

FINAL REPORT:

Restoration of Sea Oats (*Uniola paniculata*) with Mycorrhizae on Galveston Island

Rusty A. Feagin¹, Rick E. Koske², Jane N. Gemma², & Amy M. Williams¹

¹Spatial Sciences Laboratory, Department of Ecosystem Science & Management Texas A&M University, 1500 Research Pkwy., Ste. B223, College Station, TX 77845

²Dept. of Biological Sciences, University of Rhode Island, 100 Flagg Road, Kingston, RI 02881-0816

A report of the Coastal Coordination Council pursuant to National Oceanic and Atmospheric Administration Award No. NA07NOS4190144. This work was supported by National Oceanic and Atmospheric Administration (NOAA) and Texas General Land Office (GLO) grant #08-020.



This work was supported by National Oceanic and Atmospheric Administration (NOAA) award # NA07NOS4190144 and Texas General Land Office (GLO) grant #08-020 to Dr. Rusty Feagin at the Texas Agricultural Experiment Station/Texas AgriLife Research/Texas A&M University.

Dr. Rick E. Koske and Dr. Jane Gemma, University of Rhode Island, were involved in the study in the form of a subcontract, and participated in all aspects of the project. Amy Williams was involved in data analysis and writing of the report.

Contact Information:

Dr. Rusty Feagin
Spatial Sciences Laboratory
Dept. Ecosystem Science & Management
Texas A&M University
1500 Research Parkway, Ste. B223
College Station, TX 77845

+01-(979)-862-2612 (phone)

+01-(979)-862-2607 (fax)

feaginr@tamu.edu (email)

Abstract

Sea oats (*Uniola paniculata*) is native to Texas coastal sand dunes, but has been eliminated from Galveston Island in the past. We set out to re-introduce *U. paniculata*, particularly the Caminada variety, while simultaneously assessing whether Arbuscular Mycorrhizal Fungi (AMF) could assist in the restoration effort. AMF are symbiotic fungi and have been shown to be particularly important in helping plants survive in nutrient-stressed environments such as coastal sand dunes. In nursery-based experiments, we found that the addition of AMF to the sediment significantly increased the root growth of *U. paniculata* during the propagation phase. In May 2008, the plants were subsequently planted in the field at three restoration sites, yet AMF addition made no significant difference to further plant growth. In September 2008, Hurricane Ike destroyed all of the restoration sites. Still, this project revealed the difficulty of obtaining the native Caminada variety of *U. paniculata*, the importance of symbiotic AMF in the plant propagation phase of a restoration project, the susceptibility of *U. paniculata* to drought relative to other native plants that could be used, and the possibility that hurricanes are likely a major culprit involved in the disappearance of this species from Galveston Island.

Introduction

The image of sea oats (*Uniola paniculata*), with its tall stems and majestic seed-heads, is a classical icon that graces Texas coastal literature, photos, and paintings. Coastal management literature often features images of *U. paniculata*, as can be seen on the inside cover of the Texas General Land Office's Coastal Management Program Guide. Sea oats seem to be synonymous with the beach and dune ecosystem in Texas.

However, there are no *U. paniculata* plants of the native Caminada variety left on Galveston Island, except in paintings and pictures on the walls of hotel rooms. This genetic variety is apparently limited to the Western Gulf (Subudhi et al. 2005) and its seeds are essentially unviable (NRCS 2005). Restoration has been done previously using this variety (NRCS 2008) and specific recommendations have been made regarding its planting, although not on Galveston Island. This variety of the species spreads primarily through rhizomatous runners and forms large clumps on the tops of the dune. These traits are not favorable on an island where historical overgrazing and modern development have wiped out any local source from which the species could spread (Feagin et al. 2005). The few Caminada variety plants that have been propagated on Galveston were grown in the nursery, did poorly, and were never transplanted to natural dunes.

