# Possible responses of non-tidal stream and river communities to Chesapeake Bay's "nutrient diet"

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Photo by Adam Griggs


**Project:**

• requested of ICPRB by Maryland Department of the Environment

**Funds:**

• American Recovery and Restoration Act (ARRA)

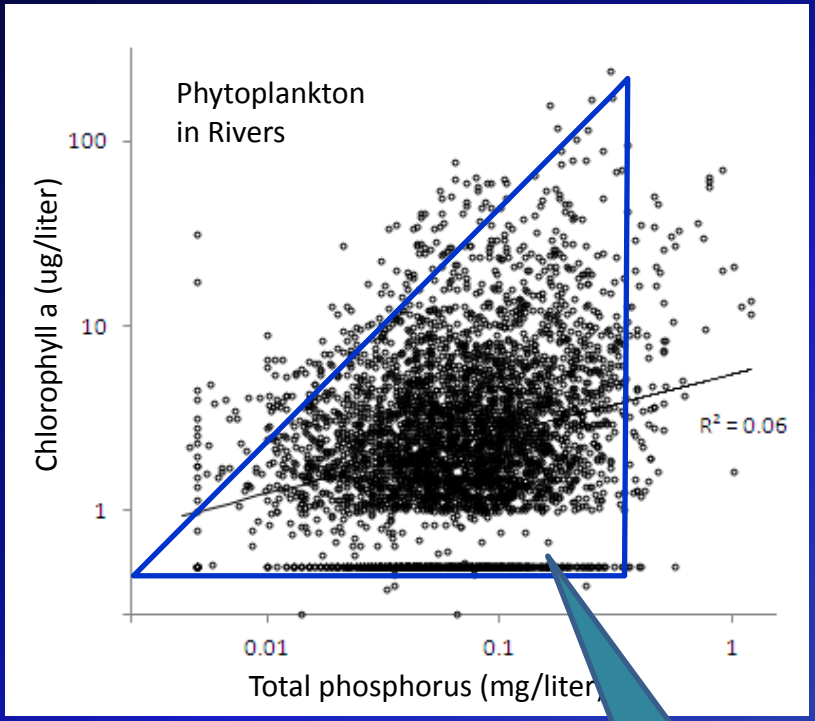
**Tasks:**

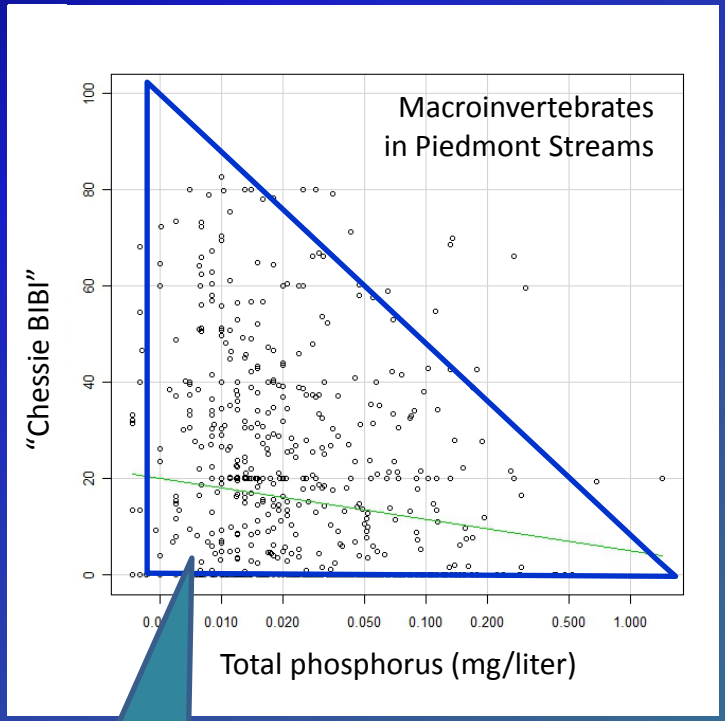
• suggest numeric criteria for nutrients in non-tidal streams and rivers,

• develop a methodology for practical application in Maryland in accordance with the Nutrient Criteria Development Plan for Maryland (MD)

# Challenge: Find TN & TP Responses Amongst Confounders

Stressor-Response graphs often produce a "classic wedge" with the biological response to nutrients obscured




*Low* Chl a in High [TP]

*Poor* BIBI Index in Low [TP]

# Data and Methodology

- Assemble and select stream & river data in Chesapeake Bay region for:

| Aquatic Group | Biometrics |
|---|---|
| Phytoplankton (MD, DE) | Water column Chl a |
| Periphyton (VA) | Attached Chl a, TP and AFDM content |
| Macroinvertebrates (MD, PA, VA) | 24 family-level metrics, Chessie BIBI |

**All biological samples have associated water quality & habitat data**

- Applied Recursive Partitioning (RPART)
  - produces a non-parametric decision tree with thresholds for splitting data
  - same as Category and Regression Tree Analysis (CART)
  - used to identify and remove/account for factors confounding nutrient responses
  - suggests multiple nutrient thresholds

- Used RPART nutrient thresholds to create a series of nutrient Bins
  - TN and TP are considered together in relative absence/context of non-nutrient stressors
  - bins are bioregion-specific when bioregion is an important factor

very low TN + very low TP → …. → high TN + high TP

# Factors Confounding Nutrient Responses

- Macroinvertebrate in 1st – 4th order streams

  remove records with:

  - high conductivity, by bioregion (>200 - 340 µmhos/cm)
  - marginal/poor in-stream habitat quality index by bioregion (<25 - 35 of 60)

    *index = riffle-frequency or riffle-quality + epifaunal substrate quality + embeddedness*
  - extreme pH levels (<6, >9) and low dissolved oxygen (<5 mg/liter)

- Periphyton in 1st – 4th order streams

  remove records with:

  - marginal/poor stream bank metrics (≤10 of 20)

    *bank stability, bank vegetation, channel alteration, riparian vegetation , cover*
  - exposure to karst geology
  - high conductivity (? µmhos/cm)

altered streamflow will impact physical habitats

- Phytoplankton in 5th – 7th order Piedmont/Ridges/Valleys rivers and in 1st – 5th order Coastal Plain streams and rivers

  include with TP and TN when creating bins:

