Hydrology and Hydroperiod Controls on Water Quality in the Greater Everglades

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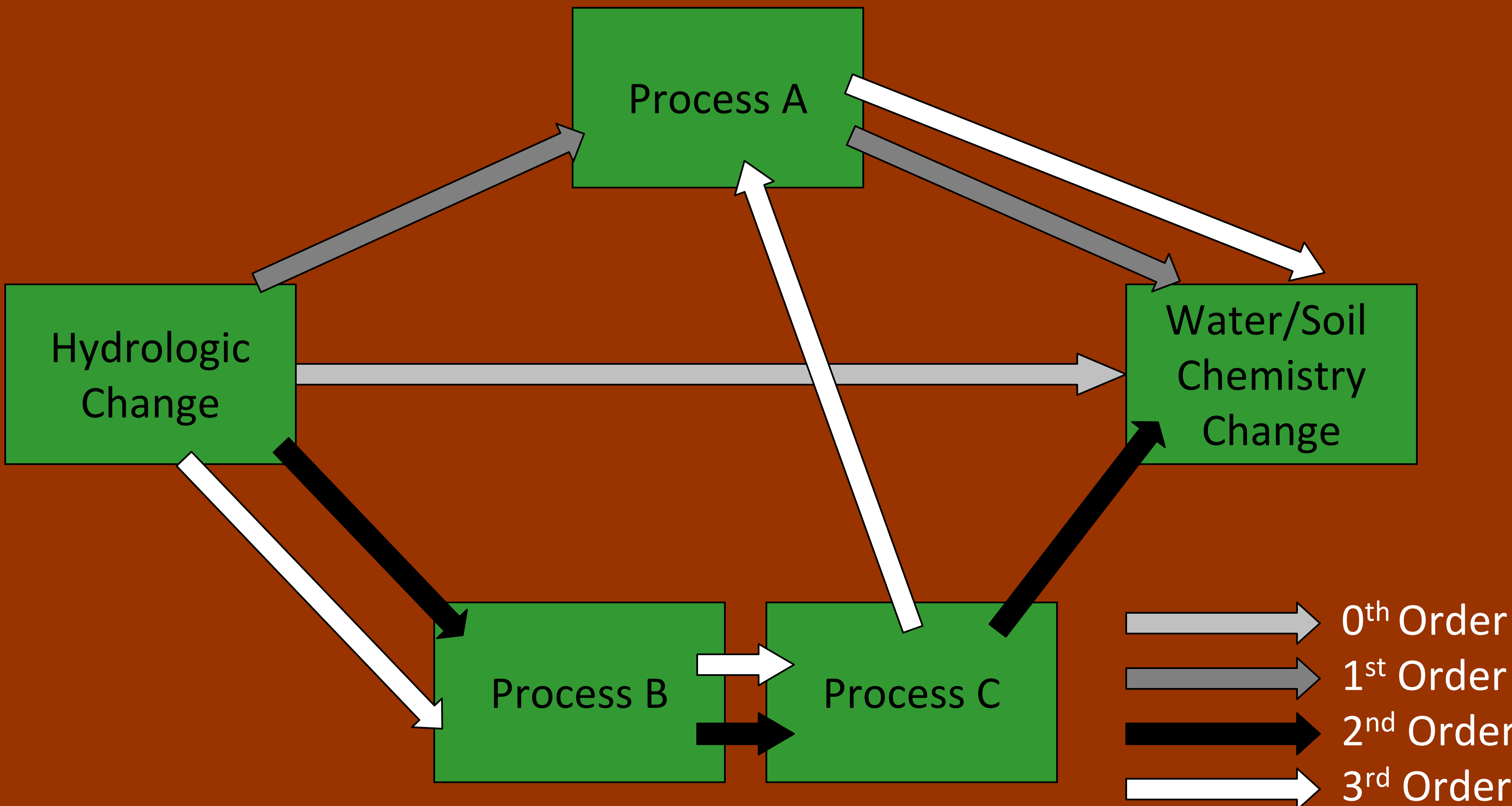
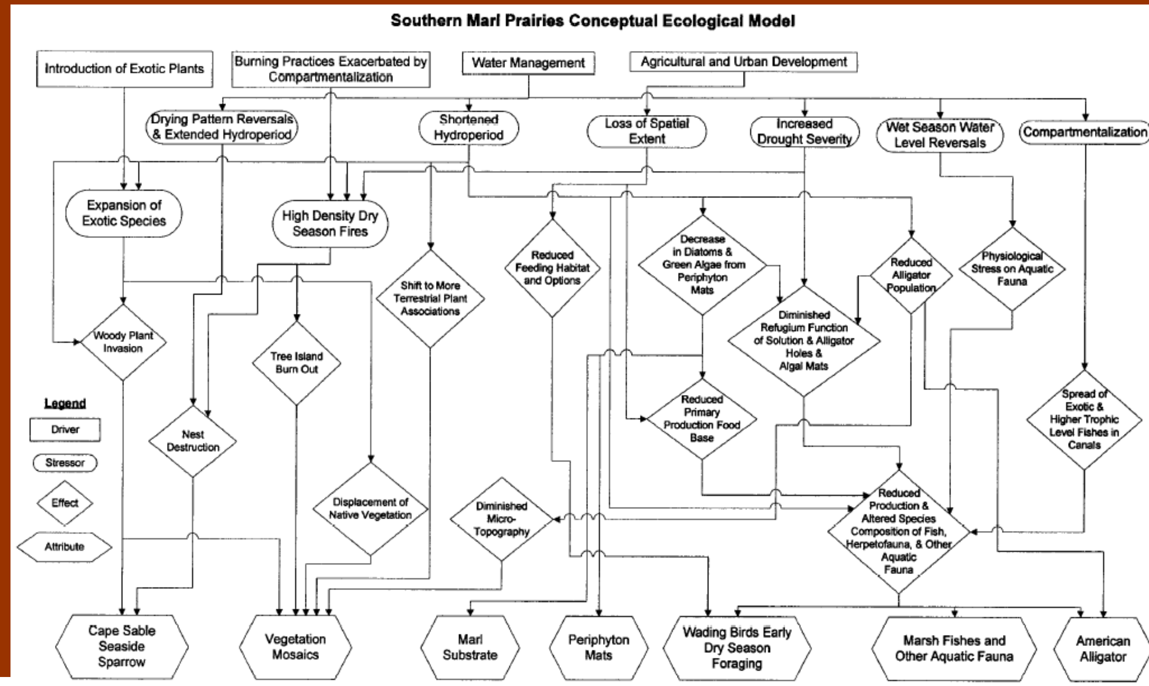
Central Premise

- Hydrology is the keystone driver of ecological processes in the Everglades
- Ecological processes in South Florida exert unusually large *reciprocal* control on hydrology and water quality
- *Ergo:* As biological processes respond to hydrological change, they engender intercessory (thus **indirect**) effects on water and soil chemistry