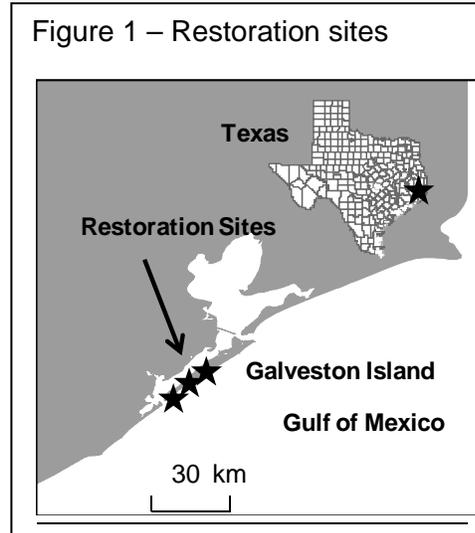
The failure of these Caminada plants to thrive at the nursery may have resulted because of the absence of symbiotic Arbuscular Mycorrhizal Fungi (AMF, organisms that grow in the roots and help the plant acquire nutrients from the sand). Coastal dune researchers have shown that plants of some of the major dune-building species often cannot establish or are very slow to grow in dune sediments when the fungi are absent (Sylvia, 1989; Gemma and Koske, 1992, 1997; Greipsson and El-Mayas, 2000). Because these AMF generally are lacking in non-vegetated sites on sand dunes (Koske and Gemma, 1997), restoration of barren dunes by seeding or planting with nursery-grown stock may be ineffective if AMF inoculum is not added. Recently, a few restoration projects on Galveston Island have begun to utilize the Eastern Gulf variety of sea oats with seeds that have high viability, are easier to propagate in the nursery, and are readily available from growers and plant material suppliers. Still, little is known about whether AMF is more beneficial to plants when incorporated into the growing medium in the nursery propagation phase or in the field during the outplanting phase. Because of its lower cost, inoculation of plants in the nursery would be preferable to that in the field.

Our primary objective was to re-introduce sea oats, *Uniola paniculata*, to Galveston Island. The secondary objectives were to determine the importance of Arbuscular Mycorrhizal Fungi as an aid for *U. paniculata* growth in dune restoration projects as well as to determine if inoculation of plants in the nursery would be effective.

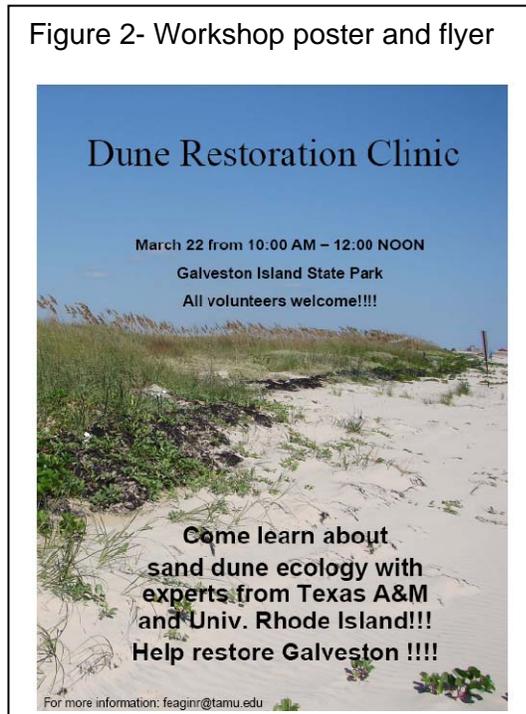
Methods

Restoration Site Selection

We chose two sites for the re-introduction of *Uniola paniculata* to Galveston Island: Galveston Island State Park and San Luis Pass. We chose these sites because they were located on public property owned by the State of Texas, and they were appropriately located to maximize the potential spread of *U. paniculata* across the island (Figure 1).



We also advertised and conducted a workshop on sand dune restoration at Galveston Island State Park on March 22, 2008 (Figure 2), where we recruited local residents to assist with the re-introduction of *U. paniculata*. Subsequently at a third site, the Gulf Palms subdivision, local residents planted *U. paniculata* with plant stock that we had provided.



Acquisition of Plant Stock

We first sought to find and buy the Caminada variety of *Uniola paniculata*, the variety that is native to the Western Gulf. We contacted the UDSA, NRCS Plant Materials Program offices in Kingsville, Texas and Galliano, Louisiana. The Kingsville office could not provide plants. The Louisiana office provided a list of growers, however only one grower claimed to have *U. paniculata* and was requesting a very high price per plant. After consulting with this grower, who refused to discuss where the sediment for the plants came from, it was inconclusive as to whether sediment in the plant pots may already be mycorrhizal. If the sediment and plant roots were already mycorrhizal, the experiment could not be carried out because there would be no control treatment (a treatment with no mycorrhizae). Moreover, we felt that there was a good chance that these *U. paniculata* plants were of the Eastern Gulf variety as well.

