

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

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Presentation to WQGIT

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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

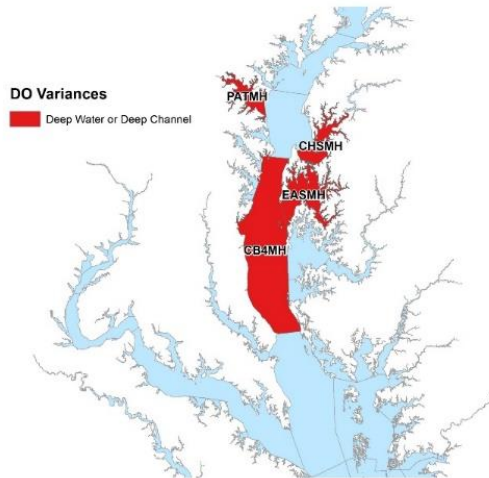


Phosphorus Load: 0.26 million pounds

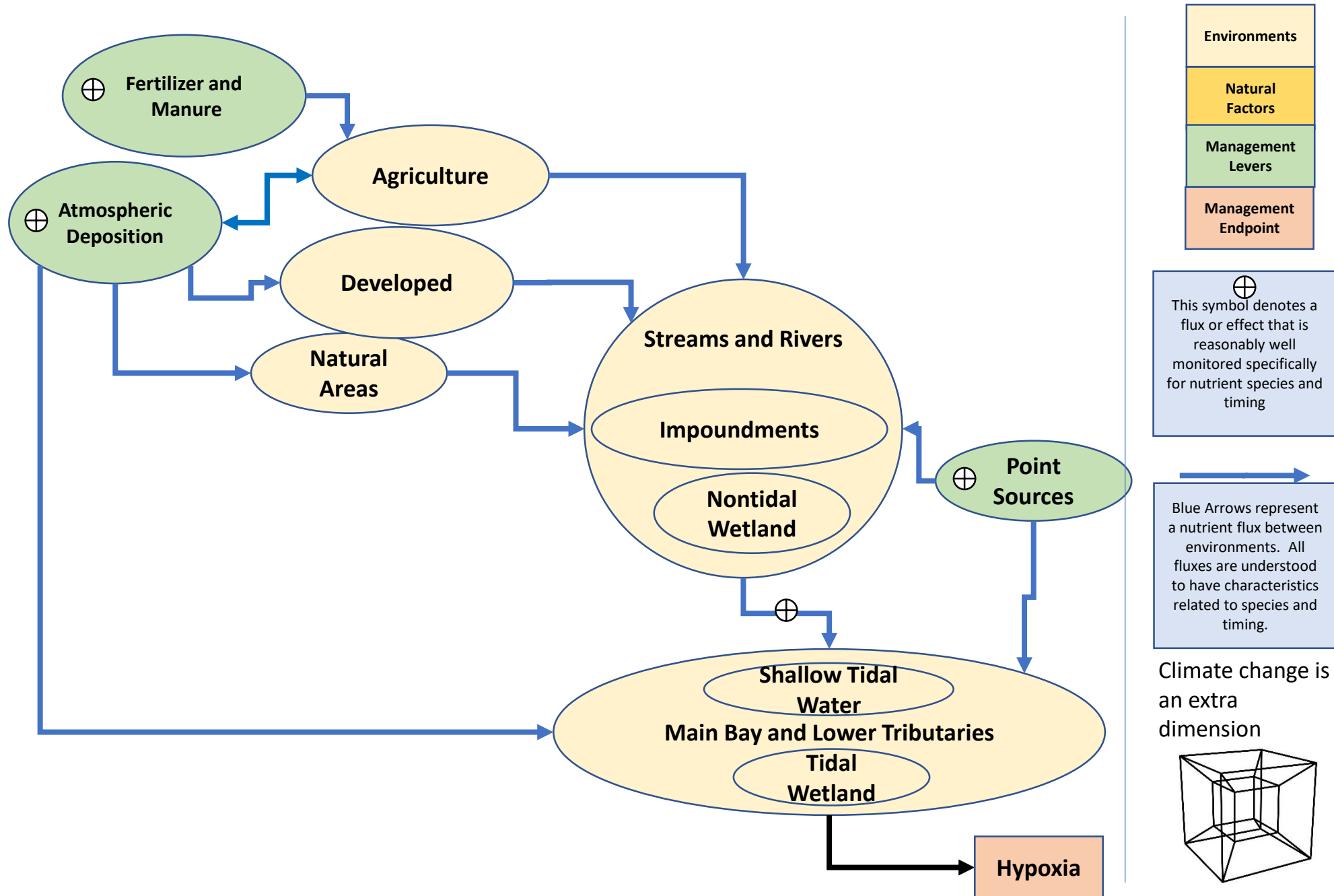
With normal bioavailability and normal flow delivery



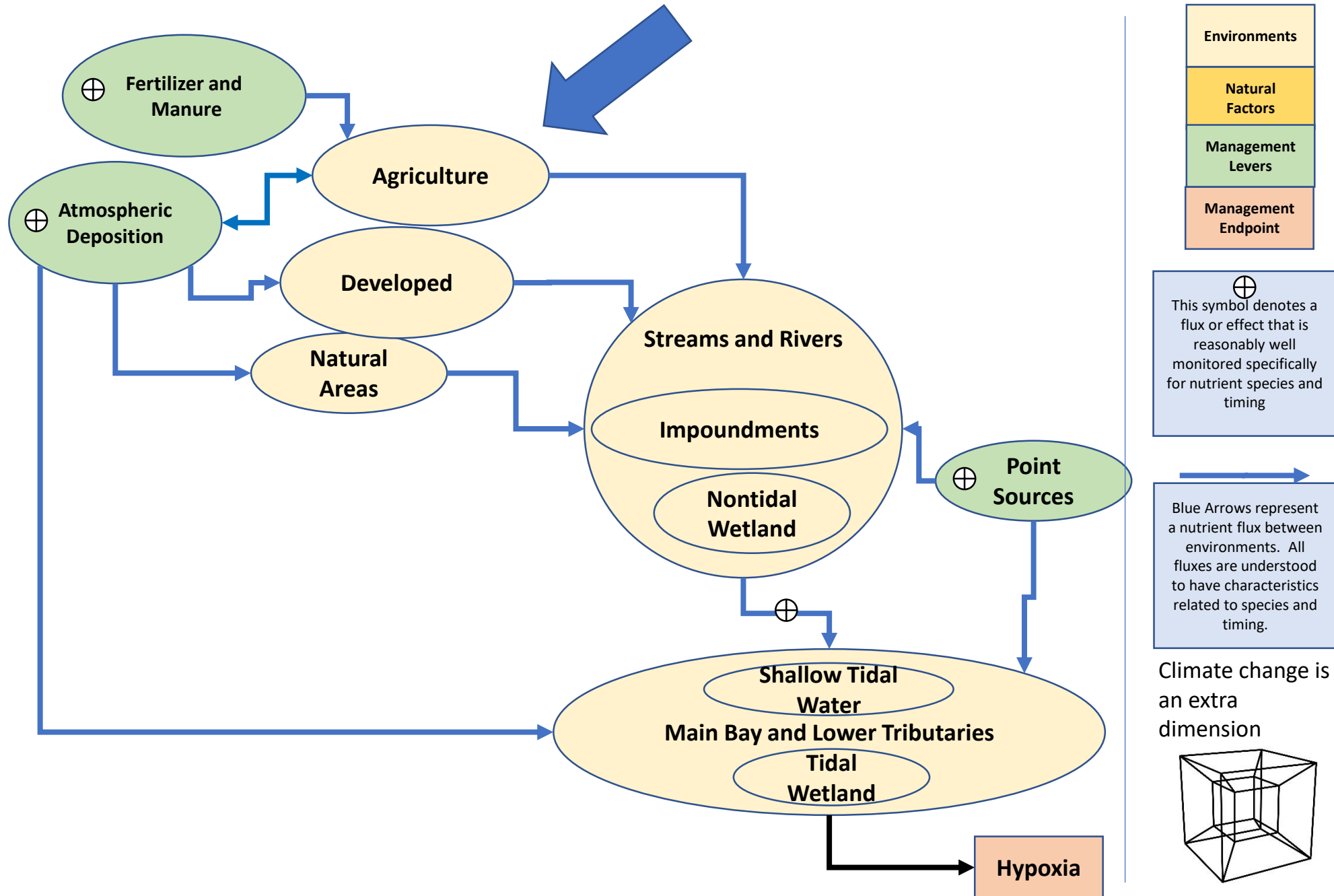
64 million cubic meters of additional low-DO water

