Salt Marsh Dieback

A literature review

By: Melanie Tymes

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History

- Florida (1990-1993)
- Louisiana (1968-1970) Small patches presumably caused by waterlogging
  - Standing dead vegetation, which turned to exposed mud flats over winter
  - Two years later only 7% of brown marsh areas showed little or no recovery
  - Marsh bare in 2001 was completely green in 2003
History

- Mississippi (2000)
  - Dieback occurred along tidal creeks and affects S. alterniflora and J. roemerianus.
  - Spring 04- Some natural recolonization had occurred at dieback sites
- Georgia (2002)
  - Dieback occurred along channel banks and affects S. alterniflora, S. patens, and D. spicata
  - Marshes have not shown signs of recovery
  - Dieback occurred along channel banks and affects S. alterniflora, S. patens, and D. spicata
  - Marshes have not shown signs of recovery
History

- Inland Bays (2006)- Dieback affects S. alterniflora in interior of marsh
  - Standing dead vegetation
Stressors

- Waterlogging
  - Sea-level Rise
  - Hydrologic Alterations
- PH fluctuation
- Drought/ Low water
- Increased Salinity
- Decreased Sediment Input
- Nutrients
- Toxins
  - Heavy Metals
  - Hydrogen Sulfide
- Herbivory
  - Snails
  - Waterfowl
Theories

- Plant pathogens
- Genetics
- Herbivores
- Water level extremes
- Salinity
- Sulfide accumulation
- Pollution or chemical spills
- Changes in soil metals
Types of dieback

• 1-3 m wide strips parallel to the banks of tidal creeks
• Mid marsh dieback areas
• Berm dieback characterized by the formation of scallop-shaped barren areas on or behind a bank levee
• Adjacent to upland border of marsh where wrack disturbance is common
Spartina Alterniflora

- Tolerant
  - Anoxic soils
  - Salinity
  - Low fertility
  - Fire
  - PH 5.5-7.5
  - Cold Temp. (-13)

- Not Tolerant
  - Drought
  - Shade
  - Hedging by wildlife
  - CaCO₃
Spartina and Overwintering

- A 1988 experiment in Lewes, DE revealed that when dead and live shoots were removed during the dormant season, no growth was experienced the following season.
- Removal of only the dead or live shoots did not kill the plant.
- In general, a decrease in oxygen supply leads to reduced growth of shoots, roots or both.
Pathogens

• Bacterial, fungal or viral pathogens can cause widespread plant mortality

• Supporting evidence
  – In Texas and Florida, a fungal involvement has been identified in connection with S. Alterniflora dieback, but was associated with stressed vegetation

• Contradictory evidence
  – Narrow range of potential pathogens
  – Black leaf spot does not cause plant death under normal conditions
  – No pathogens have been associated with dieback in other regions, including Louisiana and Delaware
Genetics

• Greater genetic diversity generally results in lower ecological vulnerability. Sudden extreme changes may exceed the genetic capacity of a single species to adjust.

• Supporting evidence
  – Research in Europe demonstrates that competition between two genetic groups of Phragmites can result in dieback between surviving population

• Contradictory evidence
  – Genetic diversity of Spartina in healthy sites and among dieback re-growth was relatively similar
Herbivores

- Herbivores can clear large areas of vegetation in a short period of time

- **Supporting evidence**
  - Some dieback areas have large concentrations of snails
  - In Delaware some areas showed signs of grasshopper damage

- **Contradictory evidence**
  - Not all dieback areas have evidence of snail feeding
  - No evidence of unusual insect outbreaks or damage in most regions
  - No periwinkles found in Delaware samples
  - Periwinkles prefer consuming dead Spartina shoots
Sea Level Rise

• Spartina alterniflora is very flood tolerant, but there are limits to its tolerance. When oxygen is cut off from the plant roots for 24 hours, the meristems will begin to die and the entire plant can succumb within a few days

• Supporting evidence
  – The lower marsh areas in the interior marsh are experiencing extensive mortality

• Contradictory evidence
  – Other species that are equally of less flood tolerant than Spartina have survived
  – Dieback is sudden and followed by recovery which does not seem to correlate with a gradual rise in sea level,
Low Water Levels and Drought

• Spartina is highly vulnerable to drought

• Supporting evidence
  – Many areas recorded low water levels at dieback sites

• Contradictory evidence
  – Low elevation sites appear to be more affected than high elevation sites
Drought and Storm Event Patterns

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</thead>
<tbody>
<tr>
<td>Drought</td>
<td>Louisiana</td>
<td>Georgia, South Carolina</td>
<td>Maine</td>
<td>Delaware</td>
<td>- Drought</td>
<td>- Drought</td>
<td>- Drought</td>
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<td>Rain Event</td>
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<tr>
<td>Dieback event</td>
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</table>

