

# Assessing the Environment In Outcome Units (AEIOU) STAC workshop 3/2019

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Presentation to Modeling Workgroup

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# Workshop questions

- The Chesapeake Bay TMDL sets a cap on ***total average annual nutrients***
- However
  - Inorganic nutrients have a greater impact on eutrophication than organic nutrients
  - Spring nutrient reductions are more effective than fall reductions
  - Other endpoints also depend on these factors
    - Monitoring data suggest localized impacts from inorganic species promoted by some BMPs
- Purpose of the workshop
  - Explore whether the science is ripe for and appropriate for calculating *eutrophying units* as a common currency
  - Compare cost-effectiveness of alternative restoration strategies

# Past use of Eutrophying Units

## Exchanges based on Geography

*ug/l Oxygen per Mlbs*

GeoBasin	N	P
Susquehanna	16.3	38.5
Western Shore	14.1	35.3
Patuxent AFL	10.9	27.5
Patuxent BFL	13.5	35.7
Potomac AFL	14.0	22.2
Potomac BFL	13.2	22.2
Rappahannock AFL	8.1	11.8
Rappahannock BFL	9.3	15.5
York AFL	4.6	9.1
York BFL	5.2	8.7
James AFL	2.6	7.7
James BFL	2.4	7.4
Upper Eastern Shore	10.7	31.8
Middle Eastern Shore	11.2	43.2
Lower Eastern Shore	9.8	25.2
Virginia Eastern Shore	15.2	20.4
Atmospheric Deposition	15.8	

In the Susquehanna, a pound of TP is worth a little over twice as much as a pound of TN

A pound of TP from the Potomac is worth almost twice as much as a pound from the Rappahannock above Fredericksburg

# Past use of Eutrophying Units

## Estimated Loads to the Bay with Conowingo Dam and Reservoir at Infill Conditions

### Conowingo infill effect

Additional Nitrogen Load: 13 million pounds



Additional Phosphorus Load: 1.8 million pounds

With low bioavailability and mostly high-flow delivery



64 million cubic meters of additional low-DO water



### Reduction effect

Nitrogen Load: 6 million pounds

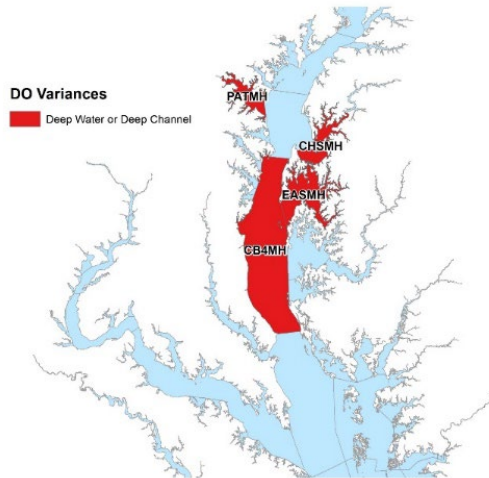


Phosphorus Load: 0.26 million pounds

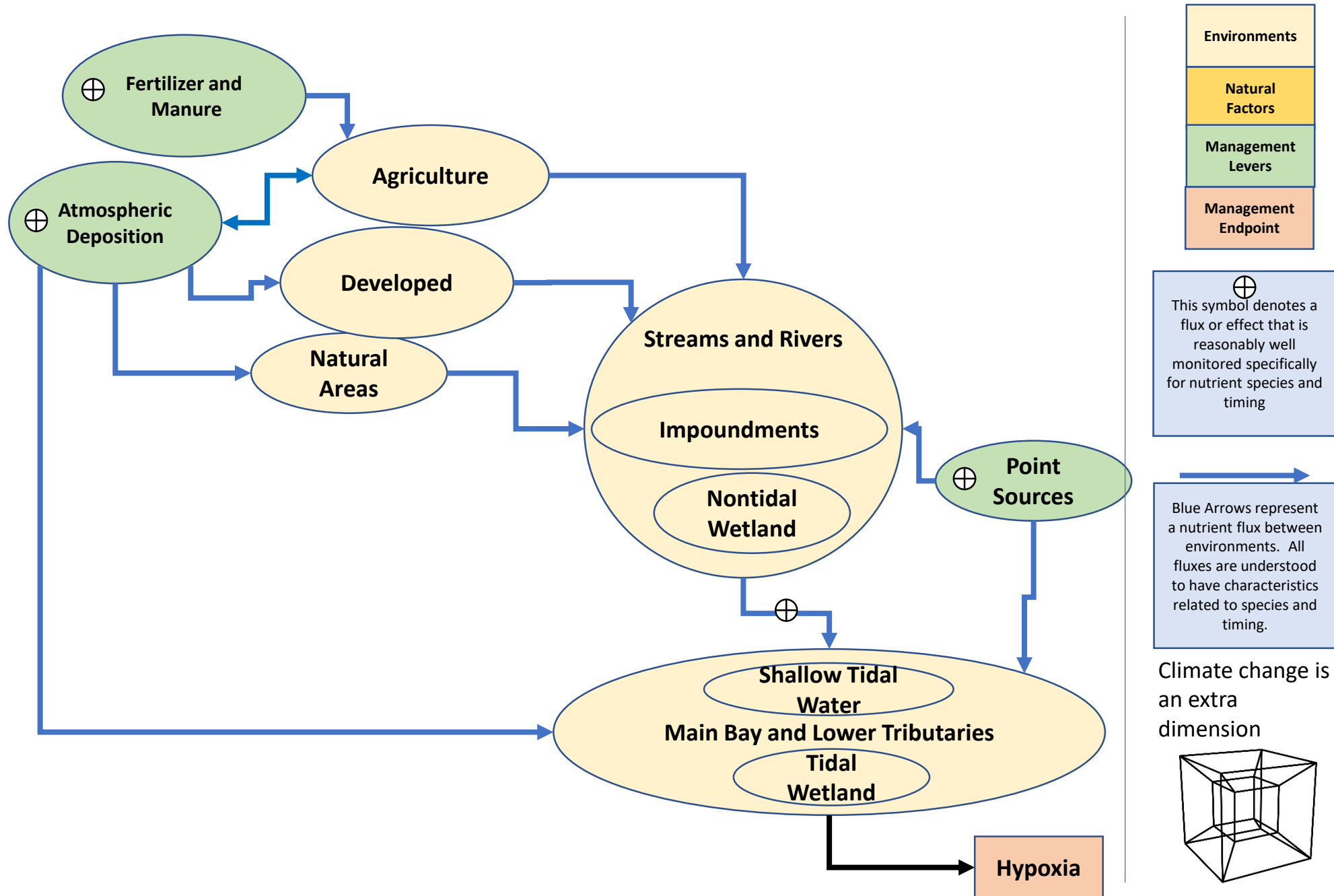
With normal bioavailability and normal flow delivery



