Understanding Wetland Vulnerability to Climate Change: An Analysis of Water Levels and Plant Species Dynamics in a Tidal Freshwater Marsh

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Restore America’s Estuaries
7th National Summit on Coastal and Estuarine Restoration
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Established Elements at Jug Bay Sentinel Site:

- Meteorological data
- Water physical and chemical data
- Marsh elevation change data (SETs)
- Vegetation monitoring
- Local geodetic control network
Sentinel Site Monitoring Infrastructure

- Weather station instrumentation
- Telemetry unit
- Continuous water quality monitoring station
- Marsh transects
- Surface elevation Table (SET)
Using static GPS and CORS to obtain high accuracy elevations

Using geodetic leveling to connect monitoring systems

Using RTK (Real Time Kinematic) GPS to obtain high accuracy elevations

Obtaining elevations from existing, published surveying monuments

Establishing SETs as permanent control points
Research Questions

Main question:
- What is the relationship between plant cover and the timing, duration and frequency of flooding during early growing season?

More specifically:
- What time period during early growing season: (March15-April14 or April15-May15) is more critical?
- Does duration of flooding, frequency of flooding, and water depth have similar effects on annual species percent cover?
- Is there a species effect?
Field and Greenhouse Experiments (Baldwin et al. 2001)

Effects of Elevation on Species Density

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of species</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10 cm</td>
<td>0</td>
</tr>
<tr>
<td>0 cm</td>
<td>1</td>
</tr>
<tr>
<td>+10 cm</td>
<td>2</td>
</tr>
<tr>
<td>Undisturbed</td>
<td>3</td>
</tr>
</tbody>
</table>

**Impatiens capensis** (A)  
3  
18  

**Pilea pumila** (A)  
3  
50  
128  

Stem length

Field April-August

- **Pilea pumila** (A)
  - 3
  - 50
  - 128
  - 28

- **Impatiens capensis** (A)
  - 18
  - 170
  - 294
  - 329
Field and Greenhouse Experiments (Baldwin et al. 2001)

Effects of Elevation on Species Density

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of species</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF</td>
<td>0</td>
</tr>
<tr>
<td>FN</td>
<td>2</td>
</tr>
<tr>
<td>NF</td>
<td>4</td>
</tr>
<tr>
<td>NN</td>
<td>6</td>
</tr>
</tbody>
</table>

- FF: Flooded continuously
- FN: Flooded, then nonflooded
- NF: Nonflooded, then flooded
- NN: Nonflooded continuously

Greenhouse April-September
Flooding Effects
Seed Bank Study

Flooding significantly reduced species density and emerging seedling density.
Experimental Design

Study Sites

- Railroad Bed
- Western Branch
- Mattaponi Creek

Transects

- T1
- T2
- T3
- T4
- T5

Plots

- T1
- T2
- T3
- T4
- T5

Study Period: 2008-2014

Did not measure vegetation plots in 2012
Assumption: elevation in plant plots did not change significantly through the study period. Used 2014 RTK data to calculate elevations.

Data Collected and Processed

Data Types

- Water Depth main channel
- RTK Elevation
- Veg %Cover

Used both data sets to populate a flooding calculator developed by Jim Lynch, NPS.
Data Collected and Processed

Start germination of annual species

Start GS

Annuals peak biomass
High % cover

1st flooding time period
2nd flooding time period

Not a cause and effect analysis
Transect’s elevation profiles
Total number of species identified at Western Branch: 61
Number of Annual species: 10 (16% of all species)
What time period: (March15-April14 or April15-May15) is more critical?

Significantly higher %flooding during Apr15-May15

P <0.01
What time period: (March15-April14 or April15-May15) is more critical?

