Dead Marsh Information
Georgia Coastal Research Council
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(Note: Appendix B is included on the GCRC web site as a separate PDF document.)

1. Background

"Dead marsh" is variously referred to as brown marsh, marsh balding, and salt marsh dieback. In Georgia, reports of dead marsh in and around Liberty County began in the spring of 2002. These are areas of salt marsh with little or no live above-ground vegetation. Both *Spartina alterniflora* and *Juncus roemerianus* have been affected along the Georgia coast, and in some areas the marsh is down to bare mud and beginning to slough into the water. Tommy Michot (USGS) has developed a color index (which has been modified here) for description of the dieback phenomenon that can perhaps be viewed as a "progression":

Green = normal plant appearance
Green/brown = some affected plants (brown, stressed)
Brown/green = more affected plants than normal plants
Brown = all plants appear stressed
Bare = widely spaced brown plants, plant stubble and/or exposed soil

There have been reports of salt marsh die-back in several other states. In Louisiana, there were historic reports of brown marsh (most sites were less than an acre) that were attributed to

sediment loss, but in 2000, a year with record low freshwater inputs, greater than 250,000 acres were impacted. This has affected both *S. alterniflora* and *S. patens*. There have also been reports of dead marsh in other places around the Gulf of Mexico (Texas in 1999; the Florida panhandle in 1990 and 1995). New York reported marsh loss in Jamaica Bay in 1998 that was thought to be due to sediment starvation and submersion. Charleston Harbor, SC experienced marsh die-off in 1986 when the Cooper River was temporarily diverted and salinities in the Harbor doubled (J. Morris, pers. comm.). They have also reported die-offs this year (2002) that resemble those occurring in Georgia.

2. Potential Causes

There are numerous hypotheses for the cause of the marsh die-off. Potential causes can be lumped into three main categories:

Drought-related (increased air, soil and water temperatures, reduced freshwater inputs, increased salinity, changes in concentration of phytotoxins [sulfide, metals])
Biotic stressors (pathogens and herbivory)
Other stressors (chemical spill, sediment starvation)

Many of these factors have been investigated in Louisiana. Below we provide information compiled by Karen McKee, Irv Mendelssohn, and Mike Matern (available on the website, http://www.brownmarsh.net/data.htm) that summarizes evidence for and against each potential cause in the context of the Louisiana brown marsh phenomenon. (Where additional sources were used, references are provided.)

a. Drought-related causes

i. High salinity:

Background: The recent severe drought, combined with low river flow, may have increased salinity in die-back marshes.

Evidence for Salinity:

- Surface salinities did increase in the past year, according to records examined thus far.
- Porewater salinity is slightly elevated in some of the dead marshes.
- Marshes close to surface water generally survived.
- More salt-tolerant species (*Batis* spp*., Avicennia germinans* [black mangrove] and *Distichlis spicata* [saltgrass]) have survived alongside the dead *Spartina.*

Evidence against Salinity:

- Measured salinities (<40 ppt) do not exceed tolerance limits of *S. alterniflora*.
- Less salt tolerant species such as *Juncus roemerianus* have survived in die-back areas. Note that this is not true in Georgia where *Juncus* is severely affected.

ii. Low water levels:

Evidence for low water levels:

- Records indicate low water levels at some locations during early part of year.

Evidence against low water levels:

- Low elevation sites appear to be more affected than high elevation sites.

iii. Buildup of sulfide / fermentation products:

Background: Organic matter is generally accumulated in wetlands, and the anaerobic carbon decomposition in wetland sediments produces a range of fermentative products that are toxic to plants (organic acids and sulfide) at high enough concentrations. This process can also create a high soil oxygen demand that can stress plants by competing for their internal oxygen.

Evidence for Phytotoxins:

- Historical die-back of *Spartina alterniflora* has been linked to sulfide accumulation in Louisiana marshes.
- Current die-back areas exhibit elevated concentrations of sulfide. However, death of plants will generate these compounds; a cause and effect relationship cannot be assumed.

