The Case of the Dying Marsh Grass

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Front cover: Mike Materne and Irv Mendelssohn: Brown marsh restoration planting experiment along Bayou Lafourche.

For more information and all reports from this study go to www.brownmarsh.net

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Brown Marsh—What is it?

While assessing nutria damage during a routine flyover in May 2000 in southeast Louisiana marshes Louisiana Department of Wildlife and Fisheries biologists noticed extensive areas of dead and dying marshes. They observed that salt and brackish plant communities of smooth cordgrass (*Spartina alterniflora*) and wire grass (*Spartina patens*) were not green, but rather various shades of brown and black–an indication that they were stressed. Yet some plants in the same areas, such as the black mangrove (*Avicennia germinans*) and black needle rush (*Juncus roemerianus*), appeared mostly healthy. As the summer wore on, brown areas and dead marsh became more widespread and concern for the survival of Louisiana's coast grew. Louisiana's intertidal salt marshes suffered from this browning throughout 2000 and 2001.

This phenomenon of browning and dieback of marsh plants has since been called "brown marsh" or salt marsh dieback. With many coastal Louisiana marshes already deteriorating rapidly and marsh loss approaching 25 square miles each year along the Louisiana coast, the brown marsh phenomenon was quite alarming to coastal managers, scientists and people living and working along the coast. Their concern was that large scale marsh losses from brown marsh would increase the rate of wetland loss and further threaten Louisiana's well being, its coastal resources and economy.

What Does Brown Marsh Look Like?

Healthy marshes from the air and ground appear intact and are a vigorous green. Brown marshes that are moderately impacted consist of intact marshes (no soil exposure) with some vegetation that is spotted, yellow, red or brown. Severely impacted marshes are characterized by most or all brown vegetation with some soil exposure. Dead marshes may have standing dead plants or stubble present with exposed soil or they may be completely without vegetation.

Salt marsh dieback severely affected interior marshes but the marsh shoreline plants were not affected.

In some areas smooth cordgrass was reduced to stubble.

The large scale dieback that occurred in 2000 was termed "brown marsh" due to its unique reddish signature. Most of the marsh was dead; by late winter of 2000 all deteriorated leaving large areas of bare and loose mudflats.

Brown Marsh Challenges the State

After evaluating risks to the safety of coastal residents and a potential annual loss of $90 to $111 million to the state's fisheries and economy, Louisiana Governor Mike Foster responded to the crisis by signing an Executive Proclamation on October 23, 2000. The Proclamation declared salt water marsh dieback in Louisiana a State of Emergency. Shortly thereafter, the National Ocean and Atmospheric Administration provided about $3 million to Louisiana for a comprehensive study of the problem in order to find possible remedies to address this and similar emergencies in the future. The research program was developed through a collaborative effort led by the Barataria-Terrebonne Estuary Program (BTNEP). The salt marshes in Terrebonne and Lafourche parishes were hardest hit by brown marsh in June 2000. About 27 percent (106,000 acres) of the intertidal salt marshes in those parishes were severely impacted and 38 percent (146,000 acres) were moderately impacted.

Few live plants survived severely affected sites.

The Brown Marsh Research Program

The brown marsh research program brought together a multidisciplinary team of 64 scientists from 17 institutions to work on determining the extent, progression and potential causes of the phenomenon. The team, which included biologists, ecologists, modelers, geographers, climatologists, geologists, chemists, soil scientists, hydrologists and agronomists, also explored ways to control nutria and remediate and restore marshes that were damaged.

To meet the challenge, coastal managers, researchers and local citizens posed many questions that were addressed in the research effort.

- How much of the coast was impacted?
- Did marshes recover or become progressively worse?
- What caused the marsh dieback?
- What were the potential economic impacts?
- What were the impacts to natural resources and coastal communities?
- How can we control nutria?
- What can be done to restore affected coastal marshes?

