Implementation of Landscape Management and Native Plantings for the Man-Made Beach in Biloxi, MS

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Introduction

The 42-km beach that extends from Biloxi to Pass Christian Mississippi is the longest man made beach in the world. It was created using dredged sand in 1951-52 to protect an existing sea wall. It has since become a recreational resource and showpiece for this coastal area. The beach creation required 4.6 M m^3 of dredged sand and cost 3 million dollars. The constructed beach width was 80 m and its maximum elevation was 1.5 m above mean sea level.

The loss of sand to erosion has occurred continuously from the time of this beach's creation, requiring periodic renourishment. Three renourishment projects have been conducted to date:

- 1973 - 1.45 million cubic meters of dredged sand at a cost of 1.8 million dollars;
- 1985 - 0.76 million cubic meters of dredged sand at a cost of 2.8 million dollars;
- 2001 - 0.84 million cubic meters of dredged sand at a cost of 5.9 million dollars.

Erosion along the 42 km takes a variety of forms. Wind, predominantly from the SE, blows sand northward over the sea wall and onto the commuter highway that runs just to the north of the sea wall. Removal of this sand has been an ongoing problem and expense for local authorities. Storm water runoff transports sand from the upper beach southward, toward the Mississippi Sound. Littoral currents, and wave erosion from occasional storms, cut into the beach and transport sand into the Mississippi Sound. Erosion mechanisms therefore transport sand both northward and southward off of the beach.

Use of plants to stabilize soil and reduce erosion is, perhaps, the oldest of biological engineering land management techniques. This approach attempts, in so far as possible, to create conditions similar to a stabilized natural site. This has been called "following the natural model." When using vegetation for this purpose, different parts of the plant function in different ways. The plant roots help to hold soil in place in much the same way that reinforcing metal rods strengthen concrete, reducing the effects of shear on adjacent soil particles and distributing erosive energy. The leaves of the plants absorb the energy of raindrops, which can dislodge unprotected soil particles. The leaves and stems increase frictional losses of fluids (air and water) that pass through the planted area. This decreases the velocity of the fluid and its capacity to transport particles. Taken together, these functions can make vegetation an effective armoring technique for reducing erosion. On recreational beaches, vegetation has most frequently been used to stabilize and promote the growth of sand dunes. In natural systems, such as seen on Mississippi barrier islands, the vegetation extends over considerable areas, minimizing erosion throughout (Figure 1).

Figure 1. Beach vegetation on the south side of Ship Island, MS.

Although many plants will provide the physical protection described above, native plants are usually chosen to provide long-term protection. This is because native vegetation is adapted to the conditions of the site and has the greatest probability of persisting over extended time periods. Additionally, species that are selected for planting are typically supplemented by natural recruitment at the site. "Volunteers" that persist often consist of species adapted for site conditions. Natural recruitment can be an important component of long-term erosion prevention.

Water infiltration rate is another factor that affects the amount of soil loss from a site. Storm water that is transported into the soil is not available for surface runoff. A highly permeable soil substantially reduces the volume of water runoff that occurs during a storm. Experiences in agriculture and logging indicate that heavy equipment (e.g., tractors and skidders) compact soil and reduce infiltration. Compaction typically increases both the volume and energy of storm water runoff and promotes concentrated flows that increase the likelihood that erosion will occur.

Use of a natural model to prevent erosion in a highly visible public area can also have an important educational component. A demonstration project can be a valuable teaching tool, both to educate the public about the importance of using sustainable design techniques to meet our needs and to teach about the fundamental processes that occur in the natural systems that the project emulates.

In 1995, the Biloxi Area Chamber of Commerce and the Harrison County Sand Beach Commission set aside a 2 ha beach site to be used in a project to demonstrate alternate and novel beach management approaches. The project, carried out by the Mississippi State University Landscape Architecture and Biological Engineering Departments, has attempted to use plantings of native vegetation to reduce erosion at the site. During the first five years of the project, the site was extensively planted with native and beach species, including *Uniola paniculata*, *Spartina patens*, *Pinus palustras*, *Sabal palmetto*, *Serona repens*, *Sabal minor*, *Myrica cerifera*, *Ilex vomitoria*, Lantana *camara*, *Iva frutescens*, *Quercus virginiana*, *Taxodium distichum*, and *Taxodium ascendens*. Figure 2 shows the experimental site as of 1998. All of these species have persisted on the site although survival rates have been low for some species, reflecting the harsh

Figure 2. Part of the experimental beach in 1998.

nature of the beach environment (2 years is usually required for non-grass species to establish themselves).

During the period 1995-2000, the site endured a number of natural and man-made stressors. The most notable occurred in 1998, when debris from hurricane Georges covered the site. During the subsequent beach clean up, heavy equipment was Inadvertently allowed onto the experimental site. The heavy equipment scraped off most of the surface vegetation. The root mass of most plants was left intact, however, and site vegetation made a rapid recovery. During the period 1995-2000, the site went from being a local topographical low point to a local topographical high point, possibly because of the effects of the vegetation at the site.

In 2000, the Mississippi Alabama Sea Grant Consortium provided funding designed to serve 2 purposes. The first goal of the support was to find a method to enhance plant survival and finish the planting process. In previous years, survival of non-grass planted species was low, due to the harshness of the beach habitat and the absence of supplemental watering. The second goal was to document and investigate the affects that the natural model had on the site that resulted in reduced erosion and accretion of sand.

Methods and Materials

The 42 km man-made beach runs generally east to west along a line from Biloxi to Pass Christian, MS. It borders the Mississippi Sound on the south and a sea wall running along US Route 90 to the north.

The 2 ha experimental site is located at Mirimar Avenue, in Biloxi, MS. The site is separated from the remainder of the beach by a line of poles placed on the east and west ends. Outside of the site, the beach is mechanically groomed using heavy equipment according to a seasonably variable schedule. The "conventionally managed" beach is devoid of vegetation, except for a thin dune line at the northern end. *Panicum amarum* and *Uniola paniculata* are the major plant species found on the dunes. Following the most recent sand renourishment, the beach was graded to extend the beach width, creating a wide flat zone between the dune line and the water's edge.

The experimental site did not receive sand during the most recent renourishment. Heavy equipment has been kept off the site, except for the clean up following hurricane Georges (described above) and occasional storm water drain maintenance near the beach-water interface. The site has not undergone mechanical grooming since 1995, when the "natural beach" was created.

Work on the current project began during March, 2000 and was completed during October, 2002. Specific tasks included:

- Planting of additional vegetation at the site. This task was undertaken to complete a master plan developed by the authors prior to the beginning of the MASGC project.
- Installation of a temporary irrigation system. Temporary irrigation was used to maximize survival and growth rate during the critical early years of vegetation establishment.
- Assessment of the effects of this management approach on the physical characteristics of the experimental beach.
- Survey of the plants found on the experimental beach site.

New Plantings. During Spring 2000, approximately 50 small shrubs were transplanted from a Mississippi Department of Transportation mitigation site to the experimental site (mainly *Iva frutescens* and *Baccharis halimifolia*). Five thousand *Uniola paniculata* were grown at Mississippi State University and planted in rows during 2001. Local high school students and college students from Mississippi State University participated in the plantings. The plants were placed on the beach to enhance the appearance of the site and approach, in so far as possible, the appearance of natural beaches found in the area.

Temporary Irrigation. A temporary irrigation system was installed at the site to increase the rate of plant survival and hasten plant establishment. The irrigation system was connected to city water via 600 m of 2.5 cm line. Water was distributed to trees and shrubs via 600 m of 16 mm irrigation tubing. Irrigation was controlled using battery powered irrigation controllers. Irrigation rate was approximately 16 l/d for each of 75 shrubs and trees during the period June through September for the course of the project. The system was monitored weekly during the first summer of the project and monthly thereafter.

Assessment of Physical Characteristics of the Beach. Selected physical characteristics of the beach were measured on and off site to document the ways that the experimental management approach may have affected resistance to erosion.

Characteristics measured included:

- beach topography
- compaction
- water infiltration rate
- Aeolian sand transport

The section of the experimental beach used for these measurements was a 0.3 ha area (approximately 86 m E/W and 35 m N/S) which represented that part of the beach planted first (in 1995). Measurements conducted on the experimental site were repeated on a 0.4 ha area (approximately 83m E/W and 48 m N/S) located just to the west of the experimental beach (hereafter called the "control site"). The longer N/S distance of the control site was due to the mechanical widening described above.

Topographical Surveys. The experimental and control sites were surveyed in May and again in October 2002, using a total station instrument (Leica, TC-500). In May, fifteen transects were established on each site. The transects ran north to south, with the northern end located at the dune line (approximately 10 m south of the sea wall) and the southern end of each transect located at a beach berm marking approximate high tide for that time of the year. The transects were approximately 6 m apart. Flagged stations on each transect were approximately 3 m apart. Planar (x,y) and vertical (z) measurements were made at each station relative to a benchmark established on the sea wall.

The survey measurements were used to generate mean beach profiles for the experimental and control sites and to calculate mean cross sectional areas for each profile. The profile areas were calculated from the beach surface to a common lower reference elevation (the approximate elevation of the existing beach berm). Since volume is equal to mean cross sectional area times site width (Brinker and Wolf, 1984), the mean cross sectional areas provided an indicator of relative volume of sand contained on each site above the reference elevation.

Following tropical storm Isadore and hurricane Lili (late September - early October, 2002), a limited topographical survey was conducted on each site using the benchmark established in the first survey. The primary purpose of this survey was to assess topographical changes on the control and experimental sites due to the storms. Three transects were shot on each site and profiles compared with the three nearest transects from the previous survey. The records from the first and second survey were then used to estimate how beach lengths (north to south) and beach profiles had changed as a result of the two storms.

Compaction. Compaction surveys were conducted May 18 and June 9, 2002. Compaction was measured on the experimental and control sites using a cone penetrometer (Spectrum, SC-900). The initial survey was limited to 3 transects on the experimental site and 3 on the control site. The transects were oriented north to south from the dune line to the water's edge and were spaced at 12 m intervals. Transect stations were 6 m apart. This survey was conducted one day after a heavy rainstorm.

The second survey consisted of 6 transects on each site. Transect and station intervals were 12 m and 6 m, respectively. This compaction survey was conducted following an extended dry period on the beach.

The second survey was used to compare compaction on the experimental and control sites. The second survey was also compared to the first to determine whether measurements immediately after rain differed from measurements following a dry period.

