One of These Things is Not Like the Other.

Evaluation of Wetland Nutrient Stoichiometry and Homeostasis in a Subtropical Treatment Wetland

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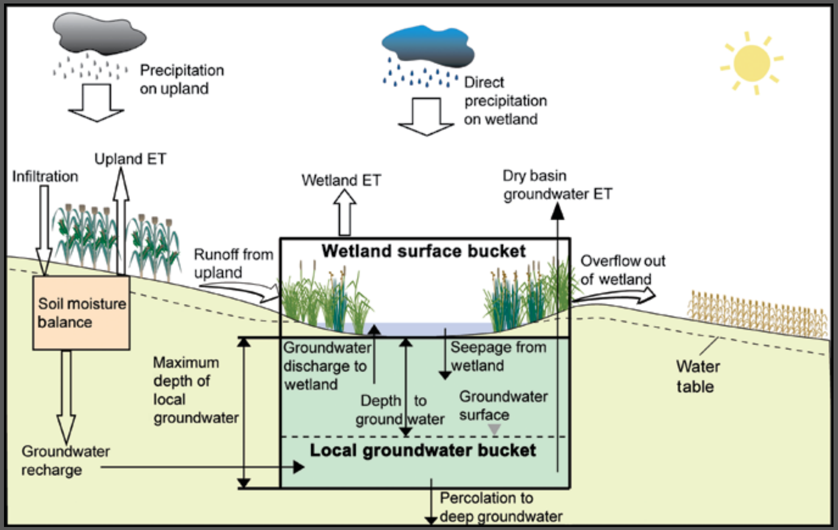
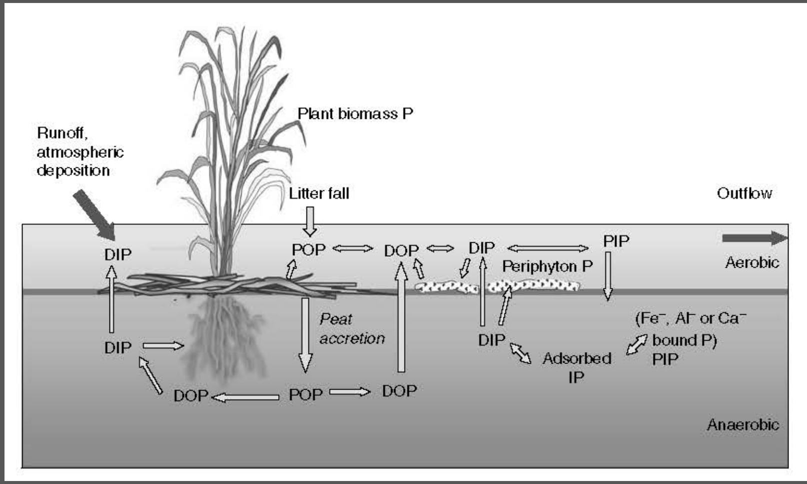
- South Florida Water Management District - Water Quality Treatment Technologies Section
- University of Florida Wetland Biogeochemistry Lab
- University of Florida Department of Soil and Water Sciences

Wetlands

Wetlands are complex and critical ecosystems that regulate global biogeochemical cycles



(Johnson et al. 2010)



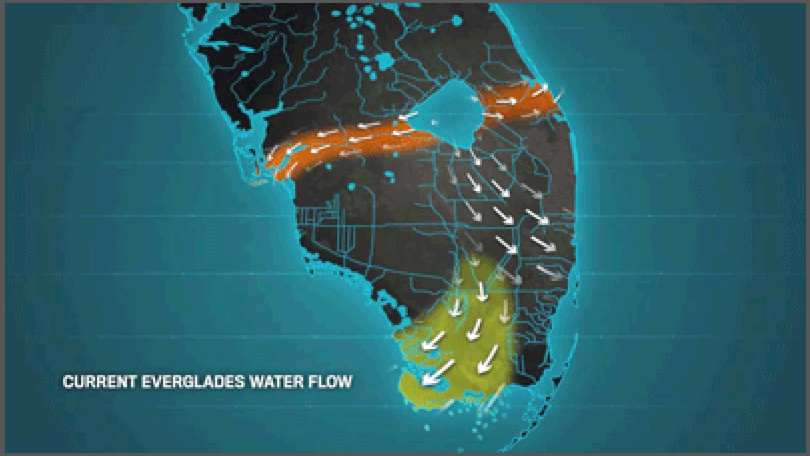
(Reddy and DeLaune 2008)

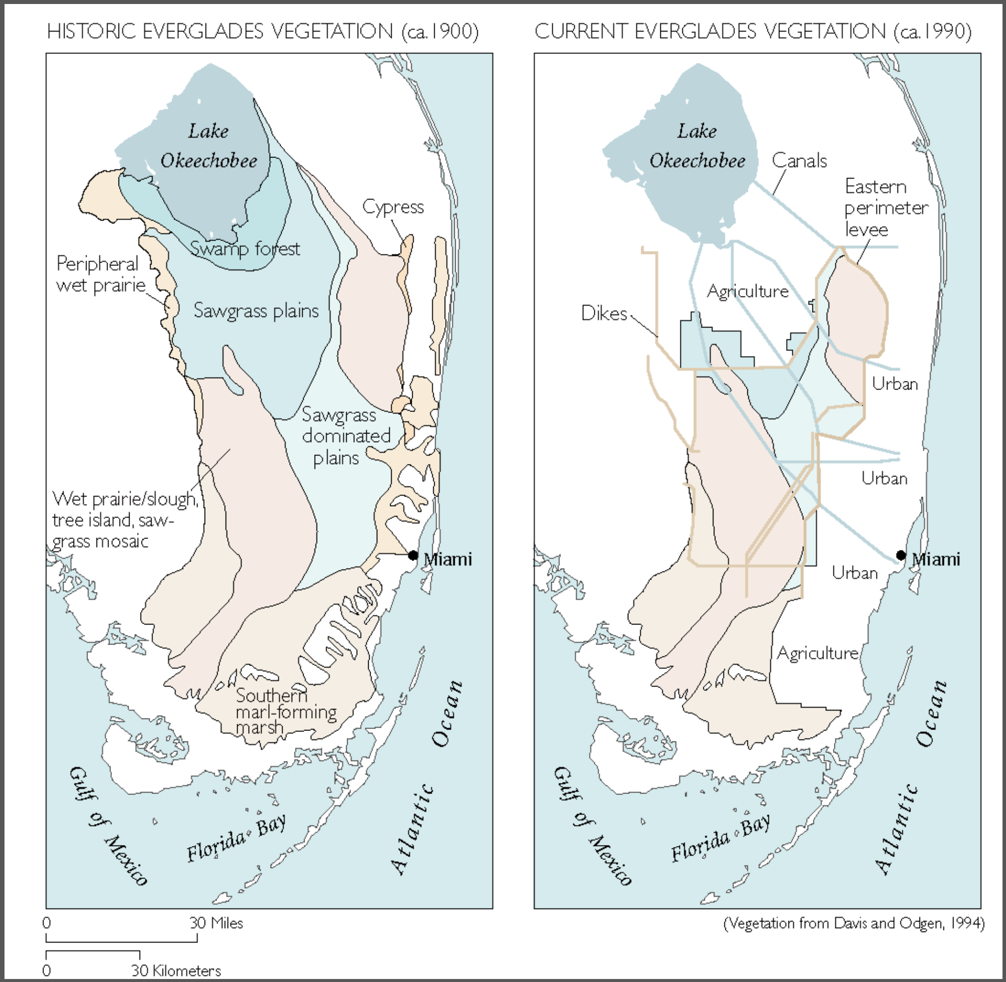
Wetlands are biologically active biogeochemical hotspots.