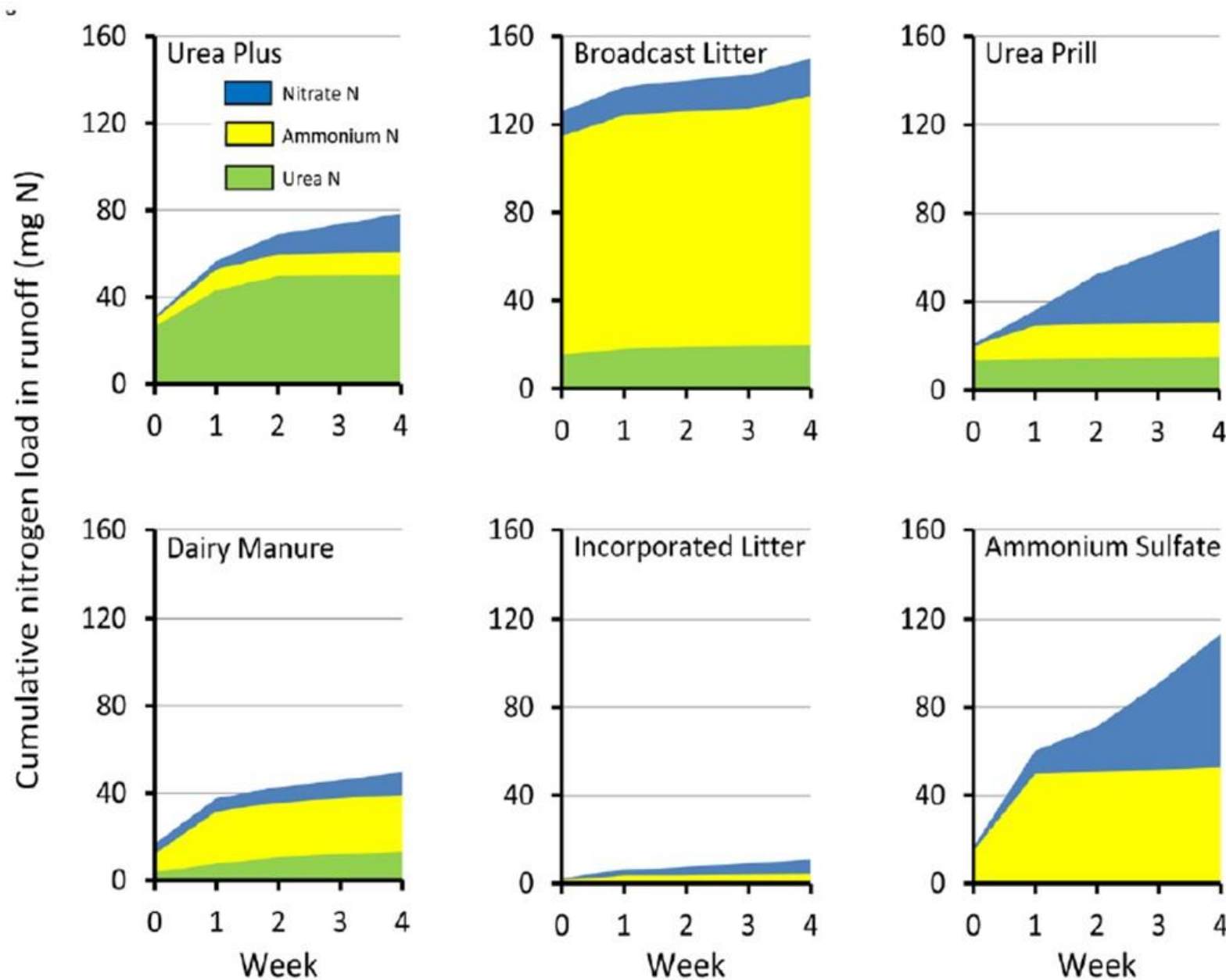


Conceptual model of nutrient-driven hypoxia related to nutrient species and timing



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





Fresh inputs on source areas may lead to high DON or 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?