Evidence against Phytotoxins:

- Unaffected species are not more tolerant of sulfide, e.g., *Avicennia germinans*.

iv. Metal toxicity/deficiency:

Background: Increased salinity could change metal bioavailability and result in decreased metal uptake, causing deficiencies in plants. Alternatively, decreased soil water might raise metal concentrations to toxic levels.

Evidence for Metals:

- "Metal mobilization due to acidification caused by reflooding of a desiccated marsh has been reported previously."
- "…the occurrence of deposits differs between streamside plants and inland plants, which happens to correlate with the marsh browning pattern."

Source: Paul Klerks (abstract from 01/11/2001 conference "The Potential Role of Soil Metal Toxicity in Marsh Dieback")

b. Biotic Stressors

i. Pathogens:

Background: Drought-caused stress may make plants susceptible to pathogens.

Evidence for Pathogens:

- In Texas & Florida, a fungal involvement has been identified in connection with *Spartina* die-back, but infection usually opportunistic on stressed vegetation.

Evidence against Pathogens:

- Examination of *Spartina* culms from LA by pathologists has so far revealed no obvious pathogens. (see also Transplant studies)

Source: Ray Schneider (LSU AgCenter Dept of Plant Pathology and Crop Physiology)

ii. Herbivores:

Evidence for Herbivory:

- Some, but not all, die-back areas have large concentrations of snails that are eating the dead vegetation.

Evidence against Herbivory:

- Not all die-back areas have high densities of snails or evidence of snail feeding on live tissue.

Evidence against Insects:

- No evidence of insect outbreaks or insect damage out of the ordinary.

c. Other Stressors

i. Chemical spill:

Background: Chemical spills can kill large areas of marsh in a short period of time.

Evidence against Spills:

- Pattern and extent of die-back is inconsistent with this hypothesis and there were no signs of a chemical spill in the die-back marshes

ii. High water levels:

Background: 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 (growing tips) will begin to die and the entire plant can succumb within a few days.

Evidence for High Water Levels:

- Pattern of die-back shows that lower elevation areas (interior marsh) are experiencing extensive mortality.

Evidence against High Water Levels:

- Other species that are equally or less flood tolerant than *Spartina* have survived.

iii. Sea level rise, submersion, "sediment starvation":

Background: A combination of decreased inflow (interrupting the normal deposition of sediment) with sea-level rise causes the marsh to sink, and the die-off occurs from the ground up.

d. Summary (from Louisiana materials)

- Factors possibly involved, with some evidence from several sites: water level extremes, salinity, natural toxins (e.g., sulfide)
- Factors possibly involved, but with little or no data from a broad survey of current die-back sites: pathogens, low genetic diversity
- Factors least likely to be involved: a chemical spill, herbivory

e. Susceptibility

Background: In addition to the cause of the phenomenon, **susceptibility** should be considered. Low genetic diversity in an area may result in a more dramatic, "clonal" dieback as each plant is equally intolerant of the unfavorable condition(s).

Evidence related to susceptibility:

- European research shows two genetic groups of *Phragmites australis* ("deep water reed" and "land reed"), each of which may be completely eliminated from an area by manipulations favoring the other genotype and preventing the establishment of new populations after old ones have been destroyed. The surviving population is more likely to experience die-back

3. Regrowth and transplant studies:

a. Regrowth observations

- Some (but not all) areas in Louisiana that were affected in 2000 have regrown, suggesting the marsh can recover. (Source: Robert Twilley, interviewed by Katina Gaudet for Houma Today 6/11/02, "Brown Marsh Perplexes Louisiana Researchers").
- Carlson et al. (2001) reported that natural recovery of die-offs in the Florida Panhandle was very slow. ("Panhandle Salt Marsh Mortality: A Prelude to Louisiana Brown Marsh" conference abstract)

b. Transplant studies

There have also been several relevant transplant studies:

i. Greenhouse study.

Background: A greenhouse transplant study was done with sections of healthy, stressed, and dead marsh in Louisiana.

