Update on Coastal Marsh Dieback in Georgia
Prepared for GA DNR – Coastal Resources Division (2013)

Georgia Coastal Research Council

Since 2001, patches of dying vegetation have been observed in Georgia marshes, generally during periods of dry or drought conditions. These events are collectively referred to as salt marsh dieback. Salt marsh dieback is characterized by the thinning and browning of *Spartina alterniflora* and other marsh grasses which eventually leads to plant death. This is a concern because salt marsh habitat is extremely important in the life cycles of crabs, fish, and shrimp, and it also provides food for many wildlife species. In addition, salt marshes help prevent or lessen local flooding.

The best documented incidence of salt marsh dieback occurred in 2001-2002 when reports of marsh areas with little or no live above-ground vegetation were received from all six of Georgia's coastal counties. Estimates of affected areas exceeded 1,000 acres. New dieback sightings were reported in 2007; however this event was not as widespread as the previous dieback episode. In September 2011, Georgia DNR Coastal Resources staff began to receive reports of new areas of marsh dieback along the Jerico River, one of the worst hit areas in the 2001 dieback. As of spring 2013, salt marsh dieback had been reported in areas along the Jerico River, the St. Simon's Island causeway, and in Camden and Chatham Counties.

Fig. 1: Marsh dieback in Georgia: (A) Aerial photograph of a marsh dieback area on the Jerico River in 2002 (Matt Ogburn); (B) Marsh dieback in Liberty County, 2011 (Jan Mackinnon); (C) Healthy salt marsh environment on Sapelo Island (www.science.kennesaw.edu).

To date, no single cause has been found for salt marsh dieback. However, it appears that drought is a crucial factor that triggers a chain of events that leads to this phenomenon. This update provides a summary of current and recent research activities that have been undertaken to evaluate salt marsh dieback in Georgia and South Carolina.

Research projects

Association with drought: A number of studies have been conducted concerning the effect of drought conditions on marsh dieback.

- A project led by L. Palomo (University of Georgia) compared soil samples from a 2009 dieback area on Sapelo Island to those from a healthy marsh to determine whether they responded differently to periodic, severe and persistent, or no drought conditions in the laboratory. The results indicated that drought induced short-term (<monthly) fluctuations in oxygen levels, which subsequently

caused significant changes in the microbial and chemical pathways of salt marsh soil. Dry conditions promoted the chemical breakdown (oxidation) of dissolved metabolites, lowered soil pH, and promoted nitrifying/denitrifying microbial activity. ***The findings suggest that 1) drought-induced soil acidification may not be sufficient to cause marsh dieback, and 2) the geochemical changes brought about by drought could affect the release of metals from marsh soils****.*

- In a 2011 study, GA DNR CRD worked with M. Alber (University of Georgia) and C. Franklin (Savannah State University) to sample marsh sites along the Jerico River that were undergoing a dieback event. *S. alterniflora* samples were collected from healthy, transition, and dieback areas and analyzed for a variety of metals to determine whether any metal concentrations were dangerously elevated. ***The results showed that the average concentrations of many metals (in particular boron, calcium, chromium, iron, potassium, magnesium, sodium, phosphorus, and silica) were highest in affected areas. However, the concentrations were generally lower than those previously reported for Georgia marshes, and did not suggest that any of the metals were directly toxic to the plants.***
- A study by a team of researchers led by A. Hughes (University of South Carolina) examined variations in marsh soil hydrology and chemistry in a salt marsh in North Inlet, SC, that experienced dieback in 2001 to determine whether drought conditions changed the chemical state of the water found in the soil (porewater). ***They found that, while seasonal chemical changes did occur in the winter and spring, they did not coincide with the marsh dieback period.*** Drought can also change porewater chemistry by increasing salt concentration through evapotranspiration. Porewater samples in this project were collected during a moderate drought and did show elevated salinity levels. Further statistical analysis found that two sharp salinity increases in marsh soil occurred at the beginning of a drought period, immediately before dieback was observed at the site. ***The researchers concluded that a large salinity increase occurring over a short time period was the probable trigger for dieback in the study area.***

<u>Insect damage</u>: Two studies have shown that infestation by stem borer larvae may play a role in marsh dieback.