Everglades Ecosystem

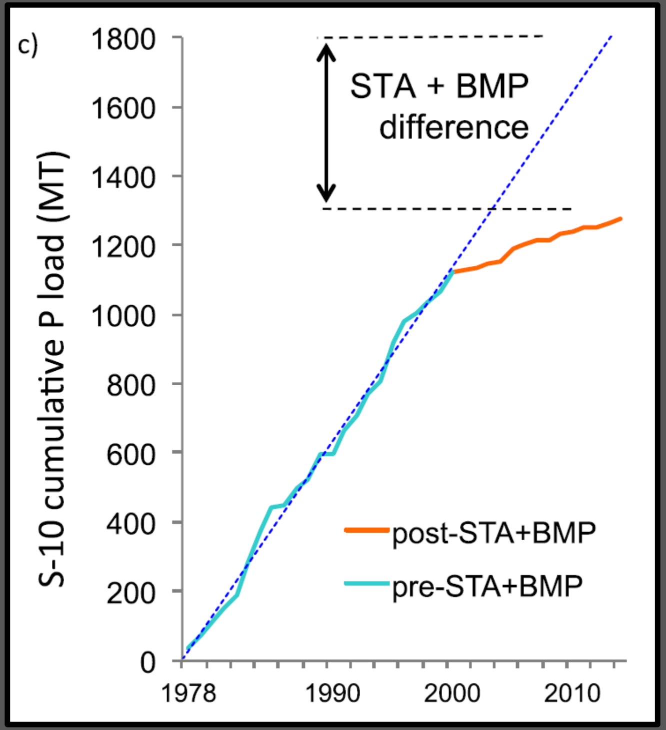
Historic Water Flow

Current Water Flow

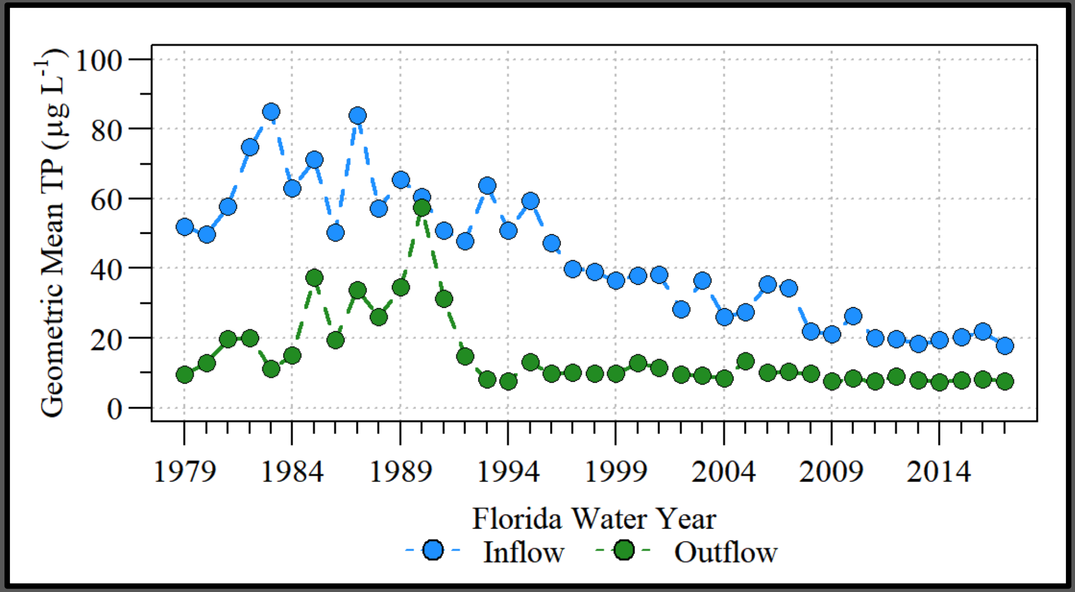




Everglades Ecosystem Restoration

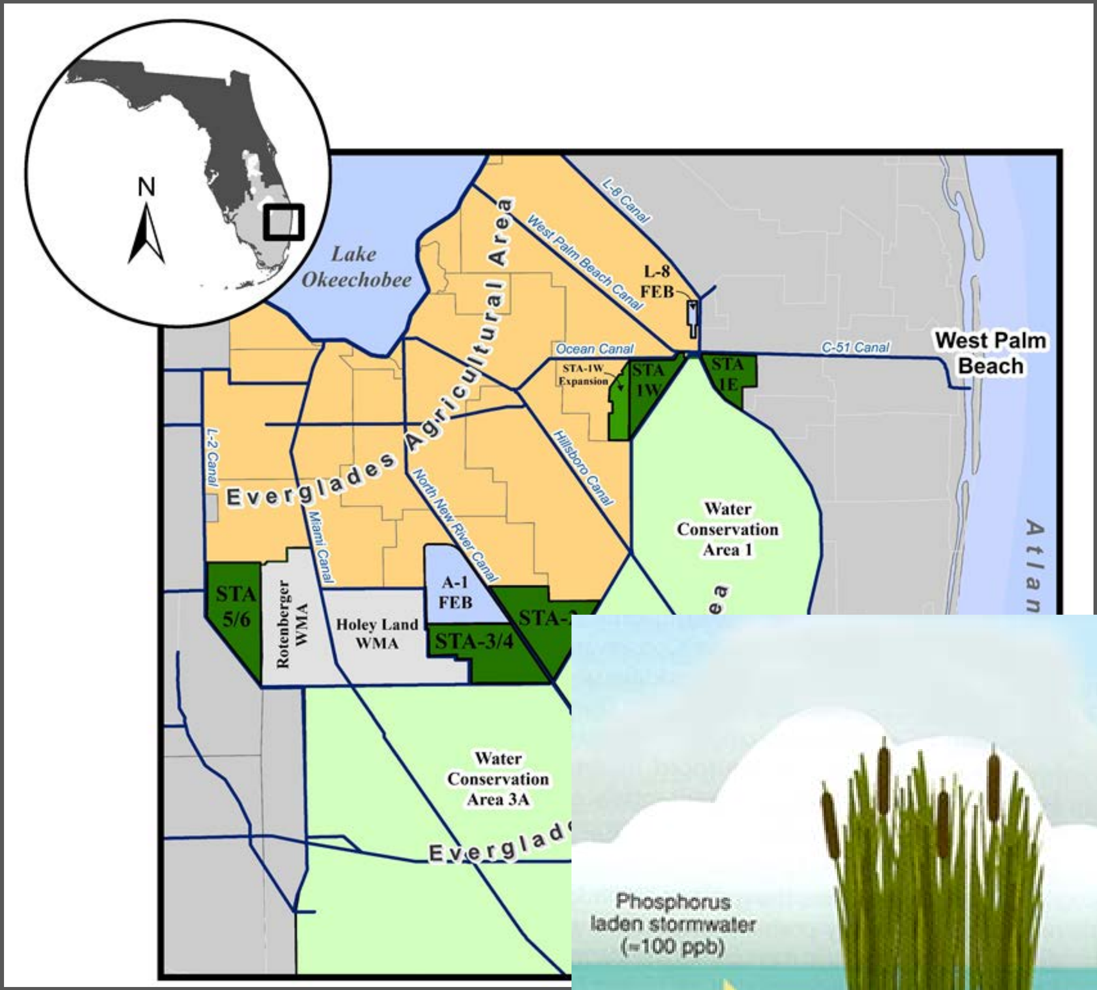


(Juston et al., 2015)



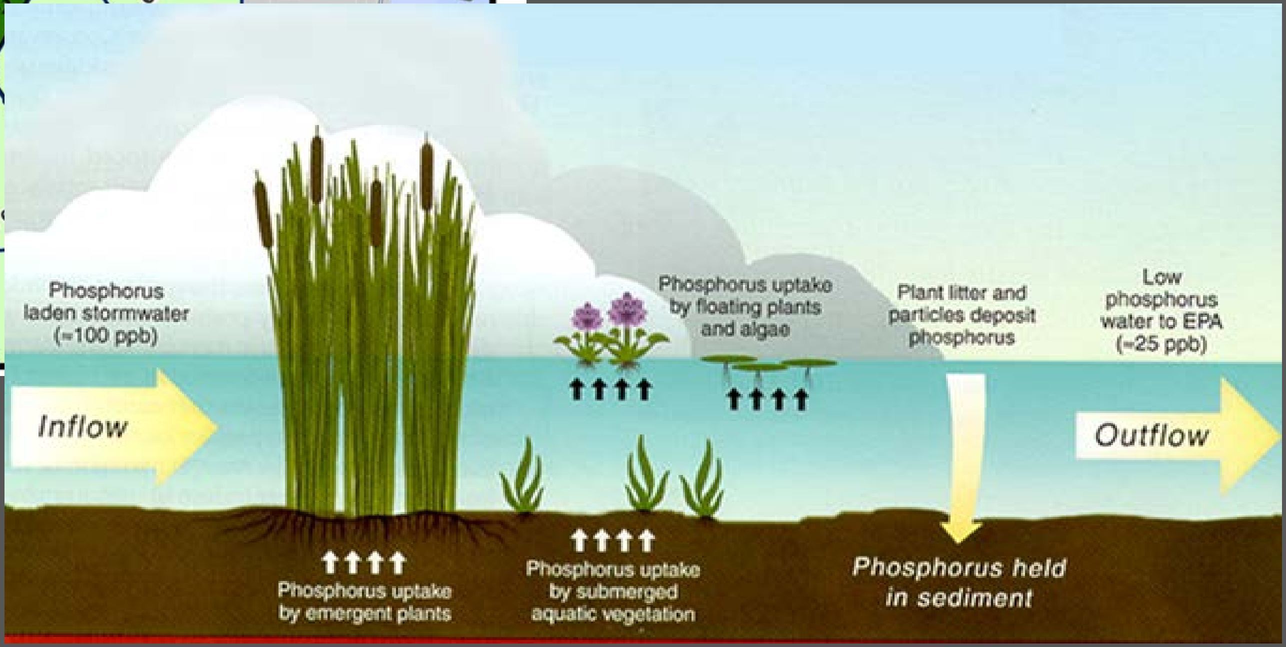
(Julian, *Unpublished Data*)

Everglades Stormwater Treatment Areas



SFWMD

- 1994 ENR (now STA 1W)
- Now 5-STAs plus support infrastructure.
- Total treatment area: 230 km^2
- Constructed to remove TP
- Removed 2.3 x 10^6 kg of TP (circa April 2017)



- Ecological Stoichiometry
  - Relates environments nutrient to biota
  - "Redfield Ratio"
    - Open Ocean
    - Homogenous reservoir of inorganic nutrients
    - C:N:P $\rightarrow$ 105:15:1 (water column)
    - C:N:P $\rightarrow$ 106:16:1 (plankton)