Results: After 9 weeks investigators found:

- Number of lives stems and max stem height in healthy sods remained significantly greater than the stressed sods.
- New stems were produced in stressed sods, but the mean number of live stems did not significantly increase over time.
- Dead *Spartina* culms did not recover (even though *Avicennia* and *Batis* stems in the dead sods continued to grow and initiate new nodes.

Source: Howard, Wells, McKee, McGinnis (USGS). Abstract from 01/11/2001 conference, "Recovery Potentail of Spartina alterniflora in Dieback Areas: A Greenhouse Pilot Study".

ii. Field transplants

Panhandle Salt Marsh Mortality: A Prelude to Louisiana Brown Marsh

Background: 4 accessions of *S. alterniflora* were transplanted to 6 die-off sites along the Florida Panhandle.

Results:

- There were consistent differences in the survival of the different *S. alterniflora* accessions at each site, suggesting genetic strain is important.
- The 2 strains with the highest survival rate also had higher levels of root alcohol dehydrogenase activity.

Source: Carlson, Yarbro, Courtney, Leary, Arnold, Leslie, Hughes and Craft (FL Marine Research Inst). Abstract from 01/11/2001 conference.

Dieback in *Spartina alterniflora* Marshes Along the Southwest Louisiana Coast

Background: Plugs of a known genotype of *S. alterniflora* were transplanted into dieback marsh in the Sabine NWR, September 2000. The chosen clone had high survivorship, high growth-rates along the elevation and moisture gradients in the test marsh, a less dense growth pattern, and taller stems compared to other clones.

Results:

- Stems of transplants turned brown by November 2000, likely due to transplant shock.
- New shoots emerged in December 2000.
- In May 2001, survivorship was measured at 70-91%.

Source: Edwards, Proffitt, and Travis. Abstract from 01/11/2001 conference.

4. Responses in other states:

a. Louisiana

Congress allocated approximately three million dollars for brown marsh research through the National Oceanic & Atmospheric Administration to the Louisiana Department of Natural Resources (LDNR). The Scientific-Technical Committee of the Barataria-Terrebonne National Estuary Program and LDNR awarded funding for tasks in five categories (status and trends; causes; synthesis and data management; nutria control program; and remediation). Research projects began in April 2001 and will conclude in the fall of 2002. A full description of these efforts is provided in Appendix A.

There was also a conference held in January 2001 "Coastal Marsh Dieback in the Northern Gulf of Mexico: Extent, Causes, Consequences and Remedies." Copies of the abstracts are available on line -- http://www.brownmarsh.net/reports.htm). Below we summarize the ongoing monitoring effort as well as relevant results from the conference.

i. Ongoing monitoring efforts:

- Surveys
  - Aerial videography (fixed wing survey), photographic and infrared
  - LANDSAT imaging
  - Boardwalk transects
- Ground site monitoring
  - Elevation
  - Snail counts
  - Vegetation assessment
    - plant stem number (live and dead)
    - plant height (live and dead)
    - plant color (% green)
  - Physicochemical (porewater [0, 15, and 30 cm from surface] and soil)
    - temperature
    - salinity
    - conductivity
    - pH
    - Eh (redox)
    - sulfides
    - nutrients (NH_4, N+N, NO_2, PO_4)

A Coast-wide Reference Monitoring System is also being proposed for Louisiana, which would have 700 reference sites, and would measure salinity, marsh elevation, water depth, duration and frequency of flooding.

ii. Research Results

<u>Sudden Salt Marsh Dieback: Update from 20 Experimental Sites in Terrebonne and Barataria Basins</u>

Background: Permanent stations in Terrebonne and Barataria basins are being monitored via both aerial and ground surveys for vegetation characteristics, pathogens, soil physicochemical composition.

Results:

- Rhizome viability – <5% viable in die-off zone, >70% viable in transition and healthy zones.
- Pathogens – two fungal species isolated, pathogenicity not established.
- Soil – salinity, sulfide, and pH were at nonlethal levels

Source: McKee, Mendelssohn, Materne (abstract from 01/11/2001 conference).

