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

Presentation to the CBP Non-Tidal Water Quality Workgroup

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Photo by Adam Griggs

Will TMDL-driven nutrient and sediment load reductions also benefit Chesapeake Bay watershed's stream & river communities?

- Answer requires identifying nutrient and sediment thresholds associated with significant biological change

Analysis supported by Maryland Department of the Environment with funding from the American Recovery and Restoration Act

Data

Assembled stream & river data in Chesapeake Bay region for:

Aquatic Group	Biometrics
Phytoplankton (MD, DE) n= 7,419	Water column chlorophyll a (ug/liter)
Periphyton (VA) n = 139	Chlorophyll a content (mg/m^2) Phosphorus content (mg/liter) Ash-free dry mass, or AFDM (g/m^2)
Macroinvertebrates (all states) n = 8,789	24 family-level metrics representing - Community composition - Taxa richness - Pollution tolerance - Feeding Guild - Habit Group "Chessie" Basin-wide Index of Biotic Integrity

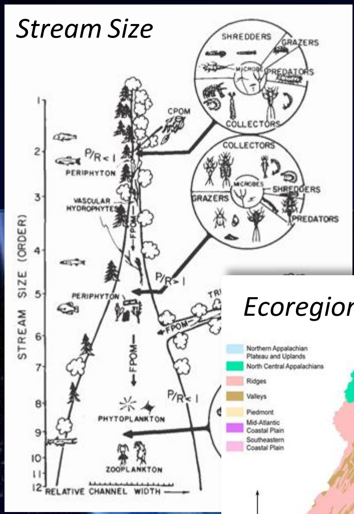
- Looking for biological samples associated with water quality & habitat data in order to identify and remove/account for factors that confound nutrient responses