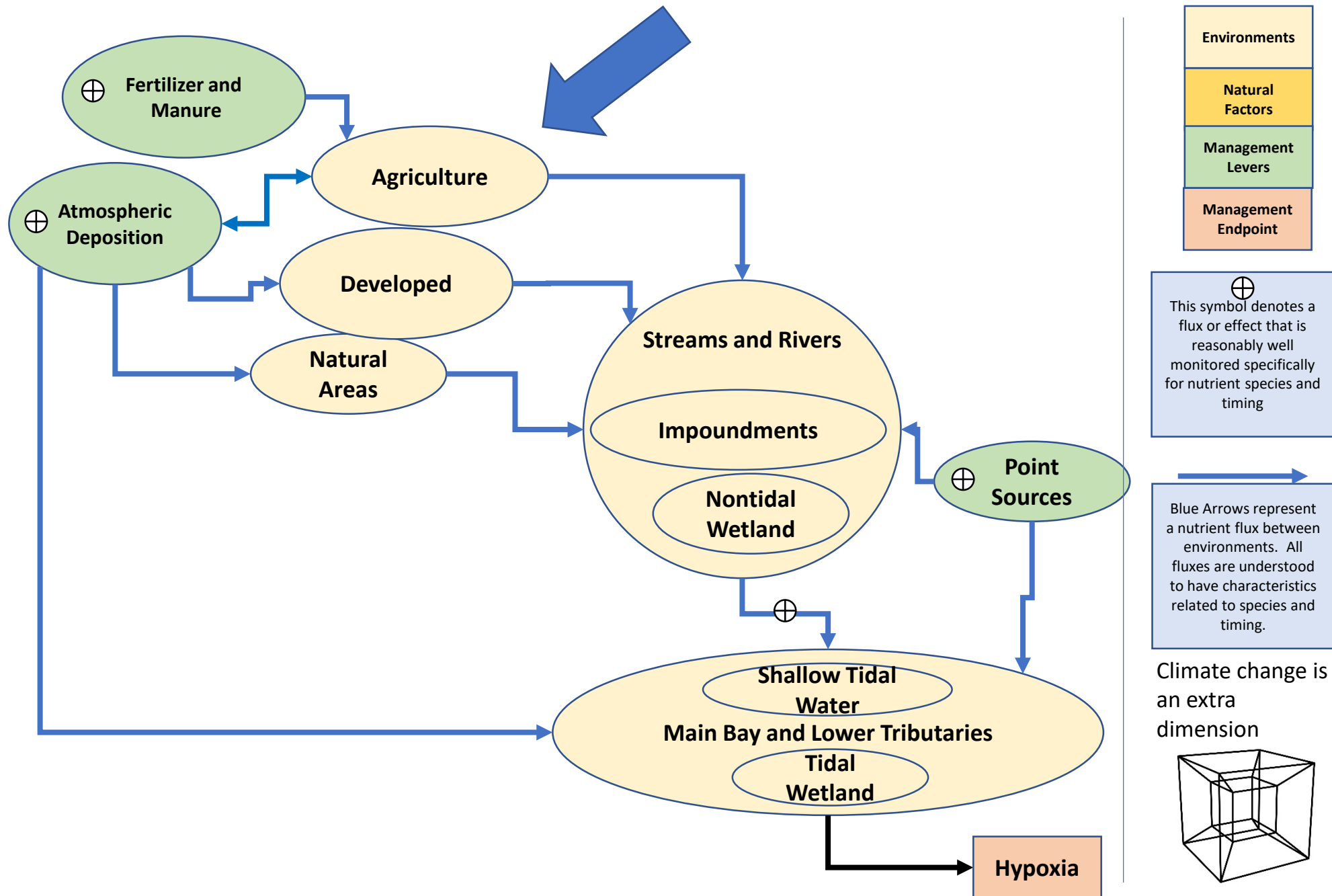
64 million cubic meters of additional low-DO water

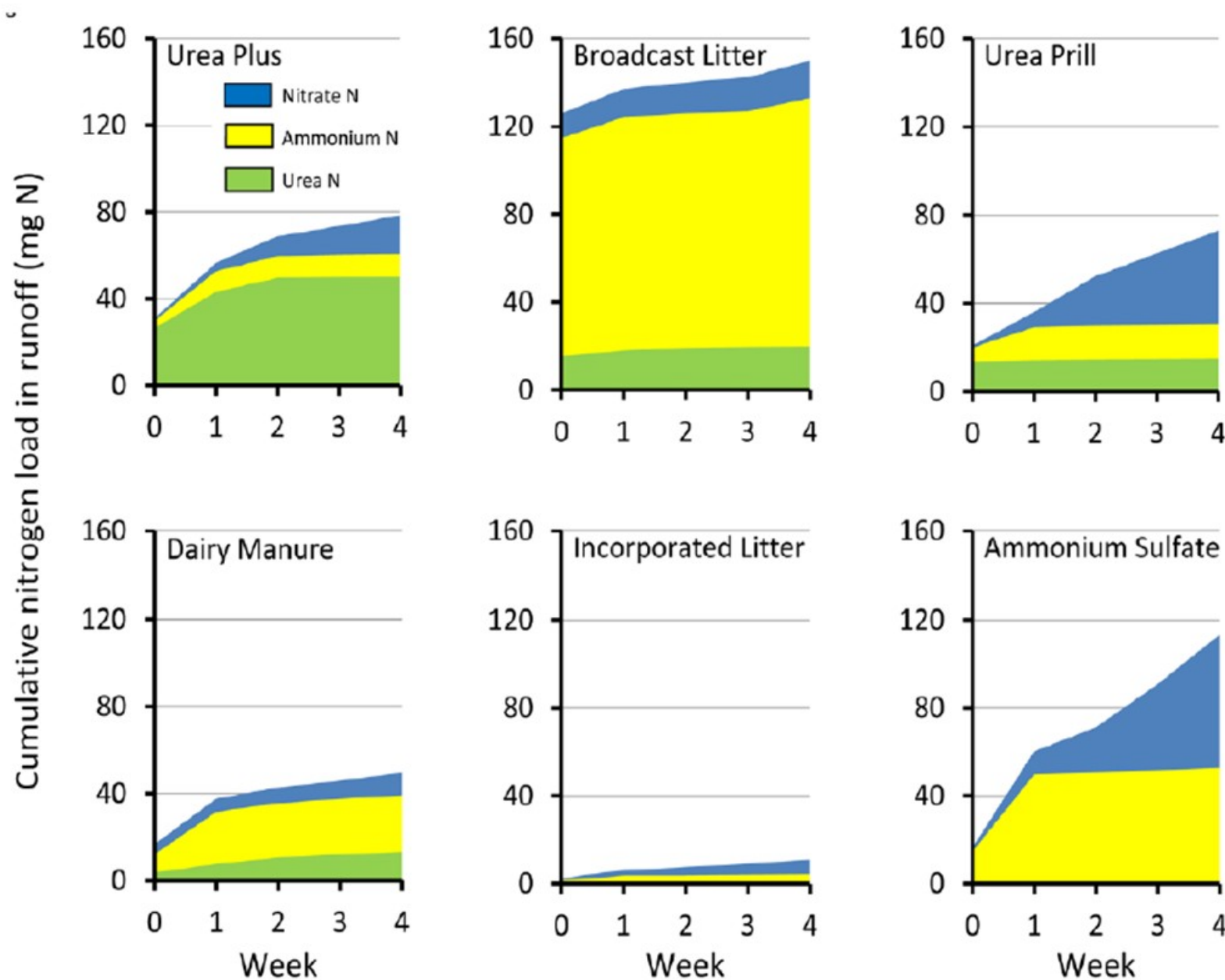


# Conceptual model of nutrient-driven hypoxia related to nutrient species and timing



# Conceptual model of nutrient-driven hypoxia related to nutrient species and timing





Fresh inputs on source areas may lead to high DON or  $\text{NH}_4^+$  runoff



Slide from Jason Kaye, PSU

Which BMPs and Landscape properties affect nitrogen speciation in loads delivered to streams?

Landscape properties:

1. soil texture
2. source areas
3. ecosystem type

BMPs:

1. no-till, cover cropping
2. manure incorporation
3. manure input history
4. inhibitors?