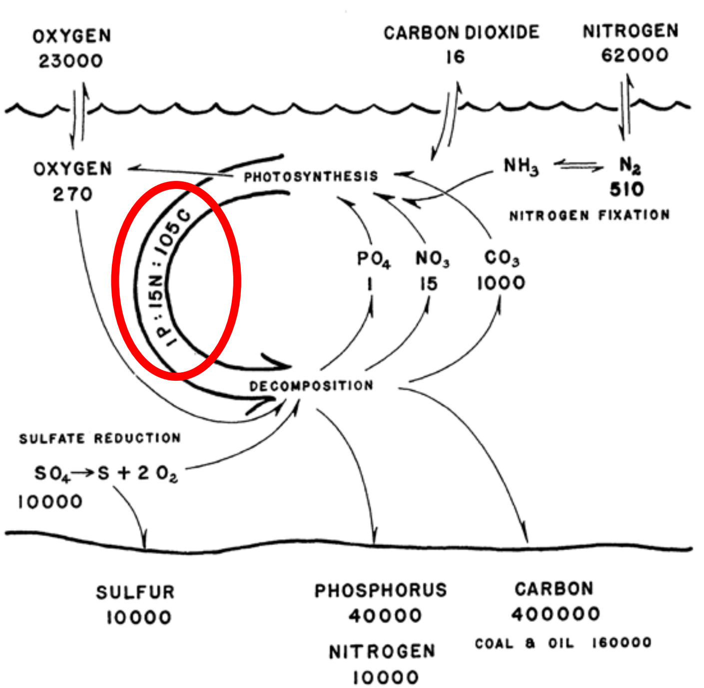


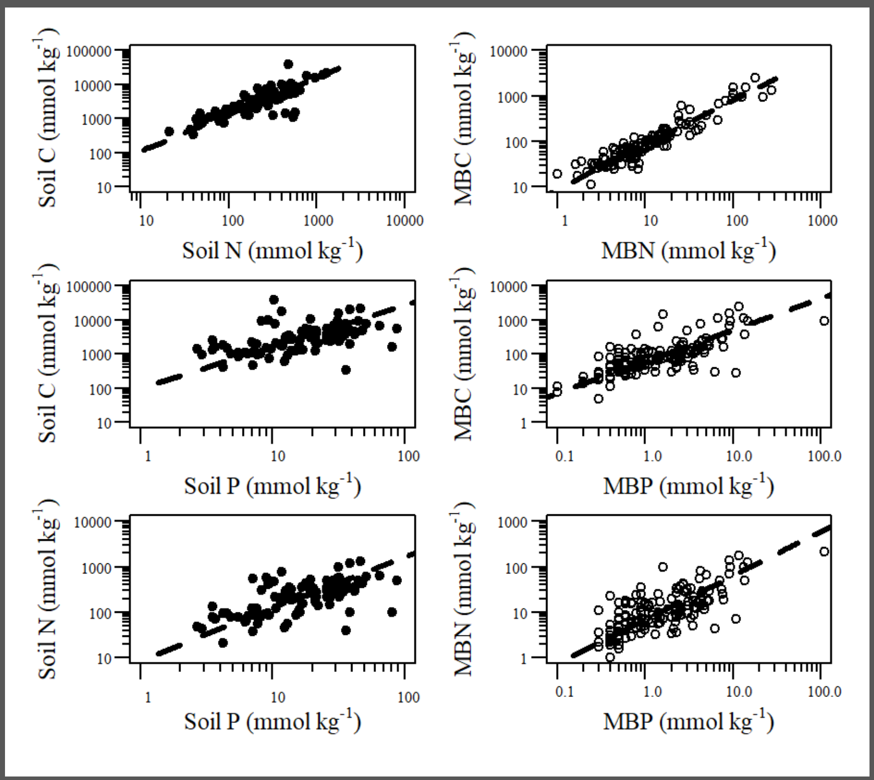
FIG. 3. The Biochemical Cycle. Numbers represent quantities of respective elements present in the atmosphere, the ocean, and the sedimentary rocks, relative to the number of atoms of phosphorus in the ocean.

Redfield (1958)

Stoichiometry (Redfield Ratio Extended)

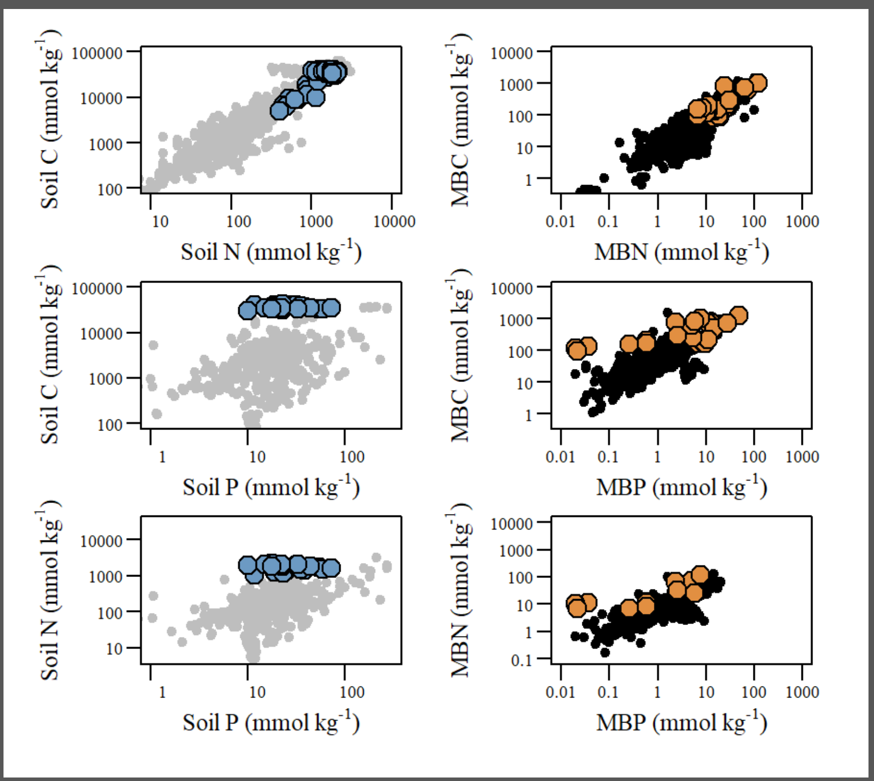
- C:N:P is well constrained in plankton biomass (Redfield 1934 and 1958).
- Is C:N:P well constrained in other ecosystem compartments elsewhere?

Forested and Grassland Ecosystems



Cleveland CC, Liptzin D (2007)

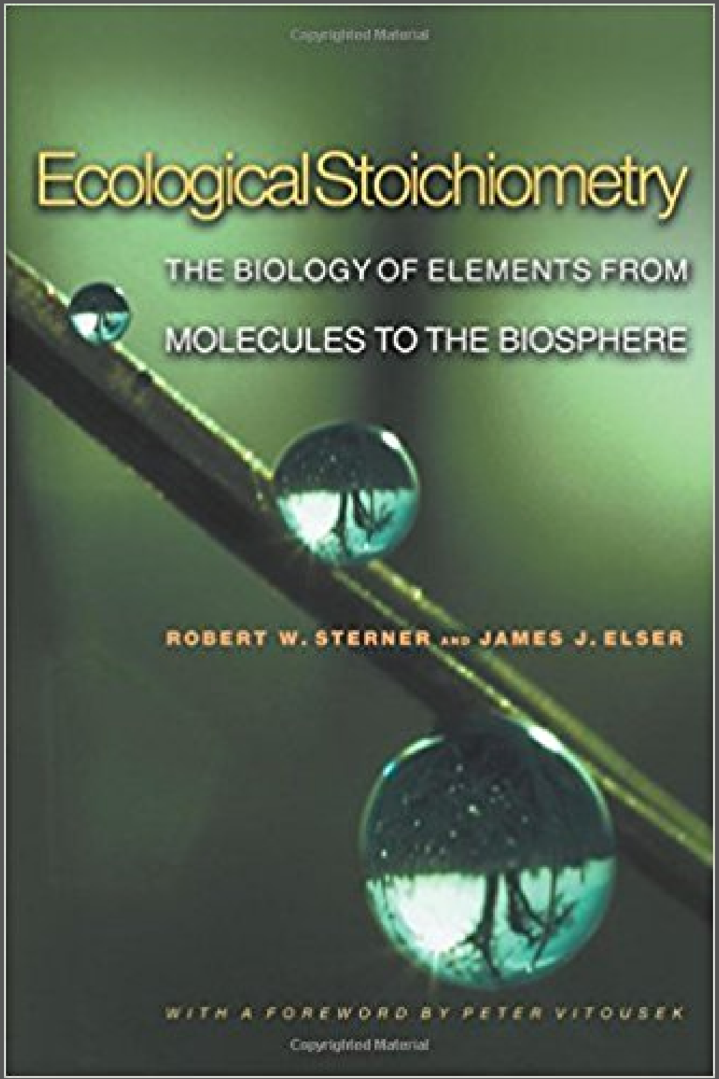
Global Versus Natural Wetland



Xu et al (2013)

Ecological Stoichiometry Redux

- Redfield and others laid the conceptual framework for Ecological Stoichiometry.
- Organism – Environment nutrient stoichiometry feedback mechanism (i.e. stoichiometric homeostasis)
- Context of ecosystem disturbances
    - Organism/Ecosystem respond to changing conditions

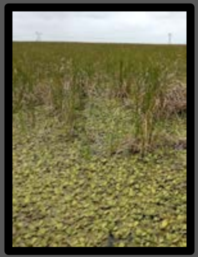


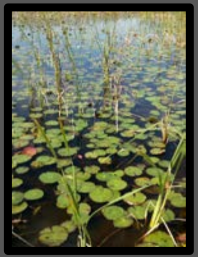
Objectives

- Overall evaluation of nutrient relationships between ecosystem compartments (water, floc, soil and veg.) between systems (EAV and SAV).
- Assess changes in stoichiometry along each flow way.

