

Who is the Colorado Nutrient Coalition and Why are we here?

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The Science

Where does it stand?



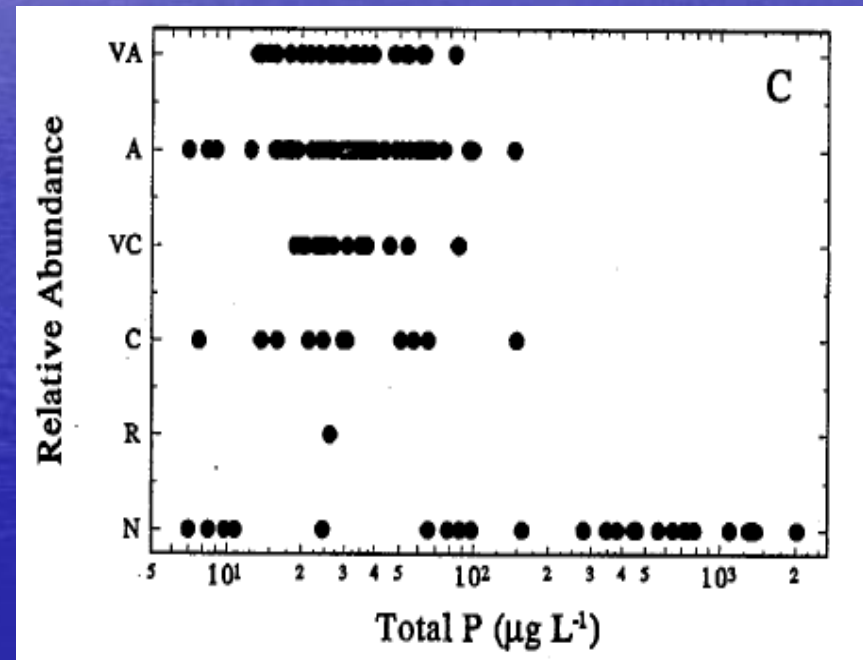
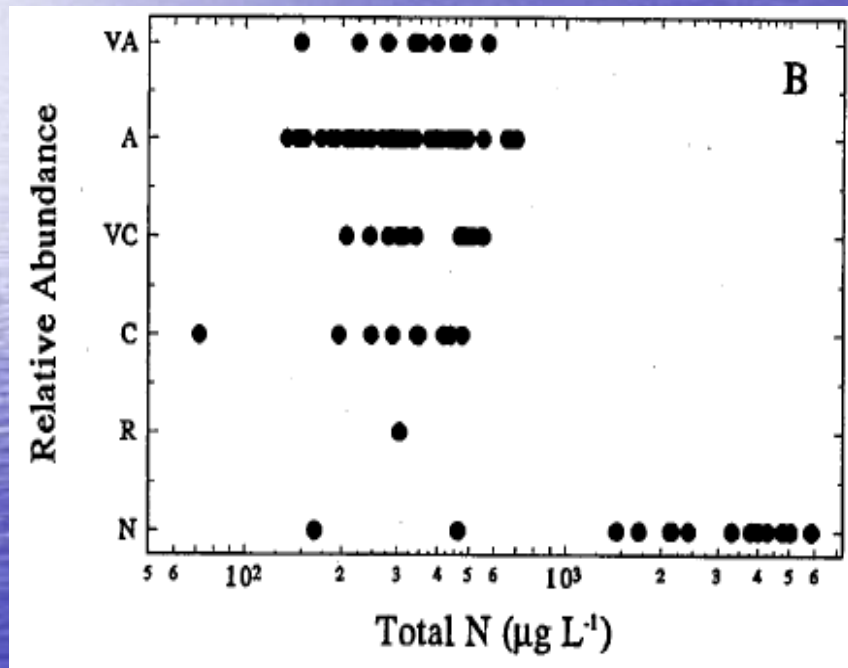
**Review of Mechanisms
Influencing Nutrient
Dynamics in Lakes and
Streams**

EPA GUIDANCE ON ALGAL GROWTH RELATIONSHIP

“The difficulty associated with understanding predictive relationships between nutrient loading and algal biomass is perhaps the biggest challenge to establishing meaningful nutrient criteria.”

(Nutrient Criteria Technical Guidance Manual–Rivers and Streams at 73)

CLARK FORK RIVER (MT) NUISANCE ALGAE (CLADOPHERA)



Relative Cladophora abundance in the Clark Fork River, MT. Abundance Scores: VA = very abundant, A = Abundant, VC = Very Common, C = Common, R = Rare, N = not present. (Dodds et al. 1997)

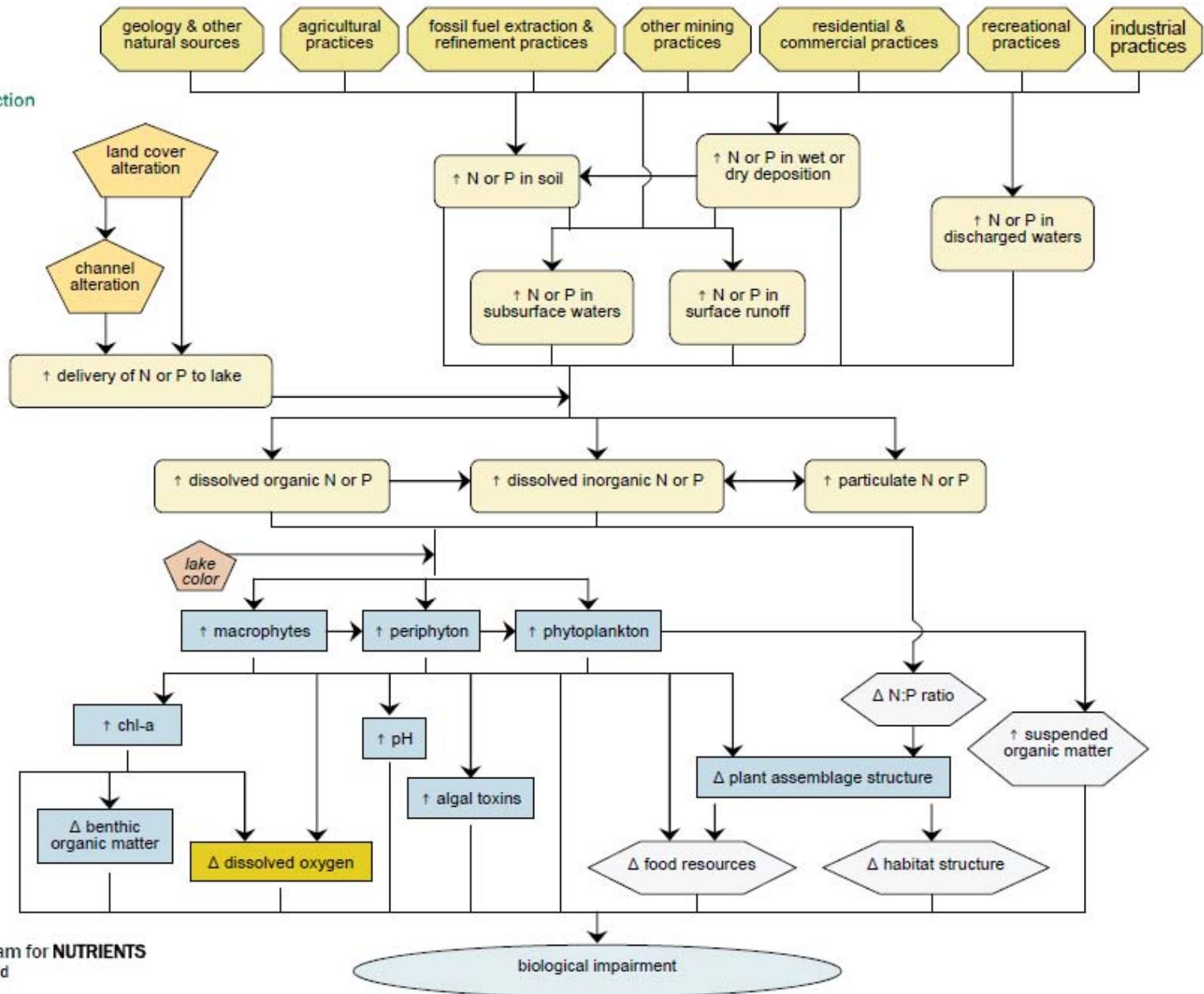
NUTRIENT CRITERIA DEVELOPMENT CONSIDERATIONS

- Nutrients (N, P) not toxic in classical sense
 - No direct effect on invertebrates directly
 - Stimulate plant growth → adverse effects
- EPA Nutrient Criteria Guidance (2000)
 - Define relationship to plants, D.O., pH, etc.
 - Set causal (TP) and response (Chl 'a') criteria
- Recent Regulatory Actions
 - Stressor-Response Empirical Analysis - SAB
 - Florida WQS Problems

NUTRIENT CRITERIA MUST CONSIDER PLANT GROWTH

[F]ish and macroinvertebrates do not directly respond to nutrients, and therefore may not be as sensitive to changes in nutrient concentrations as algal assemblages. It is recommended that relations between biotic integrity of algal assemblages and nutrients be defined and then related to biotic integrity of macroinvertebrate and fish assemblages in a stepwise, mechanistic fashion.


(EPA. 2000. Nutrient Criteria Technical Guidance Manual - Rivers and Streams at 85)



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

SAB CONCLUSION OVERVIEW

- Regression Approach Not Scientifically Defensible for Nutrient: Invertebrates; Lacks Cause/Effect Demonstration
- Need to Confirm “Impairment” Thresholds Are Biologically Significant
- Need to Account for Factors Influencing Nutrient Dynamics and Invertebrate Metrics (Habitat, DO, pH, Scour/Sediment)
- Loading Approach May Be a Better Than Concentration
- Failure to Consider Site-specific Data May Yield Inappropriate Results



**EVALUATION OF COLORADO'S
NUTRIENT CRITERIA
PROPOSAL**

BASIC CONCERNS WITH COLORADO APPROACH

- No demonstrated need for TN control in all Lakes and Streams
- Lakes – regression approach fails to reflect multiple factors controlling plant growth
- Streams – regression approach alone contrary to SAB findings – no cause and effect

NO NEED FOR UNIVERSAL TN CONTROL

*When evaluating the relationships among nutrients and algal response within stream systems, it is important to first understand which nutrient is limiting. Once the **limiting nutrient** is defined, critical nutrient concentrations can be specified and nutrient and algal biomass relationships can be examined to identify potential criteria to avoid nuisance algal levels.*

EPA. 2000. Nutrient Criteria Technical Guidance Manual – Rivers and Streams, at 74. (Emphasis added)

*Many natural factors combine to determine rates of plant growth in a waterbody. First of these is whether sufficient phosphorus and nitrogen exist to support plant growth. The absence of one of these nutrients generally will restrict plant growth. **In inland waters, typically phosphorus is the limiting nutrient** of the two, because blue-green algae can "fix" elemental nitrogen from the water as a nutrient source.*

EPA. 1999. Protocol for Developing Nutrient TMDLs First Edition at t 2-4. EPA 841-B-99-007 (Emphasis added)

An aerial photograph of a vast, deep blue lake. The water's surface is covered in fine, rhythmic ripples that catch the light, creating a shimmering effect. The horizon line is straight and divides the image roughly in half. Above the horizon, the sky is a clear, vibrant blue, dotted with thin, wispy white clouds that stretch across the upper portion of the frame. The overall mood is serene and expansive.