Many Factors Confound Biological Responses to Nutrients

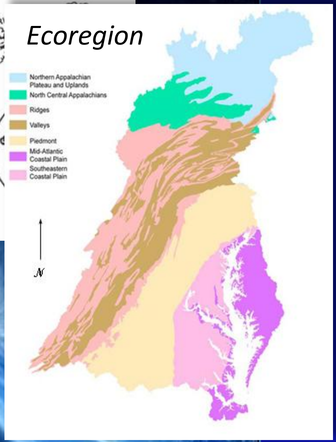
Natural Controls

Anthropogenic Stressors

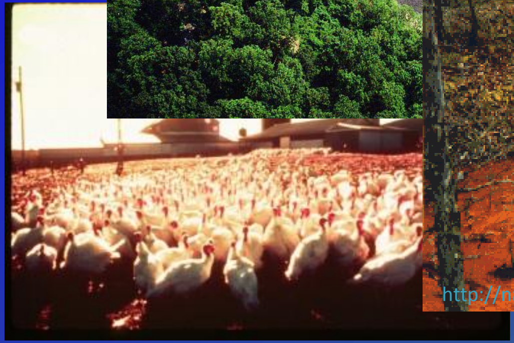
Stream Size



Ecoregion



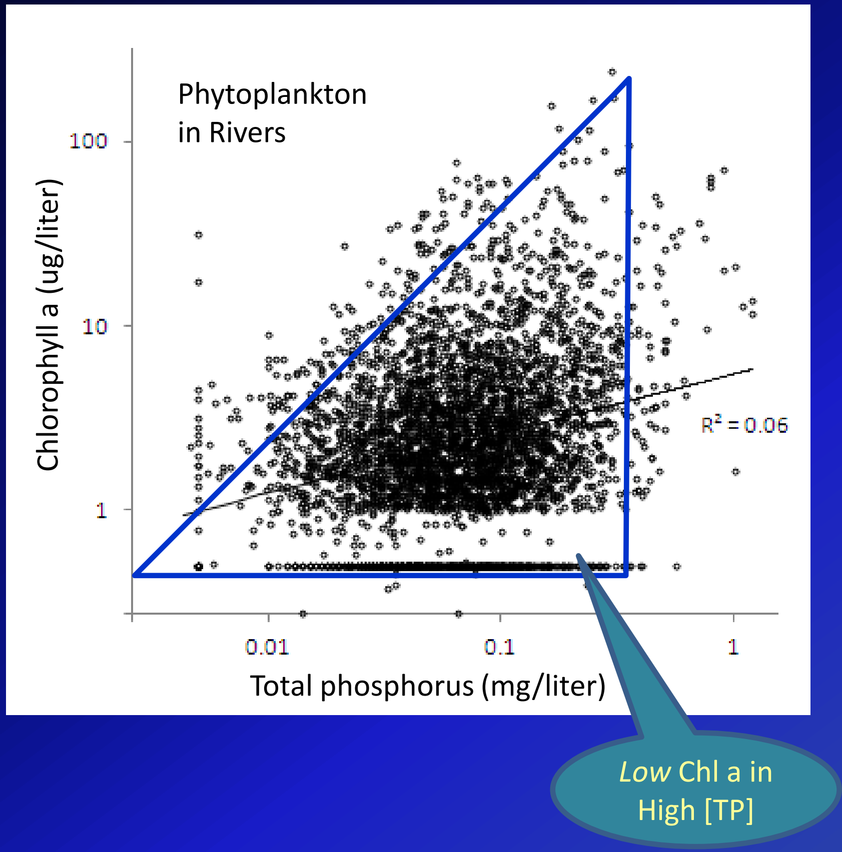
http://www.iowadnr.gov/

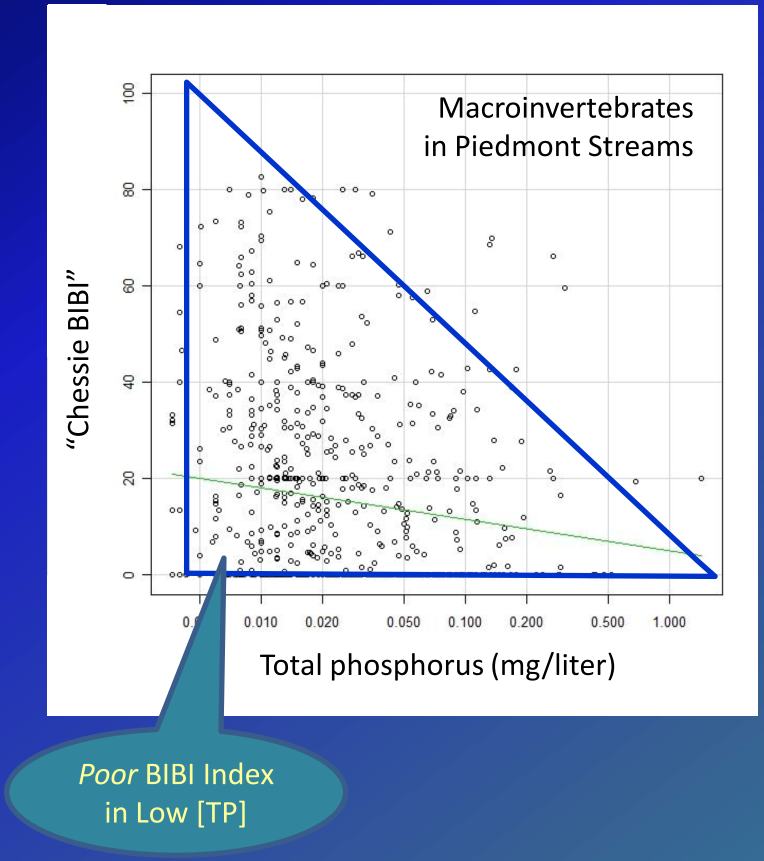


http://naturetourism.allegheny.edu/essay-acidminedrainage.htm

Challenge: Find N & P Responses Amongst Confounders

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





Several approaches are possible. Tried a recursive partitioning (RPART) method to find thresholds, followed by a "binning" approach which considers the environment and both nutrients simultaneously.

Factors Confounding Nutrient Responses

- **Macroinvertebrate in 1st – 4th order streams**

  remove records with:

  - high conductivity (~ >300 µmhos/cm)
  - marginal/poor in-stream habitat quality index (~ ≤30 of 60)

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

altered streamflow impacts physical habitats

- **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
  - exposed karst geology
  - high conductivity (? µmhos/cm)

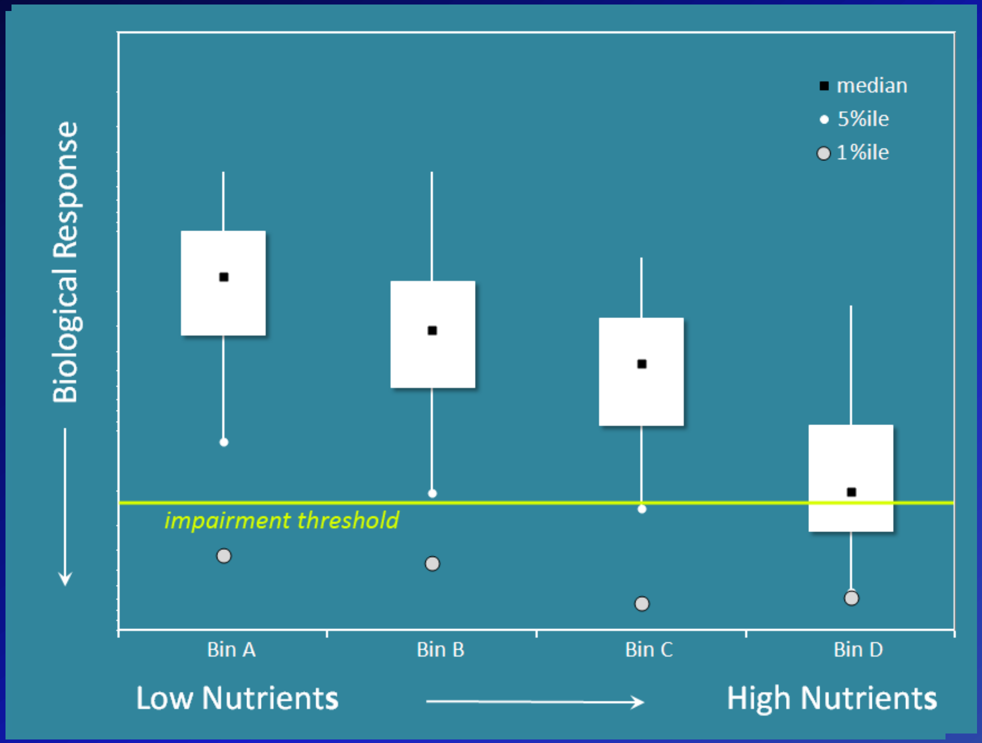
- **Phytoplankton in 1st – 5th order Coastal Plain streams and rivers and in 5th – 7th order Piedmont/Ridges/Valleys rivers**

  include with TP and TN when creating bins:

  - water clarity (surrogate = turbidity)
  - DOC

Water Quality "Bins" and Nutrient Thresholds

RPART thresholds for nutrients used to create distinct "bins"



no impairment	little/no impairment but median values are changing	some impairment	most impairment