Characterization of Plants and Soils in a Spartina alterniflora Salt Marsh Experiencing 'Brown Marsh' Dieback in Terrebonne Parish, Louisiana, USA

Background: Plants and soils in two study sites (stressed and healthy) were compared by regular (biweekly/monthly) monitoring of *Spartina* stem counts and heights (both live and dead), salinity, sulfides, pH, NH_4, N+N, PO_4, and Eh.

Results:

- Live plant heights were significantly greater in the healthy plot (42 +/- 2.92 cm) than in the stressed plot (28 +/- 2.42 cm).
- Mean stem number in the stressed plot decreased from August ([28.25 +/- 3.16] m^{-2}) to November ([8.5 +/- 1.93] m^{-2}) – due to weathering, snail herbivory, and decomposition. Mean stem height in November was only 5.28 +/- 1.41 cm.
- Interstitial sulfides, salinity, pH, and soil Eh were not significantly different by depth between sites.
- Salinity ranged from 18-30 g/L at all depths and pH was slightly basic.
- Root zone soil was oxidized in the healthy site (Eh = 48 mV), but reduced at the stressed site (-45 mV). In the stressed site, the redox was as low as -100 mV below the root zone.

Source: Michot, Ford, Rafferty, Kemmerer, and Olney (USGS). Abstract from 01/11/2001 conference.

Dieback in *Spartina alterniflora* Marshes Along the Southwest Louisiana Coast

Background: Live stem densities were measured in a 19-year old restored salt marsh in Sabine NWR since mid-August, 2000.

Results:

- Plants in affected areas appeared green and healthy in mid to late May 2000, but were dead or dying by late July 2000.
- Interior zones of the marsh suffered a dieback event that is still apparent 1 year after the initial event.
- (See also Transplant section)

Source: Edwards, Proffitt, and Travis. Abstract from 01/11/2001 conference.

Preliminary Studies of Brown Marsh in a Chenier Plain, *Spartina patens* Marsh

Background: Between March and May, 1999, total dieback was noted in 3 of 6 sites in the Rockefeller Wildlife Refuge of *Spartina patens* (Aiton.) Muhl.

Results:

- Low salinity (28 vs. 31 ppt) and high pH (6.0 vs. 5.2) was associated with the healthy sites.

Source: Nyman, Burcham, Foret, Melancon, Michot, and Schmidhauser. Abstract from 01/11/2001 conference.

b. South Carolina

Background: On 10/16/02, Jim Morris of Univ. of South Carolina worked with SC DNR to sample two transects across each of 2 die-off sites for plant, animal and soil characteristics. He noted that the dieback areas are always in an interior location, (often lower in elevation but sometimes higher) and pointed out that both lower and higher elevations, in a low sea level, dry year can cause hypersaline conditions.

Results:

- There appears to be a concentration of snails at the periphery of the dieback sites. (There were far fewer snails in healthy areas.) Morris suggests the snails are opportunistic.
- DMSP concentrations in *Spartina* tissue showed no convincing trend. They also measured the spectrum of leaf albedo and are in the process of measuring pigment concentrations.

c. Florida

Background: In 1990-1995, the Florida Panhandle had several episodes of marsh mortality. Researcher noted: "…patches of *Spartina alterniflora* up to 1 ha in area became chlorotic, wilted, and died completely with 1 month of the onset of chlorosis." "Wilting *Spartina* was rapidly consumed by salt marsh periwinkles, but herbivory impacts were clearly secondary…" "Die-off patches occurred in lower, more frequently flooded portions of each marsh, leaving a thin strip of surviving *Spartina* along the seaward edge."

Results:

- Sediment porewater sulfide (<1 mM) and salinity (<35 ppt) were normal.
- Simultaneous occurrence of die-off at two widely separated locations (St. Joseph's Bay and Adams Beach) suggested that anthropogenic stresses were not involved.
- "…we found no climatic or tidal events which coincided with salt marsh mortality"
- A fungus (*Fusarium* sp.) was isolated from dying plants, but pathogenicity was not demonstrated.