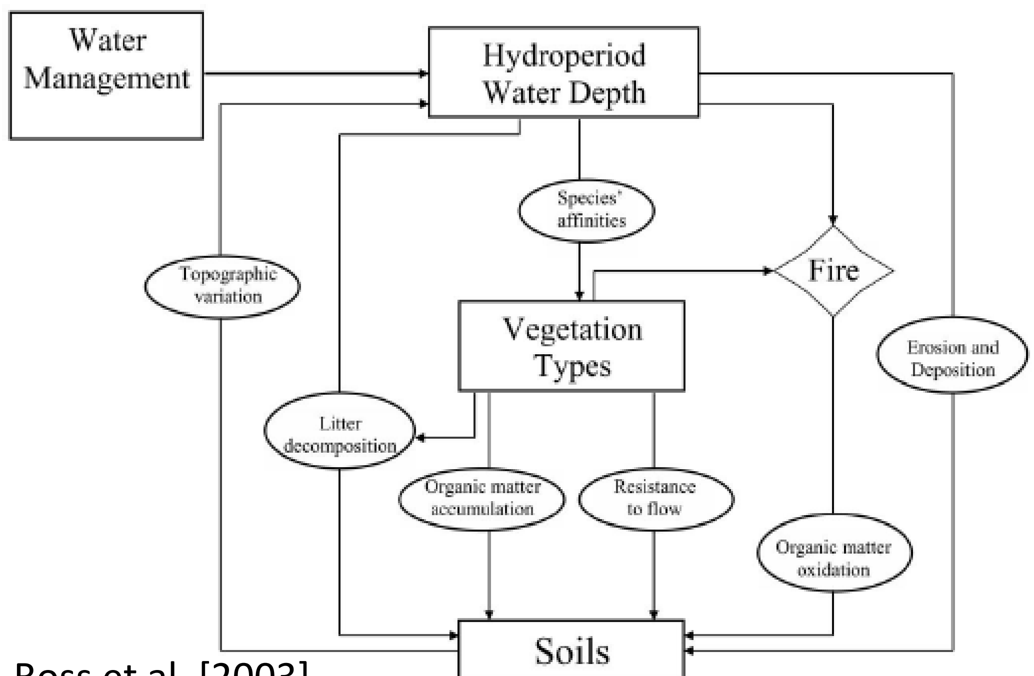
Ordering Indirect Effects



Local Examples



Davis et al. [2005]



Ross et al. [2003]

Unexplained Observation:
Why are biogenic controls on landform and geochemistry so strong in S. Florida?

- Autogenic feedbacks between water levels and plant communities create bi-modal (tri-modal) patterns in the ridge-slough (tree-island) (Larsen et al. 2007, Givnish et al. 2007)

- Autogenic feedbacks between P and calcite create regime shifts in periphyton communities (Dong et al. 2002), modulated by CO_2 production and diffusion (Browder et al. 1994)

- Autogenic feedbacks between organic acidity production and calcite dissolution create strands and cypress domes (Spangler)

0^{th} Order Effects: Flows and Loads
[Direct effects]

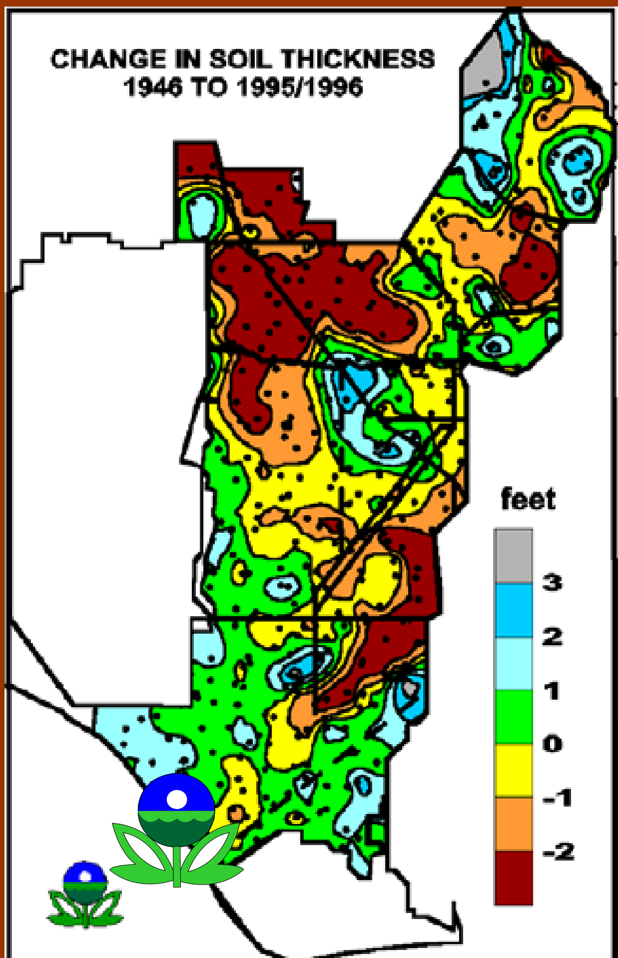
- Discharge is a power law function of water level
- Concentrations appear to be nominally independent of water level
- Fluxes scale with hydrologic change

1st Order Indirect Effects

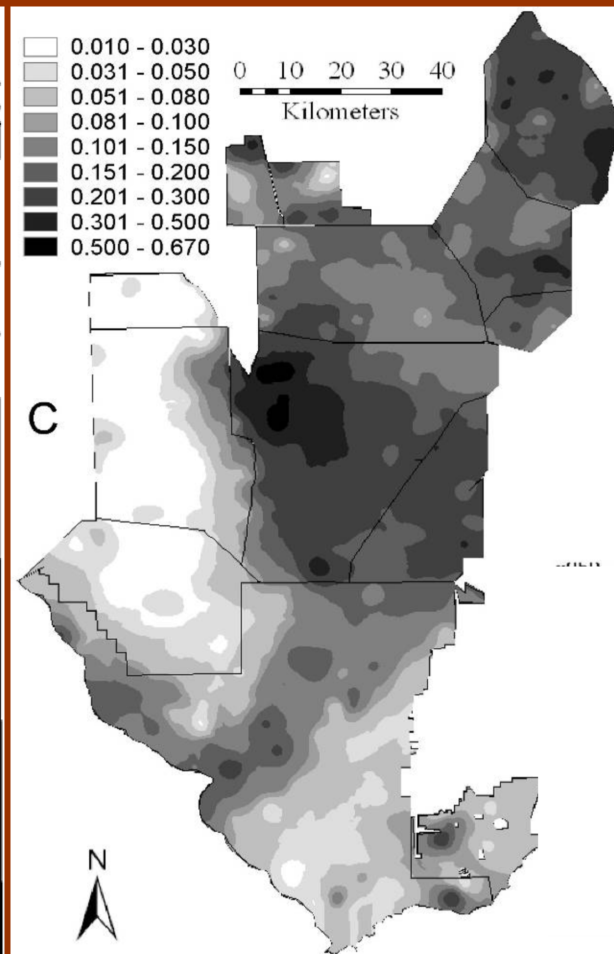
- Reduced/extended inundation affects peatland accretion vs. oxidation dynamics
- Reduced freshwater discharge alters coastal salinity gradients
- Decreased flow velocity changes particle entrainment and deposition

Total Mercury and Soil Oxidation

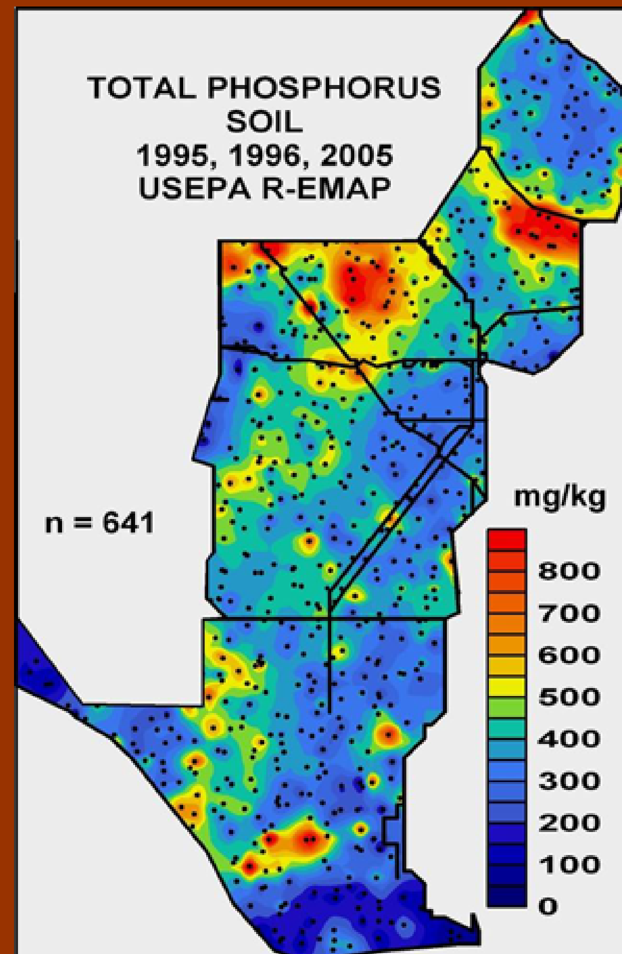
- Mechanism: Peat oxidation mineralizes trace metals (and nutrients) that elevate environmental concentrations.



