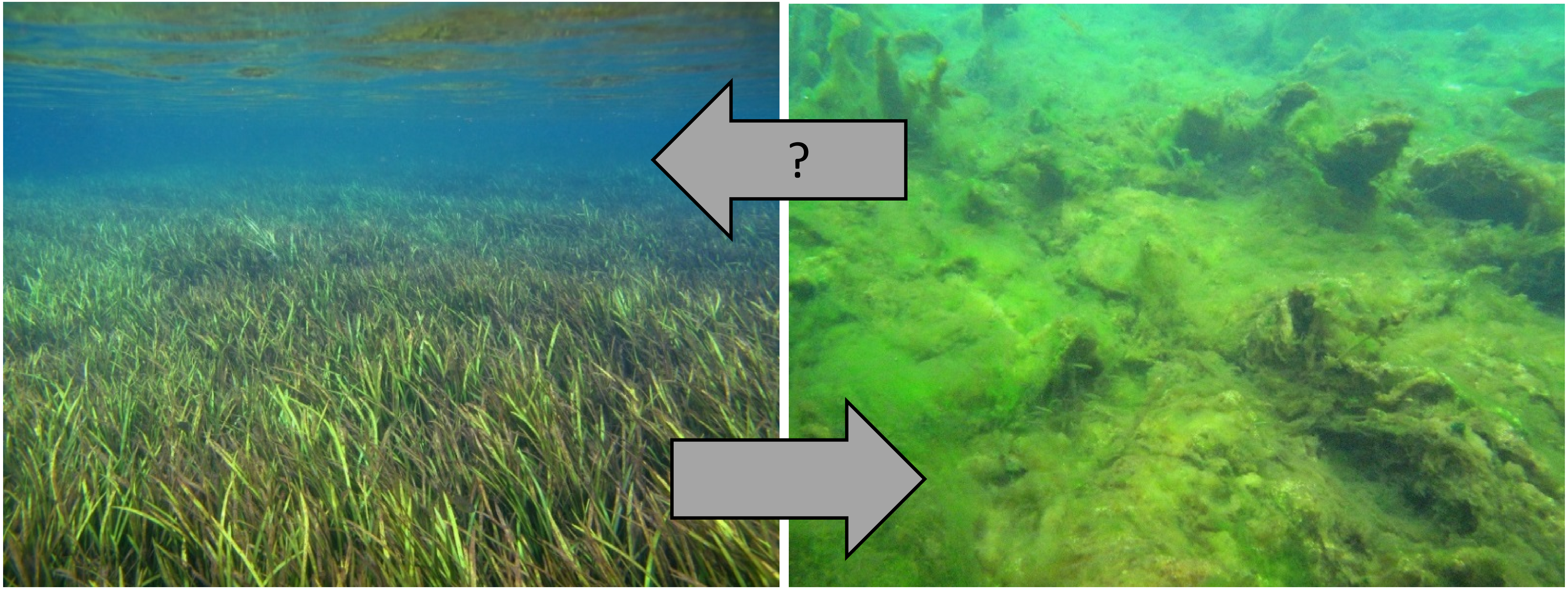
A General Hypothesis for Ecological Change in Florida's Springs

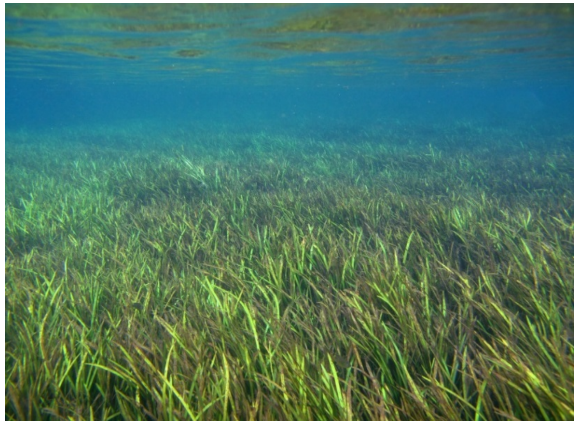
Matt Cohen

Ecohydrology Lab

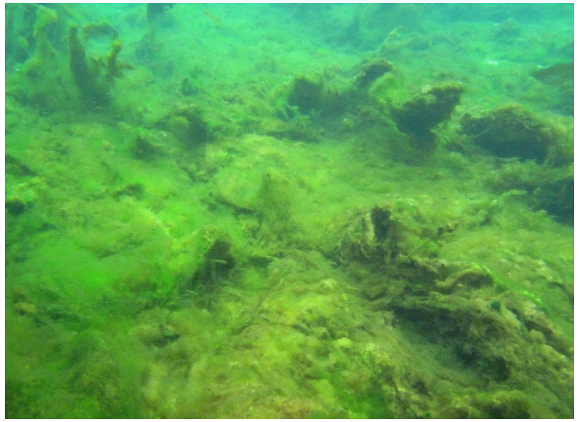
Changes to Autotroph Community Structure



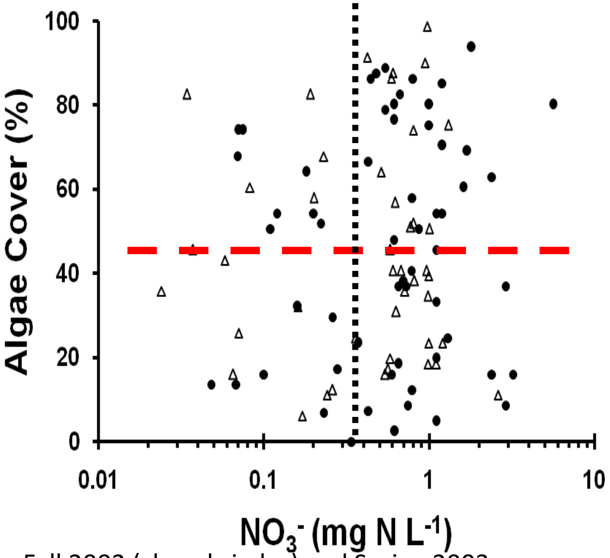
A (Brief) Case for the Insufficiency of Nitrogen



Silver Springs (1.4 ppm N-NO_3)

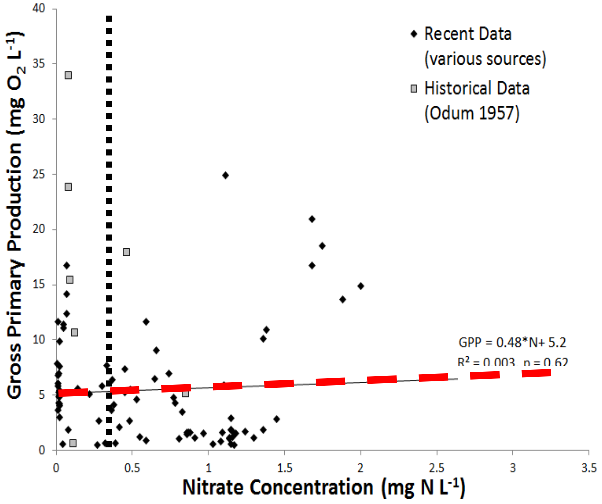


Alexander Springs (0.05 ppm N-NO_3)



Fall 2002 (closed circles) and Spring 2003 (triangles)