The research approach led scientific teams to address five general areas: status and trends, causes, nutria, remediation and synthesis. The status and trends team determined where and how much of the coast was stressed. Much of the effort was focused on mapping, using a variety of methods to assess the extent and level of damage. Ground surveys were conducted and a variety of remote sensing tools of different scale and resolution were used to get an in-depth picture of the phenomenon.

The causation team addressed several potential mechanisms that could induce marsh dieback by analyzing historic climate data and conducting field studies and a series of controlled laboratory and greenhouse experiments. This effort covered several different disciplines. Some focused on biotic agents that can damage or destroy marsh plants such as fungal pathogens and animals, while others focused on environmental factors such as hydrology (water flow), climate, drought, salinity and soil chemistry.

Nutria are known to cause problems by stripping marshes of vegetation while feeding. Because their population size could be a major factor in speeding up wetland loss, the nutria team focused on the animal's life history, the socioeconomics of the fur industry and nutria population control methods.

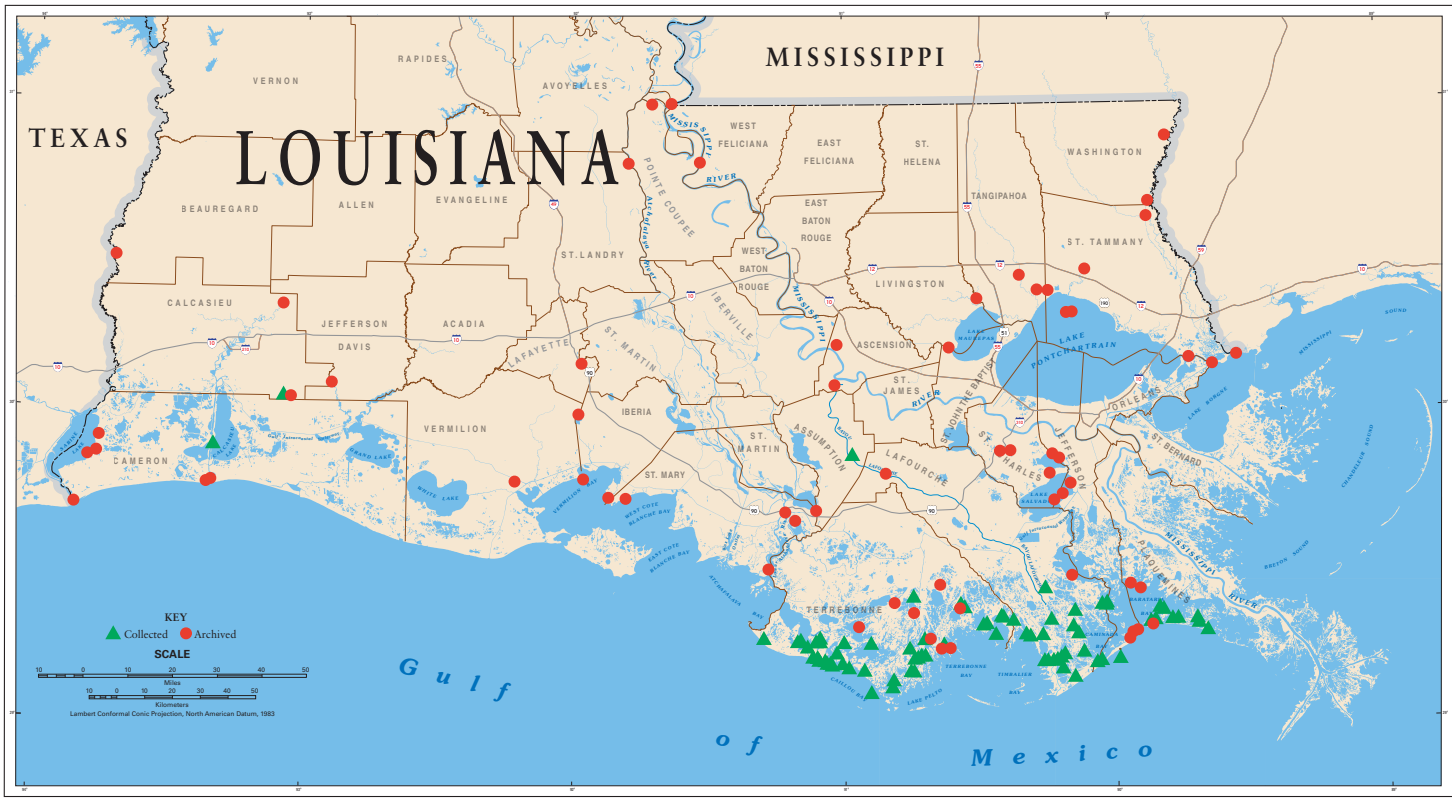
The remediation team investigated various ways to restore stressed and destroyed marshes including seed collection, broadcast seeding, vegetative planting, fiber mats, sediment application and engineering options.