  - water clarity (surrogate = turbidity)
  - dissolved organic carbon

# Nutrient Responses are Clearer When Confounded Samples are Filtered from Analysis

%Chironomidae
(non-biting midges)
in Coastal Plain

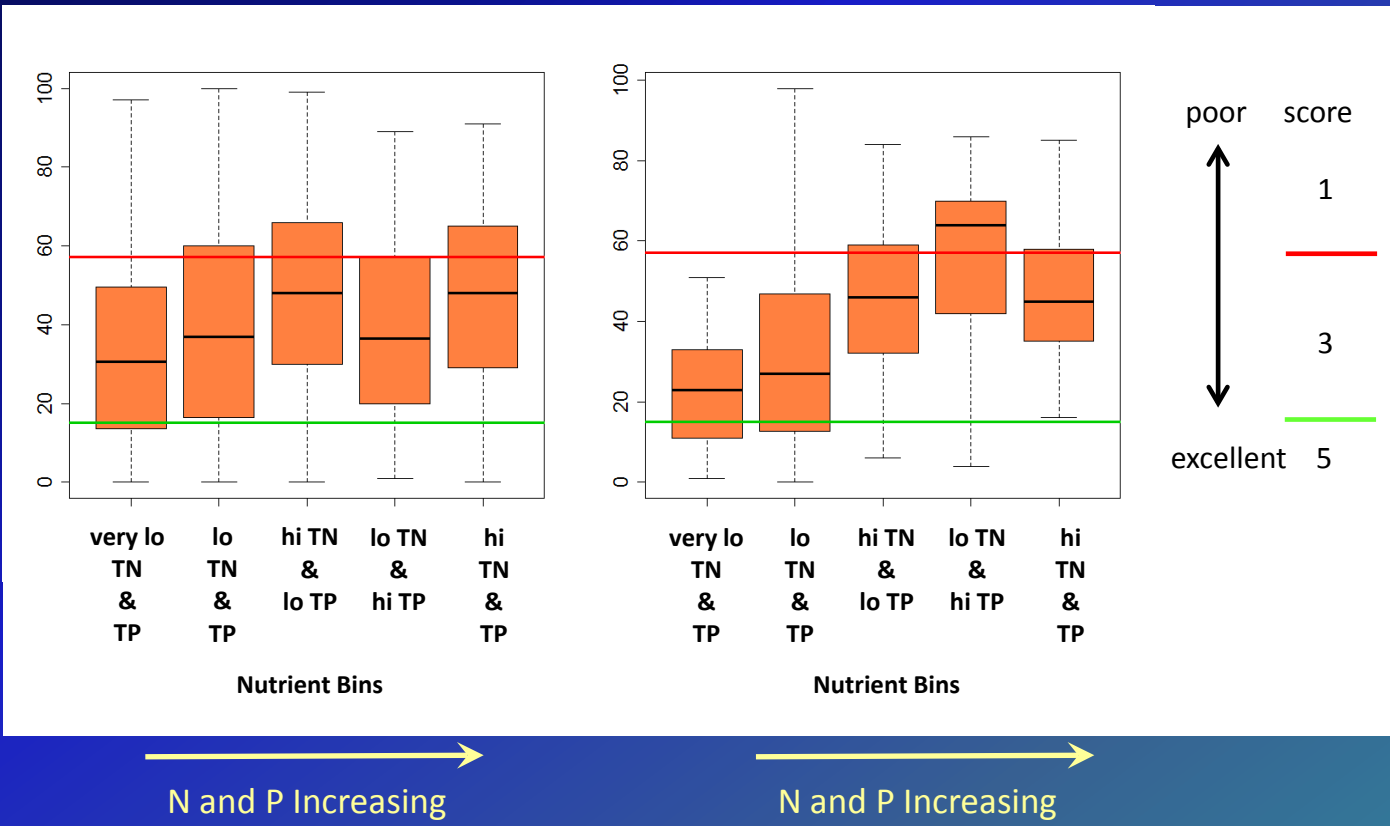
percentage increases with nutrient enrichment

