Extreme Climate Events and the Recurrent Sudden Dieback and Recovery of Salt Marshes in the Rapidly Subsiding Mississippi River Delta, Louisiana

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BATON ROUGE
Salt marshes in the Mississippi Delta in coastal Louisiana, rsl is around 1 cm per year.

Map from Andrew Tweel, LSU
“Non-acute” salt marsh dieback

Acute saltmarsh dieback

- Dieback occurs quickly, from one growing season to next
- Full recovery frequently occurs
- Occurred in Gulf and Atlantic Coast marshes in 2000s, drought primary driver

Acute salt marsh dieback
BACKGROUND
Timeline coastal Louisiana 1999-2009

CLIMATE
• Exceptional drought (1999-2000, 2006)
• Back to back hurricanes in 2005 and 2008

SALT MARSH DIEBACK
• 2000 (about 100,000 ha or 25%, widespread)
• 2009 (smaller area, regional distribution)
Range of marsh elevations with respect to local water levels
Seasonal marsh flooding, related to Gulf level

Monthly mean sea level (light blue)

WATER LEVEL IN METERS

% TIME MARSH IS FLOODED

Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug
Gulf levels vary from year to year, with long stretches remaining higher or lower than average.
Microtidal flooding regime, daily flooding alternating with extended periods of drawdown.
Volume of free water greater in low elevation marshes
2000 DIEBACK

FIRST NOTICED IN MARCH/APRIL, POSSIBLE THAT DIEBACK OCCURRED AFTER NEW GROWTH FIRST STARTED

DIEBACK LINKED TO DROUGHT

OXIC SOILS -> PH DROP -> RELEASE OF METALS TO TOXIC CONCENTRATIONS

Dieback in interior areas

*Spartina alterniflora* died back, *Juncus roemerianus* survived.

Where both survived *J. roemerianus* taller than *S. alt* where both survived

(2000 Dieback (widespread across elevation gradient) (photo Karen Mckee, USGS))
Typical layout of study site
STUDY DESIGN developed to assess field conditions post-2000 dieback

- Locate paired interior dieback and surviving marshes (N=4) replicate high and low marshes

- In field: compare relative elevations, soil salinity, drawdowns, specific yield

- In lab: soil acidification potential, metal release
### Comparisons at paired interior marshes

<table>
<thead>
<tr>
<th>Parameter</th>
<th>High B</th>
<th>High A</th>
<th>Low B</th>
<th>Low A</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>live</td>
<td>dead</td>
<td>live</td>
<td>dead</td>
</tr>
<tr>
<td>Relative Elevation (cm)</td>
<td>+3</td>
<td>+5</td>
<td>+3</td>
<td>+3</td>
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<tr>
<td>Monthly Marsh flooding (%)</td>
<td>21</td>
<td>26</td>
<td>13</td>
<td>21</td>
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<tr>
<td>Maximum Drawdown (cm)</td>
<td>12</td>
<td>13.5</td>
<td>14</td>
<td>25</td>
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<td>Specific Yield</td>
<td>0.03</td>
<td>0.08</td>
<td>0.03</td>
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<tr>
<td>Acidification Potential</td>
<td>2.6</td>
<td>2.8</td>
<td>2.9</td>
<td>3.2</td>
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<tr>
<td>Average Soil Salinity (ppt)</td>
<td>17.9</td>
<td>15.9</td>
<td>30.6</td>
<td>27.9</td>
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</tbody>
</table>
Patterns of drawdown at paired marshes

WATER LEVEL IN METERS

Low A

High A

Low B

High B

Jan 1
Jan 15
Jan 29
Feb 12
Feb 26
Mar 12

Jan 1
Jan 15
Jan 29
Feb 12
Feb 26
Mar 12
Soil pore space volume during drawdowns

WATER DRAINED FROM MARSH SUBSURFACE IN LITERS

Low A  Low B  High A  High B

winter summer  winter summer  winter summer  winter summer

DEAD  LIVE
Soil acidification potential and metal release

ALUMINUM

MANGANESE

IRON

CONCENTRATION IN MG/L

pH

High marsh A

High marsh B

Low marsh A
Time Series of Soil Salinity in 10 cm increments (00-02)

