Interactions of biological and hydrogeochemical processes facilitate phosphorus dynamics in an Everglades tree island

Tiffany Troxler¹, Carlos Coronado-Molina², Damon Rondeau³, Steve Krupa², Fred Sklar², Paul Wetzel⁴

¹Southeastern Environmental Research Center, Florida International University, Miami, FL; ²South Florida Water Management District, West Palm Beach, FL; ³Everglades National Park, Homestead, FL; ⁴Smith College, Northhampton, MA
The importance of higher plants and patch ecosystems in landscape nutrient distribution

- Alter the distribution of nutrients in soils via leaching, dissolution and interception of atmospheric deposition.


- Evident when tree patches are associated with the localization of nutrients (Barrett and Burke 2000, Wetzel et al. 2005, 2009).

- Facilitation effect is thought to promote the resilience of those patches and ecological landscape (Rietkirk et al. 2004, van Nes and Scheffer 2005).

- Poses opportunities for effective decision-making where environmental management may depend on the integrity of patch ecosystem dynamics i.e. Everglades tree islands.
Fixed tree islands in deep slough intercept P through mechanisms that accumulate P in upstream plant communities and transport P to downstream plant communities where P is efficiently recycled and retained (van der Valk and Sklar, 2002 and Wetzel et al. 2005).
Nutrient accumulation hypothesis has developed to incorporate the role of transpiration by trees in phosphorus dynamics.

An important issue for Everglades restoration

• The SFWMD, the US ACE and the CERP have identified the need to better understand the ecological and biological benefits of tree islands in the Everglades - one of the most visible indicators of the health of the Greater Everglades Landscape.

• Changes in regional hydrology that can affect the vegetation and soils of tree islands may also have serious consequences for other components of the greater Everglades ecosystem (i.e. release of P to marshes, degraded habitat for bird nesting).

• To address these restoration priorities, we investigated how biogeochemical pattern and processes operating at multiple temporal and spatial scales may influence tree island growth and patch maintenance focusing on the interaction of biological, geochemical, and regional hydrologic factors.
Spatial and temporal variability in hydrology and water quality of tree island 3AS3

• Previous research associated high soil P concentrations of dry head with high concentrations of ions, esp. Na and Cl.

• We hypothesized that water movement, mediated by hydraulic processes that were punctuated by increased tree island evapotranspiration (ET) in the dry season, influenced the precipitation of P and lateral flux of nutrients to downstream components of the tree island ecosystem.

• Our objectives were to:
  1) characterize spatial and temporal variability in diurnal ET patterns,
  2) characterize temporal local and regional hydraulic patterns, and
  3) characterize spatial and temporal hydrochemical patterns in ions (Na, Cl, Mg, K, etc.) and nutrients among four tree island plant communities and the adjacent deep water slough.
- In a region considered to resemble intact ridge-slough landscape features
- Tear-drop shape with four distinct plant communities
Tree Island 3AS3 Bulk Soil N and P Concentrations
Spatial and Temporal Variability of Phosphorus in Soil Water of 3AS3 Wet Head

Leads to large infiltration fluxes (SRP export) and net ecosystem export of $1.29 \pm 1.35 \text{ g P m}^{-2} \text{ yr}^{-1}$ from Wet Head

Whereas, ecosystem P budget of Near Tail is fairly balanced (i.e. $I=O$; import: $0.05 \pm 0.19 \text{ g P m}^{-2} \text{ yr}^{-1}$)
Potential evapotranspiration, Water Level & Soil Elevation in Tree Island 3AS3

ET potential

Wet Head (ft.)