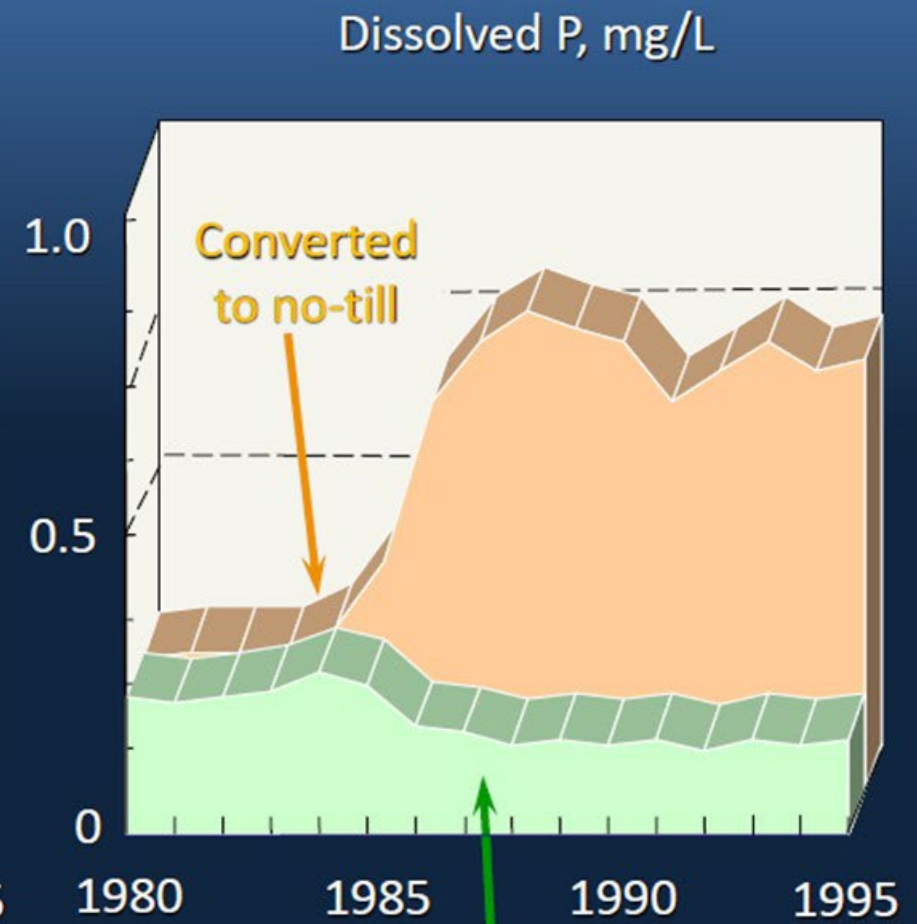
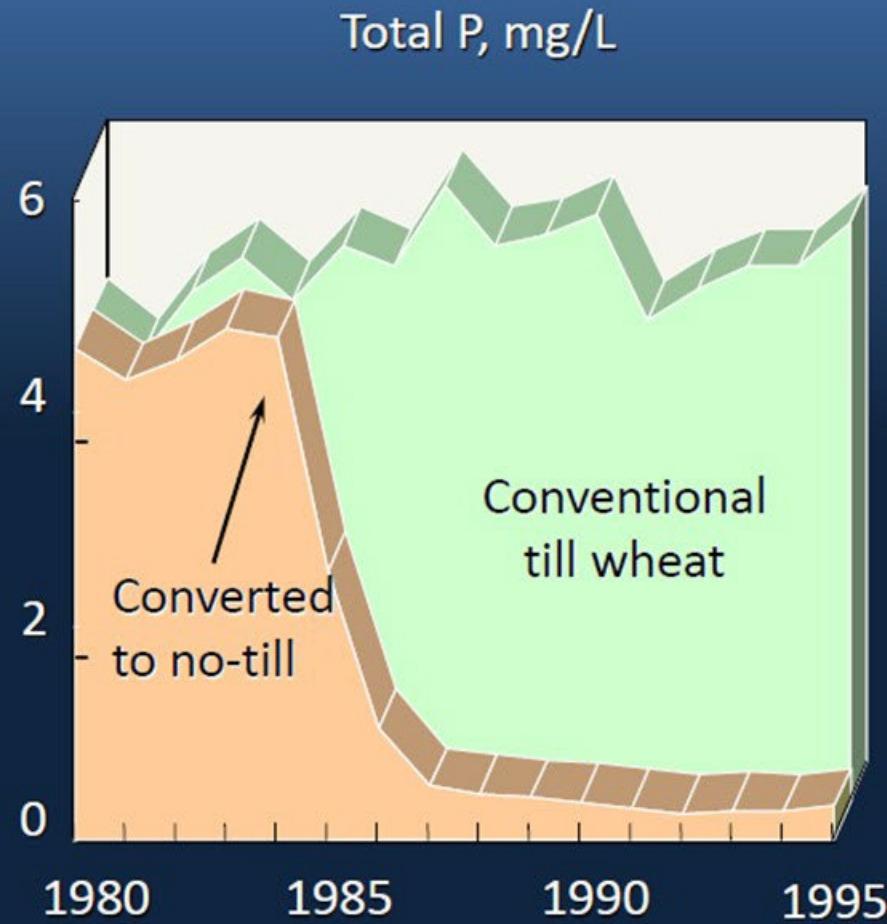
Slide from Jason Kaye, PSU

No-till  
reduced TP,  
but  
increased  
dissolved P

## Unintended Outcomes

## Conservation paradox

No-till reduced erosion by 95%

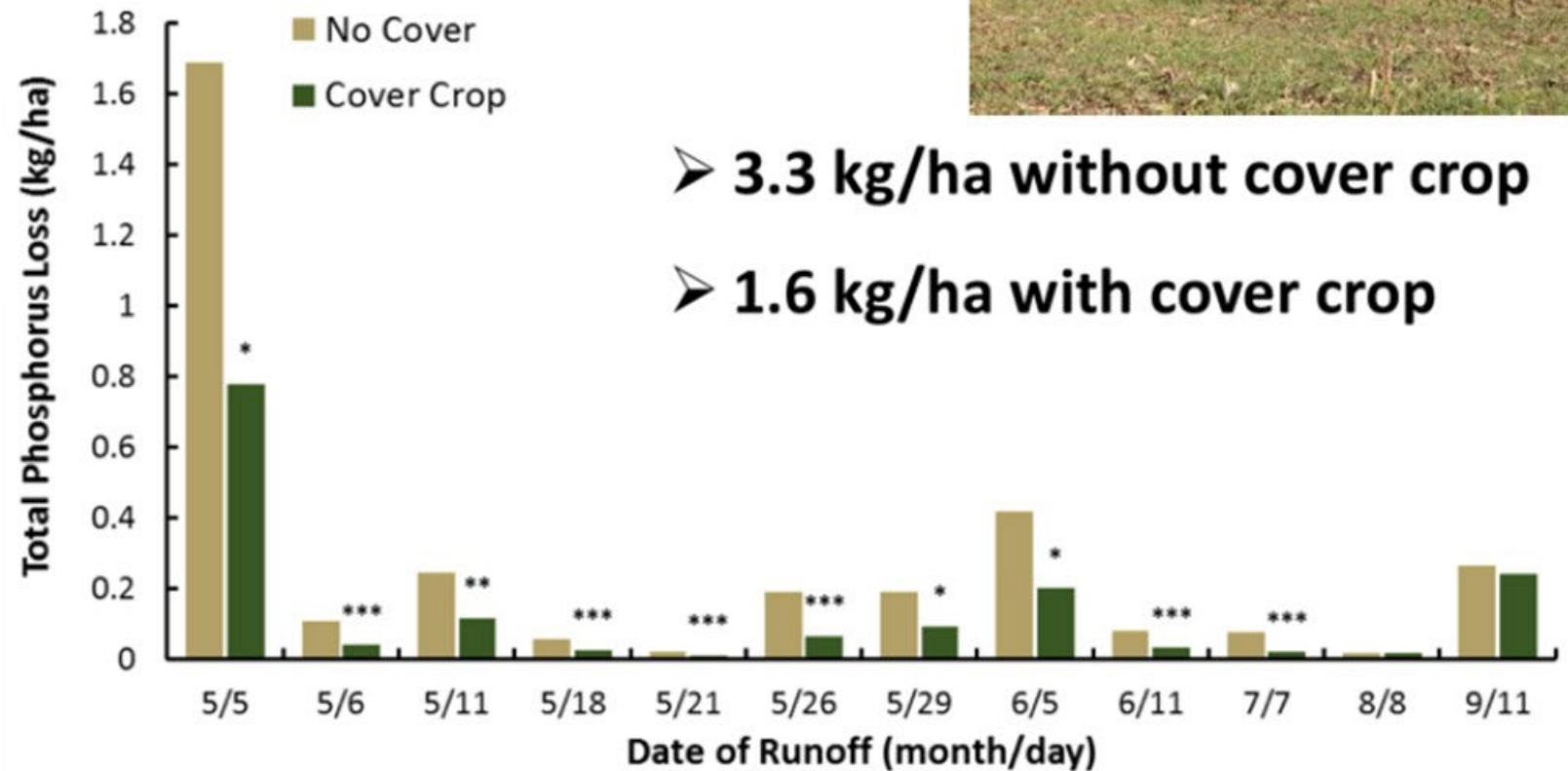


Cover crops  
reduce TP in  
the warm  
months...