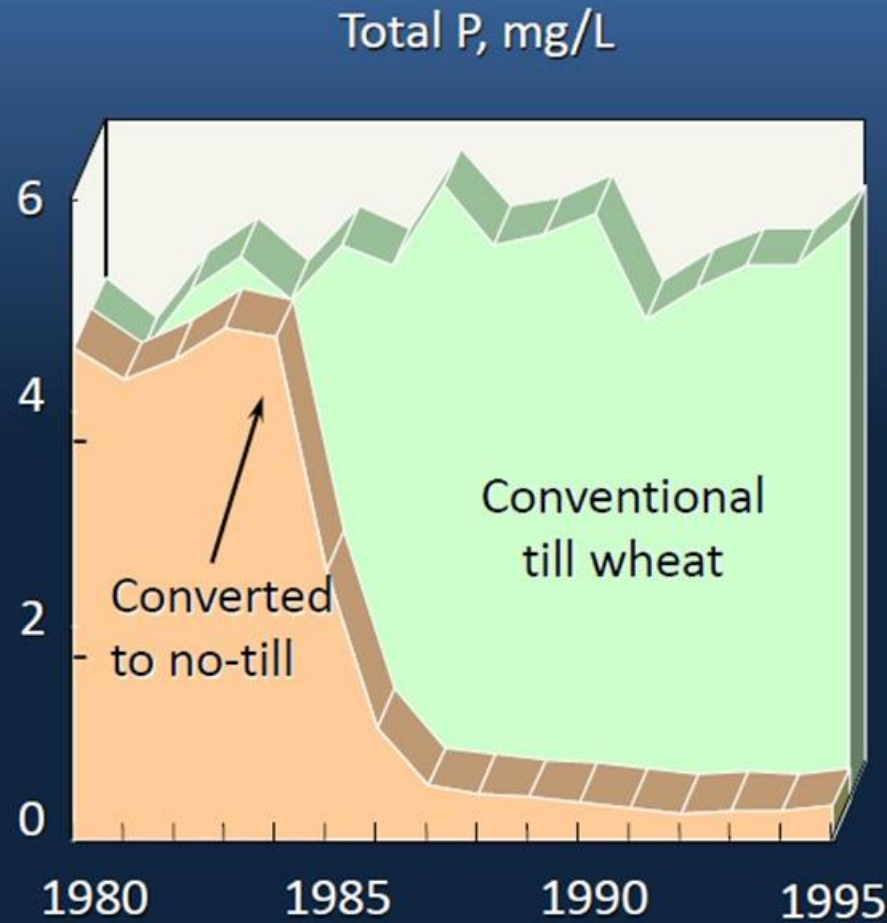
Slide from Jason Kaye, PSU

No-till
reduced TP,
but
increased
dissolved P

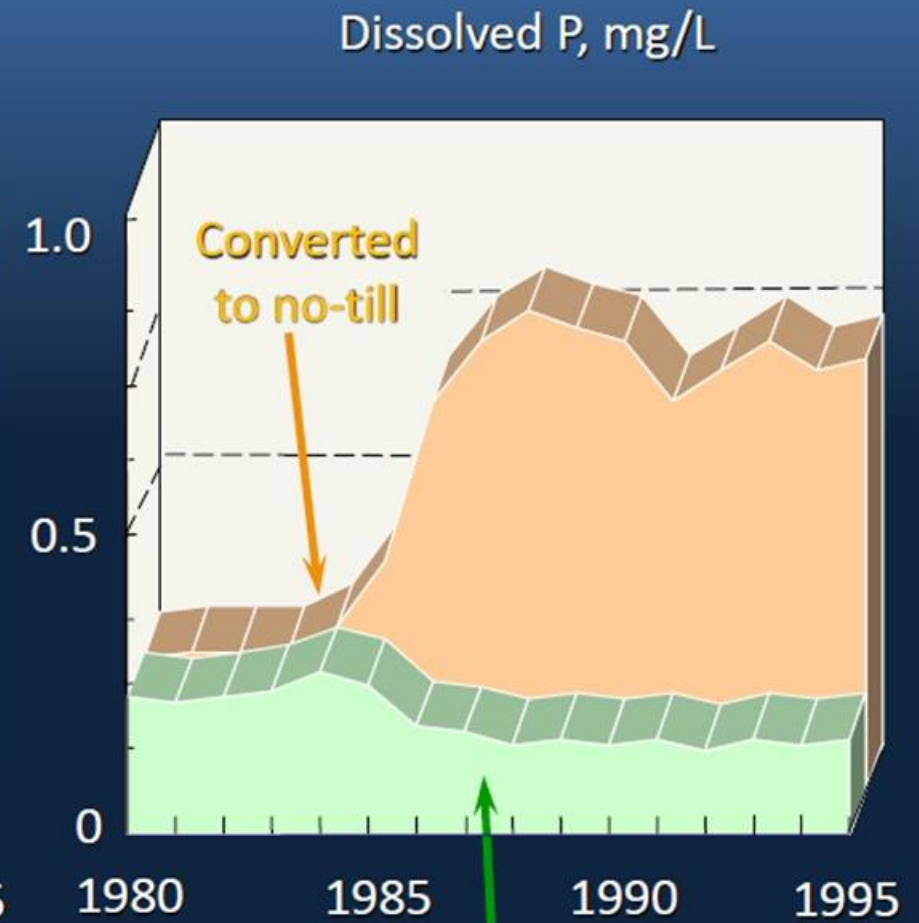
Unintended Outcomes

Conservation paradox

No-till reduced erosion by 95%



Sharpley & Smith, 1994 – El Reno, OK



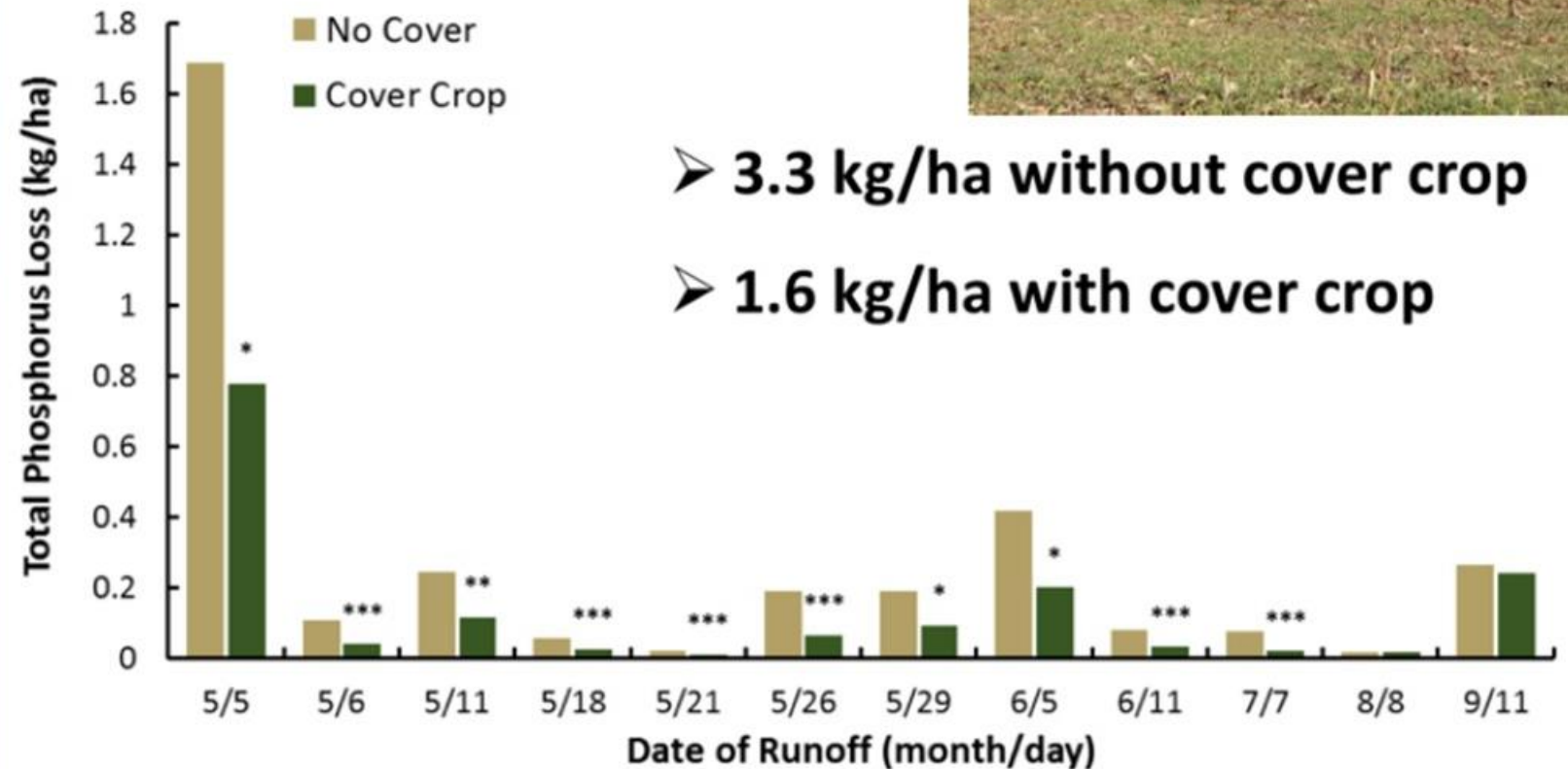
Slide from Pete Kleinman, ARS

Cover crops
reduce TP in
the warm
months...

