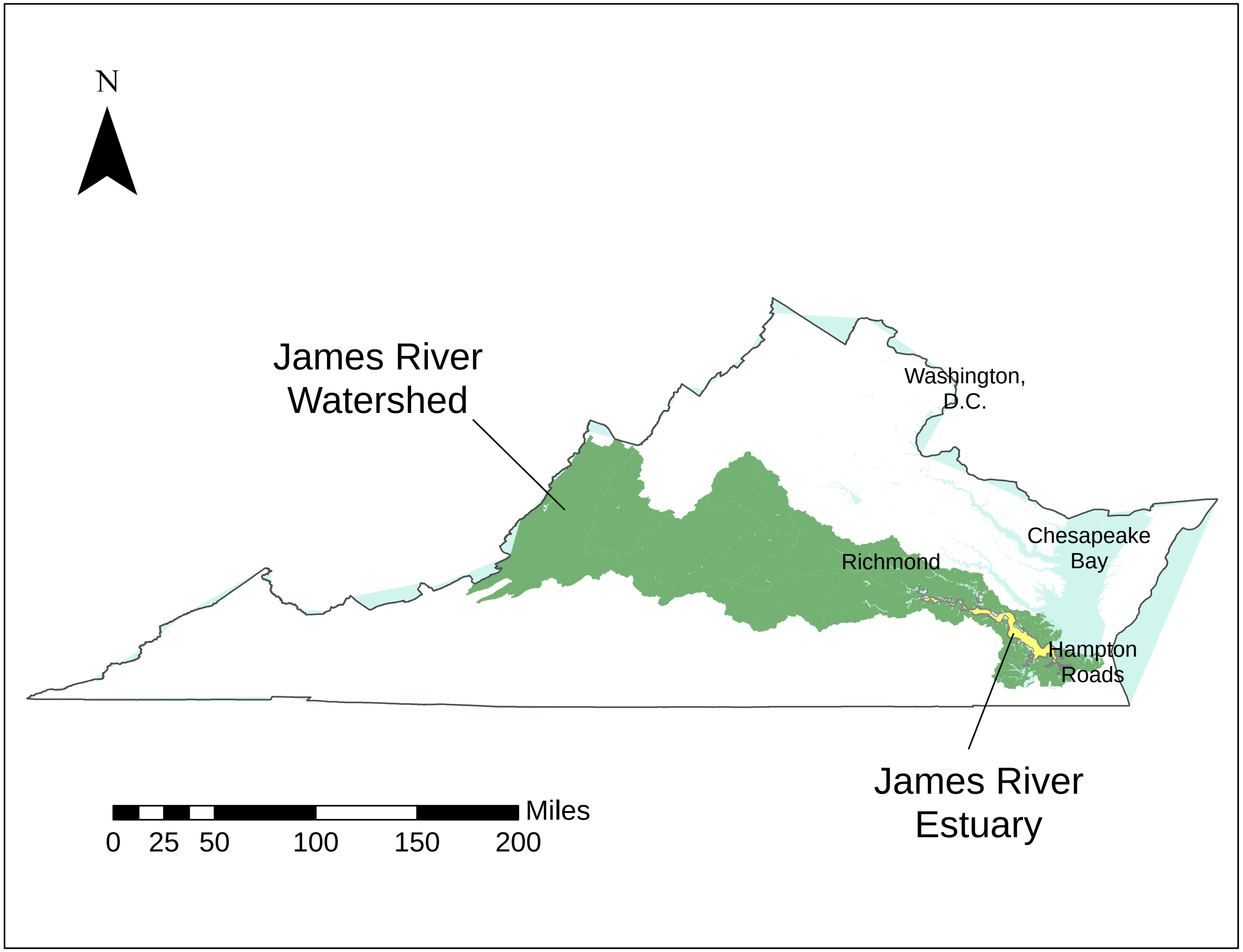


Benefits of water body specific approach for Boulder Creek

- More beneficial & cost-effective approach
  - Go beyond default goal for phosphorus
  - Moderate nitrogen controls
- Realistic expectations
- Support for tiered, adaptive implementation