## Unfiltered Data

contains all data,
confounded or otherwise

## Filtered Data

contains only subset
of un-confounded data




N and P Increasing

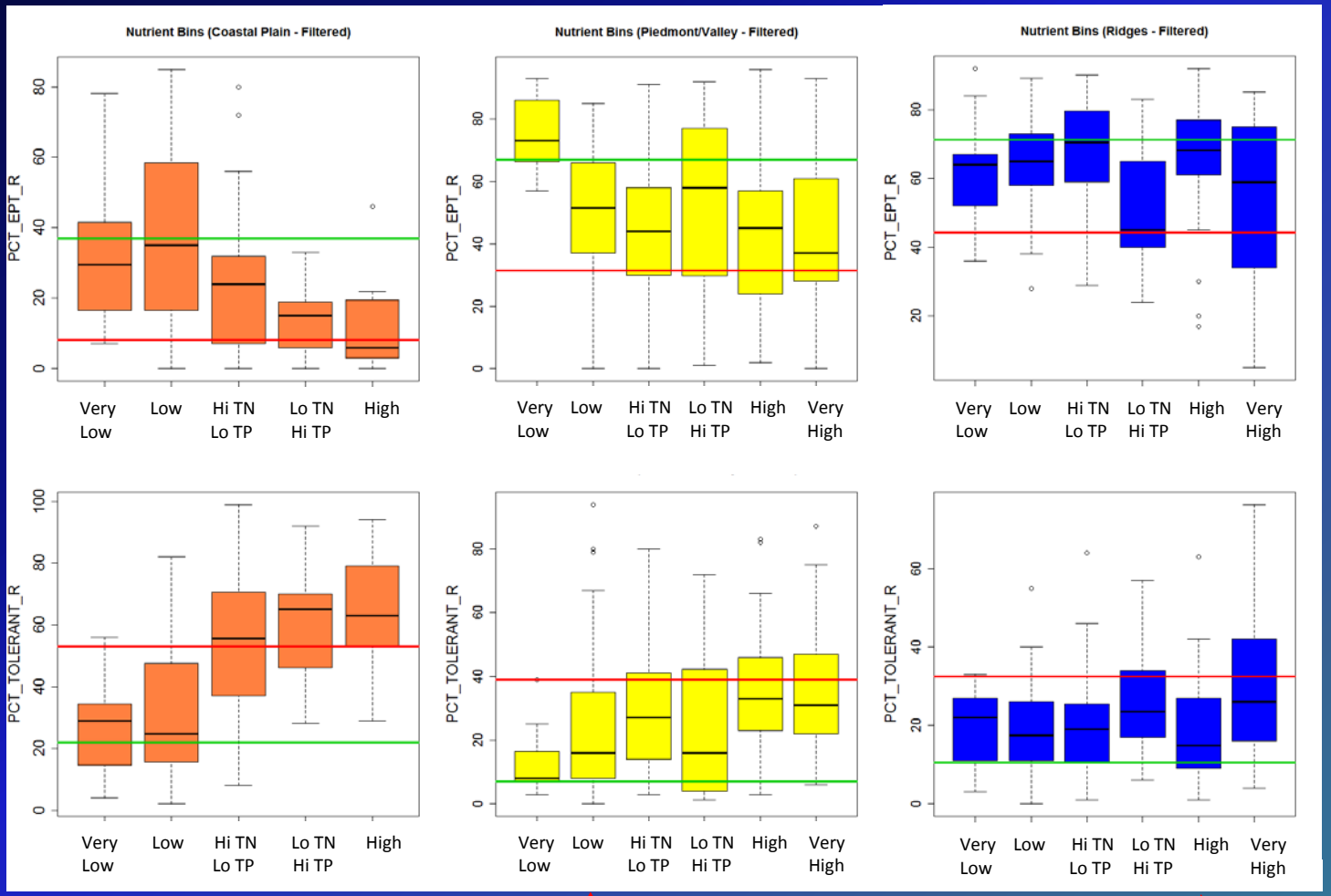
N and P Increasing

# Macroinvertebrates
(MD with some VA & PA)

- Most of the 24 family-level metrics show nutrient responses when confounders are removed

Coastal Plain | Piedmont/Valley | Ridges

% EPT




Excellent ↕ Poor

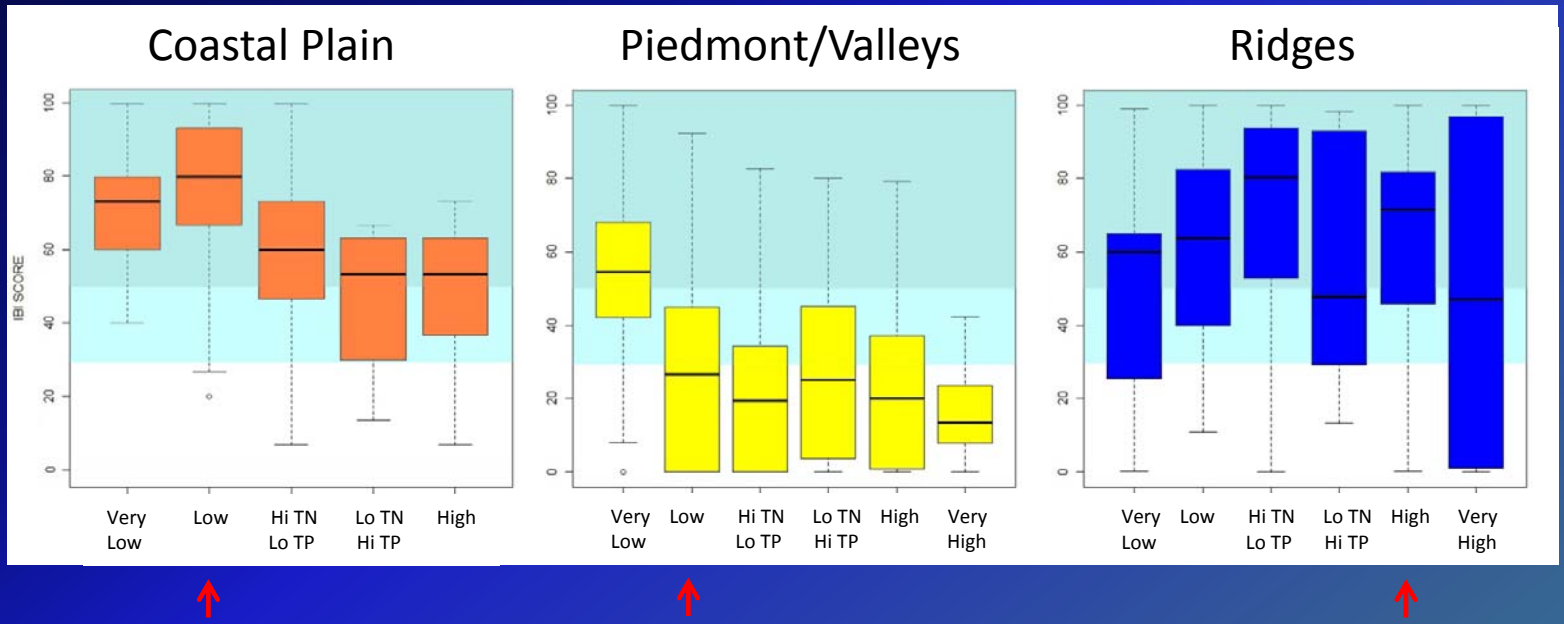
% Tolerant

Poor ↕ Excellent

↑ *roughly* comparable [TN] and [TP]