Nutrient thresholds can be:
median TP
and
median TN
of this WQ bin

"Desirable biological communities will occur most of the time when…

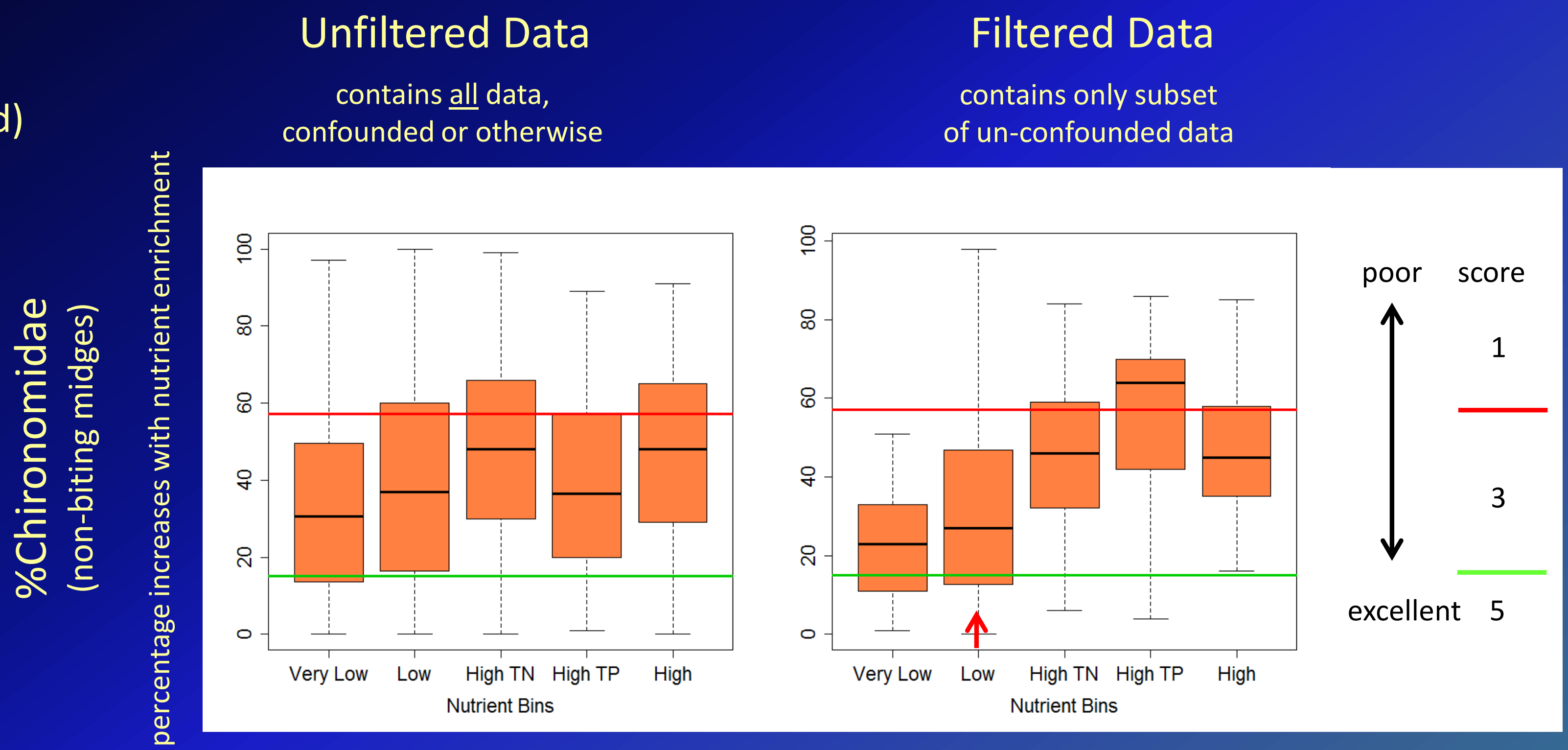
median [TP] ≤ threshold
and
median [TN] ≤ threshold
and
confounding habitat and water quality factors are removed/accounted for."

- *Notice resemblance to the TALU or Tiered Aquatic Life Use framework*

Macroinvertebrates

Coastal Plain

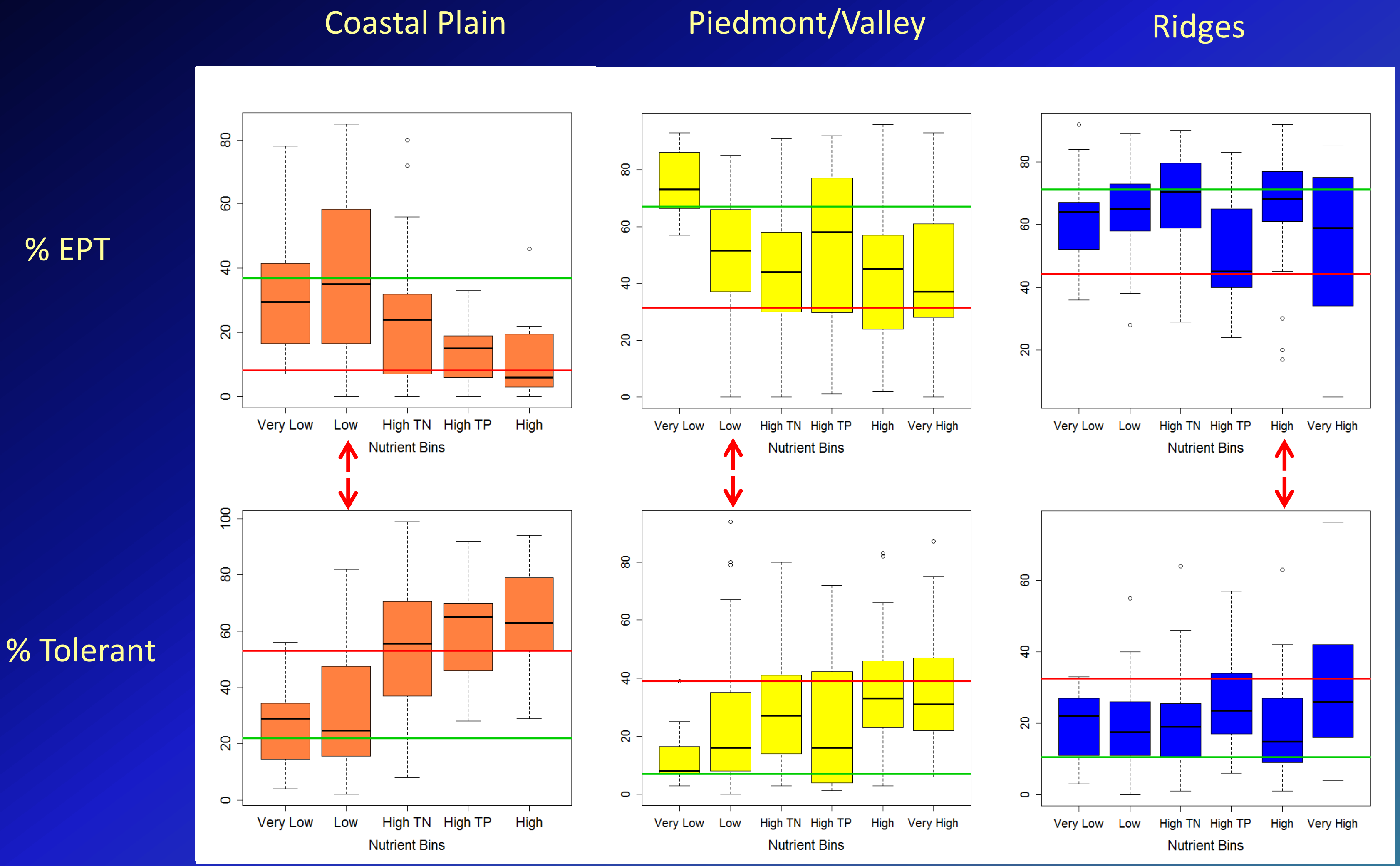
Unfiltered
(confounded)
data mask
nutrient
response