## Cover Crops

### Soil Conservation and nutrient uptake

*Kansas study, > 50% reduction in total P loss*

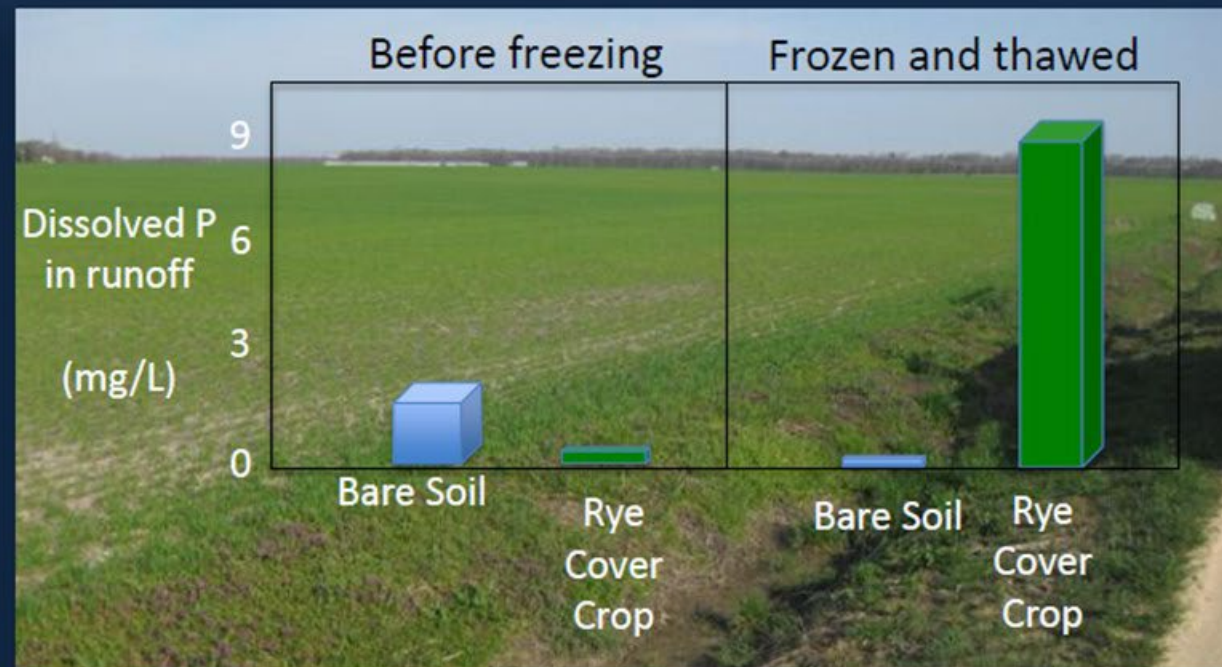
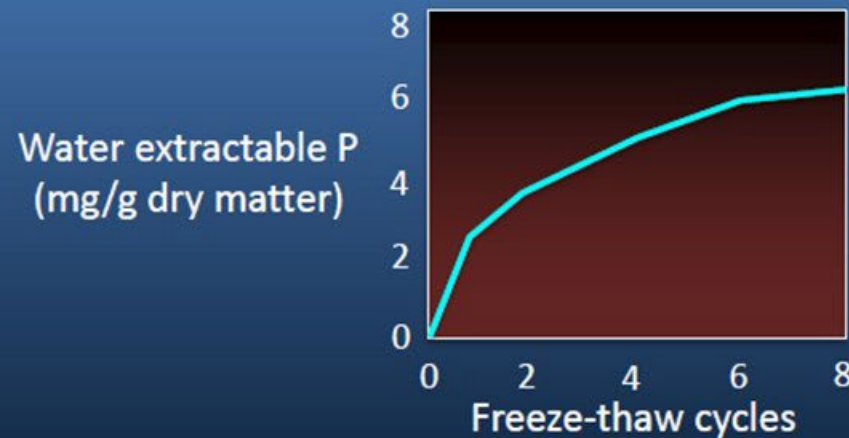


\*, \*\*, \*\*\* Indicates significant difference at  $p < 0.05$ ,  $p < 0.01$ ,  $p < 0.001$

...but give some back as dissolved P after thaw

## Unintended Consequences

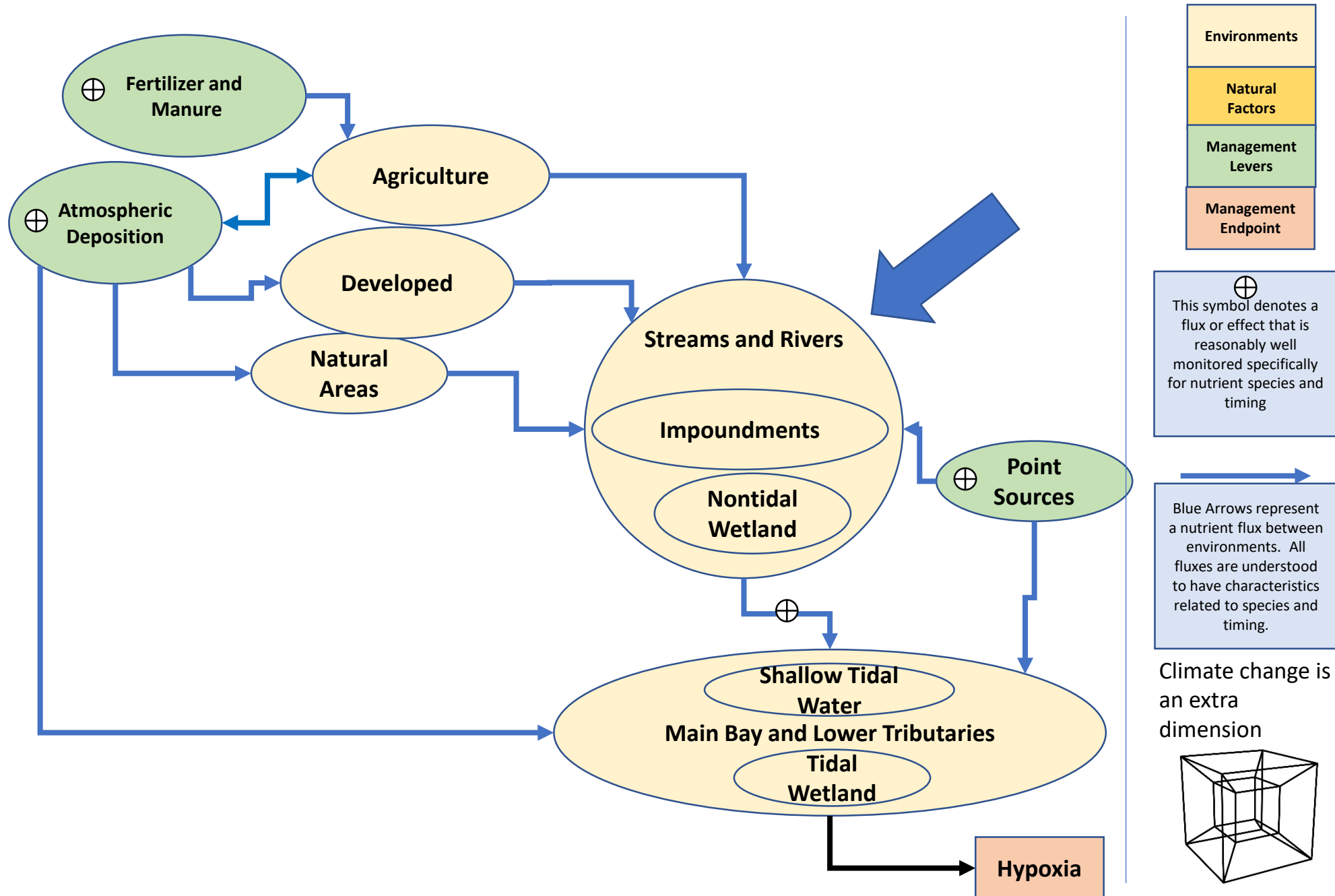
Cover crop – trade offs  
*a slow release source of dissolved P*