Stober et al. [2001]



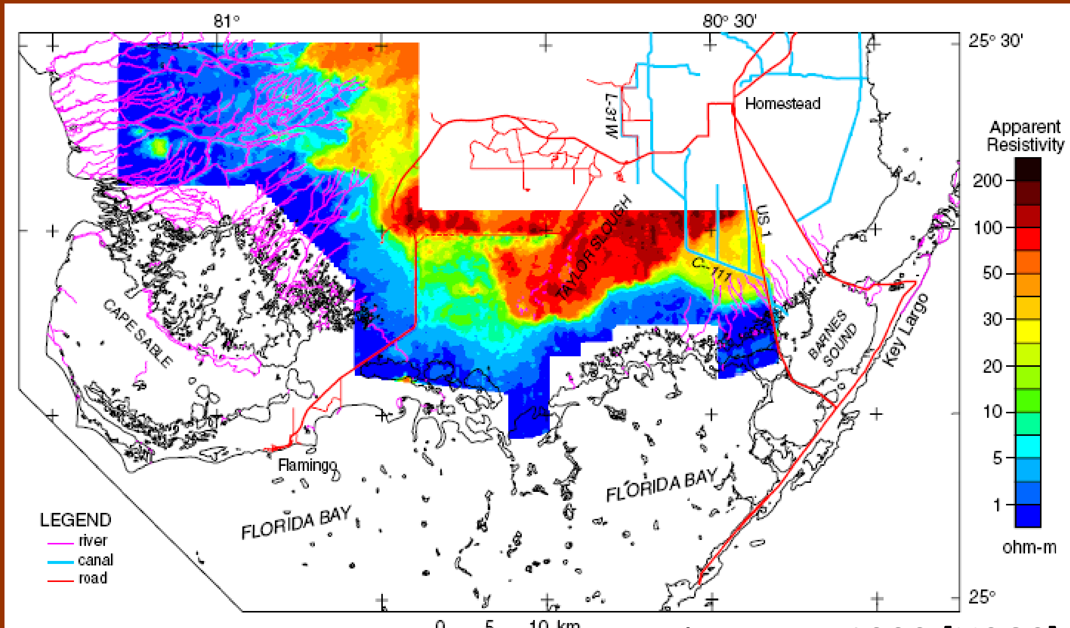
Cohen et al. [in review]



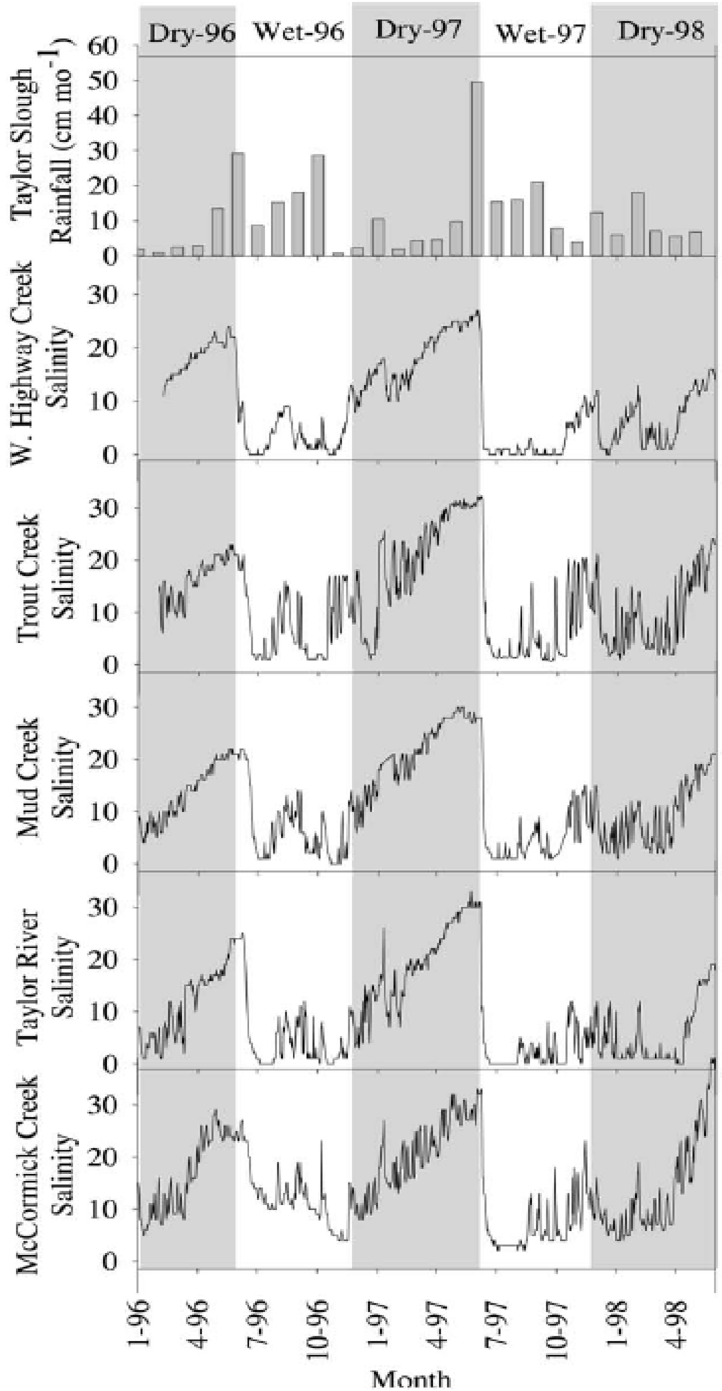
Scheidt & Kalla [2007]

Flow, Salinity Gradients and Water Chemistry

- Clear effects of changes in flow on salinity at creek mouths
- Mangrove encroachment up tidally influence channels suggests combined effects of sea level rise and reduced freshwater flow; Increased incidence of marine mollusks in soils (Ross et al. 2000)
- Advection of P-rich GoM water into Florida Bay (and southern Everglades) (Sutula et al. 2003)

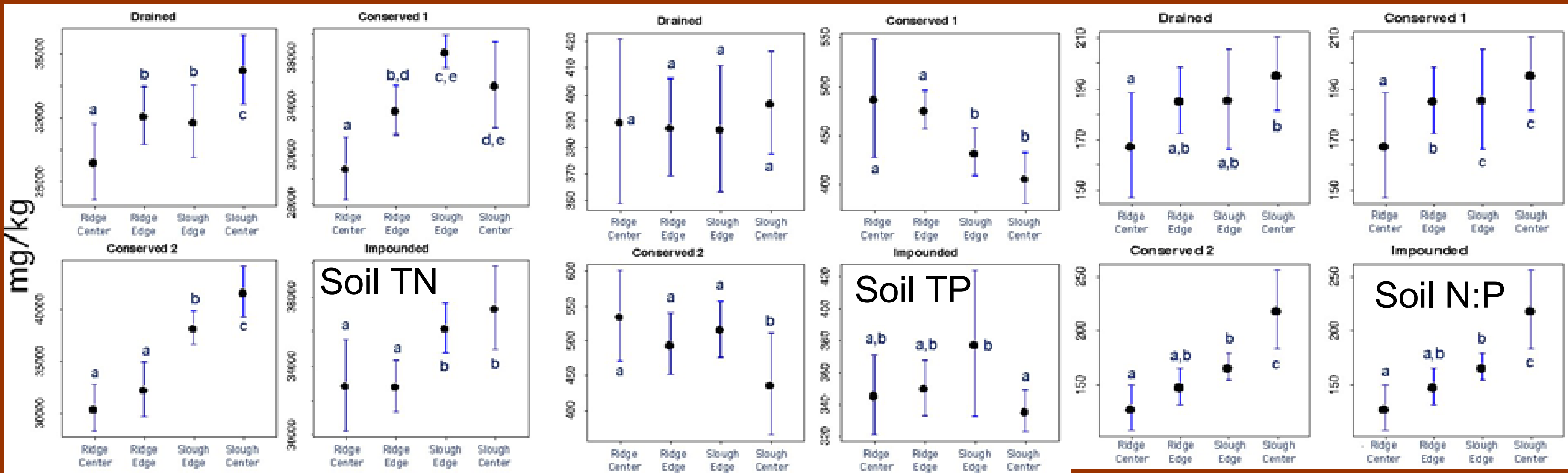


Fitterman 1999 [USGS]