LAKES

SAB CONCLUSION RELEVANT TO LAKES PROPOSAL

Plant biomass is driven by nutrient supply rates (i.e., nutrient mass loads). Ambient nutrient concentrations are not necessarily good surrogates for nutrient mass loads. Relationships between nutrient mass loads and ambient nutrient concentrations are highly system-specific and depend on many factors including inflows, hydrology, bathymetry, sediment-water exchanges and chemical-biological processes. Consequently, there may be many systems for which nutrient concentrations will not be appropriate stressor variables. For such systems it may be more appropriate, and scientifically defensible, to use site-specific mechanistic models incorporating loading to determine the nutrient controls required to attain designated uses. (at 11)

LAKE CRITERIA

Use Class	TP	TN	Chl-a
Cold	24 ug/L	490 ug/L	8 ug/L
Warm	82 ug/L	960 ug/L	20 ug/L

- Cold Lakes: Chl-a optimal for most salmonids
- Warm Lakes: Chl-a optimal for game fish
- TP/TN: linear regression of cold/warm lakes to achieve chl-a criterion.

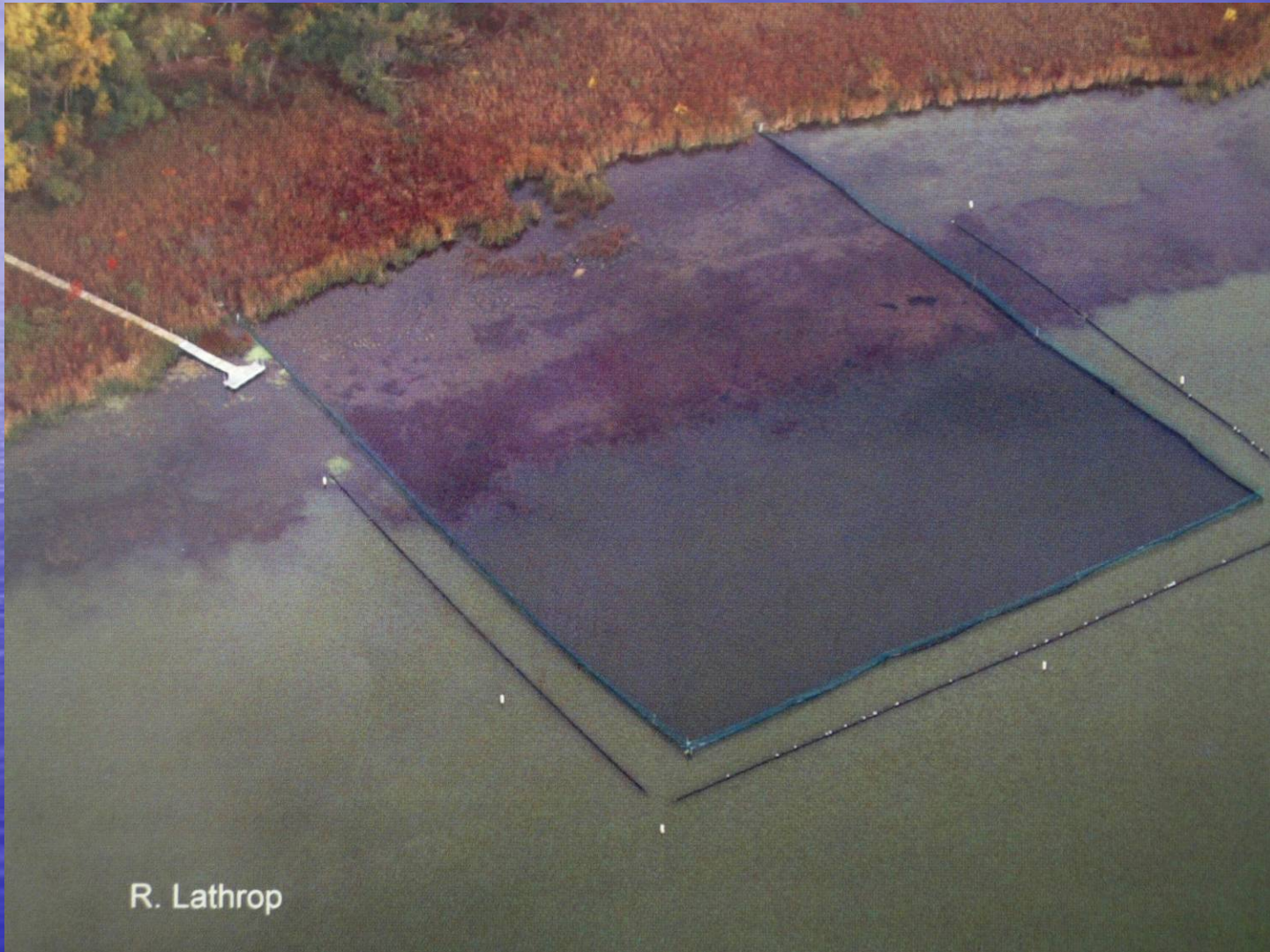
COLORADO LAKE APPROACH

- Chlorophyll-a criteria
 - Good approach (biologically significant), but
 - Only two lake categories (not enough)
 - Need more use categories/chl 'a' standards
 - Inappropriate averaging period (July-Sept vs Growing Season)
- TP Criteria
 - Used limited regression approach (SAB criticism)
 - Site-specific data show different result

OTHER FACTORS INFLUENCING CHL'a' TARGETS

- Nature of water body
 - Natural or man-made
 - Shallow or deep
 - Warm or cold, elevation
- Type of fishery
- Size of watershed (e.g., Lower S. Platte)
- Controlling use (aquatic life, drinking water, agricultural)