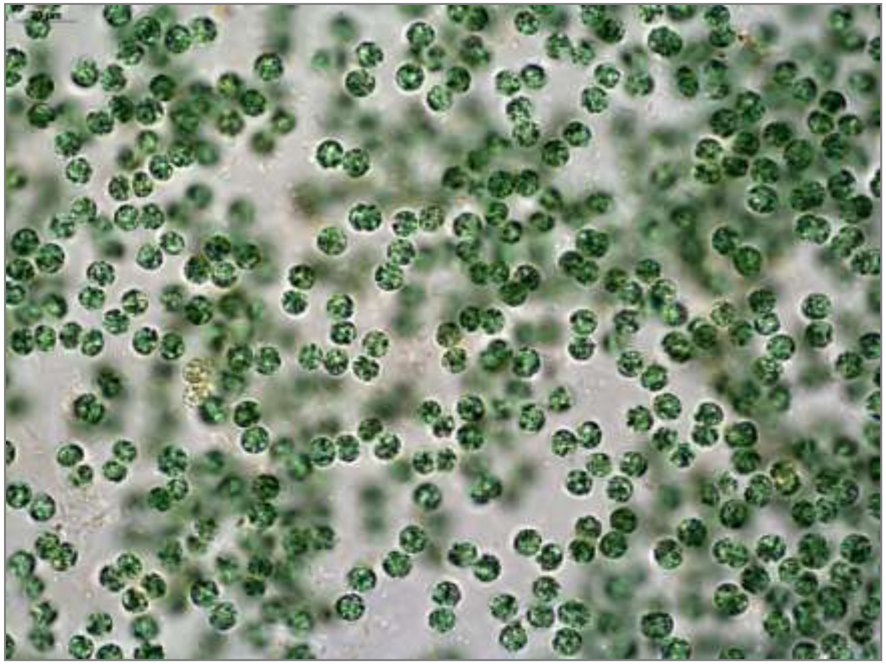


Case Study #3: Chlorophyll-a Criteria for the James River Estuary, VA



Nutrient-Related Issues

Tidal Freshwater



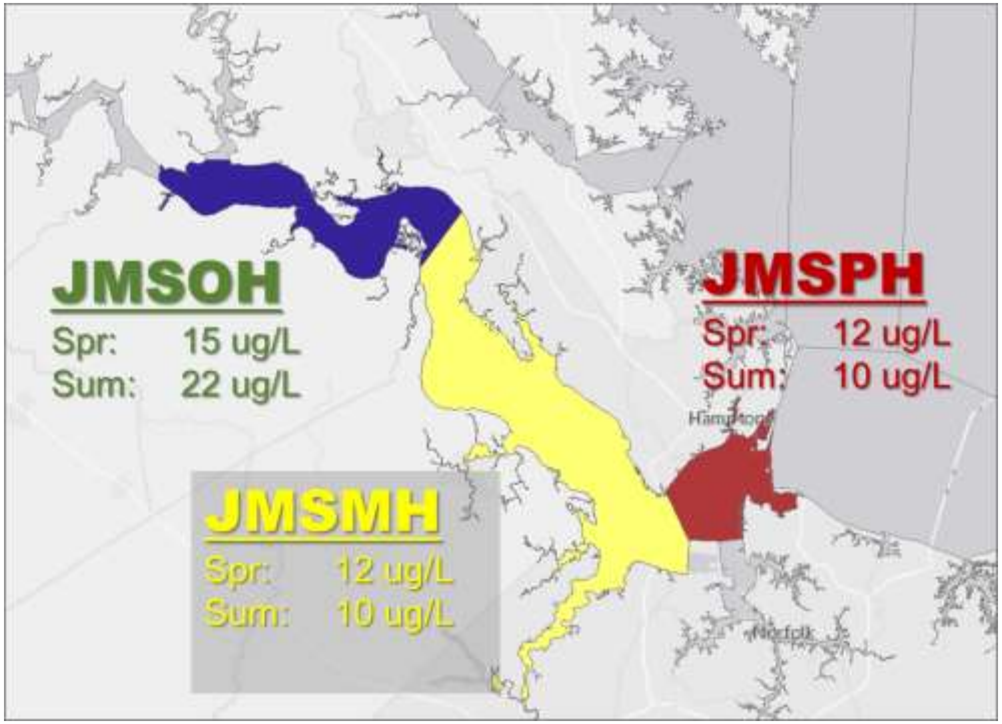
- Large chlorophyll-*a* peak
- Some cyanobacteria including *Microcystis aeruginosa*

Lower Estuary

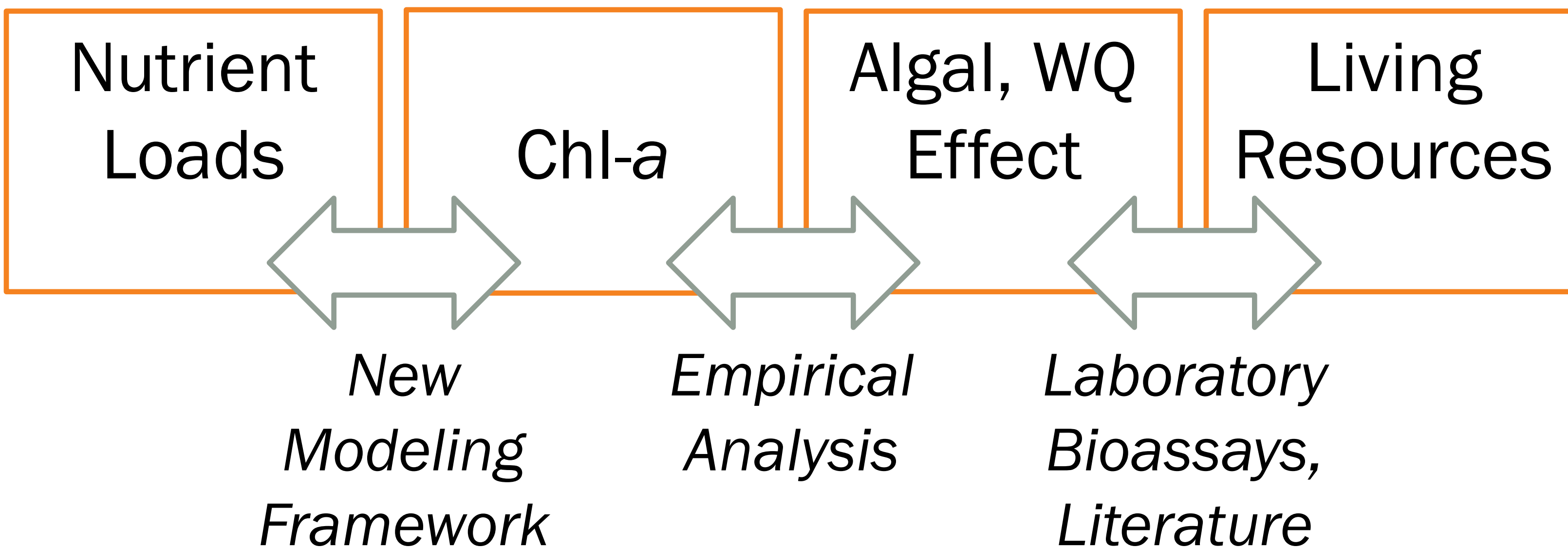
- Periodic blooms of potentially harmful dinoflagellates

Brief History of James River Estuary Chlorophyll-*a* Standards

- <u>2004-2005</u>: Virginia adopts somewhat subjective chlorophyll-*a* criteria
- <u>2010</u>: USEPA model predicts ~1 $billion additional nutrient controls needed
- <u>2011-2015</u>: Virginia conducts the James River Chlorophyll-a Study