Macroinvertebrates

All Regions
Filtered Data

- Most of the 24 family-level metrics and the “Chessie” BIBI in each region show nutrient responses when confounders are removed



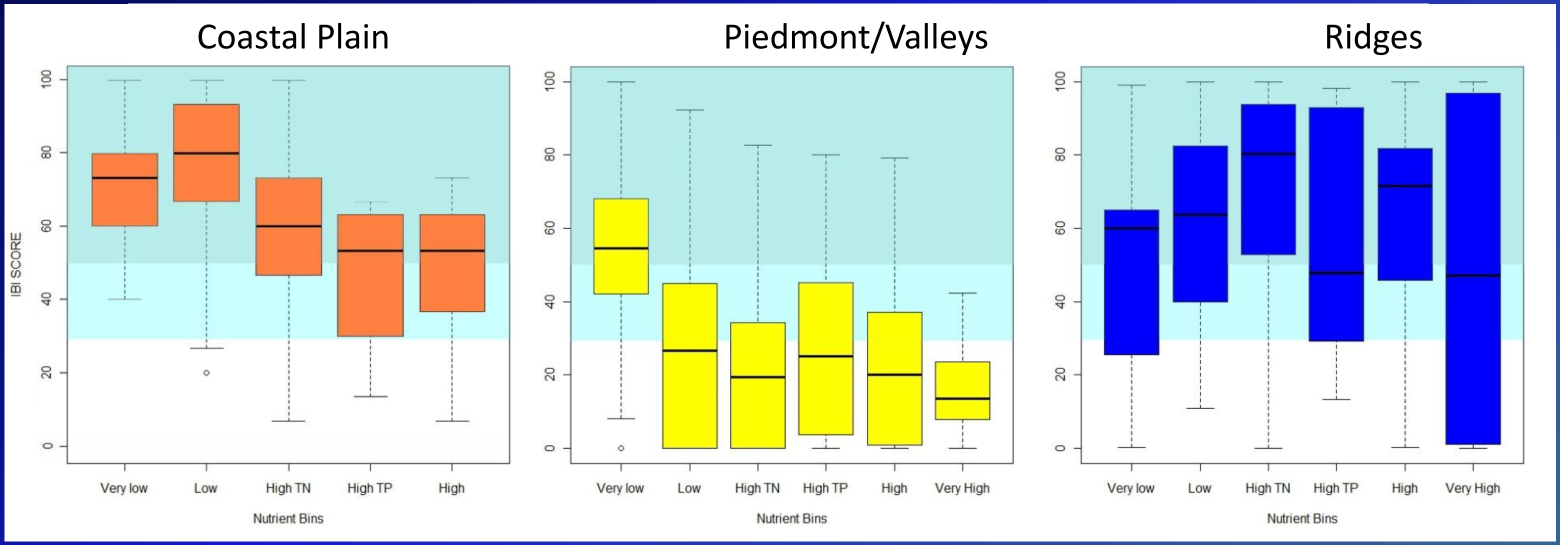
Macroinvertebrates

All Regions
Filtered Data

"Chessie BIBI"