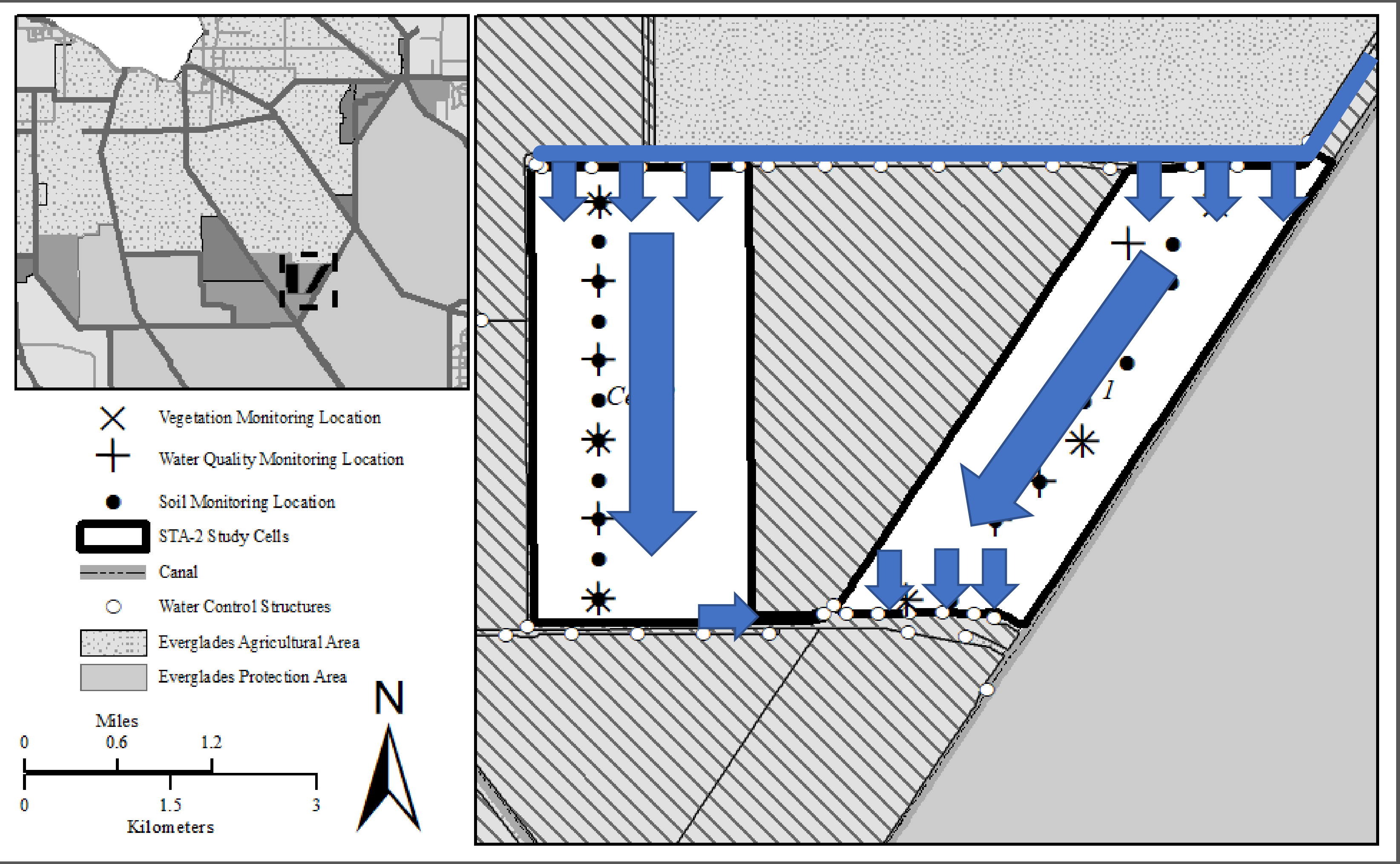
Hypotheses

- Nutrient stoichiometry will be tightly constrained across ecosystem compartments.
- Shifts in nutrient stoichiometry are likely to occur along a given flow path.





Study Area

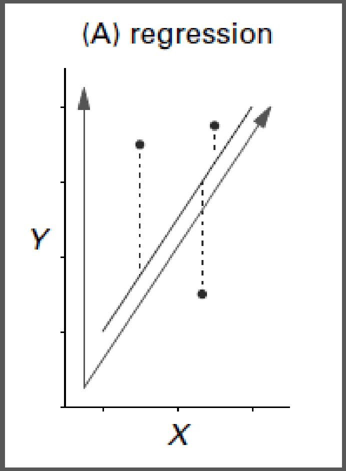


STA-2 (8 cells, 62.7 km^2)

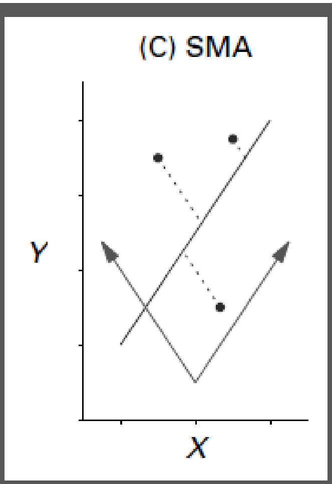
- Flow way 1: Emergent Aquatic Vegetation Dominate (7.4 km^2)
- Flow way 3: Submerged Aquatic Vegetation Dominate (9.3 km^2)

Methods

- Nutrient concentrations log-transformed.
- Standardized major axis (SMA) regression was used to evaluate stoichiometric relationships.



- Residuals are measured vertical for linear regression against a fitted axis
- Best fit line based on predicting Y given X



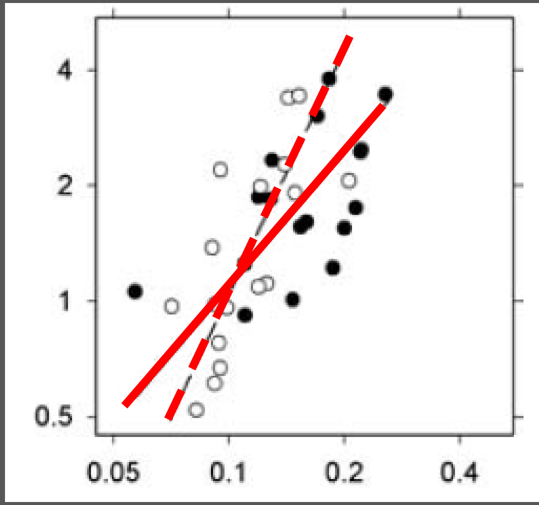
- Residuals are measured and standardized against the Y axis
- Best fit line relative to two variables

Warton et al., (2006)

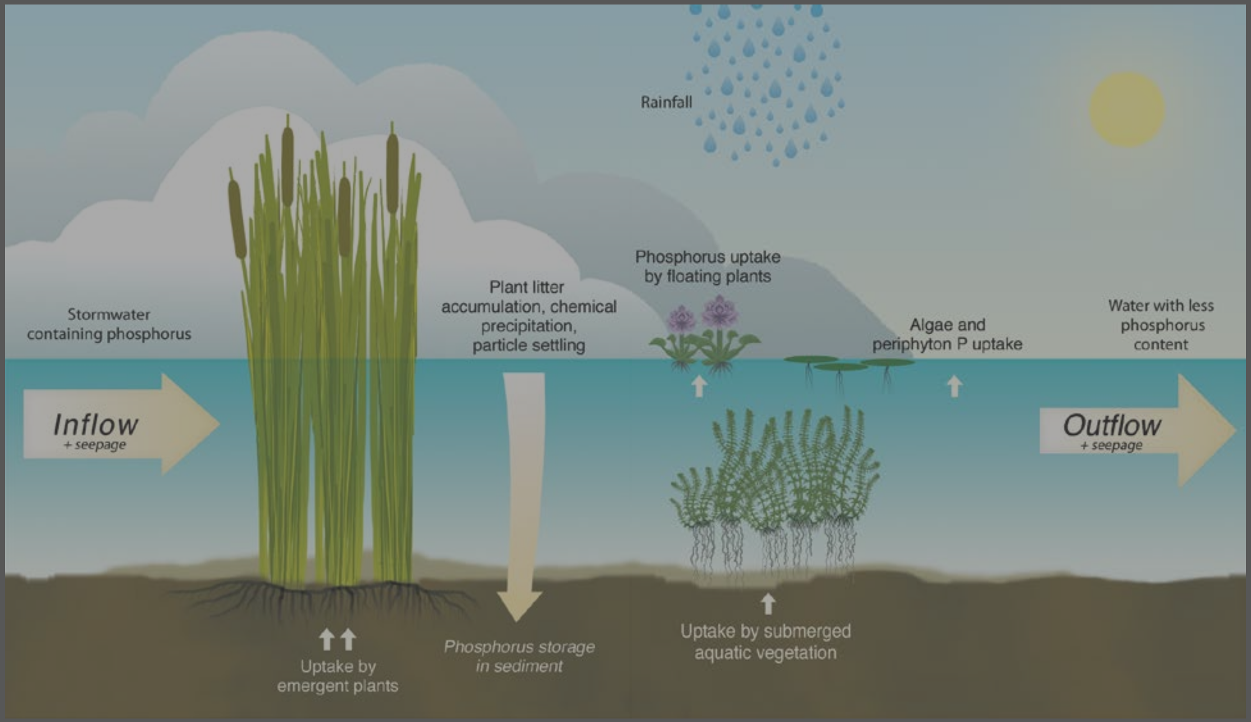
Methods

- Evaluate the slope of the Standardized Major Axis regression to be significantly different from 1.