Depth interval

Dieback marsh

Surviving marsh

SALINITY IN PARTS PER THOUSAND

6/1/00 10/1/00 2/1/01 6/1/01 10/1/01 2/1/02 6/1/02 10/1/02

10 20 30 40 50 60

1-10 cm

11-20 cm

21-30 cm

31-40 cm

41-50 cm
Drought as climate extreme

- Key to survival was ability to maintain supply of water during periods of no marsh flooding
- In one low elevation area dieback clearly related to soil acidification potential
- In remaining three areas (high and low marsh) soil acidification and/or bound water combined with high soil salinity likely contributed to plant mortality
Low Marsh A dieback site recovery; recovery by seedlings at all sites

March 5, 2002

October 24, 2003

May 2006
FIRST NOTICED IN FEBRUARY 2009, BEFORE NEW GROWTH
Dieback in interior areas

*S. alterniflora* and *Juncus roemerianus* died back

*J. roemerianus* no taller than *S. alt* where both survived

2009 dieback: limited to low elevation marsh
In 2005 hurricanes were spaced further apart and base water levels may have been a bit lower.

Hourly waterlevel at Grand Isle, August-October 2005 and 2008
(Data from National Ocean Survey)

Katrina
Gustav
Ike
Rita
Patterns of dieback

Within both low marsh sites, areas at about 18-20 cm NAVD88 elevation died back; areas > 24 cm NAVD88 survived; measurements made after dieback occurred

<table>
<thead>
<tr>
<th></th>
<th>&gt;2.5</th>
<th>&gt;7.5</th>
<th>&gt;12.5</th>
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<td>1 Aug- 31 Oct</td>
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<tr>
<td>High marsh A</td>
<td>41</td>
<td>32</td>
<td>24</td>
<td>17</td>
<td>12</td>
<td>9</td>
<td>7</td>
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<tr>
<td>Low Marsh A</td>
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<td>41</td>
<td>31</td>
<td>22</td>
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<td>12</td>
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<td>Sept 1-Oct 16</td>
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<tr>
<td>HM A</td>
<td>63</td>
<td>51</td>
<td>39</td>
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<td>17</td>
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<tr>
<td>LM A</td>
<td><strong>80</strong></td>
<td><strong>71</strong></td>
<td><strong>59</strong></td>
<td><strong>56</strong></td>
<td><strong>37</strong></td>
<td><strong>30</strong></td>
<td><strong>22</strong></td>
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</table>
Recovery at 2009 dieback sites

Stem density of *S. alterniflora* over time at plots established during 2000 dieback
Storm surge as climate extreme

- Dieback restricted to lower elevation marshes
- Both *S. alterniflora* and *J. roemerianus* affected
- Within a site, lowest elevation marshes affected
- Wild cards – spacing of storm surge may play a role as may exact storm path
Re-growth 2009 to 2010 at Low marsh A
- Drought affects marshes with different elevations equally; storm surge affects low-lying marshes.

- Climate perturbations don’t affect plant species equally.

- Regrowth through seedlings (*S. alterniflora*)

- Unexpected resilience of coastal Louisiana salt marshes to climate perturbation.

### Summary

<table>
<thead>
<tr>
<th>Year</th>
<th>HIGH A</th>
<th>HIGH B</th>
<th>LOW A</th>
<th>LOW B</th>
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<tbody>
<tr>
<td>2000</td>
<td>Healthy</td>
<td>Die-Back</td>
<td>Healthy</td>
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<td>2006</td>
<td>Healthy</td>
<td>Die-Back</td>
<td>Healthy</td>
<td>Die-Back</td>
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<tr>
<td>2009</td>
<td>Healthy</td>
<td>Die-Back</td>
<td>Healthy</td>
<td>Die-Back</td>
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<tr>
<td>2011</td>
<td>Healthy</td>
<td>Die-Back</td>
<td>Healthy</td>
<td>Die-Back</td>
</tr>
</tbody>
</table>

*For graphs and data please refer to the full document.*
- Tommy Michot, (ICEE, U. Louisiana Lafayette)
- Richard Day (USGS-BRD)
- Camille Stagg, USGS-BRD
- Bob Gambrell (LSU)
Gulf levels vary from year to year, with long stretches remaining higher or lower than average.