Utility of biofilm fatty acid signatures as a tool to characterize watershed environmental stress

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An immense challenge

Population predicted to shift from 17.7 to 20 million people by 2030
Associated demands for food, energy, clean water.

Chesapeake TMDL program (a pollution diet)
Watershed specific (EPA mandates to the state level)

"generate less pollution yet plan for the same levels given a 3-5 million population increase"

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Can we complement nutrient monitoring?

(1) How do we characterize disturbed ecosystems?

(2) What benchmarks:

Do we use to characterize the extent of disturbance?

Do we use to evaluate the success of restoration?

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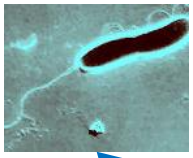
Approaches to ecological assessment

Biogeochemical
Removal as gas?

Nutrient Flux
(C, N, P,)

Biomass accrual
(C, N, P)

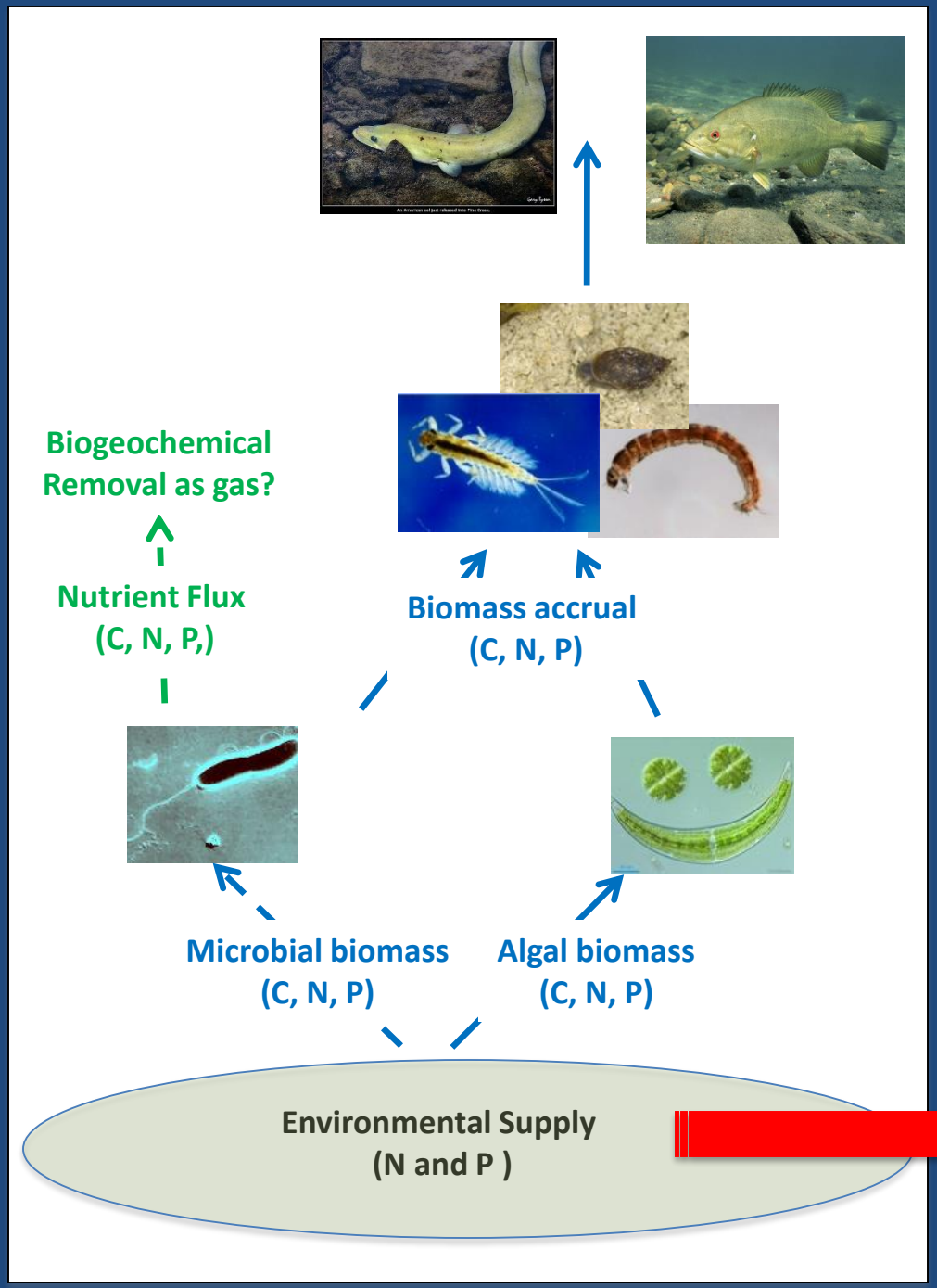


Microbial biomass
(C, N, P)

Algal biomass
(C, N, P)

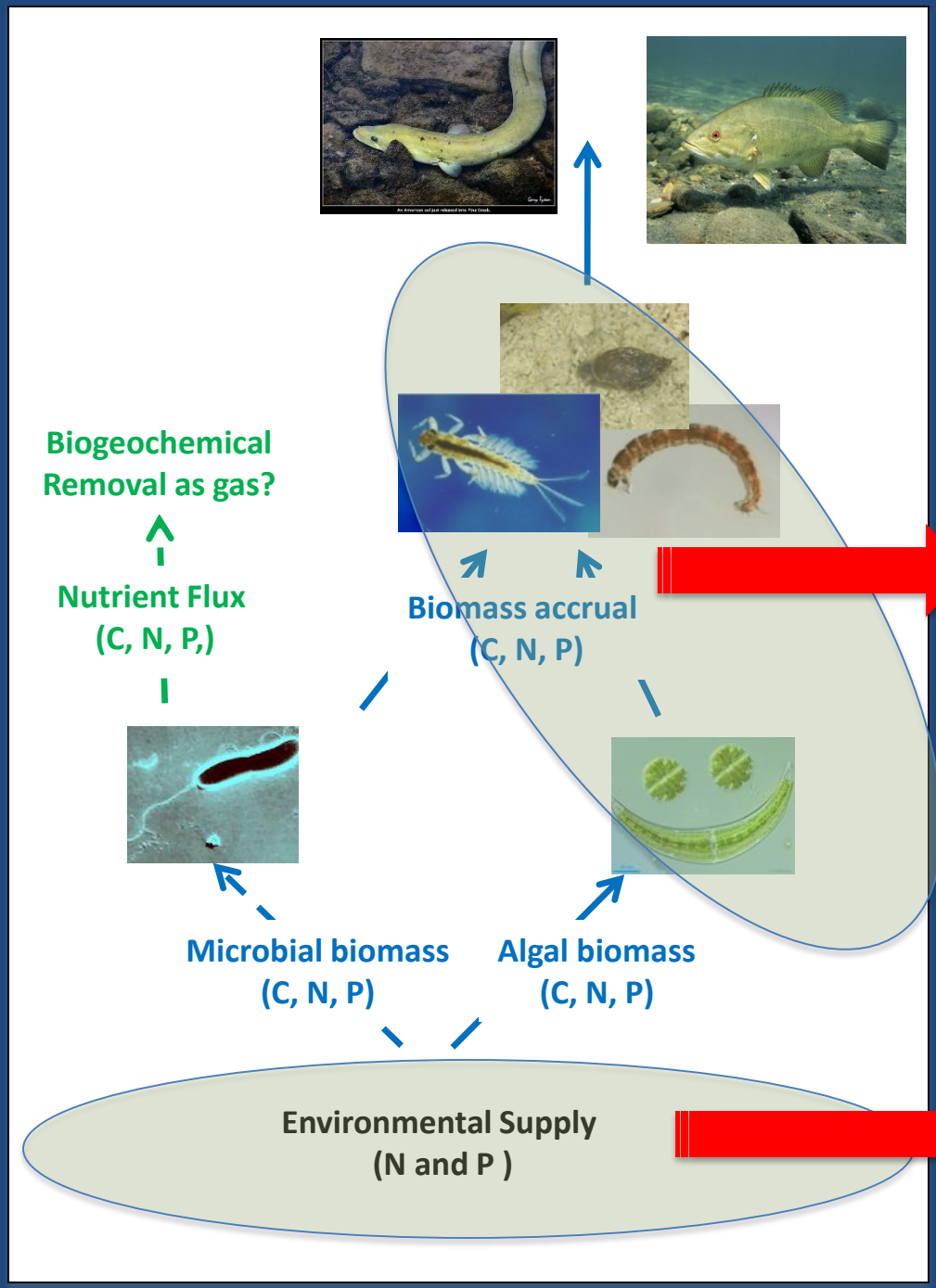
Environmental Supply
(N and P)