excellent

poor

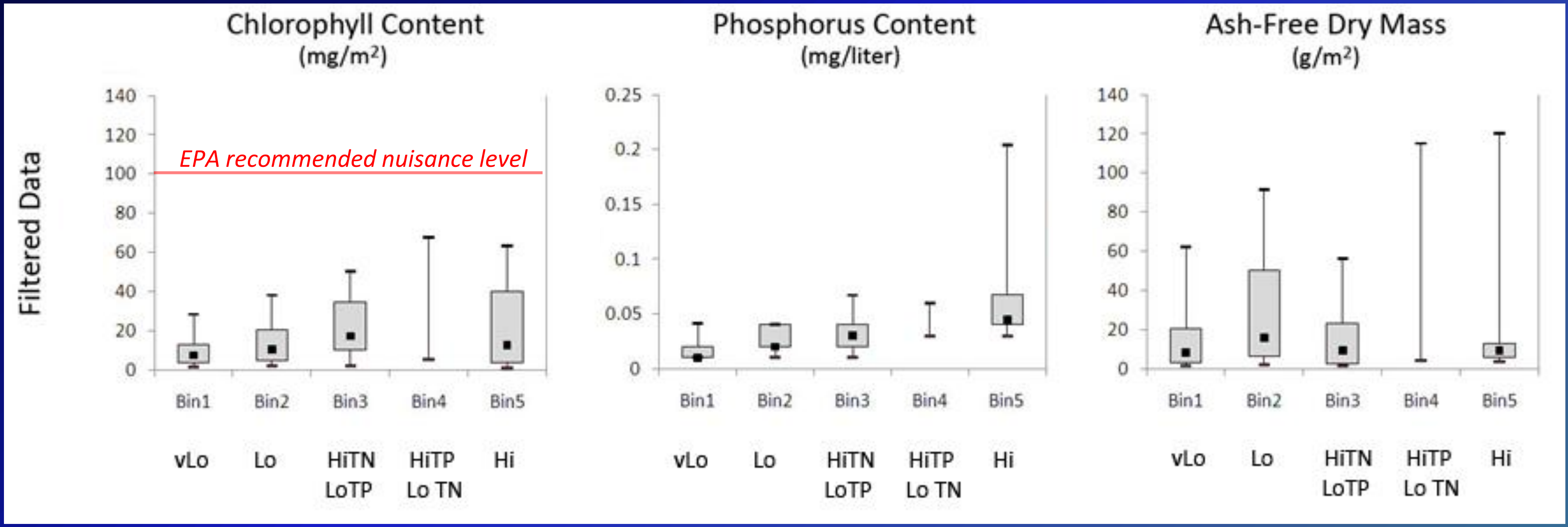


Periphyton

Piedmont & Ridge-Valley
Streams (VA)

Not all of the biometrics for an aquatic group respond to TN and TP

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

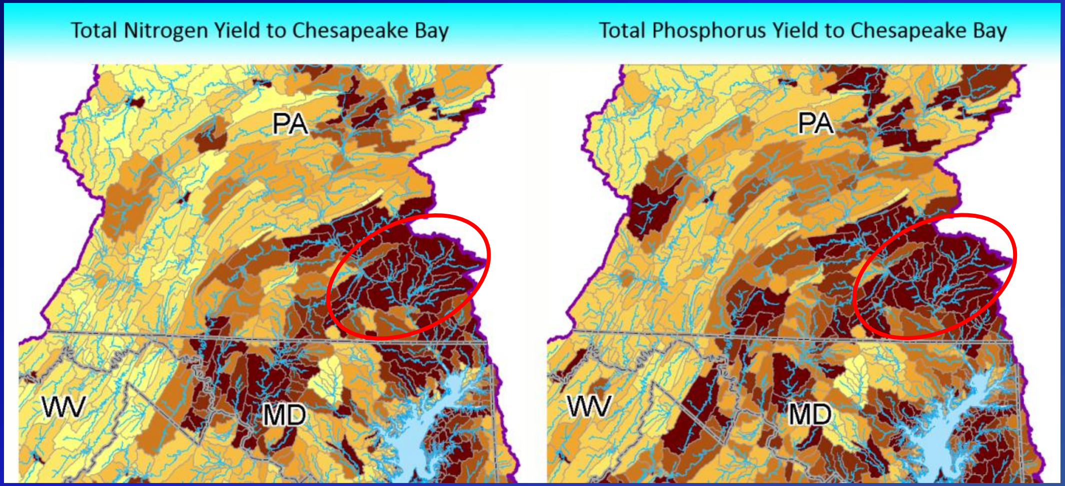


N and P Increasing

Periphyton

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

When water is nutrient-saturated and other factors are confounding, there is no clear-cut response to relatively lower nutrients



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

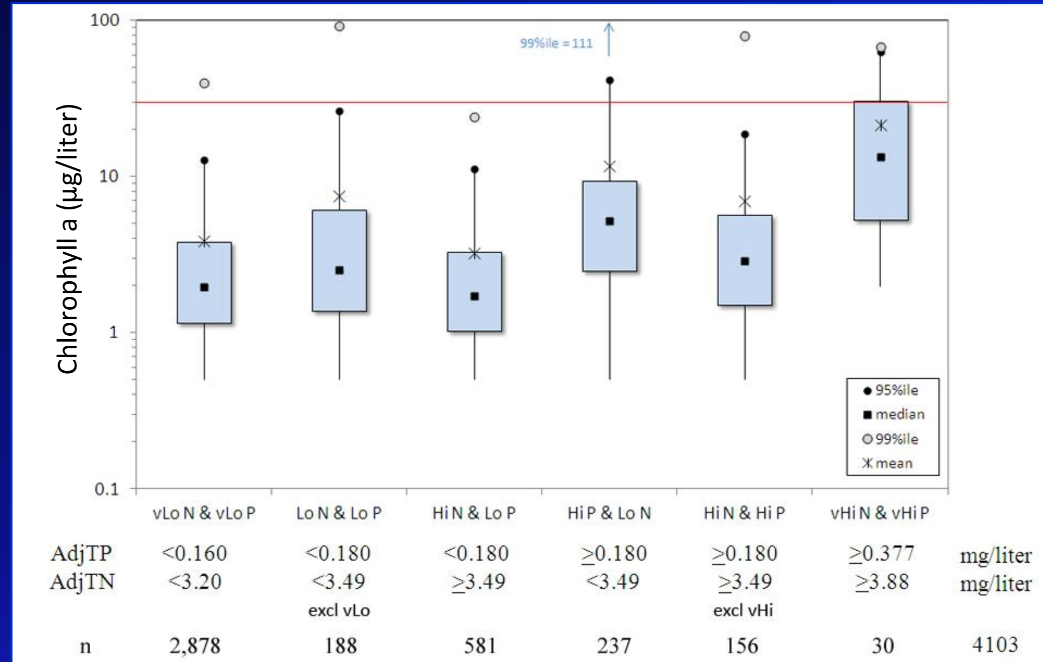
~72% of periphyton samples are above “nuisance” level of >100 Chla mg/m^2