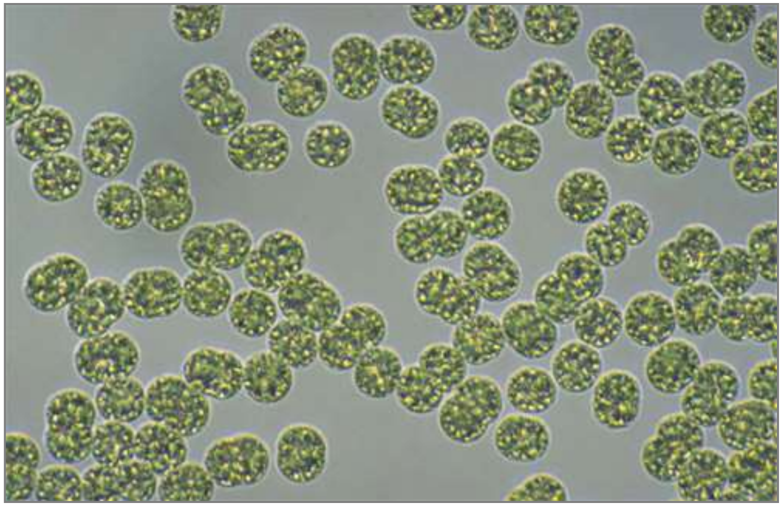


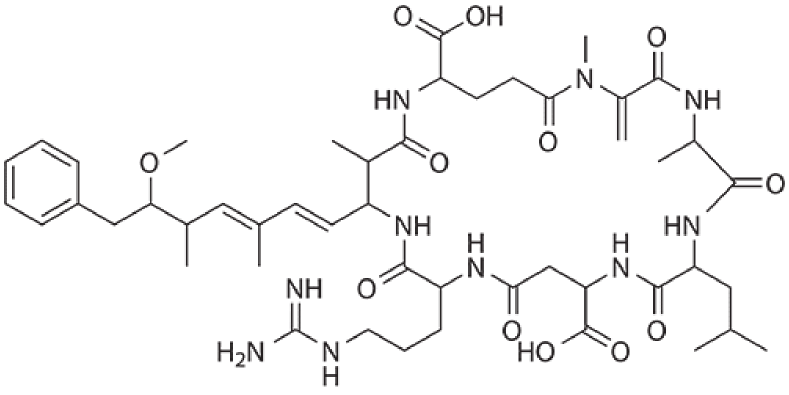
Conceptual Linkages of James River Chlorophyll-a Study



Tidal freshwater – Focus on microcystin

- Toxin produced by cyanobacteria
- Detectable at relatively low concentrations (0.1 - 5 ug/L) throughout tidal fresh segments
- Also detectable in fish and crab tissue

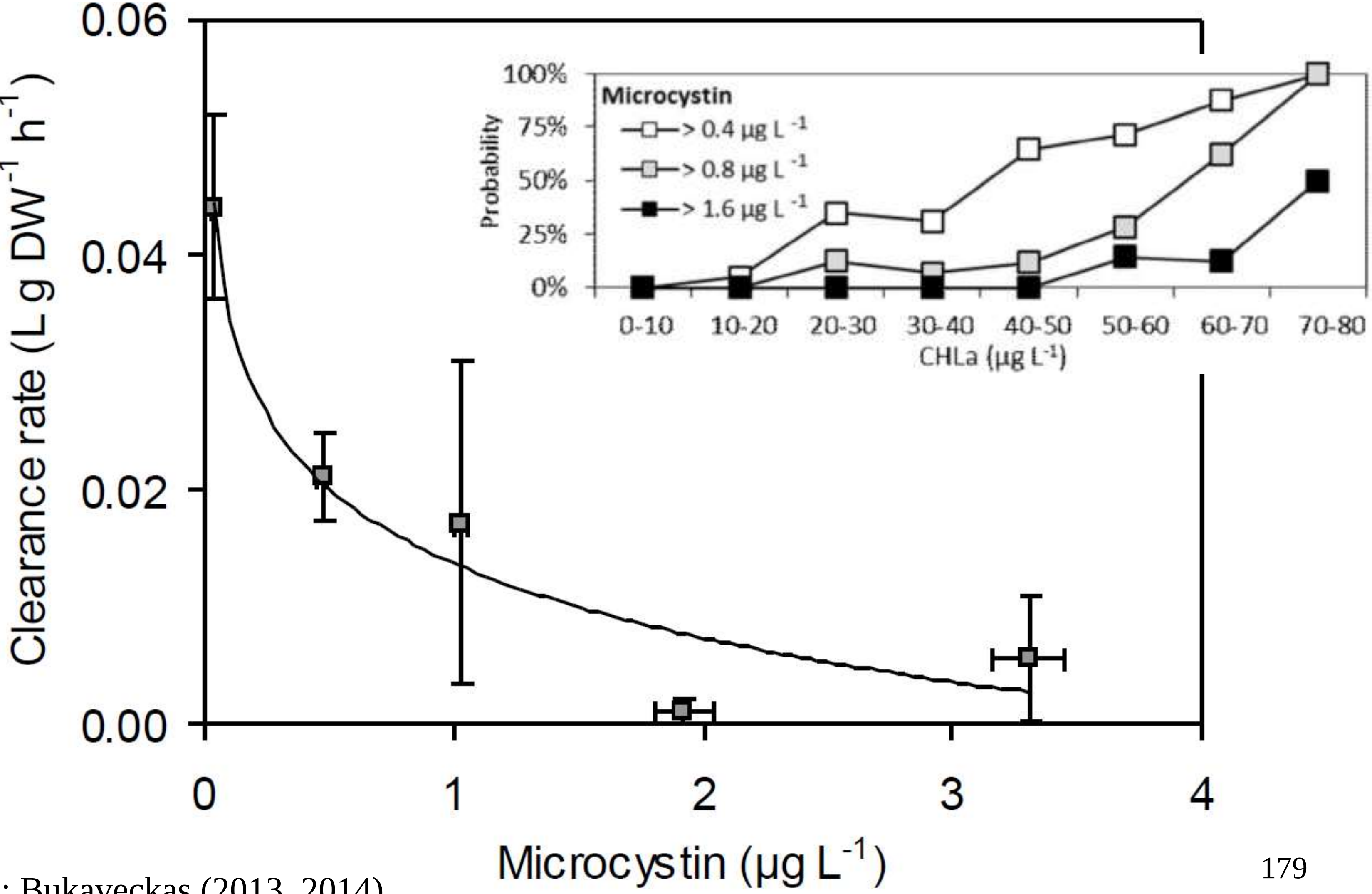




Tidal freshwater– Focus on microcystin (cont.)