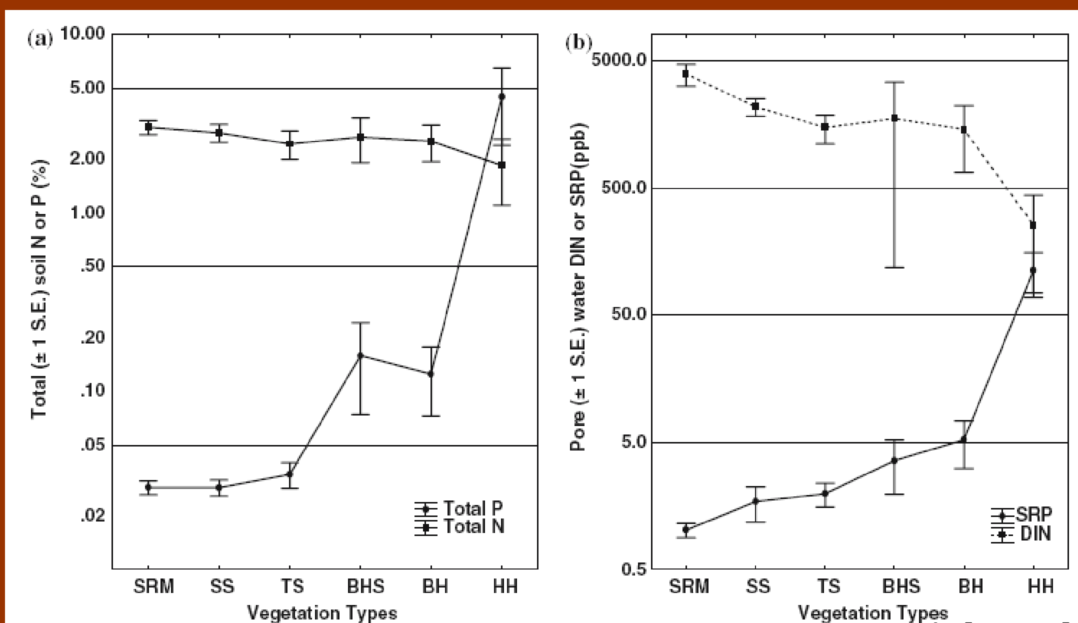


Sutula et al. [2003]

Hydrologically Induced Nutrient Gradients



D. Watts [unpublished data]

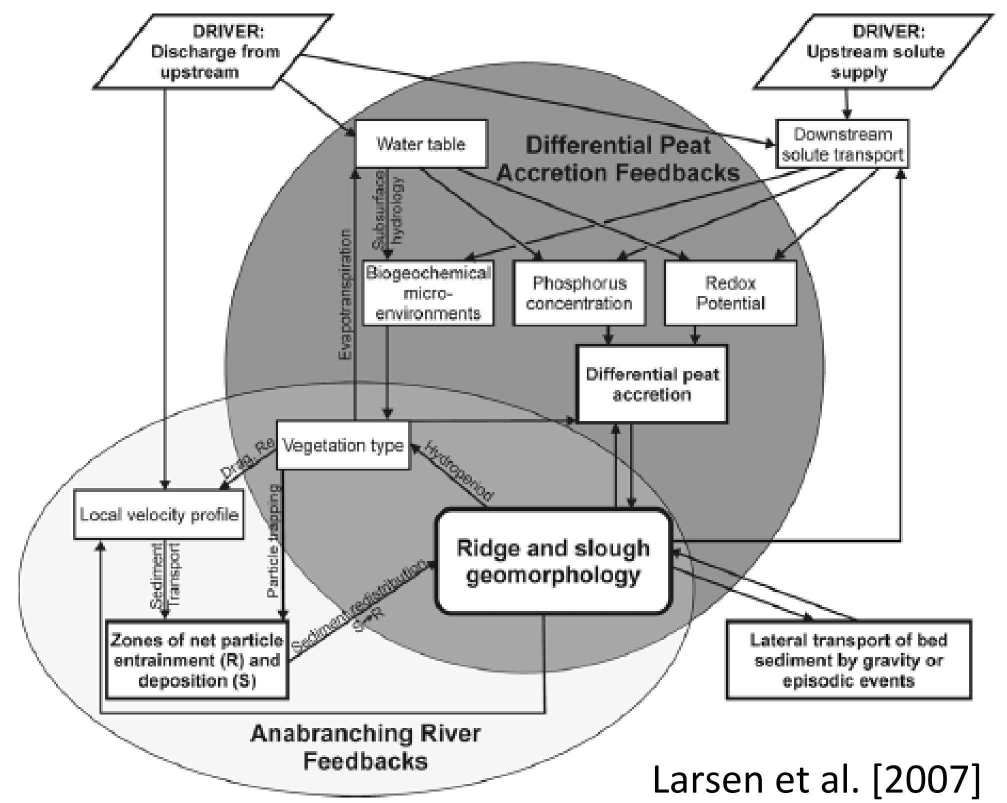


Ross et al. [2006]

- Ridges have higher N and P per mass than sloughs in hydrologically "conserved" areas
  - Stoichiometry is strongly different
- Pattern declines with hydrologic impairment
- Pattern is more pronounced (for soil and porewater) when tree islands are included
- Mechanisms?
  - 1st Order? 2nd Order? 3rd Order?

Velocity, Entrainment, Deposition

- One proposed mechanism for creation and maintenance of patterned landscape
  - Local hydraulic velocities are controlled by large-scale flows and local-scale vegetation (Leonard et al. 2006, but see Jorczak 2006)
    - Ridges ~ 0.3 cm/s
    - Sloughs ~ 0.5 cm/s
  - Entrainment and deposition may vary with community (drag coefficients) which shift regimes with hydroperiod
  - Changes in entrainment & deposition and hydroperiod induce large scale feedbacks to solute transport (e.g., oxygen, SRP)