Phytoplankton

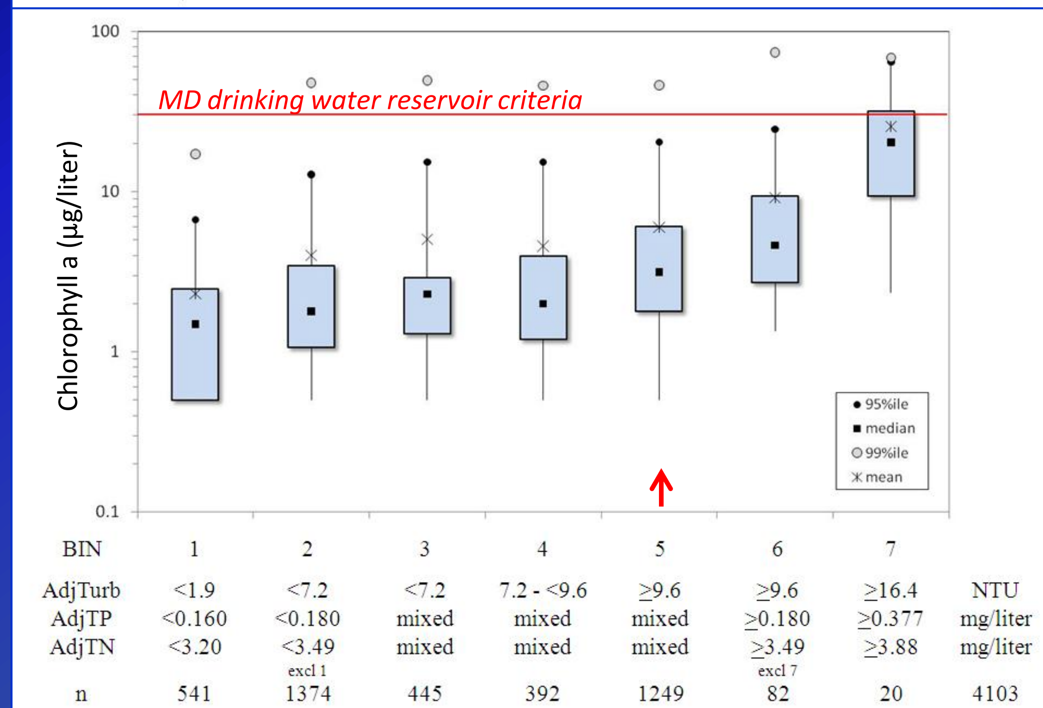
Piedmont & Ridge-Valley Large Rivers (MD)

Light is an essential resource for water column primary producers

Analysis approach is not successful for phytoplankton when light condition is *not* considered



Analysis approach is successful when light condition *is* considered



Turbidity is used as a surrogate for light attenuation

TN, TP, and Turbidity concentrations in the analysis were adjusted to removed the phytoplankton component

Increasing nutrients →

Phytoplankton

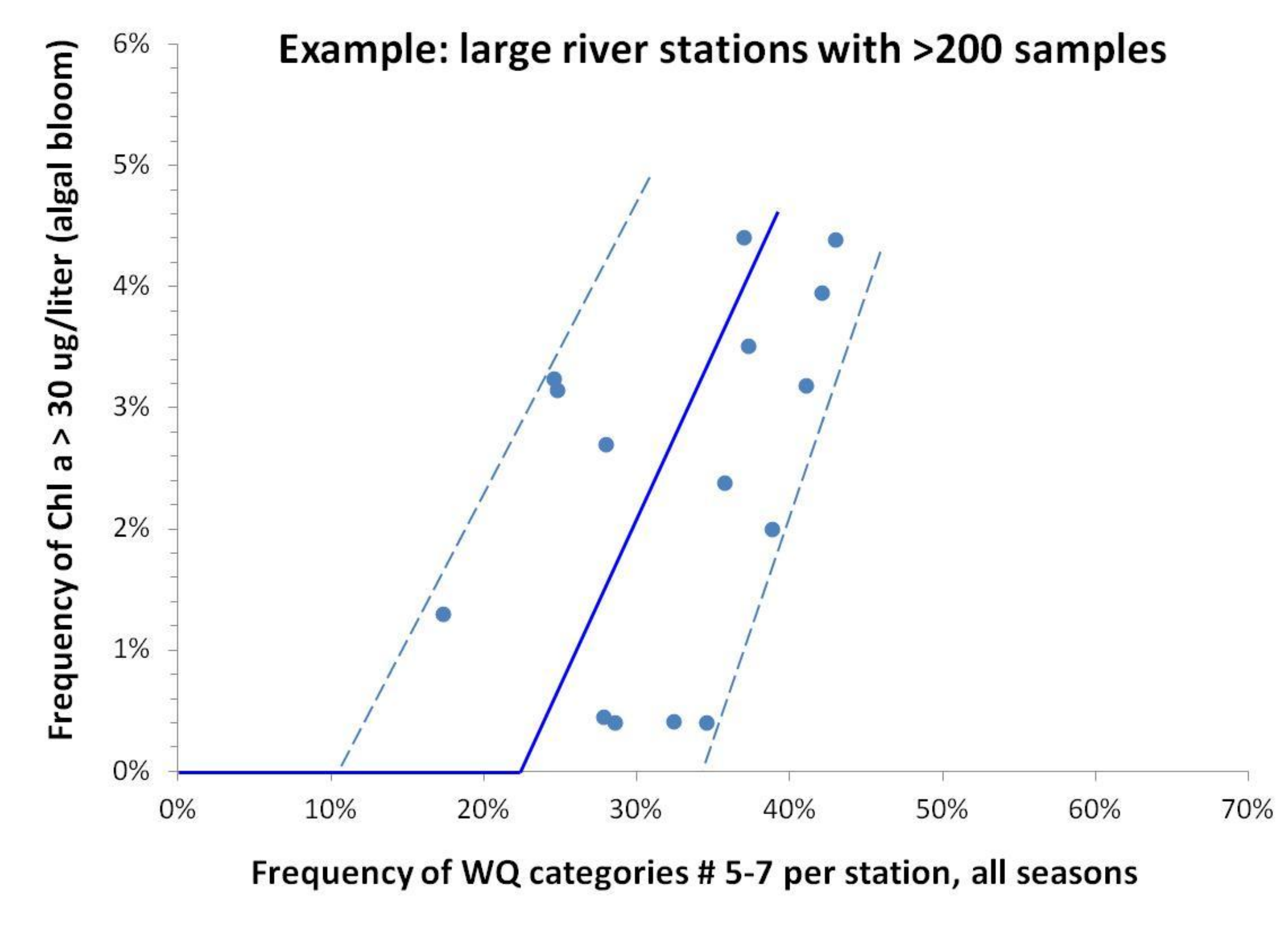
Piedmont & Ridge-Valley
Large Rivers (MD)

