Predicting the Impacts of Saltwater Intrusion on Ecosystem Dynamics in Tidal Freshwater Floodplain Forests in Coastal Georgia

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Outline

• Overview of *tidal* freshwater floodplain *forests* and global change

• Changes in cycling of:
  • Carbon (C) & Sulfur (S)
  • Nitrogen (N)
  • Phosphorus (P)

• Scaling up using SLAMM

• Discussion & Conclusions

• Unknowns and future work
Tidal Forests

• Tidal pulsing with freshwater
• Storm surge abatement and water storage
• Habitat and biodiversity
• C sequestration in woody biomass and soils
• Water quality amelioration
• GHG production: CO$_2$, CH$_4$ & N$_2$O
Tidal Forests and Global Change

• SLR results in increased inundation rates

• Saltwater intrusion results from combination of:
  • Altered precipitation regimes
  • Anthropogenic alteration of freshwater flow
  • SLR
Global Change: Consequences

• Increased inundation rates = increased duration of anaerobic conditions

• Increased salinity
  • Introduce sulfate (SO$_4^{2-}$) ion
    • Methanogenesis $\rightarrow$ sulfate reduction
    • Accelerate decomposition $\rightarrow$ subsidence?
  • Release P

• Change ionic strength
SE US Coast

Study Area

- S. Newport
- Altamaha River
- Sapelo Is.
Objectives:

- How do salinity and hydrology impact the decomposition of the roots of bald cypress (*Taxodium distichum*)?

Methods:

Healthy tidal forest    Saltwater intrusion    Brackish marsh
% Mass Remaining vs. Time (d) for different conditions:
- TFF Levee
- TFF Plain
- SN Levee
- SN Plain
- BR Levee
- BR Plain
C & S Cycling: Saltwater and GHGs

Objectives

• How does simulated saltwater intrusion impact:
  – Greenhouse gas production?
  – Sulfur cycling?
  – Denitrification?

Methods:

• Altamaha, Satilla, and Ogeechee Rivers
• Anaerobic bottle incubations at salinity of 0, 2, 5
  • Acetylene block for denitrification
• Extract acid volatile and chromium reducible sulfur

Marton et al. (2012) *Wetlands*
Evidence of Increased S Reduction

- Total reduced inorganic S increased in Altamaha and Ogeechee with salinity, indicating increased sulfate reduction.
- Ogeechee had much higher initial S in soil and water.
CO₂ Production from Sulfate Reduction

- Sulfate reduction greater than 100% of CO₂ production?
Ambient $N_2O$ Production

- Altamaha
- Ogeechee
- Satilla

$\text{ng N}_2\text{O} / g \text{ soil} / hr$

A

B

B

0 ppt

2 ppt

5 ppt
Ambient Denitrification

- **Altamaha**
- **Ogeechee**
- **Satilla**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Altamaha</th>
<th>Ogeechee</th>
<th>Satilla</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ppt</td>
<td>0.00</td>
<td>0.10</td>
<td>0.20</td>
</tr>
<tr>
<td>2 ppt</td>
<td>0.30</td>
<td>0.20</td>
<td>0.40</td>
</tr>
<tr>
<td>5 ppt</td>
<td>0.30</td>
<td>0.40</td>
<td>0.30</td>
</tr>
</tbody>
</table>

The graph shows the concentration of N$_2$O in ng/g soil/hr across different conditions and locations.
**Objectives:**

- Are tidal forest soils sources or sinks for inorganic N&P?
- How do increased salinity and inundation impact this?

**Methods:**

**Sorption/Desorption:**
- Altamaha, Ogeechee, Satilla, S. Newport
- 5 tidal cycles
- $\Delta [NH_4-N] \& [PO_4-P]$ 

**Salinity and Inundation:**
- Salinity (0, 2, 5) * Inundation (5, 10 cm)

Jun et al. (2012) *Estuaries & Coasts*
\textbf{NH}_4^-\text{-N Sorption/Desorption}

- Sinks for \text{PO}_4^{3-} \& \text{NH}_4^+

\textbf{PO}_4^-\text{P Sorption}

- Saltwater intrusion release large amounts of \text{NH}_4^+.
Altamaha River

**NH₄⁻N Sorption/Desorption**

- NH₄⁺ release increases with increasing salinity.

**PO₄⁻⁻⁻ P Sorption**

- PO₄⁻⁻⁻ sorption increases with salinity & decreases with inundation.
Scaling Up: SLAMMM

Objectives:

• Quantify wetland habitat changes on Altamaha River due to SLR

Methods:

• Sea Level Affects Marshes Model (SLAMM) 6.1
• Parameterization of the salinity sub-model
• LiDAR (2007)
• Bathymetry (from 2006)
• National Wetland Inventory (2007)
• Variable accretion rate using MEM 3.4 (Morris et al. 2002)
Salinity at MHHW

Initial Condition

2100; 1m SLR
Habitat Distribution

Initial Condition

Habitat Distribution

2100; 1m SLR
Conclusions

• Saltwater intrusion promotes N and C release
  • CH$_4$ ↓
  • Sulfate reduction ↑

• Denitrification and N$_2$O production are unclear.

• P sorption: ↑ salinity; ↓ inundation

• Up-stream/inland migration of tidal forests

From the bottle to landscape…..
Unkowns and Future Work

- Spatial Variability
- Ecosystem migration (Ability? Timing?)
- Subsidence?
- Vegetation:
  - Productivity
  - Species composition

\[
\downarrow \text{Productivity} + \Delta \text{Community} \quad \rightarrow \quad \downarrow \text{C Quantity} + \uparrow \text{C min}
\]

- Interactions with other global change factors
- Out of the bottle…
How does saltwater intrusion alter C cycling in intact plant soil systems?

**Pulse-Chase: $^{13}\text{CO}_2$**

Insight into...

- Assimilation
- Short-term plant-soil flux
- C quality/quantity controls on mineralization pathway
- Microbial players?

...with minimal disturbance
Manipulative Field Experiment

Saltwater Addition Long Term Experiment

Georgia Coastal Ecosystems LTER Project
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