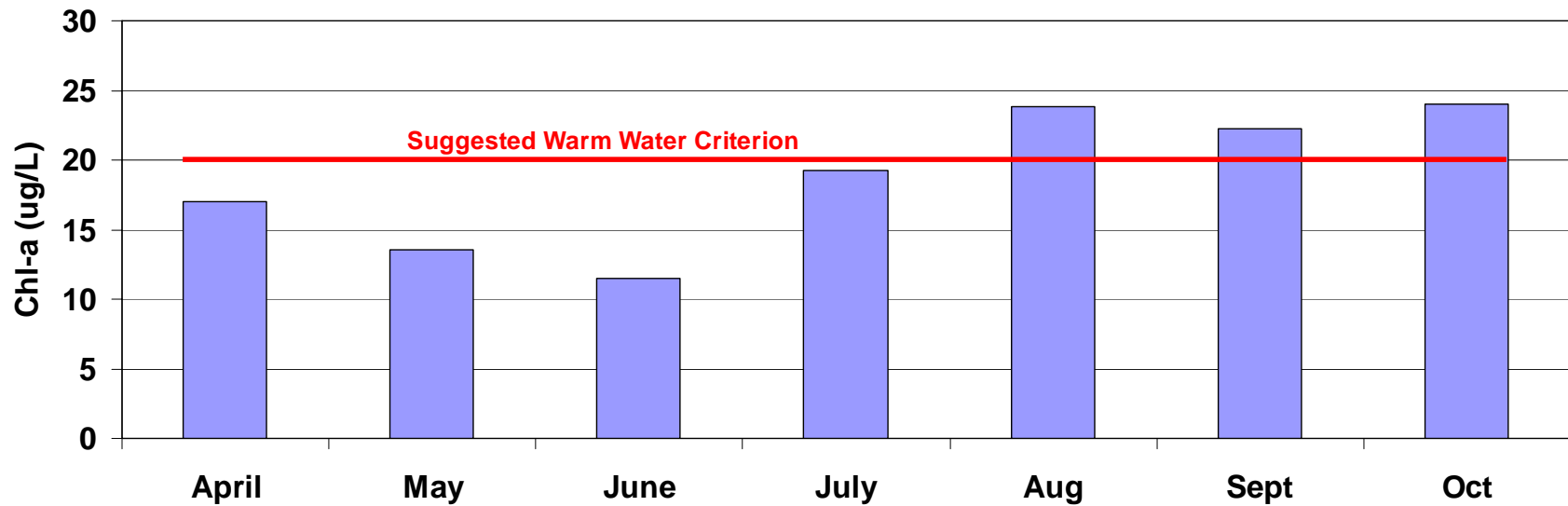
CARP INFLUENCE ALGAL GROWTH



R. Lathrop

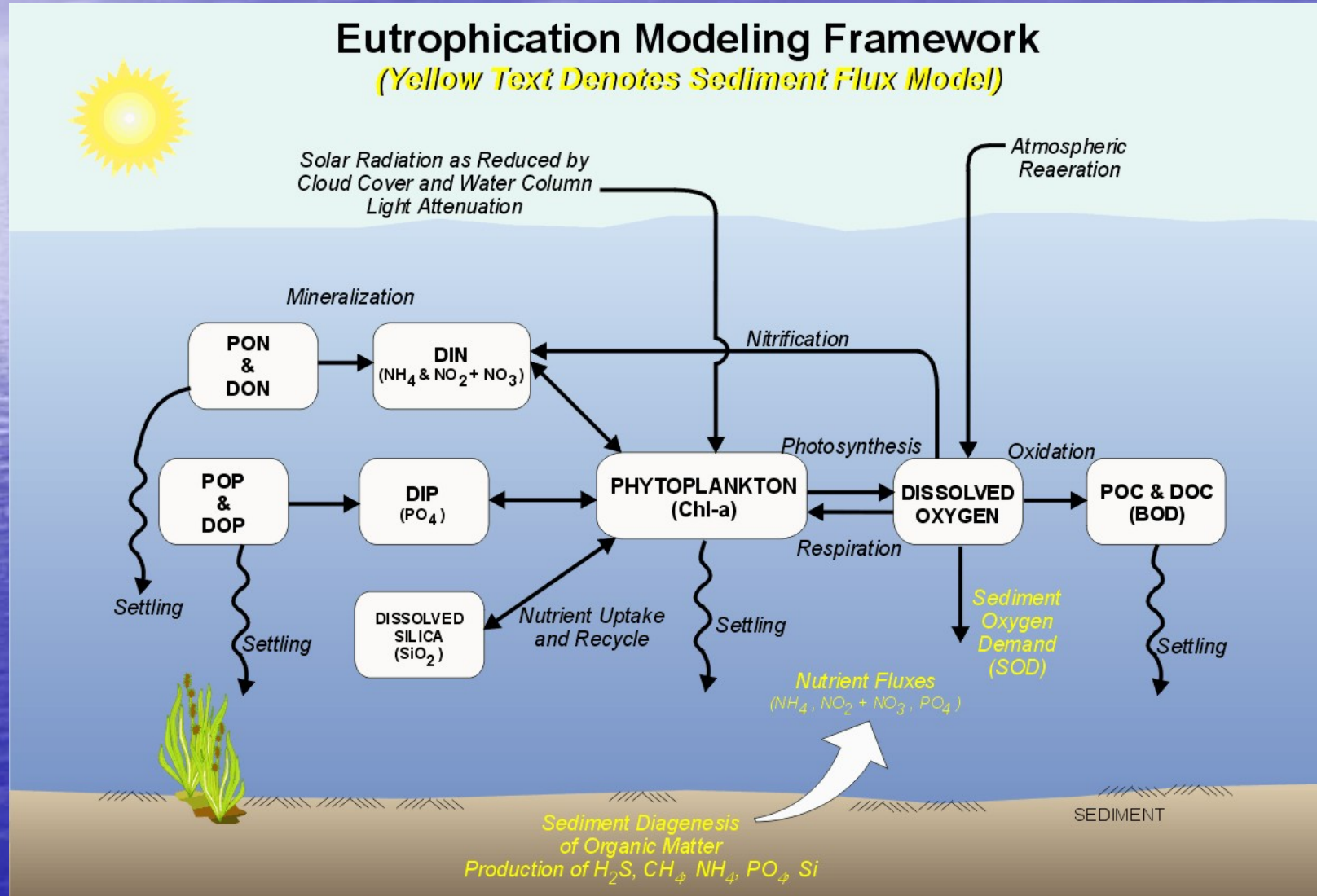
AVERAGING PERIOD

Cherry Creek Monthly Chlorophyll-a
March 1997 - September 2008



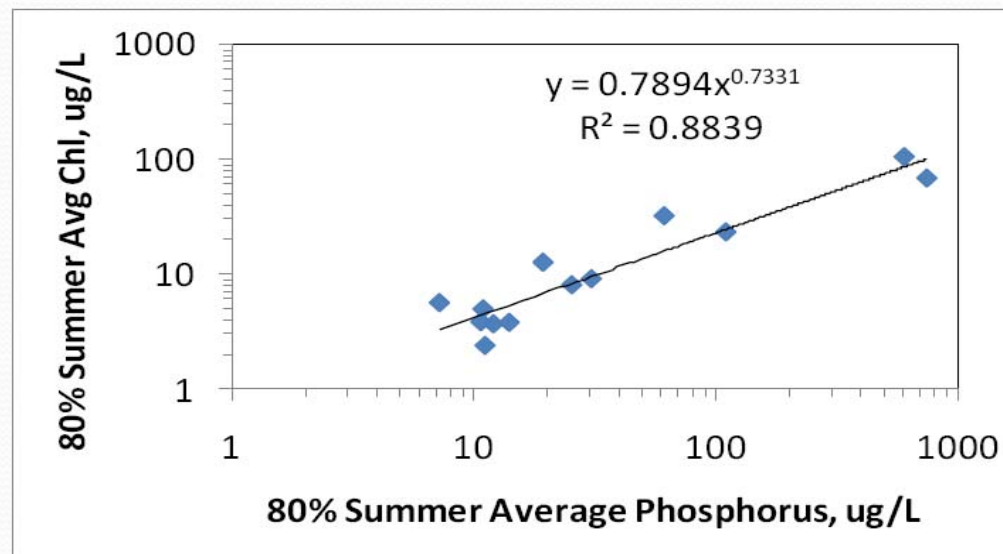
Overview of Water Quality Model Kinetics

Eutrophication Modeling Framework (Yellow Text Denotes Sediment Flux Model)



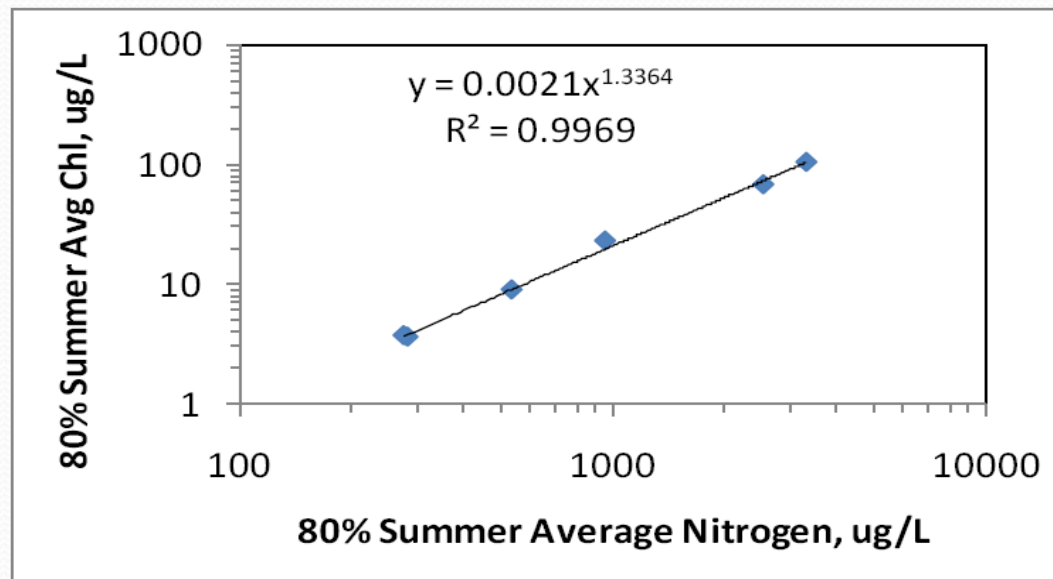
LINK CHLOROPHYLL TO PHOSPHORUS (13 LAKES)

Link Chlorophyll to Phosphorus



LINK CHLOROPHYLL TO NITROGEN (6 LAKES)

Link Chlorophyll to Nitrogen



CONCERN WITH REGRESSION APPROACH USING 80TH %ILE

- Pairing of highest 80th percentile Chl-a and TP concentrations from summer averages likely to misrepresent actual lake response
- Reduction of all data into a single point obscures variability and provides a false sense of validity

Chl-a vs. TP for EMAP Northeast Lakes Survey (Empirical Approaches for Nutrient Criteria Derivation, USEPA 2009)

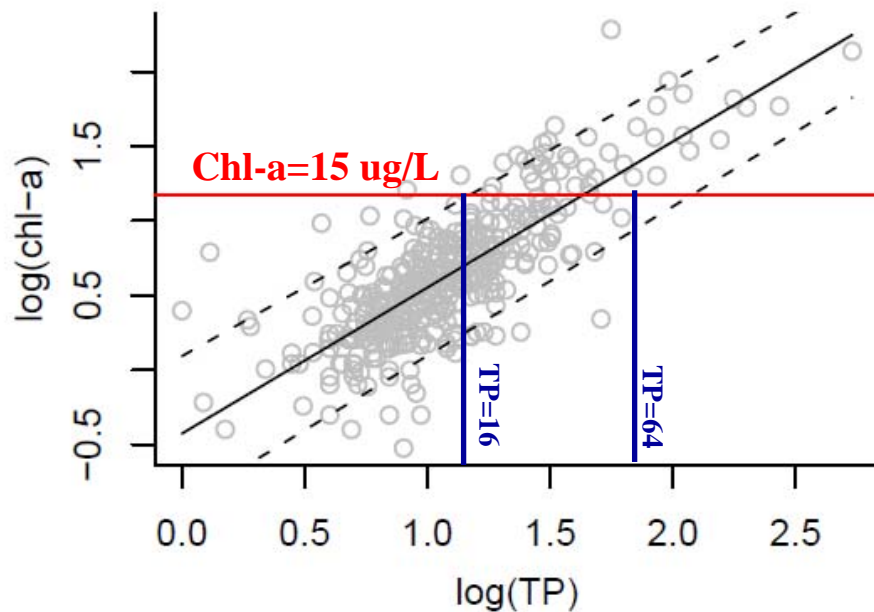
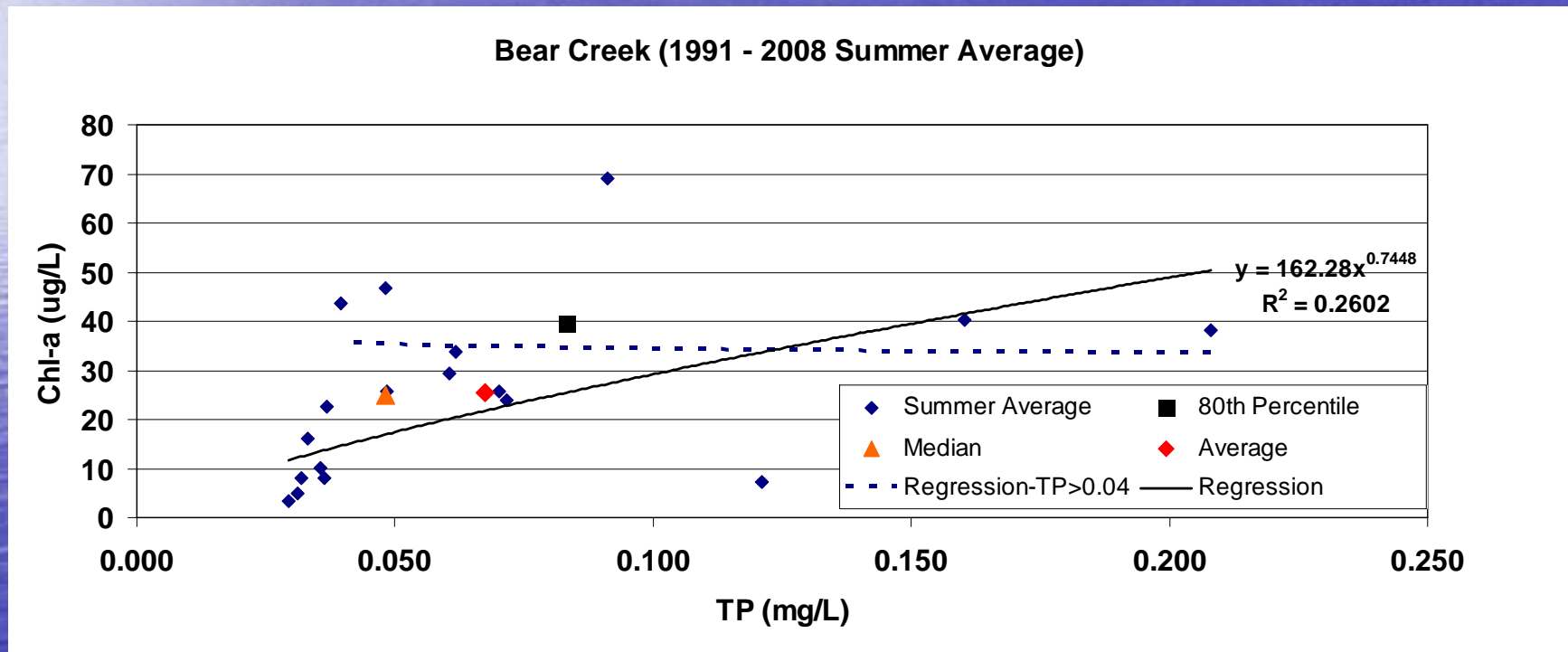