Approaches to ecological assessment



Supply side-monitor point sources and total maximum delivered loads

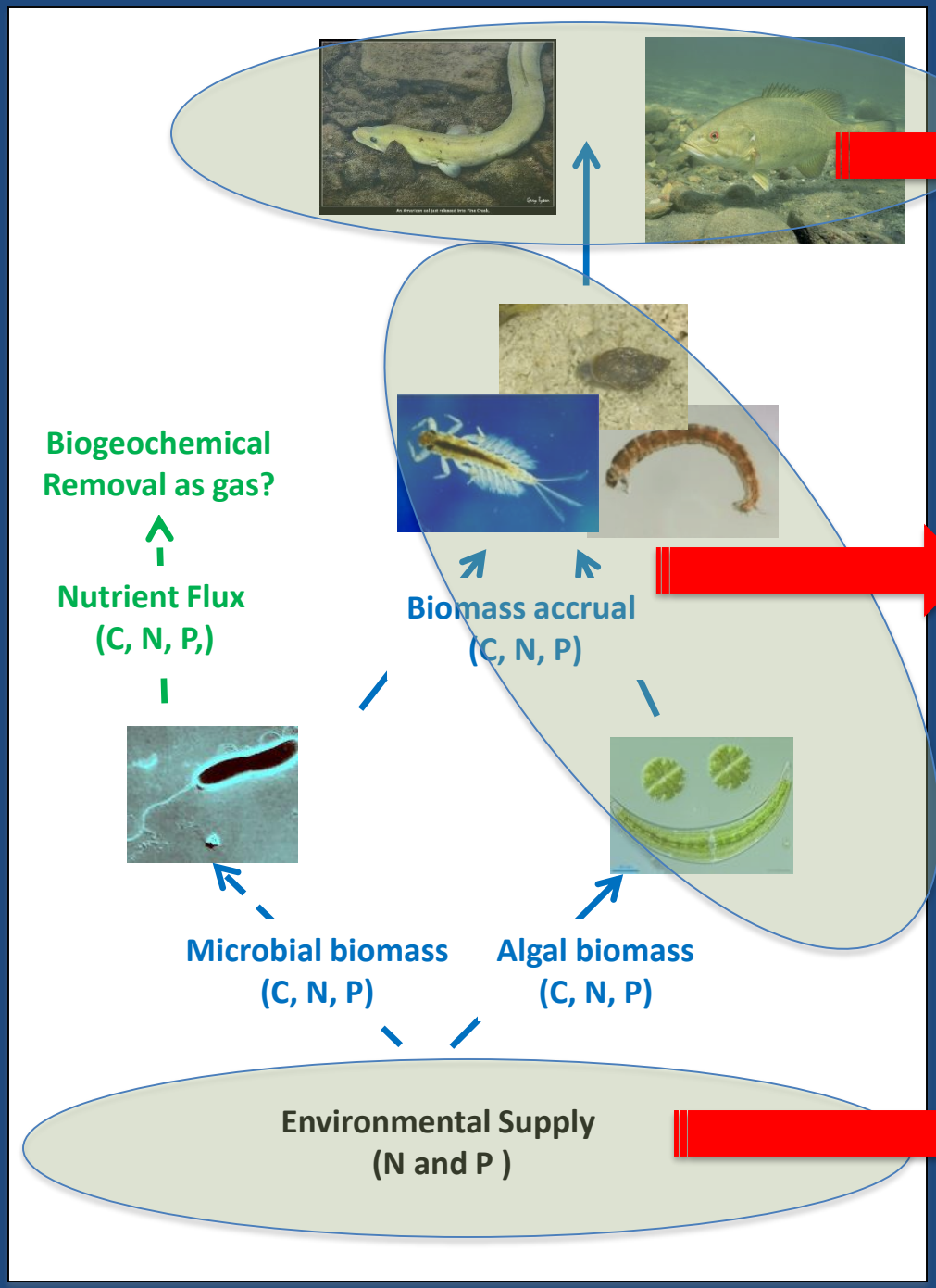
Approaches to ecological assessment



Indicator species and indices of biotic integrity

Supply side-monitor point sources and total maximum delivered loads

Approaches to ecological assessment

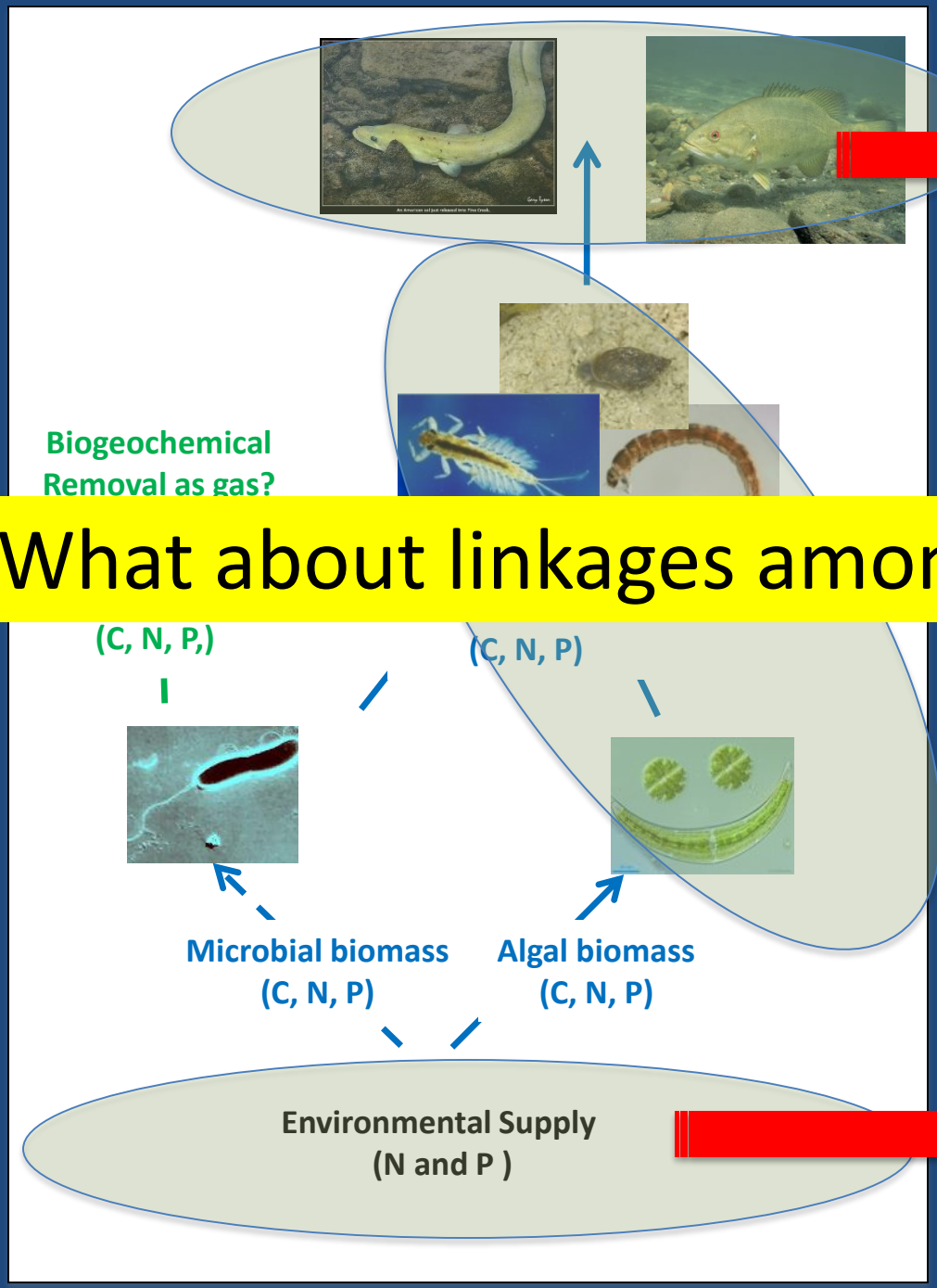


Population assessment

Indicator species and indices of biotic integrity

Supply side-monitor point sources and total maximum delivered loads

Approaches to ecological assessment



Population assessment

What about linkages among compartments?

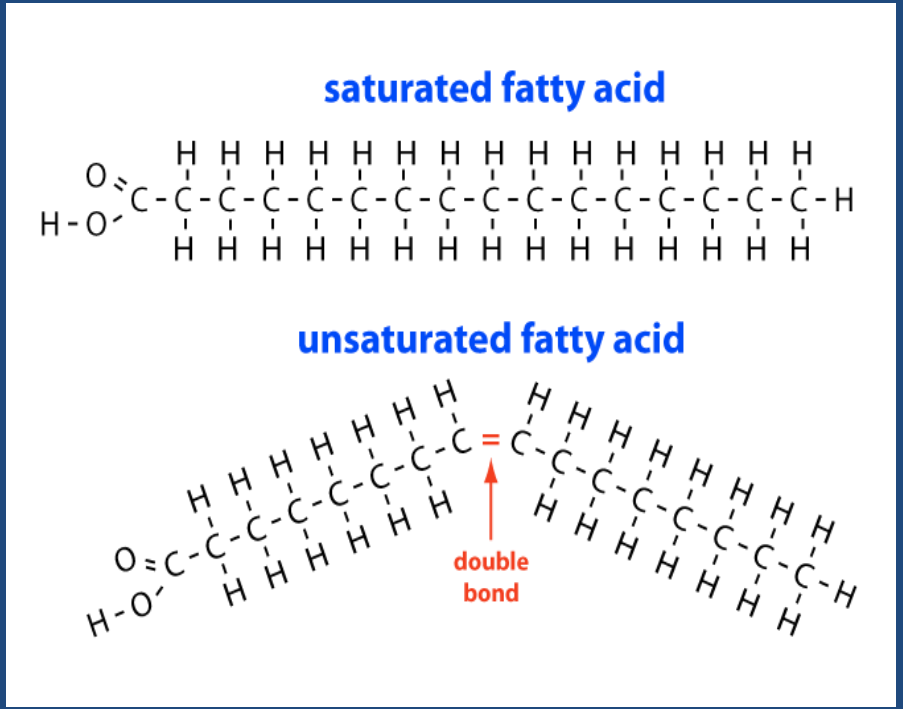
Supply side-monitor point sources and total maximum delivered loads

ECOLOGICAL NUTRITION: Study of macromolecules (lipids, carbohydrates, proteins); nutrients (carbon, nitrogen, phosphorus); and vitamins within a foodweb or ecosystem.

- Fatty acids are a group of lipids with a distinct chemical structure. Often used to assess the quality of carbon.

- Typically are bookended by a methyl and carbonyl group.

SAFA: Saturated fatty acid
MUFA: Mono-unsaturated fatty acids
PUFA: Poly-unsaturated fatty acids
HUFA: Highly unsaturated FA
w3 and w6: placement of the first double bond



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Fatty acids serve many physiological and ecological functions:

- Fundamental building blocks (macromolecule and growth)
- Promote physiological processes (visual acuity)
- Govern physiological processes (membrane fluidity)

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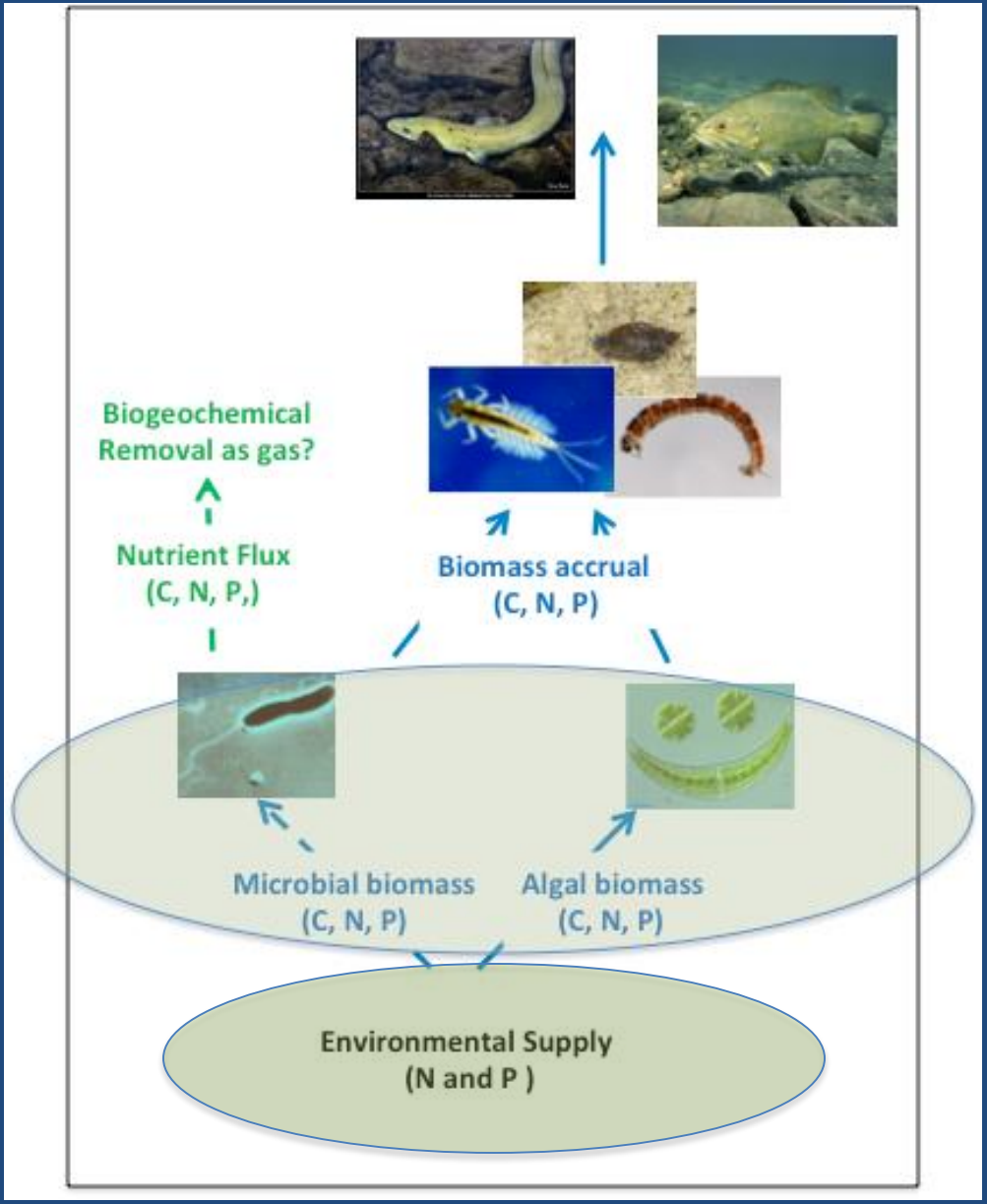
Ecologically important FA's

HUFA, PUFA and long chain fatty acids are generated via elongation and desaturation.

Only certain taxa at the base of the food web can do it *de novo.*

Ecologically important FA's are an important commodity within foodwebs.

How do watershed stressors influence fatty acid composition?



