Consequences of Interspecific Variation in N and C Pools of Salt Marsh Plants

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How and why marsh plants differ in function may be most important in the context of:

1. Environmental change
   - species composition
   - alter processes
2. How we have altered the landscape
3. Why we *need* these functions!!
   - nutrient filtration
   - carbon storage
## Climate change

**Mid-Atlantic region**

Relative to 1990 levels

<table>
<thead>
<tr>
<th></th>
<th>Year</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CO₂ (%)</strong></td>
<td>2030</td>
<td>+25</td>
</tr>
<tr>
<td></td>
<td>2095</td>
<td>+92</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Houghton et al. 1996</em></td>
</tr>
<tr>
<td><strong>Sea level (cm)</strong></td>
<td>2030</td>
<td>+19</td>
</tr>
<tr>
<td></td>
<td>2095</td>
<td>+66</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Warrick et al. 1996</em></td>
</tr>
<tr>
<td><strong>Temperature (°C)</strong></td>
<td>2030</td>
<td>+1.3</td>
</tr>
<tr>
<td></td>
<td>2095</td>
<td>+4.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Polsky et al. 2000</em></td>
</tr>
<tr>
<td><strong>Precipitation (%)</strong></td>
<td>2030</td>
<td>+4</td>
</tr>
<tr>
<td></td>
<td>2095</td>
<td>+15</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Polsky et al. 2000</em></td>
</tr>
<tr>
<td><strong>Streamflow (%)</strong></td>
<td>2030</td>
<td>+2</td>
</tr>
<tr>
<td></td>
<td>2095</td>
<td>+11</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Neff et al. 2000</em></td>
</tr>
</tbody>
</table>
How climate change will affect marsh plant community structure

1. Sea-level rise
   A. Erode at the waterward boundary
   B. Drown in place and convert to open water
   C. Marshes vertically keep pace
      - Sedimentation
      - Peat formation
   D. Migrate inland as areas above the tide become inundated
      - Landward edge unhindered by hard structure
Sea level rise

Landward migration hindered by hard structures

Response:
- high marsh shrubs die first
- mid-marsh squeezed
- low marsh dominates
How climate change will affect marsh plant community structure

2. Increase in temperature
Response:
more southerly species move northward

3. Increase in CO$_2$ concentration
Response:
increase coverage of C3 species at the expense of C4 species (Drake et al. 1996)
How climate change will affect marsh plant community structure

3. Increase in precipitation and streamflow

Response:
- neutralize salinity in the high marsh
- decrease salinity levels in the high marsh
Delaware’s fringing marshes

High marsh shrubs i.e., *Baccharis halimifolia*

*Juncus roemerianus*

*Spartina patens / Distichlis spicata*

*Spartina alterniflora*
*Juncus roemerianus* - dominated southern marsh

C3 species

Grows in moderate salinities

Potential for increasing coverage in mid-Atlantic marshes
OBJECTIVES

Differences among species:
1. Potential for sediment trapping
   - Stem density
2. N & C storage
   - Seasonal pool size
   - Nitrogen translocated to belowground
   - Loss (decomposition)
   - Soil storage
Plants enable sediment trapping

- Attenuating tidal flows and wave activity
- Adherence onto plants
- Preventing resuspension of fine grained deposits (Yang et al. 2008)

Depend on:
- Distance from the marsh edge
- Stem densities
# Stem density (# stems/m²)

<table>
<thead>
<tr>
<th>Month</th>
<th>March</th>
<th>June</th>
<th>August</th>
<th>November</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Juncus roemerianus</em></td>
<td>1798 ± 421</td>
<td>3090 ± 735</td>
<td>1838 ± 203</td>
<td>2386 ± 430</td>
</tr>
<tr>
<td><em>Spartina patens</em></td>
<td>7528 ± 918</td>
<td>14000 ± 1831</td>
<td>8136 ± 881</td>
<td>8392 ± 2066</td>
</tr>
<tr>
<td><em>Spartina alterniflora</em></td>
<td>876 ± 109</td>
<td>1062 ± 217</td>
<td>1056 ± 275</td>
<td>766 ± 247</td>
</tr>
</tbody>
</table>
N and C pools in marsh plants

Biomass * N or C concentration

- seasonal
- allocation

(above- vs. belowground)
(live vs. dead)

Juncus roemerianus
Stem bases
Fine roots
Dead big OM
Baccharis halimifolia

Juncus roemerianus

Spartina patens

Spartina alterniflora

Month

March June August November

Nitrogen (g m\(^{-2}\))

Carbon (g m\(^{-2}\))

Month

March June August November

Juncus roemerianus

Spartina patens

Spartina alterniflora

Month

March June August November
Live vs. Dead N pools

Nitrogen Resorption Efficiency

% N translocated from above- to belowground

- **Baccharis halimifolia**: 41
- **Juncus roemerianus**: 24
- **Spartina patens**: 32
- **Spartina alterniflora**: 56
Live vs. Dead C pools

Aboveground

<table>
<thead>
<tr>
<th>Species</th>
<th>Live (g m⁻²)</th>
<th>Fine Roots (g m⁻²)</th>
<th>Dead (g m⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Juncus</td>
<td>500</td>
<td>1000</td>
<td>2000</td>
</tr>
<tr>
<td>S. patens</td>
<td>2000</td>
<td>1500</td>
<td>500</td>
</tr>
<tr>
<td>S. alterniflora</td>
<td>1500</td>
<td>2000</td>
<td>1000</td>
</tr>
</tbody>
</table>