- Use impairments largely ruled out:
  - Drinking water
  - Recreation
  - Human health from fish/crab consumption
  - Acute toxicity to aquatic life
- Use impairment of concern
  - Behavioral effects on aquatic life;
    - E.g., clam feeding rates

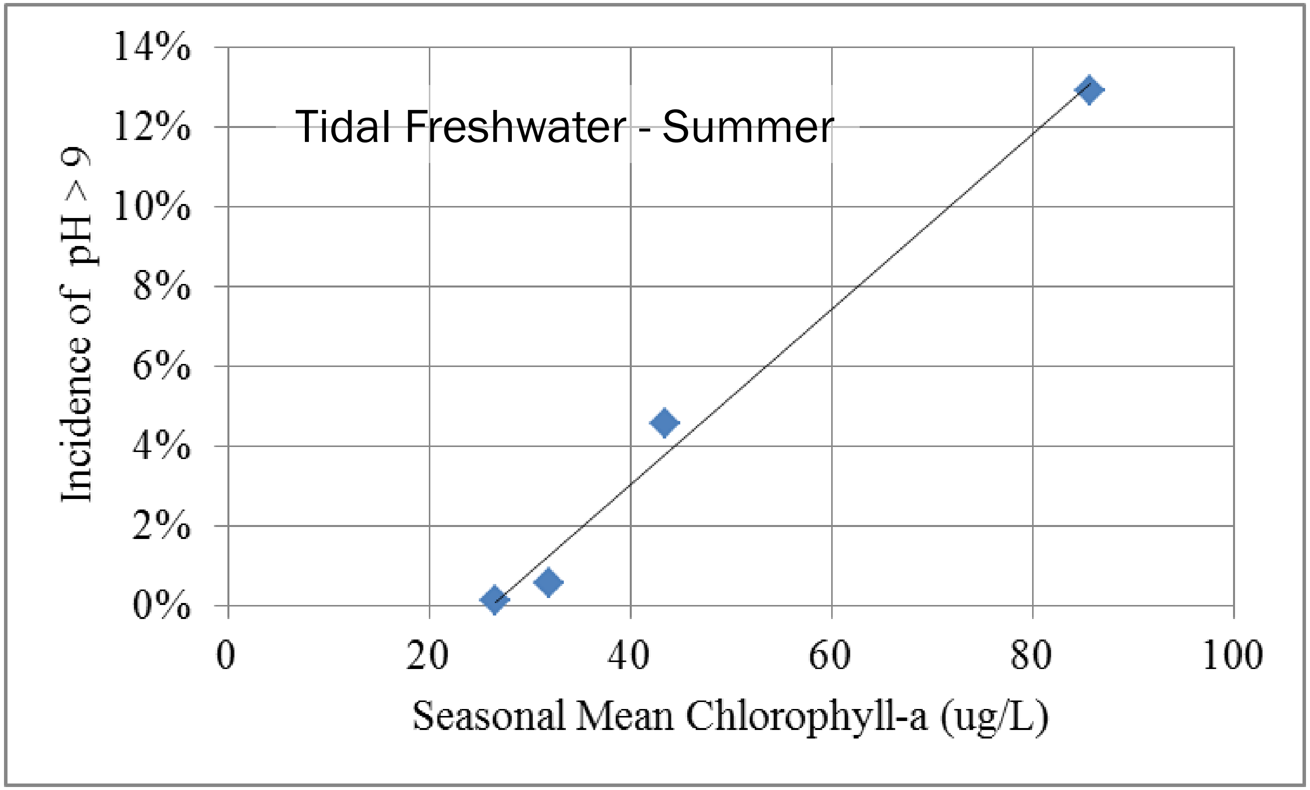
EC50s of 0.40 to 1.15 ug/L



Source: Bukaveckas (2013, 2014)