Cover Crops

Soil Conservation and nutrient uptake

Kansas study, > 50% reduction in total P loss



➤ **3.3 kg/ha without cover crop**

➤ **1.6 kg/ha with cover crop**

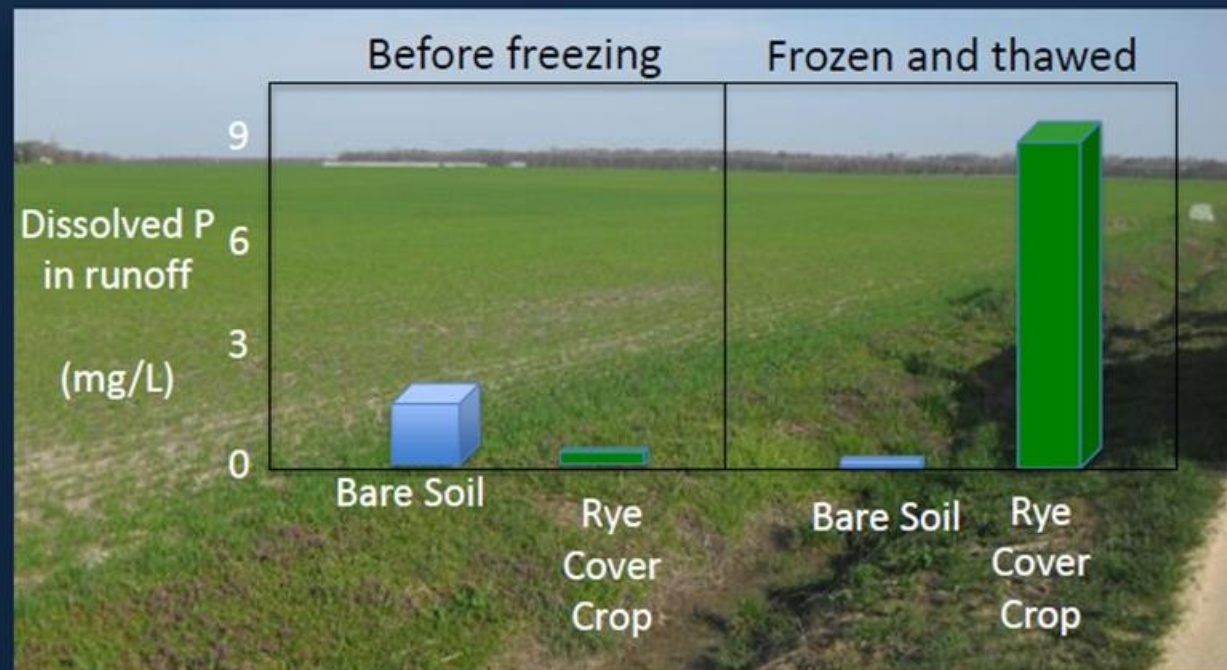
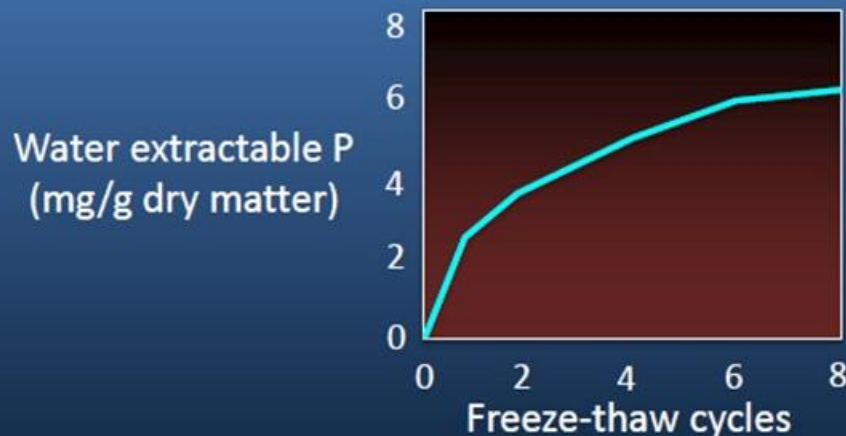
, **, * Indicates significant difference at $p < 0.05$, $p < 0.01$, $p < 0.001$*