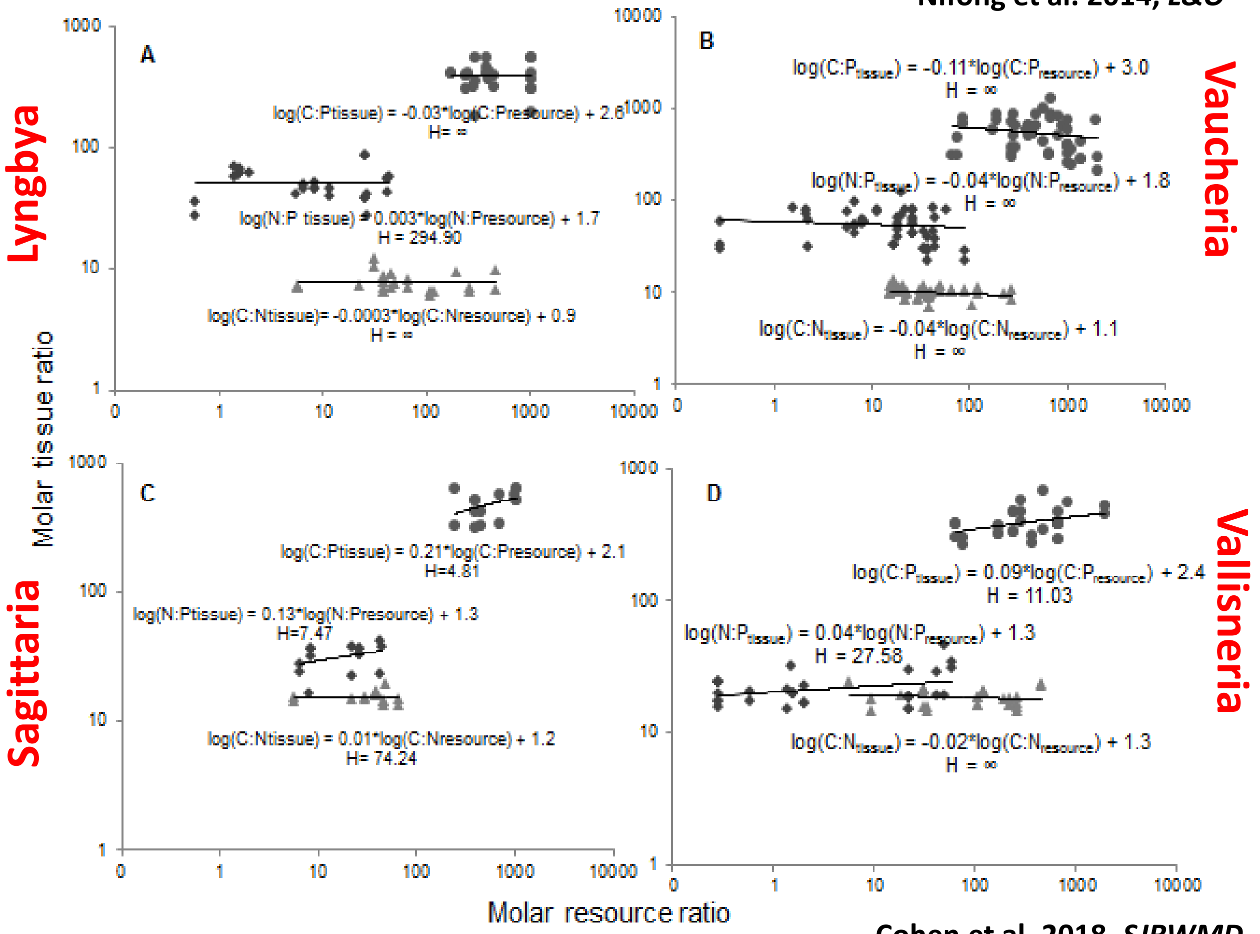
From Stevenson et al. 2004 **Ecological condition of algae and nutrients in Florida Springs** DEP Contract #WM858



Data Sources:

- Odum (1957)
- WSI (2010, 2007, 2004)
- Cohen et al. (2013)

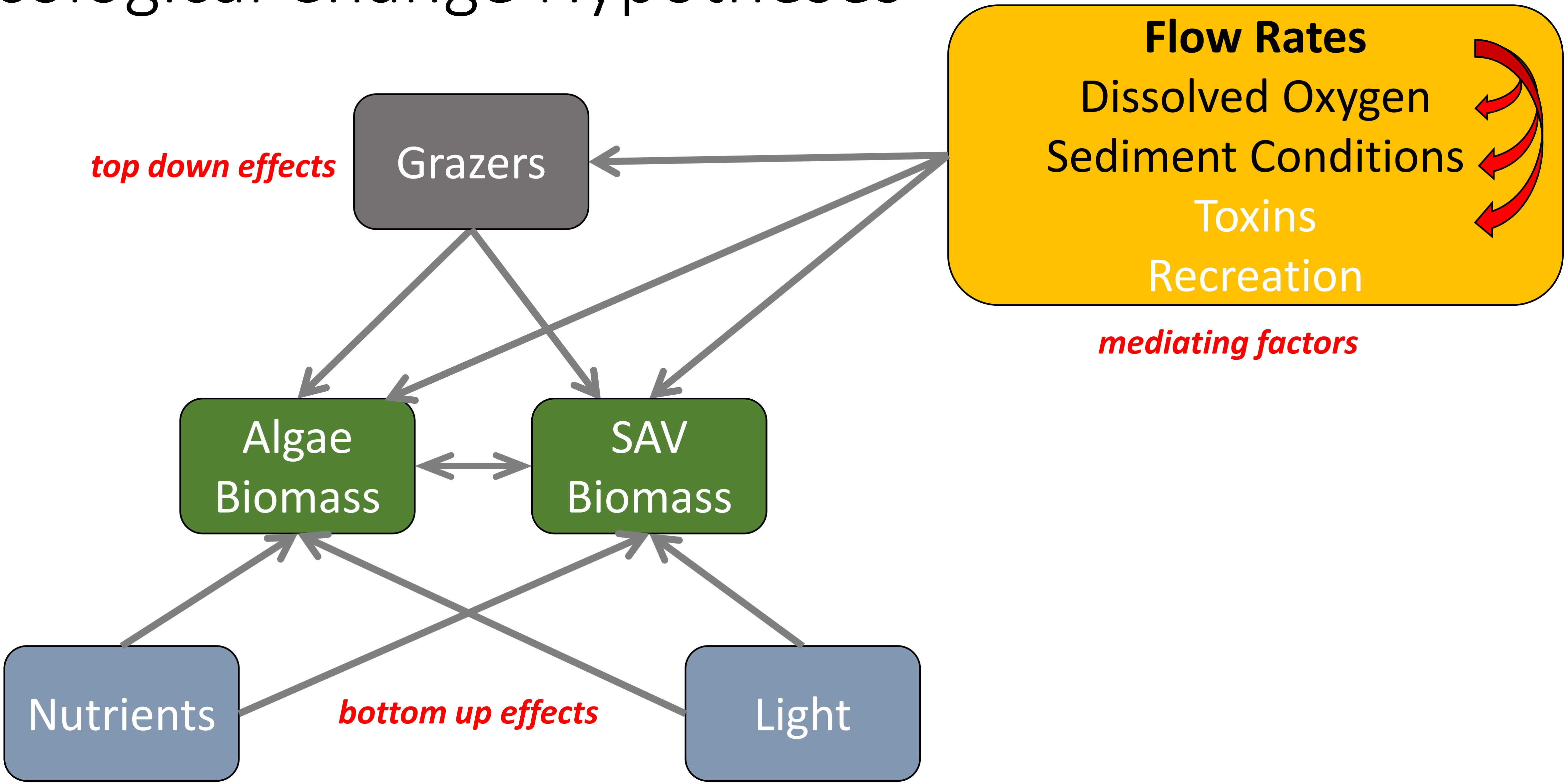
Nifong et al. 2014, *L&O*



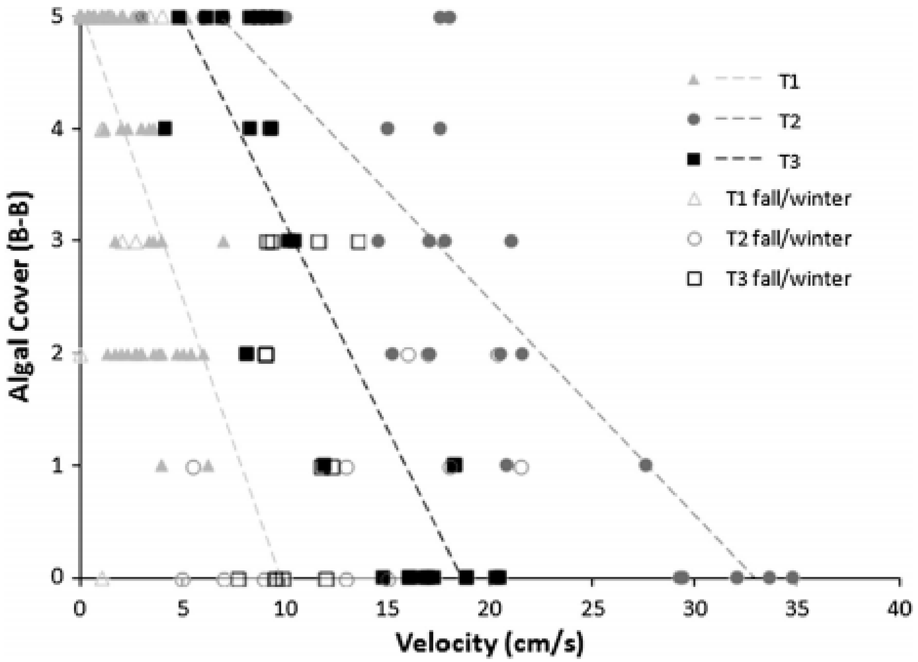
Cohen et al. 2018, *SJRWMD*

In Silver River (8 km; > 30 ha of river bottom), gross autotroph N demand (0.13 g N m^{-2} d^{-1}) is ~ 1.2% of available N supply (12 g m^{-2} d^{-1})