# Macroinvertebrates
(MD with some VA & PA)

- Chessie BIBI* shows nutrient responses when confounders are removed



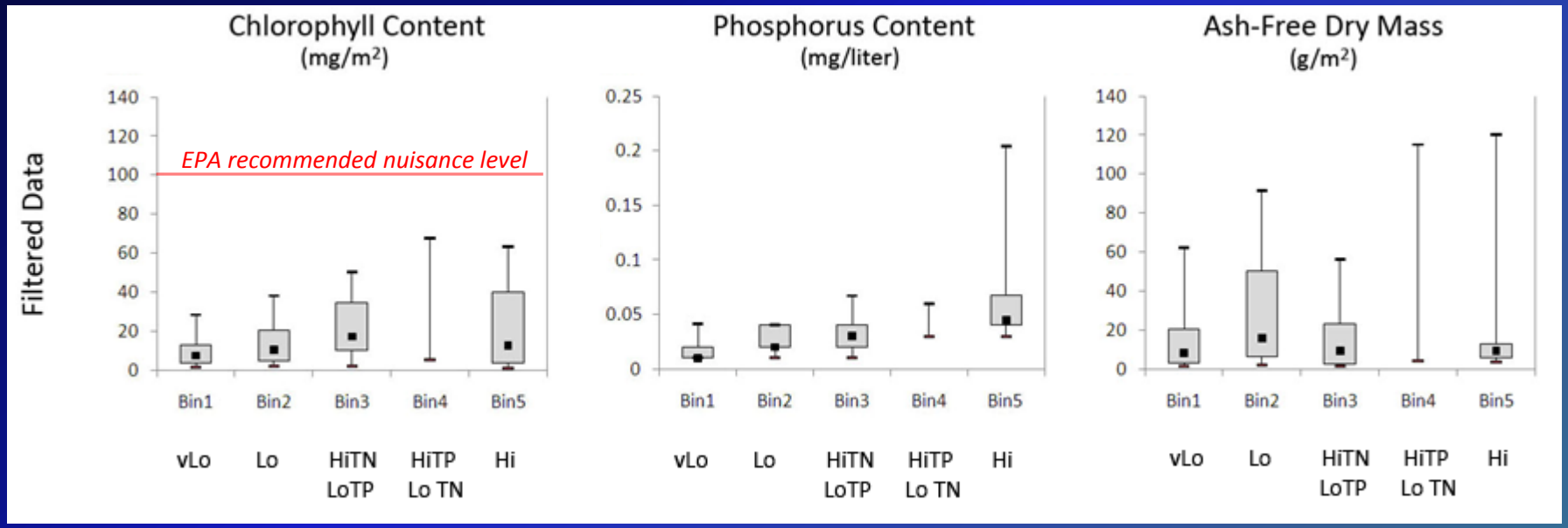

* a multi-metric macroinvertebrate index of biotic integrity for streams in the Chesapeake Bay watershed

# Periphyton

Piedmont & Ridge-Valley Streams (VA)

- Not all periphyton metrics respond to water column TN and TP – possibly because periphyton consists of heterotrophs (fungi, bacteria) as well as algae

*…responds* *…responds* *…doesn't respond*



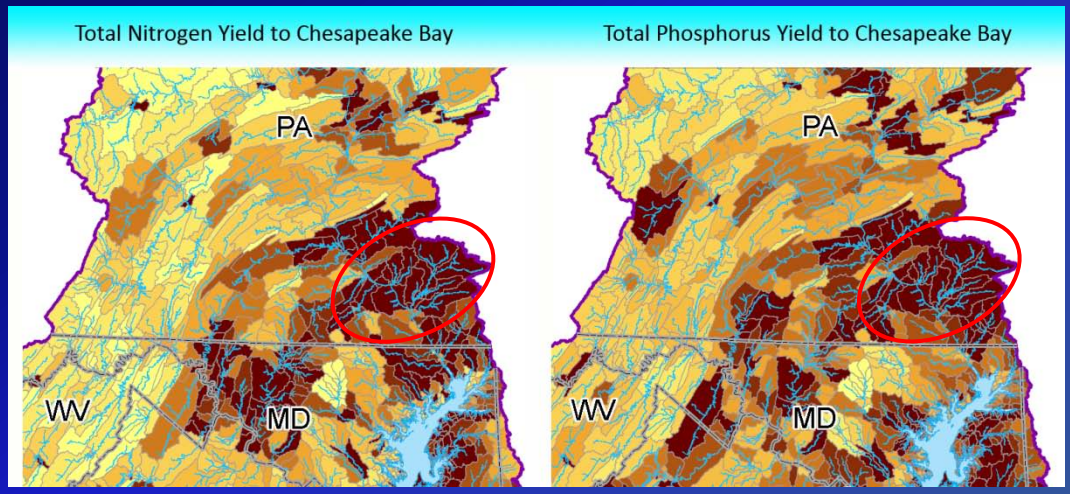

N and P Increasing

Reminder: data filtered to exclude sites with marginal/poor habitat scores, high conductivity, and karst geology.

# Periphyton

Piedmont Streams in Highly Enriched Conestoga River Watershed (SRBC, PA)

- No clear-cut nutrient responses when all waters are heavily enriched with TN and TP




Source: www.chesapeakebay.net

Conestoga River watershed:

- average yearly concentrations of TN and TP at monitoring stations are high
  - TN: 0.39 – 17.71 mg/liter
  - TP: 0.013 – 0.663 mg/liter
- conductivity and total alkalinity levels are high
- many sites have poor habitat (stream bank) conditions

~ 72% of periphyton samples are above “nuisance” level of >100 Chla mg/$m^2$

# Phytoplankton

Piedmont & Ridge-Valley
Large Rivers (MD)

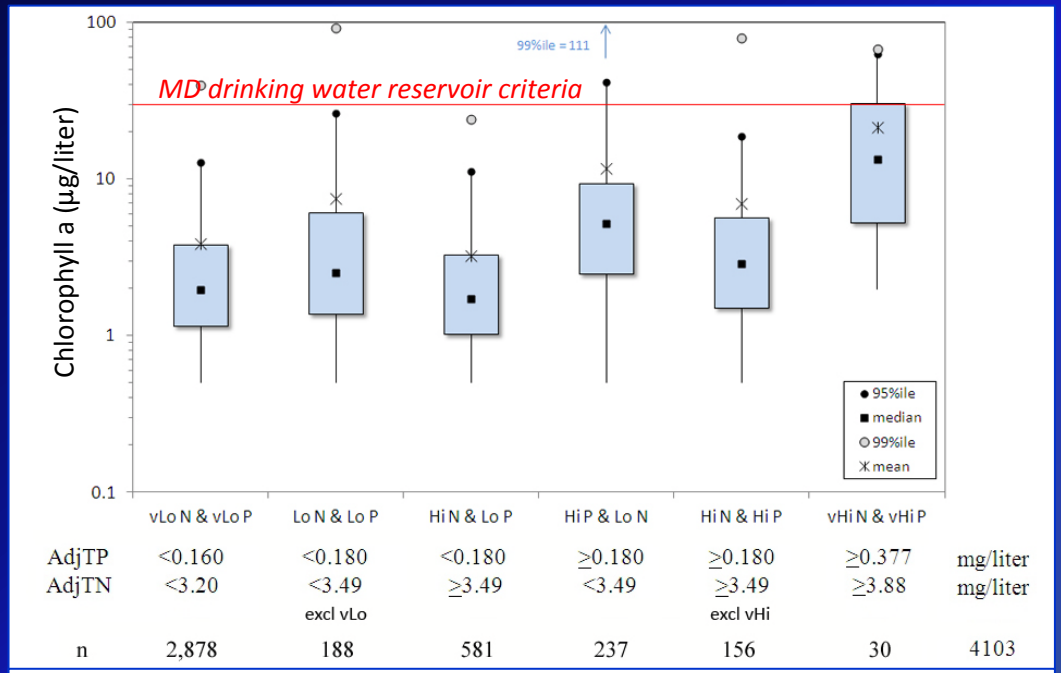
Light is an essential resource for phytoplankton