Significantly different	*Not Significantly different*
Independent scaling between variables (allometric)	*Proportional scaling between variables (isometric)*

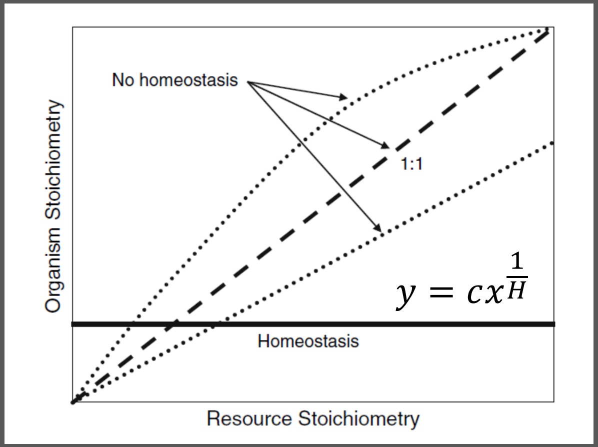


Nutrient Homeostasis



Nutrient Source:

- EAV mine P from soils
- SAV assimilate P from water column

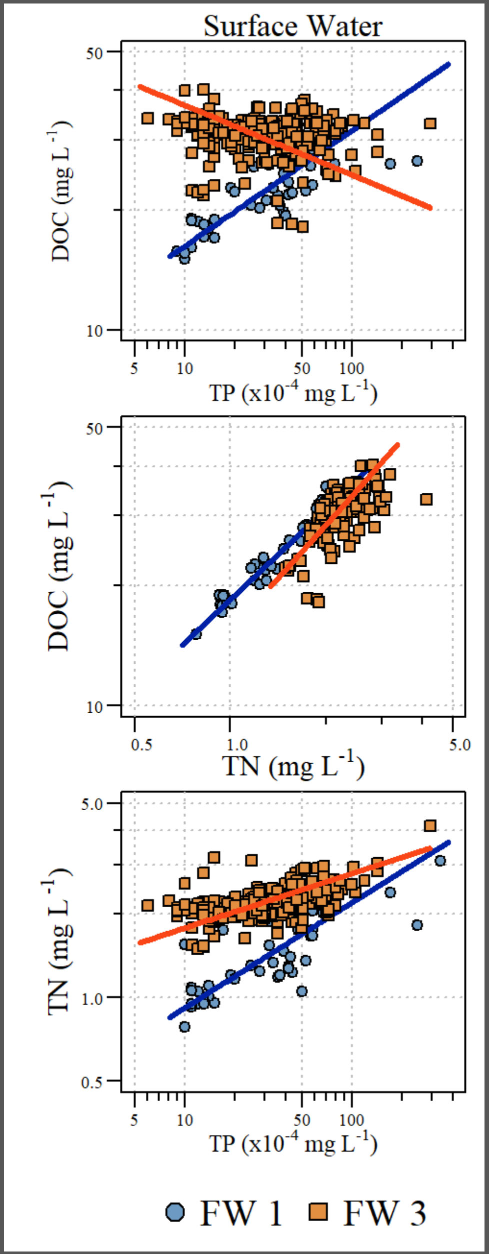


$$\frac{1}{H_{N:P}} = \frac{\log(y) - \log(c)}{\log(x)}$$

Y = Organism N:P
X = Resource N:P
C = Intercept

$\frac{1}{H_{N:P}} < 0.5$ Homeostatic

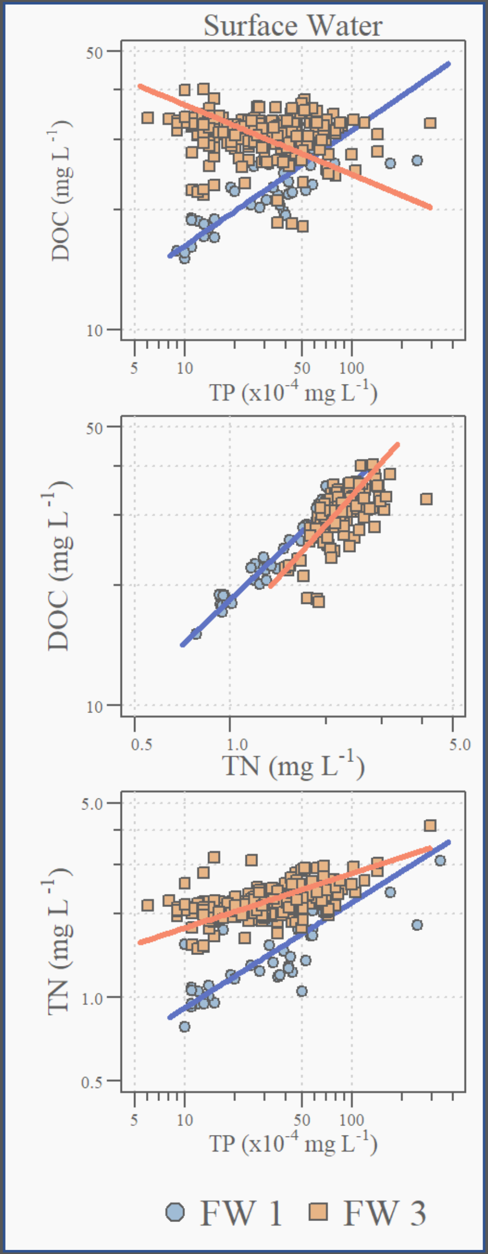
$\frac{1}{H_{N:P}} > 0.5$ Non-Homeostatic

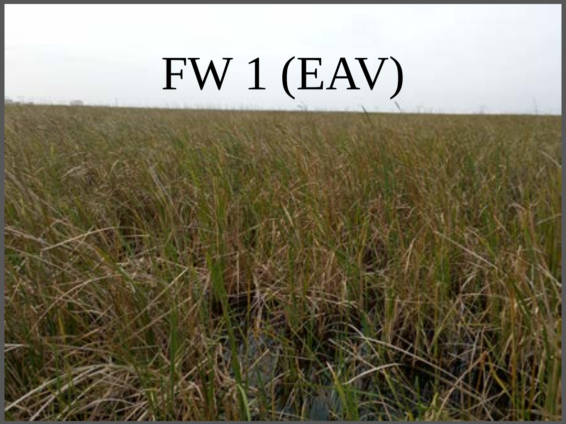


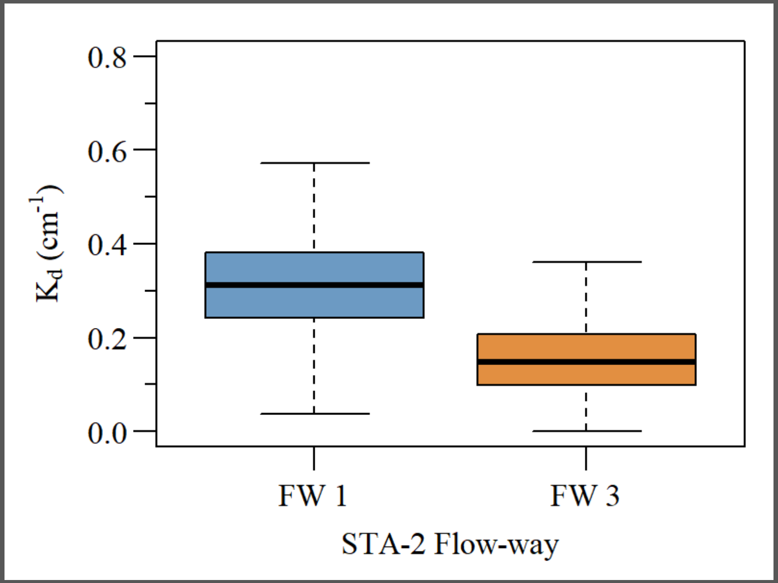
Log-Log regression results of Standardized Major Axis regression between water column variables.

Y	X	Flow way	R^2	Slope	Intercept	ρ-value
DOC	TP	FW 1	0.50	0.29	2.65	<0.01
		FW 3	0.02	-0.18	-0.30	<0.01
DOC	TN	FW 1	0.75	0.75	2.42	<0.01
		FW 3	0.34	0.89	2.61	<0.01
TN	TP	FW 1	0.57	0.37	0.31	<0.01
		FW 3	0.28	0.20	-0.49	<0.01

- All surface water relationships did not proportionally scale (i.e. “allometric” scaling; Slope ≠ 1).
- Different relationships of DOC-TP between FWs.
- Majority of TN is organic N.
- Organic matter dynamics differ between cells.