HH soil elevation

Lowest soil elevation (WH)

Dark circles show sampling events
I. Diurnal hydraulic patterns – low water, dry down period, low precip, high ET

Early dry season (April 21-27, 2008) hydraulic head levels at 15 min. intervals in central dry head (X12D) and wet head (N3D) locations at 60cm depth.
I. Diurnal hydraulic patterns – high water, rising water table, high precip, high ET

Early wet season (September 11-17, 2008) hydraulic head levels at 15 min. intervals in central dry head and wet head locations at 60cm depth.
I. Diurnal hydraulic patterns – moderate water table, dry down with precipitation event, low ET

Late wet season (December 8-13, 2008) hydraulic head levels at 15 min. intervals in central dry head and wet head locations at 60cm depth.
The physiological influence of tree island plants & plant communities on local and regional hydrology

Maximum daily transpiration rate coincides with greatest hydraulic head drawdown at 0.6m depth but also evidence for influence at 2.8 and 8.4m depths

Wetzel, Sklar, Coronado, Troxler, Krupa, Ewe et al. In review. Critical Reviews in Environment and Technology.
II. Local hydraulic patterns – potentiometric surface at 30cm (shallow) depth

Hydraulic head levels (mm) in February 2008. Axes plot locations are in UTM. Dashed line is tree island boundary showing High Head, Wet Head and Near Tail.

February 2008

August 2008
III. Local Hydrochemical Patterns (shallow) – TDP

Total dissolved phosphorus (TDP) at 30cm depth. Axes plot locations are in UTM. Dashed line is tree island boundary showing High Head, Wet Head and Near Tail.

AUGUST 2007 - TDP (umol L⁻¹)
20 30 cm depth

FEBRUARY 2008 - TDP (umol L⁻¹)
20 30 cm depth
III. Local Hydrochemical Patterns (shallow) – TDP

Total dissolved phosphorus (TDP) at 30cm depth. Axes plot locations are in UTM. Dashed line is tree island boundary showing High Head, Wet Head and Near Tail.

AUGUST 2008 - TDP (umol L⁻¹)  
20 - 30 cm depth

FEBRUARY 2009 - TDP (umol L⁻¹)  
20 - 30 cm depth

Only sampling where water was present at 30cm in HH
III. Local Hydrochemical Patterns – Na.

Sodium (Na) concentrations in August 2008. Axes plot locations are in UTM. Dashed line is tree island boundary showing High Head, Wet Head and Near Tail.
### IV. Average Local and Regional Hydrochemical Patterns

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Na (meqL⁻¹)</th>
<th>Sp Cond (uS/cm)</th>
<th>TDP (μmol L⁻¹)</th>
<th>Na (meqL⁻¹)</th>
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**Legend:**
- **Dry Head**
- **Wet Head**
- **Near Tail**
- **Far Tail**
IV. Average Local and Regional Hydrochemical Patterns

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Dry Head</th>
<th>pH</th>
<th>TDP (μmol L⁻¹)</th>
<th>Wet Head</th>
<th>pH</th>
<th>TDP (μmol L⁻¹)</th>
<th>Near Tail</th>
<th>pH</th>
<th>TDP (μmol L⁻¹)</th>
<th>Far Tail</th>
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S=supersaturated, A=approximately saturated, and U=undersaturated with respect to calcite
Model for biological and hydrochemical interactions in P cycling

1) Evapotranspiration & mineral precipitation/dissolution
2) TDP lateral transport
3) TDP lateral transport, infiltration & precipitation
4) Plant uptake, peat deposition, leaching and transport

Regional hydrology influences the rate of ET & concentration level of phosphorus
Conclusions

• Mineral precipitation contributes to tree island stability – trees (esp. *C. icaco*) influence this process via exclusion of Na & biogenic mineral saturation

• Precipitation/dissolution reactions likely contribute to TDP lateral transport (but on short time scale) – do extreme dry downs/pH gradients enhance P dissolution & transport?

Future Directions

• Continuous conductivity measurements to capture potential for dissolution
• Carbonate rock dissolution experiments to assess potential for P release
• Completed installation of similar piezometer network in a “Ghost” tree island – little carbonate rock/soils present
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