Infiltration. Water infiltration on the experimental and control sites was measured during June, 2002, using a double ring infiltrometer (Turf-Tec International). The time required and the difficulty of measuring infiltration precluded use of transects. Instead, multiple replicates were made at three locations on each site: near the dune line, at mid beach, and just to the north of the beach berm. These locations were chosen because they had differing exposure to beach processes. Sand near the berm was assumed to be most often reworked by wave action. Sand near the dune line was assumed to be relatively protected from heavy equipment on the control site, and sand at mid beach was assumed to be most vulnerable to the compacting effects of heavy equipment on the control site. Results of these measurements were then compared.

<u>Aeolian Sand Transport</u>. Leatherman tubes (Leatherman, 1978) were constructed in the Biological Engineering shop and used to compare sand transport northward on the experimental and control sites. Six tubes (Figure 3) were located at approximately 15 m intervals near the northern end of each beach site. The tubes were placed on the sites with approximately 1 cm of tube surface exposed above the sand surface to ensure that most collected sand was due to wind transport. The tubes were sampled periodically (periods of 1 day to 2 weeks) through the months of May and June, 2002. Disturbance of some tubes on the control site was relatively common during May-June. After July 1, sampling was discontinued because high beach traffic led to regular disturbance of all tubes on the control site.

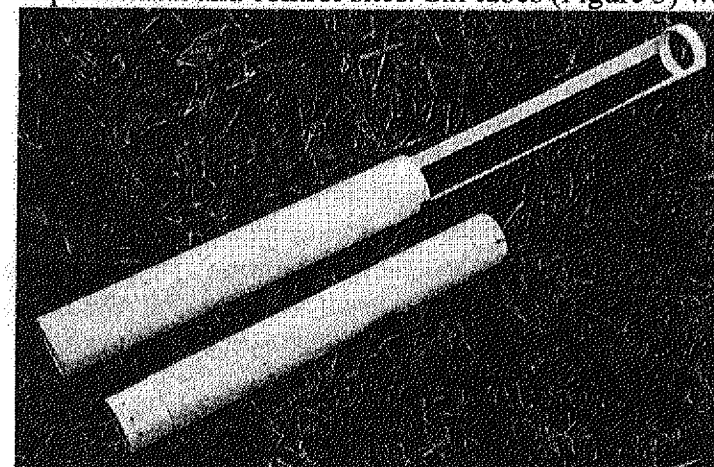


Figure 3. Leatherman tubes used to measure Aeolian Transport on the beach.

Sand samples were air dried after collection. The mass of sand from each tube was measured in the MSU Biological Engineering Water Quality Laboratory using a laboratory balance. Sand masses from the control and experimental sites were then compared.

Survey of the Plant Community. During spring/summer, 2002, a plant survey was conducted. Plants were identified and locations were noted. A site map was then prepared showing plant concentrations on the experimental beach and dominant species in each area. A study guide for the experimental site was prepared which included original plant drawings as well as descriptions for all of the plants identified on the site.

Results and Discussion

New Plantings. The addition of sea oats (*Uniola paniculata*), wax myrtle (*Myrica cerifera*), marsh elder (*Iva frutescens*), and groundsel (*Baccharis halimifolia*) was completed by summer, 2001. Although site coverage would probably have increased naturally, the additional plantings gave the beach a more finished appearance and enhanced its visual attractiveness. Figure 4 provides a planar view of the experimental site at the conclusion of this project. The woody shrubs, when added to the live oak, long leaf pine, and pond cypress already on the site, provide vertical definition to the site. This effect will only increase as the woody shrubs continue to grow.

Plant survival. The sea oats grown at Mississippi State University appear to be doing very well. It's difficult to quantitatively assess survival of so many individual plants, but historically these plants have shown good survival on this site. In the past, growth has been vigorous and planted areas have tended to spread, rather than recede. This appears to be the case for the current crop of *Uniola* as well.

The temporary irrigation system has serviced nearly all the shrubs and trees on the site. For most species there has been nearly 100 percent survival of the shrubs and trees during the course of this project. The exception has been the pond cypress, which appears to be ill suited to the beach environment.

Assessment of Physical Characteristics of the Beach.

Measurements made of selected beach physical characteristics showed pronounced differences relative to the control site.

Beach Profiles. Figures 5 and 6 represent surveyed beach profiles as of May, 2002. The elevations shown are tied to the same benchmark but are not referenced by a standard datum (such as mean sea level). For this reason, the "y" axis of each graph is labeled "Relative Elevation." The profiles for the experimental and control sites differ greatly. Figure 7 shows an overlay of the 2 profiles. The experimental site has a greater elevation than the control site at the northern end of the beach. The control site shows the effects of grading and widening that followed the sand renourishment of 2001.

At first glance, the greater width of the control site would lead one to the assumption that the control site contained a greater volume of sand than the experimental site. As the control site received sand during the recent renourishment and the experimental site did not, this might appear to be a reasonable assumption. When the cross sectional area of each profile is calculated, a somewhat different picture emerges. Using a reference elevation of 0.38 m for the lower boundary of each profile area (the lowest elevation measured on the control site; very near to the current high tide mark), the experimental beach cross section had an area of 15.15 m^2 while the control site cross sectional area was 14.87 m^2 (Figure 8). Surveyors routinely use mean cross sectional areas to calculate volume (Volume = (mean cross sectional area) x (site length)). The nearly identical cross sectional areas indicate that the experimental and control sites contained nearly equivalent volumes of sand above the reference elevation per unit width.

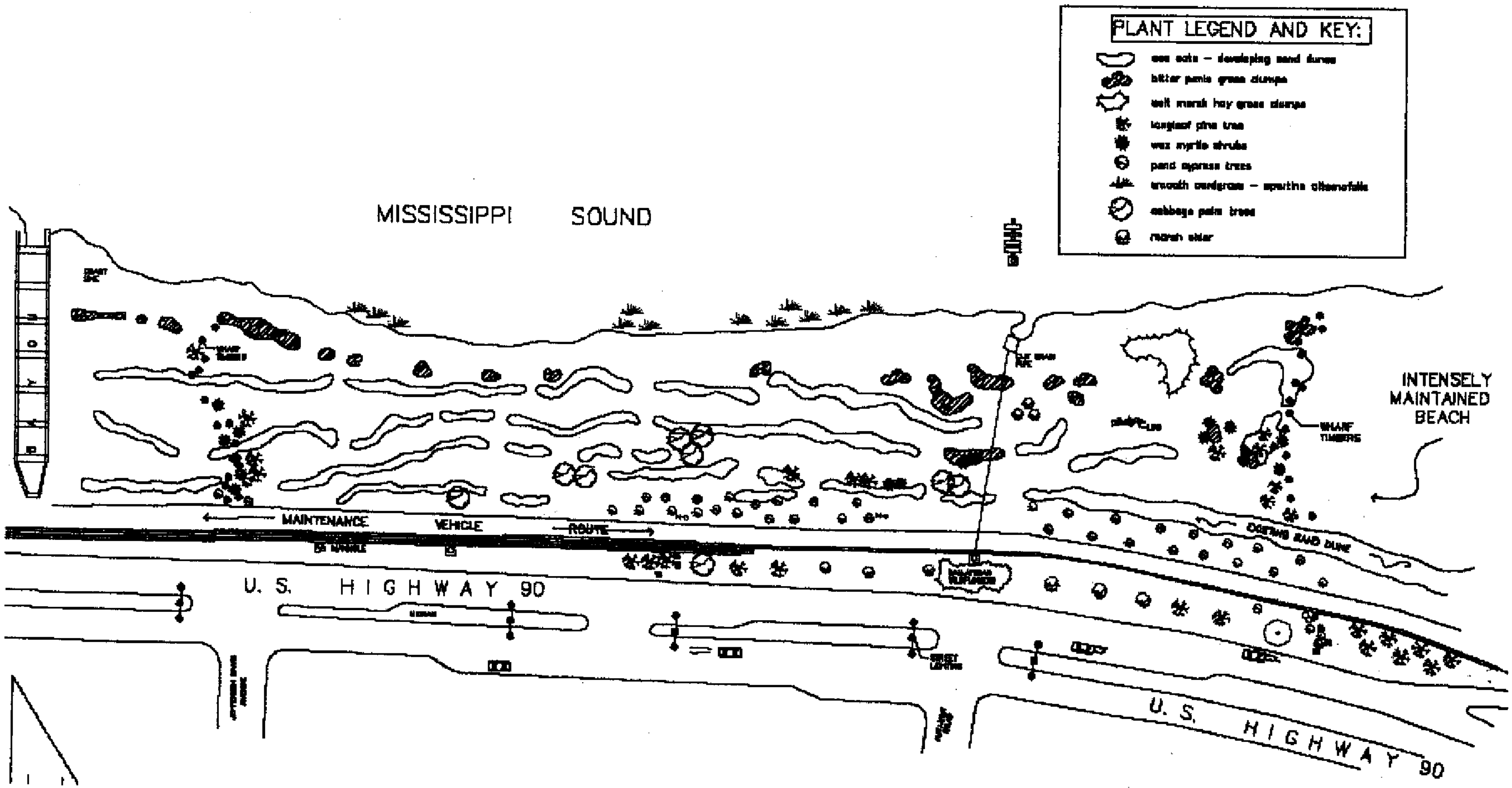


Figure 4. Planar view of the 2 ha experimental site located in Biloxi, MS.

The relative equivalence of sand volumes is surprising. It suggests either that the control site contained substantially less sand than the experimental site prior to renourishment or that the renourished sand was lost after the renourishment process was completed. The first explanation appears more probable given the short time interval between the end of renourishment and the surveys (about 1 year). A third possibility is that the experimental site benefited indirectly from the renourishment that occurred on either side. This is unlikely given the fact that most of the sand volume on the experimental site has accumulated high on the beach. It is difficult to imagine a mechanism by which sand addition to the upper beach could have occurred in the absence

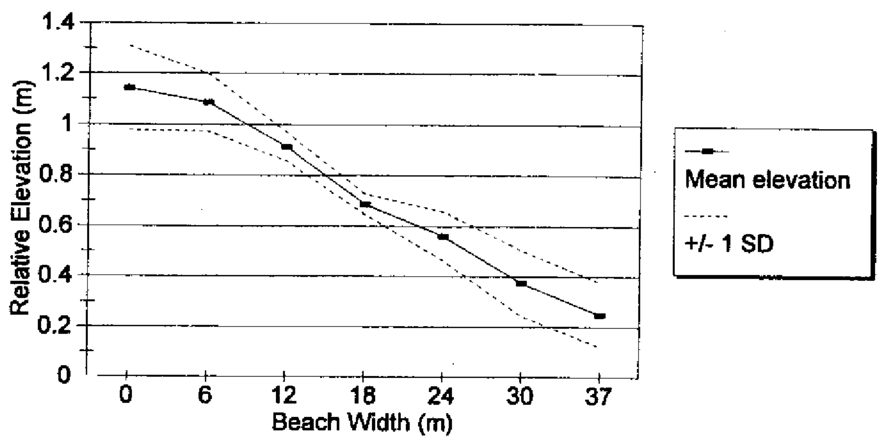


Figure 5. Mean profile elevations and standard deviations for the experimental beach site. Elevations are based on 15 transects.