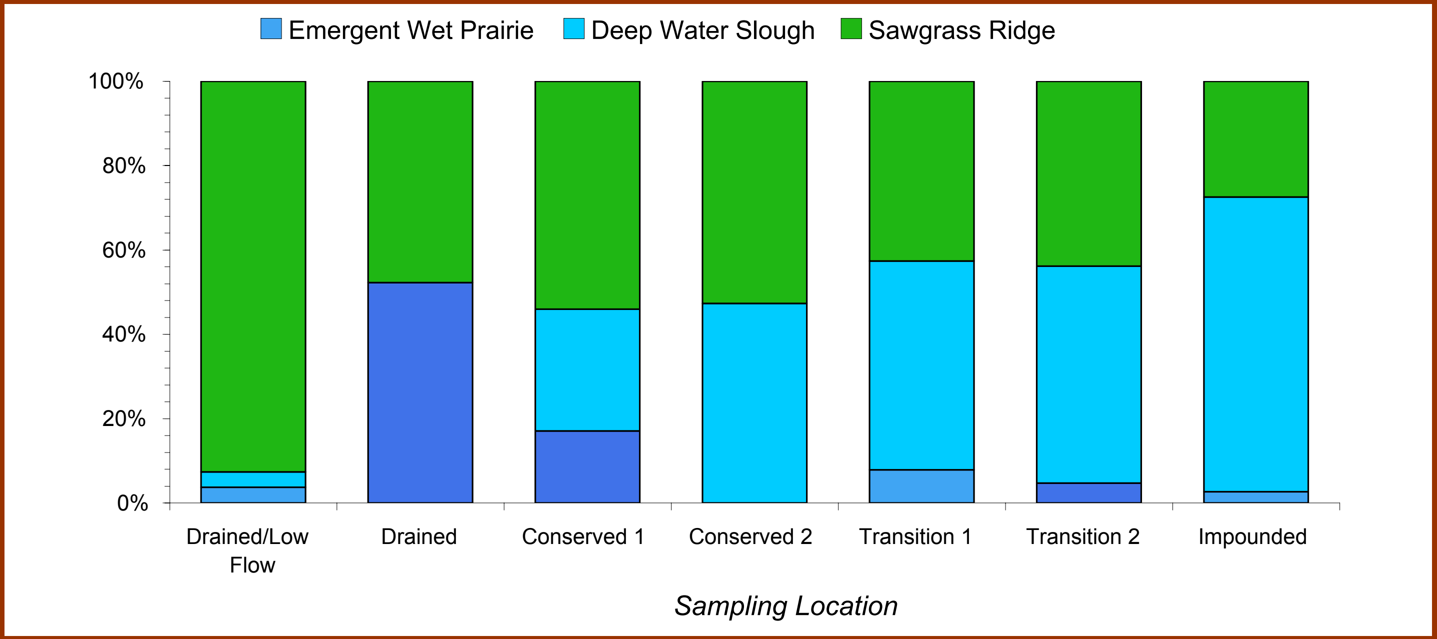
Larsen et al. [2007]

2^{nd} Order Indirect Effects

- Hydrology → Community Composition → Water Chemistry
- Hydrology → Community Composition → Soil Element Budgets
- Hydrology → Peat Fire Frequency → Water Chemistry

Hydrologic Change and Community Composition

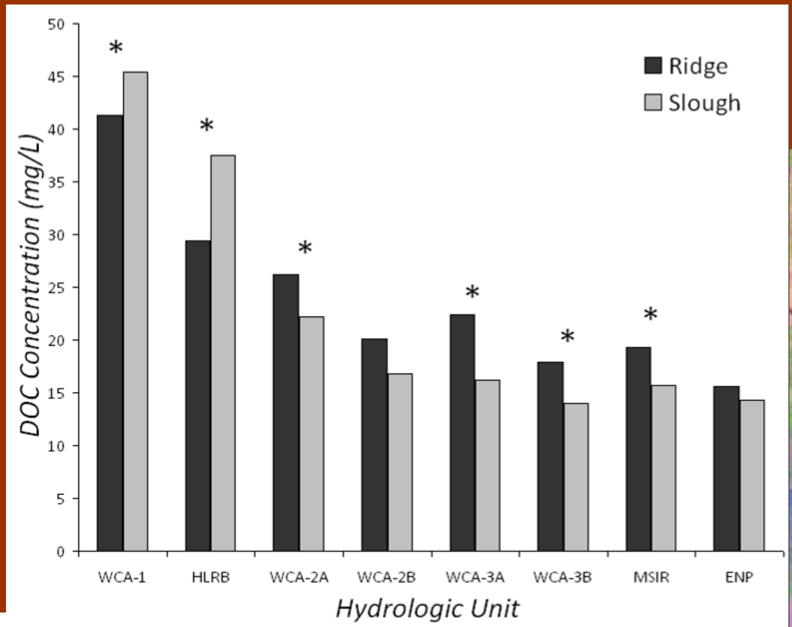
- Hydrologic gradient from north of Alligator Alley (WCA3AN - dry) to Tamiami Trail (WCA3AS - wet)
  - Changes in prevalence of ridge, slough and wet prairie
  - Loss of landscape morphology (leading vegetation change)



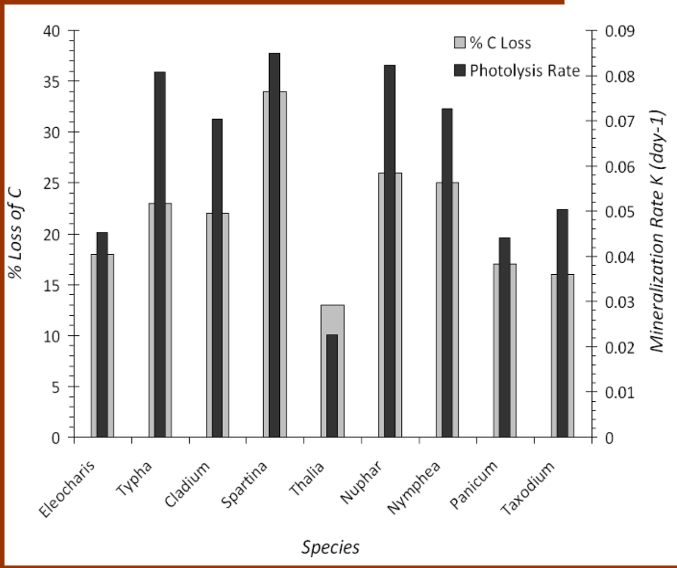
D. Watts [unpublished data]

Community Controls on Photolysis: Implications of Landscape Leveling

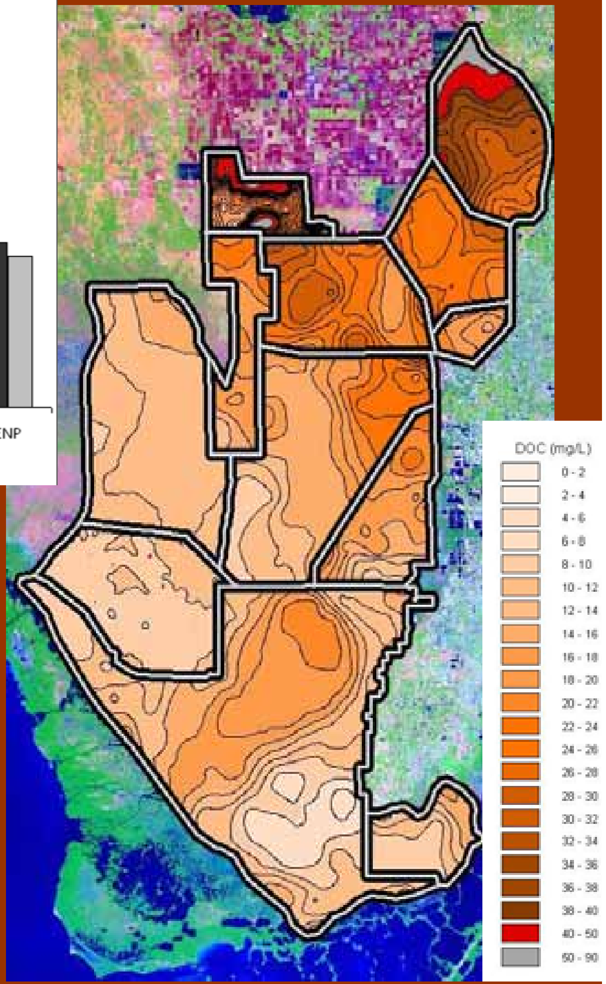
- Photolysis (abiotic DOC loss) is a C sink
  - –Photolysis rate is species specific
  - –Photon flux is community specific
  - –DOC conc. is community sensitive



Osborne et al. [in preparation]