- Research by C. Franklin (Savannah State University) found that stem borer larval damage to *S. alterniflora* can lead to loss of apical (tip) growth. ***Morphological study of injured stems revealed xylem vessels that were clogged with what was possibly a buildup of metal salts (Fig 2).*** Findings suggest that drought-induced changes in pH may result in higher mobility of heavy metals such as iron in the marsh sediment. This in turn leads to higher plant absorption of metals and greater accumulation in the xylem vessels. As the clogged vessels become increasingly unable to transport water, plant death ensues.

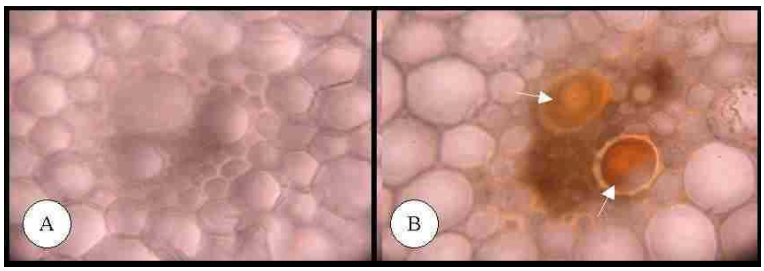

Fig.2. Cross sections of rhizomes of *S. alterniflora* plants from healthy marsh (A) and dead marsh (B) sites. Clogging of xylem vessels (arrows) is seen only in samples from dead marsh sites (Franklin 2013).

- A research project by J. Gaeta and M. Kornis (University of Wisconsin) measuring the frequency of stem borer larvae in healthy marshes and dieback areas on Sapelo Island, found that stem borer

frequency was nearly three times higher in dieback sites compared to that found in sites with healthy *S. alterniflora*. ***The researchers suggest that, while not a direct cause, stem borer infestation may worsen marsh dieback conditions.***

Plant stress: Early detection of disturbed areas before the vegetation shows visible signs of stress can be difficult. Several recent studies have looked at concentrations of metals and organic molecules in *S. alterniflora* as potential indicators of environmental stress.

- W. Kiehn and J. Morris (University of South Carolina) measured the concentrations of DMSP in *S. alterniflora* collected from a South Carolina dieback site. DMSP (short for dimethylsulfoniopropionate), is a chemical that is synthesized by the plant and thought to be converted to DMSO (dimethyl sulfoxide) in response to stress. Elevated DMSP levels were found in plants receiving salicylic acid treatment, indicating that DMSP production is linked to the salicylic acid pathway. Salicylic acid is directly involved in physiological responses to salt and osmotic stress in plants. ***Lower levels of DMSP were observed in the leaves of plants nearest the edge of a dieback area compared to those farthest away, suggesting that DMSP concentration responds to environmental conditions connected with salt marsh dieback.***
- A research project conducted by C. McFarlin (University of Georgia), examined both the DMSO:DMSP ratio and the metal content of *S. alterniflora* collected from areas affected by marsh dieback and other disturbances. The highest concentrations of 19 of the 20 metals evaluated were found in plants collected at edge and disturbed areas. In addition, the DMSO:DMSP ratio was found to be higher in plants from disturbed areas as compared to nearby healthy areas. ***These results, which occurred in plants that appeared healthy (chlorophyll levels were not affected), suggest that the DMSO:DMSP ratio and leaf metal concentrations can potentially provide an early indication of stress in S. alterniflora.*** As a follow-up to these observations, McFarlin is now working on a project for CRD to evaluate the DMSO:DMSP ratio of *S. alterniflora* in 20 salt marshes that span the length of coastal Georgia in order to determine whether it is possible to establish index values for DMSO:DMSP that can be used to evaluate marsh health more broadly.

Invertebrate abundance: It is not just plants; marsh invertebrate populations are also affected by dieback.