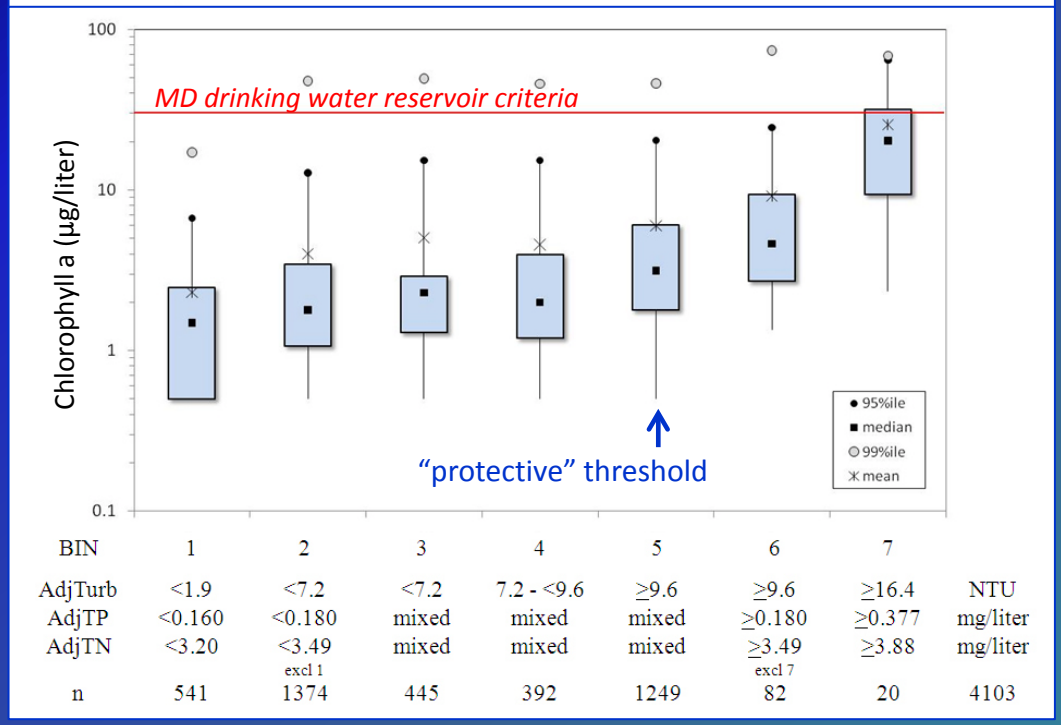
- Binning approach is not successful when light condition is *not* considered

- Analysis approach is successful when light condition *is* considered

  - Used Turbidity as a surrogate for light attenuation

  - TN, TP, and Turbidity concentrations in the analysis adjusted to remove phytoplankton component




Increasing nutrients →

# Phytoplankton

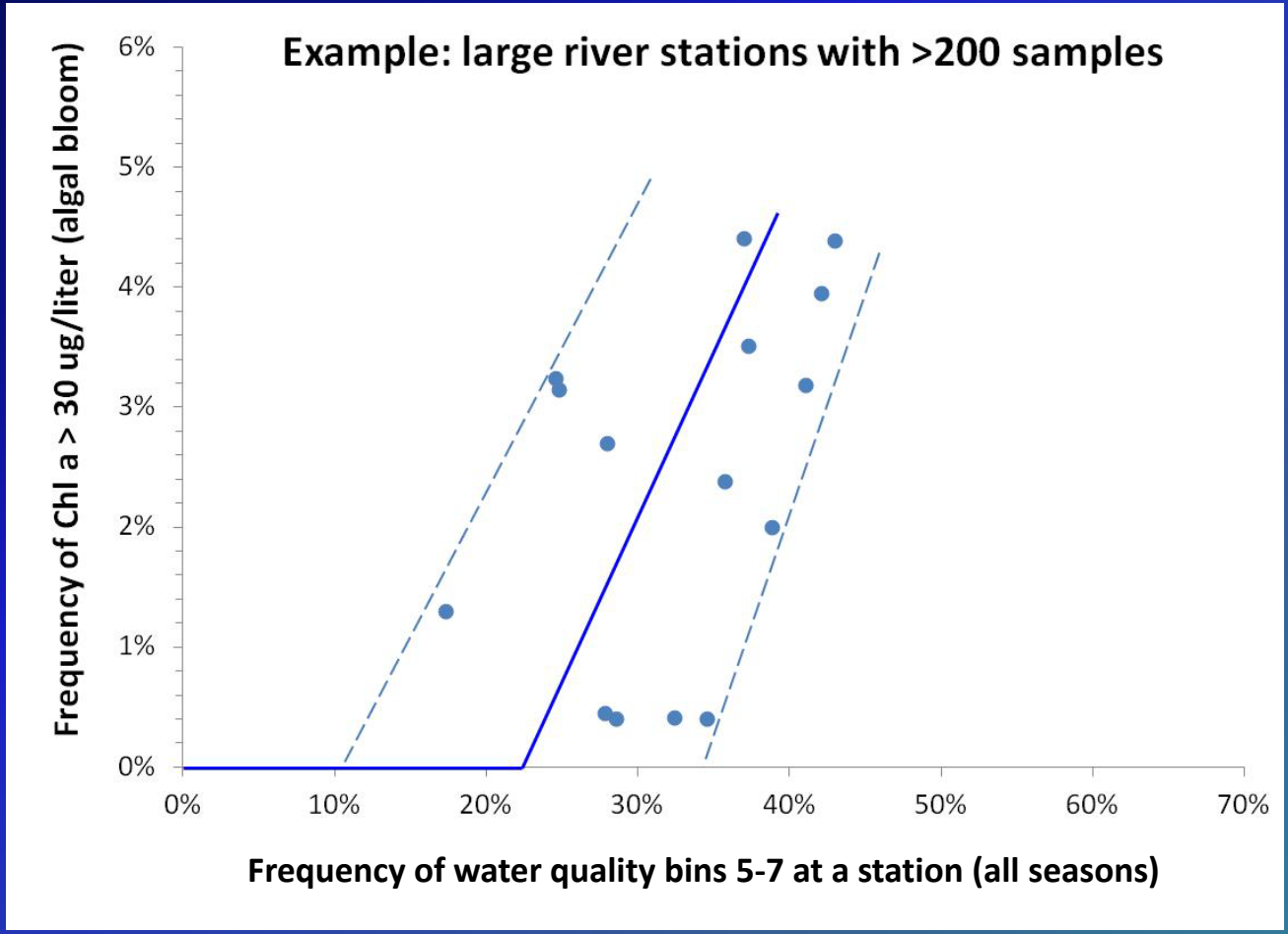
Piedmont & Ridge-Valley Large Rivers (MD)