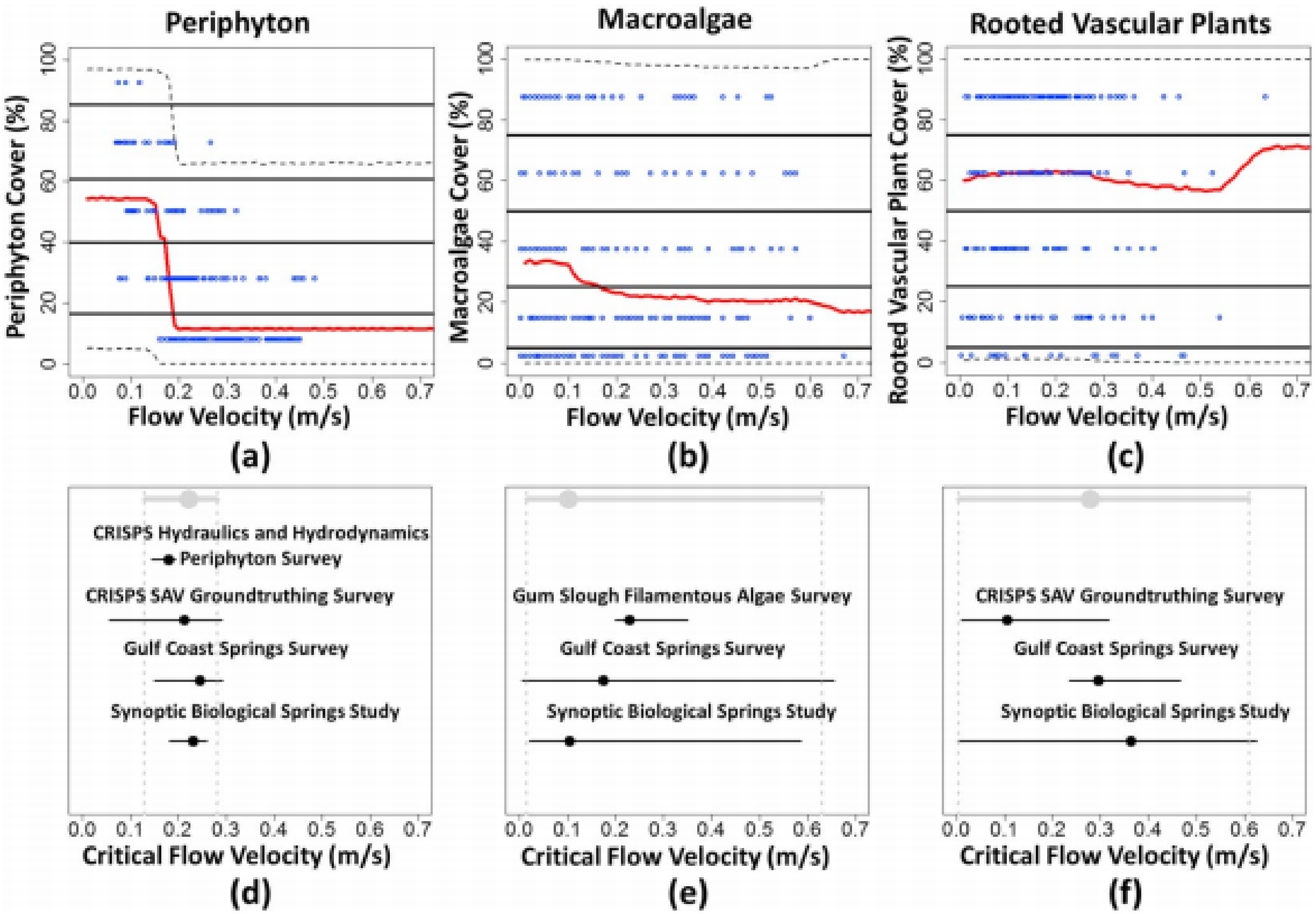
Ecological Change Hypotheses



Direct Flow Controls *(Velocity-Scour Hypothesis)*



King 2014, *Hydrobiologia*



Reaver et al. 2019, *GRL*

<u>Velocity Thresholds</u>

Periphyton ~ **0.13 – 0.28 m/s**

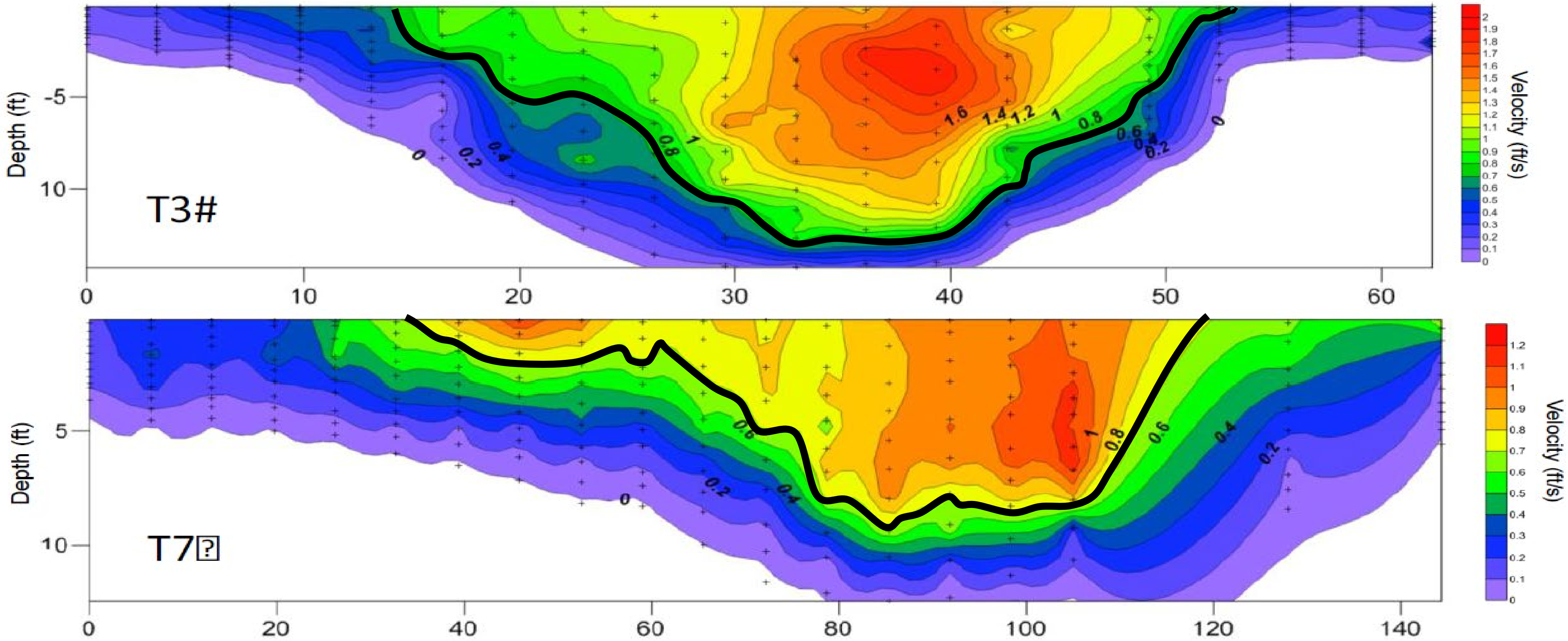
Macroalgae ~ 0.02 – 0.63 m/s

SAV ~ 0.02 – 0.61 m/s

Limitations of Velocity-Scour

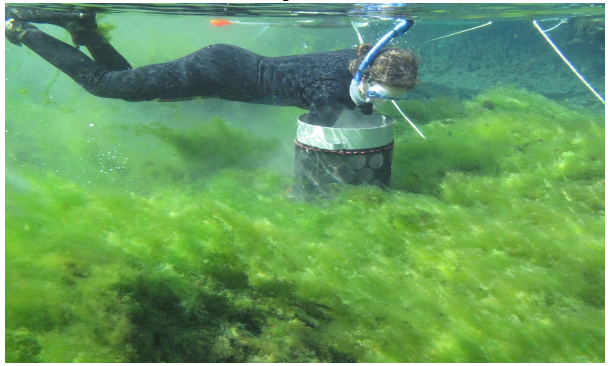
- No evidence for macroalgal effect (despite strong effects on periphyton)
- Natural channels have (and always had) distributions of velocity