Category 5 thresholds	Lo DOC	Hi DOC
Turbidity (NTU)	10	10
TN (mg/liter)	2.44	2.37
TP (mg/liter)	0.036	0.087

When the frequency of water quality categories 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 categories 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.



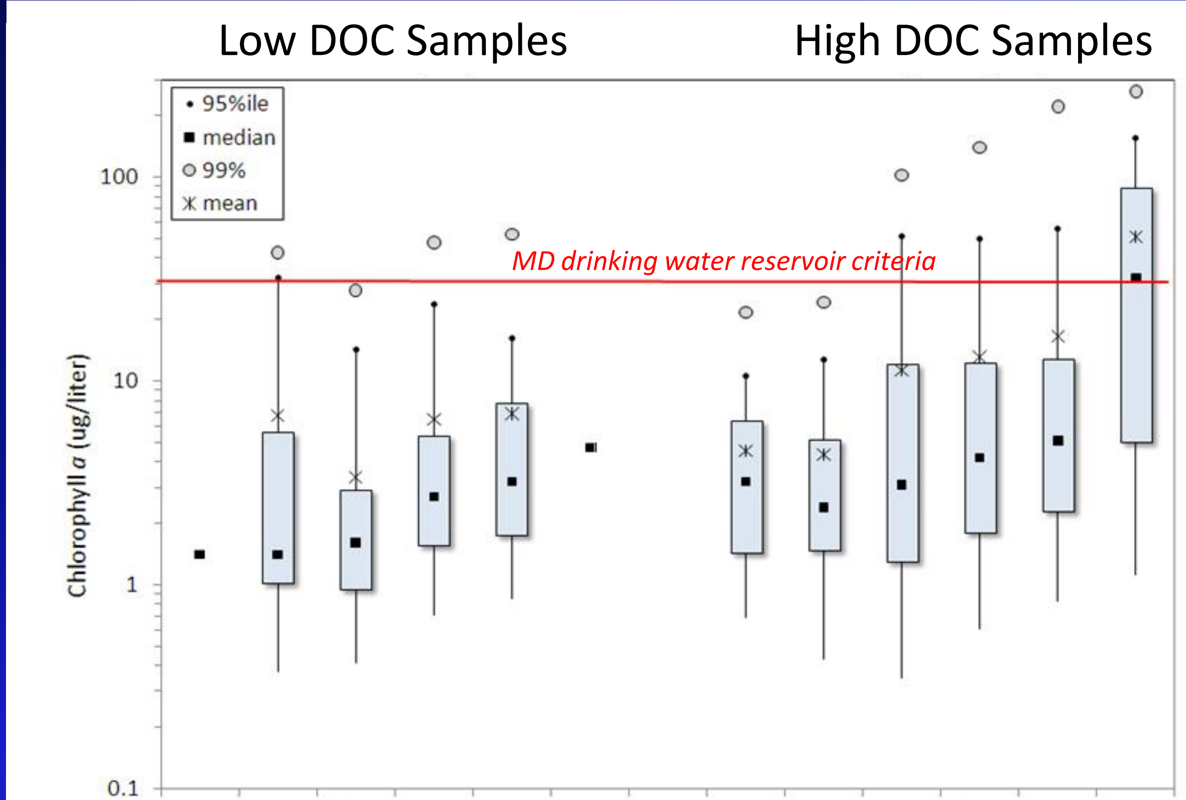
Phytoplankton

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

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

1. proportions of TN and TP "species" differ

2. DOC also attenuates light



Bin	1	2	3+ 5	4+6	7	8	1	2	3+ 5	4+6	7	8
Turb	vLo	Lo	Lo	Hi	Hi	vHi	vLo	Lo	Lo	Hi	Hi	vHi
TP	vLo	Lo	Mix	Mix	Hi	vHi	vLo	Lo	Mix	Mix	Hi	vHi
TN	vLo	Lo	Mix	Mix	Hi	vHi	vLo	Lo	Mix	Mix	Hi	vHi
n	19	23	144	55	63	15	29	53	579	536	211	56

Increasing nutrients → total n = 319

Increasing nutrients → total n = 1,464

Nutrient Thresholds*

	Phytoplankton						Periphyton	Macroinvertebrate		
Desirable levels (biology)	Chl *a* <30 ug/liter						Chl *a* <100 mg/m^2	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)