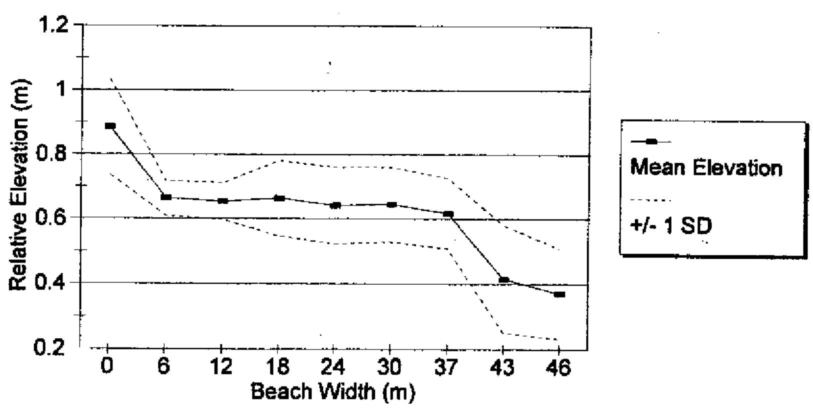


Figure 6. Mean profile elevations and standard deviations for the control beach site. Elevations are based on 15 transects.

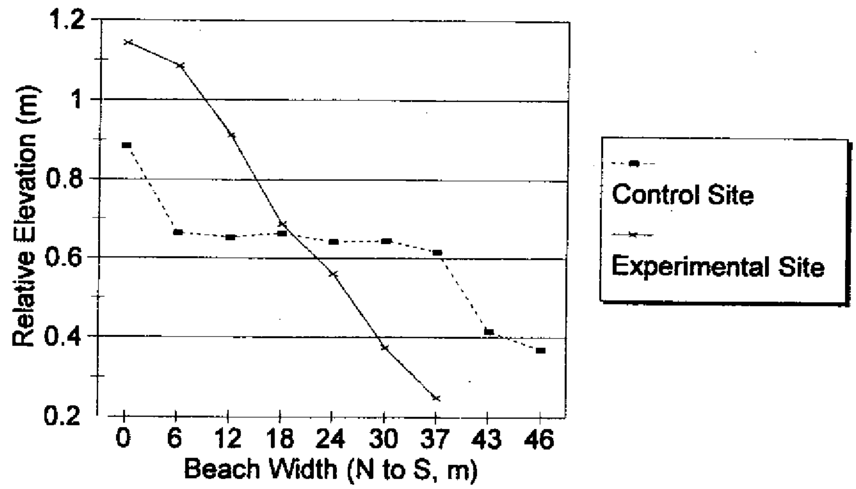


Figure 7. Beach profiles from the experimental and control sites.

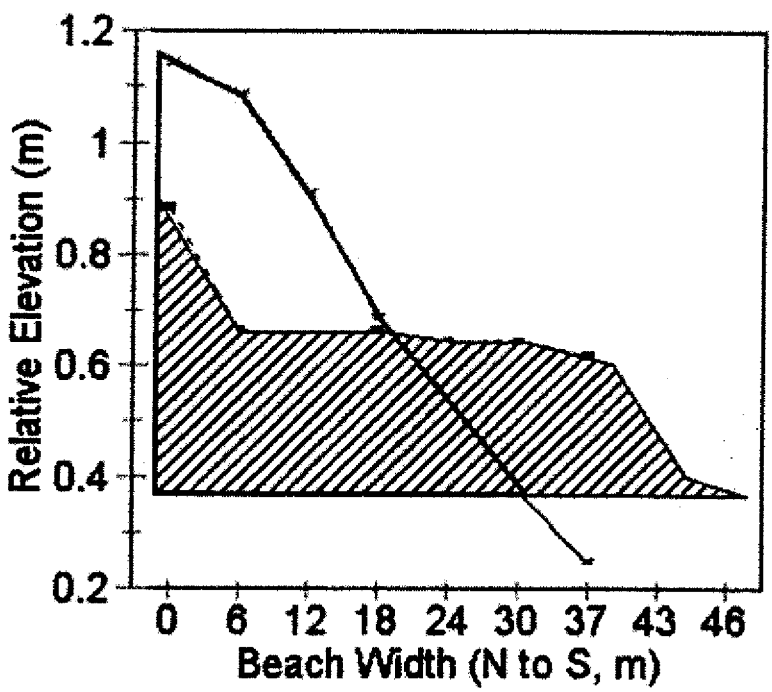


Figure 8. Cross sectional areas based on mean beach profiles. The dark outline represents the experimental site cross section. The filled region represents the control site cross section.

of large storms (there were relatively few significant storm events between the renourishment and the surveys).

The limited survey conducted following tropical storm Isadore and hurricane Lili (September-October 2002) resulted in marked changes in both sites. Figures 9 and 10 show mean experimental and control site profiles, respectively, before and after the

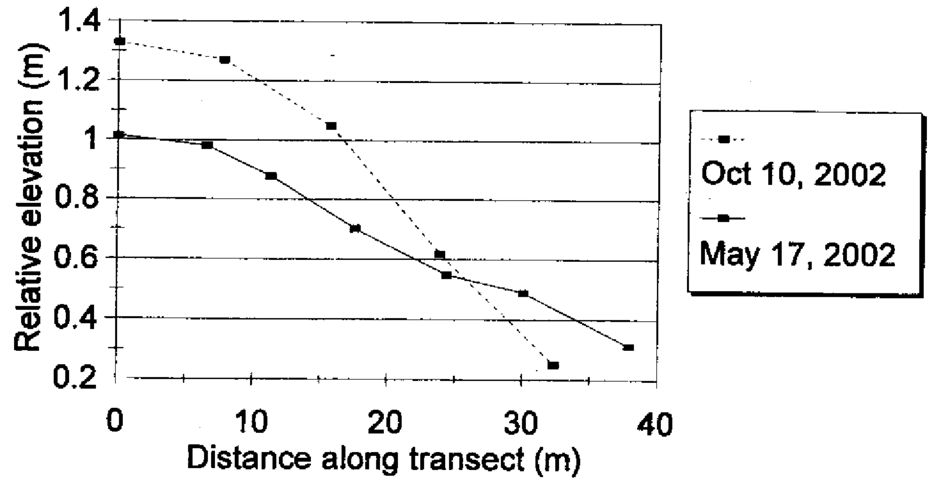


Figure 9. Experimental site mean profiles before and after tropical storm Isidore and Hurricane Lili. Three transects surveyed after the storm were compared to the nearest 3 transects from the pre-storm survey.

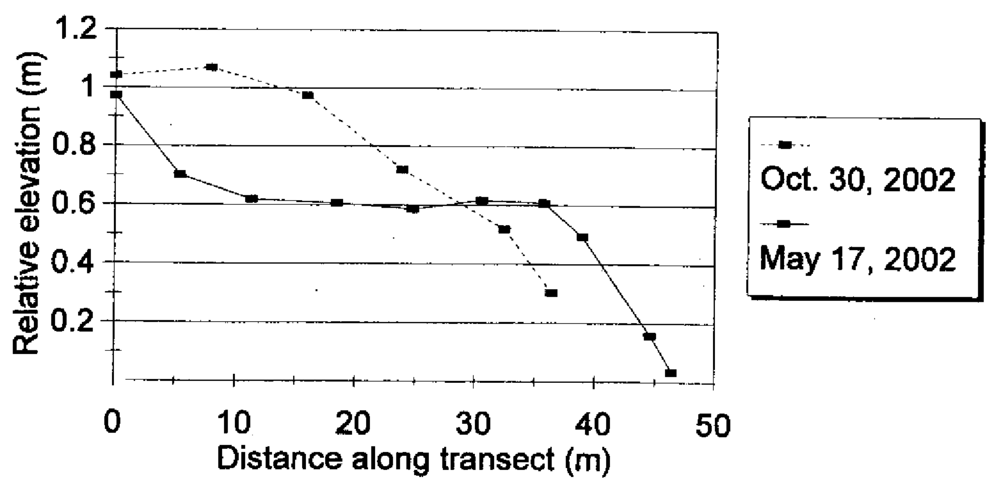
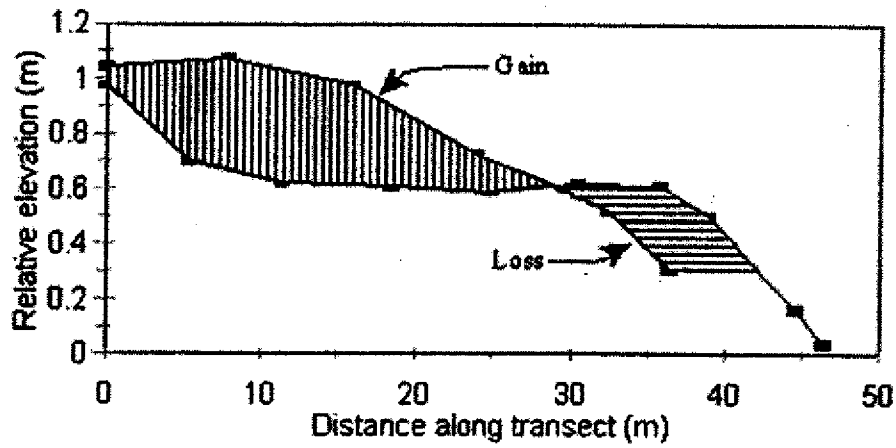


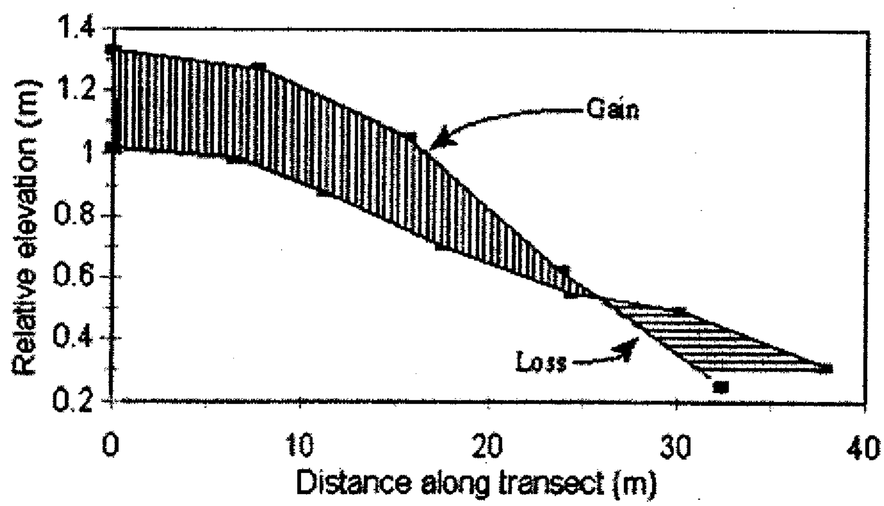
Figure 10. Control site mean profiles before and after tropical storm Isidore and Hurricane Lili. Three transects surveyed after the storm were compared to the nearest 3 transects from the pre-storm survey.

storms. The profile comparisons are based on the 3 transects shot on each site after the storms and the 3 nearest transects on each site from the original survey.