Kaplan et al. 2018, *SJRWMD*

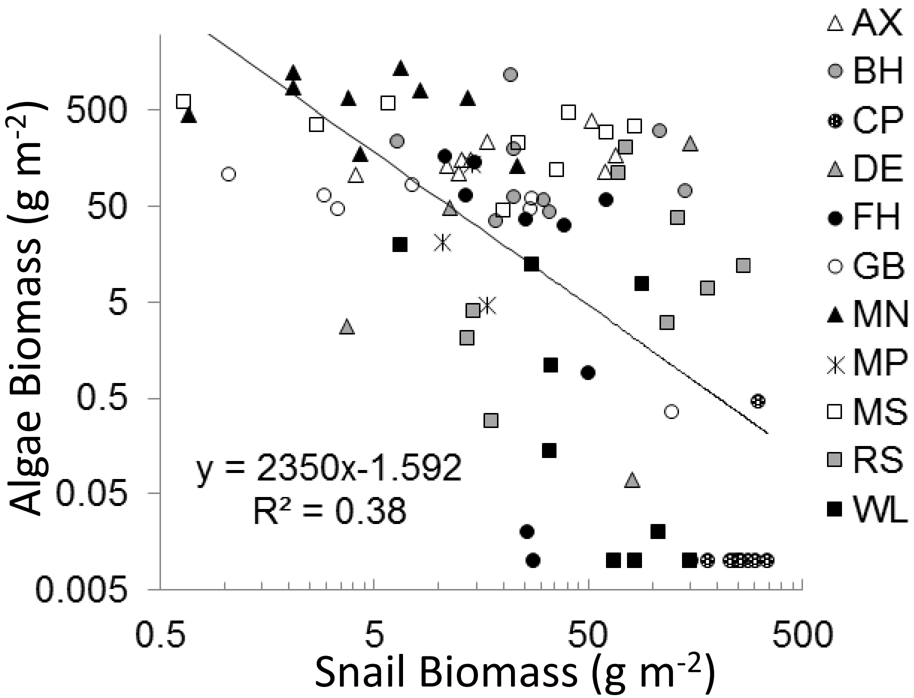


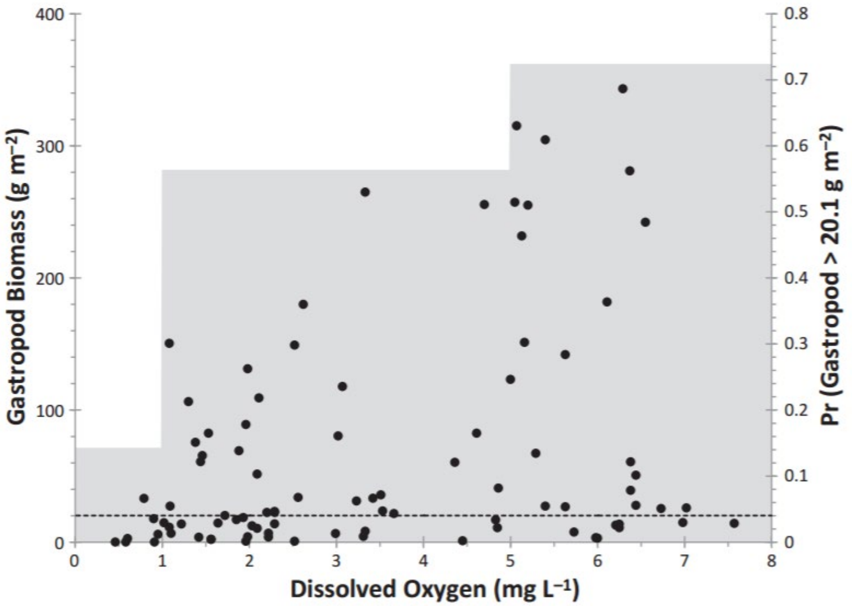
Observational Evidence for Trophic Cascade

Elimia floridensis



Dina Liebowitzii





Algae ~ f(snails, flow, light)
Explains > **50%** of algae variation

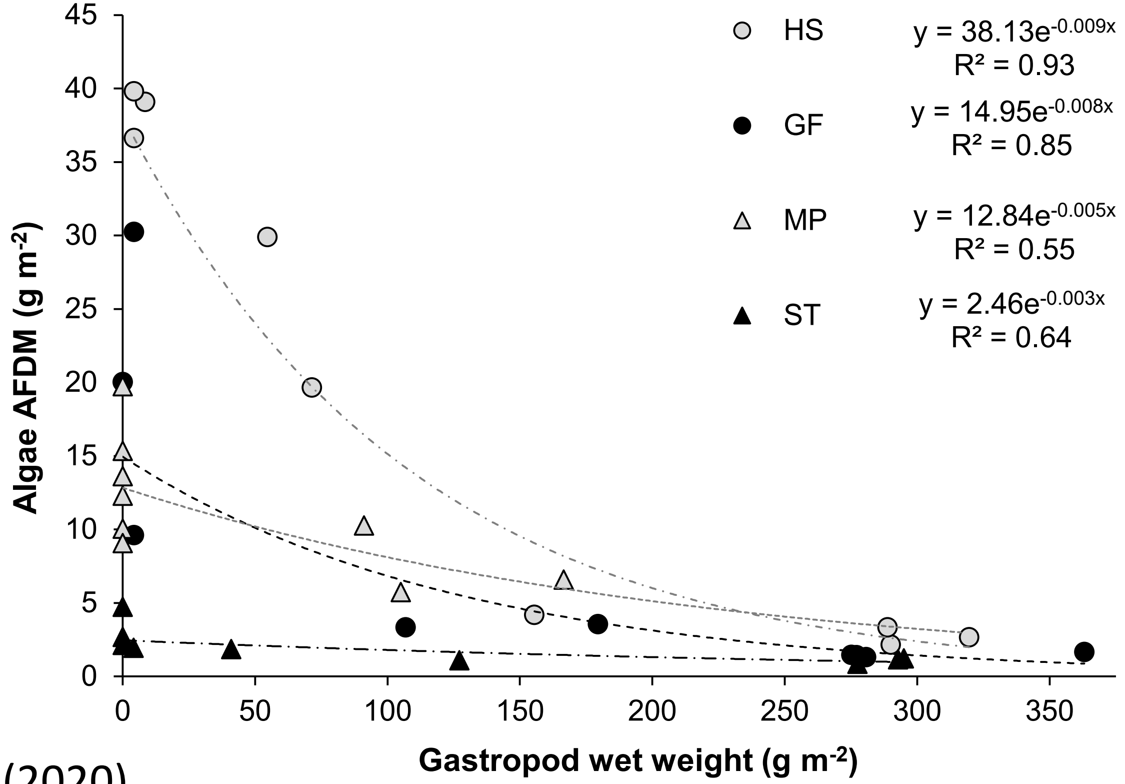
Snail density ~ f(DO + SpC + Light + SAV)
Explains **>60%** of snail variation

Key Limitations:

- Gastropod biomass ≠ grazing
- Gastropods are isotopically distinct from mature macroalgal biomass (Nifong et al. 2018); they don't eat it.

Further Experimental Evidence for Trophic Controls

- *In situ* enclosures with **low initial algae** @ 4 locations, 3 snail densities (zero, ambient, high)
- Snails effectively control algal biomass accrual