- The mean Chl *a* concentration can indicate the likelihood of algal blooms (Walker 1984)
- The frequency of turbid, nutrient-enriched waters can indicate the likelihood of algal blooms

When the frequency of water quality bins 5-7 at a station exceeds ~22%, the probability of Chl a > 30 ug/liter (algal blooms) increases above zero

and

when the frequency of bins 5-7 is ~40% at a station, there is presently a 1 in 20-25 probability that monthly samples will have Chl a > 30 ug/liter.



# Phytoplankton

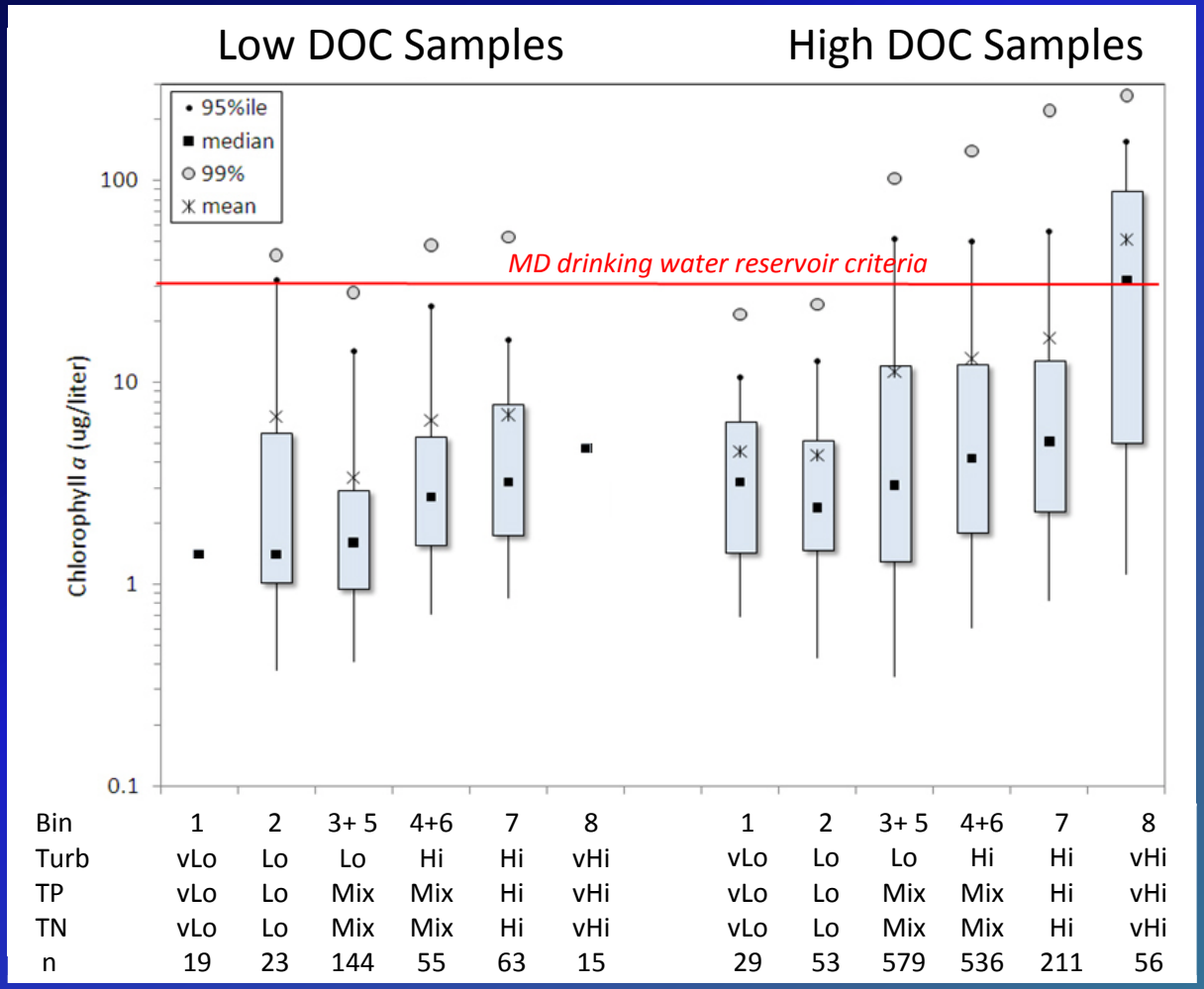
Mid-Atlantic Coastal Plain Streams & Rivers (MD, DE)

Slow moving waters in Coastal Plain make water column Chl *a* a useful indicator in streams as well as rivers

- Nutrient responses in "blackwaters" (high DOC) are somewhat exaggerated

1. proportions of TN and TP "species" differ
2. DOC also attenuates light

- Local water chemistry is important



# Major Findings

- Nutrient thresholds protective of high quality streams are clearly seen and excess nutrients significantly degrade aquatic communities

- Protective nutrient response thresholds are most evident when the impacts of confounding stressors are removed or accounted for
  - *In-stream habitat and riparian/bank conditions*
  - *Conductivity*
  - *pH*
  - *Dissolved Oxygen*
  - *Water clarity (phytoplankton)*

- Protective nutrient thresholds vary by biological group and/or by physiographic region