The synthesis team reviewed economic implications, ecological impacts and long term impacts and sought long-term lessons. All the research is reported in technical reports which can be viewed at www.brownmarsh.net.

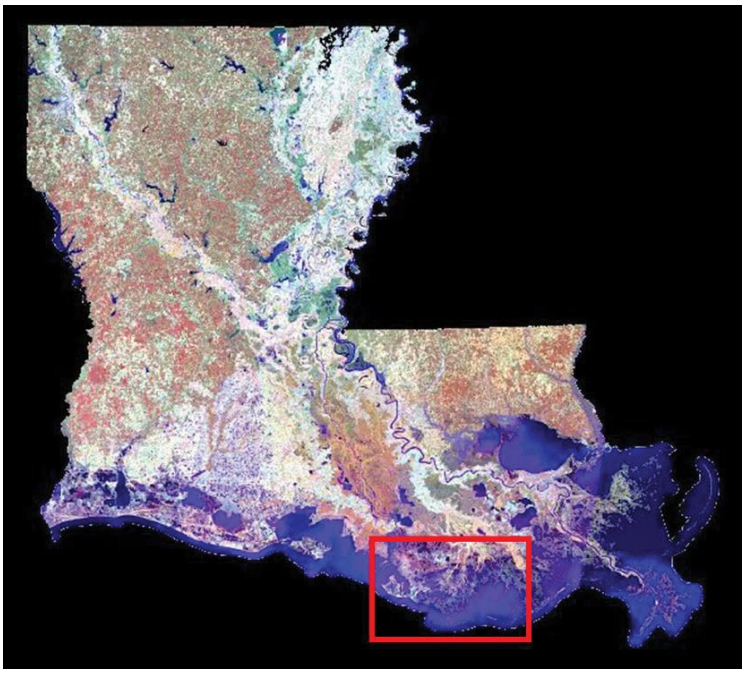
The brown marsh research covered different disciplines in the laboratory and in the field.

Nutria Adds to the Problem

Nutria are invasive animals in Louisiana. Annual surveys have revealed that about 80,000 acres of Louisiana coastal wetlands can be impacted at any one point in time by these animals. They feed voraciously by pulling up entire plants to eat tender shoots and roots of marsh plants, turning lush marsh into bare mud. One way to reduce the negative effects of nutria on the health of marshes is to control the size of the population using poisons, alterations in fertility or capture programs. The Coastwide Nutria Control Program, administered by the Louisiana Department of Wildlife and Fisheries, is the state's current best option for nutria control. It offers trappers and hunters a $4.00 incentive per nutria tail and has been very effective. Since the program began, the area impacted by nutria has been reduced by one-third. Nutria herbivory damage continues and many damaged sites may not recover naturally. The state continues with aggressive nutria control to help maintain the stability of Louisiana's marshes.



Brown marsh affected the entire coast of the state. Red dots depict locations where historical data was used and green triangles are sites where data was collected during the brown marsh project.