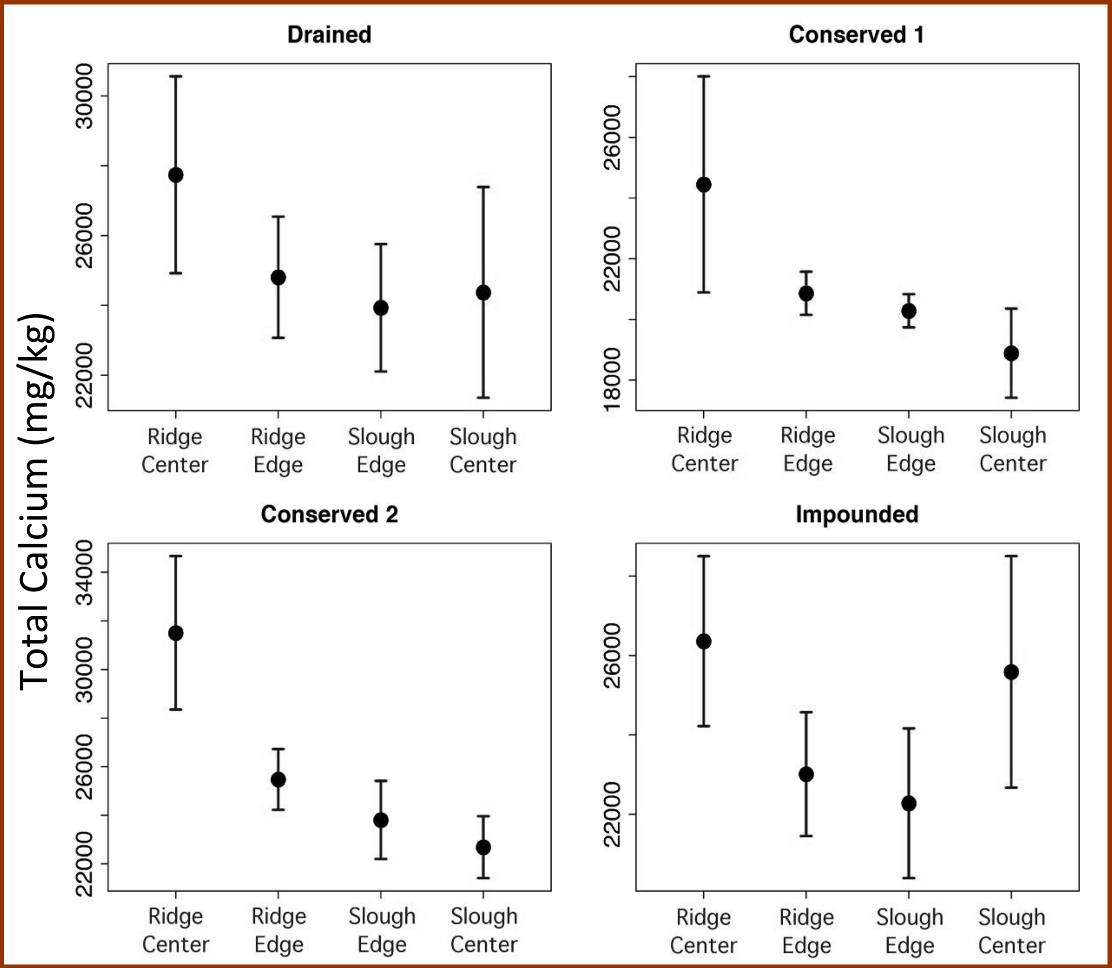


Osborne and Reddy [in preparation]



Ridge-Slough Corollary: Changes in Landscape Calcium Budgets

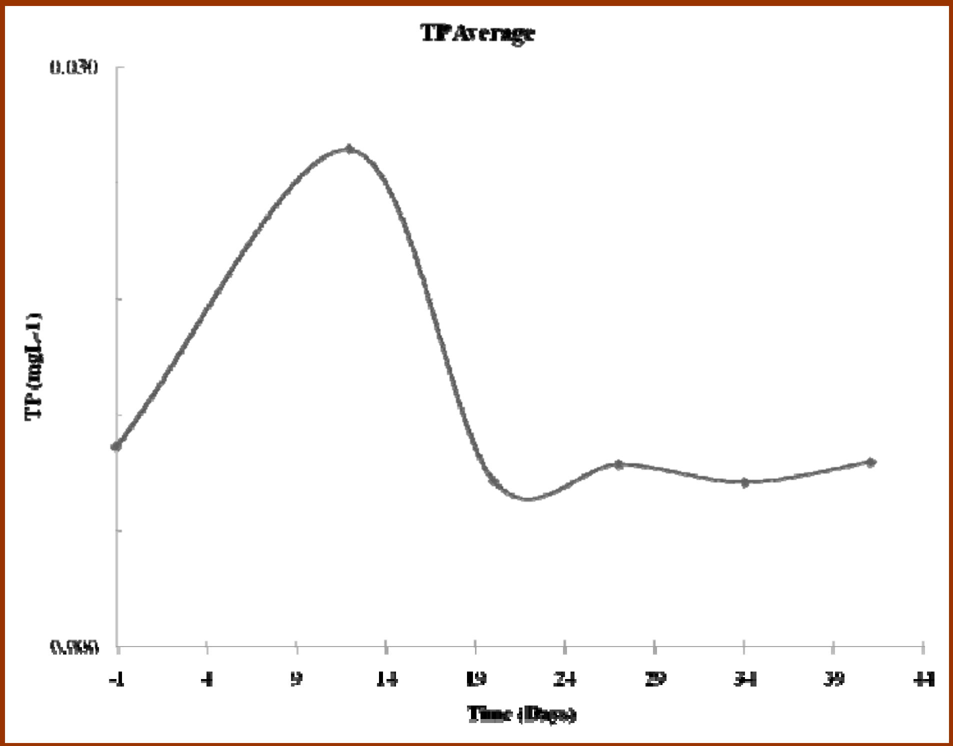
- Conserved RS landscape maintains strong (and largely unexpected) Ca gradients from ridges to sloughs
- Hydrologic change appears to erode this gradient
  - Effects on pH?

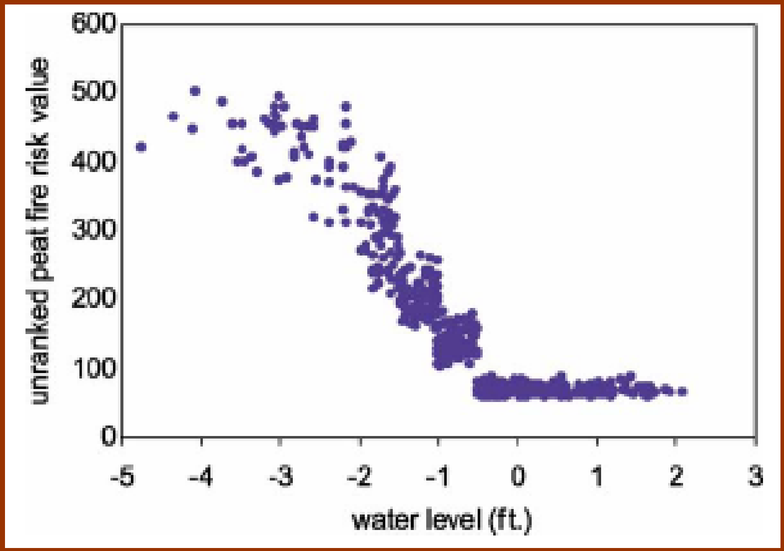


D. Watts [unpublished data]

Drying, Fire Frequency and Nutrient/Metal Mineralization

- Rotenberger Fire in 2006 (Zamorano et al. 2008)
  - Surface fires increased mineral P fraction (28 → 65%)
  - Peat fire raised mineral P fraction more (28 → 87%)