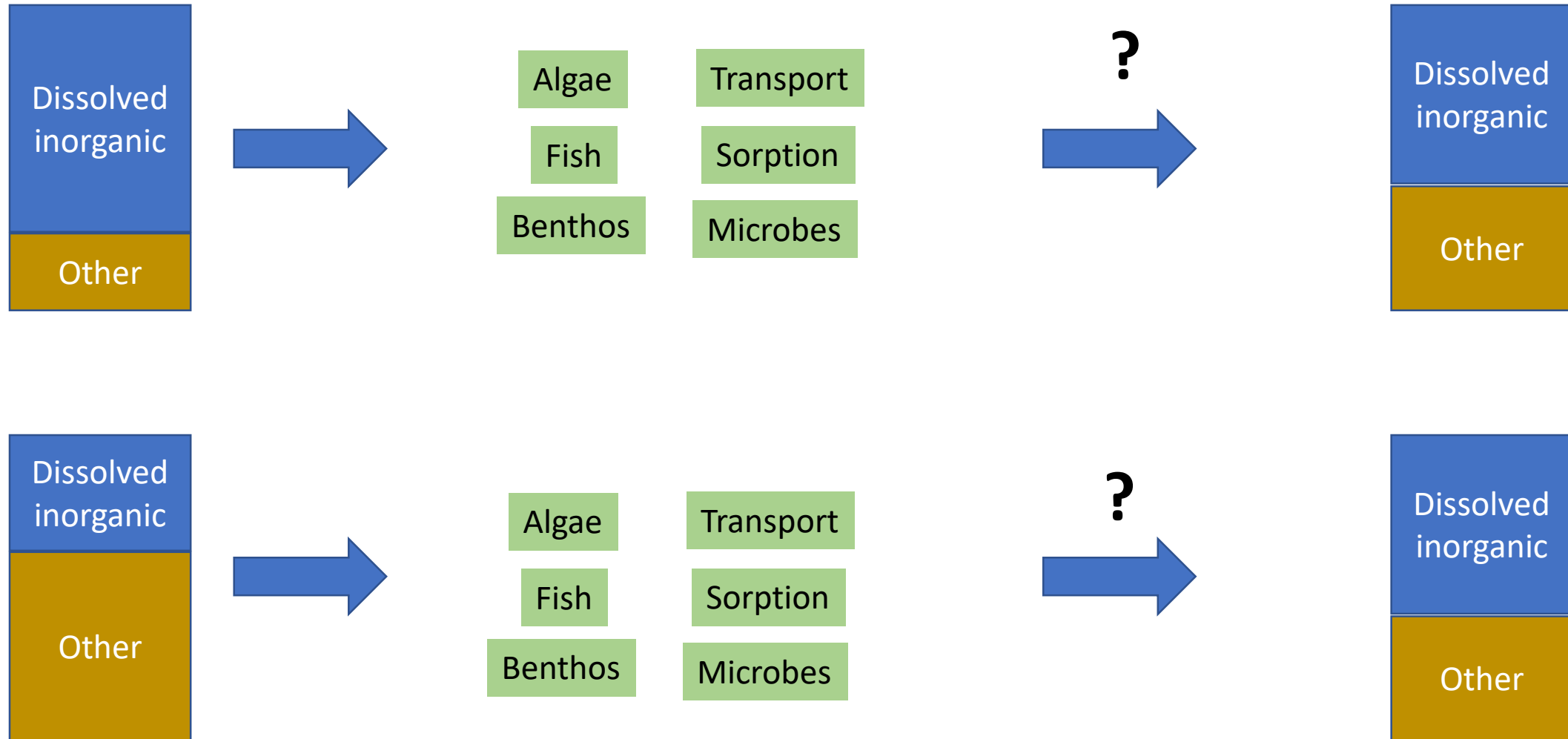
Bechmann et al., 2005  
J. Environ. Qual.

Slide from Pete Kleinman, ARS

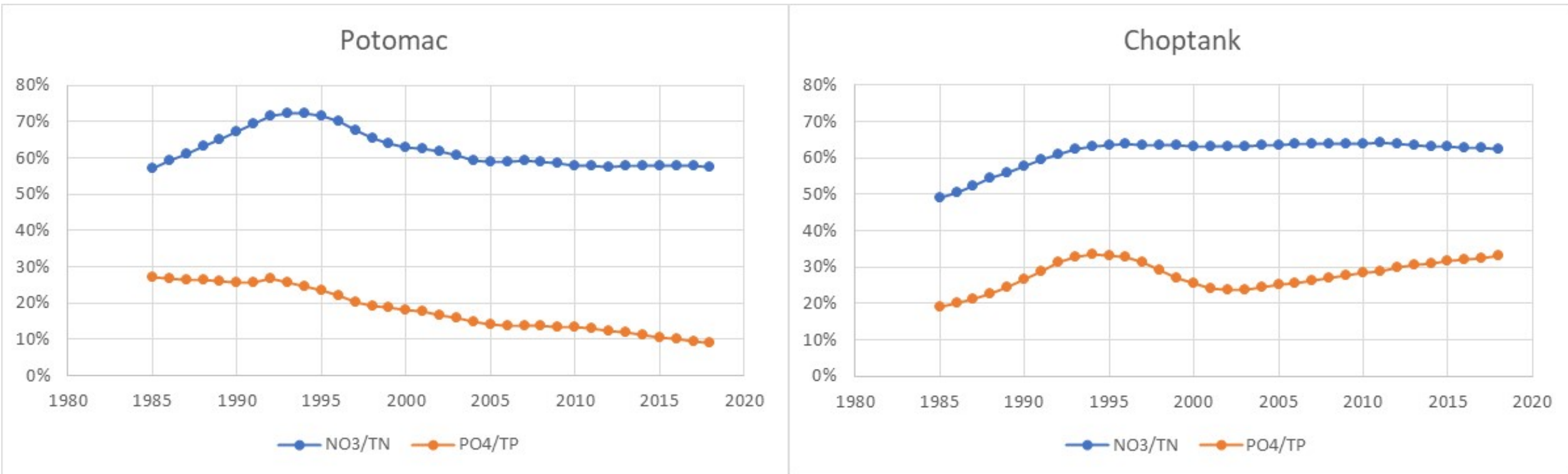
# Conceptual model of nutrient-driven hypoxia related to nutrient species and timing