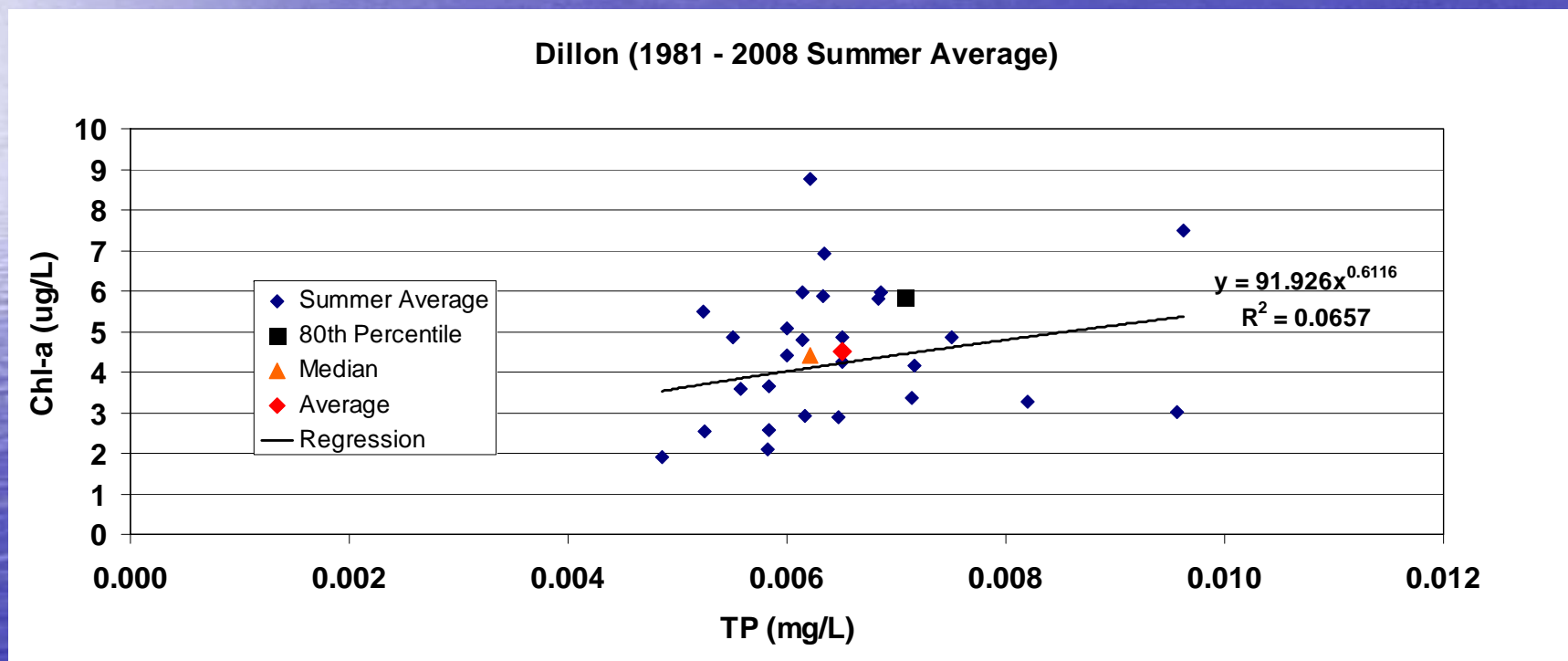
Figure 15. $\log(\text{TP})$ vs. $\log(\text{chl } a)$ for EMAP Northeast Lakes Survey. Dashed lines are the 5th and 95th percentile estimated by quantile regression. Solid line is the 50th percentile. Red line indicates where chlorophyll $a = 15 \mu\text{g/L}$. Units are $\mu\text{g/L}$.

ACTUAL COLD WATER LAKE DATA



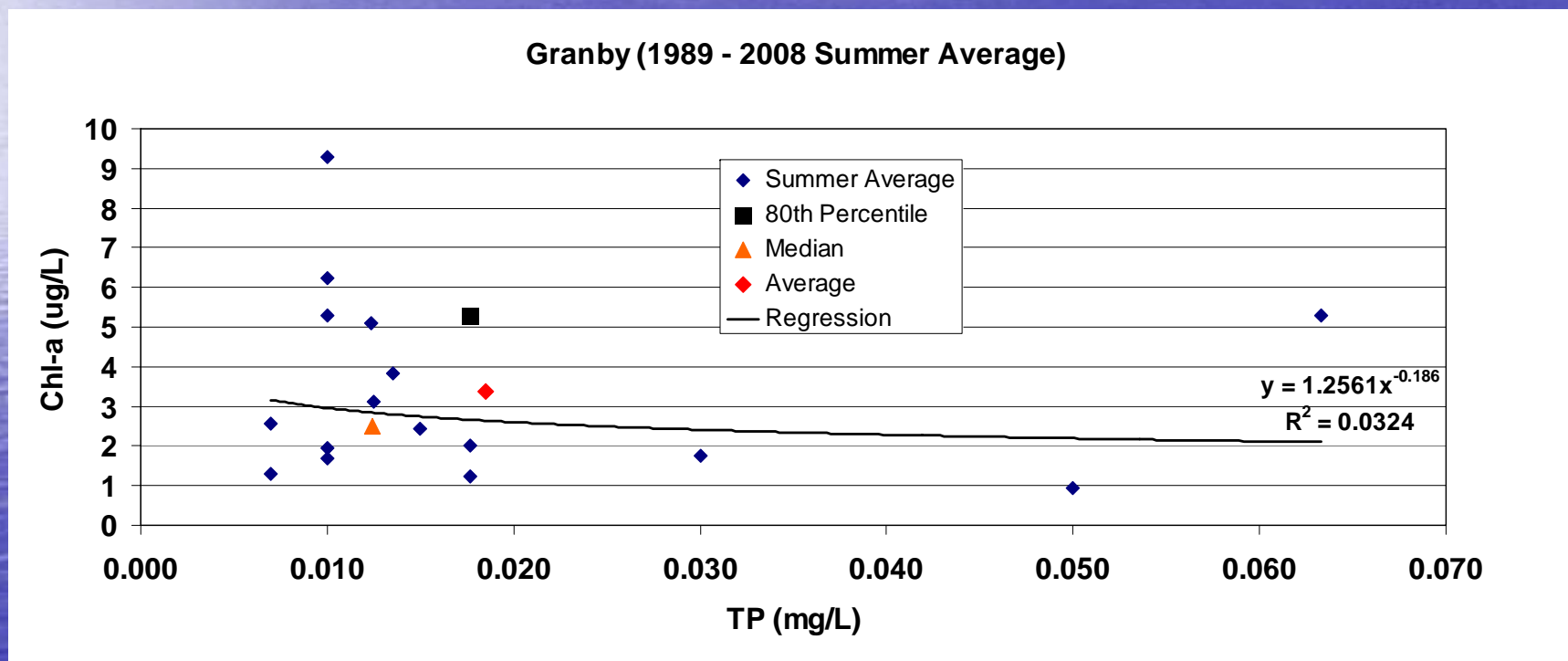
$R^2=0.26$; 80th percentile overestimates regression by 50%

ACTUAL COLD WATER LAKE DATA



$R^2=0.07$; 80th percentile overestimates regression by 33%

ACTUAL COLD WATER LAKE DATA

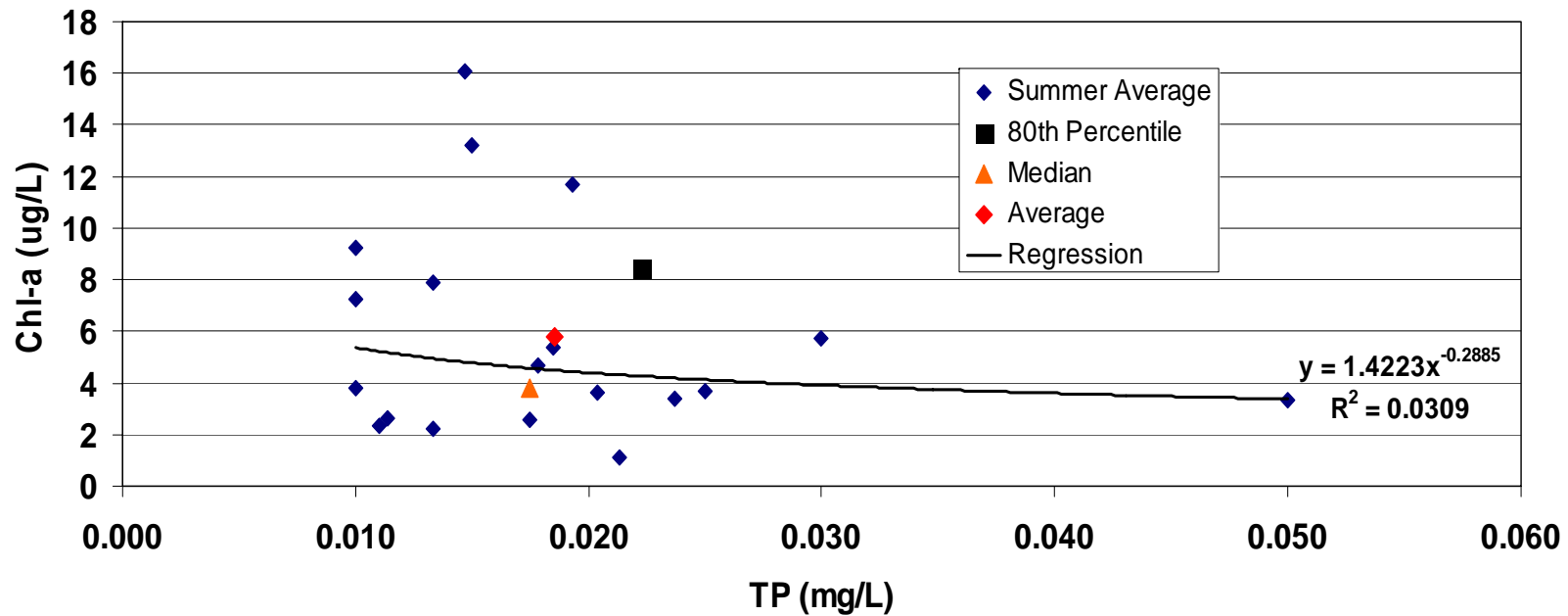


$R^2=0.03$; 80th percentile overestimates regression by 100%

Proposed TP WQS – 0.024 mg/l not needed

ACTUAL COLD WATER LAKE DATA

Shadow Mountain (1989 - 2008 Summer Average)