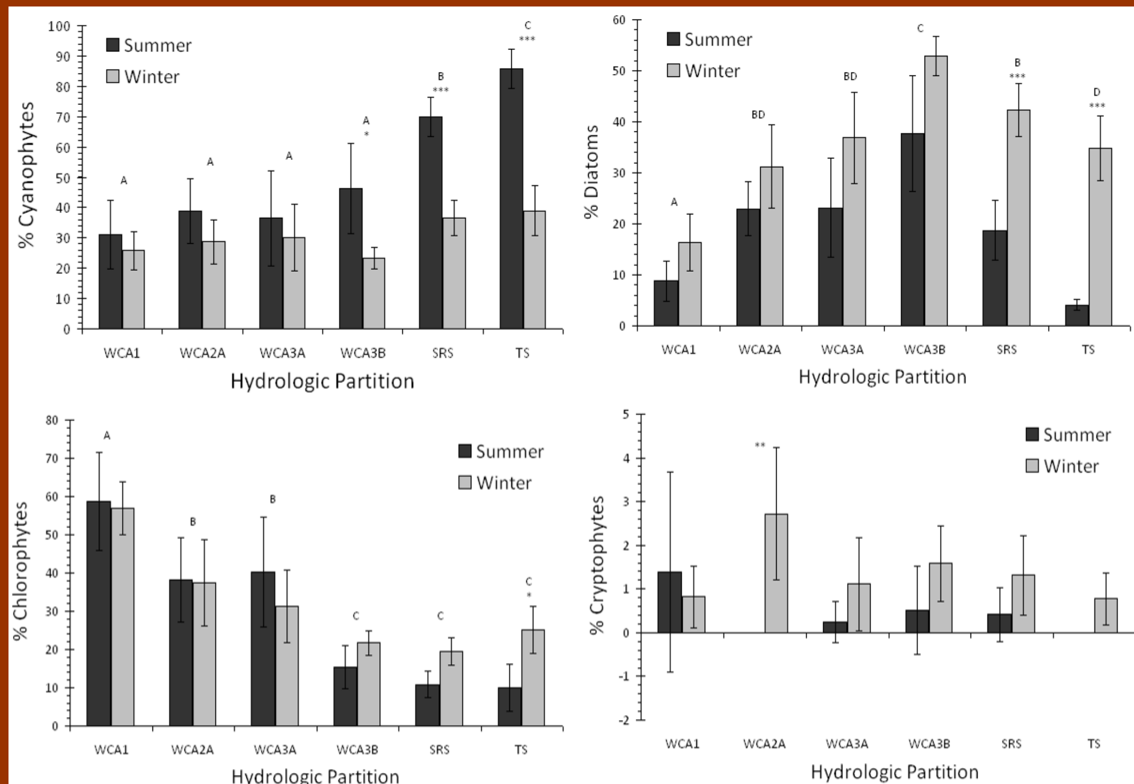




Smith et al. 2003 [JEM]

Emergent Vegetation Success and Periphyton

- Thomas et al. (2006) document effects of shade on periphyton production
  - Loss of diel DO production
  - Loss of calcite
- McCormick et al. (1998) and Cohen and Lamsal (unpublished) showed strong seasonal component to algal composition
  - Wetter periods dominated by cyanophytes
  - Implications for N fixation? (Inglett et al. 2004) P dynamics? (McCormick et al. 1996)



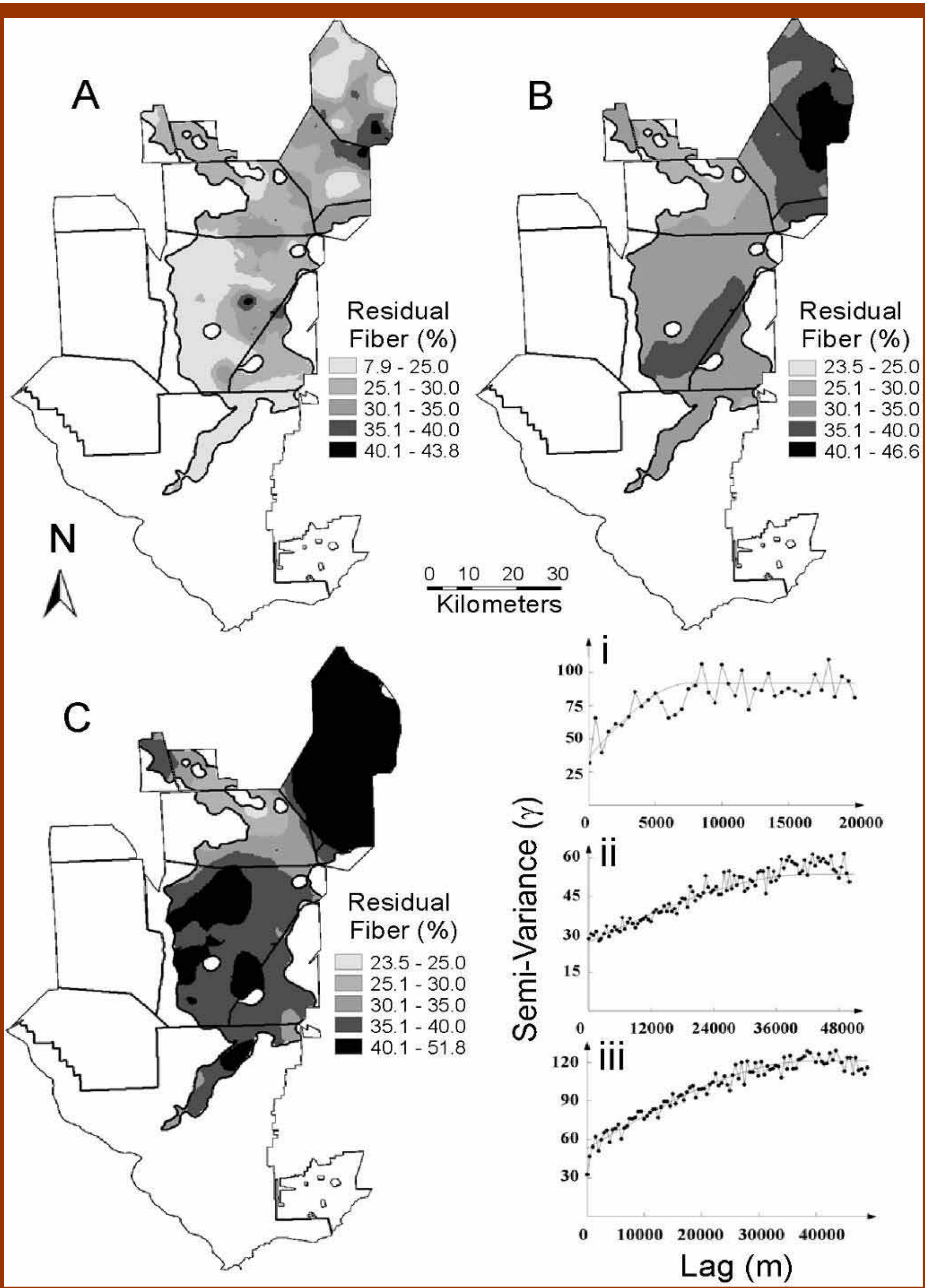
Cohen and Lamsal 2008 [SFWMD]

To 3rd Order Indirect Effects and Beyond…

- Hydrology → Community Composition → OM Quality → Water Chemistry/Hydrology
- Hydrology → Predator dispersal → Nesting success → Nutrient subsidies
- Hydrology → Algal Species → Calcite encrustation → P chemistry