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

Unintended Consequences

Cover crop – trade offs

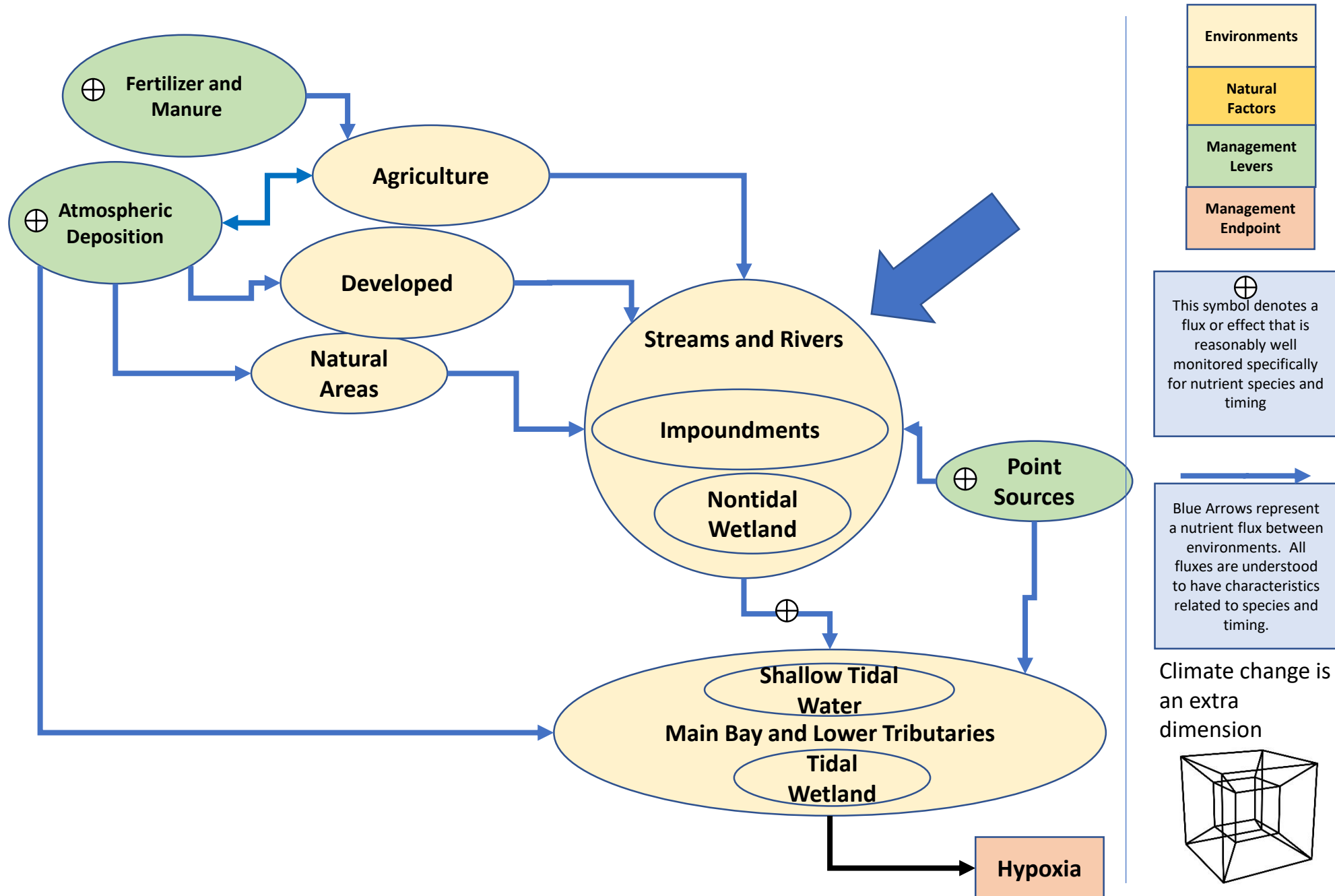
a slow release source of dissolved P



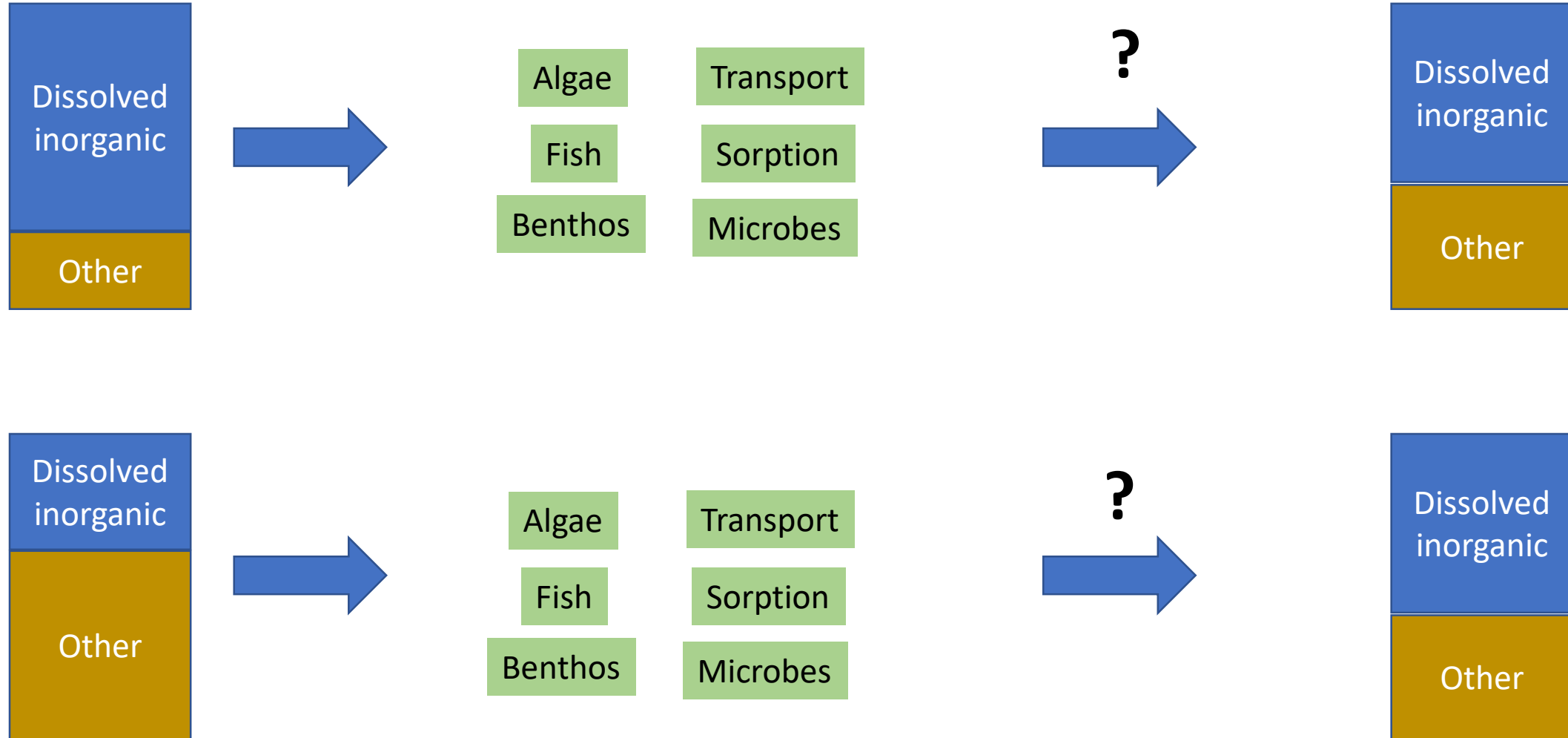
Bechmann et al., 2005
J. Environ. Qual.

Slide from Pete Kleinman, ARS

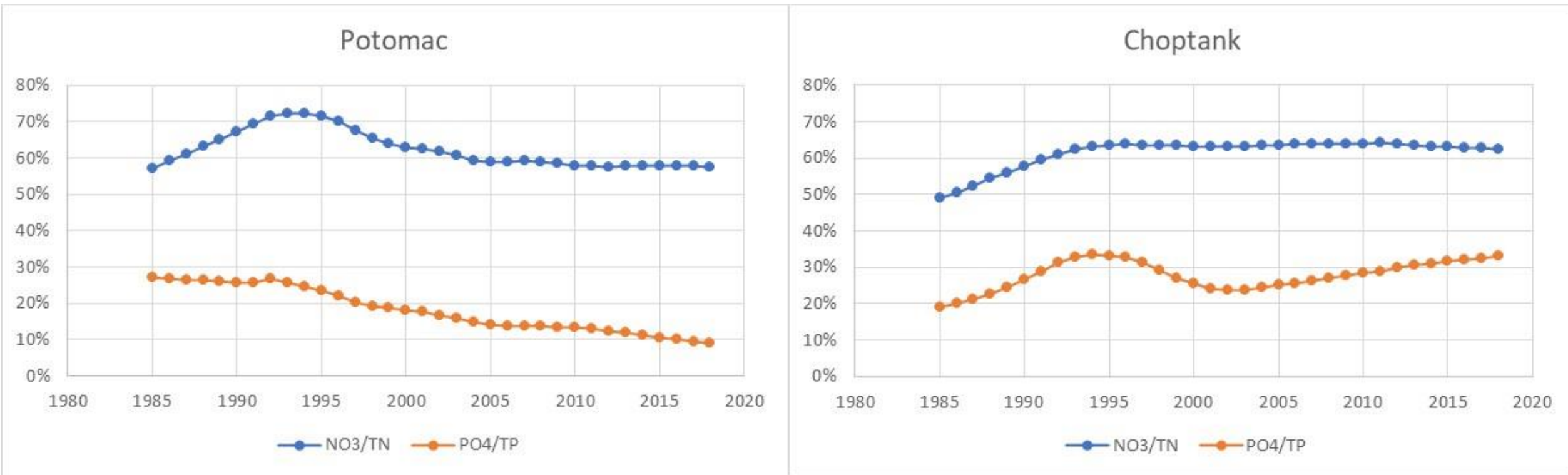
Conceptual model of nutrient-driven hypoxia related to nutrient species and timing