# Spiraling in rivers

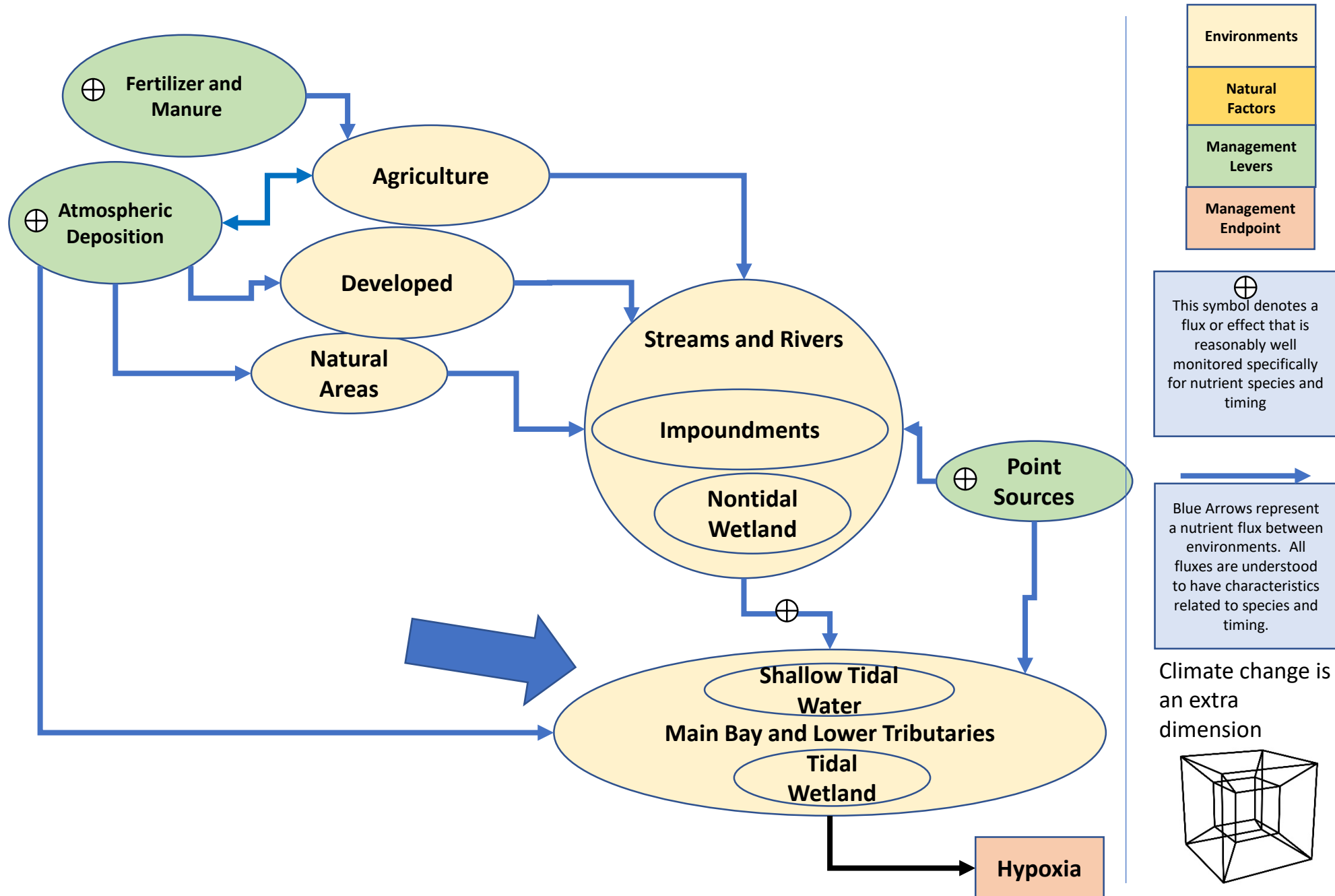


# Dissolved inorganic Fractions

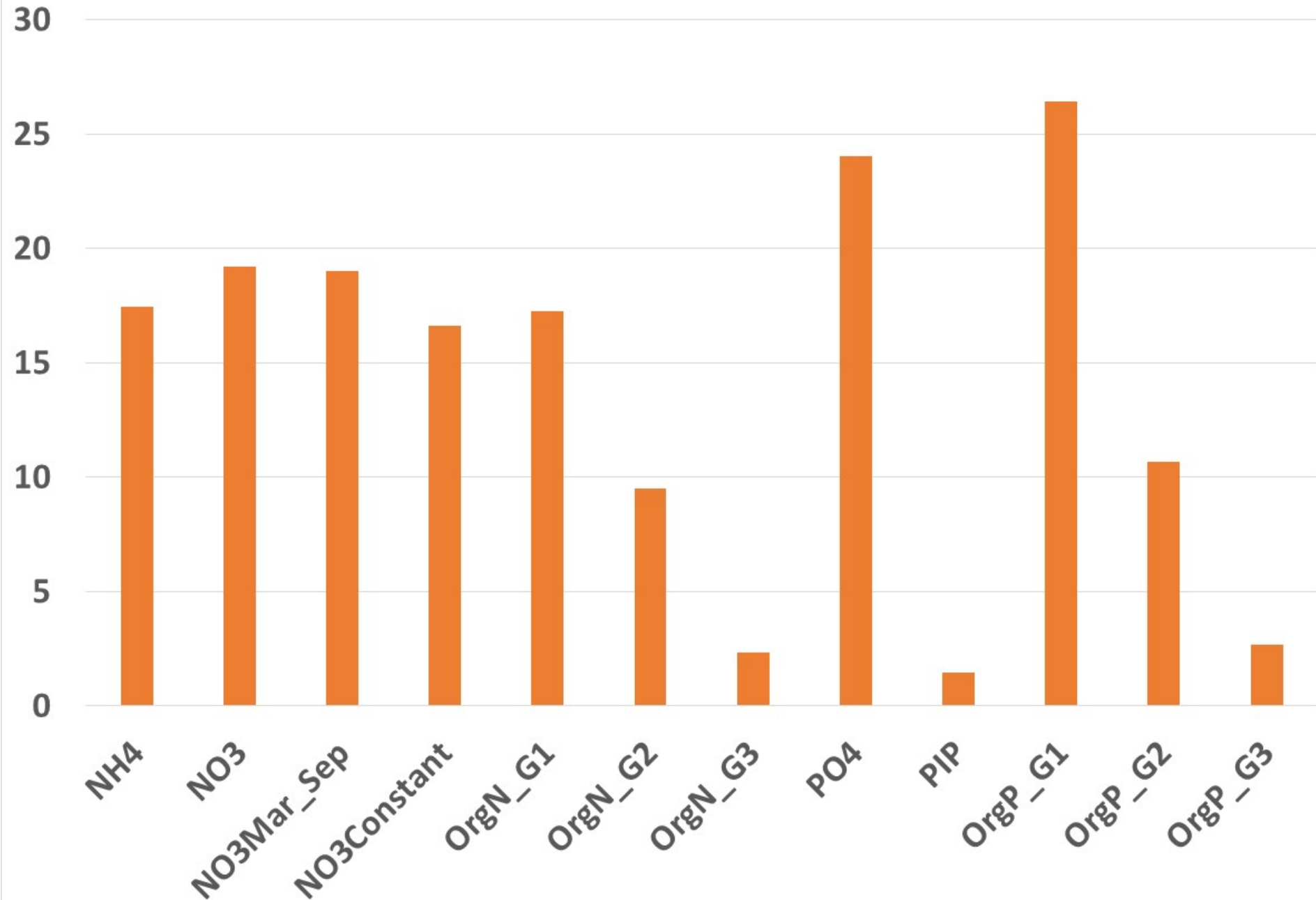


- NO3 between 50% and 70% of the flow-normalized load
- PO4 between 10% and 30% of the flow-normalized load
  - Opposite trends in the Potomac and Choptank