Belowground

<table>
<thead>
<tr>
<th>Species</th>
<th>Live (g m⁻²)</th>
<th>Fine Roots (g m⁻²)</th>
<th>Dead (g m⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Juncus</td>
<td>500</td>
<td>1000</td>
<td>2000</td>
</tr>
<tr>
<td>S. patens</td>
<td>2000</td>
<td>1500</td>
<td>500</td>
</tr>
<tr>
<td>S. alterniflora</td>
<td>1500</td>
<td>2000</td>
<td>1000</td>
</tr>
</tbody>
</table>
# Dead N pools and losses

### Aboveground

<table>
<thead>
<tr>
<th>Specie</th>
<th>N pool (g m⁻²)</th>
<th>N pool loss (g g⁻¹ day⁻¹)</th>
<th>Turnover (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Baccharis halimifolia</em></td>
<td>0.3 ± 0.07</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td><em>Juncus roemerianus</em></td>
<td>26 ± 0.5</td>
<td>0.0030</td>
<td>333</td>
</tr>
<tr>
<td><em>Spartina patens</em></td>
<td>32 ± 0.5</td>
<td>0.0027</td>
<td>367</td>
</tr>
<tr>
<td><em>Spartina alterniflora</em></td>
<td>13 ± 0.4</td>
<td>0.0074</td>
<td>135</td>
</tr>
</tbody>
</table>

* microbial colonization

### Belowground

<table>
<thead>
<tr>
<th>Specie</th>
<th>N pool (g m⁻²)</th>
<th>N pool loss (g g⁻¹ day⁻¹)</th>
<th>Turnover (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Juncus roemerianus</em></td>
<td>5.6 ± 0.9</td>
<td>0.0029</td>
<td>350</td>
</tr>
<tr>
<td><em>Spartina patens</em></td>
<td>10.3 ± 1.1</td>
<td>0.0021</td>
<td>470</td>
</tr>
<tr>
<td><em>Spartina alterniflora</em></td>
<td>14.8 ± 1.3</td>
<td>0.0009</td>
<td>1057</td>
</tr>
</tbody>
</table>
# Dead C pools and losses

## Aboveground

<table>
<thead>
<tr>
<th>Species</th>
<th>C pool (g m(^{-2}))</th>
<th>C pool loss (g g(^{-1}) day(^{-1}))</th>
<th>Turnover (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Baccharis halimifolia</em></td>
<td>12 ± 3</td>
<td>0.0015</td>
<td>810</td>
</tr>
<tr>
<td><em>Juncus roemerianus</em></td>
<td>368 ± 7</td>
<td>0.0034</td>
<td>307</td>
</tr>
<tr>
<td><em>Spartina patens</em></td>
<td>328 ± 6</td>
<td>0.0010</td>
<td>993</td>
</tr>
<tr>
<td><em>Spartina alterniflora</em></td>
<td>144 ± 4</td>
<td>0.0076</td>
<td>131</td>
</tr>
</tbody>
</table>

## Belowground

<table>
<thead>
<tr>
<th>Species</th>
<th>C pool (g m(^{-2}))</th>
<th>C pool loss (g g(^{-1}) day(^{-1}))</th>
<th>Turnover (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Juncus roemerianus</em></td>
<td>308 ± 41</td>
<td>0.0015</td>
<td>684</td>
</tr>
<tr>
<td><em>Spartina patens</em></td>
<td>685 ± 72</td>
<td>0.0011</td>
<td>938</td>
</tr>
<tr>
<td><em>Spartina alterniflora</em></td>
<td>983 ± 66</td>
<td>0.0019</td>
<td>552</td>
</tr>
</tbody>
</table>
Soil N & C

<table>
<thead>
<tr>
<th>Species</th>
<th>Nitrogen (%)</th>
<th>Carbon (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baccharis</td>
<td>0.4</td>
<td>1.6</td>
</tr>
<tr>
<td>Juncus</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>S. patens</td>
<td>0.8</td>
<td>10</td>
</tr>
<tr>
<td>S. alt</td>
<td>0.2</td>
<td>0.4</td>
</tr>
</tbody>
</table>

The diagram shows the nitrogen and carbon levels for different species at two depths: 7.5 cm and 22.5 cm.
Scenarios

Marshes vertically keep pace with sea level rise
Increase temp, CO₂, precip, streamflow
Response:
Increase in coverage of *Juncus roemerianus*
Competition with *Spartina patens*
Implications:
Stem density: reduced by 78%
N & C pools: Belowground → Above = Below
Lower NRE (25%)
Faster N & C loss rates belowground
Soil N: 1.2 → 0.3%
Soil C: 30 → <10%
Scenarios

Hindered landward migration

Response:
High marsh shrubs die out first

Implications
Aboveground storage of N and C
Litterfall minor and loss of N and C very slow
Scenarios

Hindered migration

Response
Low marsh dominates (short *Spartina alterniflora*)
Encroachment into *Spartina patens* community

Implications
Lowest stem density – affect sedimentation
High NRE
Fast loss of N and C pools aboveground
Similar slow loss of large OM belowground
Similar large C pool stored in dead material
Conclusions

• Changes to plant community structure imply changes to the functioning of salt marshes
  - nutrient filtering
  - C storage

Ex: Delaware
21% marshland flooded with rise of 2’
< 1% developed – potential for horizontal migration
Questions?