Tidal Freshwater - Other Useful Potential Chlorophyll – Use Linkages

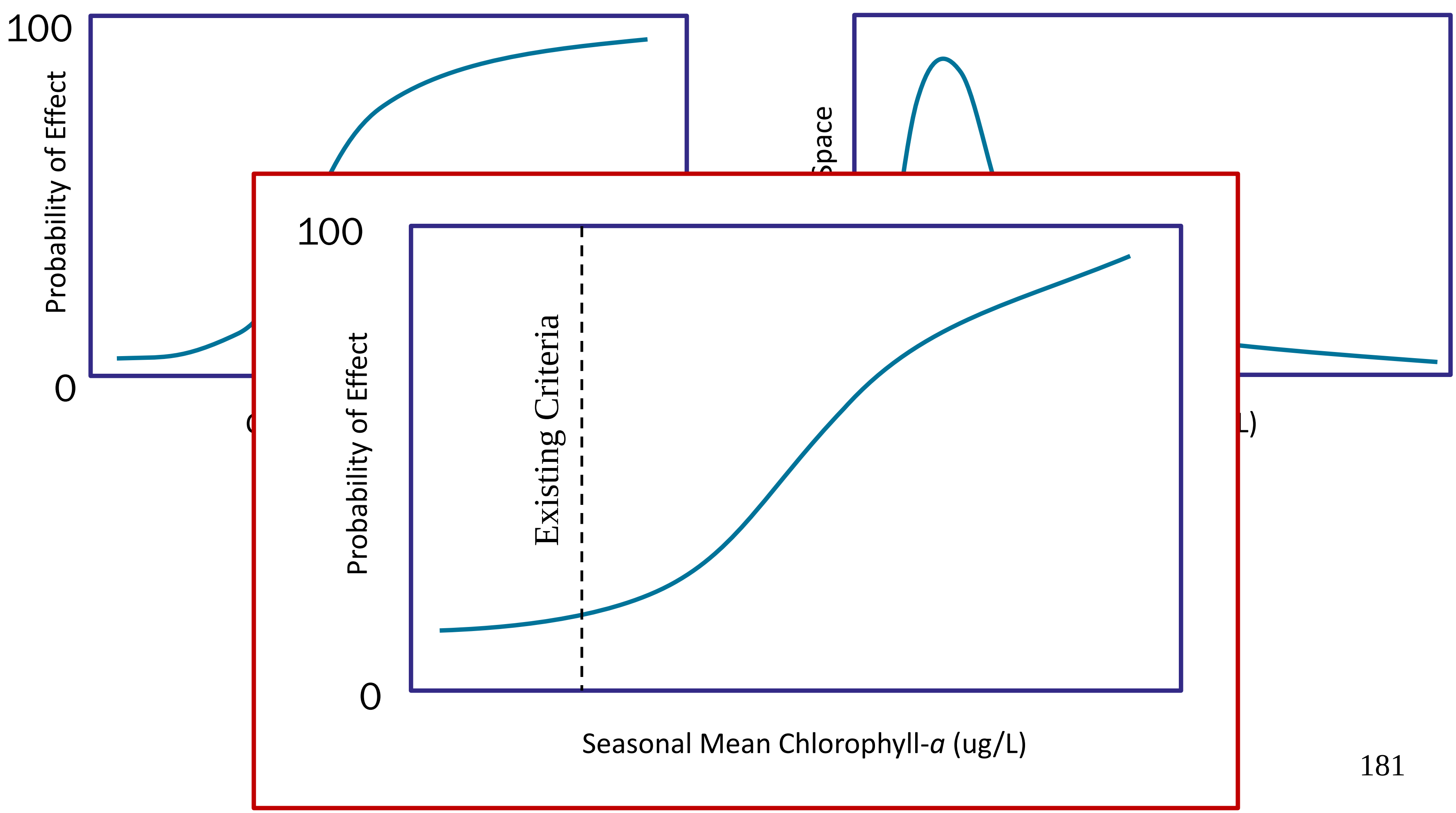
- *Microcystis aeruginosa* > 20,000 cells/mL
- pH > 9



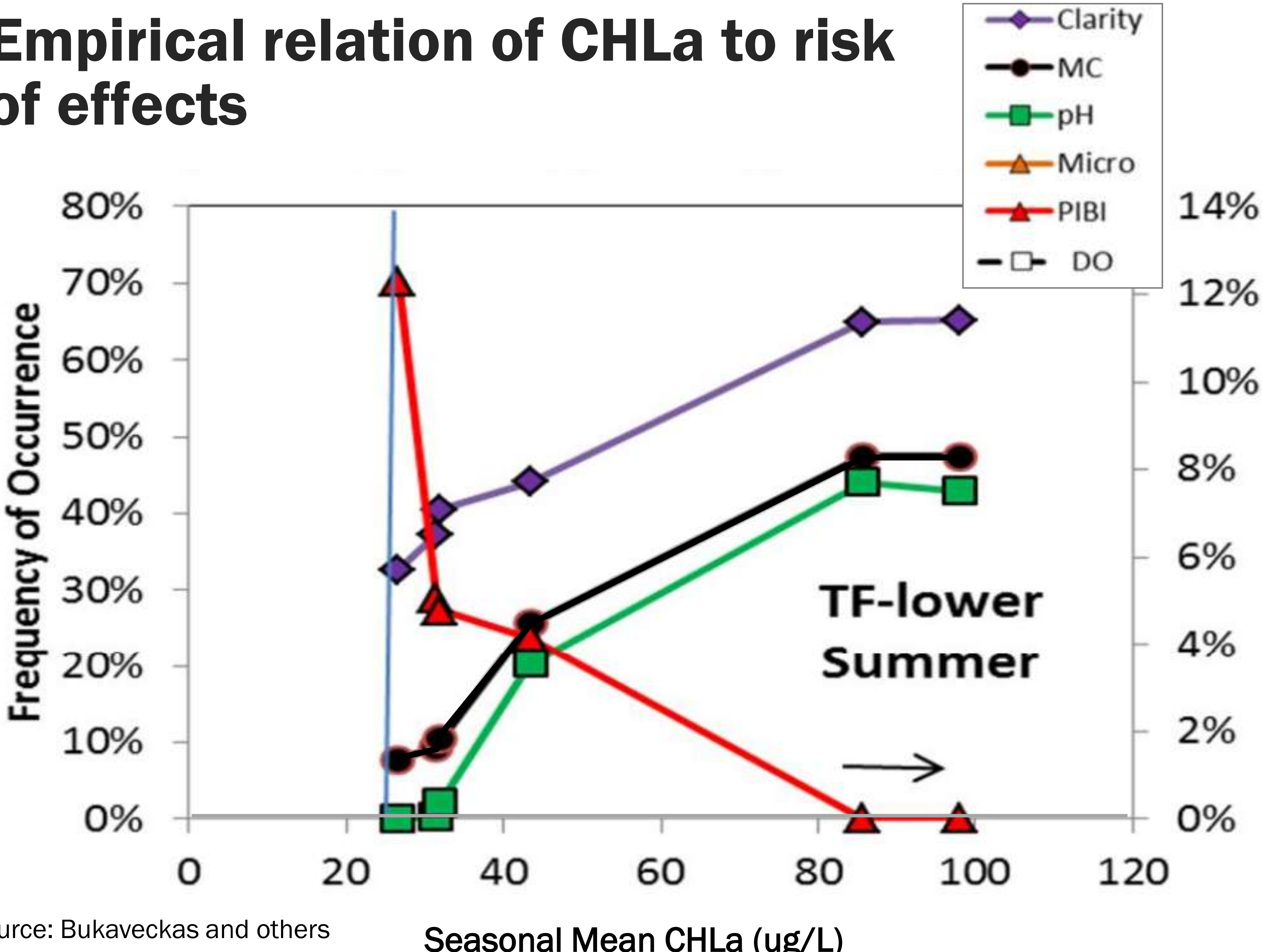
Combined Probability Approach for Relating Quantifying Risk