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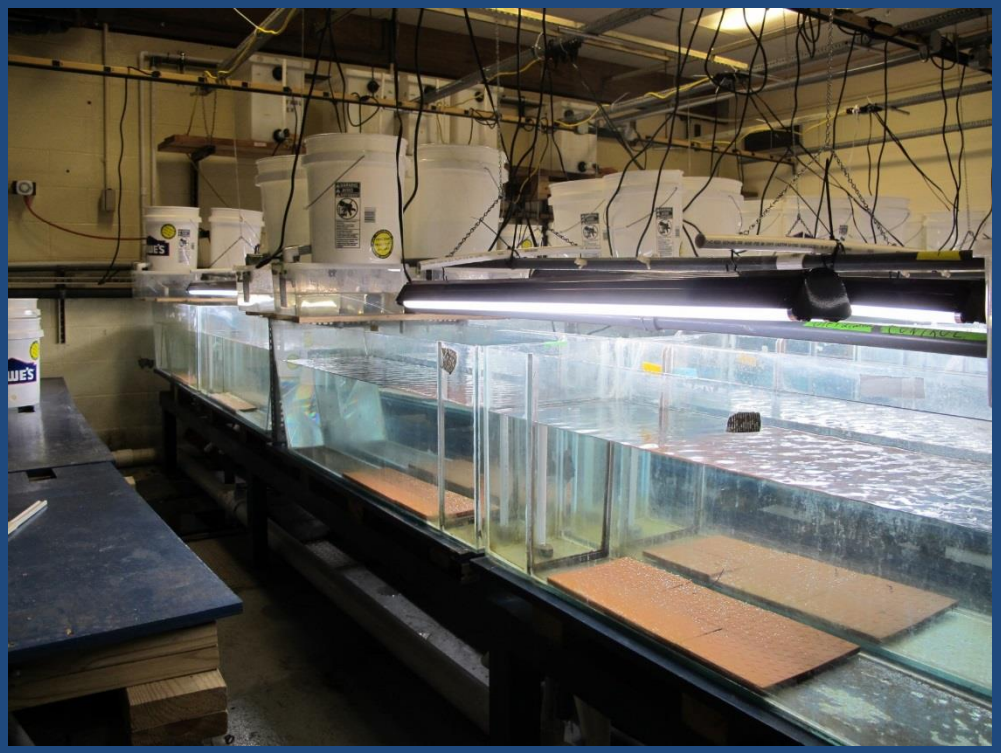
Can we use biofilms to characterize nitrogen, phosphorus, and sediment stressors?

Approach:

- Flow through 110 L mesocosms connected to solenoids.
- Manipulated sediment, nitrogen, phosphorus
- Colonized each stream with the same slurry collected from nearby Straight Run.
- Incubated the streams for 30 days



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Experimental design

Analogous to a 3 way ANOVA

	No Sediment	
	Low N 0.3 mg N	High N 6.0 mg N
Low P	nps	Nps
High P	nPs	NPs

	Sediment	
	Low N 0.3 mg N	High N 6.0 mg N
Low P	npS	NpS
High P	nPS	NPS

Individual treatments

nps, Nps, nPs, NPs, npS, NpS, nPS, NPS

n = 4

Specific treatments

n, N

p, P

s, S

n =16

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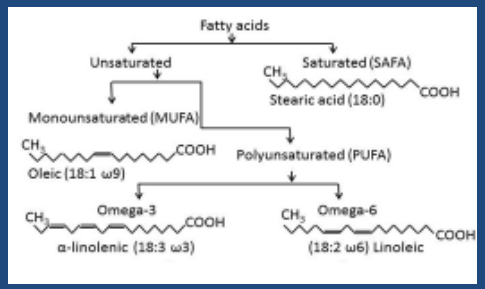
Response measures (conventional)

- Biomass accrual
- Algal community structure
- Total and dissolved nutrients

Functional responses

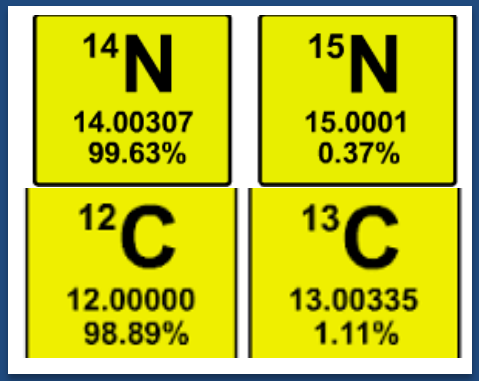
Fatty acids



Enzyme activity

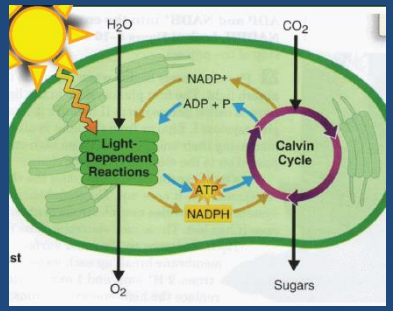
P-ase
N-ase
C-ase

Stable isotopes



ambient
labeling study
(N uptake)

Metabolism



GPP
Respiration

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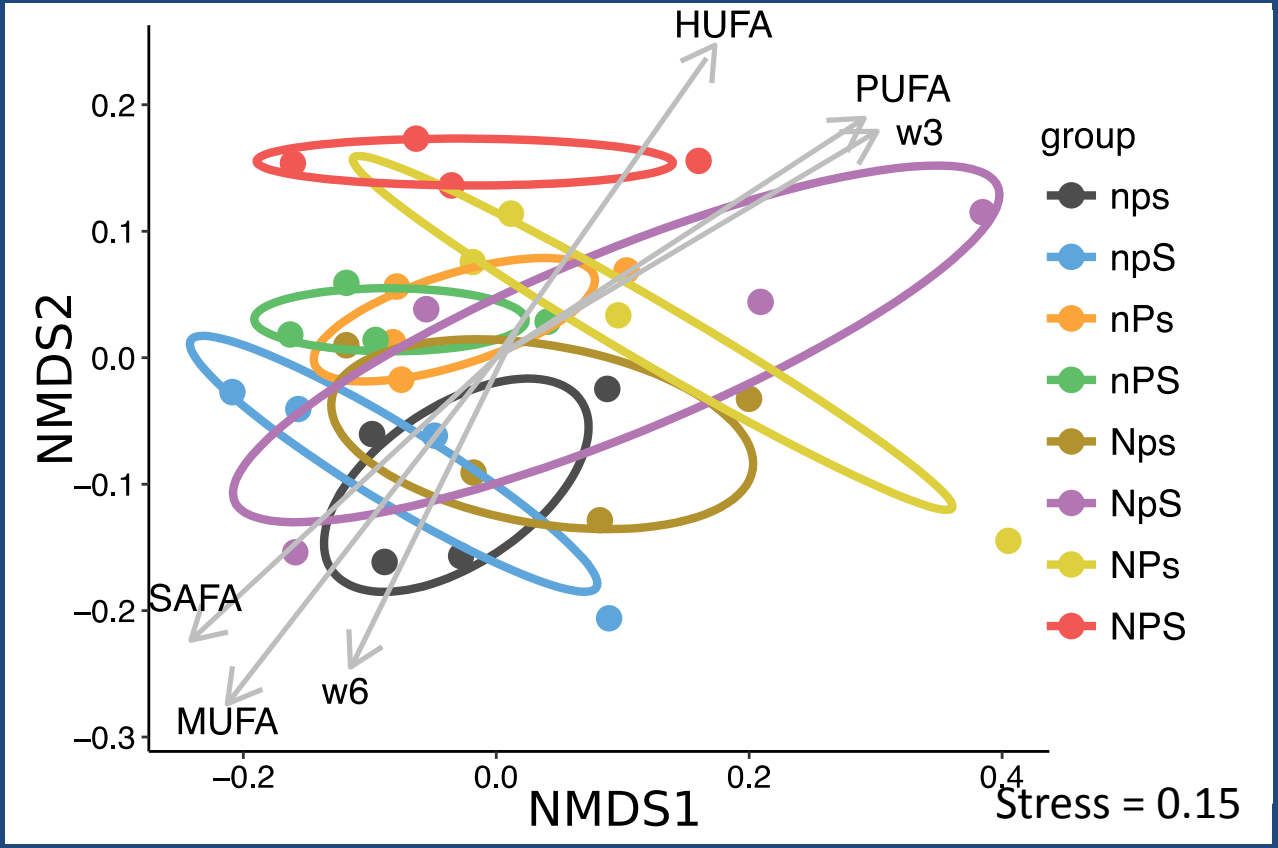
Fatty acids



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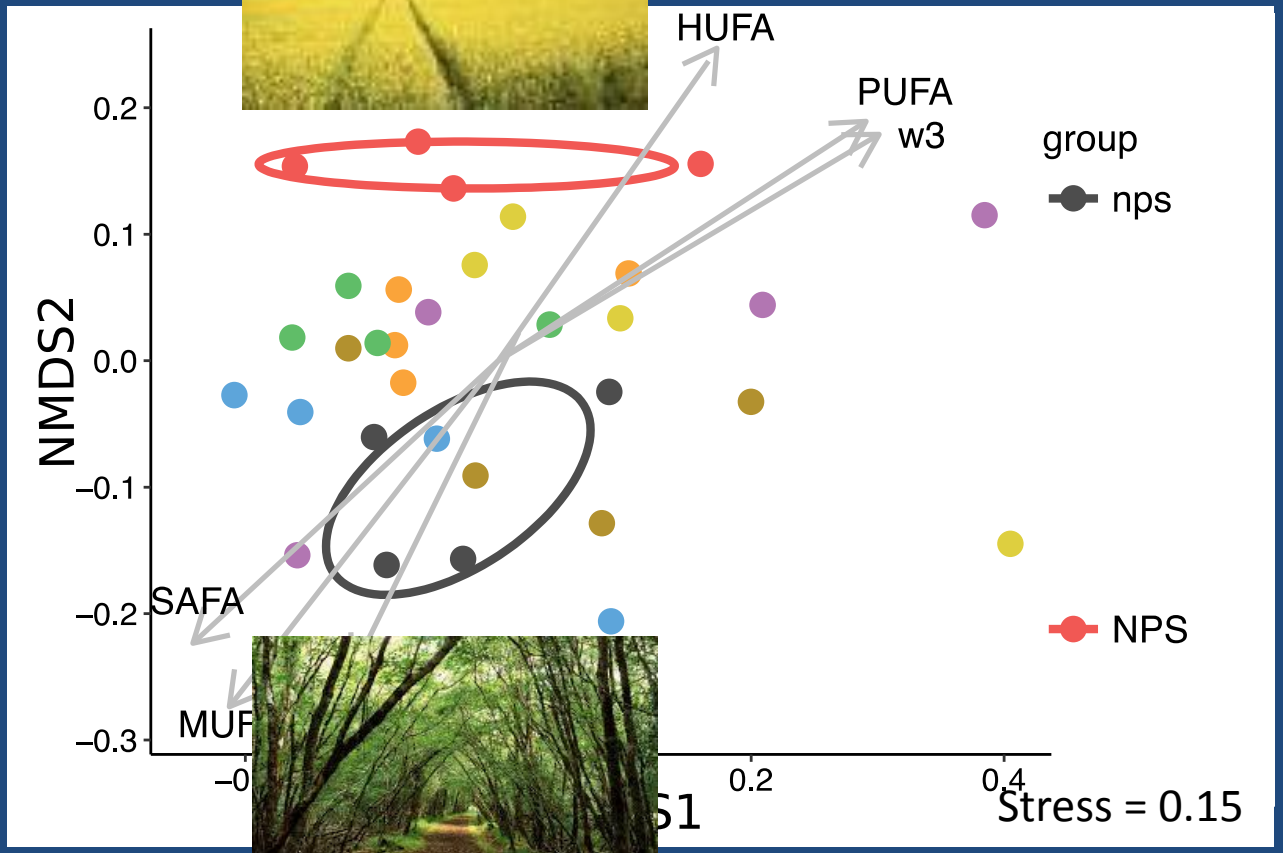
Fatty acids