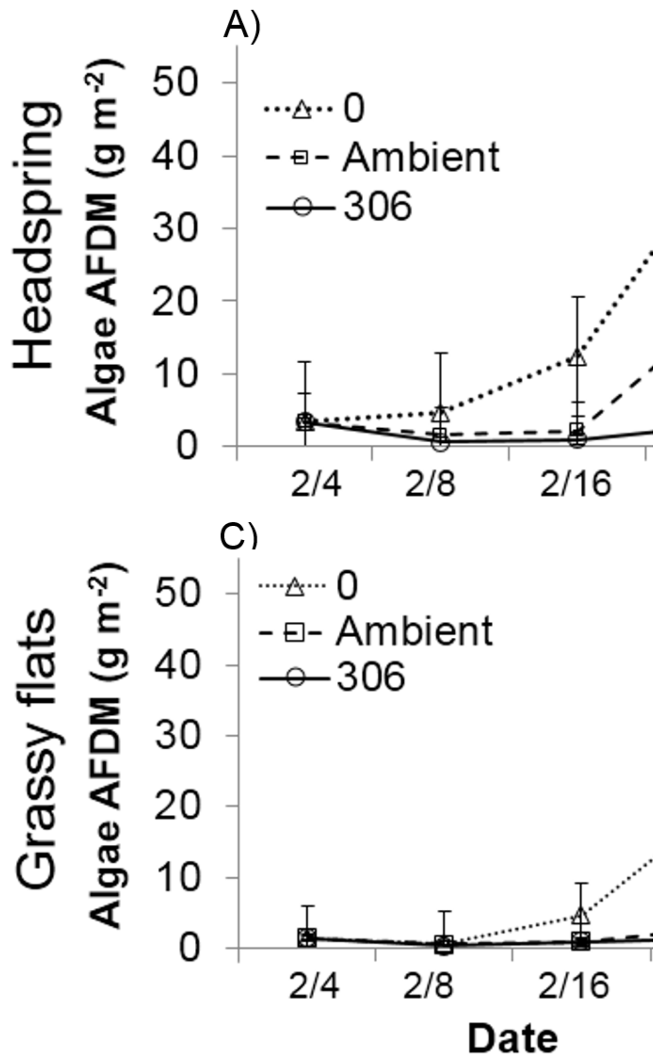


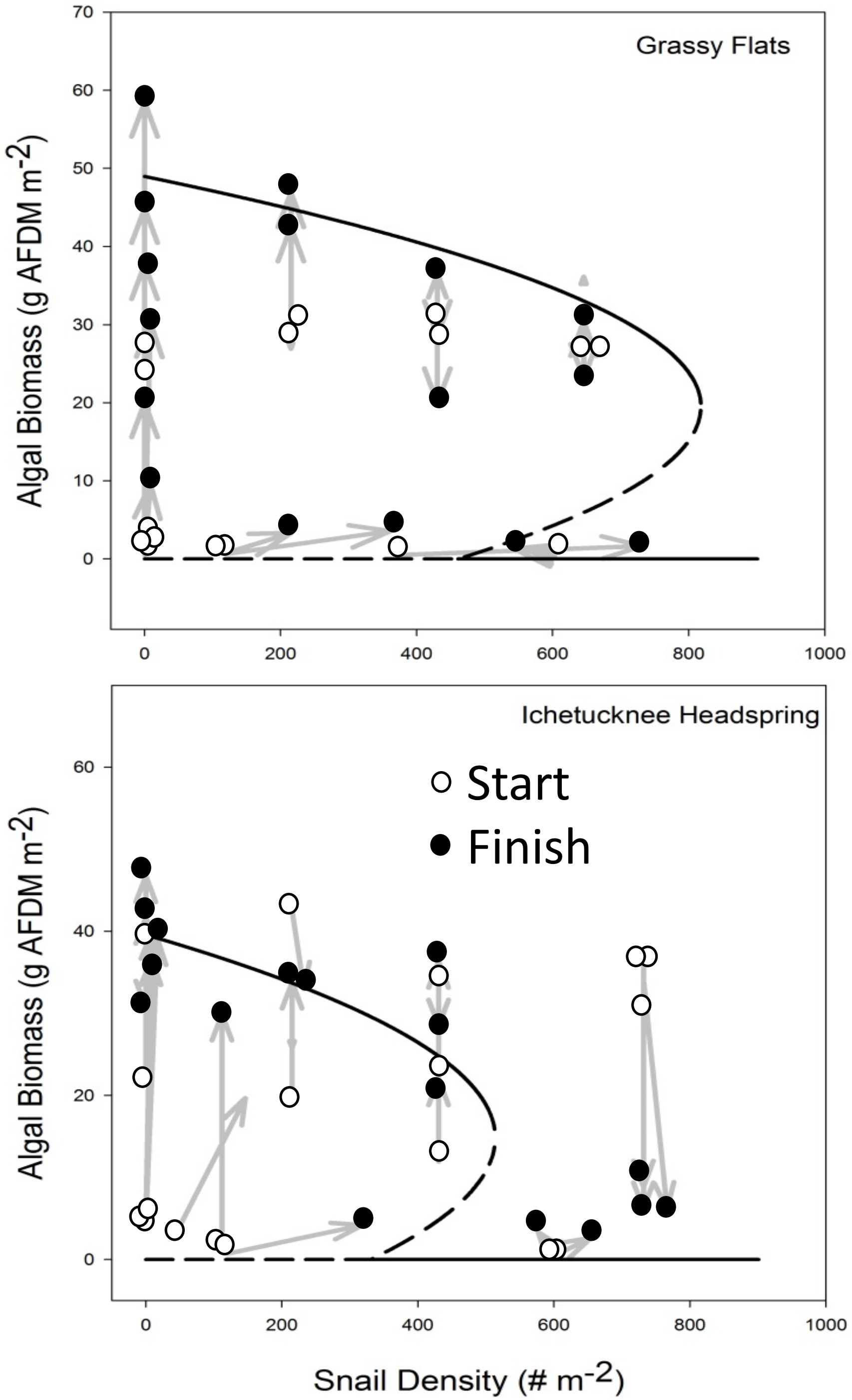
Liebowitz et al. (2020)

Algal State Resilience

- Replicate experiment at **high initial algal** density
    - 4 snail densities

- Fitted state stability model suggests algal state resilience, but with high site specificity