For these reasons, we chose to purchase *U. paniculata* from growers in Florida. This plant material was almost certainly the Eastern Gulf variety, as the seeds were viable. Although we preferred the Caminada variety, use of any variety would enable the experiments to be conducted more generally, and would also allow the plants to potentially spread in the future.

Sediment and Mycorrhizae on Extant Dunes

Prior to restoration, sediment samples were taken at the Galveston Island State Park and San Luis project sites. Samples were extracted from the top 12 cm of the extant sand dunes and then analyzed for grain size distribution, pH, soluble salts, nitrogen (N), phosphorus (P), and potassium (K) content.

Root samples from other native plant species were also collected from the sites. The root samples were processed to identify the major species of AMF that were present and to estimate the extent of root colonization by AMF. Eight samples were collected, with two samples for each of four plant species: *Croton punctatus* (forb), *Panicum amarum* (grass), *Sporobolus virginicus* (grass), *Spartina patens* (grass). We then took several 60 cc subsamples from each sample, isolated all AMF spores, then counted, measured, and identified them.

Propagation Experiments

Prior to reintroducing *Uniola paniculata* at the restoration sites, we conducted an experiment to assess the potential benefit of introducing mycorrhizae into the soil during the plant propagation stage. All 1008 plants were started from seed on February 5 2008 (Environmental Plant Resources, Parrish, Florida), in approximately 200cc tapered liners (5.75 inches X 2.125 inches), and initially fertilized with Actino-Iron (Natural Industries, Houston, TX 77066), as is standard practice in the *U. paniculata* propagation industry. Plants were subsequently grown at the nursery until May 1 2008.

Plants were subjected to one of the following three treatments in the nursery: (1) an inoculation with AMF (a mix of equal amounts of *Glomus deserticola*, *Glomus intraradices* (AZ), and *Glomus clarium*; Reforestation Technologies International, Salinas CA) along with a carrier for the inoculum, (2) the carrier only, (3) a control where nothing was added. We subsequently took 20 plants from each

treatment and dried them, separated the belowground portions (roots) from the aboveground portions (shoots and leaves), weighed root and shoot biomass, and calculated the root-to-shoot biomass ratio.

Restoration and Field Planting Experiments

On May 5-6 2008, we planted the nursery plants at the restoration sites (Figure 3). At Galveston Island State Park, we placed the plants where the back beach graded into the dunes, in an area with low embryonic dunes that were already vegetated (Figure 4). We chose this less-than-ideal location along the beach-dune gradient because the area immediately seaward was covered with beach wrack, denoting an elevation and location that is often inundated during high tides, and the area immediately inland was already covered with 100% plant cover, which likely would have resulted in high competition for the re-introduced plants.

There were six treatments in the field: (1) inoculation (9.2 cc, same as previously-described), (2) 'GroWin' (0.44 g of nutrients), (3) inoculation and 'GroWin', (4) carrier (9.2 cc, same as previously-described), (5) carrier and 'GroWin', (6) nothing added. Each of these six treatments was crossed with each of the three treatments from the propagation portion of the experiment, resulting in a total of 18 different treatment combinations. Treatment combinations were randomly assigned to one of 18 plot locations in the long-shore direction, within a single block. There were two blocks, representing two replications of each treatment combination, resulting in a total of 36 plot locations.