Using a reference elevation of 0.3 m, both sites lost about 6 m of beach width (i.e., N/S planar distance) as a result of the storms. The equivalence of the losses is not surprising. There was relatively little vegetation on the experimental beach near the beach water interface, so there was not a protective root system to help hold sand in place. Cross sectional areas on the experimental and control sites showed a net increase of sand on both sites, despite the loss of beach width. The control site cross sectional area showed an increase of 5.6 m^2 while that of the experimental site showed an increase of 5.4 m^2 (Figure 11). The maximum elevation of the experimental site increased by about 0.3 m while the maximum elevation of the control site only increased by about 0.04 m. The reshaping of the control site by the storm resulted in a beach profile that closely resembled that of the experimental site.



A. Control Site



B. Experimental Site

Figure 11. Mean profile cross sectional area changes on the control site (A) and the experimental site (B) as a result of tropical storm Isadore and hurricane Lili.

Compaction. The amount of sand compaction affects the route taken by storm water runoff. Less compacted soils are more permeable than compacted soils, allowing greater abstraction of precipitation. This is important because surface runoff can be highly erosive. On the Biloxi beach, surface runoff carries sand toward the Mississippi Sound where it can be carried away by littoral transport.

Results from the cone penetrometer measurements are shown in Figure 12. Mean values are based on 6 transects on each beach site. The control site showed a much greater degree of compaction than seen in the experimental site. For equivalent depths, mean compaction pressures were 1500 to 2000 kPa greater in the control site than in the experimental site.

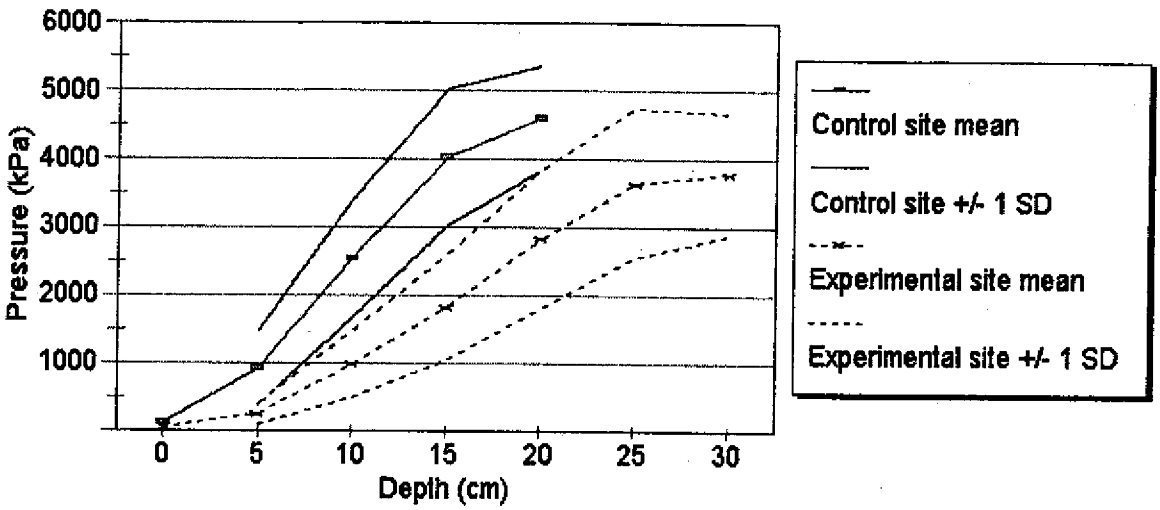


Figure 12. Mean compaction values and standard deviations from 6 transects on the experimental site and 6 transects on the control site.

There are at least 2 possible explanations for the observed compaction differences. First, renourished sand stored on the control site was used to extend the length of the beach seaward. Grading equipment, in the process of moving the sand, may have scraped down into the previous beach profile, exposing what had formerly been subsurface (i.e., more highly compacted) sand. A second explanation for the compaction differences is that the heavy equipment used on the beach may have compacted control site sand. In addition to reshaping the beach following renourishment, heavy equipment is routinely used for beach maintenance and grooming. It has long been known from both logging and agriculture that heavy equipment irreversibly compacts soil, decreasing its permeability to water (Adams, 1998; DeJong-Hughes et al., 2001). It is not possible to determine whether the reshaping process exposed compacted sand. It is likely, given the experience in logging and agriculture, that the presence of the heavy equipment contributed to sand compaction.

Water Infiltration Rate. Differential compaction measurements suggest that water infiltration rate will be greater on the experimental site than on the control site but do not convey information about the magnitude of the difference. Direct measurements of infiltration were made on the experimental and control sites using a double ring infiltrometer (Table 1).

	Location on beach	Mean Infiltration Rate (cm/s)	Standard Deviation (cm/s)	Number of Observations
Experimental Site	Upper	9.6	1.4	3
	Middle	8.3	2.0	8
	Lower	13.4	4.8	3
Control Site	Upper	3.9	1.4	5
	Middle	1.4	Range = 0.2 – 3.8[1]	8
	Lower	1.5	0.4	6

[1] Non-normal distribution (6 observations less than 1.25 cm/s; 2 observations 2.55-3.80 cm/s)

Table 1. Infiltration rate measurements on the experimental and control beach sites. Upper beach = near the dune line; Lower beach = just to the north of the beach berm; Middle beach = roughly equidistant from the beach berm and the dune line.

Near the dune line (upper beach), mean infiltration rate on the experimental site was approximately 2.5 times the magnitude of that measured on the control site. At mid beach, the ratio of infiltration rates was nearly 6 to 1. Near the beach berm, water infiltration on the experimental site was nearly 9 times that of the control site.

The ratio of infiltration rates near the dune line was the smallest of the 3 beach zones considered. This was consistent with the assumption that the extreme upper beach would experience the smallest amount of traffic from heavy vehicles and hence show the least compaction. The highest ratio occurred very close to the beach water interface. It was assumed that sand near the water's edge would be reworked most frequently by waves and that this would result in relatively high infiltration rates. This assumption appears to have been correct on the experimental site, which recorded the highest infiltration rates seen anywhere on the beach. On the control site, however, the mid-beach and lower beach sites had nearly identical mean infiltration rates (1.5 and 1.4 cm/s, respectively). A possible explanation for the site-specific disparity of infiltration rates lies in the measured compactions at the southern end of each site. Figure 13 shows mean compaction for 3 locations on each site: approximately 6 m to the north of the beach berm, at the berm, and just to the south of the berm (just above the water line). On the experimental site, compaction showed a steady decrease from north to south across the berm. On the control site, compaction measurements increased at the berm and decreased slightly at the water's edge.

Differences in compaction on the control and experimental sites lend credence to the assumption that beach equipment and vehicles affects compaction and infiltration rates. The southernmost 10 m of the experimental site is relatively devoid of plants. The only difference between the sites is that beach equipment and vehicles are prevented from entering the site. Use of heavy equipment for beach grooming and grading has already been mentioned. It is interesting to note, in addition, that the beach patrol SUV's drive

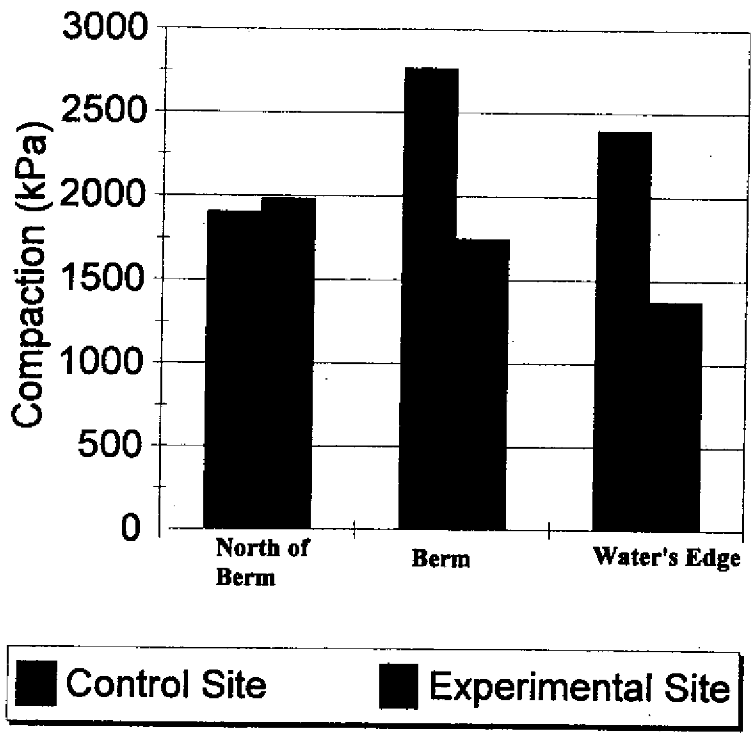


Figure 14. Mean experimental and control site compaction measurements in the vicinity of the beach berm.

most of the beach on a daily basis, and that their preferred route outside of the experimental site is along the beach berm. It is possible that the daily patrols also contribute to compaction near the water's edge.

The measurements of infiltration occurred under dry conditions and it cannot be inferred that these rates will remain constant throughout a rainstorm. The measurements do suggest, however, that more precipitation will infiltrate the beach on the experimental site and correspondingly less will migrate to the Mississippi Sound along the surface of the beach. This is consistent with observations following rainstorms of standing water on the control site and no standing water on the experimental beach.