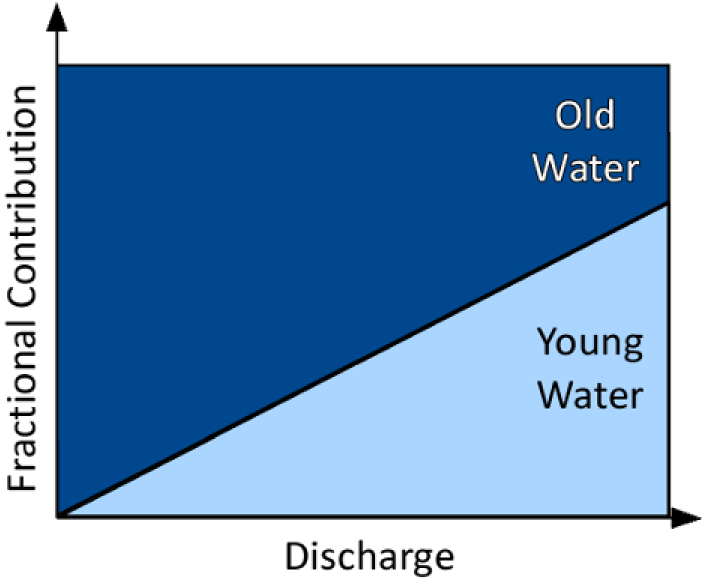


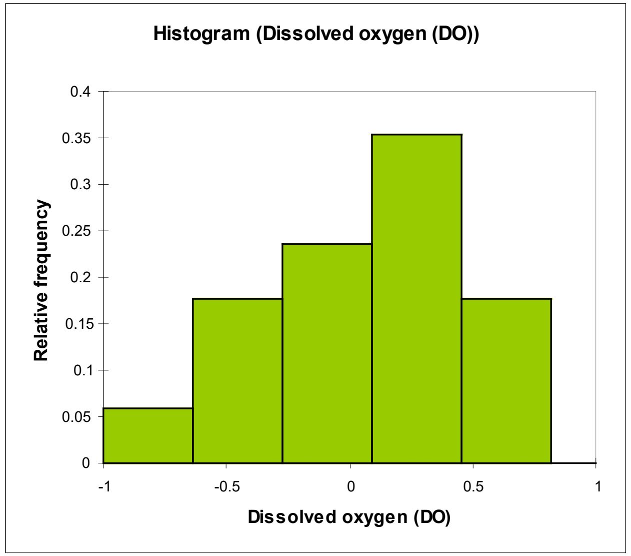


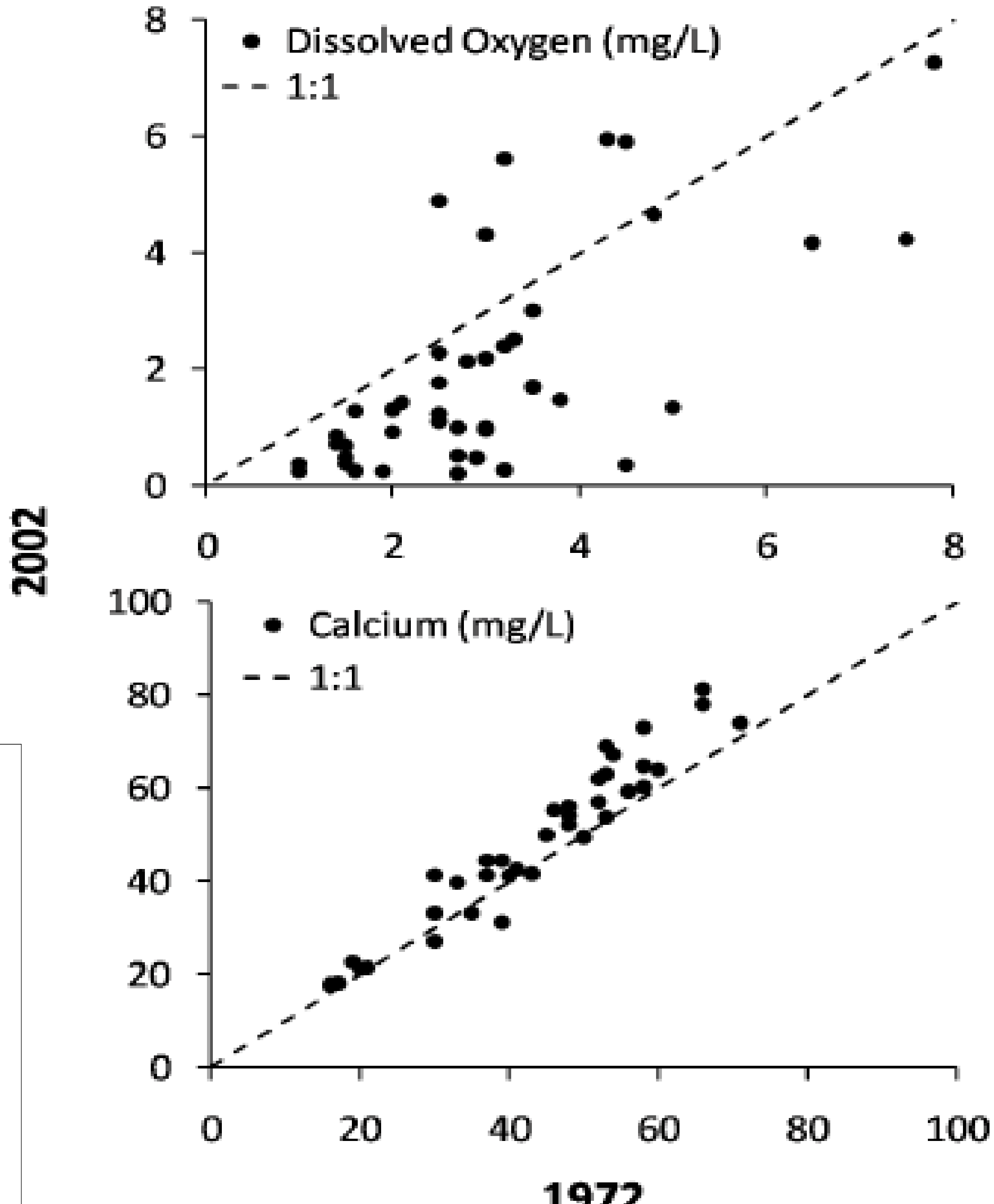
Liebowitz et al. (2020)

Press Disturbances in DO

- DO concentrations are relatively constant, vary with flow over climate cycles
  - Wet → High Q → High DO
  - Dry → Low Q → Low DO
  - Unknown effects of human BOD loading
- ***A long slow snail suffocation***
  - Long lived, slow moving, late breeding







Strong et al. (2012)

Indirect Flow Controls #2 – Flow Reversals

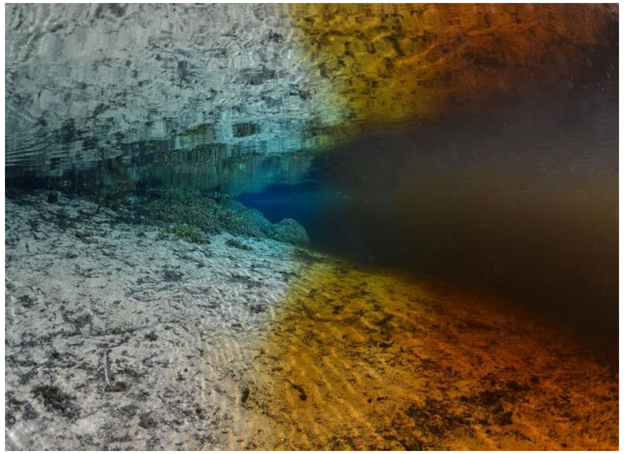
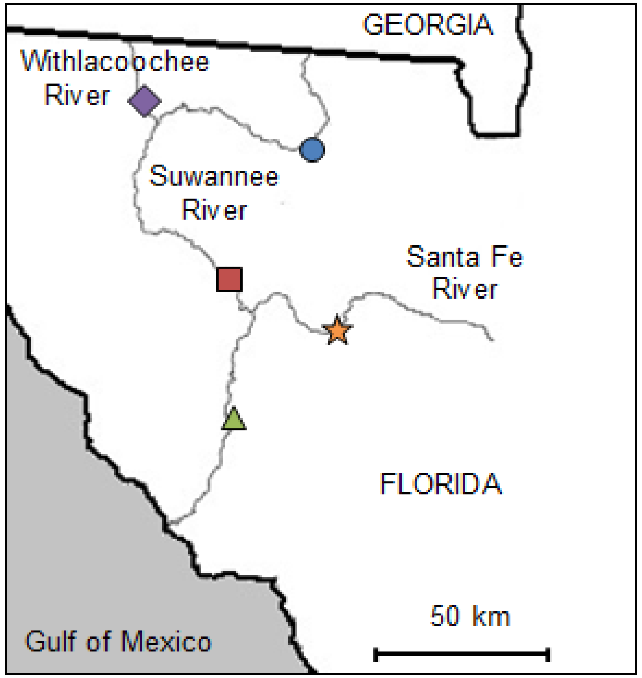


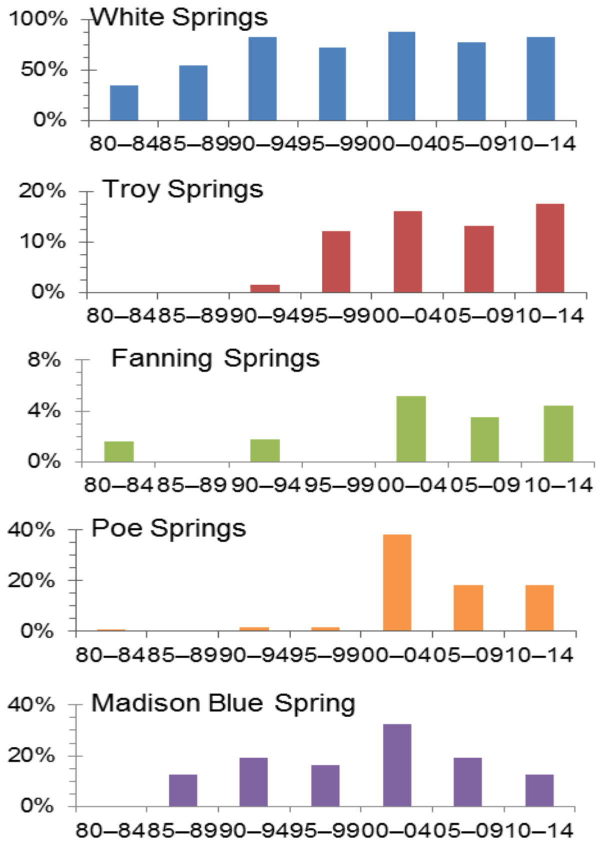
Photo: Jenny Adler

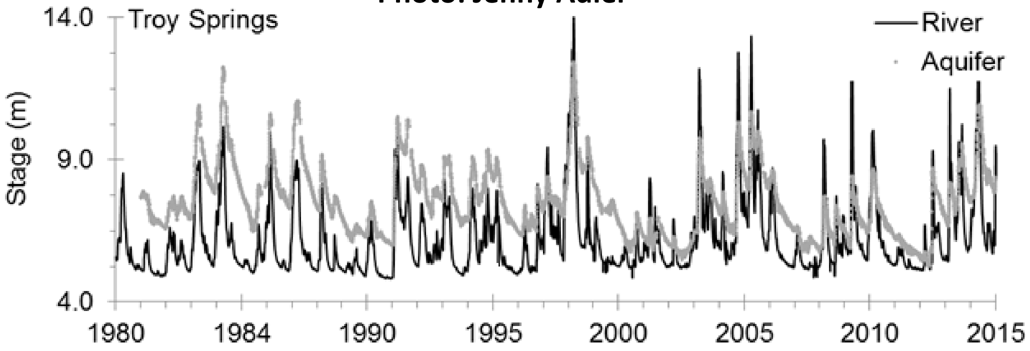
Florida’s Rivers have **two personalities** (clear, tannic)

