A General Hypothesis for Ecological Change in Florida’s Springs

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Changes to Autotroph Community Structure
A (Brief) Case for the Insufficiency of Nitrogen

Silver Springs (1.4 ppm N-NO₃)  Alexander Springs (0.05 ppm N-NO₃)

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

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

Data Sources:
- Odum (1957)
- Cohen et al. (2013)

Nifong et al. 2014, L&O

Lyngbya

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)

Data Sources:
- Cohen et al. 2018, SJRWMD
Ecological Change Hypotheses

**Flow Rates**
- Dissolved Oxygen
- Sediment Conditions
- Toxins
- Recreation

**mediating factors**

**bottom up effects**
- Algae Biomass
- SAV Biomass
- Nutrients
- Light

**top down effects**
- Grazers
Direct Flow Controls (Velocity-Scour Hypothesis)

Velocity Thresholds
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

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

Snail Biomass (g m⁻²)
Algae Biomass (g m⁻²)
y = 2350x⁻1.592
R² = 0.38

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

\[
y = 38.13e^{-0.009x} \\
R^2 = 0.93
\]
\[
y = 14.95e^{-0.008x} \\
R^2 = 0.85
\]
\[
y = 12.84e^{-0.005x} \\
R^2 = 0.55
\]
\[
y = 2.46e^{-0.003x} \\
R^2 = 0.64
\]
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
Florida’s Rivers have **two personalities** (clear, tannic)

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

**Why is this Happening?**

- Declining aquifer levels (climate, consumptive use)
- Increasing storm responses (climate, land cover)
What Happens During a Reversal?

- Reduced flow velocity
- $\downarrow$ Light $\rightarrow$ bottleneck for plant competition
- $\downarrow$ pH $\rightarrow$ calcite weathering (snails)
- $\uparrow$ Respiration of OM $\rightarrow$ $\downarrow$ DO (redox, grazers)
- **Pulse** vs. **press** low oxygen disturbance

![Graph showing benthic algal cover (%)](image1)

Hensley and Cohen 2017, *Freshwater Science*

![Graphs showing various environmental parameters](image2)

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).

\[
\begin{align*}
\text{NO}_3 & \sim 0.14 \text{ mg/L} \\
\text{NO}_3 & \sim 1.31 \text{ mg/L}
\end{align*}
\]

\[
\begin{array}{c|c|c|c}
\text{Main effect} & \text{Silver River} & \text{Alexander Springs Creek} \\
& \text{Standardized slope} & \text{Standard error} & \text{t-value} & \text{Standardized slope} & \text{Standard error} & \text{t-value} \\
\hline
\text{Canopy} & -0.30 & 0.11 & -2.65 & -0.19 & 0.08 & -2.43 \\
\text{Redox @ 4.5 cm} & 0.35 & 0.17 & 2.07 & 0.47 & 0.11 & 4.16 \\
\text{PW_OrthoP} & -0.65 & 0.19 & -3.44 & -0.30 & 0.10 & -2.88 \\
\end{array}
\]
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
The Coherence of Flow Induced Changes

- **Climate**
- **Consumption**
- **Land Use Change**

**Flow Reduction**
- Increased Incidence of $u < u_{critical}$
- Reduced hyporheic exchange
- Decreasing dissolved oxygen
- Increased freq. duration of flow reversals

**Storm Flow Increases**
- Increased Algal Accumulation (reduced scour)
- Reduced SAV Growth (redox inhibition)
- Reduced Algal Grazing (trophic cascade)

**Shifts in Primary Producer Community Structure**

**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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