Spiraling in rivers

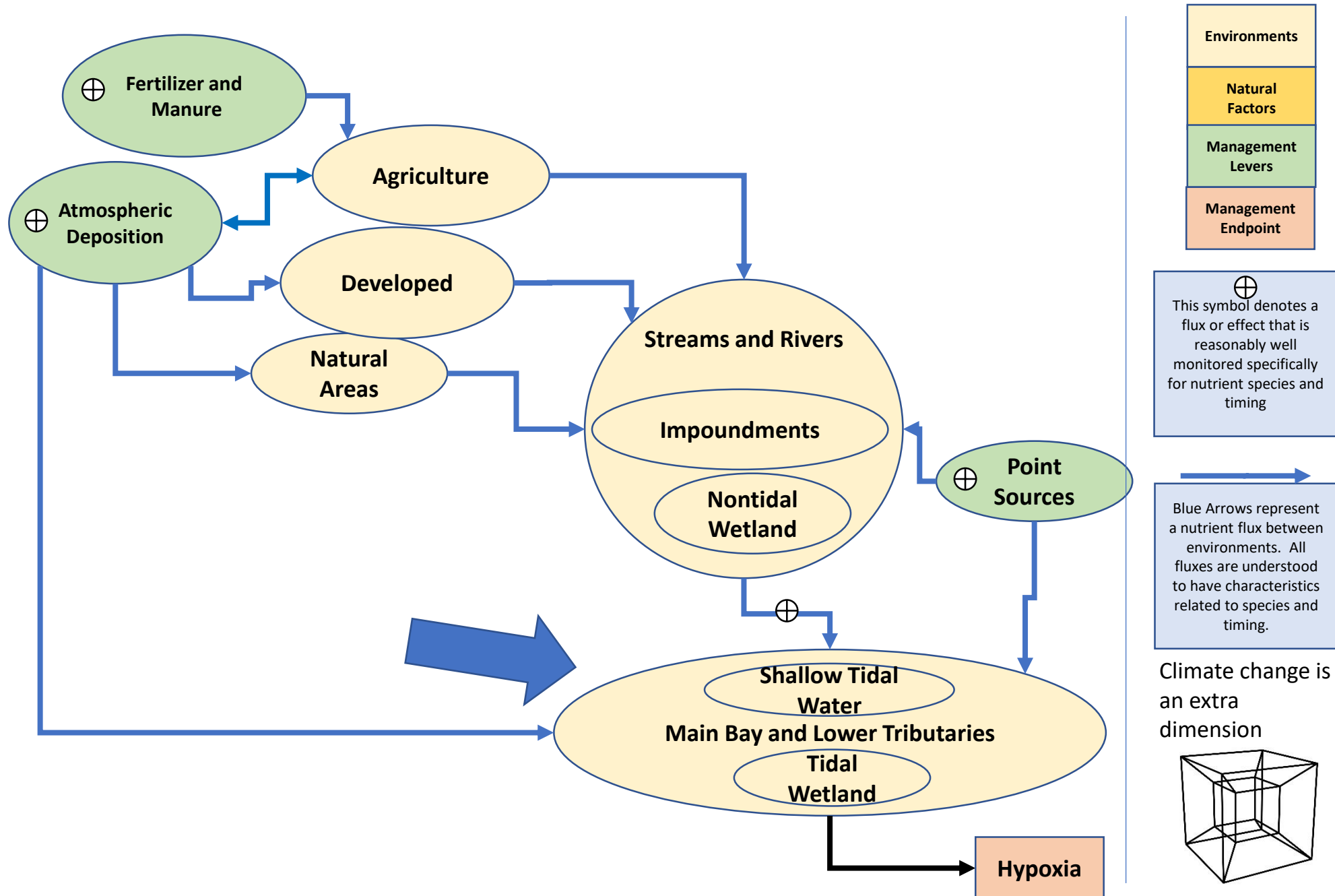


Dissolved inorganic Fractions

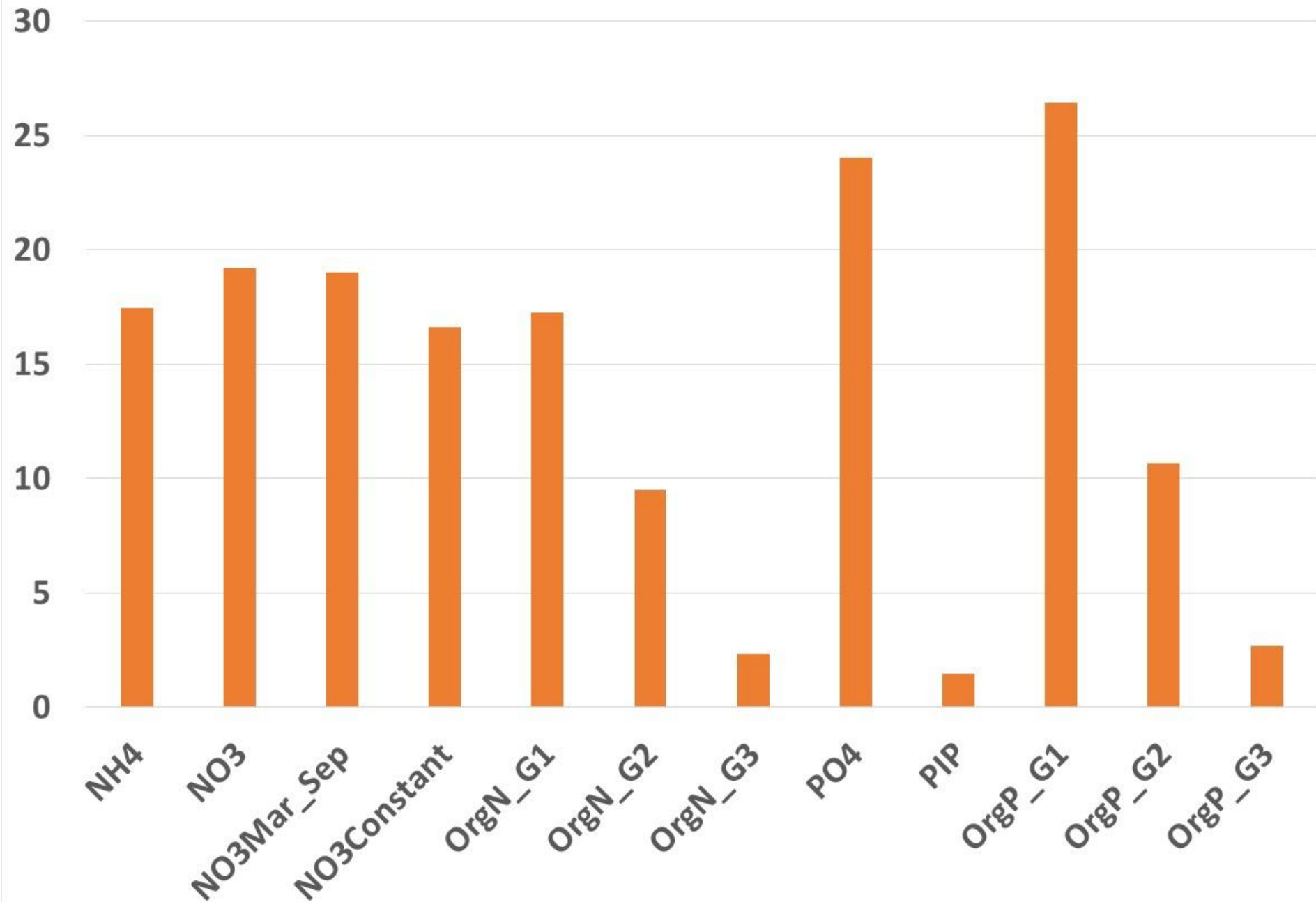


- NO₃ between 50% and 70% of the flow-normalized load
- PO₄ between 10% and 30% of the flow-normalized load
 - Opposite trends in the Potomac and Choptank