Figure 3- *Uniola paniculata* on the day of the restoration plantings, Galveston Island State Park

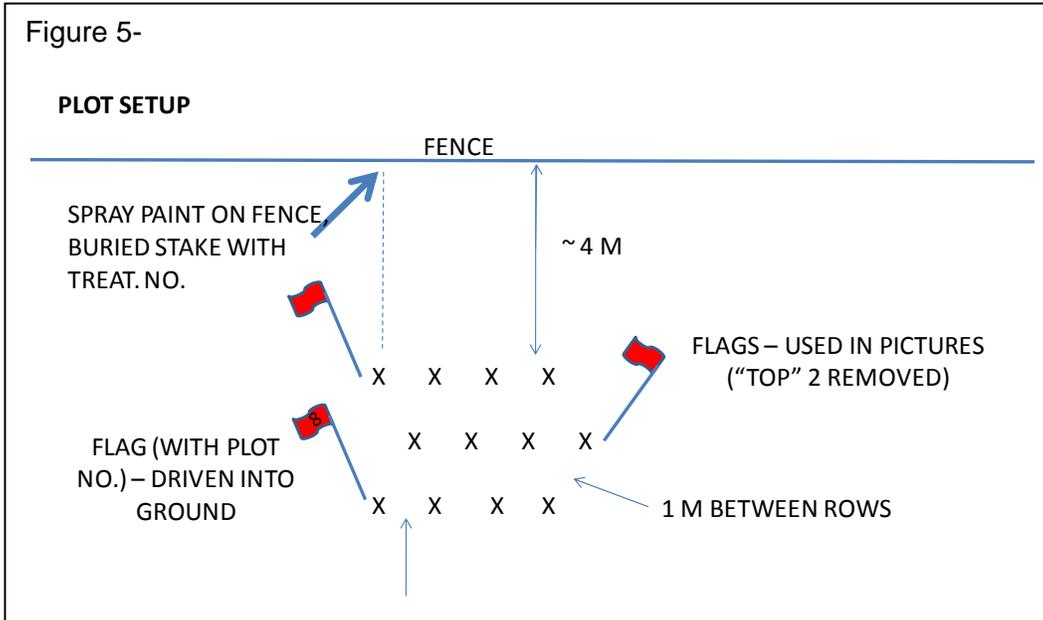


Within a single plot location, all plants were subjected to the same treatment (Figure 5). Individual plants were spaced at 0.5 m intervals in the long-shore direction, and 1 m intervals in the cross-shore direction (between rows). Rows were offset from each other by 0.5 m, and plot locations were offset from each other by 1.5 m.

Figure 4- Location of plantings along beach-dune gradient at Galveston Island State Park



Figure 5-



For planting, we first dug a small hole ten inches deep, added one of the six possible treatment materials and mixed it with sand at the bottom of the hole. We then planted a single plant, and refilled the hole with the original sand. We did not water the plants and no additional fertilizer was added, although the sand was damp up to two inches below the surface due to recent rains. We took pictures and recorded the species and percent cover of vegetation surrounding each planting location and plot.

After the restoration, a minor drought occurred and no rainfall fell for approximately 1.5 months. We monitored all plants on July 22 2008 for survival, number of stems, length of each stem, and total vegetative length (sum of all stem lengths).

At the San Luis Pass restoration site, we planted the nursery plants in an area with no other vegetation present (Figure 6). We directly planted all plants into the ground without further amendments in the field (thus there were three treatments, based upon the propagation experiment amendments). All plants were planted with 18 inches of space between them, and treatment locations were randomly assigned on a single plant basis. We recorded the location of the plantings using the Global Positioning System, as there were no obvious benchmarks or permanent markers to record location in the nearby area. One corner of the planting area was at 29° 5' 12.222" N and 95° 6' 44.020" W. At this site, monitoring was limited to taking photographs on July 22 2008 and no subsequent measurements were taken of plant growth.

Figure 6- *Uniola paniculata* on the day of the restoration plantings, San Luis Pass



Results

Sediment and Mycorrhizae on Extant Dunes

The sediment at the Galveston Island State Park site was primarily finely-grained sand (Table 1). This grain size is quite fine compared to most beaches and dunes around the USA.

Category	Size (mm)	% Total
gravel or coarser	>2	0
very coarse sand	1-2	0.010
coarse	0.5-1	0.014
medium	0.25-0.05	0.52
fine	0.1-0.25	95.77
very fine	<0.5	3.71

The sediment was also high in salts and low in nutrients (Table 2).