The ground team visited many areas across the state to evaluate brown marsh and recovery. Detailed studies of hydrology, soil chemistry, and plant cover, condition and recovery were focused on four main sites that were hardest hit. These sites were at Bay Junop/Bayou de Grand, Lake Felicity, Old Oyster Bayou and Bayou Sale.

Brown Marsh – Is it Unique?

Marsh diebacks are not uncommon; in fact they have been reported in many parts of the world. Recent small scale salt marsh diebacks have occurred in Texas, Florida, South Carolina and Massachusetts. In 2002, Georgia's coastline suffered about 1,000 acres of salt marsh dieback.

In the natural cycle of marshes, diebacks usually occur when plants are submerged for too long, which causes changes in the soil chemistry. The plants suffer from these changes, especially from hydrogen sulfide toxicity. They become stressed and/or die. These dieback areas generally are small – less than one acre – and the plants often grow back within a few years. These are considered historic diebacks because they occur frequently when water levels remain unusually high for a longer-than-normal period. The sudden brown marsh that occurred in Louisiana in 2000 was different. It was a sudden dieback which appeared to have been triggered by *too little* water rather than too much.

Can Stressed Plants be Detected Using Satellite Imagery?

Hyperspectral analysis uses optical image data collected from a new generation of satellite sensors. The sensor directly assesses plant health by analyzing plant leaf pigments and structural changes. One task during this project tested and linked changes in the hyperspectral data to the health of marsh plants at the leaf level. Results of this task were then used to monitor overall marsh health thus providing a reliable way to regionally monitor and assess marsh health from satellite image data.

Marsh diebacks are not new to Louisiana either. Dieback of smooth cordgrass and wiregrass marshes in Louisiana was reported as early as 1970. However, these historic diebacks were limited to small patches in localized areas and were presumably caused by waterlogging. The 2000 marsh dieback was different. It was extensive and the cause was not waterlogging. In fact, Louisiana's salt marsh dieback in 2000 and 2001 was the largest ever reported in the U.S. Dieback areas averaged about 32 acres and ranged from ¼ acre to about 1,100 acres.

Brown Marsh – How Extensive?

To determine how much and where Louisiana's marshes were affected by the dieback event, several tools were used following the Louisiana Department of Wildlife and Fisheries' initial estimate of 100,000 acres of affected marsh in 2000. Remote sensing capitalized on high resolution satellite imagery of the entire Louisiana coast, detailed photo interpretation of high-altitude aerial photography in the Barataria-Terrebonne estuary, hyperspectral analysis of specific areas, monthly low-altitude aerial surveys of the coast and helicopter surveys combined with nutria surveys and ground assessments at specific sites. Together these approaches for interpreting the landscape created a more in-depth picture of where and how extensive the damage was, the progression of the phenomenon and the rate of recovery.