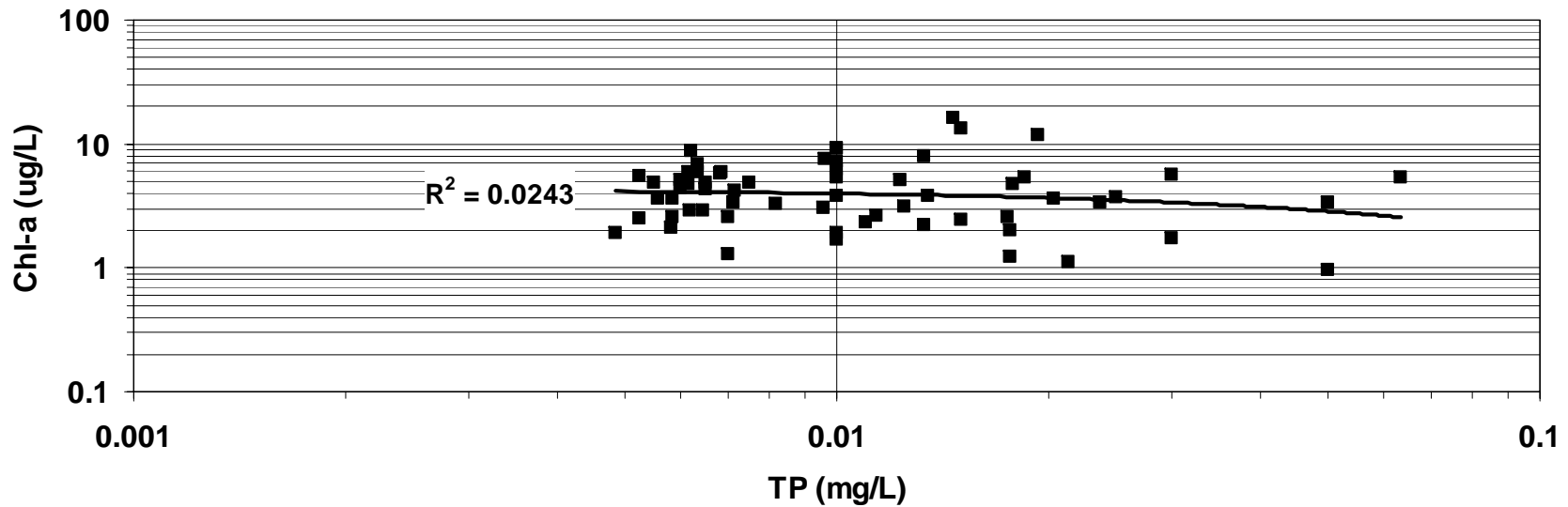


$R^2=0.03$; 80th percentile overestimates regression by 100%

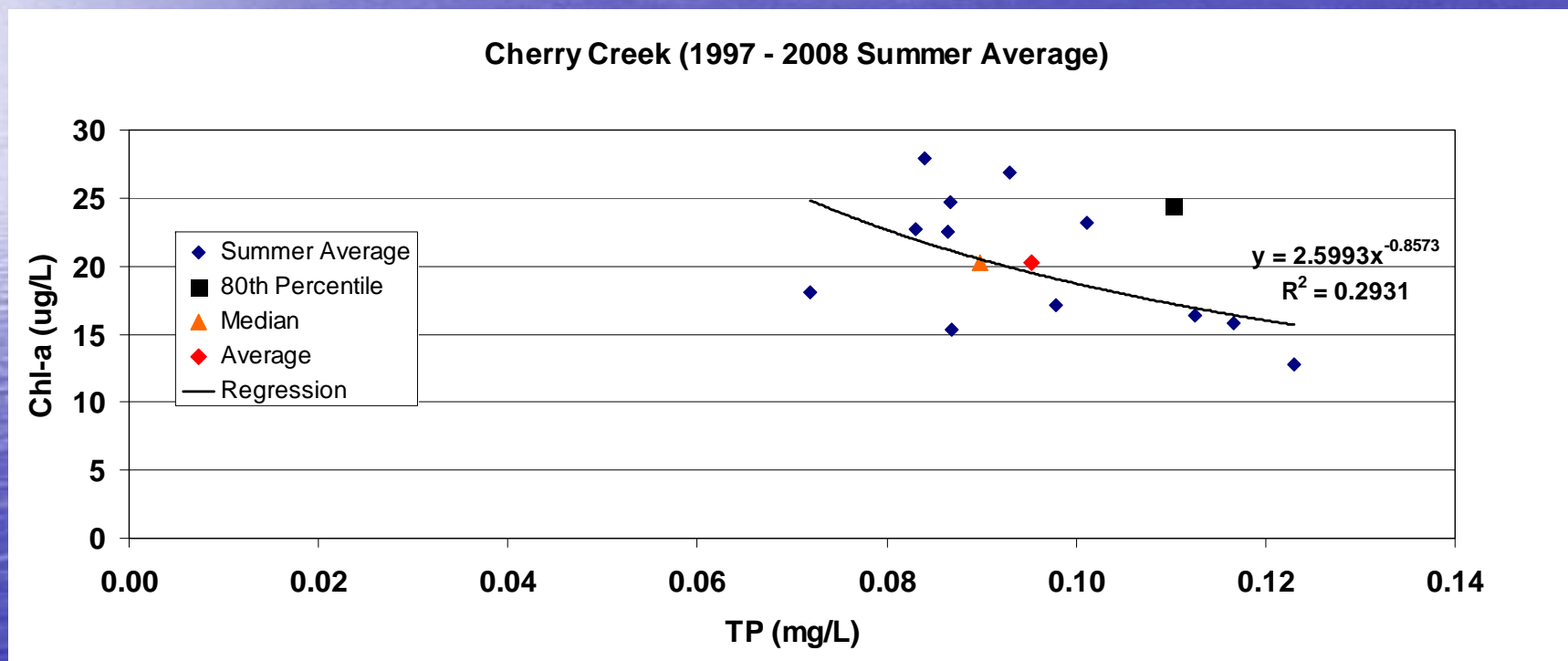
ALTERNATE REGRESSION

24 UG/L TARGET INAPPROPRIATE

Cold Water Lakes
Summer Average Observations for Dillon, Granby, and Shadow Mountain



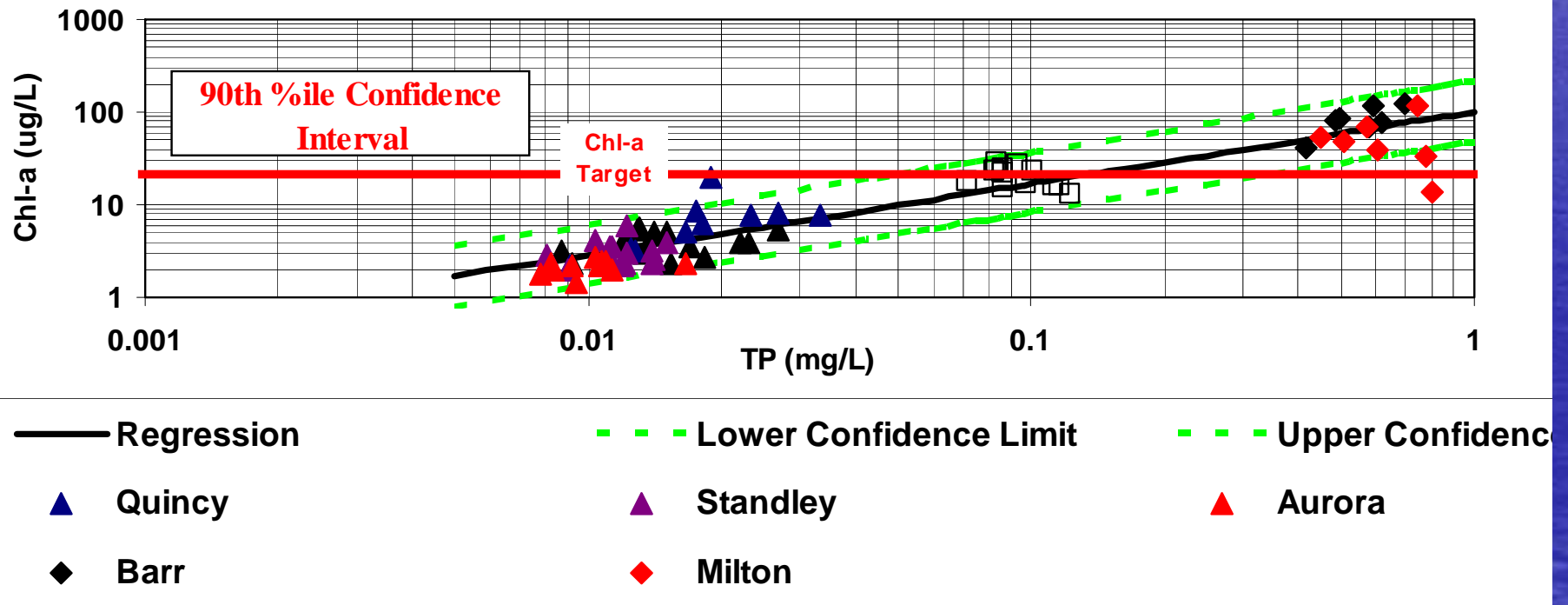
ACTUAL WARM WATER LAKE DATA



$R^2=0.29$; 80th percentile overestimates regression by 33%

WARM WATER VARIABILITY

Colorado Warm Water Lakes



Confidence Interval for 20 ug Chl-a/L: 50 – 300 ug TP/L

SUMMARY OF LAKE MECHANISMS TO CONSIDER IN CRITERIA DERIVATION

- Chl-a Threshold
 - Use designation
 - Aquatic life
 - Drinking water
 - Agricultural
 - Fishery type
 - Cold
 - Warm
 - Rough (carp/bullheads)
 - Morphology
 - Depth
 - Size of watershed
 - Natural vs Man-made
- Factors affecting TP-Algal biomass relationship
 - Areal loading rate
 - Transparency
 - Residence time
 - Thermal stratification
 - Aquatic life
 - Bottom-feeding fish
 - Grazer population
 - Sediment kinetics
 - Emergent Plants

SUGGESTED LAKE APPROACH

- Set chl 'a' targets to fit primary use/physical setting for each reservoir
- Unmanaged lakes use AQ life protection
- Chose range of acceptable TP concentration to meet target
- Use site-specific data to pick value within range
- Outside of range – site specific standard
- TN Control – site specific determination

A blue-tinted photograph of a vast ocean under a cloudy sky. The word "STREAMS" is centered in white text.