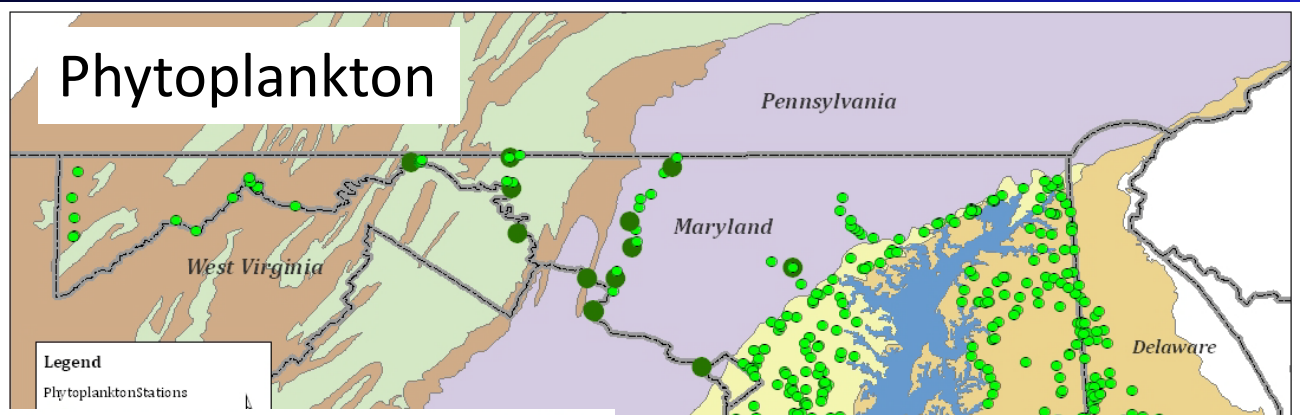
| | |
|---|---|
| TP | 0.012 – 0.087 mg/liter |
| TN | 0.58 – 2.67 mg/liter |
| Turbidity | 4.7 – 10.0 NTU (phytoplankton only) |

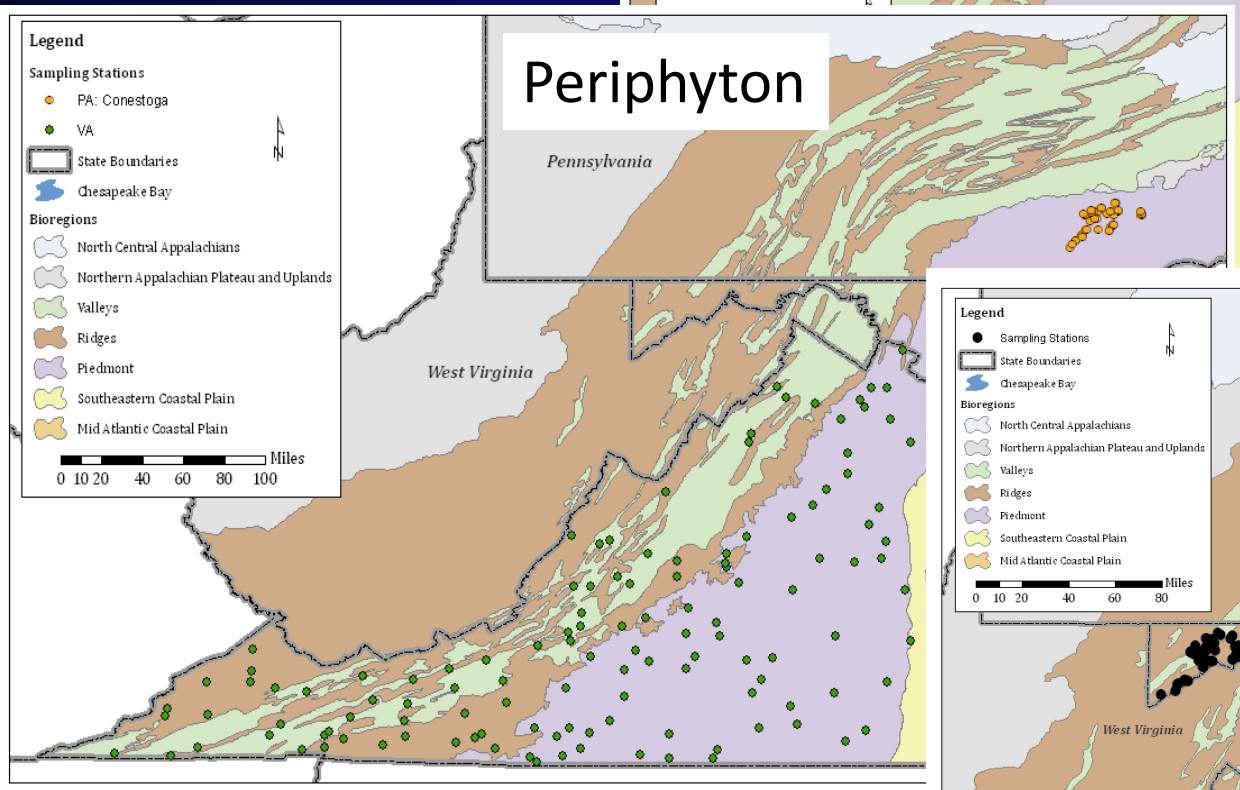
# Major Findings

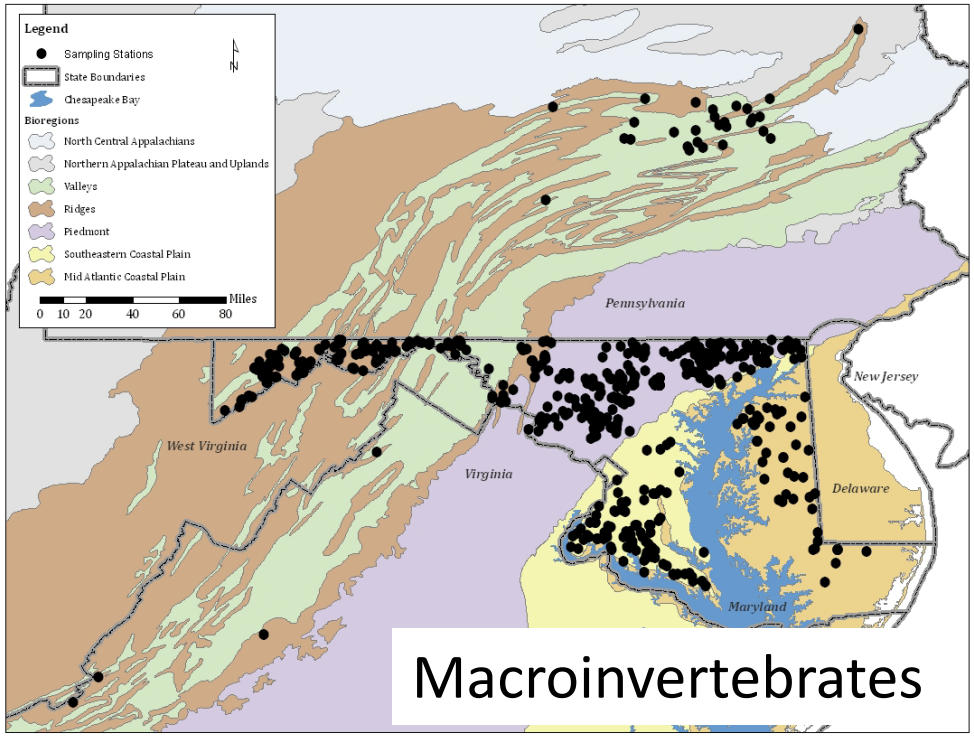
- Degraded communities are not necessarily “impaired”
- Macroinvertebrates appear to have lower TN and TP thresholds than the two algal types
- In “blackwaters” (high DOC), TP thresholds are higher and TN thresholds are lower, suggesting thresholds are affected by differences in regional water chemistry
- Degradation caused by excess nutrients is likely occurring even when masked by confounding stressors, but impacts are difficult to quantify
- In rivers and streams, nutrient impacts on aquatic communities might be secondary to other stressors