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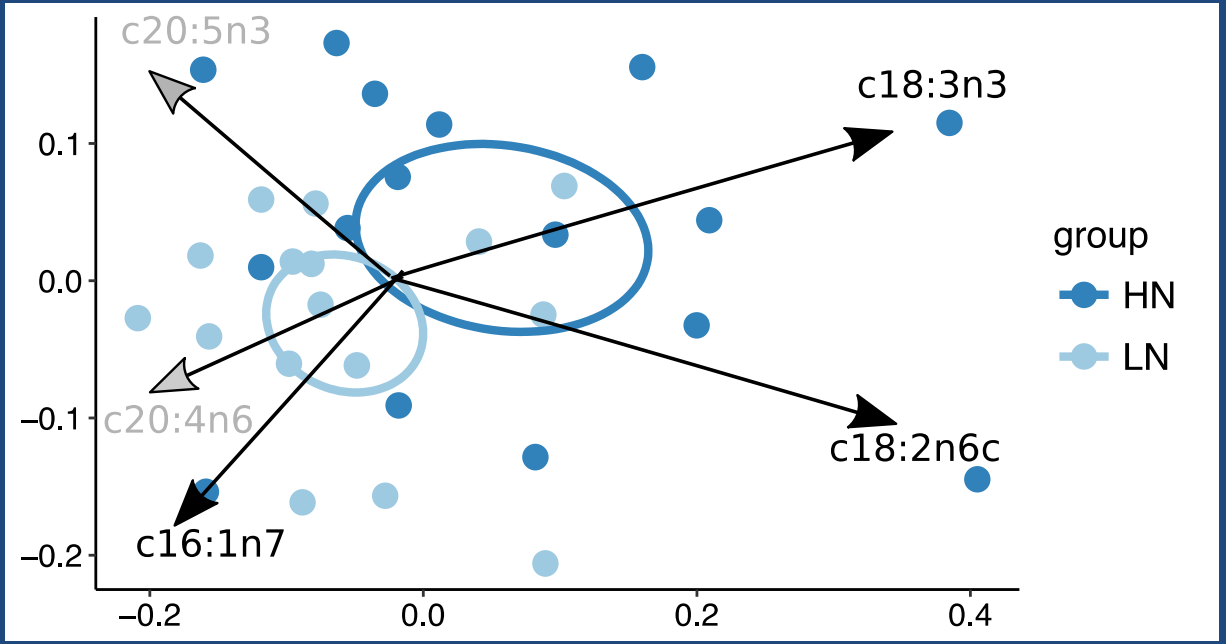
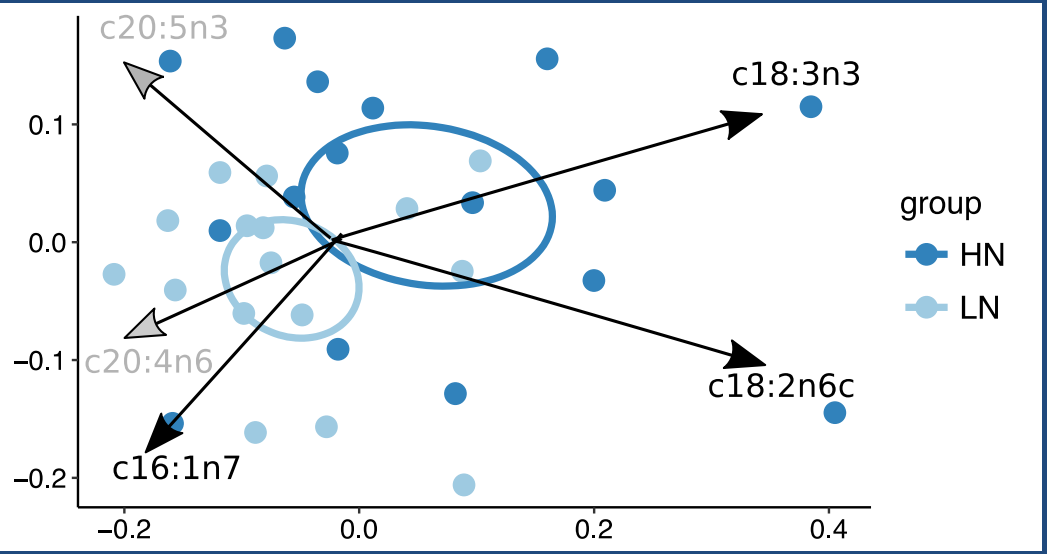
SIMPER Analysis
(Similarity of Percentages)

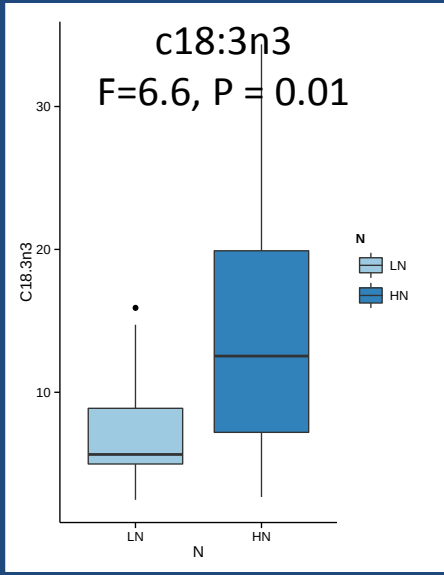
Characterize which fatty acids explain differences in treatment assignment.

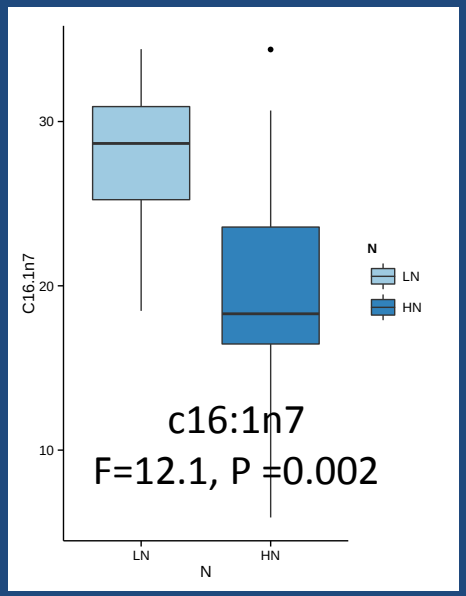
Low versus high nitrogen

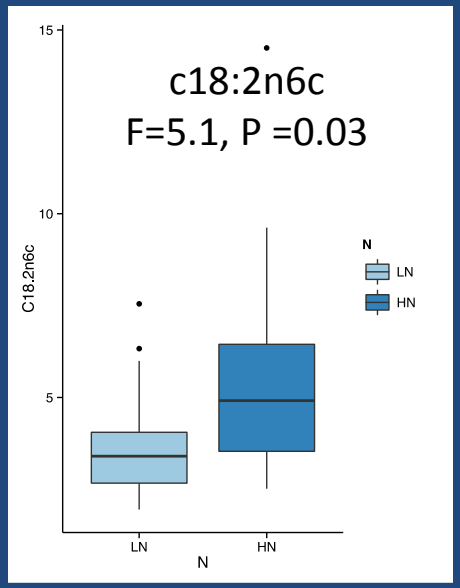


Treatments organized according to low versus high nitrogen

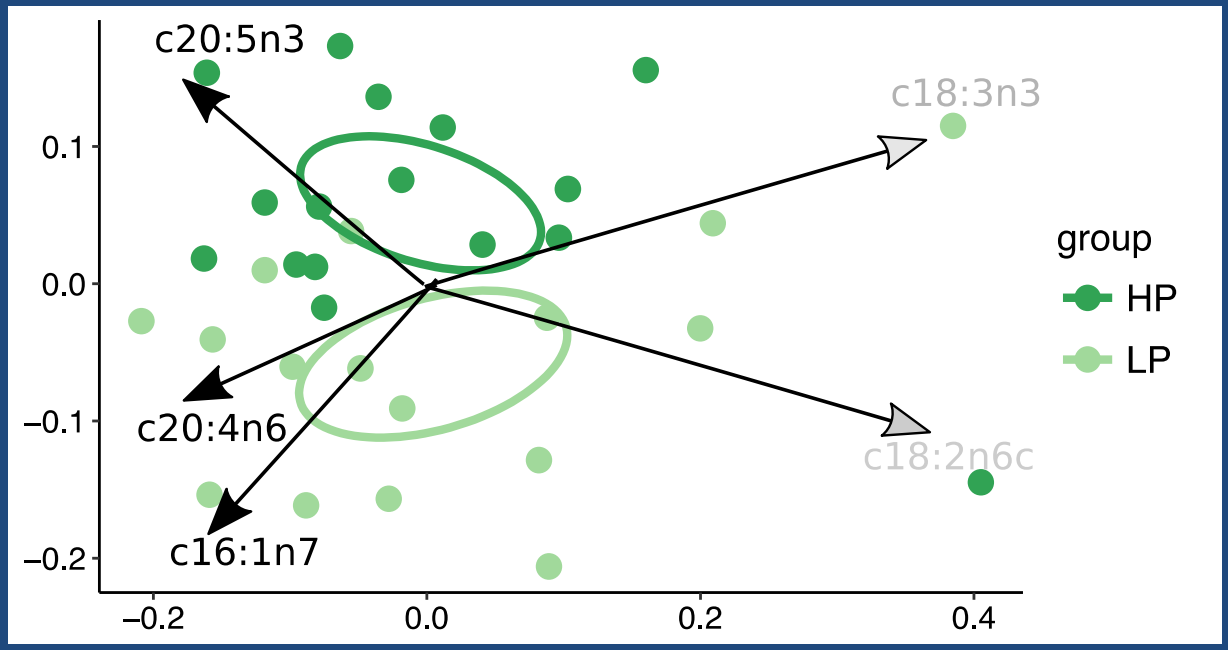








Treatments organized according to low versus high phosphorus



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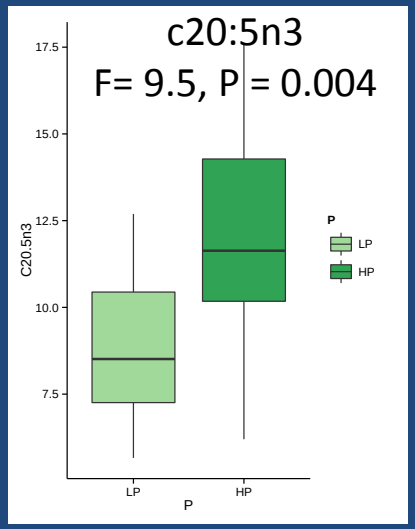
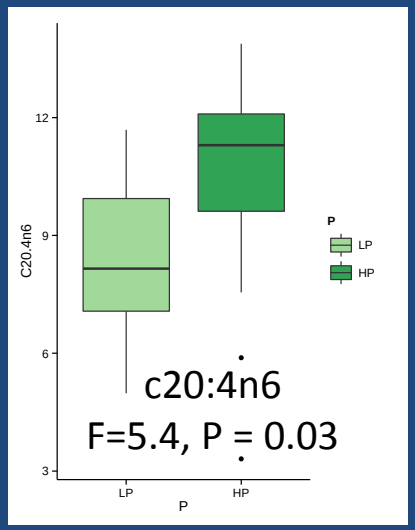
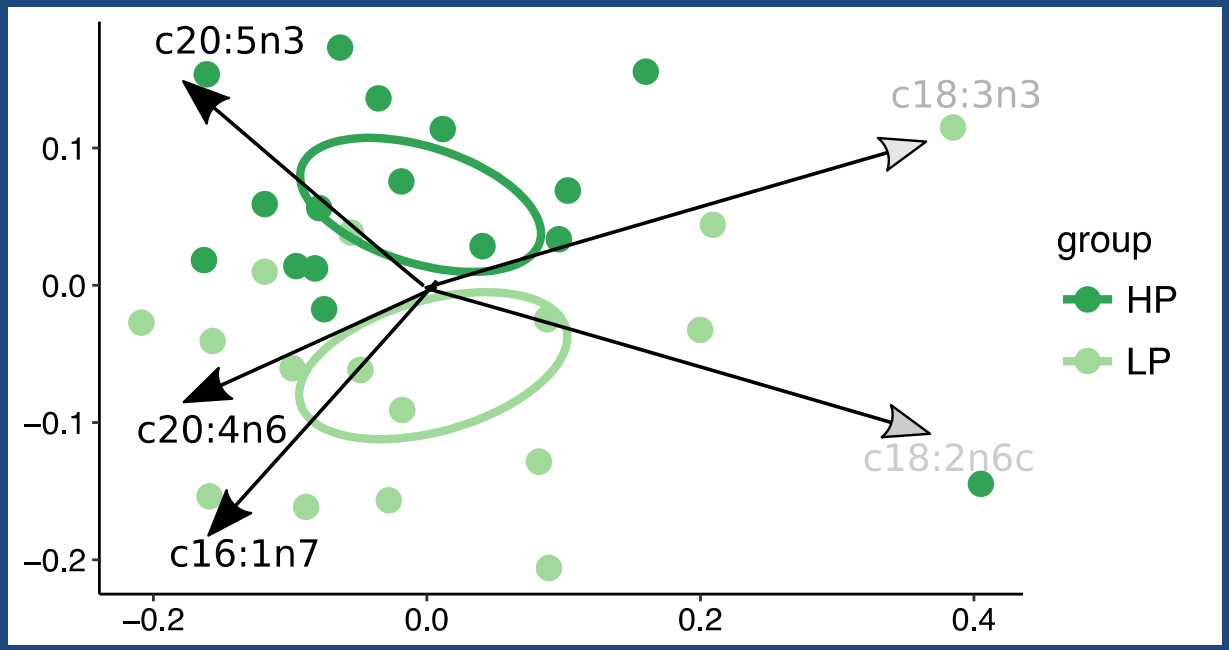
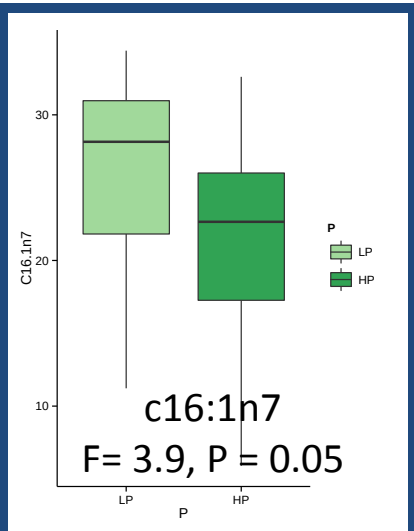