Risk of Effect vs. Chl-a

Chl-a Distribution in a Season



Empirical relation of CHLa to risk of effects

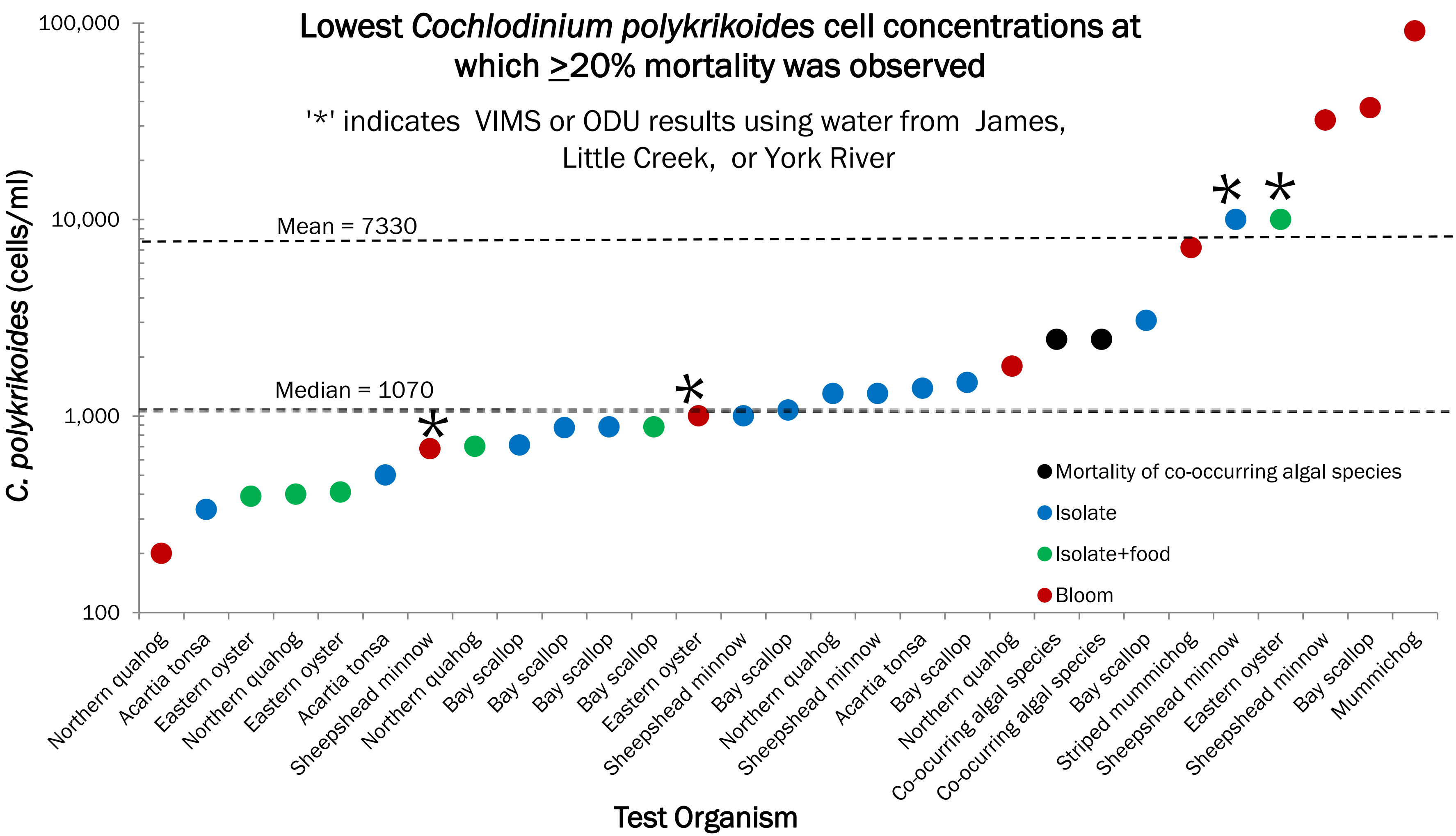


Source: Bukaveckas and others (2013) - Draft

Lower Estuary
Potential Chla – Use Linkages

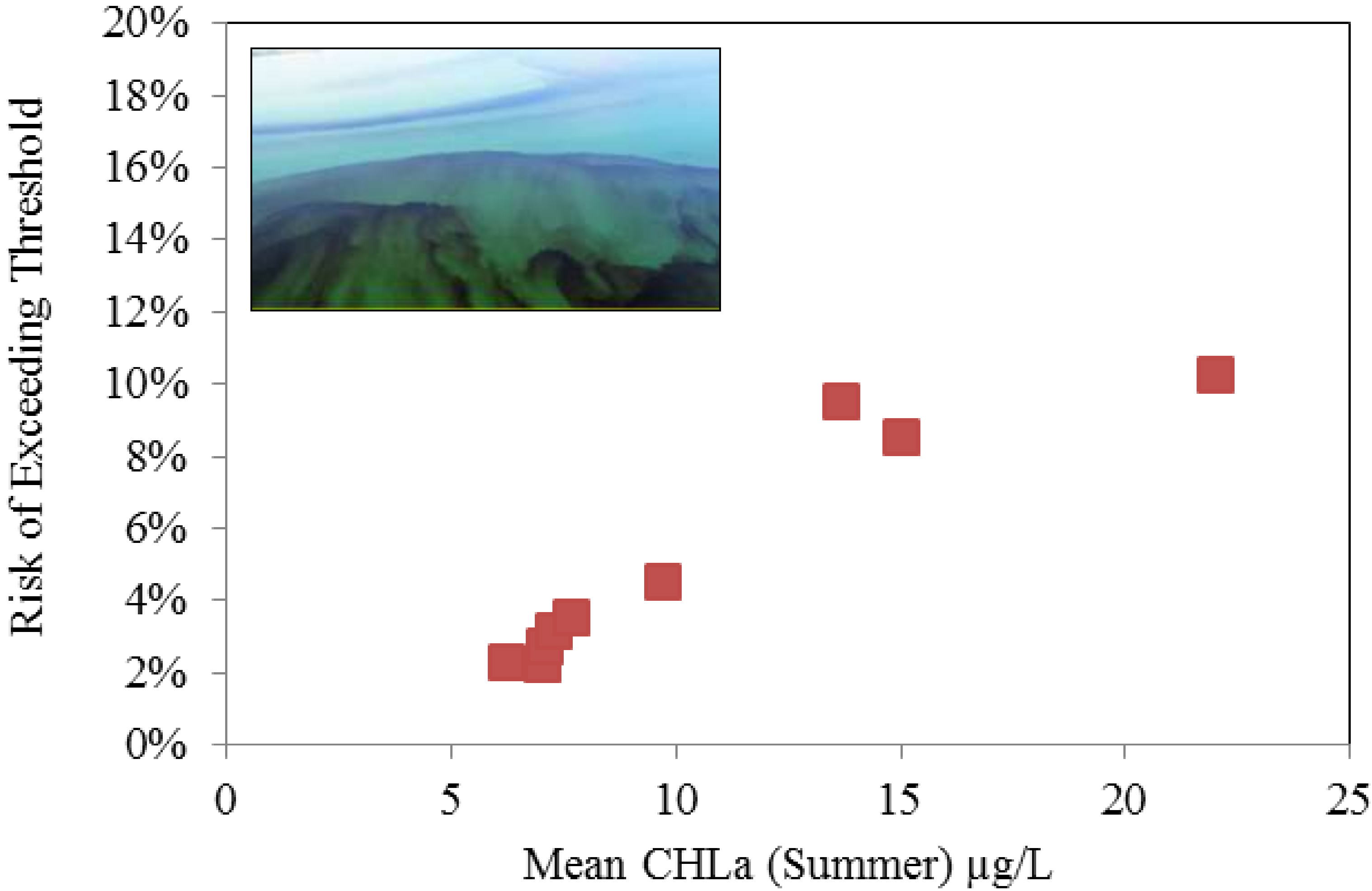
- Dinoflagellate blooms
- Phytoplankton community metrics
- Phytoplankton IBI (P-IBI)
- Low DO (<5)
- High pH (>9)
- Water clarity