Aeolian Sand Transport. Unlike storm water runoff, that transports sand from north to south, wind erosion on the beach tends to be from south to north. This is a result of the prevailing (mainly southeast) winds experienced along the Mississippi Gulf Coast. This has caused a continuing problem of Aeolian sand transport from the beach onto U.S. Route 90, which runs east to west just north of the 42 km beach. Historically, considerable expense and effort has been required to remove wind blown sand from the highway. Artificial sand dunes have been constructed on much of the 42 km beach to prevent sand transport onto the highway. Although effective in areas where they have been used, the artificial dunes have been resisted in some areas because they block beach views of residents. Additionally, use of beach grooming equipment in close proximity to the dunes has given the dunes an unnaturally straight appearance and has often damaged the dunes themselves.

Measurements of wind blown sand using Leatherman tubes suggest that beach plants do an excellent job reducing Aeolian transport (Table 2).

	Sampling Date	Mean Sample Mass (g)	Range (max/min, g)	Number of Observations
Experimental Site	5/22/02	0.272	0.076 – 0.776	6
	5/31/02	1.851	1.432 – 2.567	6
	6/06/02	0.459	0.009 – 1.700	6
	6/09/02	1.519	0.238 – 4.909	6
	6/10/02	0.754	0.520 – 1.220	6
Control Site	5/22/02	7.863	2.11 – 14.99	3
	5/31/02	201.28	13.15 – 578.30	4
	6/06/02	127.45	53.86 – 197.75	5
	6/09/02	320.88	18.10 – 488.70	5
	6/10/02	54.58	20.95 – 95.35	6

Table 2. Leatherman tube measurements on the experimental and control sites.

Very large sand masses (in excess of 100 g) may have occurred because standing water following a rainstorm immersed one or more tubes on the control site. The tubes were equally spaced at the northern end of both sites. A portion of the control site did not have a sand dune at the northern extreme and this area may have experienced heavy storm water runoff following rain events. When that occurred, the sand laden water may have contributed to sand found later in some of the Leatherman tubes. It should be noted, however, that some of the tubes on the control site were protected by sand dunes to the north and these also captured sand masses that were 1 to 2 orders of magnitude greater than tubes on the experimental site. A particularly good example of differential sand transport occurred on June 9-10. The sampling period was 15 hours and there was a strong wind (17 to 30 km/hr, according to local records) from the southeast. During this time period, sand transport due to wind on the control site was approximately 70 times the magnitude of transport on the experimental site (Figure 15).

The efficacy of planted surfaces for reducing wind erosion is well accepted (e.g., James and Croissant, 1994). In addition to the protection afforded by the plants, it is also possible that the general shape of the beach may have further reduced Aeolian sand transport on the experimental site. The experimental beach had a nearly uniform slope of about 2.5 percent. The control site, by comparison, was virtually flat for more than half of the total distance from the dune line to the water's edge.

Recommendations and conclusions based on site-specific differences in physical characteristics. Erosion on the 42 km beach appears to have 3 components: Aeolian transport northward, transport due to storm water runoff to the south, and littoral transport at the water's edge. Erosion due to storm water runoff does not, of itself, remove sand from the beach. It appears, however, to deliver sand to the beach-water interface at which time littoral transport carries it away.

The vegetation and the high infiltration rate of the uncompacted experimental site appear to reduce both Aeolian and storm water transport. The steeper slope of the

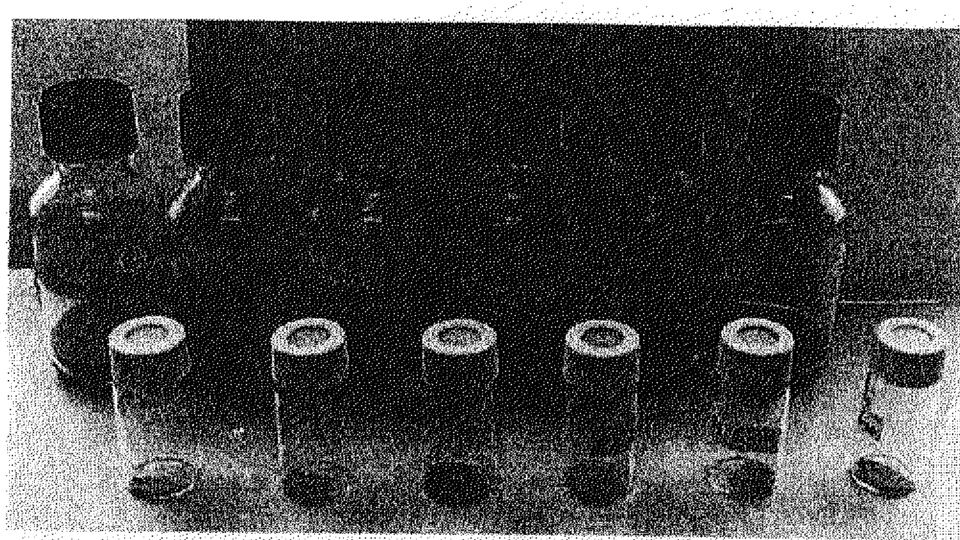


Figure 16. Sand captured by Leatherman tubes on the experimental (small bottles) and control (large bottles) sites over a 15 hour period (6/10/02).

experimental site may exacerbate runoff somewhat. Visual observations on the site, however, only occasionally revealed locations where surface water transport appeared to carry sand southward. In general, surface runoff on the experimental site appeared to be a relatively rare event, with most incident precipitation infiltrating the beach surface.

Given the demonstrated efficacy of planted surfaces for Aeolian sand transport reduction, it appears likely that a strip of vegetation at the northern end of the 42 km beach may perform as well or better than the existing system of dunes. The vegetated areas have the advantage of not blocking the view of the beach and, with proper planning, can be made both natural and attractive in appearance. The optimal width of the vegetated strip is not known but can probably be determined empirically during the creation process.

By necessity, heavy equipment must be kept out of such a planted area. The absence of heavy equipment will allow a modest accumulation of sand in the planted area and may improve infiltration. It is possible that a planned implementation of this approach may include planted areas that extend much of the distance from Rt 90 to the beach-water interface. The capacity of the site to inhibit erosion is probably, to some extent at least, a function of area coverage. The greater the area covered, the greater will be the reduction in erosion due to storm water runoff and the wind.

The experimental site, in its present form, has little effect of littoral transport. Establishment of beach plants nearer to the water's edge and establishment of emergent wetland plants in the water itself is only possible with some sort of temporary or permanent protection from wave energy. Experiences to date on the experimental site (unrelated to the present project) have shown that emergent vegetation can be established, and will persist, given temporary protection from wave energy. It is possible that a temporary structure to allow beach and emergent plants to become established may allow the application of this approach to the water's edge.

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Natural Beach Landscape Environmental Study Guide

Miramar Road and Highway 90– Biloxi, Mississippi

Colony of Emergent Smooth Cord Grass

Biloxi Bay Chamber of Commerce
Department of Marine Resources
Sand Beach Department

Supported by a Mississippi Tidelands Grant
And the Mississippi/Alabama Sea Grant Consortium

Created by the Center for Sustainable Design – Mississippi State University
Departments of Landscape Architecture,
and Agricultural and Biological Engineering
Pete Melby, ASLA, Landscape Architect, Tom Cathcart, Biological Engineer
September 2002

Introduction to the Natural Beach Landscape and Beach Ecology

This natural beach landscape began to establish itself in 1995. At that time beach management equipment stopped regular grading, and weekly sifting of sand to eliminate plants from the white beaches and for picking up debris. It was decided the beach would be left to evolve and stabilize itself. Renown Biloxi artist Joe Moran always said "if folks would just quit messing with the sand on the beach it would stabilize itself and not be such a problem." And, that is what has happened on this site. A little help has been extended by students and club groups to plant about 2000 sea oats that are in the process of building dunes on the site. Landscape architecture and biological engineering students at Mississippi State University developed designs for the 5 acre beach restoration, and a combination of students and nature has been helping with the project ever since.

Beaches have interesting roles in shoreline protection. There is a natural, sand-sharing system that occurs continuously. Waves pick up sand and pile it up on the shore where it dries, and is then blown up the beach by a prevailing south to southeast wind. The sand blows up beach onto dune areas where the velocity of the sand-laden wind is slowed by plant leaves, and the sand drops out. Dunes evolve this way. As the dune gets higher, sea oats move up and down the dune, covering it with arching grasses and an extensive root system. In fact, most of the biomass of the sea oat plant is below ground, armoring the sand from wind and water. Multiple lines of dunes develop on the beaches and when storm events occur, the energy of the waves is absorbed by the dunes. Sometimes sand dunes are completely knocked down by storm tides and surges. But, they will grow back as part of the natural sand-sharing system.

Plant roots are what is responsible for stabilizing the sand and preventing sand from blowing on the highway and washing into the Mississippi Sound. The roots have armored the sand and are holding it in place. This site is actually growing in elevation, and is about 45 cm (1½ ft) higher in elevation than the adjacent, highly maintained by beach equipment sites. A study on wind blown sand conducted in 2002 concluded that the amount of blowing sand is 300 times greater on the adjacent, maintained, beach sites than on the natural beach landscape. Please enjoy the site and take pictures or do sketches of the plants. These plants are providing many services for people and they are attractive, as well. You will be studying about plants that are growing in a very difficult area that is subject to heat, wind, drought, and salt spray. These plants are special and this area is their ecological niche. We are excited you are here to study and contribute to the natural beach landscape.