**Red line corresponds to 95% of the values**
Start germination of annual species

Start GS

Mar    Apr    May    Jun    Jul    Aug    Sep    Oct

Annuals peak biomass
High % cover

1st flooding time period

Mar15-Apr14 < Apr15-May15

2nd flooding time period

Mar15-Apr14 Restricted to 20% flooding
Apr15-May15 Restricted to 40% flooding

Considering SLR trends: 40% flooding for the Mar15-Apr14 period will be reached between 10-25 years
Field and Greenhouse Experiments (Baldwin et al. 2001)

Effects of Elevation on Species Density

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<th>Treatment</th>
<th>Greenhouse April-September</th>
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<tr>
<td>FF</td>
<td>Flooded continuously</td>
</tr>
<tr>
<td>FN</td>
<td>Flooded, then nonflooded</td>
</tr>
<tr>
<td>NF</td>
<td>Nonflooded, then flooded</td>
</tr>
<tr>
<td>NN</td>
<td>Nonflooded continuously</td>
</tr>
</tbody>
</table>

Number of species

- FF: 0
- FN: 2
- NF: 4
- NN: 8
Relationship between frequency of flooding (# flooding events) and percent cover?

**Annuals**

- March 15 - April 14
  - Mean: 22.9%
  - Min: 7.0%
  - Max: 58.0%

- April 15 - May 15
  - Mean: 29.7%
  - Min: 11.0%
  - Max: 57.0%

**Perennials**

- March 15 - April 14

- April 15 - May 15

# Flooding events: Mar15-Apr14 < Apr15-May15 (p < 0.01)
Relationship between **water depth** and percent cover?

**Annuals**

- March 15 - April 14
  - Mean: 6.8%
  - Min: 2.1%
  - Max: 34.0%

- April 15 - May 15
  - Mean: 9.5%
  - Min: 3.4%
  - Max: 39.6%

**Perennials**

- March 15 - April 14

- April 15 - May 15

*Water depth: Mar15-Apr14 < Apr15-May15 (p < 0.01)*
Species Effect – Impatiens capensis

% Flooding

March 15 - April 14

April 15 - May 15

Similar patterns for other annual species
Field and Greenhouse Experiments (Baldwin et al. 2001)

Effects of Elevation on Species Density

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<td>c</td>
</tr>
<tr>
<td>0 cm</td>
<td>b</td>
</tr>
<tr>
<td>+10 cm</td>
<td>a</td>
</tr>
<tr>
<td>Undisturbed</td>
<td>a</td>
</tr>
</tbody>
</table>

Field April-August

-10 cm = 24% flooding
+10 cm = 1.4% flooding

Stem length

*Pilea pumila* (A)  
Impatiens capensis (A)

<table>
<thead>
<tr>
<th>Plant Species</th>
<th>Treatment</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Pilea pumila</em></td>
<td>+10 cm</td>
<td>128 a</td>
</tr>
<tr>
<td><em>Impatiens capensis</em></td>
<td>+10 cm</td>
<td>294 ab</td>
</tr>
<tr>
<td></td>
<td>0 cm</td>
<td>50 b</td>
</tr>
<tr>
<td></td>
<td>-10 cm</td>
<td>3 c</td>
</tr>
<tr>
<td></td>
<td>Undisturbed</td>
<td>28 bc</td>
</tr>
</tbody>
</table>
Next Steps

- Incorporate data set of additional 2-study sites in analysis
- Correct for changes in elevation – using 2011 RTK data
- Continue to measure elevation in vegetation plots annually if possible

Results significance

- Flooding species sensitivities important to inform restoration efforts.
- Increase flooding during the start of growing season as a result of climate change will increase vulnerability of tidal freshwater annual species.
- 40% flooding for the Mar15-Apr14 period will be reached between 10-25 years
Acknowledgments

NOAA – Chesapeake Bay National Estuarine Research Reserve in Maryland

NOAA – National Geodetic Survey (Dr. Philippe Hensel and Galen Scott)

Field assistants: CBNERR-MD and Volunteers from Jug Bay Wetlands Sanctuary
Species Effect

March 15 - April 14

IMCA  PEAR  PESA  PIPU  % Flooding

Percent Cover vs Year

% Flooding

2008 2009 2010 2011 2013 2014

2008 2009 2010 2011 2013 2014
Species Effect

April 15 - May 15

Percent Cover

Year

IMCA  PEAR  PESA  PIPU  % Flooding

April 15 - May 15