Location	Soil pH	Soluble Salts (mmho/cm)	N (ppm)	P (ppm)	K (ppm)
<i>Galv. Island. St. Park</i>	9.1	0.61	<1	4	55
<i>Galv. Island. St. Park</i>	8.7	0.80	<1	4	50
<i>Galv. Island. St. Park</i>	8.7	0.84	<1	3	55
<i>Galv. Island. St. Park</i>	9.1	0.55	1	3	58
<i>Galv. Island. St. Park</i>	8.8	1.18	<1	3	55
<i>San Luis Pass</i>	8.7	2.06	3	5	70
<i>San Luis Pass</i>	9.6	0.09	1	5	49
<i>San Luis Pass</i>	9.5	0.10	<1	5	43

All root samples from both sites contained AMF structures in 60-90% of the length of the roots. (Figure 7). The abundance of spores in the sediment ranged from 120 to 210 per 100 cc of soil, a relatively high value for sand dunes. We found 15 distinct AMF types (Figure 8). Nine of these were identifiable at the species level, the remainder were limited to the genus level.

Acaulospora scrobiculata

Gigaspora spp.

Glomus – 7 species including *G. aggregatum*, *G. microaggregatum*, and *G. etunicatum*

Scutellospora – 6 species including *S. fulgida*, *S. gregaria*, *S. persica*, *S. verrucosa*, and *S. weresubeae*

Figure 7- Stained roots of *Uniola paniculata* from the nursery. Large blue-stained objects are vesicles formed by the AM fungi.

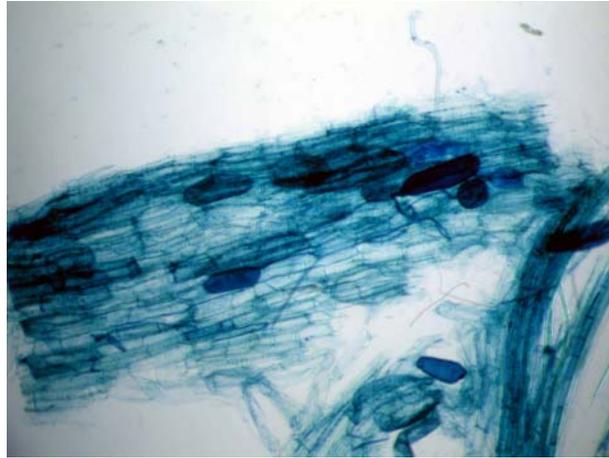
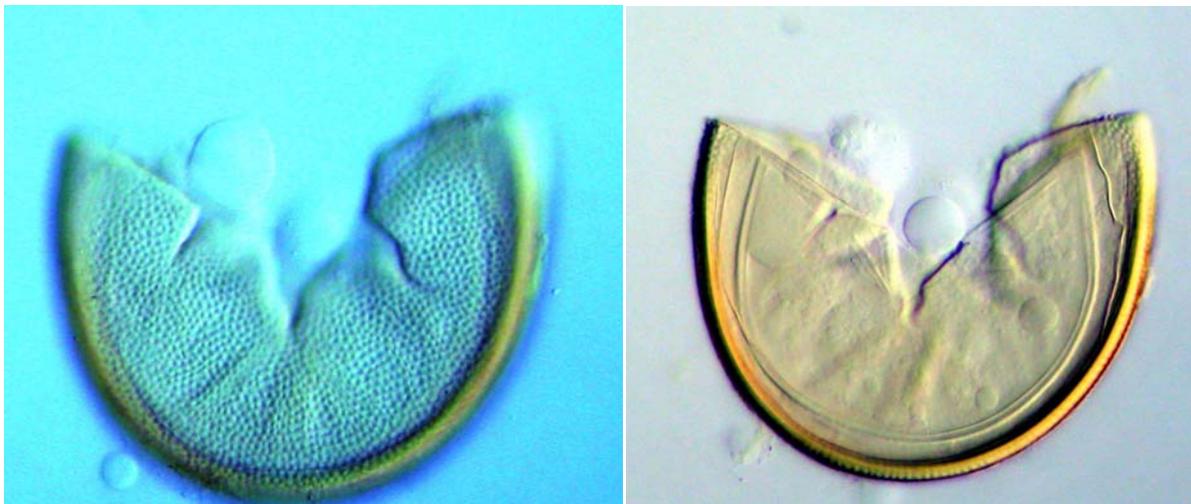
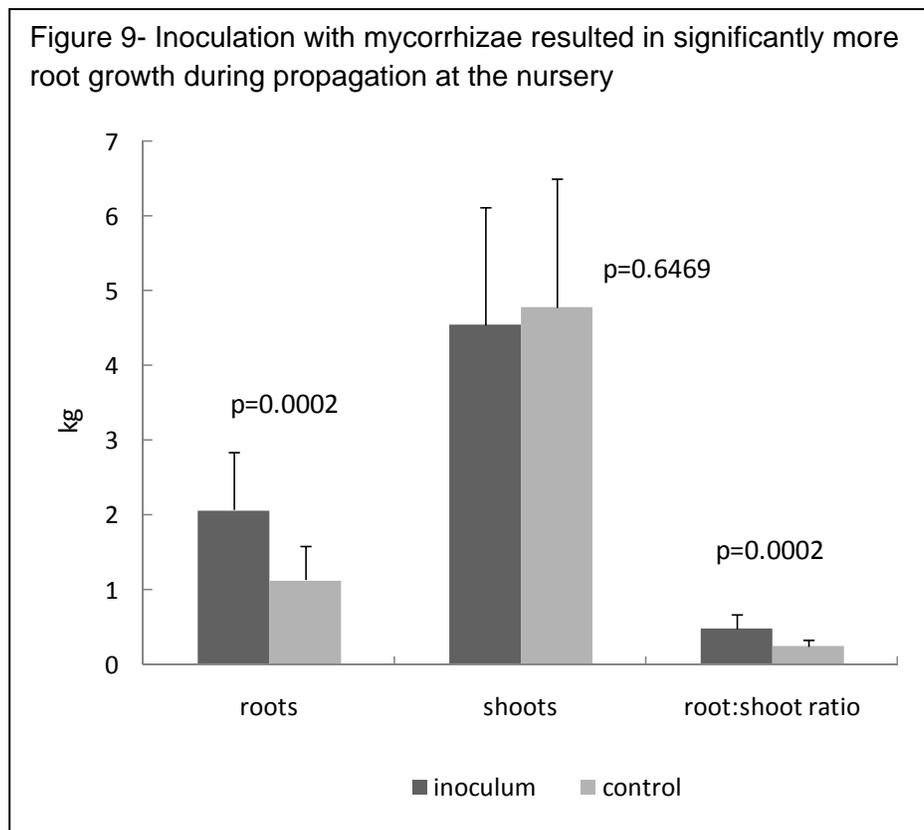