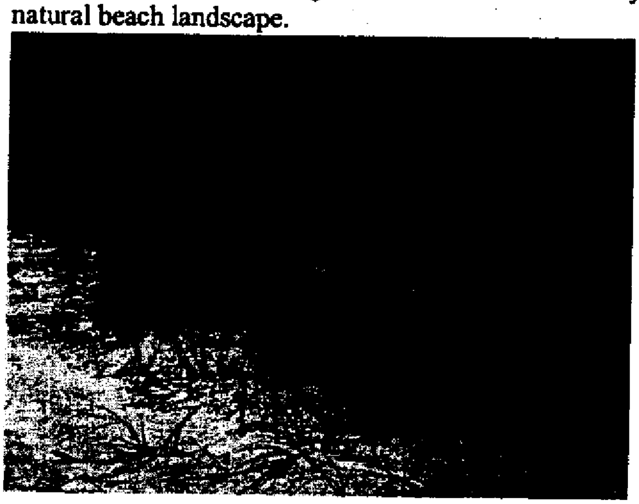
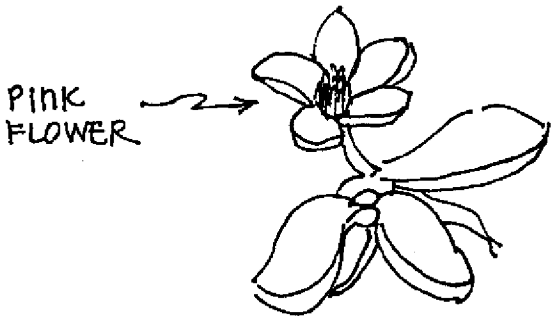
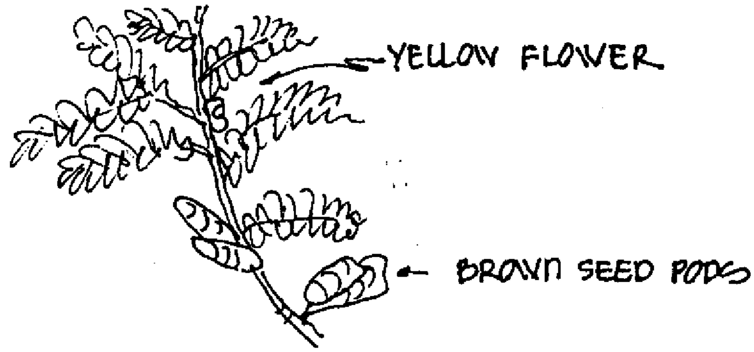


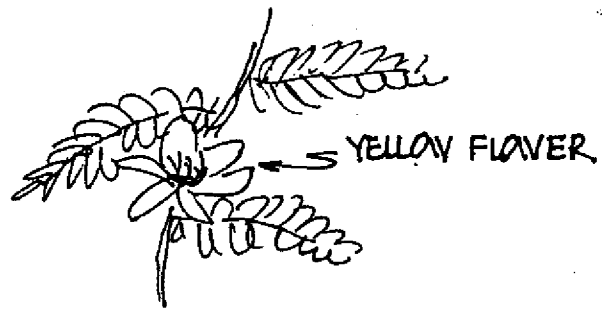
Figure 1 Sea Oats and Dunes Being Formed





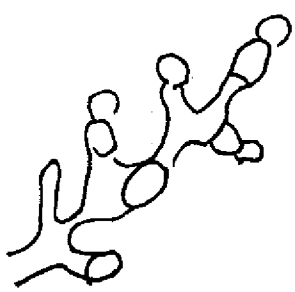
Sesuvium portulacastrum **Sea-purslane**
Carpetweed Family
This thick-leaved small shrub-like plant is found on upper beaches, the soils of dried pools, and mini-dunes. It blooms from April until frost.

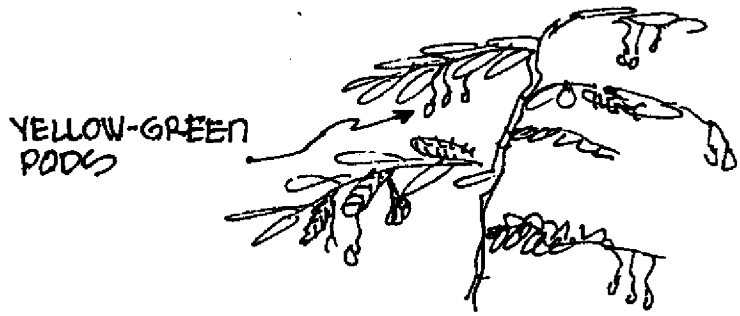
Cassia aspera **Partridge-pea**
Bean Family
The seeds of this common annual are an important source of food for wild birds. It is commonly found on dunes and on disturbed areas.



Odontonychia corymbosa **Whitlow-wort**
Pink Family
This coarse textured plant is a perennial found abundantly throughout the site. It is quite attractive with its geometrically shaped, cream colored blooms and taupe colored leaves and stems.

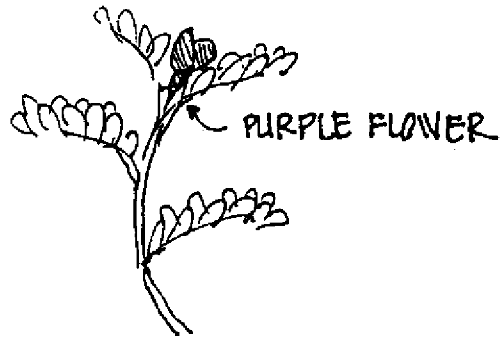
Cassia fasciculata **Partridge-pea**
Bean Family
This is a slightly different variety of Partridge-pea. The seeds of this common annual are an important source of food for wild birds. It is commonly found on dunes and on disturbed areas, but prefers the more moist and protected areas between dunes.



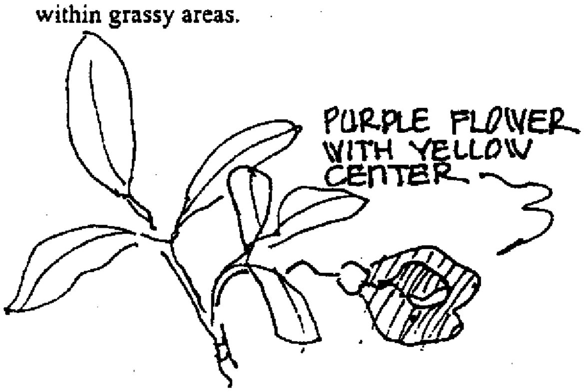


Cakile edentula **Sea-rocket**
Mustard Family
Sea-Rocket is a succulent annual common on sea beaches, low and actives, and along the edges of salt marshes.

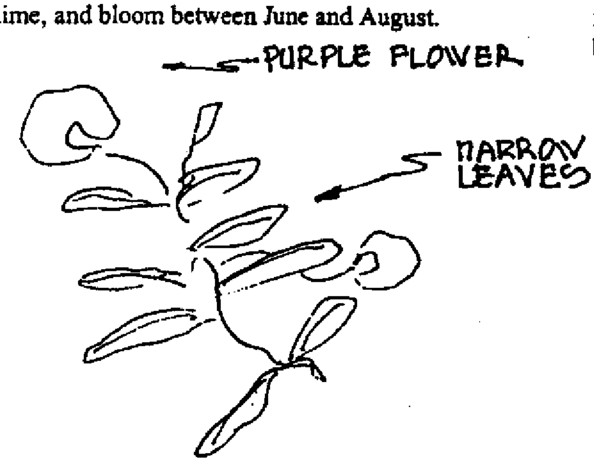
Sesbania vesicaria **Bladder-pod**
Bean Family
This annual tree-like plant will grow to 4 m tall before being killed by frost. The seeds of Sesbania are very poisionous. It is occasionally found in low areas, between stable dunes, and along the edges of marshes where there is adequate moisture for survival.



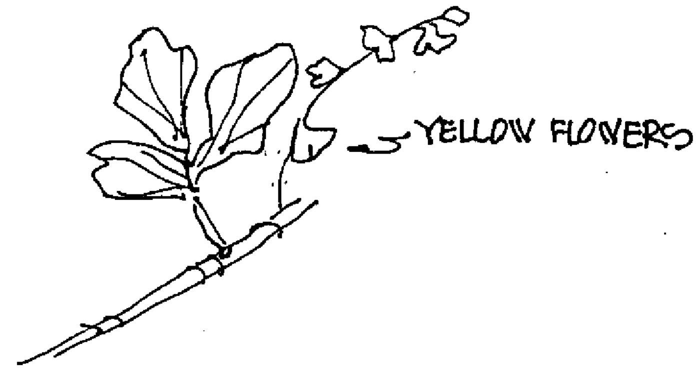
Vicia angustifolia **Narrow-leaved Vetch**
Bean Family
This vine-like plant is an important source of food for animals. It is a legume and provides nitrogen to sandy soil environs. Vetch is common throughout the upper beach including within grassy areas.



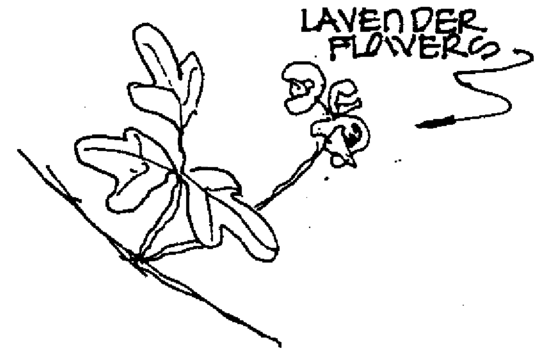
Clitoria mariana **Butterfly-pea**
Bean Family
This is an attractive twining and trailing perennial common to well-drained soils, dry flats, and between stable dunes. The flowers are white and purple in color, about the size of a dime, and bloom between June and August.



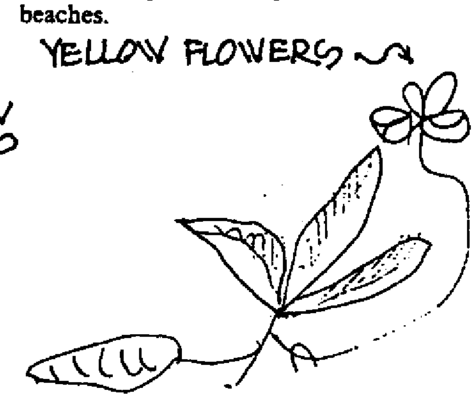
Centrosema virginianum
Climbing Butterfly-pea
Bean Family
This twining, perennial vine is commonly found on well-drained places in the sand dune environment. It has showy blossoms from March through September.



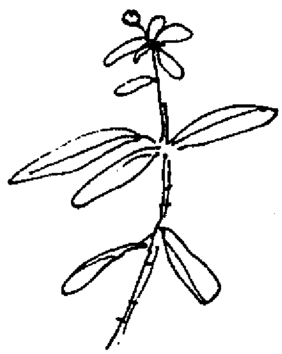
Rhynchosia minima **Climbing Rhynchosia**
Bean Family
A perennial vine, this legume produces seeds which are a food source for animals. Birds are especially fond of the fruit of this vine. It is only found occasionally in beach landscapes and prefers stable dunes.



Strophostyles helvola **Wild Bean**
Bean Family
This trailing and twining annual has leaves arranged in threes, and flowers are in dense clusters, along with bean pods. The commonly found plant prefers sandy soils in low dunes and beaches.