- High K_d less light in water column.
- Stimulation of benthic algae influencing P flux and C consumption.

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Effects of light on sediment nutrient flux and water column nutrient stoichiometry in a shallow lake

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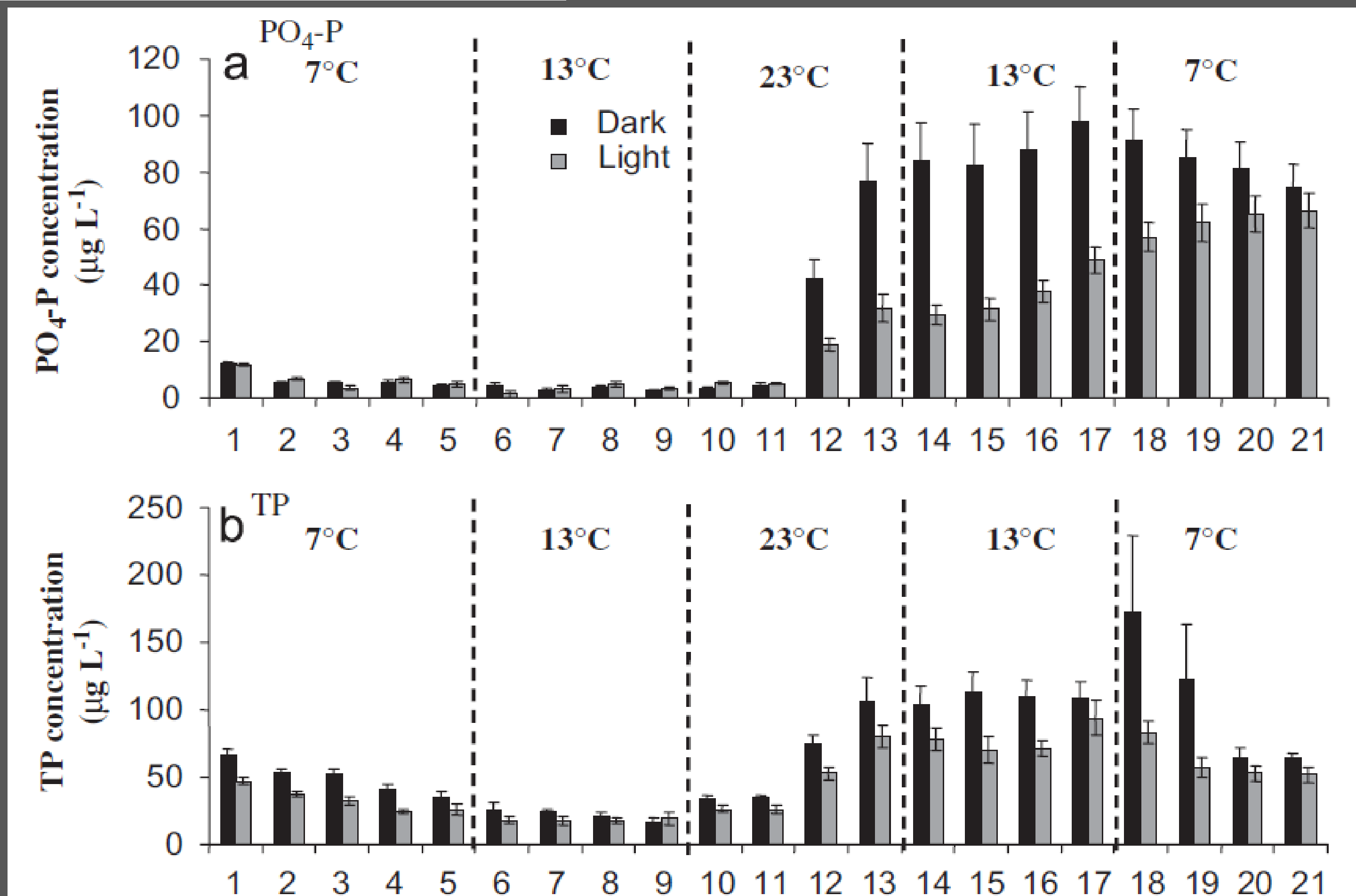
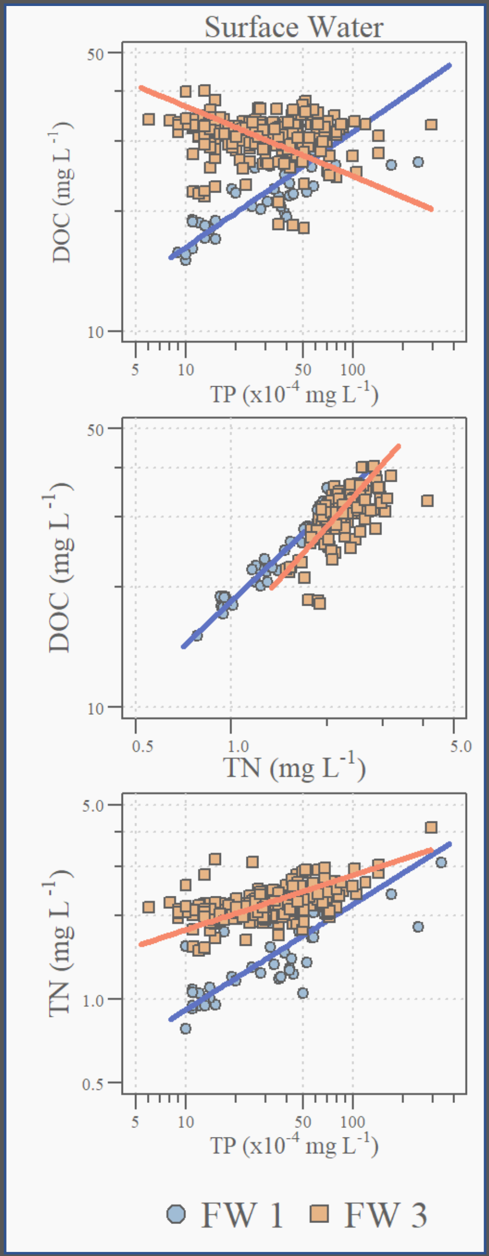
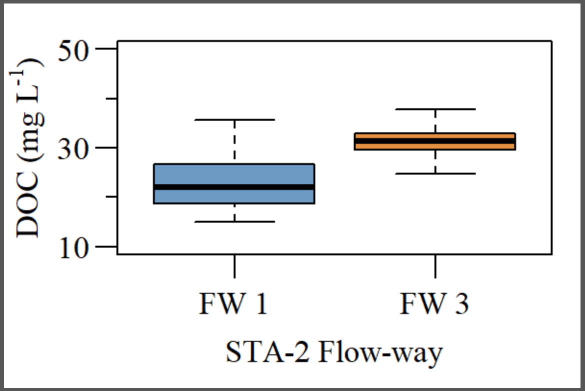
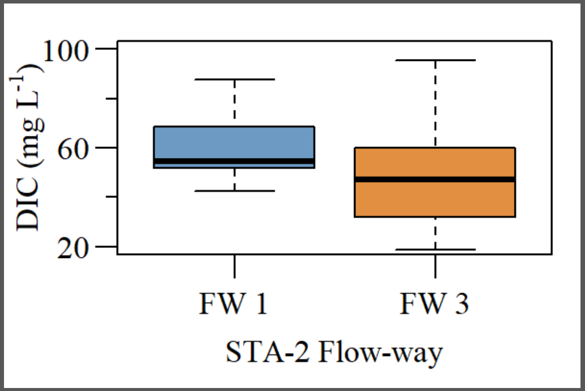
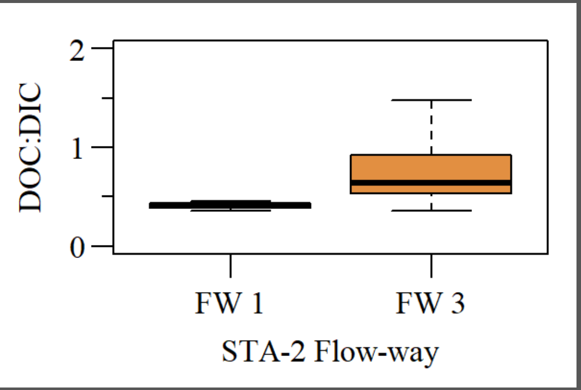


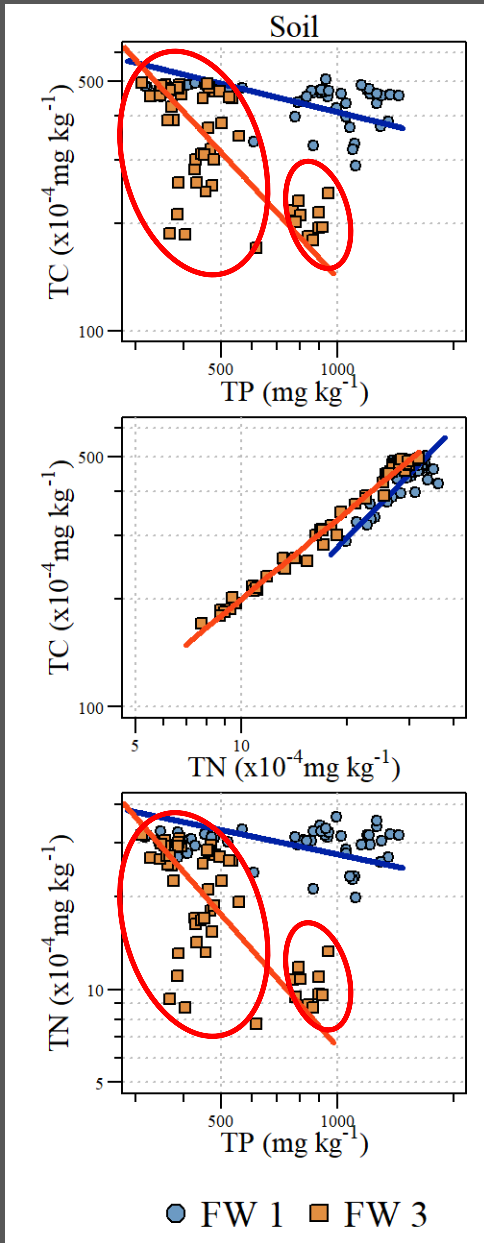








- Differences in carbon balance, flux and storage.
- Possible higher C flux in FW 3.