Treatments organized according to low versus high phosphorus





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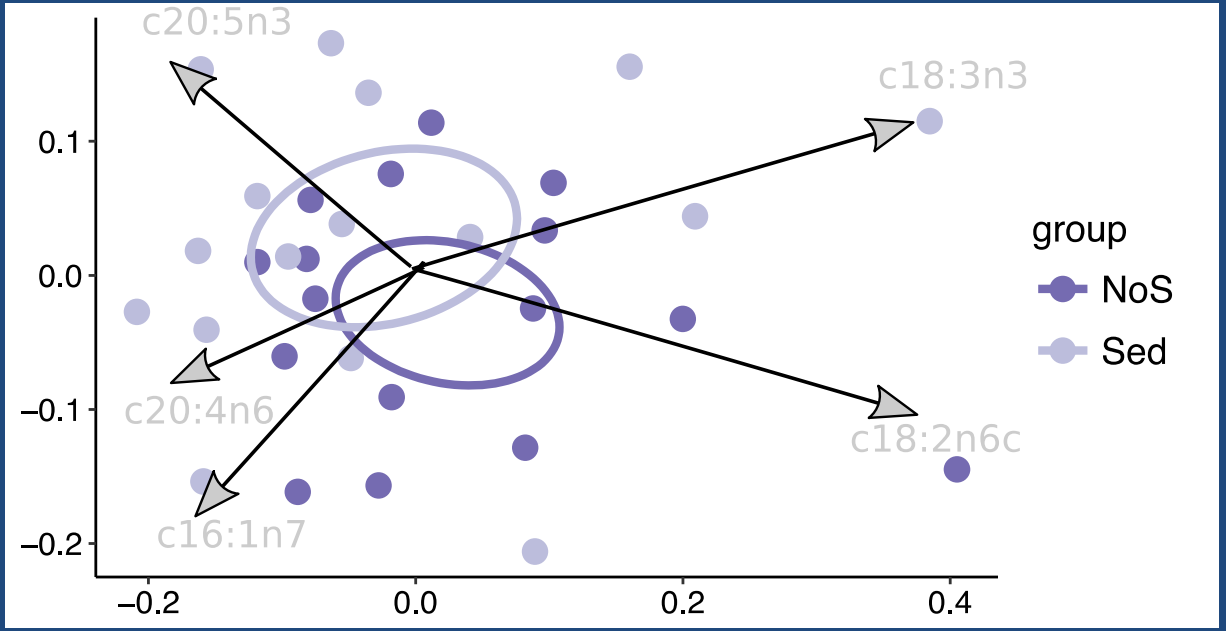
Treatments organized according to low versus high sediment



Can we detect a threshold ?

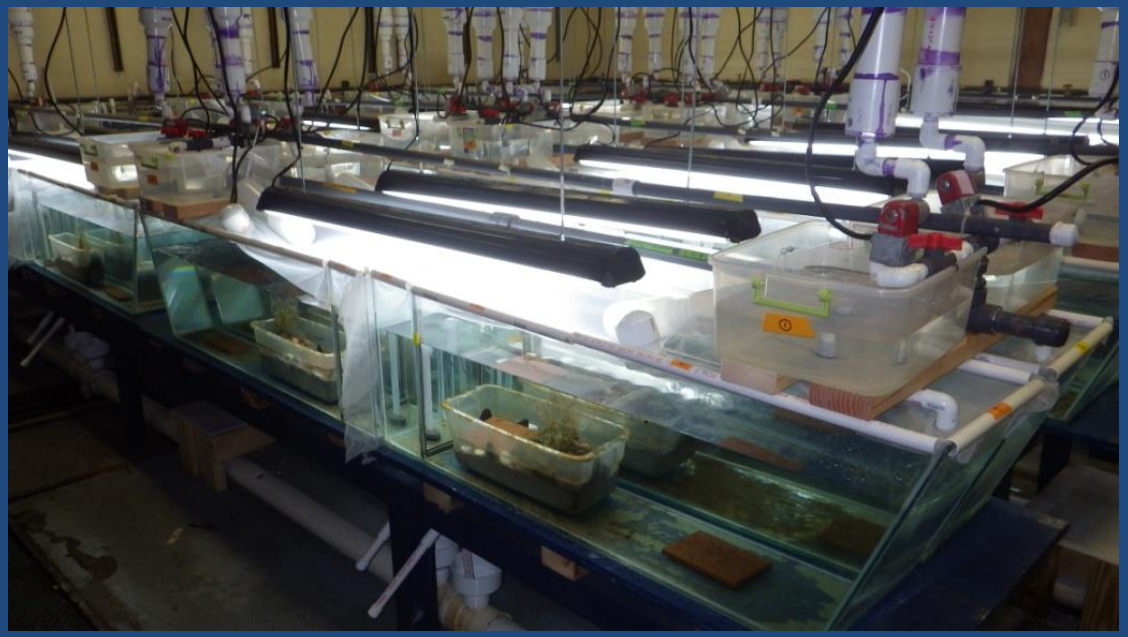
ANCOVA approach

Mussels
Eels
Control (no mussels or eels)
Mussels +eels

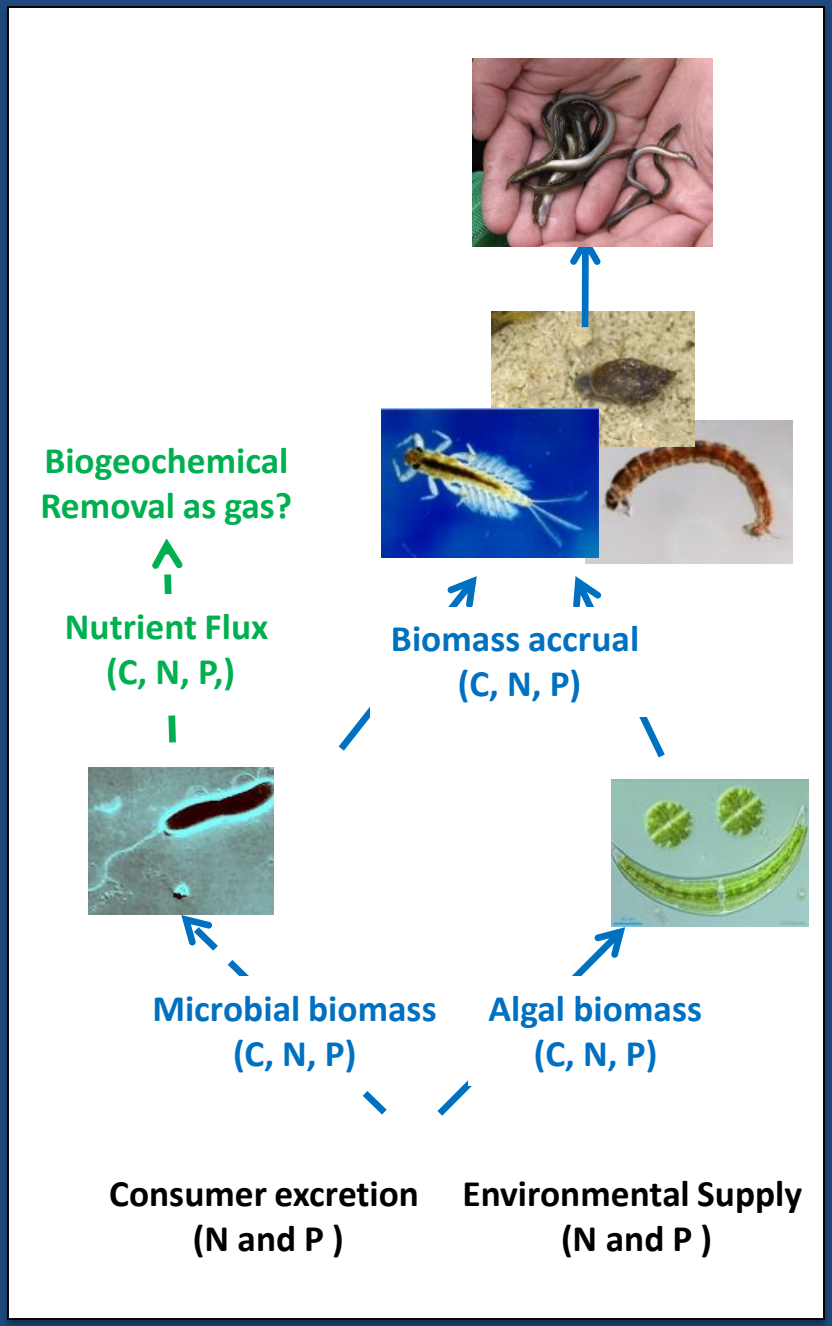
24 different nitrogen loading regimes

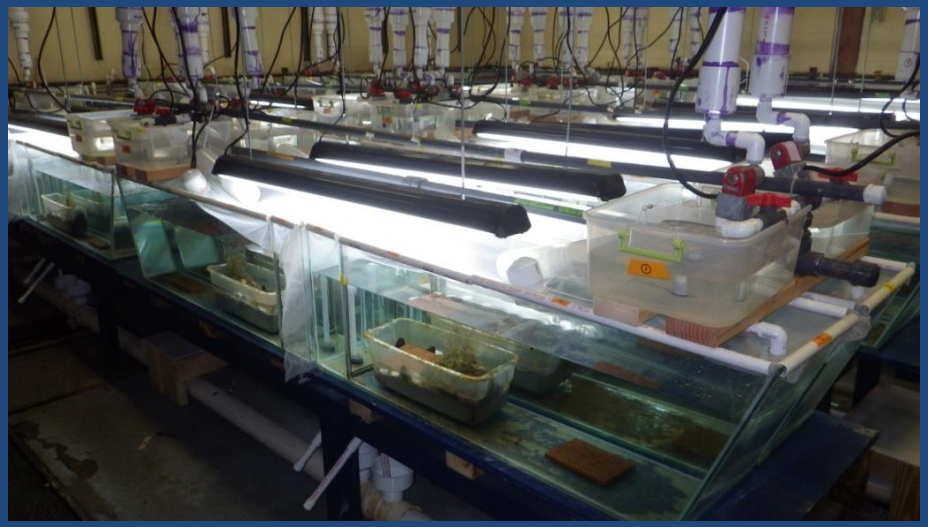
0.005-6 mg L NO_3^{-1}

Blocks of eight loadings per treatment per round



Can we detect a threshold of ecological function ?