STREAMS

SAB CONCLUSIONS RELEVANT TO STREAM PROPOSAL

[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)

STREAM CRITERIA

Use Class	TP	TN	MMI
Cold	90 ug/L	824 ug/L	66.5
Warm	135 ug/L	1,316 ug/L	57

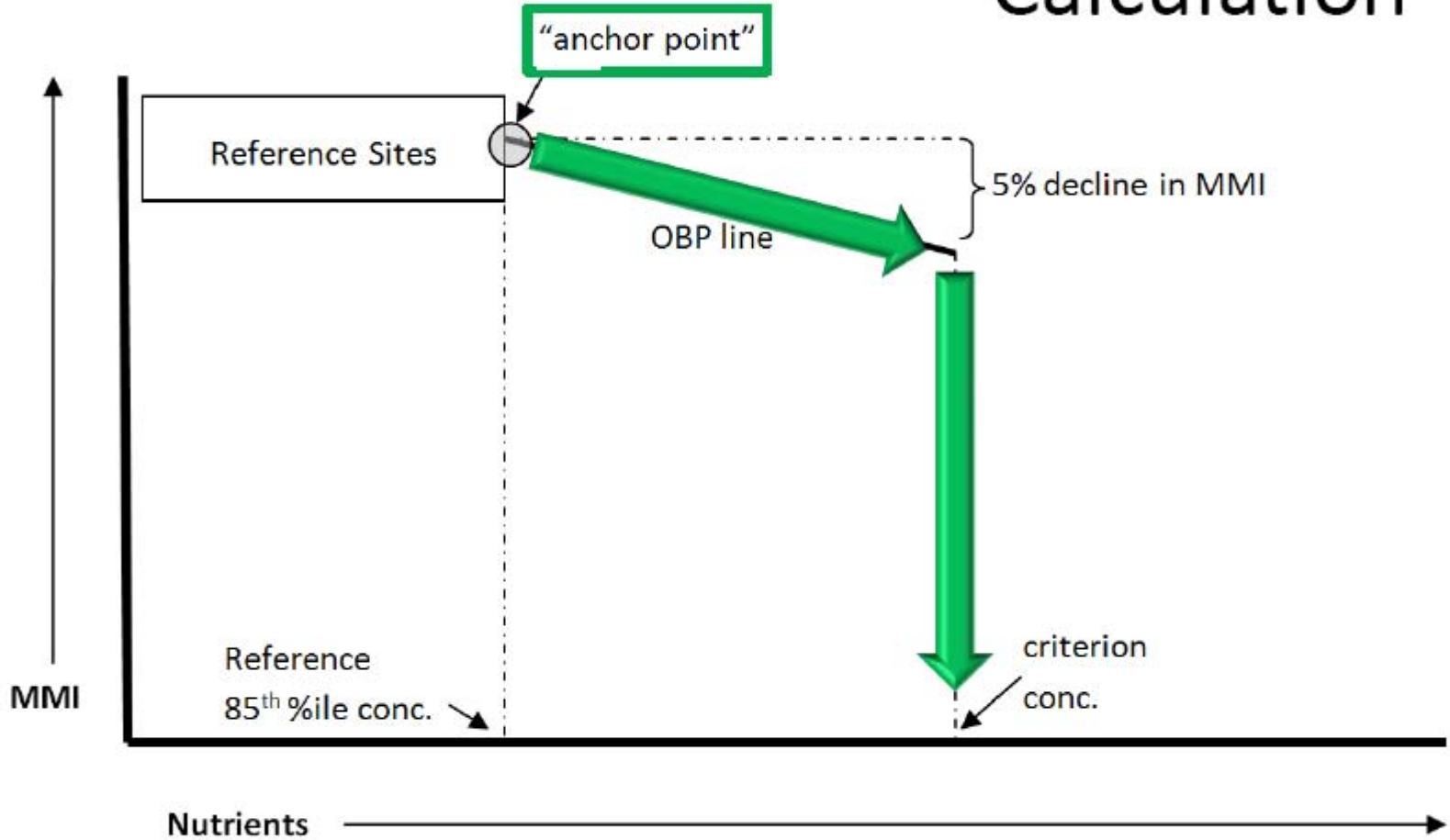
- MMI targets based on 5% reduction from Reference Stream median MMI
- Anchor Point set at 85%ile of Reference Stream nutrient concentration
- TP/TN: linear regression of Observed Biological Potential

Observation: *Nutrient control occurs ABOVE saturation growth rate concentration so no effect on plant growth level expected*

COLORADO STREAM APPROACH

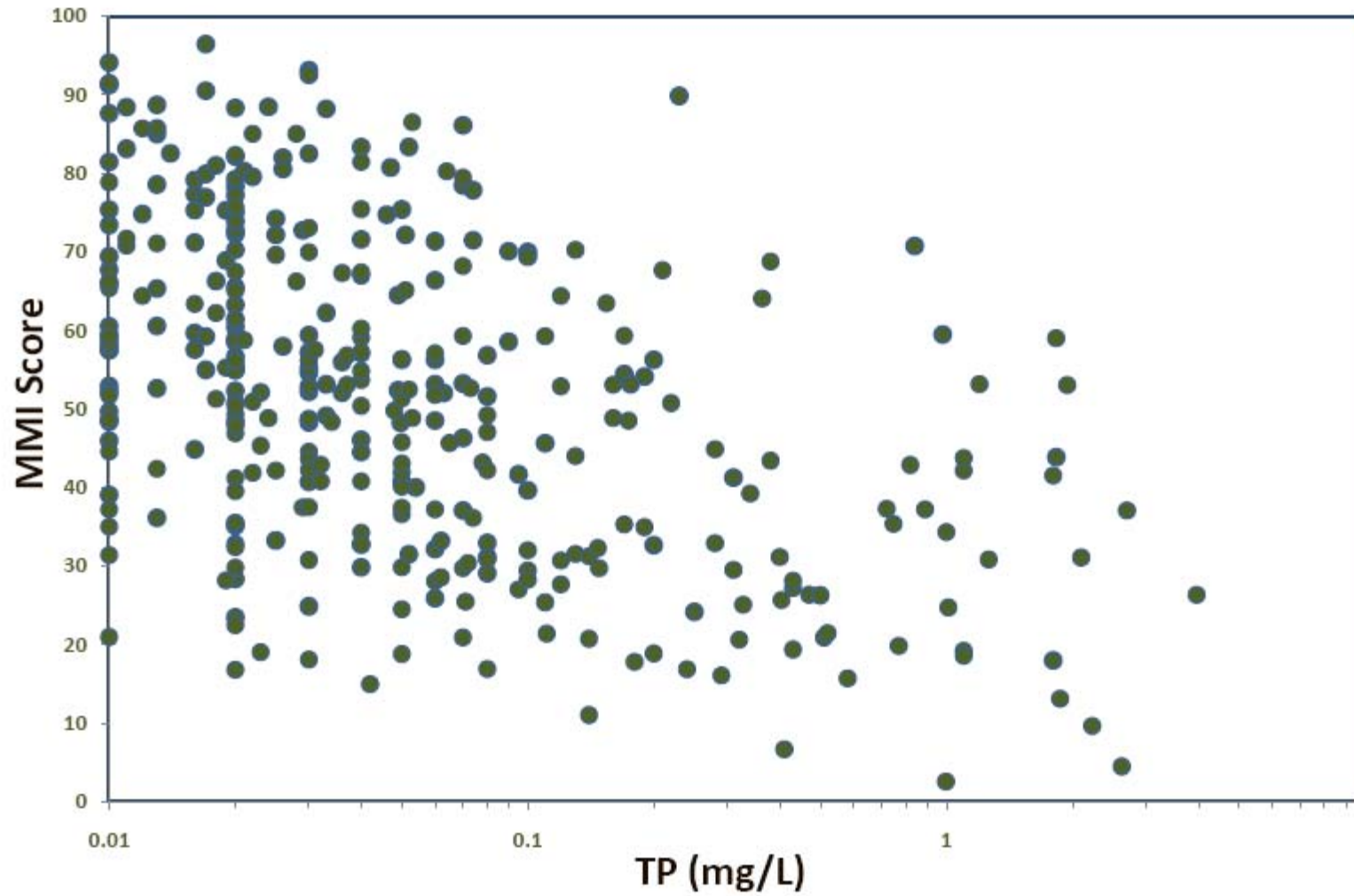
- MMI targets
 - Biologically significant, but
 - No demonstrated relationship to TP
 - Significant influence of confounding factors
- Plant Growth Ignored
- TP Criteria
 - Based on regression approach (\neq SAB findings)
 - Mechanistic Model Needed