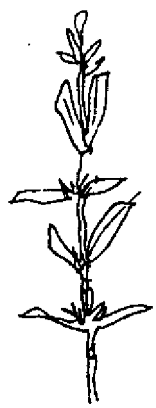


Vigna luteola **Vigna or Savi**
Bean Family
A perennial vine, this legume is found occasionally in moist places near beaches and among dunes. It is also found in thin wooded areas near the upper beach landscape. Flowers are yellow and bloom from March to November.

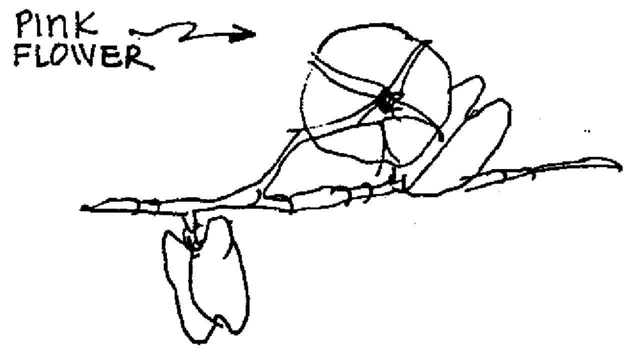


Croton glandulosus **Croton**
Spurge Family
An annual, this silvery-green colored plant blooms from May through October. Male and female flowers are on the same plant. It is commonly found in dry sandy areas, especially between stable dunes.

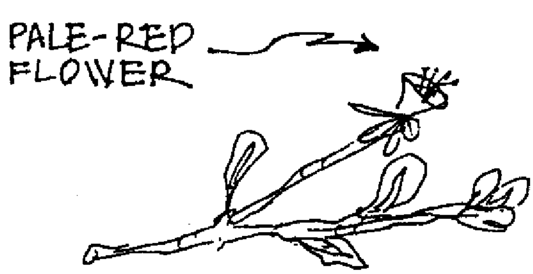
Hydrocotyle umbellata **Marsh Pennywort**
Parsley Family
This unusual round-leafed plant is commonly found in clusters in beach and other moist seaside areas. The pennywort has cream-colored flowers that bloom April through November.



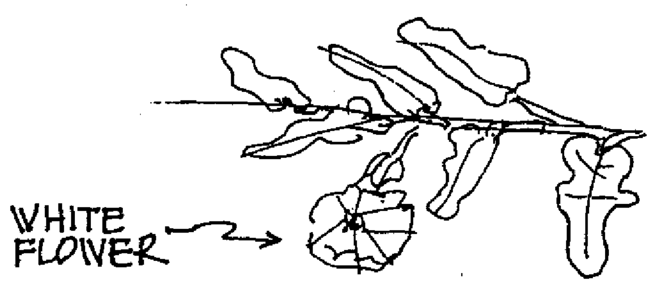
Rotala ramosior **Toothcup**
Loosestrife Family
This small annual plant is found occasionally along ditches and other wet and open places in the beach landscape. It grows to 30 cm tall. Leaves are opposite and simple.



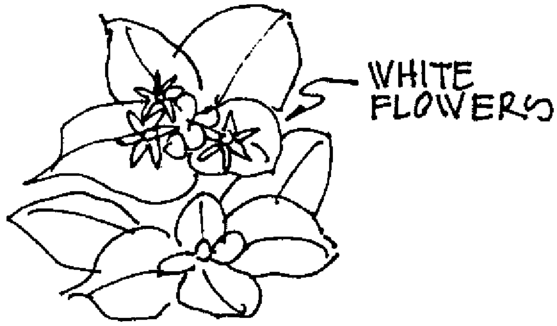
Ipomoea brasiliensis **Railroad-vine**
Morning-glory Family
This prostrate trailing plant is a perennial. With blossoms that are from pink to red in color. The showy, coarse textured vine will root at nodes to extend its domain. It can be found trailing as long as 31 meters across dune areas. It is common and blooms from June through November.



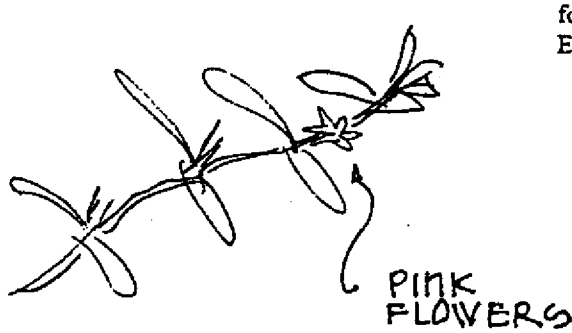
Oenothera laciniata **Cut-leaved Oenthera**
Evening-primrose Family
A small and visually insignificant looking plant, the toothcup is found in seaside sandy areas, and brackish meadows. Its pale red flower blooms from March through July.



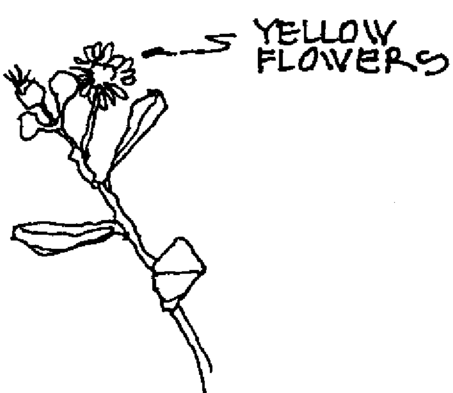
Ipomoea stolonifera
Fiddle-leaf morning-glory
Morning-glory Family
This morning glory is much smaller in size than the railroad vine. It produces creamy white blossoms in the morning from April through November. It is generally found on dunes, sand flats, and drift areas.



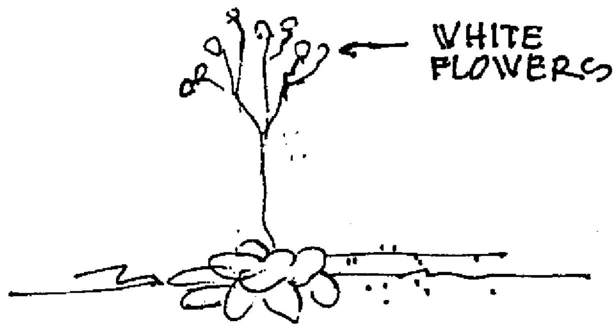
Richardia brasiliensis Gomez
Mexican-Clover
Madder Family
A spreading perennial with woody rootstock, Mexican clover is hairy and dull green in color. It is located only occasionally in dune areas and blooms tiny white flowers from May until frost.



Diodia teres **Rough Buttonweed**
Madder Family
This small erect to spreading annual is common in dry soils and in dune areas. It is common in dry conditions on the lower and upper beach landscape.

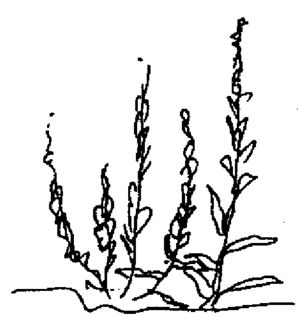


Heterotheca subaxillaris **Camphorweed**
Composite Family
This annual, and sometimes biennial, gives off a camphor-like odor when crushed. The coarse textured and fleshy plant is one of the most prevelant in the beach landscape being located on primary and other dunes as individual plants and in groupings of from 3 to 6 plants. The yellow daisy-like flowers are visually significant and attractors of butterflies and bees. Camphorweed blooms from July to October.

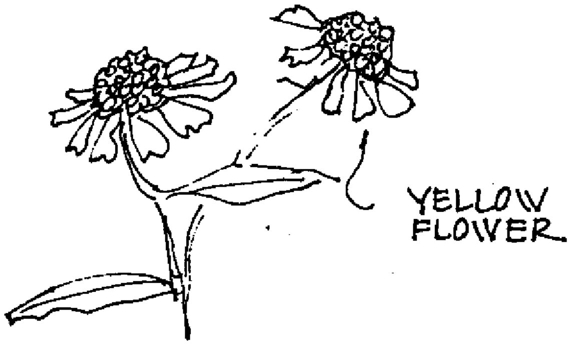


Erigeron vernus **Robin's-plantain**
Composite Family
This perennial is found primarily in moist places. Small white flowers occur from March through July. The plant begins as a very prostrate cluster of thick and fleshy, dark green leaves. A single bloom spike will emerge from the center of the cluster and burst forth with a cluster of white flowers. Robin's-plantain is unusual and only found occasionally on the Biloxi Beach Experimental site.

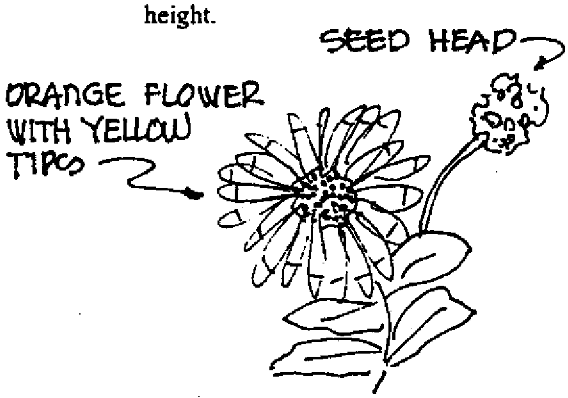
Solidage sempervirens **Seaside Goldenrod**
Composite Family
Seaside goldenrod is an annual plant with alternate leaves up to 10 mm wide. It is commonly found on the edges of fresh and salt water marshes, swales, and dunes. The blooming period is from August through November.



Solidage Canadensis **Tall Goldenrod**
Composite Family
This plant is found only occasionally along the beach and then only in moist places. Leaves are narrow and upright and give a whirled-like appearance. It prefers the location behind established dunes, and will bloom from September through October.

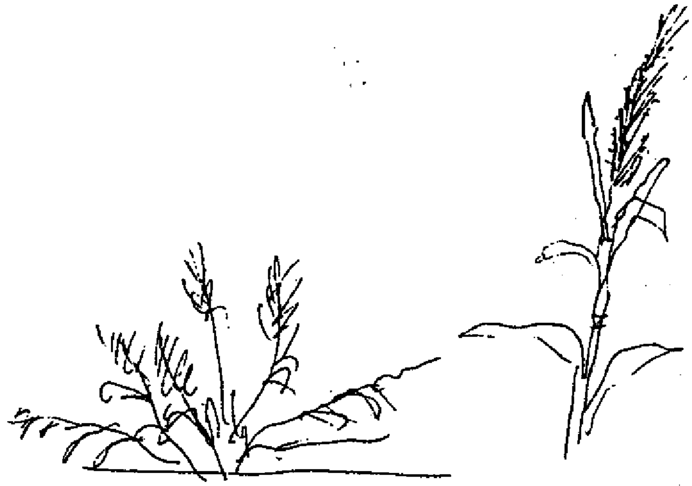


Helenium autumnale **Sneezeweed**
Composite Family
Sneezeweed is a perennial that is poisoness when eaten. It is found infrequently on the beach landscape and prefers moist to wet places. The yellow blooming plant will grow to 2 m in height.