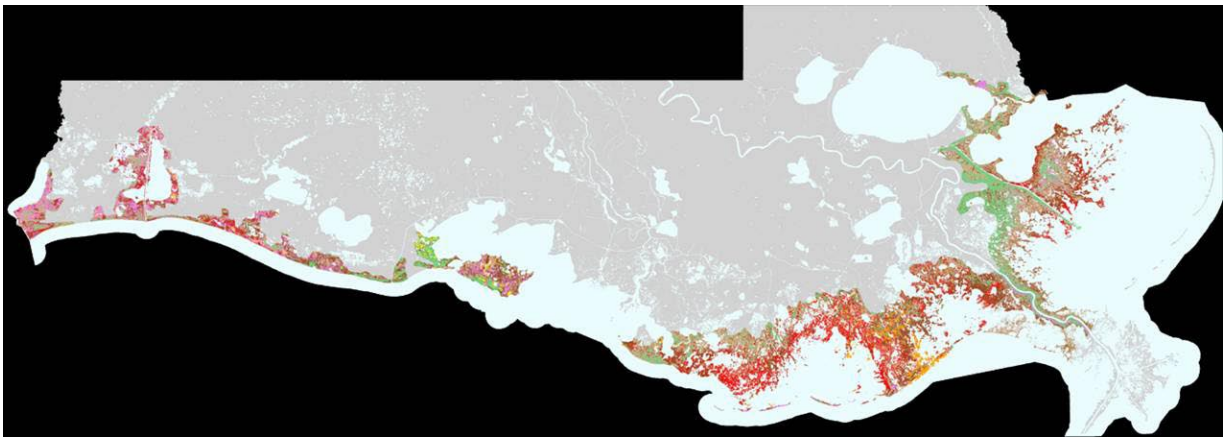
Landsat 7 satellite imagery taken from three miles above the earth in November 2000 and 2001 provided an overall view of the state. Satellite data was used to measure plant vigor by estimating chlorophyll levels. About 120,000 acres of Barataria-Terrebonne estuary's most severely browned areas were evaluated using high altitude (60,000 feet), color, infrared aerial photography from October 2000 and 2001. Based upon these analyses, researchers found that about 66,000 acres of the estuary's marsh was weakened or dead and a year later, in 2001, only 42,000 acres were affected in some way.

The satellite images and high altitude photography provide only a snapshot of the event at one specific point in time for each year. The monthly aerial surveys flown at 150 feet painted a slightly different picture by revealing monthly changes in the marsh and the impacted areas. This approach in conjunction with the ground surveys documented a progression of degrading or recovering marsh each month**.** This method may give a less accurate account of the actual affected acreage, but it shows progression and it is quick—results can be determined shortly after the flight with photographs to prove it. Based upon data from monthly aerial surveys, the area impacted by brown marsh statewide was about 35,000 acres in June 2000, and peaked at 126,000 acres by March 2001. The extent of brown marsh in these aerial surveys appeared to begin to decrease at the end of 2001, and to decrease to about 16,000 acres by June, 2003 when the surveys were completed.

The aerial and helicopter surveys also were able to detect unique patterns in marsh dieback. Spatially, marsh interiors appeared to be severely affected, while the marsh shoreline appeared relatively healthy. Brown marsh also appeared to affect only specific plant species. Both of these observations were confirmed on the ground. In the salt marsh, smooth cordgrass and wire grass were most affected while other plants in the same areas such as black mangrove and black needle rush were mostly healthy, and appeared unaffected.

Not all estimates of aerial extent of the dieback were within the same range. Satellite based estimates of total brown marsh area were about four times greater than the aerial surveys and the aerial photo interpretation. These differences could be due to the date the image was taken or the limits of the index used for the satellite estimates. The satellite analysis may have identified all types of plant stress whereas the aerial surveys and aerial photo interpretation were specifically identifying brown marsh.

Monthly aerial surveys of brown marsh sites were flown in USGS's small Cessna 185 amphibious aircraft with a pilot and observer.



Satellite imagery shows general areas of brown marsh. The red, brown and yellow depicted areas severe, moderate and low impacts from brown marsh.

The brown marsh patterns were different in the state's eastern and western marshes. Three-fourths of the state's total brown marsh occurred in the salt marshes east of the Atchafalaya River and 97 percent of that brown marsh occurred in saline and brackish marshes. Of the remaining 25% of dieback, west of the Atchafalaya River, almost all was in fresh or intermediate marshes. We do not know why there was a difference.

Environmental Conditions Set the Stage

Before the brown marsh event, several climate related conditions came together to set the stage for the unusual circumstances that affected Louisiana's marsh communities. The brown marsh phenomenon occurred towards the end of one of the most severe droughts recorded in south Louisiana. In1999 and during the brown marsh event of 2000, salinity of coastal Louisiana waters was at the highest levels recorded in 30 years. In addition, these high salinity levels persisted well into the summer, lasting three to four times longer than usual. Lower-than-normal coastal water levels added to the stress. Fresh water flow into the system was low, too. This was caused by a combination of unusually low precipitation (rainfall two-thirds to one-half normal), low Mississippi River flow and low local stream flow. A climate factor that may have contributed to these conditions was La Niña. It appears that 1998 through 2000 was dominated for 18 months by a La Niña event which resulted in far-below normal rainfall. Together these climatic conditions or "drivers" created harsh conditions that stressed wetland communities and may have increased their vulnerability to another stressor.