Measured:

1) Nutrient uptake (isotope labeling)
   Gas emission (N_2O, N_2, CH4, CO_2)

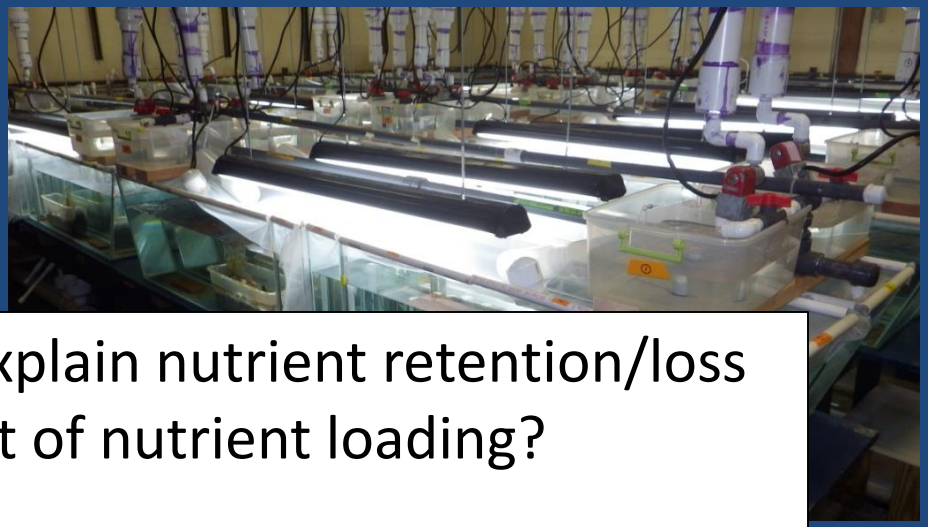
2) Macroinvertebrate community structure

3) Microbial and algal community (phenotype and fatty acid composition)

4) Mussel/Eel physiology and excretion

5) Dissolved nutrient flux (inflow vs. outflow)

Can we detect a threshold of ecological function ?

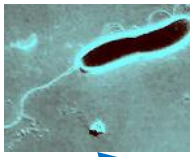


(1) What factors best explain nutrient retention/loss along a gradient of nutrient loading?

(2) Do consumers have the ability to alter this threshold?

Biogeochemi
Removal as g

Nutrient Flu
(C, N, P,)



Microbial biomass
(C, N, P)

Algal biomass
(C, N, P)

Consumer excretion
(N and P)

Environmental Supply
(N and P)

Gas emission (N_2O, N_2, $CH4$, CO_2)

2) Macroinvertebrate community structure

3) Microbial and algal community (phenotype and fatty acid composition)

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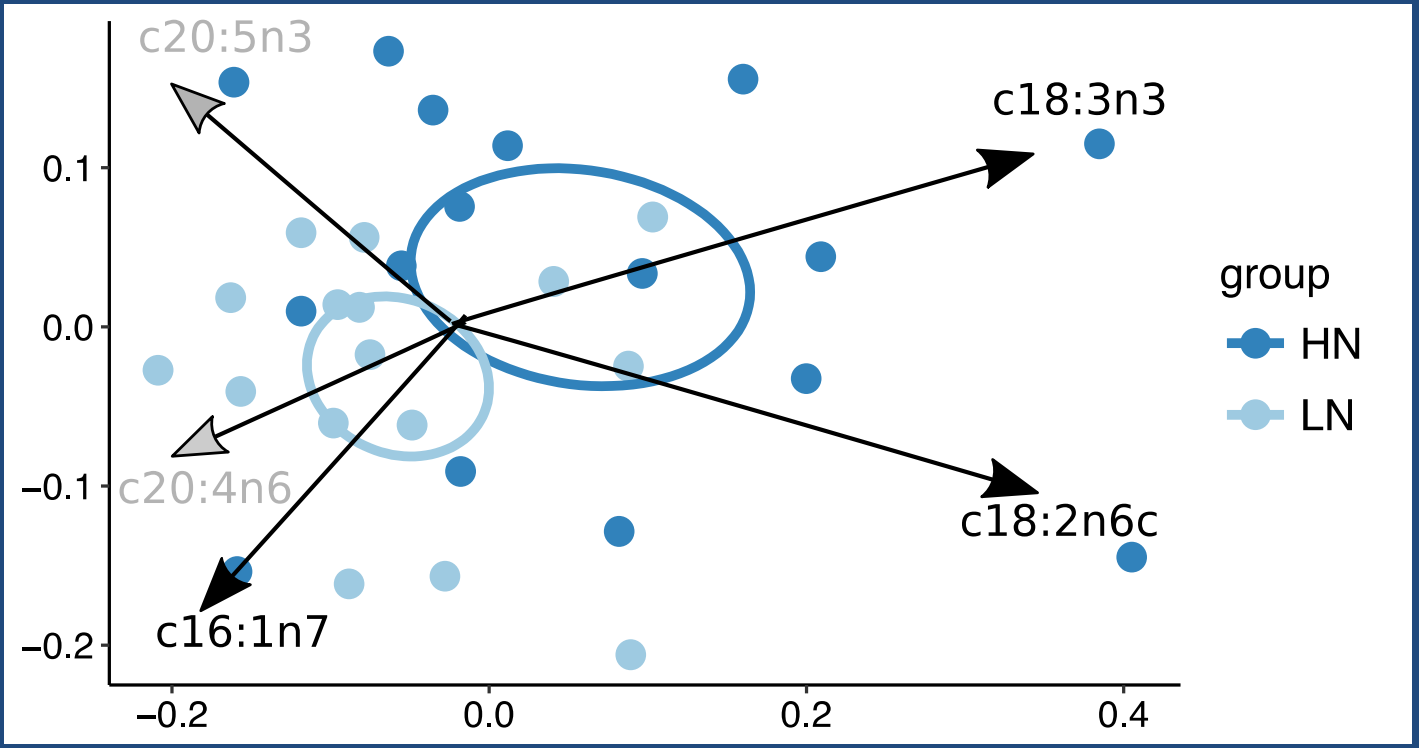
Key fatty acids that may be indicative of nitrogen stressors



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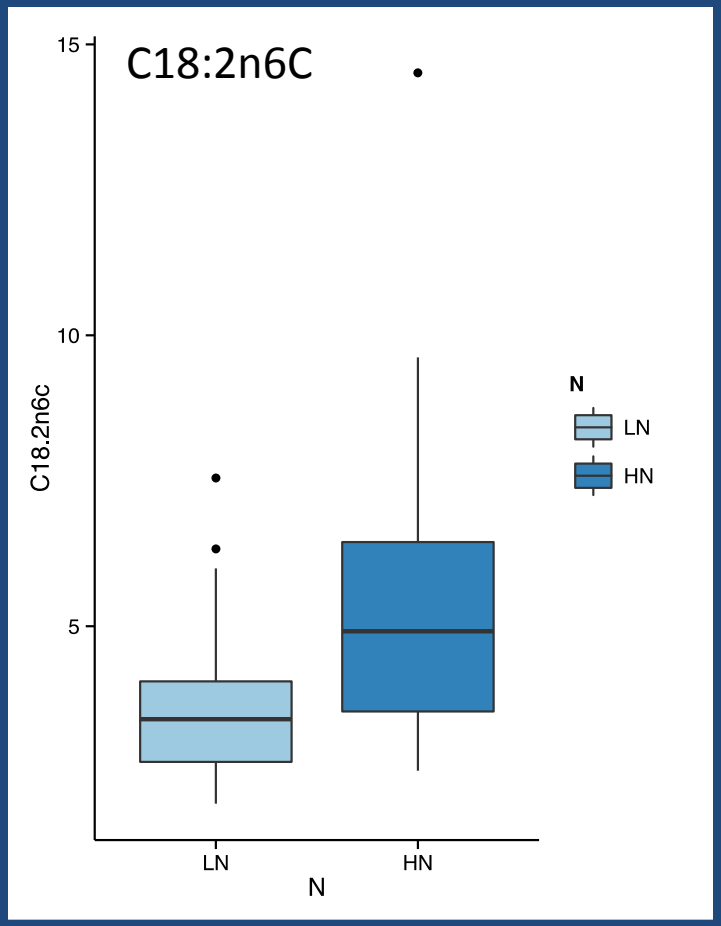
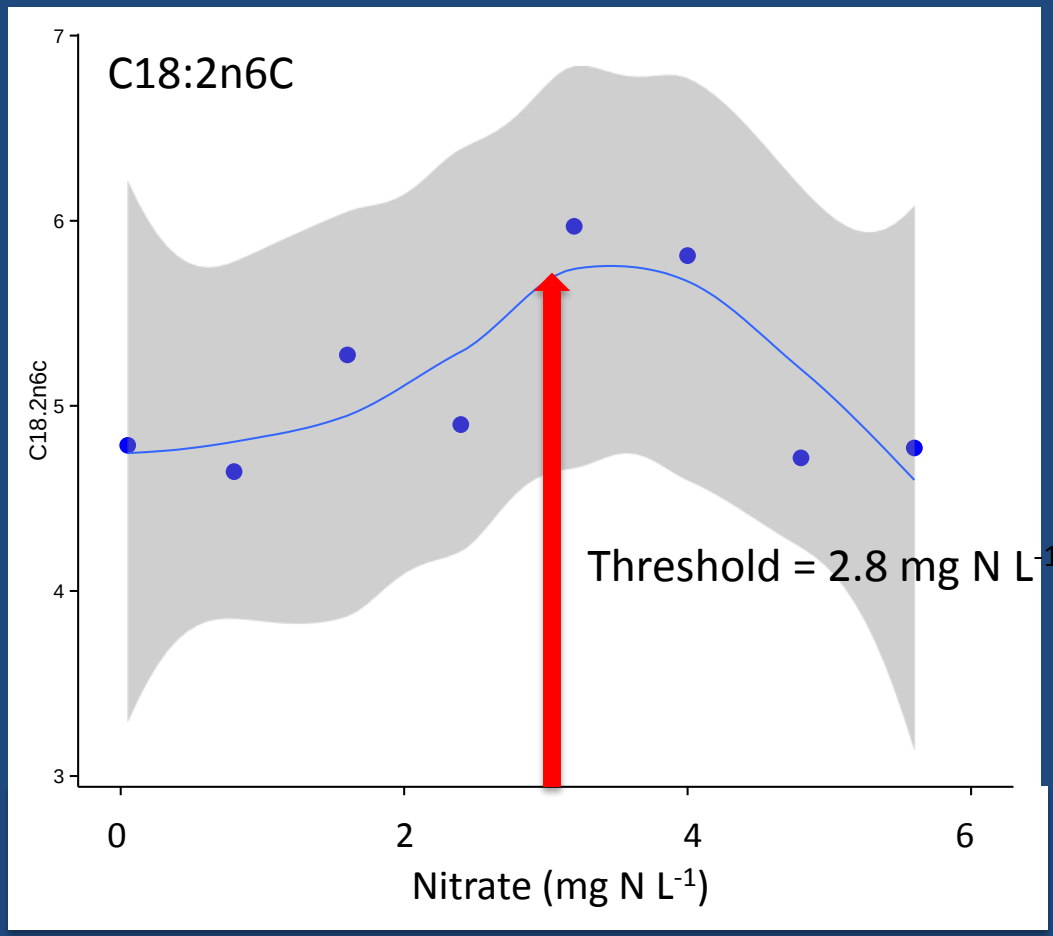
Key fatty acids that may be indicative of nitrogen stressors