Bioassays of mortality from *Cocholodinium polykrikoides*



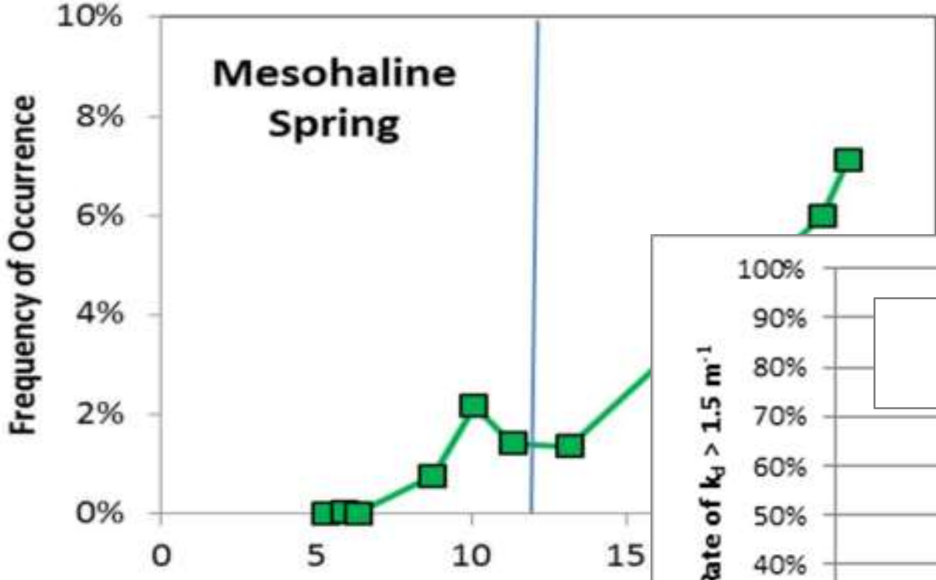
Source: Anne Schlegel, VADEQ

Chlorophyll-*a* linked to risk of C polykrikoides > 1,000 cell/mL

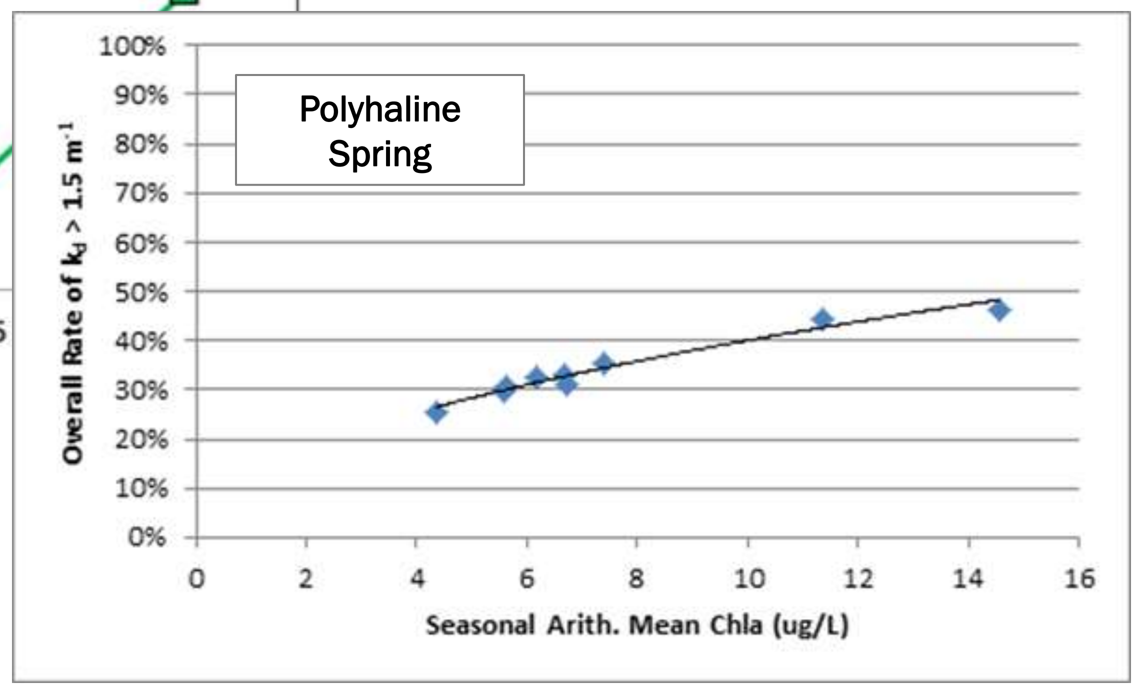


Some significant relations of chlorophyll-a with…

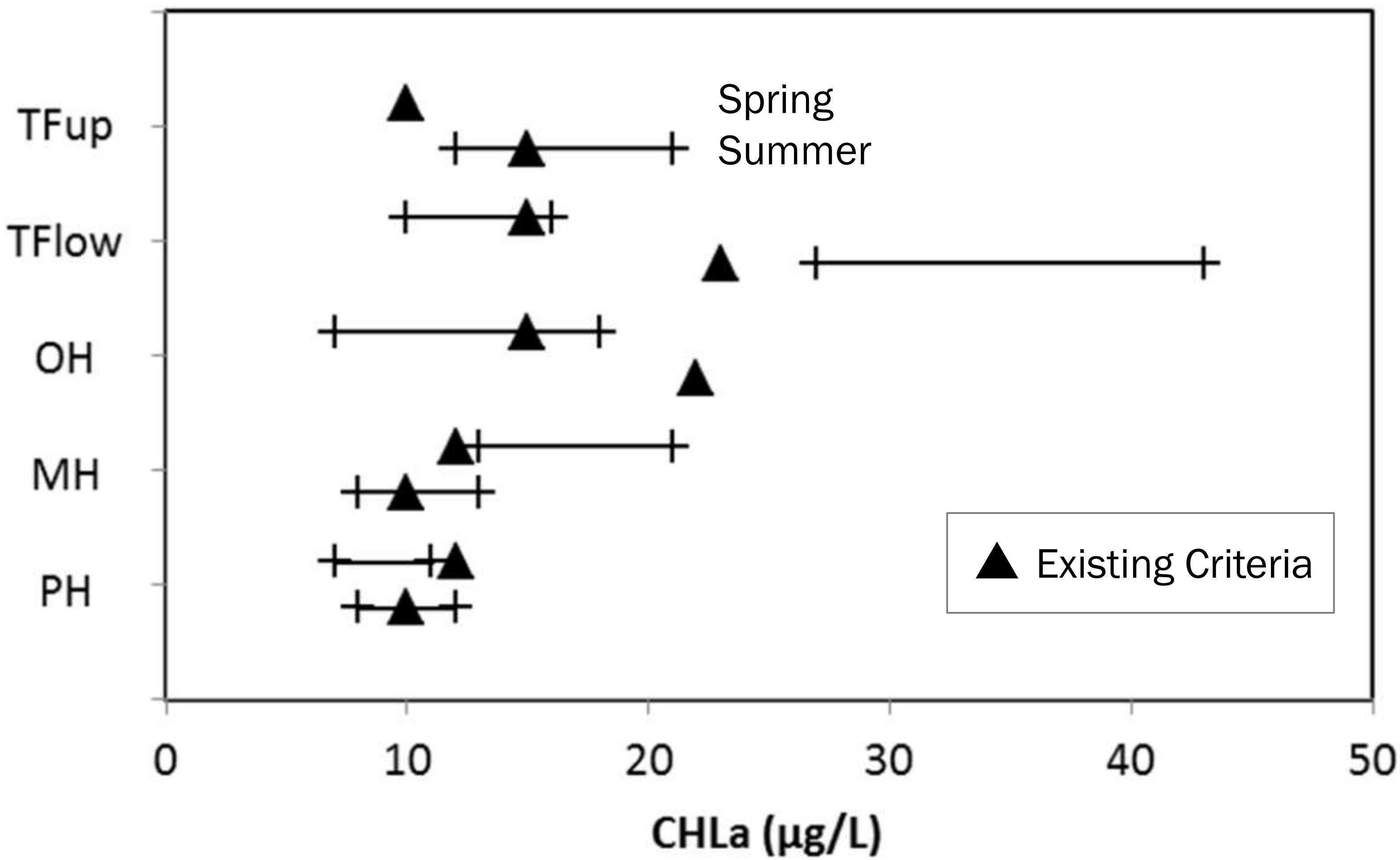
pH > 9



Light attenuation < 1.5 m^{-1}



Combined results were used to define "defensible ranges" of chlorophyll-*a* criteria



Source: Bukaveckas and others (2013) - Draft

Next Steps

- 2015
  - Finalize“defensible ranges” of criteria
  - Reevaluate assessment protocol
  - Perform ***alternatives analysis*** with new modeling framework
    - Load-response linkages
    - Evaluate attainability and “diminishing returns”
- 2016
  - Develop regulatory proposals

Conclusions

- Multi-million dollar investments in nutrient removal merit a strong understanding of how designated uses will (and will not be) affected.
- Water body-specific approaches result in better science, better management.
- We have the methods and tools.

Nutrient Loads ⟷ Chl-*a* ⟷ Algal, WQ Response ⟷ Living Resources

Calibrated Models | *Empirical Relations* | *Laboratory Bioassays*