(See also Transplants section)

Source: Carlson, Yarbro, Courtney, Leary, Arnold, Leslie, Hughes and Craft (FL Marine Research Inst). Abstract from 01/11/2001 conference, "Panhandle Salt Marsh Mortality: A Prelude to Louisiana Brown Marsh".

4. Initial response in Georgia

Since the first report of dead marsh along the Georgia coast, there have been several preliminary efforts to document the phenomenon.

i. Georgia Sea Grant

Background: Dr. Mac Rawson responded to a request for assistance from Laura Devendorf, the owner of Mellon Plantation in Liberty County. He visited her site in June 2002, took photographs, soil, and plant samples.

Results:

- Soil was also analyzed for pH, Ca, K, Mg, Mn, P, Zn, conductivity.

Sample	S	J
pHw	7.30	6.00
Ca (lbs/acre)	940.9	624.0
K (lbs/acre)	415.3	374.7
Mg (lbs/acre)	882.5	887.0
Mn (lbs/acre)	33.70	5.089
P (lbs/acre)	45.38	38.51
Zn (lbs/acre)	6.052	1.322
SS (mmhos)	12.96	11.37

- Elemental analysis was made by total acid digestion.

Sample	S	J
Al	6223	3025
B	16.18	15.53
Ca	1273	717.0
Cd	0.9400	0.6300
Cr	8.740	5.290
Cu	5.100	<0.5000
Fe	3698	2146
K	1248	672.9
Mg	2203	1270
Mn	71.31	13.44
Mo	<0.5000	<0.5000
Na	11810	5725
Ni	3.910	2.030
P	267.8	230.8
Pb	<2.5000	<2.5000
S	2393	1094
Zn	16.25	5.270

All values are reported as parts per million.

ii. Helicopter overview

On 9/19/02 CRD provided a helicopter for Mac Rawson, Merryl Alber, and Janice Flory to view the extent and patterns of dead marsh in coastal Georgia and take aerial photographs.

iii. LTER sampling

On 10/16/02, a team from the Georgia Coastal Ecosystem LTER and CRD went on a sampling trip to the Jericho River site. Their report is included here as Appendix B.

6. GCRC contacts

We have been in touch with scientists from Louisiana and South Carolina regarding this phenomenon.

i. Louisiana:

Robert Twilley (Univ. of Louisiana at Lafayette) wrote:

> Sounds interesting. The patterns you describe are very similar to our situation. We are in the process of wrapping up more results and working on a synthesis. Some persons have recommended a session at the SWS [Society of Wetland Scientists] meeting in New Orleans in June 2003. This would be good time to compare notes. We have a synthesis meeting on 20 Nov and will try to send you an update from that meeting. The connection and comparison with drought is particularly interesting to us. And we have a modeling team that is working on some of the mechanisms. Will let you know when our synthesis conference is scheduled – should be in April 2003.

ii. South Carolina

James Morris (Univ. South Carolina) wrote:

> very interesting! I have heard reports from SC about his happening this summer and I have been advising the SC DNR about how to collect samples. They have not been able to tell me much about it and I have not seen the sites (neither have they). They were about to visit the sites and collect soil samples for me when the rains came. I have seen this happen in Charleston Harbor in 1986. That dieback was widespread around the harbor, in the higher elevations of the marsh, and happened the summer after the Cooper River flow was reduced (harbor salinity doubled) and also corresponded to a drought. That one I think was pretty easy to pin down. There are a number of related variable to look for. If the culprit is salinity, I would expect the diebacks to be in the interior or high marsh areas. Was local water level low during the summer months? Is there an upland area that might be a source of ground water and could this flow of ground water have been reduced due to drought? High salinities can occur on high ground, and it can happen in depressions where flood water collects and evaporates. There is a group of pathologists from LA who hypothesize that plant pathogens can cause Spartina die back. This has never been proven and support is weak at best, but it remains a possibility. There are some, also in LA, who think snail 'eat outs' occur. Indeed, high snail densities have been observed on dead Spartina plants. In my opinion they are attracted to the dead plant and are not the cause of widespread mortality. And there are some who think sulfides might be a cause. Again, I think high sulfides follow a dieback, they do not precede it. Unfortunately, this is one of those phenomena that is always observed after the damage is done, and no one is ever around to collect sample before or during the event.