- Drought
- Rain Event
- Dieback event
- - Drought
Drought Monitor

September 7, 1999

U.S. Drought Monitor

March 30, 2004

U.S. Drought Monitor

February 26, 2002

U.S. Drought Monitor

April 11, 2006

U.S. Drought Monitor

Released Thursday, April 1, 2004

Author: Brad Rippey, U.S. Department of Agriculture

http://drought.unl.edu/dm

Released Thursday, April 13, 2006

Author: Rich Tinkler, CPC/NEP/NWS/NOAA

http://drought.unl.edu/dm
High Salinity

• Severe drought may have increased salinity in dieback marshes

• Supporting evidence
  – In some regions where dieback occurred, surface salinities did increase
  – Some regions also observed elevated porewater salinity in dead marshes
  – Plants with a greater salt tolerance have survived alongside dead Spartina

• Contradictory evidence
  – The salinities measured, while elevated, did not exceed tolerance limits of S. alterniflora
  – Less salt tolerant species have also survived in dieback areas
Sulfides

- Anaerobic carbon decomposition in wetland sediments produces fermentative products that can be toxic and create high soil oxygen demand.

- **Supporting evidence**
  - Some cases of dieback in Louisiana have been linked to sulfide accumulation.
  - Other regions also exhibit elevated concentrations.

- **Contradictory evidence**
  - Plant death can generate these compounds and does not prove a cause and effect relationship.
  - Species more vulnerable to sulfide have survived.
  - Tests in some dieback regions revealed non-lethal sulfide levels.
Cycle
Pollution

• Chemical spills can kill large areas of marsh in a short period of time

• Supporting evidence
  – No evidence of any spills

• Contradictory evidence
  – No dieback marshes exhibited any signs of chemical spills or pollution damage
  – Pattern and extent of dieback is not consistent with observed dieback areas
Metal Toxicity or Deficiency

- Increased salinity could change metal bioavailability and result in deficiencies in plants, decreased soil water could concentrate metals to toxic levels

- Supporting evidence
  - Metal mobilization due to acidification caused by re-flooding of a desiccated marsh has been reported
  - Deposit patterns correspond with marsh dieback pattern

- Contradictory evidence
  - No concrete evidence against changes in metal concentration or plant responses to these changes
# Oxidation/Reduction Sequence

<table>
<thead>
<tr>
<th>Redox Potential</th>
<th>Element</th>
<th>Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>+350 mV</td>
<td>Oxygen</td>
<td>$O_2 \sim H_2O$</td>
</tr>
<tr>
<td>+220 mV</td>
<td>Nitrogen</td>
<td>$NO_3^- \sim NO_2^-, N_2, NH_4^+$</td>
</tr>
<tr>
<td>+200 mV</td>
<td>Manganese</td>
<td>$Mn^{+4} \sim Mn^{+2}$</td>
</tr>
<tr>
<td>+120 mV</td>
<td>Iron</td>
<td>$Fe^{+3} \sim Fe^{+2}$</td>
</tr>
<tr>
<td>-150 mV</td>
<td>Sulfur</td>
<td>$SO_4 \sim H_2S$</td>
</tr>
<tr>
<td>-250 mV</td>
<td>Carbon</td>
<td>$CO_2 \sim CH_4$</td>
</tr>
</tbody>
</table>
Laboratory Studies of Time Sequence for Oxidation/Reduction

Days after waterlogging

Days: 1/0/1900, 1/2/1900, 1/4/1900, 1/6/1900

O2: 200 ppm (O2 in % x 10)
NO3-: 50 ppm
Mn+2: 150 ppm
Fe+2: 100 ppm

Graph showing changes in O2, NO3-, Mn+2, and Fe+2 over time.
PH

- Increased salinity could change metal bioavailability and result in deficiencies in plants, decreased soil water could concentrate metals to toxic levels

- Supporting evidence
  - Soil pH of the affected marshes was typically acidic

- Contradictory evidence
  - The measured levels in Delaware were within the range tolerable to the plants
  - Species less tolerant to higher PH were not effected
# Plant Characteristics