- C. McFarlin worked with a team of researchers from Georgia and Louisiana to evaluate the effect that dieback has on marsh organisms. She found that in Georgia marshes the abundance of all groups of organisms including snails, fiddler crabs, and both larger and smaller organisms found in the soil, decreased in dieback as compared to healthy areas, and that their abundances increased in association with increases in *S. alterniflora* density. A second drought led to a further decrease in organisms, particularly in the dieback areas. ***The study concluded that the presence of vegetation corresponded to increased soil moisture and better habitat for organisms***.

Marsh dieback recovery: Researchers are studying the recovery of areas affected by dieback.

- University of Florida researchers C. Angelini and B. Sillman found that *S. alterniflora* transplanted into dieback areas in the wet 2009 season varied in their ability to withstand the dry conditions of 2010, with smaller patches of dieback being more vulnerable. *S. alterniflora* transplants in smaller patches (< 1 m^2) showed little expansion unless competing neighboring plants and snail grazers were removed, whereas larger patches (> 20 m^2) were able to migrate into dieback areas. ***These results***

indicate that the size distribution of remnant marsh patches as well as the frequency and intensity of stressful events (e.g., droughts) affect the speed of recovery and the ability of marshes to withstand stress.

- Investigators affiliated with the Georgia Coastal Research Council continue to monitor recovery in areas originally affected by dieback in 2001. C. McFarlin (University of Georgia) analyzed ten years of data collected at two of these sites (one with *S. alterniflora* dieback and one with *Juncus roemerianus* dieback). ***Dieback areas in both sites had begun to recover by September 2004 in plots closest to the healthy marsh, and by 2012 plants in the Spartina site were of similar height, whereas those in the Juncus site were still significantly different in 2009 (Fig 3).*** Soil conditions fluctuated temporally but did not differ between healthy and dieback areas over time. This recovery pattern suggests that proximity to healthy marsh is important for regrowth in the dieback areas, and that the process occurs slowly.

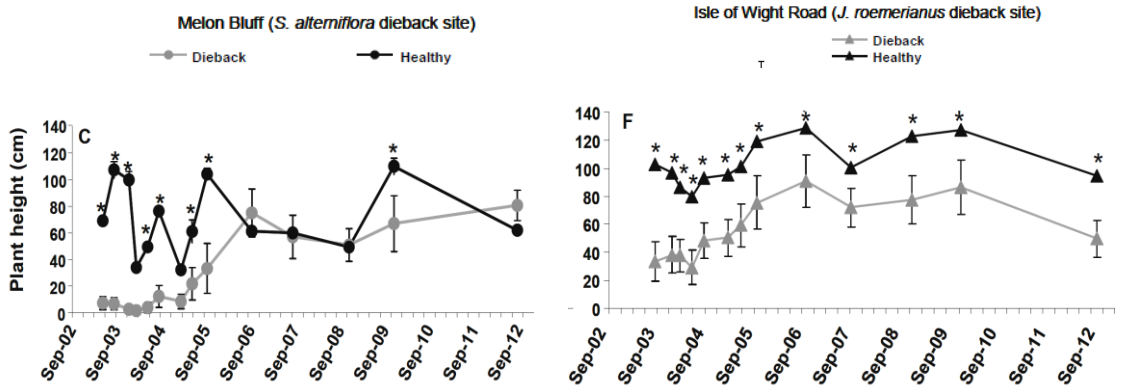

Fig. 3. The variation in plant height of the five tallest plants within healthy and dieback plots over time at the *S. alterniflora* dieback site Melon Bluff (C) and at the *Juncus* dieback site Isle of Wight Road (F). Asterisks indicate that the healthy and dieback zones were significantly different on sampling dates.

- M. Frischer (Skiddaway Institute of Oceanography) led a team of researchers that sampled pristine, recovered, recovering, and constructed marshes over an annual cycle. They used plant, water quality, and animal data to **develop a model that can be used to classify the health and productivity of *Spartina alterniflora* dominated salt marsh environments,** based on a scale from 1 – 32. Using this model, the researchers were able to ascertain that ammonia levels in die-back impacted marsh areas are higher than in unaffected areas.

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