This aerial view shows that marshes at Bay Junop/Bayou de Grand were completely dead in March 2001. In this area the plants along the marsh shoreline are relatively unaffected.

This marsh at Bay Junop/Bayou de Grand was severely affected by marsh dieback in May 2000. The dark green areas are mangroves.

All of the marshes on Pelican Island (between East Bay Junop and Gulf of Mexico) suffered from marsh dieback, however mangroves (green) were not.

Black needlerush alone in the middle of dead marsh.

One pattern of marsh dieback was that interior marshes were affected by brown marsh but marsh shorelines were not.

Salt marsh dieback affected smooth cordgrass (brown, red/brown and yellow areas) but not mangroves (green) or black needlerush.

Causes of Brown Marsh

Brown marsh dieback posed many challenges to the state's research community. To identify potential causes of dieback, the causation team assessed several factors that affect marsh plant health in field, laboratory and greenhouse experiments. The team investigated hydrology, rainfall, soil drainage and soil moisture and evaluated soil chemistry by testing soils for pH, salinity, metals and toxins such as sulfide.

Once in the field, they found that these factors individually were within the known tolerance limits of smooth cordgrass. Unfortunately they had no way of knowing what the conditions were like before the dieback because there was little field data available for these areas prior to discovery of the dying marsh. The problem presented to the causation team was puzzling. What kind of stressor would affect smooth cordgrass, but not mangroves and black needlerush?

Field studies by LSU and the USGS in Baton Rouge and at the National Wetlands Research Center in Lafayette were initiated by late summer 2000 at a variety of sites in dieback areas throughout the Barataria-Terrebonne estuary to characterize soil and plant conditions and assess vegetative recovery. The researchers examined vegetative cover by species, assessed the condition of the plant communities, looked for patterns in the dieback areas over time and investigated the possibility of snail, insect and fungal pathogen infestation. They eventually pointed to a regional factor that interacted with local patterns of soil chemistry and/or hydrology as a possible cause of the dieback.

El Niño, La Niña

La Niña is part of the El Niño Southern Oscillation which is a global-scale atmospheric phenomena in which sea surface temperatures in the eastern tropical Pacific Ocean oscillate between a phase when there is abnormal warming of the surface waters (El Niño), and a phase when the surface waters are cooler (La Niña). Due to large scale atmospheric interactions, the Gulf of Mexico coast is characterized by wetter than normal winters and springs during an El Niño event, and drier than normal winters and springs during a La Niña event.

Laboratory studies of soil salinity tolerance of black mangrove, black needlerush and smooth cordgrass revealed that smooth cordgrass had a higher tolerance to salinity than black needlerush.

The ground team evaluated plant density at brown marsh sites using a grid to count plants.

Early on, it was agreed that the drought, low water levels and low stream flow allowed salinity levels to increase and stay high over a longer-than-normal period. Because of this, salinity was first targeted as the cause, but there were doubts. Although salinity was high, it was within the tolerance levels of all the species of plants that were affected. At most, salinity appeared to play a secondary role in the dieback.

Eventually, researchers concluded that brown marsh formed as a result of several interacting factors that were triggered by drought conditions. There was no single cause, no smoking gun. In a nutshell, under severe drought conditions and other interacting factors, plants became stressed or died because of low soil moisture combined with physical and chemical changes in the soil that likely resulted in soil oxidation, soil acidification and metal toxicity. Somewhat elevated salinities and fungal pathogens may have played a secondary role in salt marsh dieback by further stressing the already weakened plants.