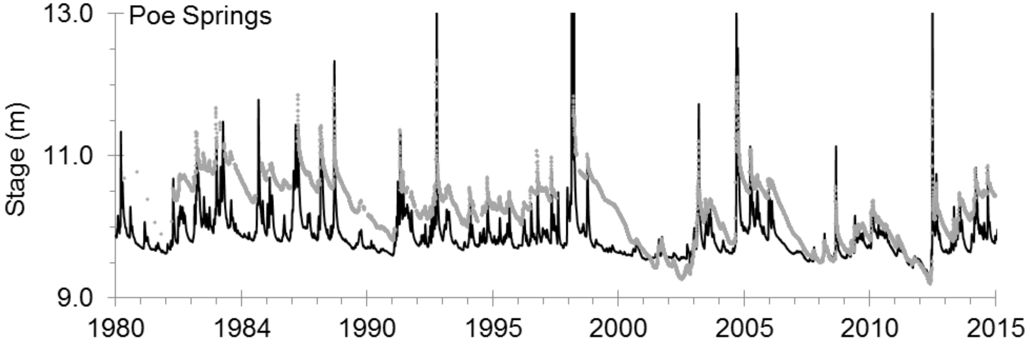
During blackwater river floods, spring flow can reverse, sending high DOC, acid water into the aquifer



Hensley and Cohen 2019, *Freshwater Science*





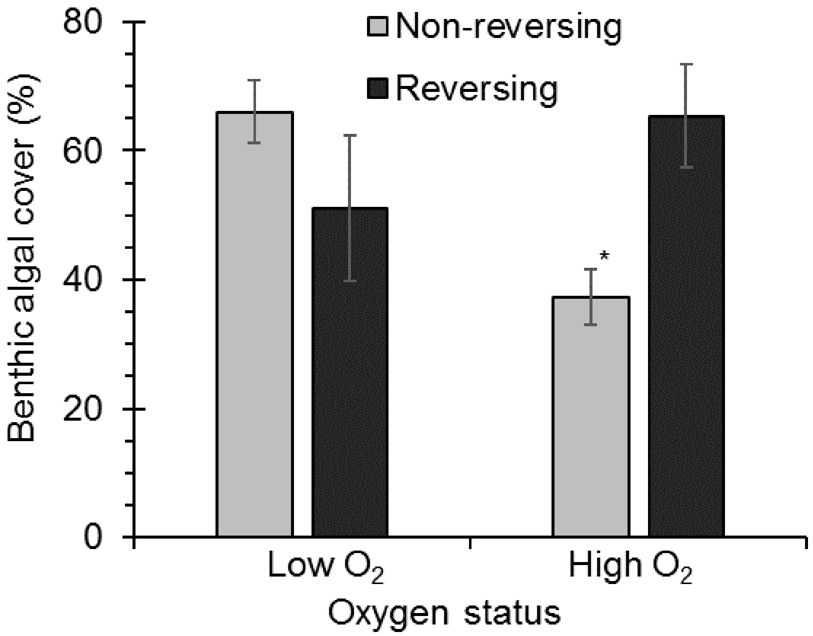


Why is this Happening?

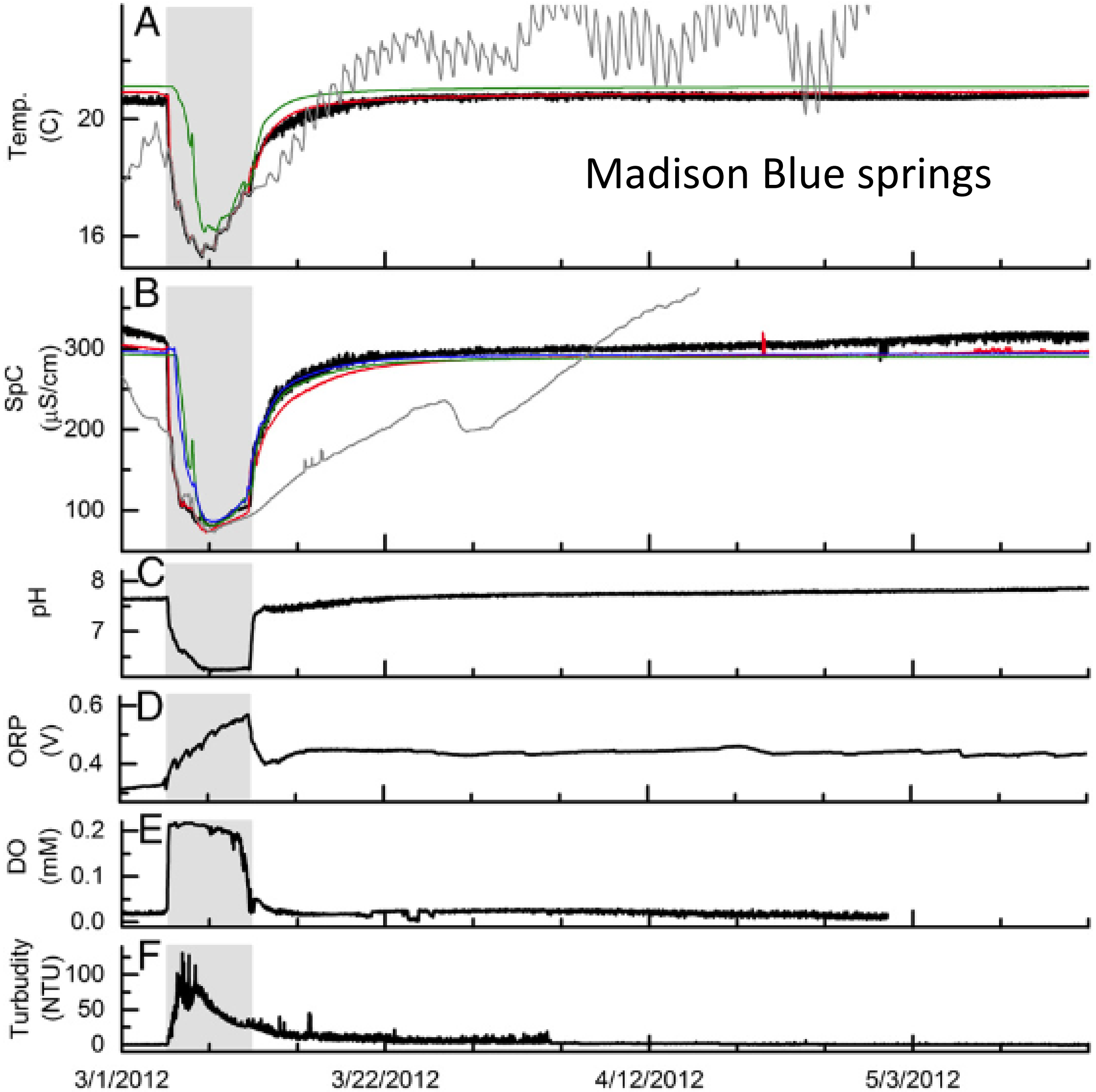
- Declining aquifer levels (climate, consumptive use)
- Increasing storm responses (climate, land cover)

What Happens During a Reversal?

- Reduced flow velocity
- ↓ Light → bottleneck for plant competition
- ↓ pH → calcite weathering (snails)
- ↑Respiration of OM → ↓ DO (redox, grazers)
- **Pulse** vs. **press** low oxygen disturbance