ANOVA (N,S,P) study



Threshold study



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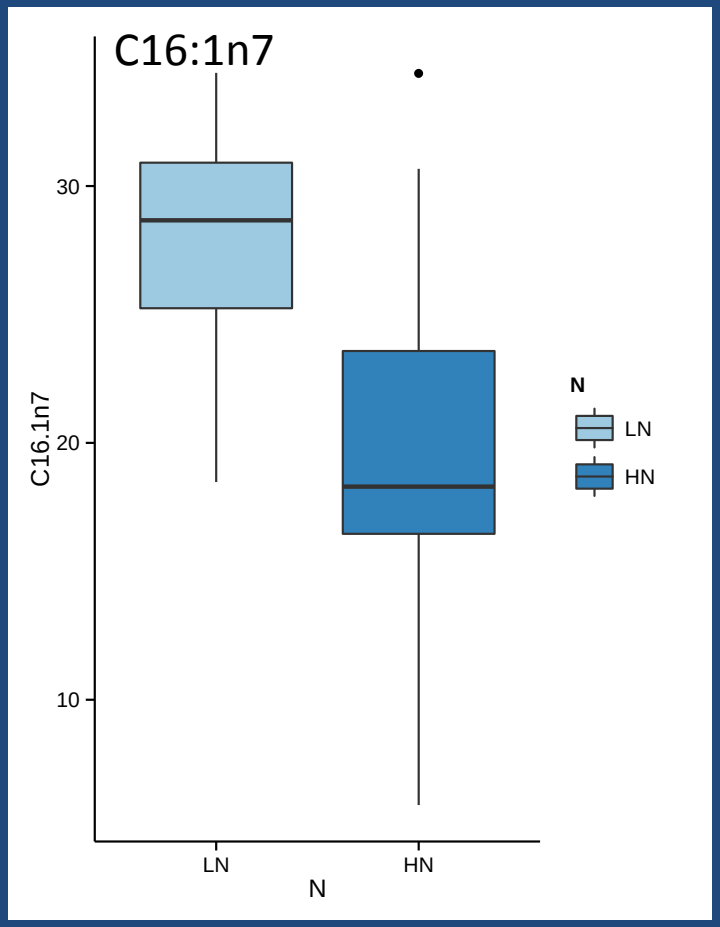

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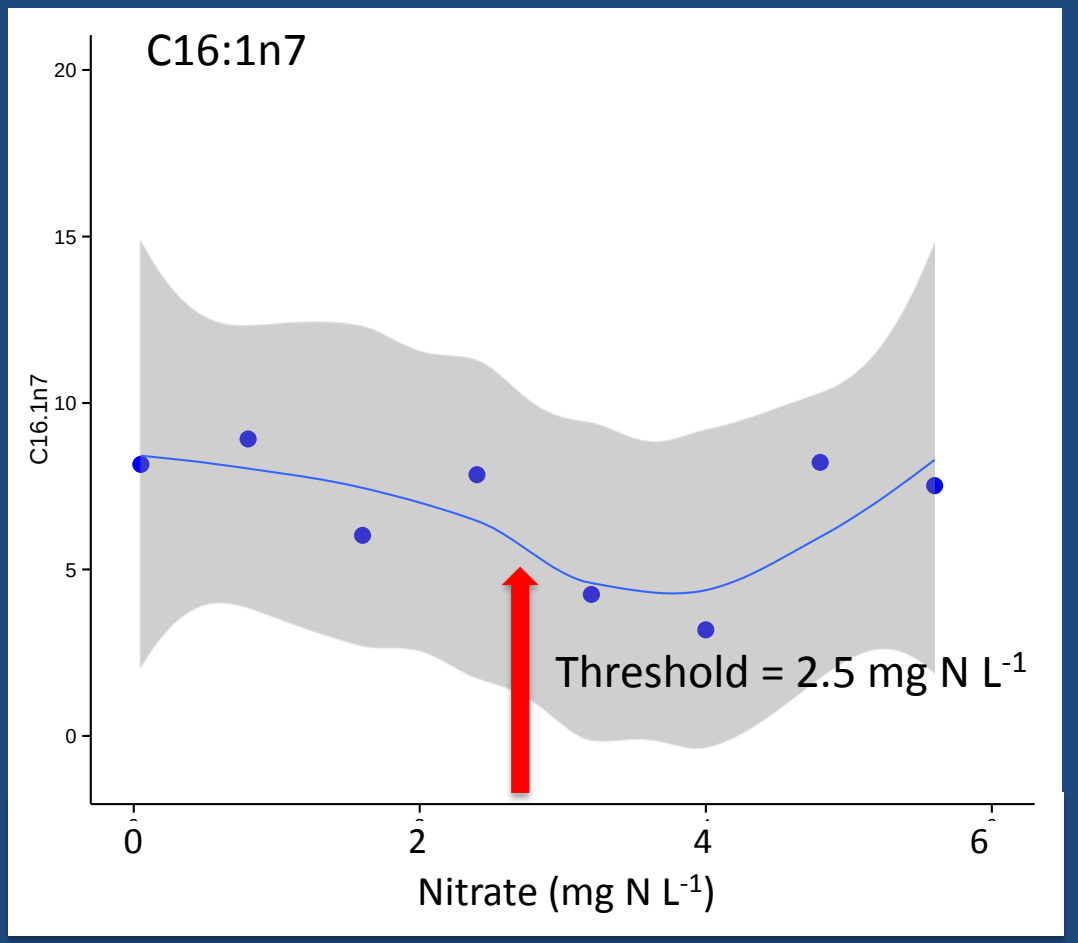

Key fatty acids that may be indicative of nitrogen stressors

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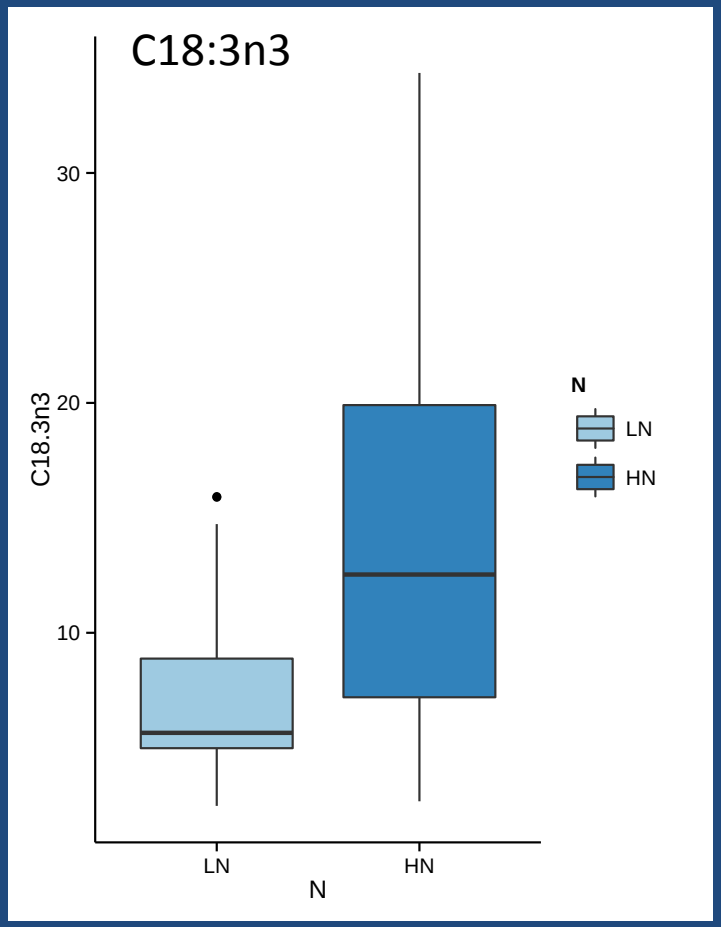

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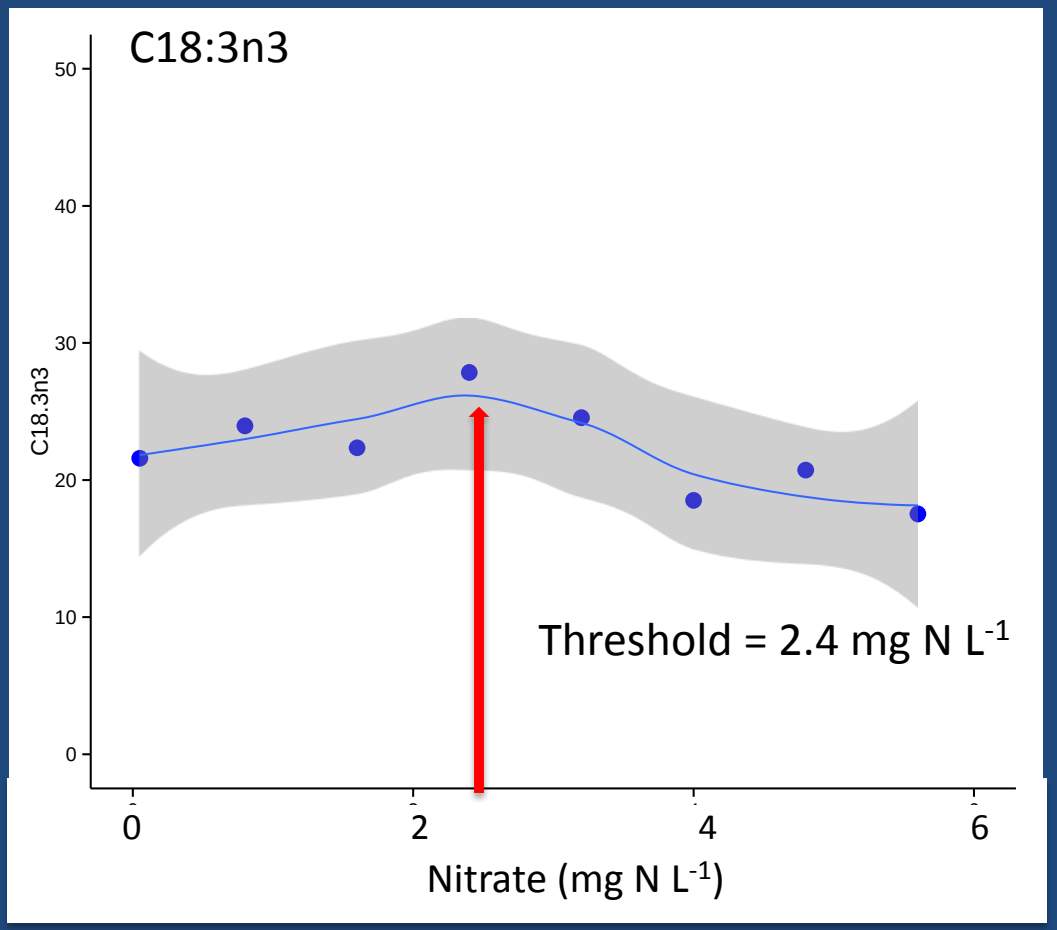