Will streams and rivers in Chesapeake Bay watershed benefit directly from Bay TMDL nutrient reductions?

CAVEAT:
Answer reflects the locations of the "filtered" data used in study



# Phytoplankton (Chlorophyll *a*) Sampling Events

| Data are from MD and DE portions of Chesapeake Bay watershed | Piedmont/ Ridges/ Valleys Rivers (≥5th order) | Coastal Plain Rivers and Streams |
|---|---|---|
| # of Chl *a* samples with TN, TP, DOC and turbidity data: | 741 | 3255 |
| % stressed by high turbidity and excess nutrients<br>• Direct nutrient TMDL benefit is not quantifiable or immediately obvious? | 35% | 11% |
| % stressed by high turbidity but not by nutrients<br>• **NO direct nutrient TMDL benefit** | 10% | 25% |
| % stressed by excess nutrients but not by turbidity<br>• Direct nutrient TMDL benefit | 8% | 34% |
| % not stressed by nutrients or turbidity<br>• **NO direct nutrient TMDL benefit** | 47% | 30% |

# Macroinvertebrates Sampling Events

| **Data are from portions of MD, PA, and VA in Chesapeake Bay watershed** | **Coastal Plain** | **Piedmont** | **Valleys** | **Ridges** |
|---|---|---|---|---|
| # of samples with full suite of water quality data: | 778 | 557 | 116 | 261 |
| % stressed by pH, DO, conductivity, and/or habitat quality as well as excess TN and/or TP<br>• Direct nutrient TMDL benefit is not quantifiable or immediately obvious? | 77% | 56% | 64% | 41% |
| % stressed by excess TN and/or TP (conductivity, DO, pH, and habitat quality are all in acceptable ranges)<br>• Direct nutrient TMDL benefit | 9% | 33% | 14% | 3% |
| % not stressed by TN, TP, or other water quality parameters<br>• **NO direct nutrient TMDL benefit** | 14% | 11% | 22% | 56% |

# Conclusions

- Significant numbers of stream and river sites do not need nutrient reductions to protect local water quality because they have TN and TP concentrations below the protective thresholds

- For streams impacted by excess nutrients ***and*** confounding factors, nutrient reductions may not be effective in improving local stream condition unless confounding stressors are also addressed

- Additional data and analysis will clarify best course of action for each stream


ICPRB Report 11-2 available online at:
www.potomacriver.org, "Publications" tab, "ICPRB Publications"

*Photo by Adam Griggs*

# Compilation of Protective Nutrient Thresholds*

| Desirable levels (biology) | Phytoplankton<br>Chl *a* <30 ug/liter | | | | | | Periphyton<br>Chl *a* <100 mg/m$^2$ | Macroinvertebrate<br>avg. score of the nutrient-sensitive metrics is ≥3 in ≥80% samples | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Physiographic Region(s) | Piedmont, Ridges, & Valleys | | Mid-Atlantic Coastal Plain (MACP) | | Southeastern Plain (SEP) | | Piedmont, Ridges, & Valleys | Piedmont & Valleys | Ridges | Coastal Plain (MACP & SEP) |
| Strahler Stream Order | 5$^{th}$ – 7$^{th}$ | | 1$^{st}$ – 5$^{th}$ | | 1$^{st}$ – 5$^{th}$ | | 1$^{st}$ – 4$^{th}$ | 1$^{st}$ – 4$^{th}$ | 1$^{st}$ – 4$^{th}$ | 1$^{st}$ – 4$^{th}$ |
| DOC level | Lo | Hi | Lo | Hi | Lo | Hi | | | | |
| Median TP (mg/liter) | 0.036 | 0.087 | 0.012 | 0.030 | 0.059 | 0.085 | 0.050 | 0.012 | 0.013 | 0.029 |
| Median TN (mg/liter) | 2.44 | 2.37 | 2.36 | 2.15 | 2.67 | 1.19 | 0.93 | 1.13 | 0.85 | 0.58 |
| Light Co-Variant | | | | | | | | | | |
| Median Turbidity (NTU) | 10.0 | 10.0 | 5.0 | 4.7 | 6.3 | 8.9 | | | | |
| Median DOC (mg/liter) | 2.16 | 3.81 | 2.37 | 4.73 | 2.37 | 4.85 | | | | |

*Conditional requirements are met (confounding habitat and water quality factors are removed/accounted for)

# Diverse Macroinvertebrate Metrics Respond to Nutrients

| Selected Nutrient-Sensitive Metrics | | Coastal Plain | Piedmont/ Valleys | Ridges |
|---|---|---|---|---|
| Composition | % EPT | X | X | X |
| | # EPT Taxa | | | X |
| | % Plecoptera | X | | |
| Pollution/Disturbance | # Sensitive Taxa | | | X |
| | % Tolerant | X | X | |
| | Hilsenhoff FBI | X | X | |
| | % Chironomidae | | X | |
| | ASPT Modified | | | X |
| Feeding Guild | % Collector | | X | |
| Habit | % Swimmer | | | X |
| | % Clinger | X | | |

Baseline: select five nutrient-sensitive metrics, identify bins for which ≥ 80% of samples have an average metric score of ≥3 (1-3-5 scale)

Nutrient Thresholds: median TN and TP of last bin meeting baseline conditions