- 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)
- 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

Nutrient Thresholds*

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

- Nutrient response thresholds are evident only when the impacts of confounding stressors are removed or accounted for
  - *Conductivity (~300 umhos/cm)*
  - *In-stream habitat and riparian/bank conditions*
  - *Water clarity*
  - *pH, dissolved oxygen*
- Degradation caused by excess nutrients are probably occurring even when masked by confounding stressors

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

Macroinvertebrates in 1st-4th order streams

WV, MD, and DE portions of Chesapeake Bay watershed	Coastal Plain	Piedmont	Valleys	Ridges
Total # samples with full suite of water quality data	778	557	116	261
% stressed by pH, DO, conductivity, and/or habitat quality (excess nutrients sometimes an underlying stressor) **NO direct TMDL benefit from reducing nutrients**	77%	56%	64%	41%
% stressed by excess TN and/or TP (DO, pH, conductivity, and habitat quality are all in acceptable ranges) **Direct TMDL benefit from reducing nutrients**	9%	33%	14%	3%
% not stressed by TN, TP, or other water quality parameters **NO TMDL benefit from reducing nutrients**	14%	11%	22%	56%

Phytoplankton (Chlorophyll *a*)

MD and DE portions of Chesapeake Bay watershed	Piedmont/Ridges/ Valleys Rivers ($\geq$5th order)*	Coastal Plain Rivers and Streams*
# Chl *a* samples with TN, TP, DOC and turbidity data	741	3255
% stressed by high turbidity and excess nutrients	35%	11%
% stressed by high turbidity but not by nutrients	10%	25%
% stressed by excess nutrients but not by turbidity	8%	34%
% not stressed by nutrients or turbidity	47%	30%

ICPRB Report 11-2 available online at:
www.potomacriver.org/cms/publicationspdf/ICPRB11-02.pdf

Questions?

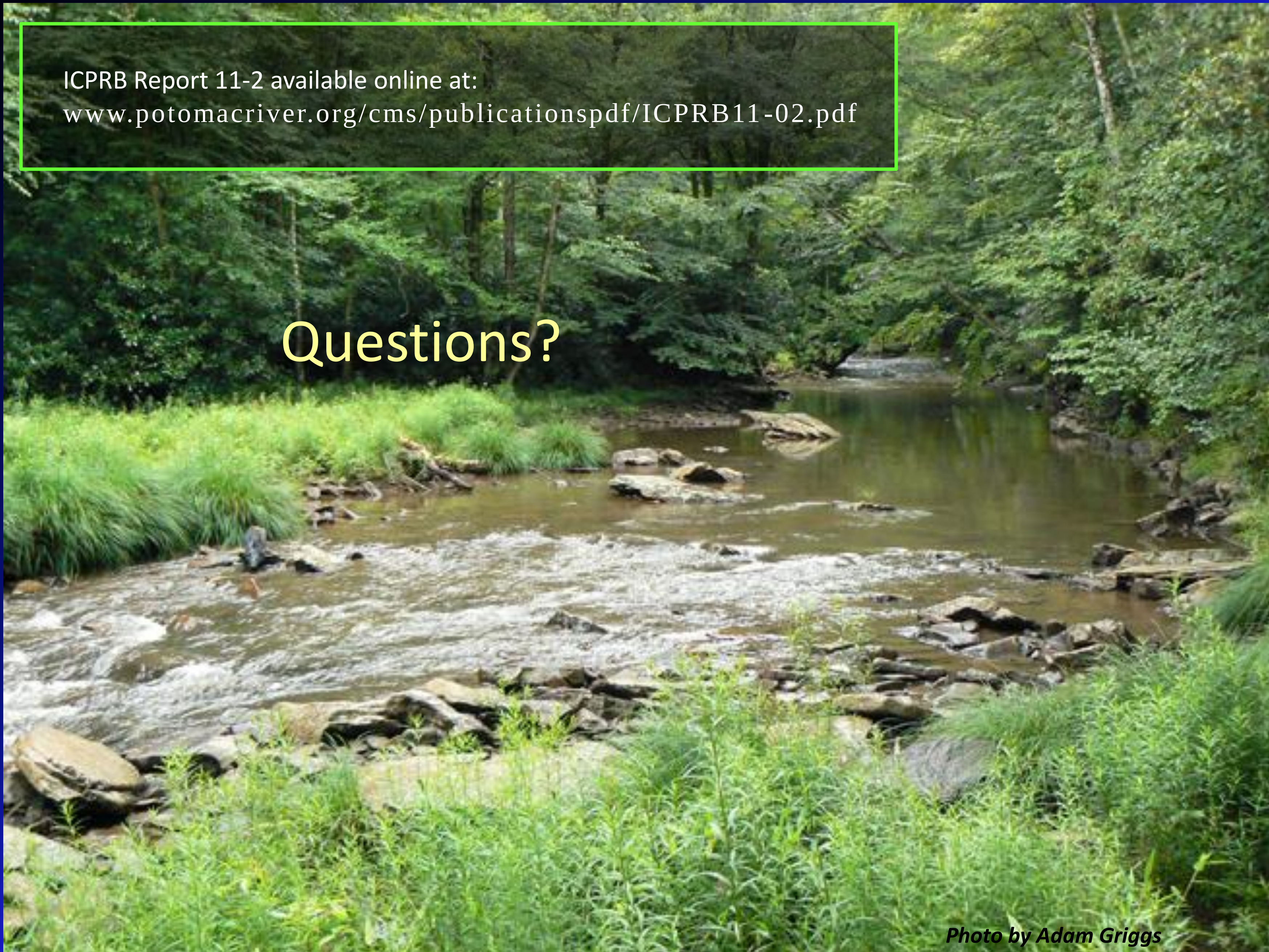

Photo by Adam Griggs