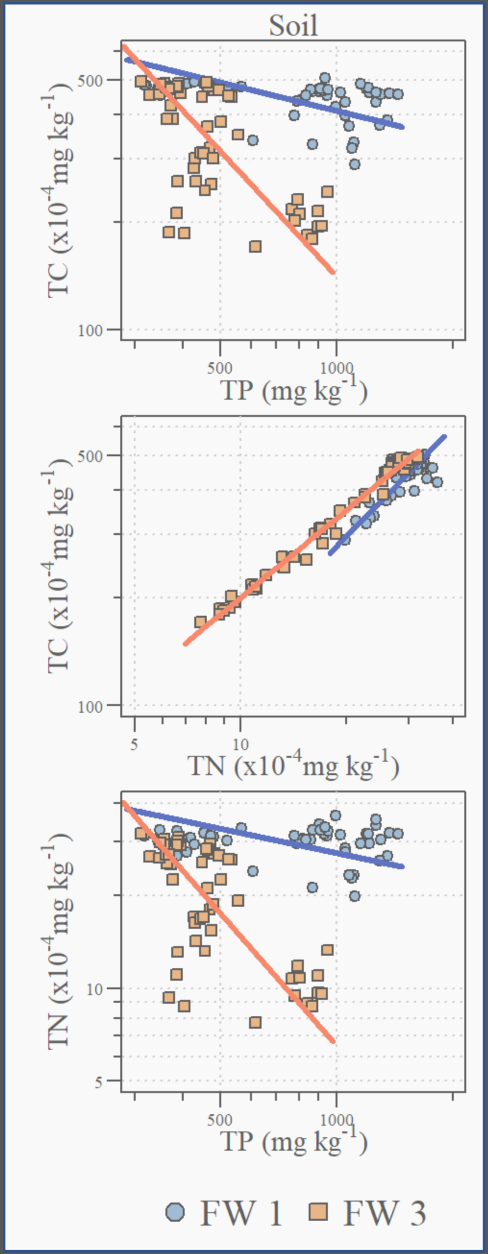


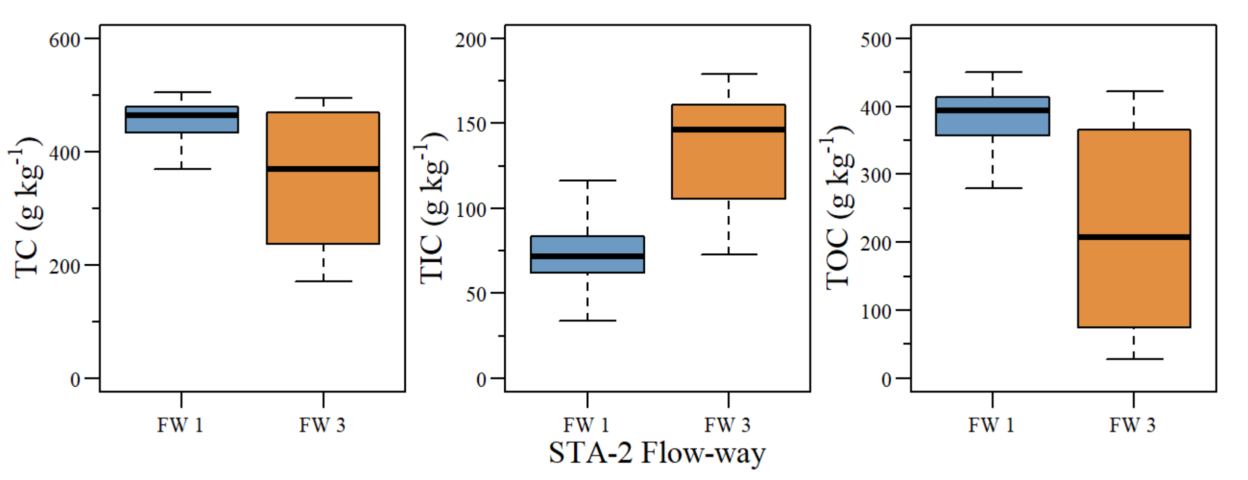
Log-Log regression results of Standardized Major Axis regression between soil variables.

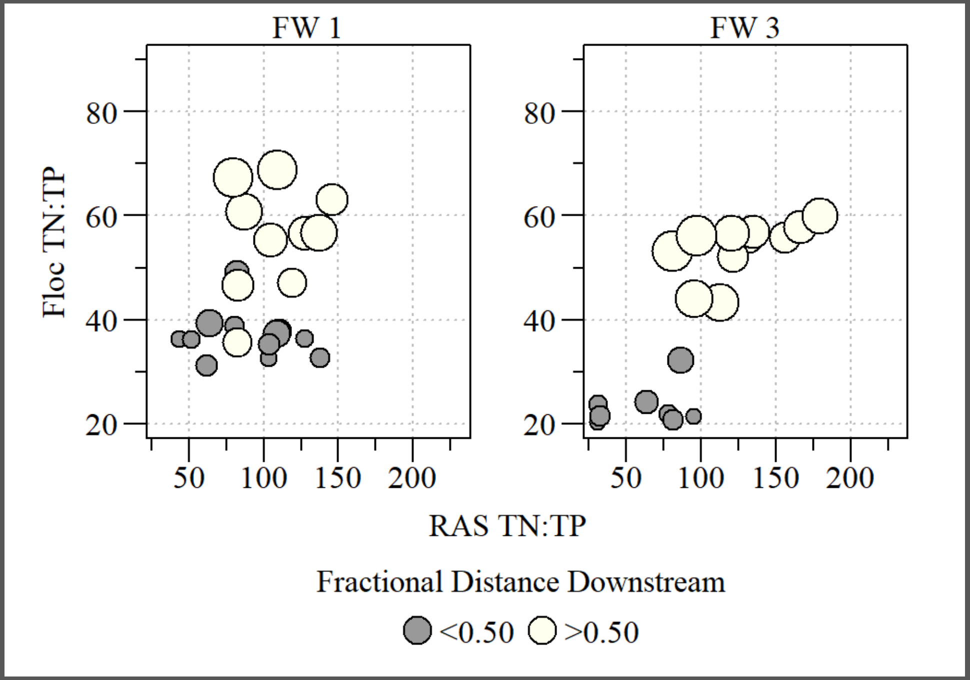
Y	X	Flow way	R^2	Slope	Intercept	ρ-value
TC	TP	FW 1	0.16	-0.26	11.35	<0.01
		FW 3	0.44	-1.17	13.43	**0.15**
TC	TN	FW 1	0.65	1.00	2.82	**0.96**
		FW 3	0.99	0.82	4.36	<0.01
TN	TP	FW 1	0.01	-0.26	8.49	<0.01
		FW 3	0.45	-1.43	11.11	<0.01

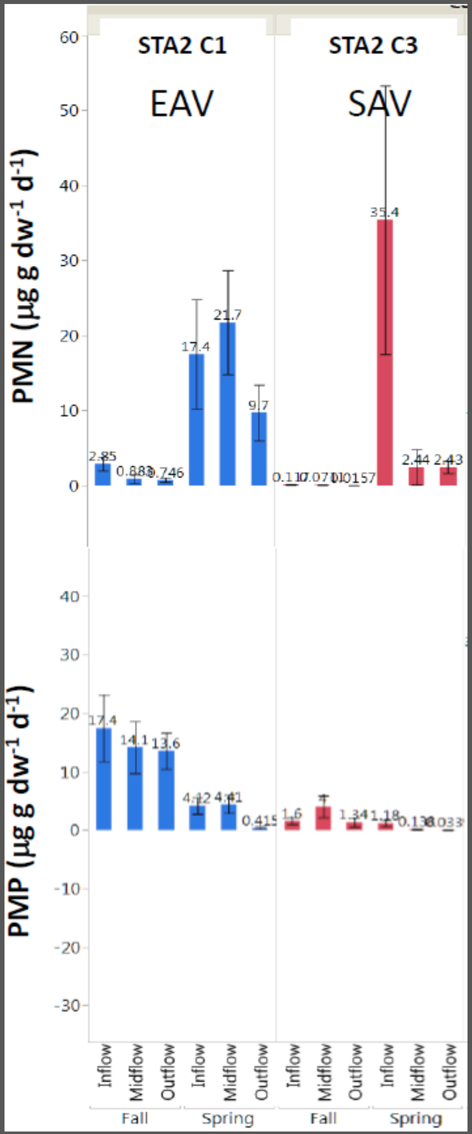
- Most relationships did not proportionally scale (i.e. allometric scaling; Slope ≠ 1).
- TC – TN (FW 1) and TC – TP (FW3) isometrically scaled (Slope = 1; ρ>0.05).