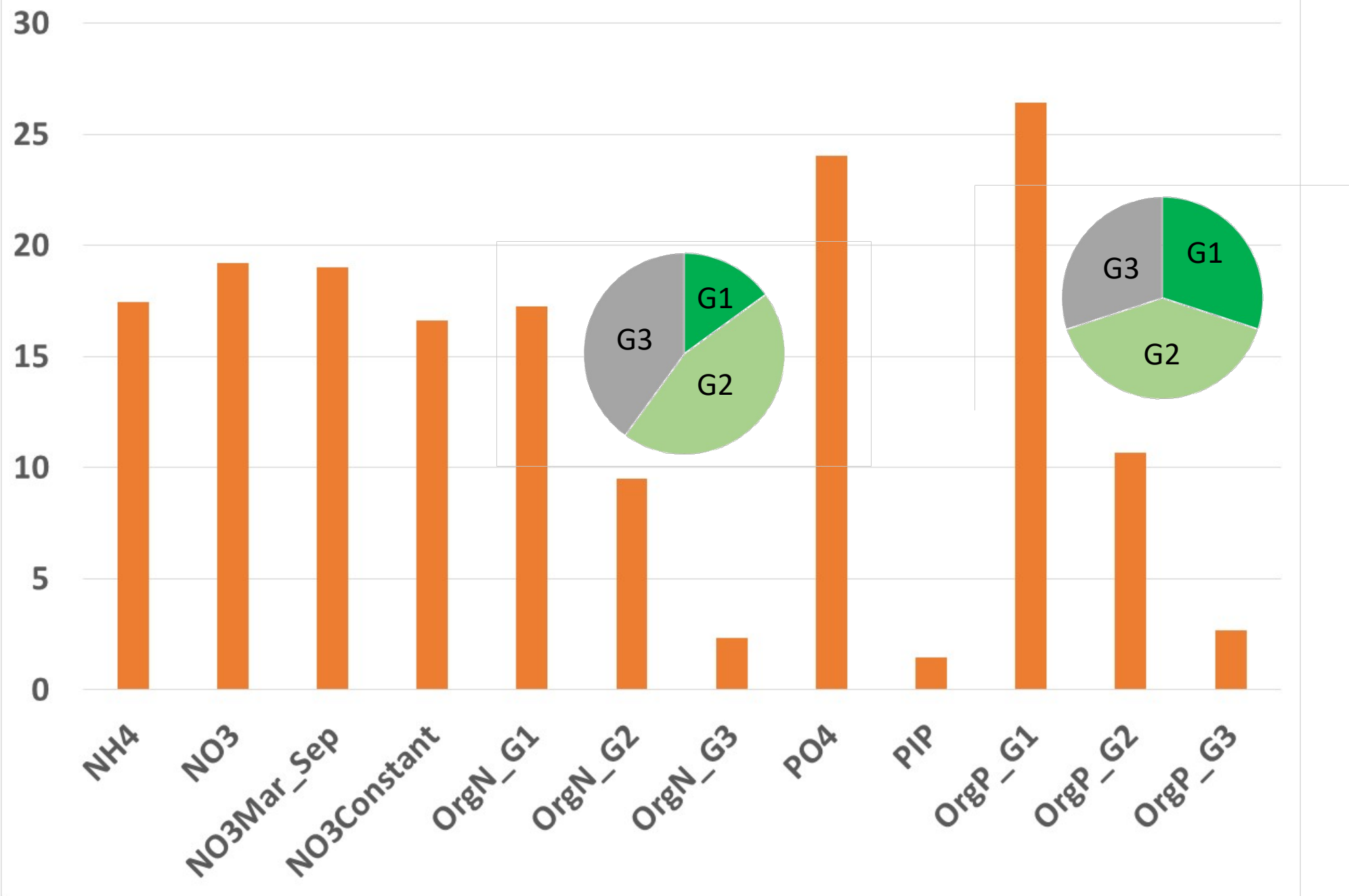
# Conceptual model of nutrient-driven hypoxia related to nutrient species and timing



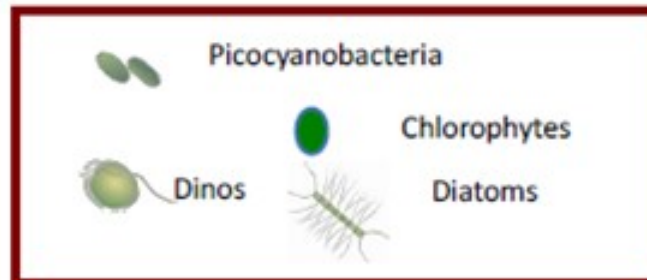
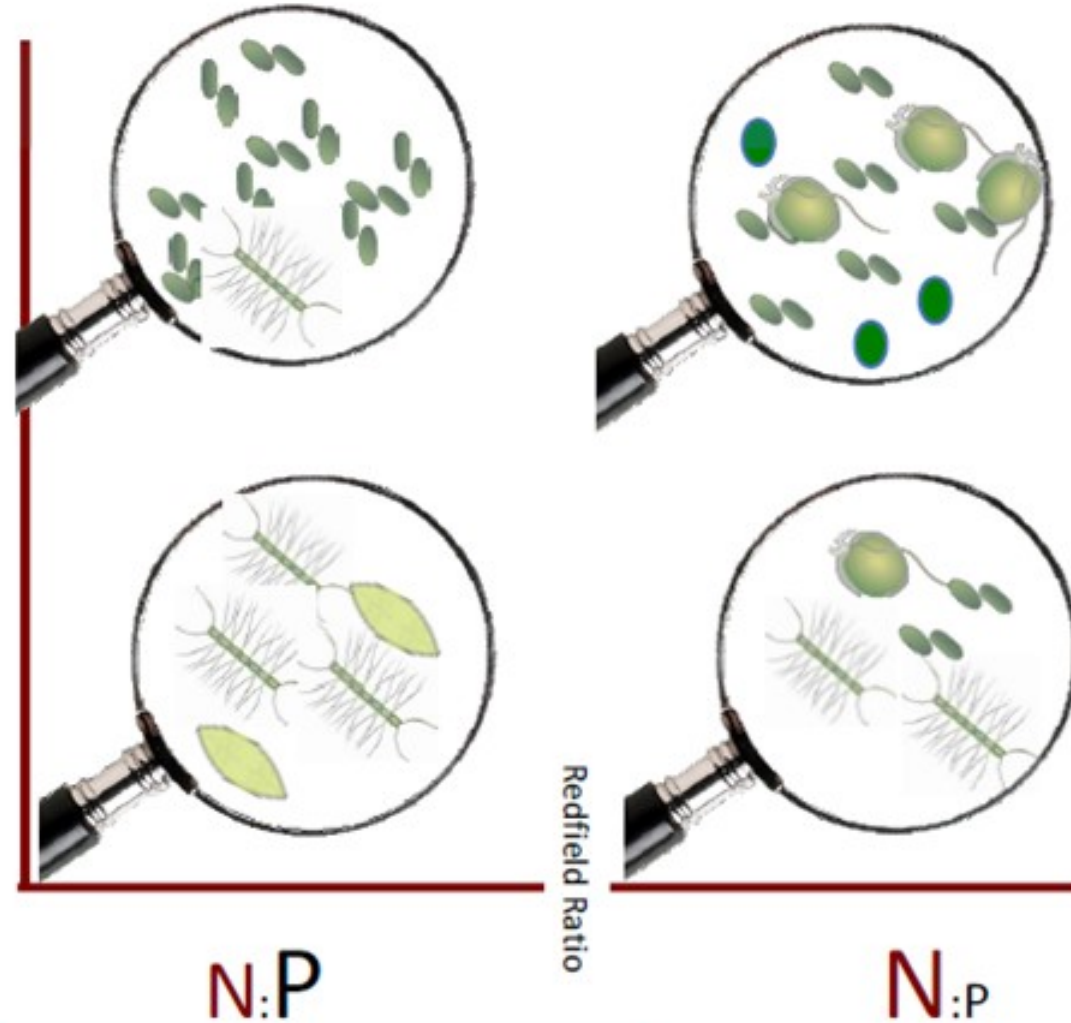
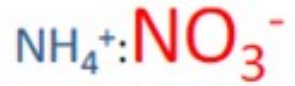
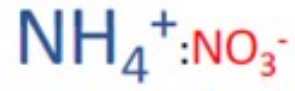
Cubic meters of Hypoxia (< 3mg/l) per Pound