Researchers outside Louisiana point to the snail, Littorina as contributing to some salt marsh dieback. Although dense populations were observed in some dieback areas in Louisiana, the snails were not always present in the dead and dying marshes. The research team found no evidence that snails played a major role in the dieback in Louisiana although they may have played a minor role by accelerating decomposition of dead grasses.

Greenhouse experiments found that the effect of different degrees of drought on plants across three different marsh soil types and different salinities was variable on the soil biogeochemistry.

Fungi may have played a secondary role in salt marsh dieback. Many harmless fungi are normally found in smooth cordgrass, but when plants are under stress these fungi can cause a stalk rot that results in dieback symptoms.

Recovery

From the air, signs of recovery became evident after spring 2001. Aerial surveys documented an increase in brown marsh areas statewide through March 2001 which reached a peak of 126,000 acres. A year later, brown marsh areas were half the 2001 peak. By June 2003, only about 7 percent (17,000 acres) of brown marsh areas showed little or no recovery. Recovery in these areas may have been slow for a number of reasons. Perhaps rhizomes did not survive, soil chemistry was unsuitable or the marsh elevation may have been too low for plants to regenerate.

Ground teams also began to see recovery of dieback in several areas by spring of 2001. Recovery seemed to depend upon whether plant rhizomes survived in the area and/or seed germination was successful. In some recovering marshes, very healthy robust communities came back, indicating that the conditions causing dieback were no longer present and not likely to inhibit future plant recovery.

The Bay Junop site was severely impacted by brown marsh. The lines in the photo (top) are boardwalks set up by the ground research team. By June 2003 (bottom) the area was recovering and the boardwalk is difficult to see from the air. The marsh that was bare in 2001 was completely covered with green vegetation in 2003.

Ecological Impact of Brown Marsh

Animals that are highly dependent on salt marsh habitat such as Sheepshead minnow, Diamondback terrapin and Reddish egret were of concern if brown marsh persisted. Twelve resident fishes, reptiles and birds and four wintering birds had the greatest risk because they would be most affected by the reduction of habitat and food sources associated with marsh dieback. Fortunately, much of the affected area recovered and no permanent ecological impact on these populations was detected.

January 2001

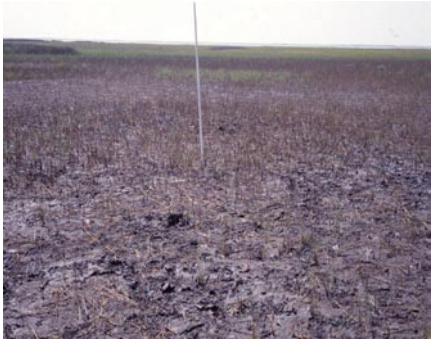
February 2001

August 2001

June 2002

The marshes at the boardwalk at Bay Junop were completely bare in January 2001. In August some plants recovering and by June 2002 the areas were well into recovery.

Marsh dieback occurred in interior marshes while marshes along the shoreline are healthy. Marshes recovered from 100 percent dead in August 2000. By September 2001, this site was recovering and had 60 percent live plant cover.



Ground studies documented severe dieback in August 2000 at some locations and saw vigorous recovery in 2001.

Remediation and Restoration

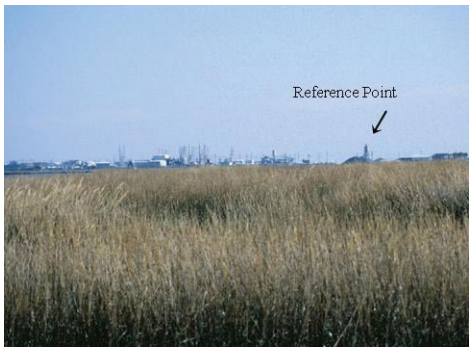
Time is essential. When land loss occurs suddenly and once vegetated areas become bare, immediate restoration is important before hydrologic or other processes further degrade the marsh. Fortunately, natural recovery occurred in many dieback areas within a year, suggesting that the conditions causing the plant dieback were gone and that remediation of the affected areas could be successful and speed up restoration. Therefore several remediation methods were tested on dieback areas.