Inundation and Peat Quality

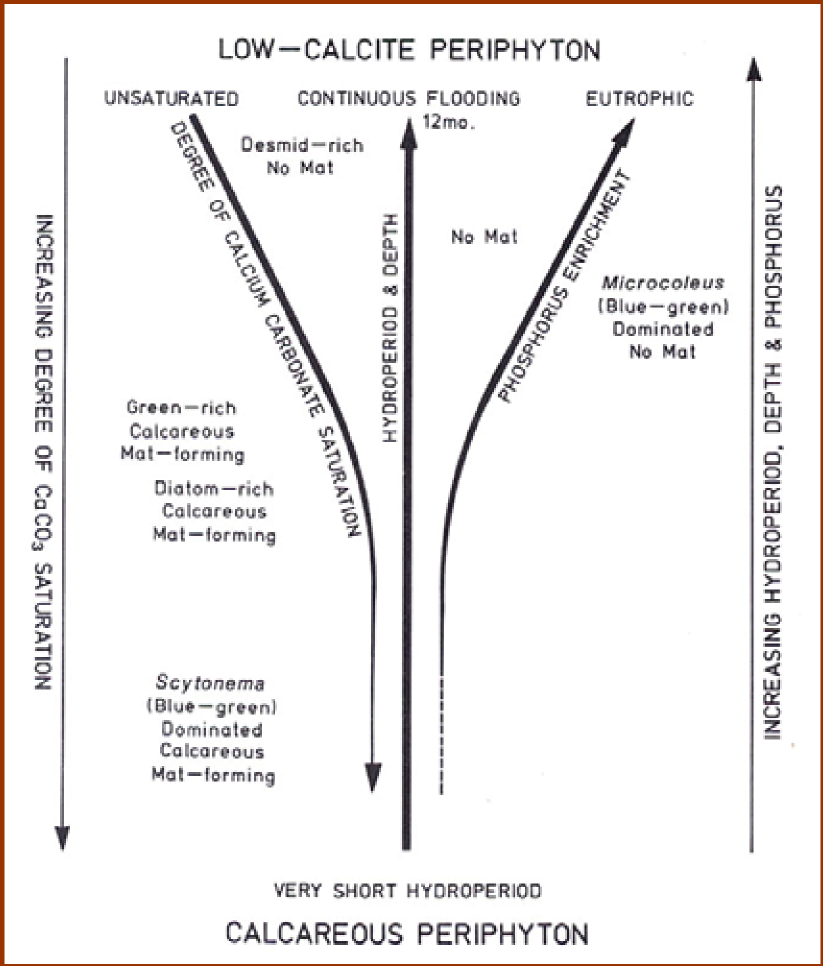
- Hydrology induces community shifts
- Community changes in peat stoichiometry
  - $C:N_{ridges}$ ~ 18:1
  - $C:N_{sloughs}$ ~ 13:1
- Peat quality affects mineralization dynamics which can affect both water chemistry AND hydrology (biogeomorphology)



Cohen et al. in review [SSSAJ]

Periphyton – A Keystone in Higher Order Indirect Effects

- Clear nutrient effects
  - Community composition shifts away from calcite encrusting mats towards desmid rich communities which do not form mats
- Evidence of hydrologic effects:
  - Depth matters (calcareous periphyton absent above ~ 60 cm depth)
    - pCO_2 α $CaCO_3$ conc. needed for encrusting
    - pCO_2 increases with depth due to diffusion constraints (deep water)
  - Duration matters (calcareous periphyton found in short hydroperiod marshes)
    - pCO_2 decreases when decomposition occurs in air (short hydroperiod)
- Reciprocal relationships?
  - Does hydrologic change reduce P binding locally (is that P refractory)? Changes in dissolved oxygen? Altered incidence of undersaturated water?

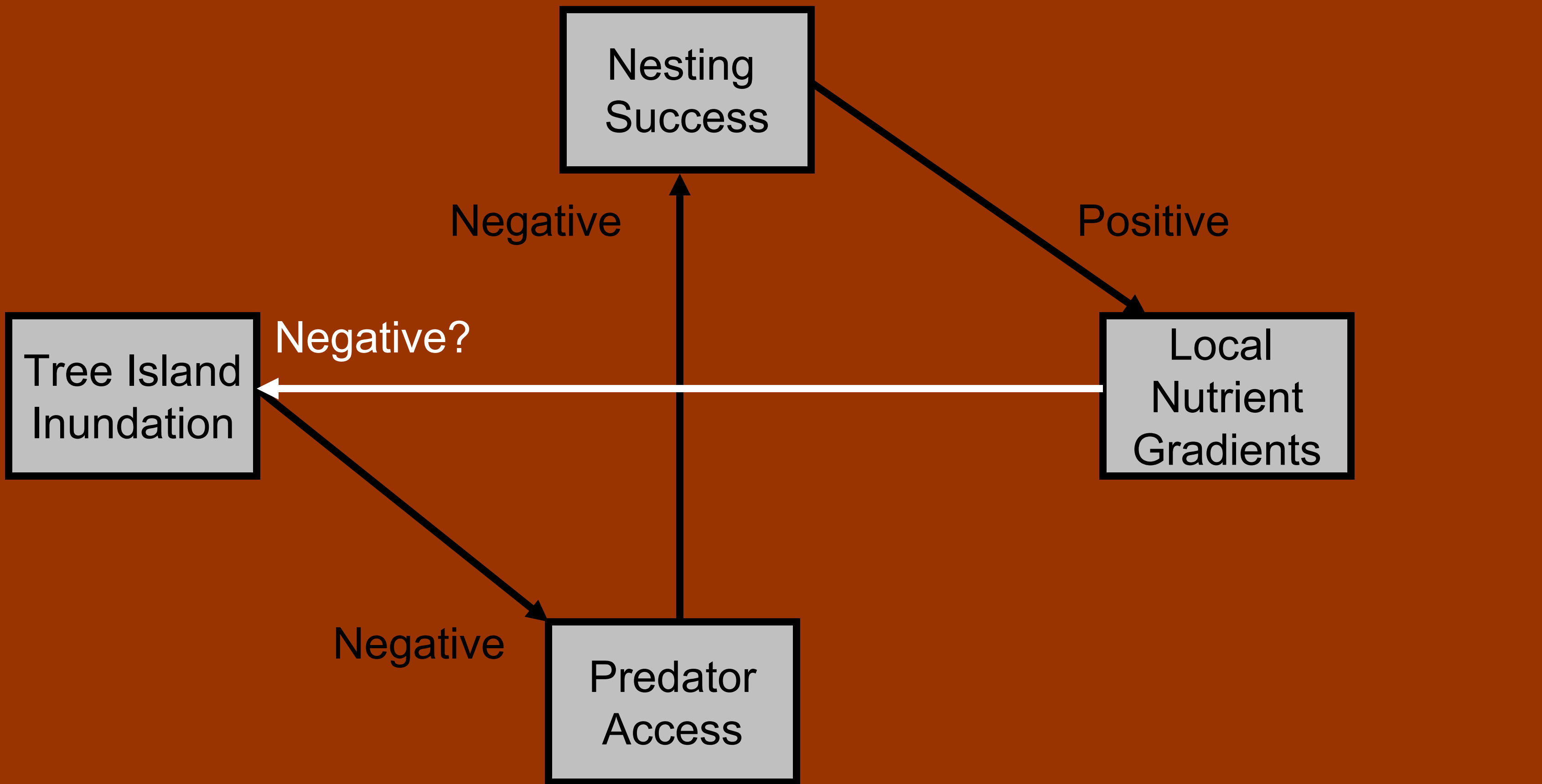


Browder et al. 1994 [in Davis and Ogden]

Water Levels, Predator Occupancy and P Subsidies from Tree Islands

- Water level controls terrestrial predator access *[Frederick and Collopy 1989]*
  - 5-10 cm of inundation limits terrestrial predator access to tree islands
- Terrestrial predators control nesting site selection *[Frederick and Collopy 1989]*
  - 69% of nest failures due to predation by terrestrial predators (snakes, raccoons, foxes, rats)
- Birds concentrate P (and N) *[Frederick and Powell 1994]*
  - Historical P loading at nesting sites was 120 g $P/m^2/yr$ (3000 times atmospheric deposition)
  - Contemporary populations yield less (0.9 g $P/m^2/yr$)
  - Legacy effects?
- Tree Islands are epicenters of local autogenic P enrichment gradients *[Givnish et al. 2007]*

Influence Diagram Version



Summary

- The South Florida ecosystem exhibits myriad ways in which biota intercede to exert reciprocal control on water quality (and indeed hydrology)
  - Water quantity links to water quality are above 0^{th} Order
- Interpretation of any given water or soil quality observation needs to account for local and regional patterns
  - Selection from amongst a multitude of potential mechanisms
  - Evidence is clear in some cases, speculative in others
- Note: Reverse effects (water quality effects on hydrology) are also noted
  - Nutrient enrichment alters peat accretion rates, which alters flow and inundation regimes [Reddy and DeBusk 1993]
  - Nutrient enrichment impacts peat pop-up probability, affecting local hydrologic gradients

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Questions?
Pet indirect effects?
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