Figure 8- Crushed spores of *Acaulospora scrobiculata*, one of the most common AM fungal species in the dunes. Spore surfaces are covered with indentations similar to those on a golf ball.



Propagation Experiments

In the nursery experiment, *Uniola paniculata* grew more root biomass (kg) when inoculated with mycorrhizae, when compared with those of the control (nothing added) over an approximately 3 month time period (Figure 9). This difference was statistically significant ($p = 0.0002$, where p is a measure of significance, ie here we are 99.98% confident that this difference was not by chance). However, in terms of shoots and leaf biomass, there was no significant differences between the inoculated plants and those of the control ($p = 0.6469$). There was a significant difference for the root:shoot ratio between the two treatments ($p = 0.0002$), due to the fact that the roots were so prolific on the inoculated plants, and this factor weighed heavily in the ratio. We do not present the results of the carrier only treatment here, as they were qualitatively similar to that of the control.



Restoration and Field Planting Experiments

Due to the minor drought that immediately followed the restoration plantings, survival was relatively low. The survival rate for all plants at Galveston Island State Park site was 22.91%. Although such a value is typical of many inland restoration projects, it is quite low for coastal sand dune projects in our previous experience. Still, those plants that did survive were growing well (Figure 10).

Figure 10- *Uniola paniculata* plants growing on August 4 2008 (before Hurricane Ike)



After approximately three months, there were no significant differences for any of the various treatments at the Galveston Island State Park site.