One successful remediation method to speed up natural recovery that was demonstrated during the brown marsh project was seed broadcasting from small planes. Aerial seeding reestablished vegetation on dieback areas and disturbed soils in saline marshes efficiently and effectively. Another method was replanting with vigorous strains of the plant. Because surviving plants from the dieback areas were believed to be more resilient to stress, some plants and seeds from several dieback sites were collected and cultivated in the laboratory and then successfully planted in dieback areas. The research showed that a combination of aerial seeding and direct planting in areas affected by brown marsh were ideal methods for restoring destroyed marshes quickly.

Preventing erosion of exposed marsh soil is a critical concern in dieback

Aerial seeding of smooth cordgrass offers an attractive, cost efficient, and non-invasive way to re-vegetate large areas. Aerial seeding has the potential for vegetative restoration in inaccessible areas in coastal environments. One acre can be planted in about eight seconds.

March



December

Aerial applied smooth cordgrass seed has proven to be an effective means of establishing vegetative cover on highly disturbed soils and in marsh creation projects.

Dispersing smooth cordgrass seed from the air was successful. This ground view shows an even distribution of seeds on moist exposed soils where seeds are quickly embedded.

Vegetative planting was one method tested to restore dead marshes at the Felicity site. This photo shows the typical pattern of dead marsh interior with a transition to a healthy marsh in the background.

Seedling survival and growth 90 days after aerial seeding yielded one plant per square foot. This is a significant improvement compared to hand planting using vegetative transplants.

Smooth cordgrass seedlings became well established in coconut mat experiments.

A small dredge was used near Leeville to test the success of restoring brown marsh sites by applying a layer of sediment before replanting.

areas following plant death. Substrates need to be high enough for seeding or replanting to be successful. Coconut fiber mats that were impregnated with vegetation proved to be a good option to stabilize eroding shorelines. Smooth cordgrass was easily established in the geotextile fiber while several other species including seashore paspalum *(Paspalum vaginatum)* successfully colonized denuded marshes in the field and proved to be ideal for restoration of degraded wetlands.

Many dieback areas were too low to seed or plant. In these cases, adding sediment was necessary before seeding or planting could occur. A dieback area near Leeville was used to test restoration techniques using a small dredge. Researchers examined both the practicality of applying dredged material to interior marsh areas and the importance of elevation for successful vegetative marsh restoration. The small dredge method was a success for applying sediment to interior marsh areas to elevations ranging from 5 to 14 inches thick–a difficult task for conventional dredges. These results are important because the ability to deposit the optimum elevation of sediment is extremely important to successfully establish vegetation. These restoration studies increased understanding of marsh restoration and may stimulate quick-response restoration actions in the future.

Future of the Louisiana Marsh

Louisiana's marshes are valuable nursery areas and habitat for birds, mammals, fish and people. Marshes have many functions. They provide a livelihood for those who live there and recreation for those who visit. They provide storm surge protection and filter pollutants for the immediate and adjacent lands and water. Marsh loss is serious, whether long-term from erosion and subsidence or sudden from marsh dieback or storms. Because the plants bind the sediment together, as plants die, coastal land loss is accelerated and habitat diminished. Clearly, the vitality of marsh plants is extremely important to sustain healthy marshes. The key to survival and regeneration of marshes is to restore them under conditions that are favorable to plant growth.

The brown marsh project brought together many scientists of many disciplines from universities, federal and state agencies and the private sector to solve a problem that was critical to the health of Louisiana's marshes. The result of the work is an increased understanding of the processes that affect marshes and ways to remediate and restore them, whenever or wherever brown marsh or other sudden diebacks occur again.