7. Sources of information

http://www.brownmarsh.net/default.htm
Home page "Salt Marsh Dieback in Louisiana, Brown Marsh Data Information Management System", (aka, The Brown Marsh Site)

http://www.brownmarsh.net/data.htm
Data index linking to specific projects.

http://www.brownmarsh.net/reports.htm
Abstracts for the January 2001 Conference "Coastal Marsh Dieback in the Northern Gulf of Mexico: Extent, Causes, Consequences and Remedies."

http://www.savelawetlands.org/
Louisiana Department of Natural Resources.

http://www.savelawetlands.org/site/crdpage.html
This site includes information on coastal restoration projects.

Appendix A

The continuing research efforts in Louisiana are well-described on the web site, http://www.brownmarsh.net/default.htm.
This site is a source for ongoing results. What follows is an excerpt from that on-line material.

Brown Marsh Response Effort

I. Status & Trends

Aerial photos, satellite imagery, ground assessments

II. Causes

Task II.1
Conduct experimental studies of *Spartina alterniflora* and associated salt marsh plants to determine their tolerance to various environmental stressors and their interactions. Possible stressors may include, but are not limited to, salinity, pH, moisture, metals, and pathogens.

Task II.2
Conduct experimental studies to determine how different hydrologic drivers and different saline marsh soil types will generate plant stressors evaluated in Task II.1. Studies may also include plant-soil interactions. Possible hydrologic drivers may include, but are not limited to, elevation in relation to tidal inundation, tidal exchange, surface and ground water recharge, location relative to adjacent surface water bodies, precipitation, evapotranspiration, and soil permeability.

Task II.3
Conduct field studies to identify site-specific hydrologic drivers and soil characteristics at the salt marsh study sites already established in 2000. Possible hydrologic drivers may include, but are not limited to, elevation in relation to tidal inundation, surface and ground water recharge, location relative to adjacent surface water bodies, precipitation, evapotranspiration, and soil permeability. Possible soil characteristics may include, but are not limited to, soil chemistry, and mineralogy.

Task II.4
In a subset of the salt marsh study sites already established in 2000 and noted in II.3, conduct monthly in-depth vegetative assessments and analyze selected soil physiochemistry variables. Possible biological variables may include, but are not limited to, live and dead stem densities, growth and survival of tagged shoots, expansion or decline in area of surviving patches, stem heights, stem/leaf stress categories, and production of flowers/seeds. Environmental variables, measured in adjacent waterways and at the surface and various depths in the marsh root zone, may include, but are not limited to, Eh, pH, salinity, sulfides, and nutrients.

Task II.5
Compile and analyze historical data sets of external environmental drivers potentially

contributing to the 2000 marsh dieback. Drivers may include, but are not limited to, climate, riverine discharge, coastal water levels, and salinities.

III. Synthesis & Data Management

Websites, workshops, reports on trends, causation, and socioeconomic considerations.

IV. Nutria Control Program

The nutria control projects aims to eliminate damage to wetlands and establish and/or enhance markets resulting in increased price, harvest and control of nutria. Short term objectives 1). To compile, analyze, summarize data that will provide guidance in the development of a nutria control program and 2). Provide data to better explain to the public and decision-makers the consequences of this damage and the need for funding a nutria control program. This information will be essential in seeking funding for a comprehensive nutria control program.

V. Remediation

Projects were awarded on a non-competitive basis with the objective of identifying severely impacted areas and assessing potential for recovery using dredging and vegetative planting.