- Carbon dynamics differ between cells
- OM decomposition mechanisms differ
- Depositional environment is differ


Soil
TC (x10^-4 mg kg^-1)
500
100
500
1000
TP (mg kg^-1)
TC (x10^-4 mg kg^-1)
500
100
5
10
TN (x10^-4 mg kg^-1)
TN (x10^-4 mg kg^-1)
10
5
500
1000
TP (mg kg^-1)
FW 1
FW 3


TC (g kg^-1)
600
400
200
0
FW 1
FW 3
TIC (g kg^-1)
200
150
100
50
0
FW 1
FW 3
TOC (g kg^-1)
500
400
300
200
100
0
FW 1
FW 3
STA-2 Flow-way





(P. Inglett Unpublished Data)

- Differences in OM decomposition
- Variable N and P mineralization rates
- Mechanism differ across FWs potentially linked to microbial communities (bacteria vs fungal; *P. Inglett Unpublished Data*)

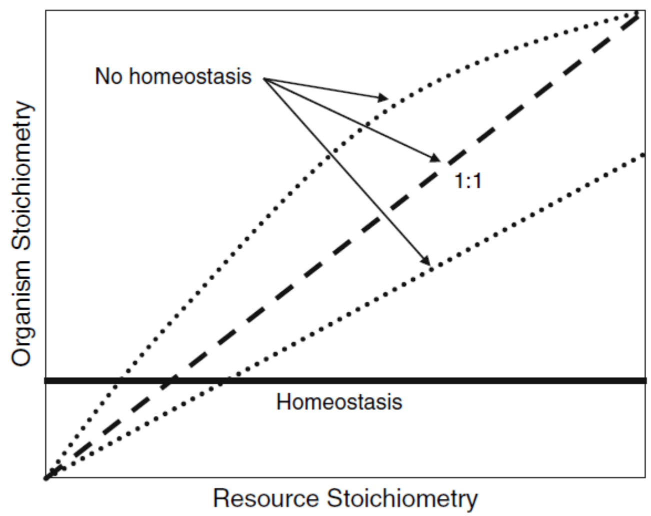
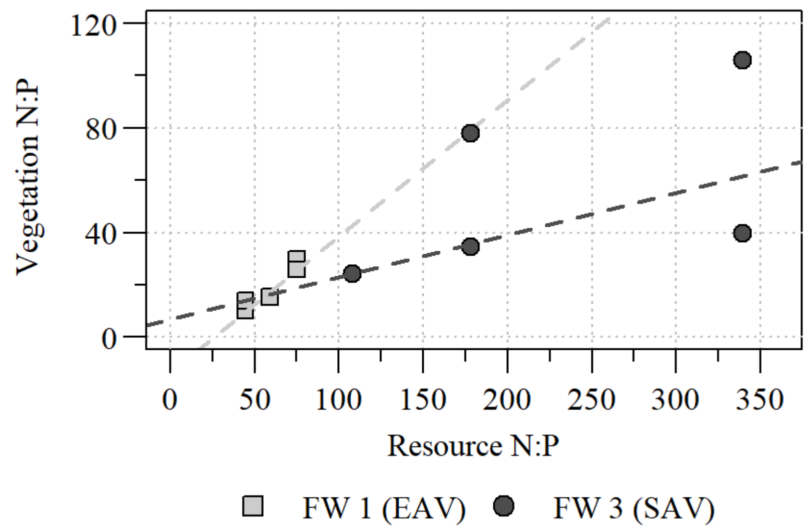
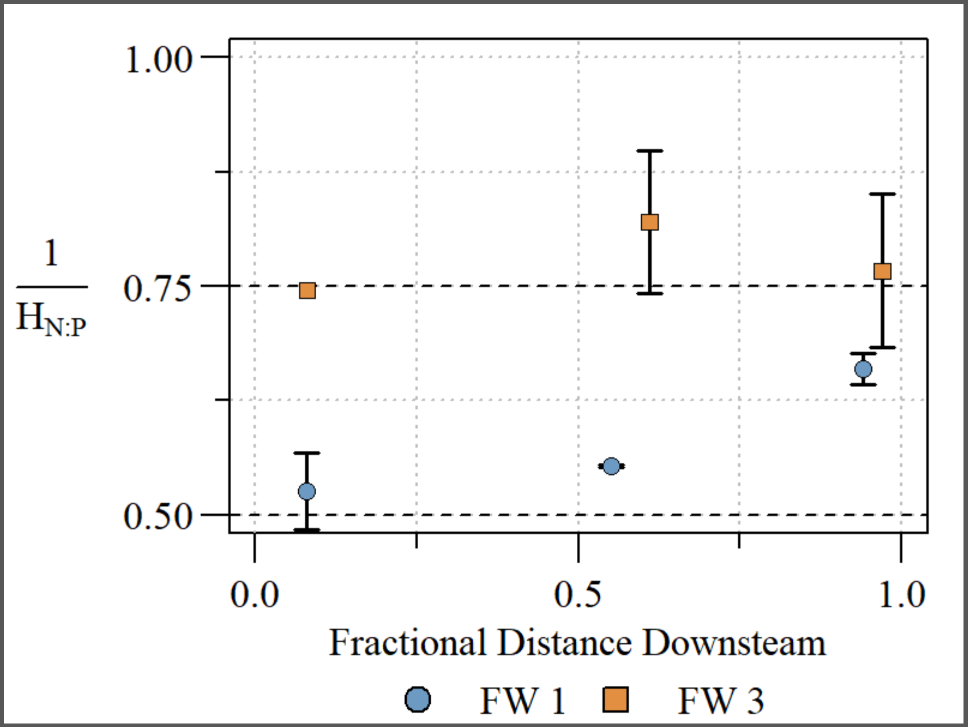


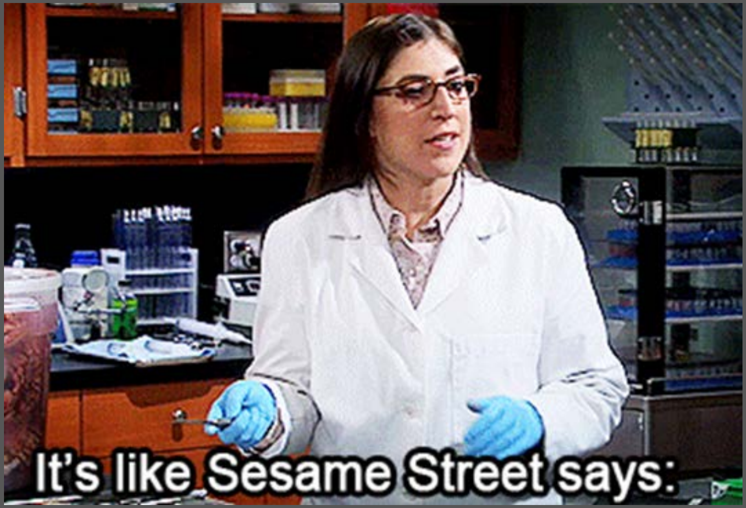
Fig. 1 Potential patterns relating resource to consumer stoichiometry. The stoichiometry of *homeostatic* organisms (solid line) is strictly defined, and changes in resource stoichiometry do not influence organism stoichiometry. The stoichiometry of *non-homeostatic* organisms may match resource stoichiometry in a 1:1 relationship (large dashes) or in a relationship (small dashes) that diverges from the 1:1 line (Adapted from Sterner and Elser 2002)





- Both EAV and SAV are non-homeostatic with respect to ambient environment.
- $1/H_{N:P}$ and fractional distance was not significantly correlated for both FWs (r=0.71, ρ=0.12 and r=-0.21, ρ=0.73).
- $1/H_{N:P}$ significantly different between FW1 and FW3 (χ^2=7.5, ρ<0.05) suggesting a divergent stoichiometric homeostasis.
  - Physiological and biochemical mechanisms associated with nutrient retention and uptake.

- Stoichiometry is highly variable between systems (i.e. FW 1 and FW 3) and within ecosystem compartments (water, floc, soil, veg.).
- N and P mineralization processes differ between EAV and SAV systems.
- EAV and SAV are non-homeostatic to facilitate luxury uptake and nutritional structural investments.



Questions

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@SwampThingPaul

Paul Julian (Bird Rookery Swamp)

Methods

Collection

Water Column	• Surface water sampled weekly (via grab sample) during semi-prescribed flow events • Analyzed for TP, TN and DOC
Vegetation	• 4 – 8 randomly placed 0.25 m^2 quadrat adjacent to sampling location sampled 2015 and 2016 wet season • Analyzed for TP, TN and TC
Soil	• Push core method sampled 2015 ad 2016 wet and dry season • Analyzed for TP, TN and TC

Data Handling & Statistics

- All concentrations were converted to molar concentrations (mM or mmol kg^{-1})
- Any value below the MDL was assigned the MDL