Calculation

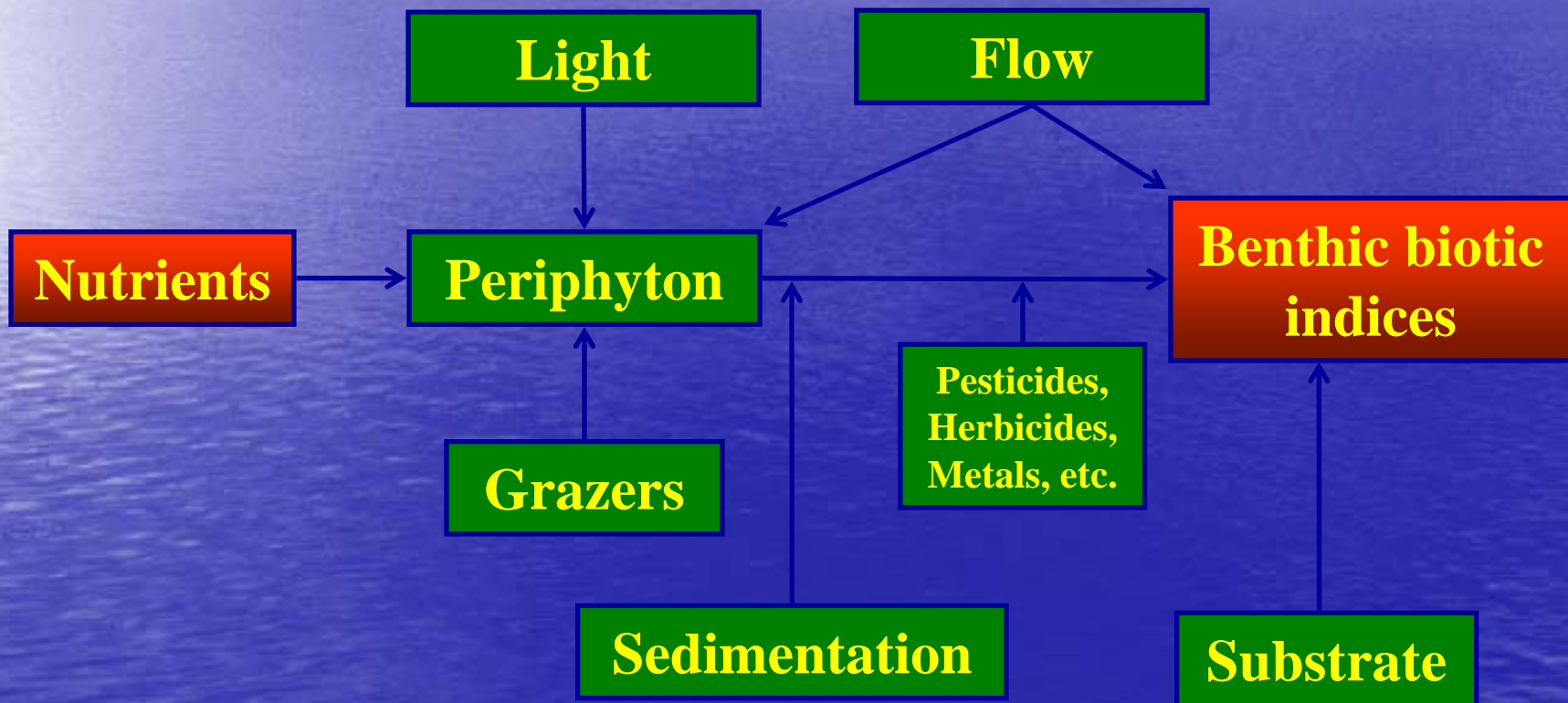


$$\text{Anchor} + (5\% \text{ decline} / |\text{slope}|) = \text{Criteria}$$

Wedge Plot



RELATIONSHIP BETWEEN NUTRIENTS AND BENTHIC LIFE IMPAIRMENT



CONSIDERATION OF FACTORS INFLUENCING NUTRIENT DYNAMICS/IMPAIRMENT METRIC, SAB Report

For criteria that meet EPA's stated goal of "protecting against environmental degradation by nutrients," the underlying causal models must be correct. Habitat condition is a crucial consideration in this regard (e.g., light [for example, canopy cover], hydrology, grazer abundance, velocity, sediment type) that is not adequately addressed in the Guidance. Thus, a major uncertainty inherent in the Guidance is accounting for factors that influence biological responses to nutrient inputs. Addressing this uncertainty requires adequately accounting for these factors in different types of water bodies. (at 36,37)

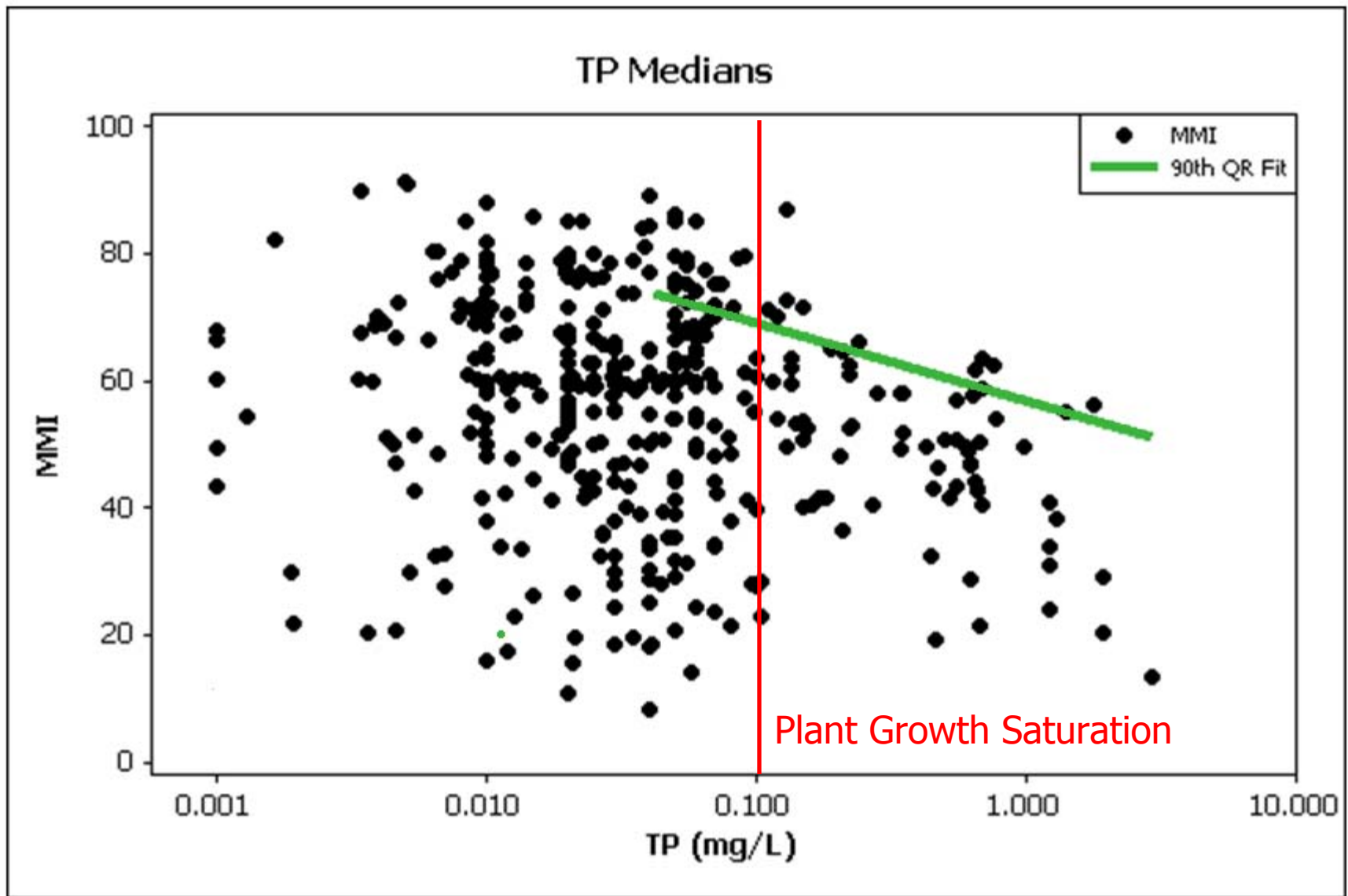
PERIPHYTON: TP RELATIONSHIP UPDATE

Dodds (2006)

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

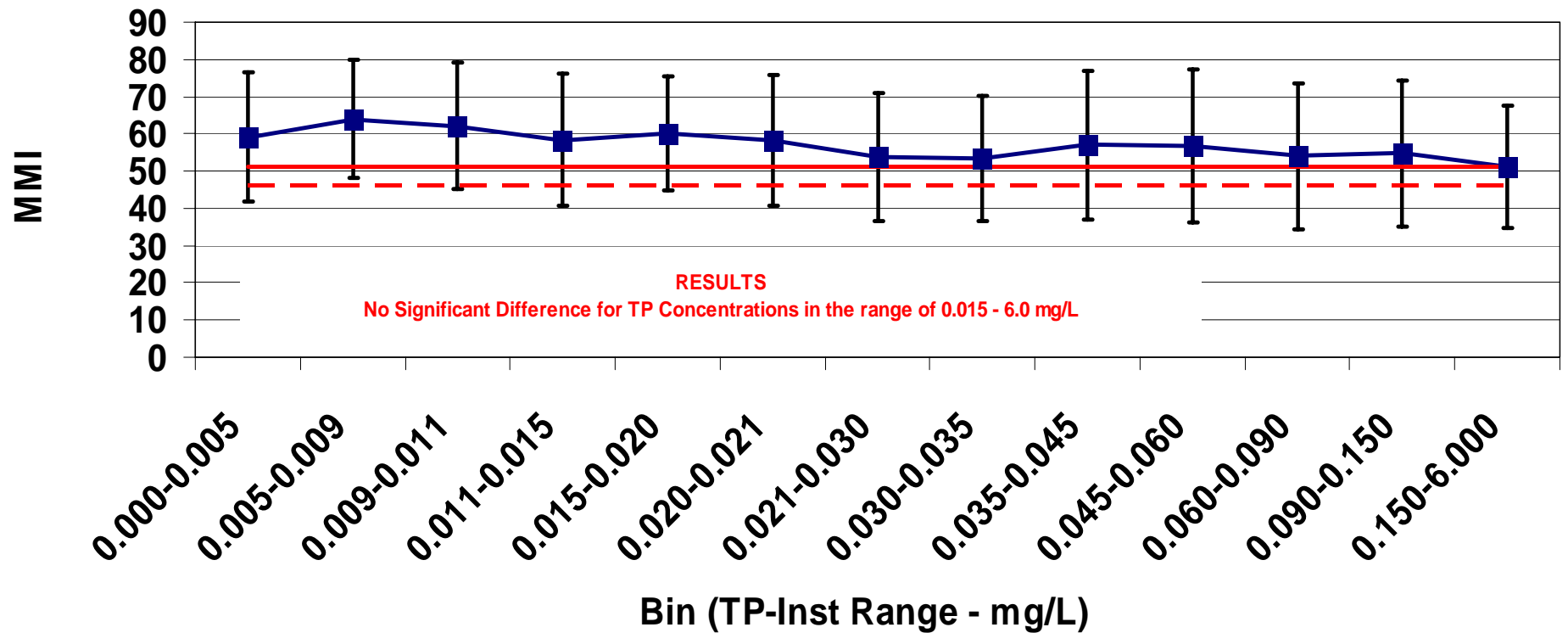
Paul and Zheng (2007)

The highest algal biomass [in PA targeted watersheds] occurred at sites where TP concentrations were relatively low (14 – 35 $\mu\text{g/L}$). [**Upstream of POTWs**]