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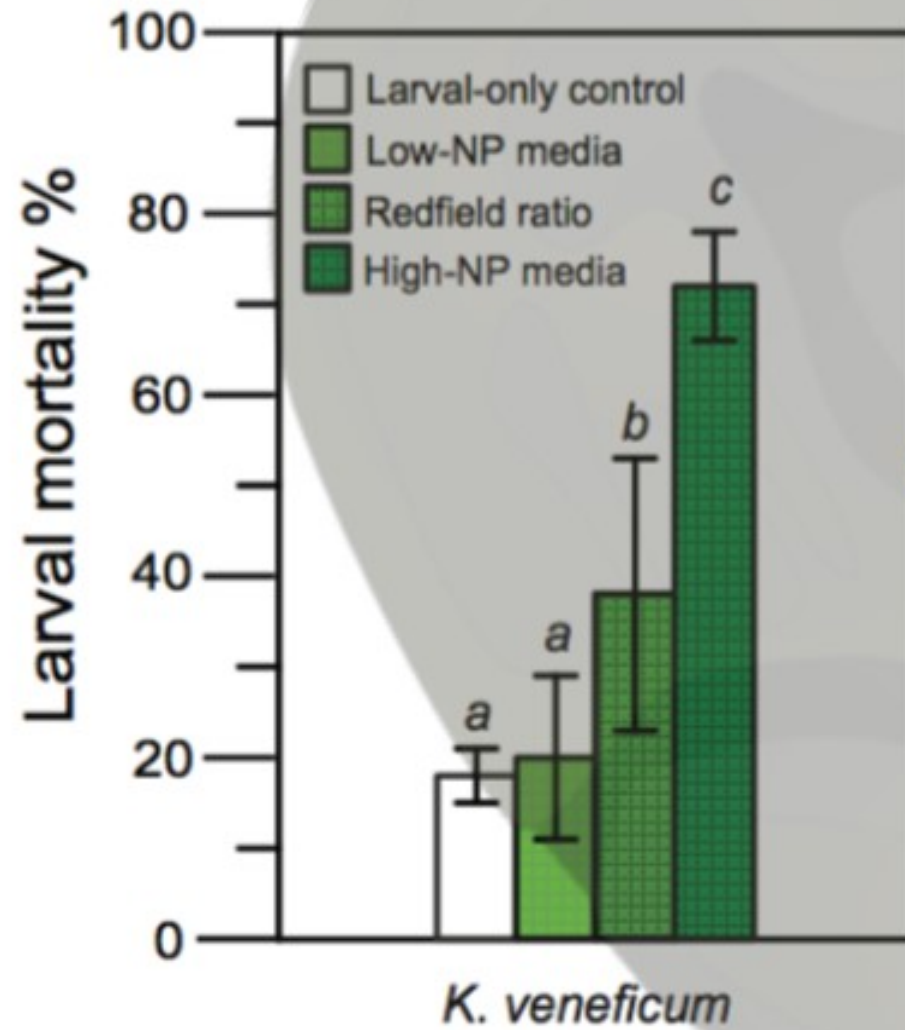


*Nutrient forms and ratios  
set the biodiversity trajectory*



Slide from Pat Glibert, UMCES

Glibert 2016 Mar Poll Bull



The mixotroph *Karlodinium veneficum* is more toxic at high N:P (oyster larvae bioassay)

Slide from Pat Glibert, UMCES

Lin et al.2017 Aq. Microb. Ecol.

# Recommendation – Use eutrophying units

- The CBP should move to set program goals and assess progress through “eutrophying units” that characterize algal and hypoxia effects, as soon as feasibly possible.
- Because this transition may take some time, it is critical that the CBP begin working towards this goal in 2020, and not wait until 2025. For example, speciation is well understood in wastewater treatment effluent, providing a good starting point for differential credit.

# Recommendation – Develop Analytical Framework - Watershed

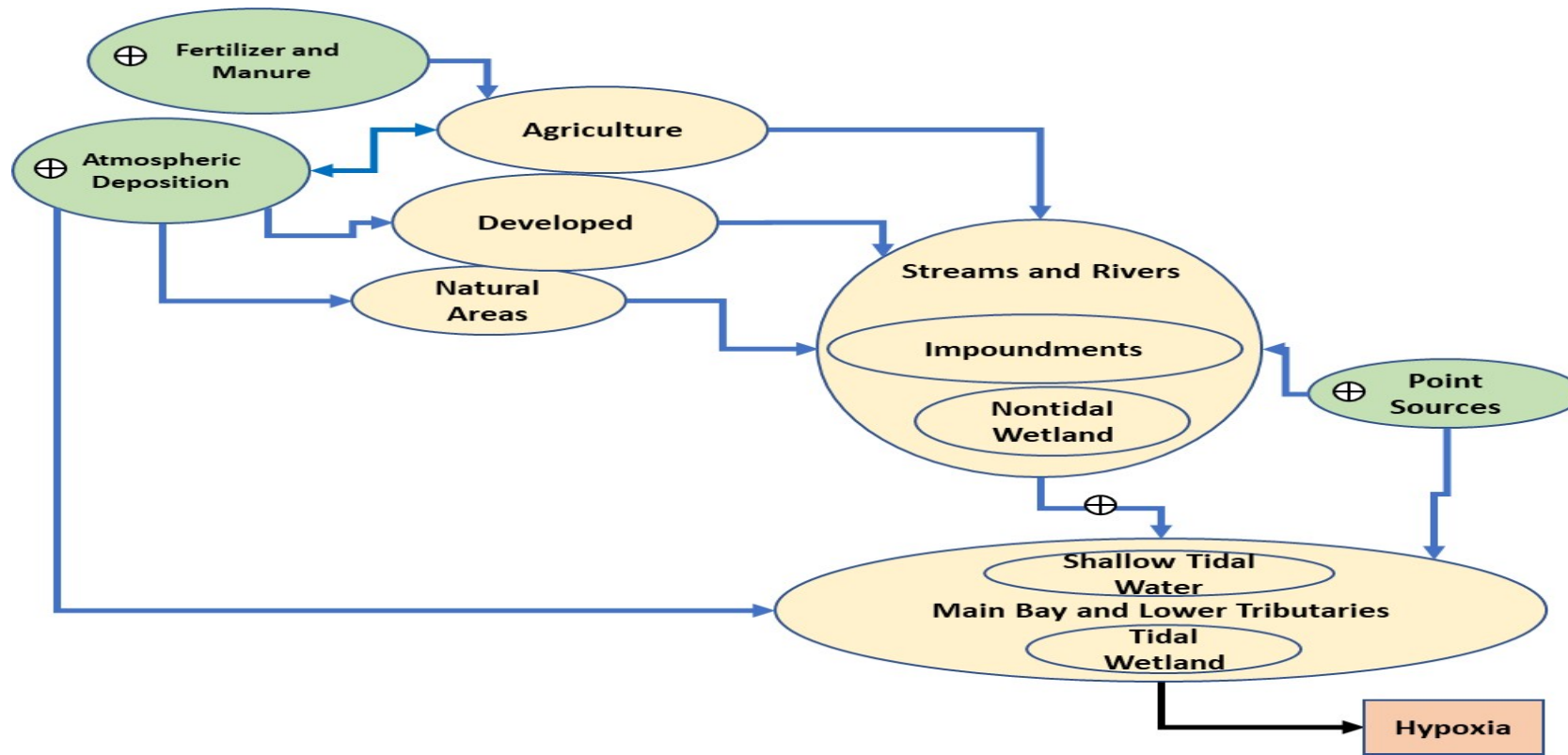
- Determine the speciation effects of
  - Land use
  - Best Management Practice (BMP) type
  - Transport effects in the soil
  - Transport effect in streams and rivers
- Evaluate watershed environmental endpoints

# Recommendation – Develop Analytical Framework - Estuary

- The reactivity of the various types of organic matter entering the estuary via the watershed needs to be better understood
- The hydrodynamic model must be improved in the shallow waters where considerable nutrient transformations occur.
- Evaluate hypoxia and HABs as environmental endpoints

# Recommendation – Develop Analytical Framework

- Conceptual models that synthesize existing science can suggest important endpoints and processes to track.



# Summary

- There is a lot to gain through tracking nutrient speciation
  - Cost-effective practices
  - Benefits to multiple environmental endpoints
- Extensive research necessary for a complete picture
- The CBP is already familiar with the concept and can make incremental headway toward full speciation tracking.