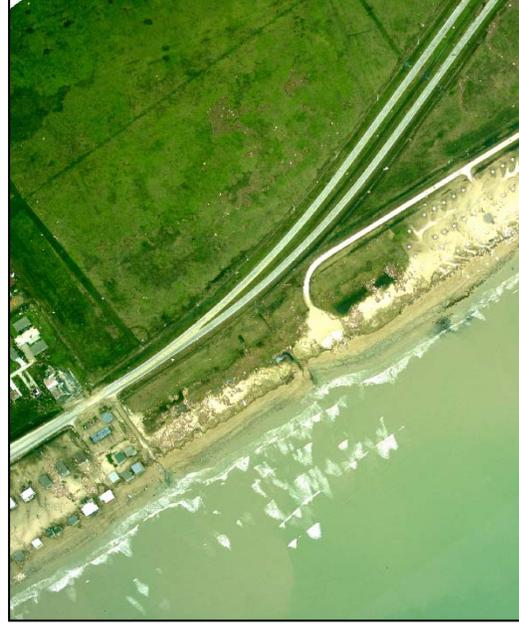
On September 13 2008, Hurricane Ike destroyed all of the restoration sites that we and our volunteers had planted. At the Galveston Island State Park site, the location which had previously been restored sat at the waterline shortly after the storm (Figure 11). At the San Luis Pass site and the Gulf Palms site planted by volunteers, the dunes were completely leveled and the plants were washed away. Thus, after approximately six months, there was 0% survival for all three sites.

Figure 11- Hurricane Ike destroyed the Galveston Island State Park restoration site. Left images are before Ike, right are after Ike. Top images show the general area, bottom images are zoomed in. Restoration plantings were placed even with the black line in the bottom picture, which sits at the exact same location in both pictures. Imagery courtesy of Texas Natural Resource Information System (TNRIS).

Before Ike



After Ike



Discussion

Hurricane Ike ultimately destroyed all of our restoration sites, leaving no plants. Still, we learned several valuable lessons that can be passed on to future attempts at re-introducing *Uniola paniculata* (sea oats) to Galveston Island.

First, there is no seed stock available for the genetic Caminada or Western Gulf variety of this plant, nor is there any readily-available plant stock, regardless of the fact that the USDA had worked to build such a stock in the past. The Western Gulf variety has sterile seeds with effectively zero viability. All of the *U. paniculata* that is currently available is actually a genetic variety from the Eastern Gulf. Although it is ideal to obtain the Western Gulf variety for the restoration projects west of the Mississippi River, it is not possible. The only other possibility is to take cuttings from already established Western Gulf plants growing in the field, but this is both destructive to the few plants that remain on the Upper Texas Coast and has never been proven to work in our experience. Thus, this explains why all restoration projects use the Eastern Gulf variety. Since the Eastern Gulf variety has viable seeds, the long-term outcome of this restoration practice is that *U. paniculata* will likely become a more resilient species on the Upper Texas Coast, but genetic diversity may be lost (Franks et al. 2004).

Second, restoration practitioners should add AMF inoculum to the soil while initially propagating *U. paniculata*. In our experiments, the addition of mycorrhizae significantly increased root growth. However, since mycorrhizae are already present in natural dunes on Galveston Island, a further addition is unlikely to be of similar benefit during field planting stages.

Third, in terms of planting survival, *P. amarum* is likely to be a much better choice than *U. paniculata* for Galveston Island dunes. *U. paniculata*, if planted, needs to be consistently watered for at least the first three months. In our previous experiences, we have seen *Panicum amarum* withstand much longer periods of drought than the *U. paniculata* plants withstood in this project, with little to no adverse effects on their long-term growth (Feagin 2005). Thus, if *U. paniculata* re-introduction is not a priority, we suggest using *P. amarum* for restoration in the Galveston area. Another potential strategy is to plant a mixture of the two plants, with the majority being *P. amarum*, as recommended by NRCS (2008).

Fourth, hurricanes are a fact of life on Galveston Island, and when coupled with the low seed viability of the native Western Gulf variety of *U. paniculata* and historical usage of Galveston for cattle grazing and modern development of the landscape immediately behind most dunes on the island, may explain their absence from Galveston Island. The plants cannot simply re-establish, and for this reason it may be good practice to introduce the Eastern Gulf variety and allow the two varieties to interbreed. Future work could attempt to breed these two varieties in a planned manner, so as to preserve as much genetic diversity as possible while also re-introducing the species to Galveston Island.

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