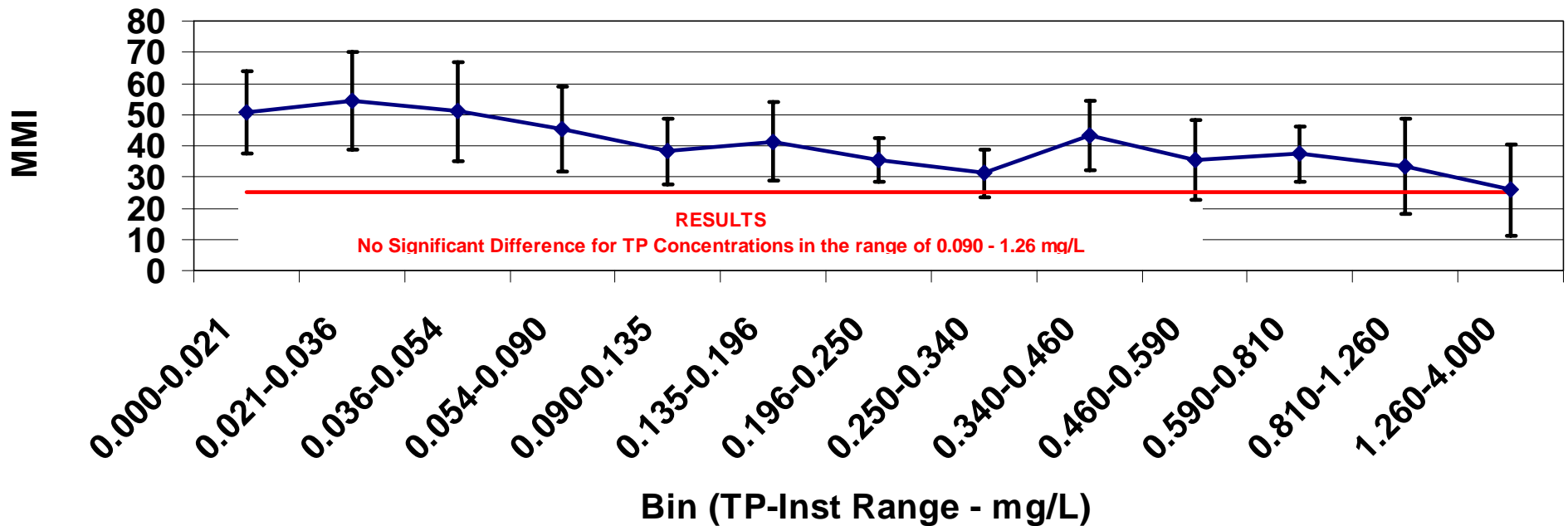
COLD WATER STREAMS

Colorado Cold Water Rivers and Streams: MMI vs Inst TP



WARM WATER STREAMS

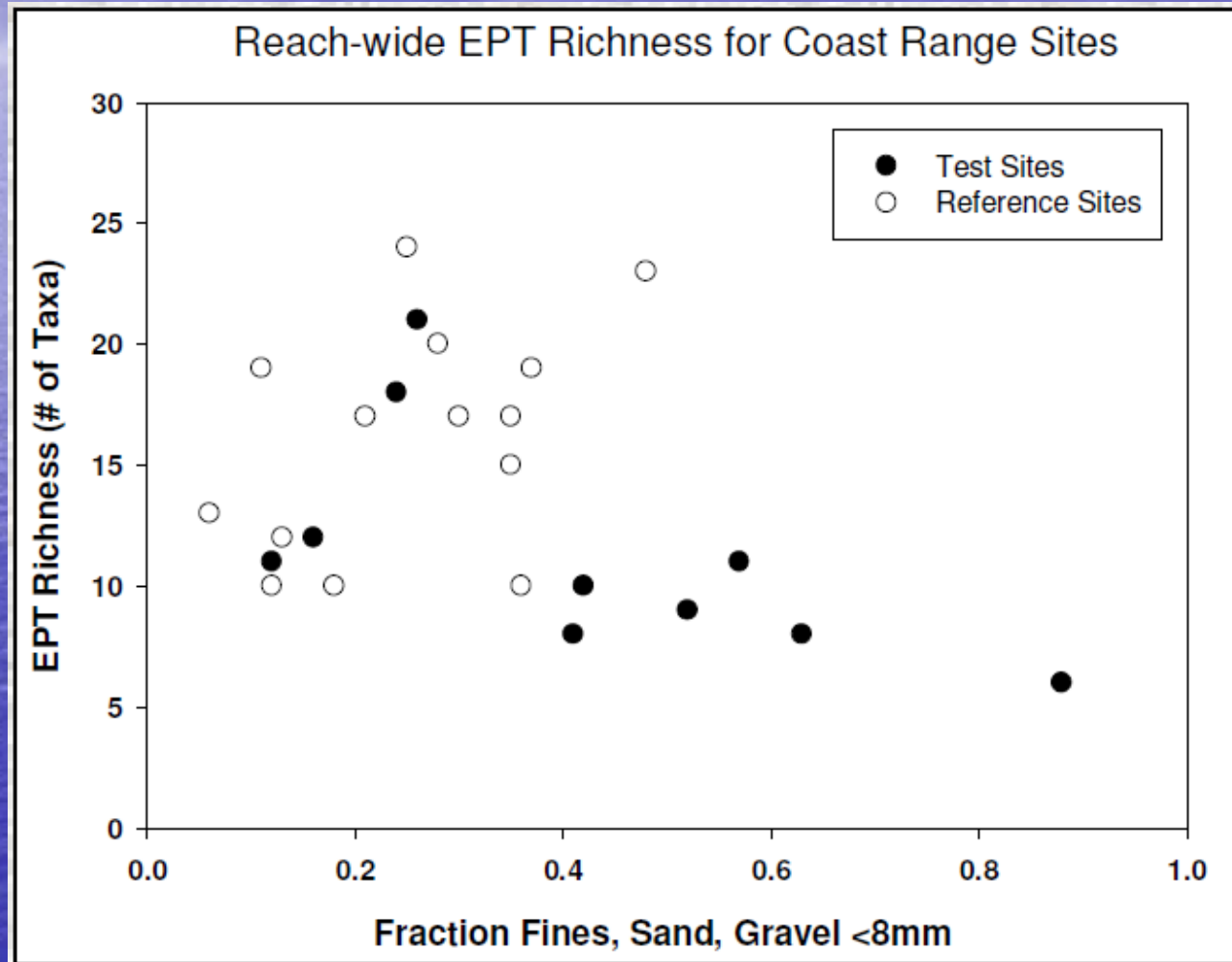
Colorado Warm Water Rivers and Streams: MMI vs Inst TP



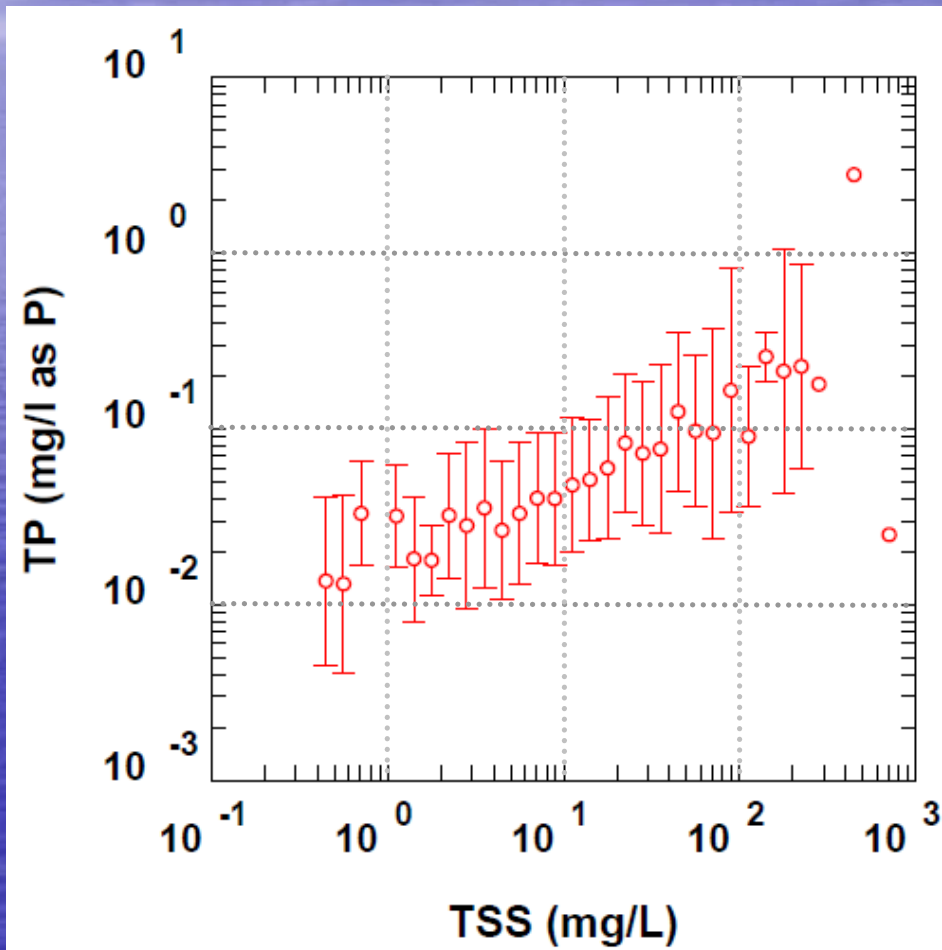
BIOLOGICAL SIGNIFICANCE/USE IMPAIRMENT THRESHOLD RELATIONSHIP, SAB Report

- The Committee emphasizes the importance of choosing the biological endpoints (i.e., response variables) that respond specifically to nutrients. We note that responses of benthic indices can be related to many types of stress. We question why periphyton would not be a better receptor to measure. (at 15)
- 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)

CONFOUNDING FACTORS MUST BE CONSIDERED



COVARYING FACTORS MUST BE CONSIDERED



Covariance of
Stream TP with
TSS (Panhandle
Region - Florida)

SUGGESTED MODIFICATION TO INITIAL PROPOSALS

- Use Narrative Approach to Set Site-Specific TN Standards Where Necessary to Protect Uses
- Lake Approach Likely Both Over/Under Protective
- Set Additional Subcategories for Lakes and Reservoirs
- Consider Site-Specific Reservoir Uses and Watershed Factors in Setting Chlorophyll-a Standards
- Set Range of Acceptable TP Concentrations and Use Site-Specific Water Body Response Data to Select TP Value
- Streams – Determine Trigger Value Considering SAB Recommendations
- Use Site-Specific Data To Confirm Nutrient Related Impacts