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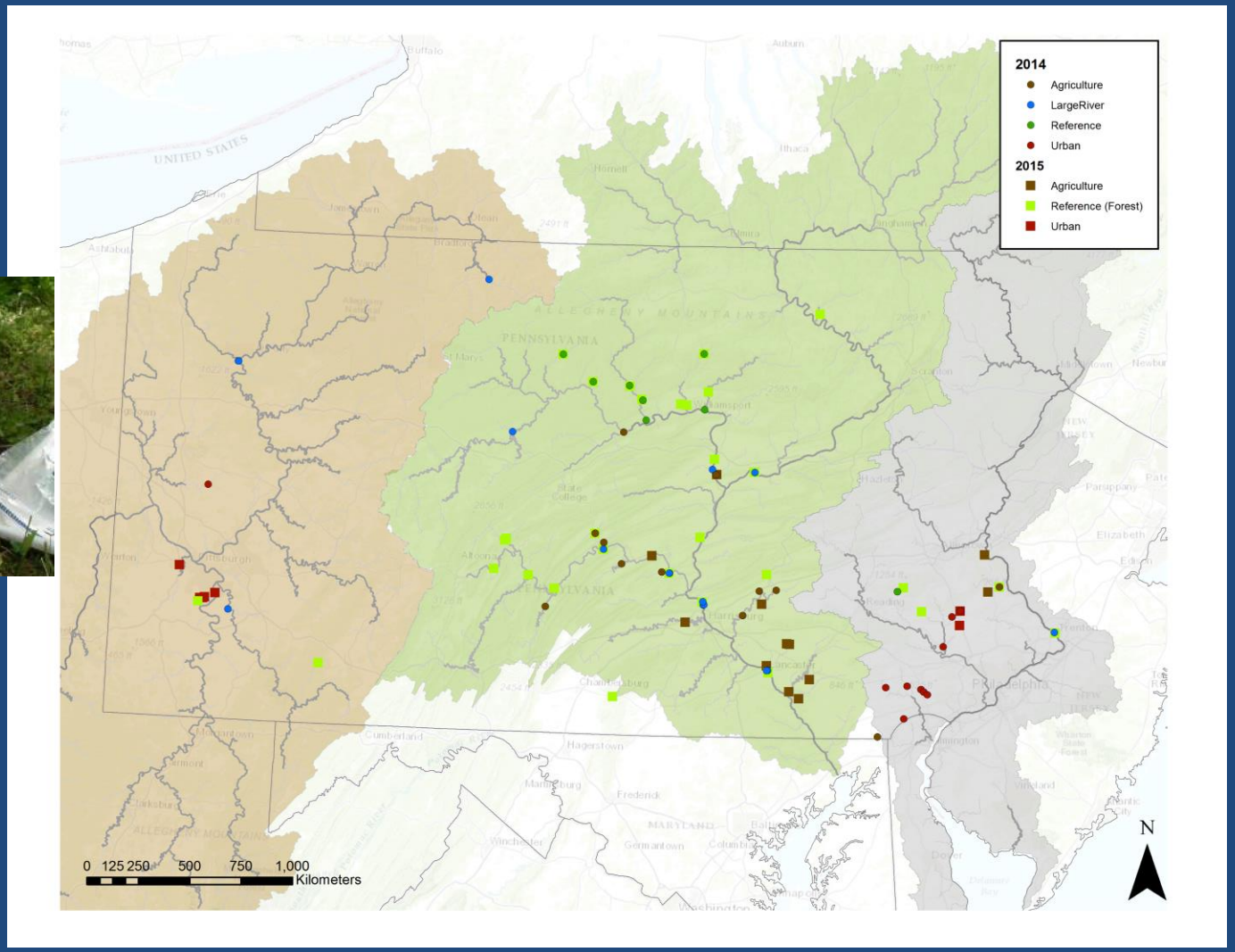
Scaling up to the real world!

Collaboration with DEP 2014 and 2015
Biofilm Fatty acids
Gradient of watershed land-use and nutrient loading

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION



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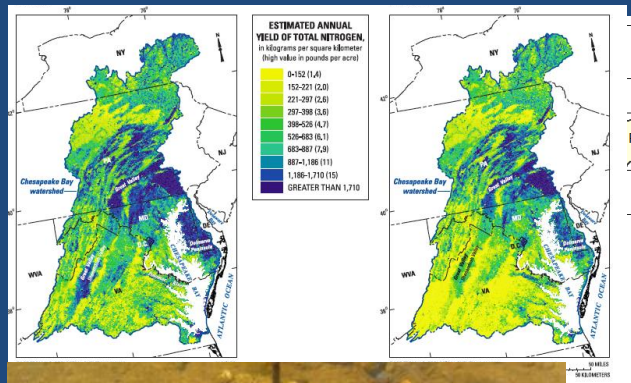
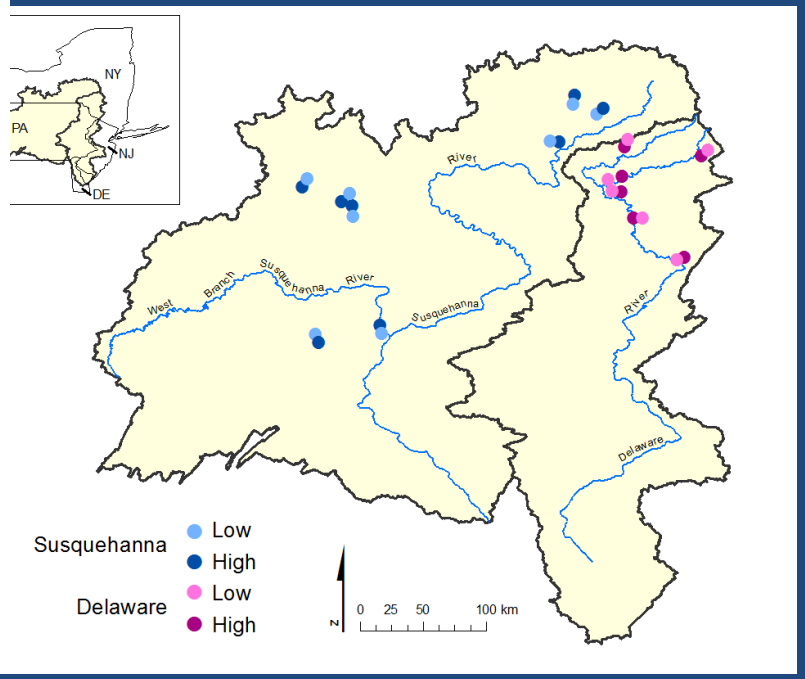
Integrating nutritional indices into other USGS capabilities

Linking nutrition to ecological function and SPARROW

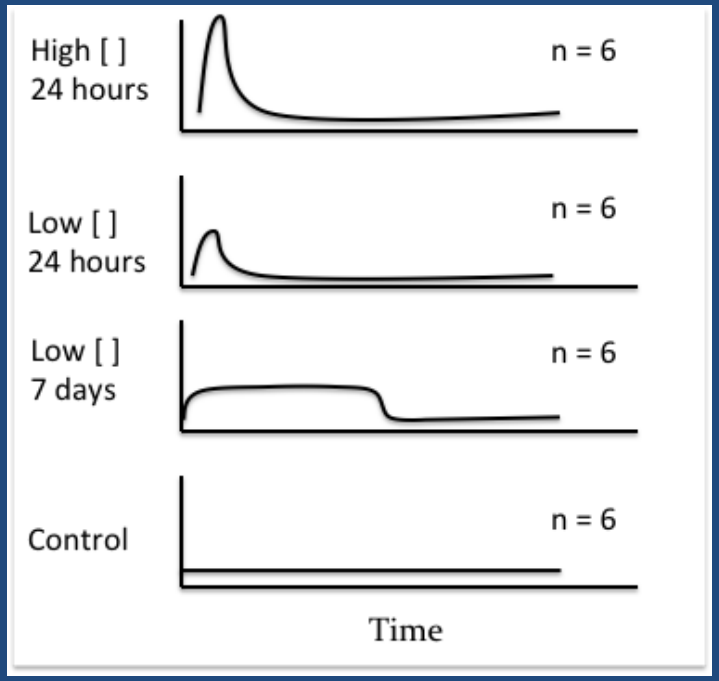


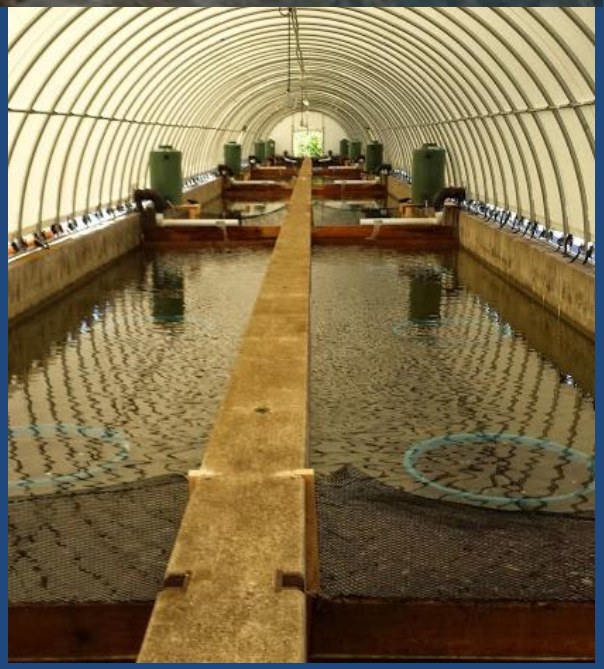


Nutritional studies in other systems with different stressors

Simulated brine spill

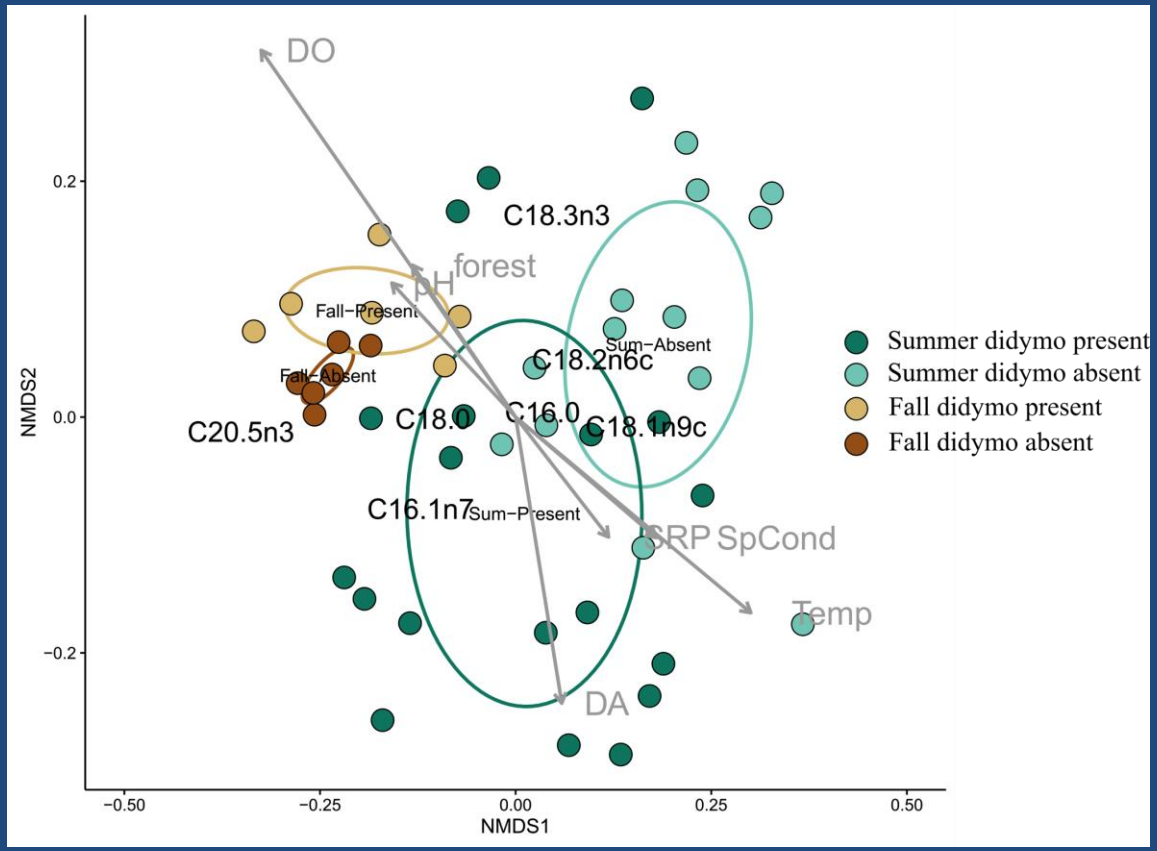
Ecosystem approach to understanding unconventional gas exploration





Collaboration with Susquehanna River Basin Commission (SRBC)

Fatty acid profiles of biofilms with and without Didymo



Still a lot of science needs to be done!

Methodological caveats

- How to sample and where to sample?
- Contamination?
- Lab-specific variability in chemistry and interpretation?

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Thank you!
Field and lab assistance

Cara Campbell
David Dropkin
Heather Galbraith
Gary Walters
Carrie Blakeslee
Hillary Abraham
Andrew Hughes
Kelly Maloney
Matt Shank

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