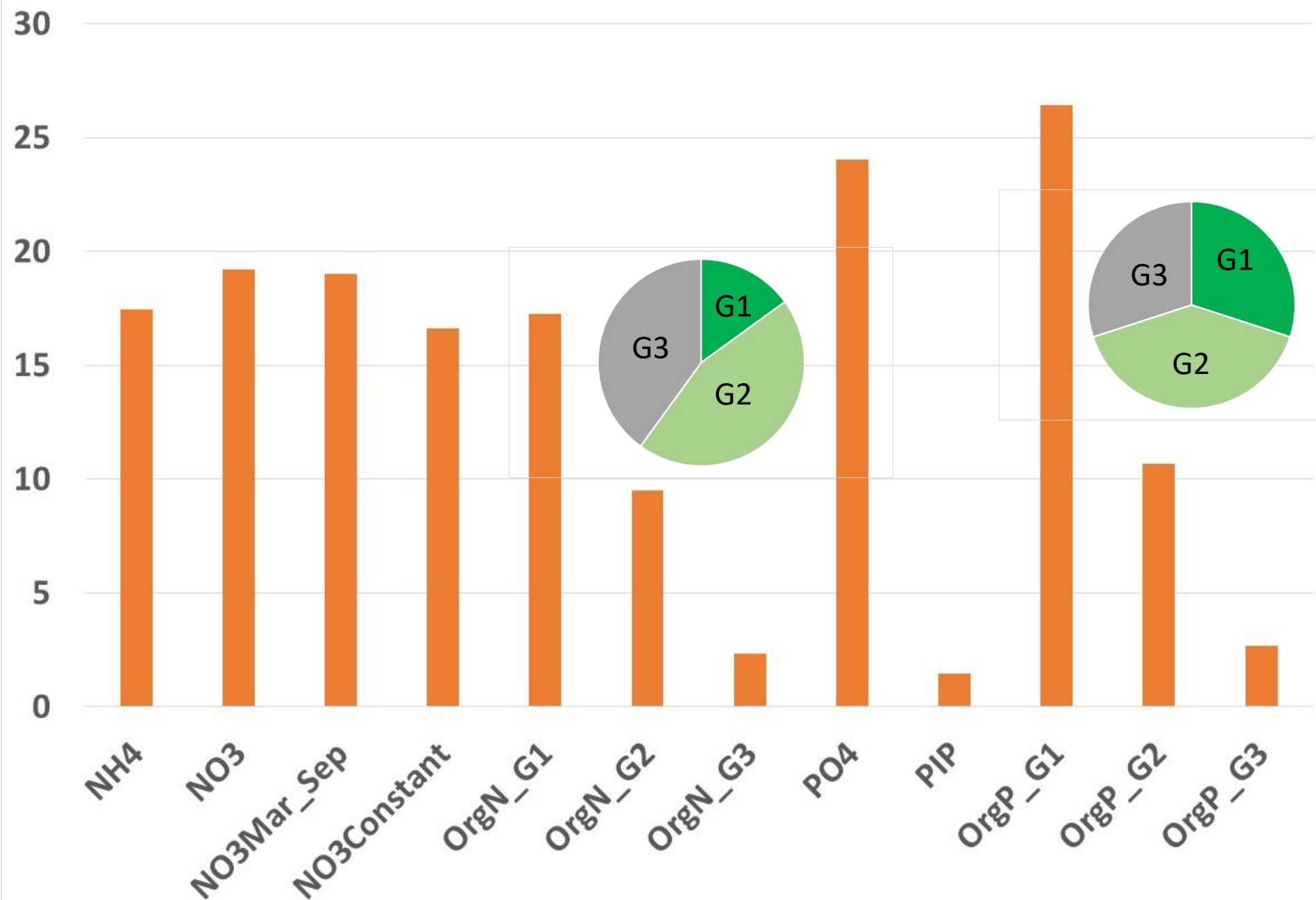
Conceptual model of nutrient-driven hypoxia related to nutrient species and timing



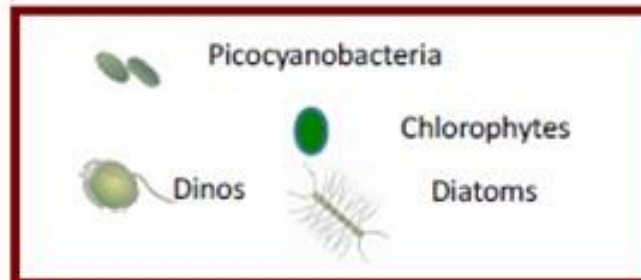
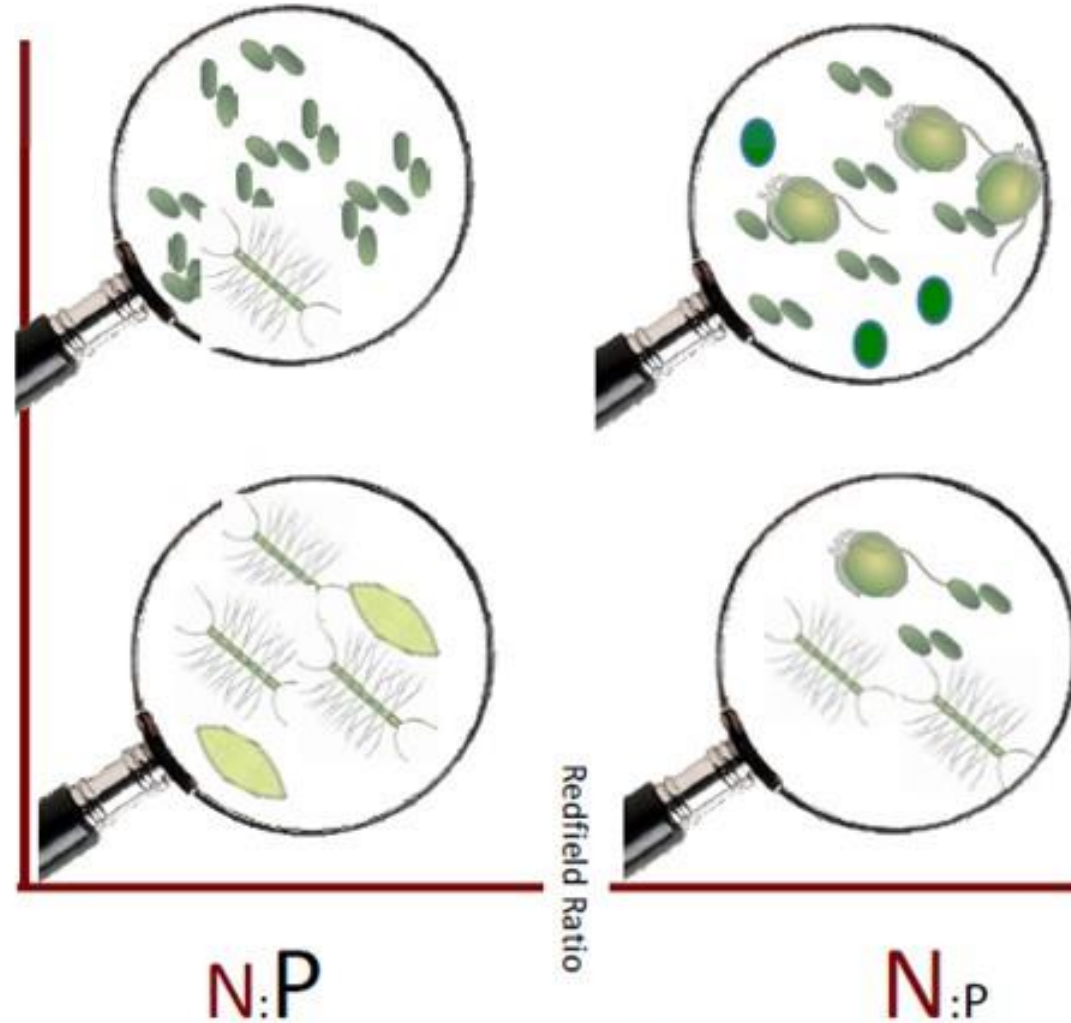
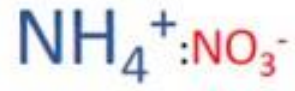
Cubic meters of Hypoxia (< 3mg/l) per Pound