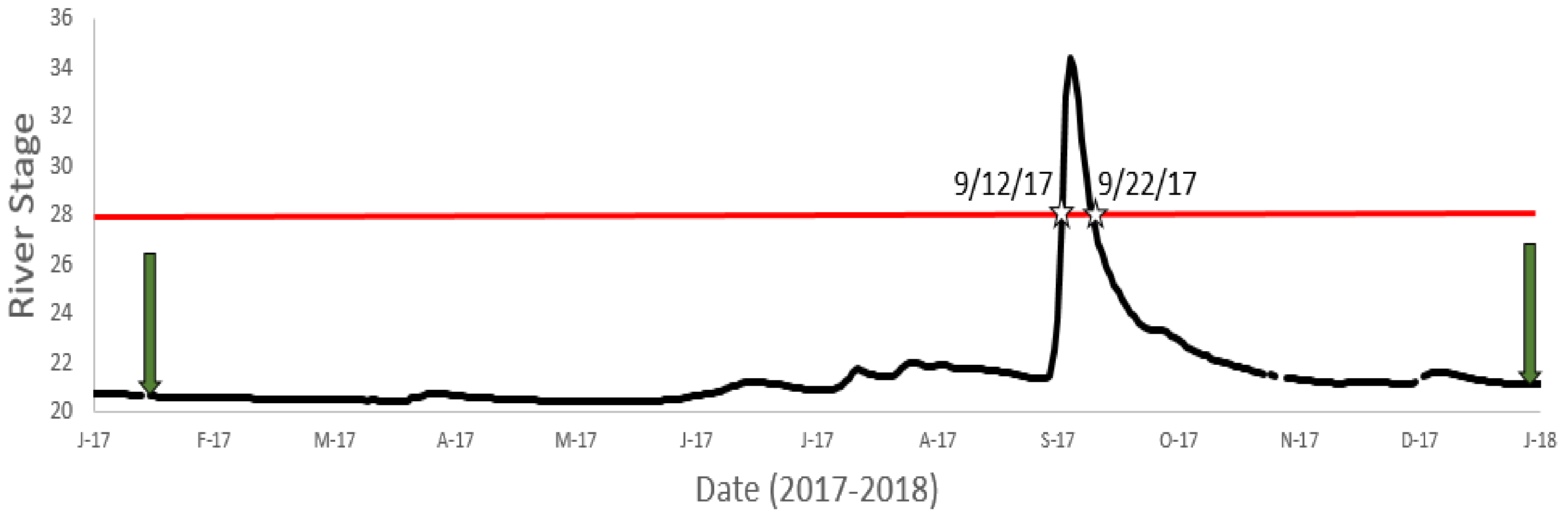


Hensley and Cohen 2017, *Freshwater Science*

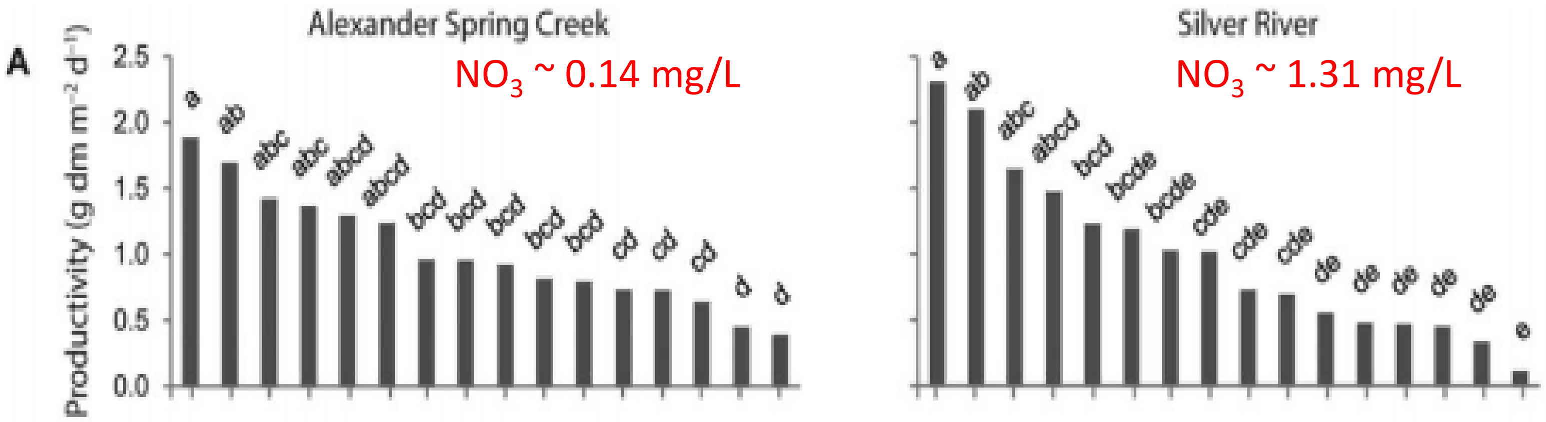


Brown et al. 2017, *Chemical Geology*

Hurricane Irma & Pulse Disturbance in Gilchrist Blue



Indirect Flow Controls #3 – SAV Growth



- Large spatial heterogeneity within sites.
- No differences between sites.
- Modest seasonality (summer peak)
- Mean Biomass Turnover ~ 3-4 yr^{-1}

- Nearly identical models across sites.
  - ~50% variation explained
- Strong positive light effects
  - *(more canopy, less growth)*.
- Strong positive redox effects
  - *(more oxic, more growth).*
- Strong negative P effects
  - *(more P, less growth).*

	Silver River			Alexander Springs Creek		
Main effect	Standardized slope	Standard error	*t*-value	Standardized slope	Standard error	*t*-value
Canopy	−0.30	0.11	−2.65	−0.19	0.08	−2.43
Redox @ 4.5 cm	0.35	0.17	2.07	0.47	0.11	4.16
PW_OrthoP	−0.65	0.19	−3.44	−0.30	0.10	−2.88

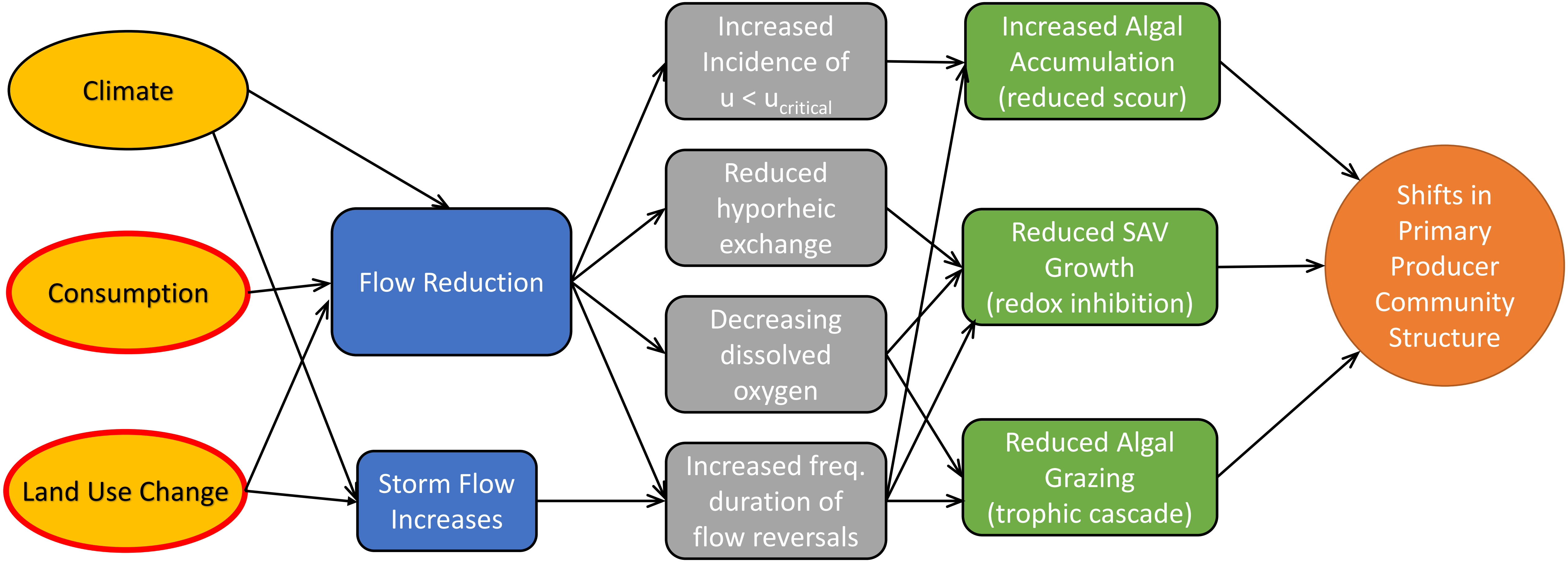
McBride and Cohen 2020, *Freshwater Science*

Redox Growth Controls

- Fine-grained sediments indicate low hyporheic exchange
  - Low delivery rate of electron acceptors
- Organic rich sediments indicate high electron acceptor demands
  - Rapid depletion of favorable options (DO and nitrate)
- Feedbacks
  - Vascular plant oxidation of the root zone (more plants, lower redox)
- Water column DO
  - Low in many springs, temporally dynamic
  - Spatial proximity of vastly different SAV condition in Ichetucknee

John Moran, Then and Now (Devil's Eye, Ichetucknee)

The Coherence of Flow Induced Changes



Hooking these mechanisms to the MFLs?

Synthesis and Knowledge Gaps

- Convergence of evidence on flow effects leads to a general hypothesis:

  Flow variation controls primary producer community structure via direct, indirect, and trophic cascade effects.

- Primary mechanisms
  - Direct scour
  - Redox controls for SAV
  - DO controls on algal grazing
  - Pulse disturbances (reversals) impact all
- Knowledge Gaps:
  - High frequency biology
  - Springs hydraulic typologies
  - Long term data
- Applications to the logic of environmental flows (MFLs)

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