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Drought Tolerance</th>
<th>PH</th>
<th>Moisture Use/Flood Tolerance</th>
<th>Sulfide Tolerance</th>
<th>Salinity Tolerance</th>
<th>Precipitation Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spartina alterniflora</td>
<td>None</td>
<td>5.5-7.5</td>
<td>High</td>
<td></td>
<td>High</td>
<td>40-60 in</td>
</tr>
<tr>
<td>Avicennia germinans</td>
<td></td>
<td></td>
<td></td>
<td>Less tolerant</td>
<td>High (more tolerant)</td>
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</tr>
<tr>
<td>Batis maritima</td>
<td>Medium</td>
<td>4.0-7.9</td>
<td>Medium</td>
<td></td>
<td>High (more tolerant)</td>
<td>28-60 in</td>
</tr>
<tr>
<td>Distichlis spicata</td>
<td>Medium</td>
<td>6.4-10.5</td>
<td>Medium</td>
<td></td>
<td>High</td>
<td>5-70 in</td>
</tr>
<tr>
<td>Juncus roemerianus</td>
<td>None</td>
<td>4.0-7.0</td>
<td>High</td>
<td></td>
<td>High (less tolerant)</td>
<td>40-60 in</td>
</tr>
</tbody>
</table>
General Observations

- Recovery correlates with increased acetylene reduction activity
- Survival of transplants equal in dieback and healthy areas
- Sulfide accumulation noted in Louisiana
- Concentration of NH$_4$ has been observed to be significantly higher in dieback areas
- All dieback events occurred during extreme drought conditions
- Root zone soil was oxidized in the healthy site and reduced at the dieback sites
Delaware Observed Measures

- Indian River- 10 sites
- pH Range: 6.3-7.6
- Salinity Range: 14.5-28.8ppt
- No periwinkles observed within plots
Restoration

- Louisiana shows recovery, while New England States have little recovery
- Seeding has been the most effective method in Louisiana
- Live planting and coconut mat planting also used to some success
Summary

• Least likely factors
  – Chemical Spill
  – Pathogens
  – Low genetic diversity
  – Sea level rise
  – Mosquito ditches
  – Snails
  – Snow Geese

Although the cause of dieback is currently unknown, plant and soil characteristics in most areas were consistent with temporary soil desiccation that may have reduced water availability, increased soil salinity, caused soil acidification or increased uptake of toxic metals such as Fe or Al.

• More likely factors
  – Stresses during the dormant period
  – Drought and water level extremes
  – Natural Toxins
Literature Resources

- Adamowicz, Susan C. and Wagner, Lindsay, **Northeast Sudden Tidal Wetland Dieback Workshop**, Parker River National Wildlife Refuge, April 1, 2005.


- Cantor, Ryan and Rudolph, Douglas, **Periwinkle Littoraria irrorata tracking preferences towards live and dead Spartina alterniflora and the effects of predatory cues** Aquatic Chemical Ecology Group, School of Chemistry and Biochemistry, Georgia Institute of Technology, Atlanta, GA 30332.

- Cogburn, Stephanie, **Literature Citations of Salt Marsh Ecology Relative to the Marsh Dieback Syndrome Research Program in Coastal Louisiana,**


• Daugherty, Christine J. and Musgrave, Mary E., **Characterization of populations of rapid-cycling Brassica rapa L. selected for differential waterlogging tolerance**, J. Exp. Bot., March 1994; 45: 385 - 392.


• Edwards, Dr. Keith, LA Environ. Res. Center, McNeese St. University; Proffitt, Dr. Edward, U.S. Geological Survey, National Wetlands Research Center; Dr. Travis, Steven E., U.S. Geological Survey, National Wetlands Research Center, **SPARTINA ALTERNIFLORA DIEBACK IN SOUTHWESTERN LOUISIANA: STEM DENSITIES, GENETIC DIVERSITY, AND GROWTH OF TRANSPLANTS**.

• Flory, Janice and Alber, Merryl, **Dead Marsh Information**, Gerogia Coastal Research Council, November, 2002.

• Grasso, Raelyn and Bickel, Katie, **Salinity Tolerance: From Cellular Mechanisms to Community Structure**, Duke University.

• Lindstedt, Diane M. and Swenson, Erick M., **The Case of the Dying Marsh Grass**, Louisiana Department of Natural Resources, 2006.


• Rublee, Parke A., Cammen, Leon M. and Nobbi, John E., Bacteria in a North Carolina Salt Marsh: Standing Crop and Importance in the Decomposition of Spartina Alterniflora, North Carolina State University.


Web Resources

- **Brown Marsh Data Information Management System. Salt Marsh Dieback in Louisiana Webpage. in. Louisiana Department of Natural Resources -- Coastal Restoration Division.** [http://www.brownmarsh.net/](http://www.brownmarsh.net/)


- **National Resource Conservation Service: Plants Database-Characteristics of Spartina Alterniflora**
  [http://plants.nrsc.usda.gov/cgi_bin/topics.cgi?earl=plant_attribute.cgi&symbol=SPAL](http://plants.nrsc.usda.gov/cgi_bin/topics.cgi?earl=plant_attribute.cgi&symbol=SPAL)


- **Sudden Wetland Dieback in New England,** [http://wetland.neers.org](http://wetland.neers.org)