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

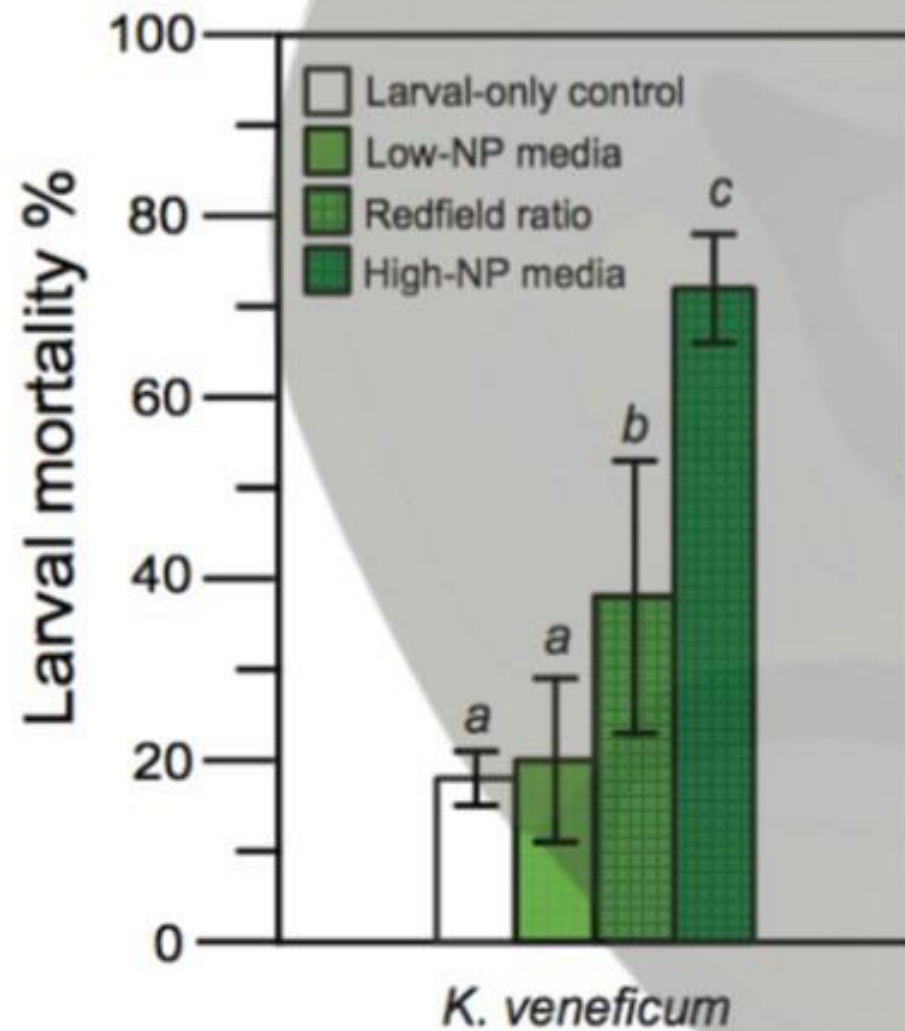


*Nutrient forms and ratios
set the biodiversity trajectory*



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

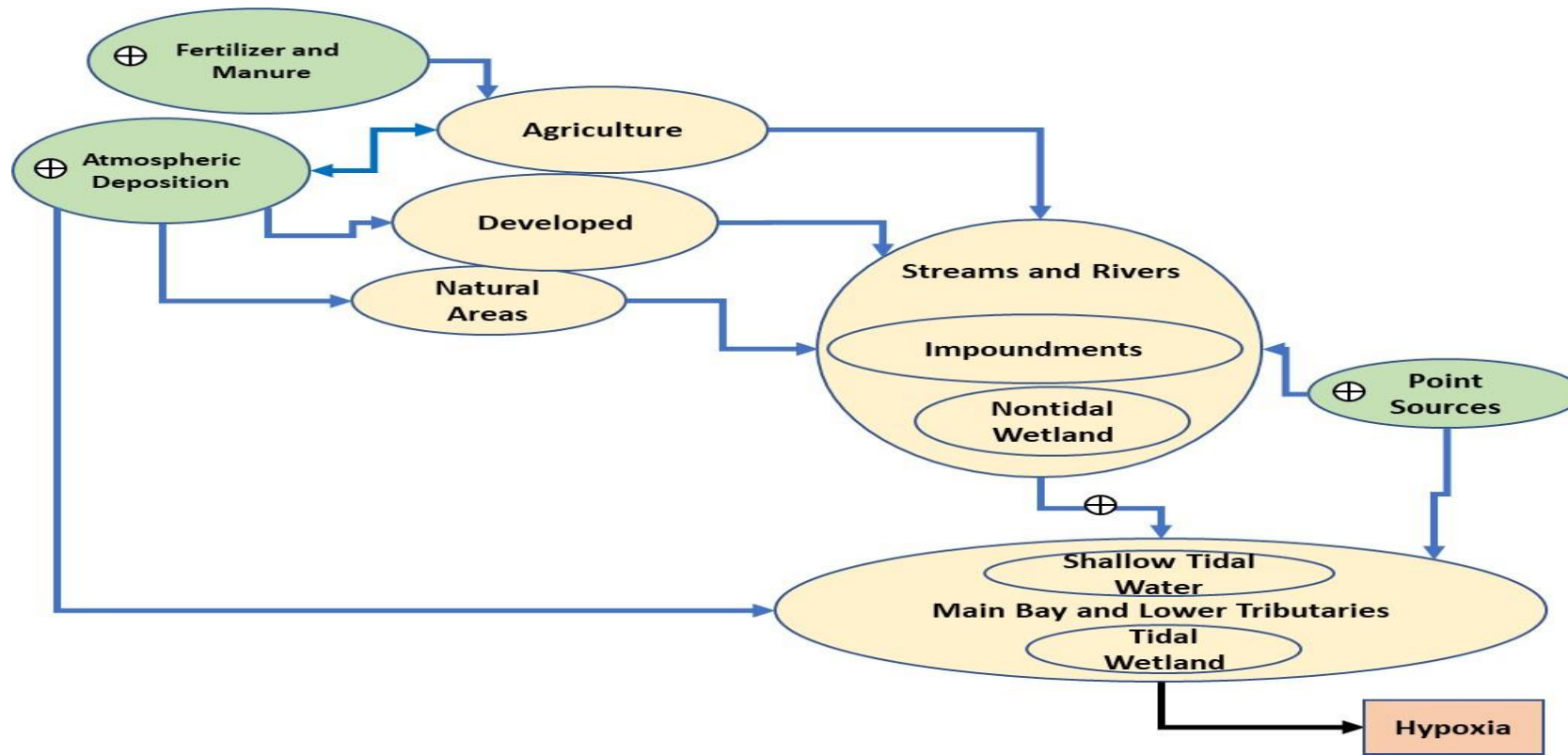
- Determine the speciation effects of
 - Land use
 - Best Management Practice (BMP) type
 - Transport effects in the soil
 - Transport effect in streams and rivers
- Evaluate watershed environmental endpoints

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.