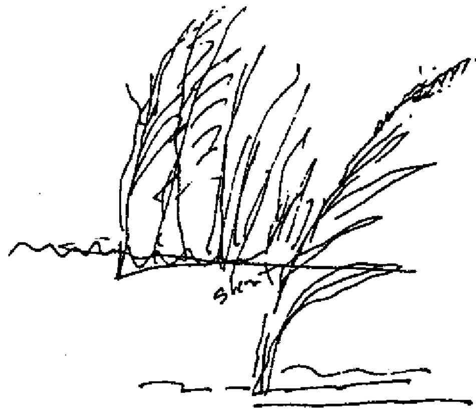
Gaillardia pulchella
Gaillardia or Firewheel
Composite Family
This annual and sometimes biennial has alternate leaves and is common to sandy soils and sand dunes. It has attractive orange colored flowers from April through the first frost, which is usually in November or December.

Paspalum notatum **Bahia Grass**
Grass Family
Bahia grass is usually found in dense mats in the beach landscape. It is coarse in texture and has vigorous rhizomes which prefer the moving sand of active dunes. It is also planted for forage and as a soil stabilizer along highways. Seed heads will be apparent from June through October.

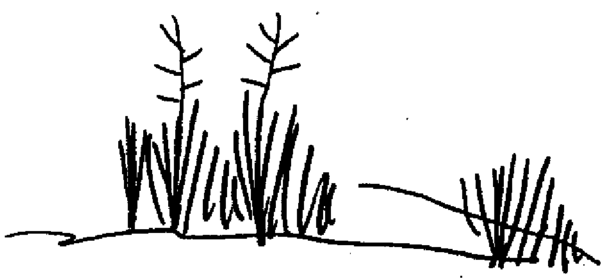


Panicum amarum **Bitter Panic Grass**
Grass Family
Panic grass is very healthy and aggressive in moist areas on the beach landscape. While is has often been interplanted on dunes along with sea oats, the plant prefers a more moist location such as nearer the beach and surf landscape. On dunes, the plant dries out in the winter and is brown and coarse textured most of the summer.. Nearer the surf line the plant thrives due to the presence of moisture.

Cenchrus incertus **Coastal Sandbur**
Grass Family
This grass is an annual found in stable dune areas. It blooms and produces sandburs from July through October. Even though it is an annual, it will over winter in the beach landscape. The plant is composed of short rhizomes and leaf blades are 2-6 mm wide. Coastal sandburs are more prevalent in sandy areas without much native vegetation. Once there is an established natural beach landscape, coastal sandburs are encountered less frequently.

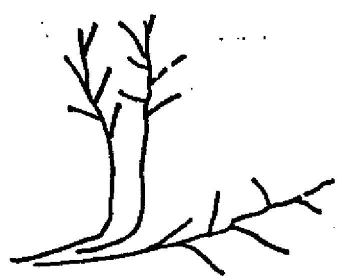


Spartina alterniflora **Smooth Cordgrass**
Grass Family
This is the most important plant species in the saltmarsh. An emergent plant, smooth cordgrass grows to a height of from 45 cm to greater than 1 m. This is the plant that provides cover for aquatic animals, and large amounts of biomass in the form of leaf and stem droppings. Throughout the salt marsh spartina is about 45 cm tall but along the edges of tidal creeks and bayous, it becomes 1 m or more in height. This is primarily due to the abundance of nutrients being flushed along the edges of the creeks. Interestingly, over 90% of the plant's biomass is below the surface of the mud and sand in which it is anchored.



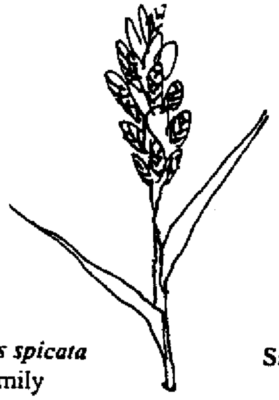
Spartina patens **Marsh Hay, Salt Hay**
Grass Family
This fine textured seaside habitat plant grows in small clumps to about 35 cm, and has wiry rhizomes sent out from the main plant to establish more salt hay clumps. It grows above the mean tide line and into low dunes. Inconspicuous blooms occur from June through September. The wiry grass used to be cut and used for hay.

Eustachys petraea **Fingergrass**
Grass Family
Fingergrass is a perennial plant that grows to 60 cm tall, with short rhizomes. It prefers swales and sandy flats, and it produces a finger-like seed head from June through October.

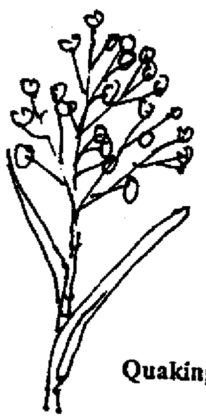


Triplasis purpurea **Purple Sandgrass**
Grass Family
This showy and abundant resident of the beach landscape is purple colored. Its stems are usually erect, but sometimes nearly prostrate. It is common in dunes, especially in areas devoid of other plants. A seed head is produced from September through October.

Uniola paniculata **Sea Oats**
Grass Family
This striking, fine textured erect grass is the image of many beach photographs. Sea oats is a perennial that is up to 2 m tall, with creeping rhizomes below the sand spreading the plant up and down the dunes. It is highly important in stabilizing dunes and is common in loose sand, on dunes, and near seashores. It produces golden seed heads with thick stems from June through September.



Distichlis spicata **Saltgrass**
Grass Family
This perennial grass is no taller than 40 cm and has an extensive rhizome system. Plants are located in dense colonies or in linear patterns as stems arise from rhizomes. The plant is unisexual, that is, sexes are on different plants. It is common, and one of the most important plants in salt marshes. Saltgrass is located in higher portions of salt marshes, on salt flats, and on overwash areas. It produces a showy seed head from June through October.



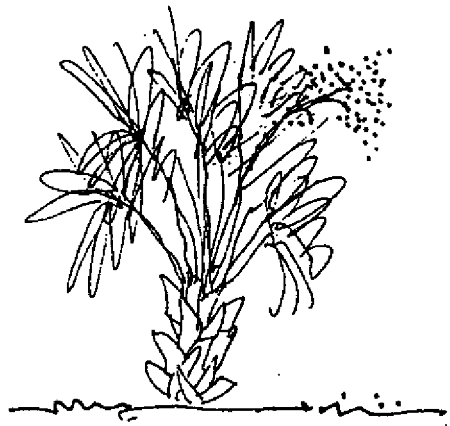
Briza minor **Quaking Grass**
Grass Family
This fine textures grass grows to 70 cm tall and is found occasionally in swales on the beach landscape. It produces a seed head from March through May.

Cyperus esculentus **Yellow Nutgrass**
Sedge Family
Yellow nutgrass has a yellow-green appearance and is a perennial that will grow to 70 cm tall. Slender rhizomes spread the plant quickly beyond its original area of growth. It is common in beach sands, and along dunes and swales. It will spread quickly in mulched areas. A showy seed head is produced from June through November.

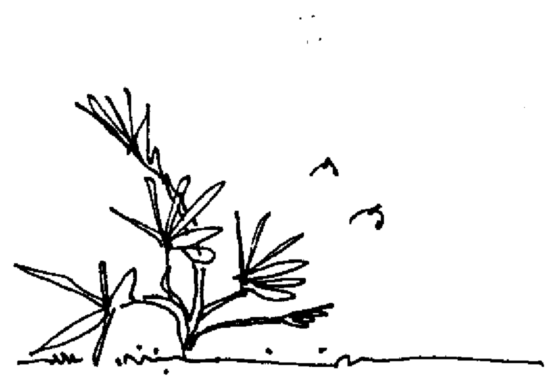
Cyperus haspan **Leafless Sedge**
Sedge Family
This is a short-lived perennial from 20-70 cm tall that flowers the first year. It has sharply angled stems that are soft and weak. The plant is common and prefers shallow water, swales, and depressions. It produces a showy seed head from June through October.

Scirpus americanus **Swordgrass**
Sedge Family
This erect perennial has unbranched stems that are sharply triangular in shape and up to 1.5 m tall. Rhizomes responsible for spreading this dramatic looking plant are coarse, and reddish in color.

Pinus palustris **Longleaf Pine**
Pine Family
The longleaf pine is native to the pine savannahs along the Gulf Coast Region. The pines are able to tolerate moist or dry soil conditions and they grow very tall, producing a clear log that is very long. Longleaf pines are able to tolerate fires, which are necessary for maintaining grassland, savannah-like conditions. They will grow more than 50 cm in height per year.

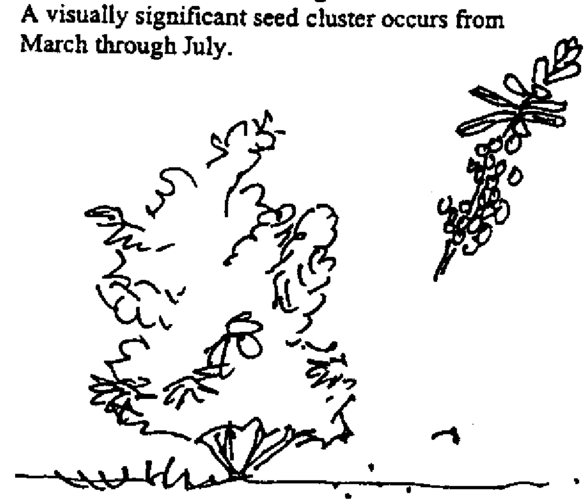


Sabal palmetto **Cabbage Palm**
Palm Family
This palm is native to areas from Florida to North Carolina. It is also found in the swamps and bayous of southern Louisiana and Mississippi, although whether or not it was originally native is questionable. A significant seed head forms in June and July and persists until the next spring. The cabbage palm is a tree that grows to 25 m tall. Where it is native it exists in pure stands or is often mixed with broadleaved evergreen trees or pine trees. It prefers a moist habitat such as along the edges of marshes and dunes. Once established it can take long periods of drought.

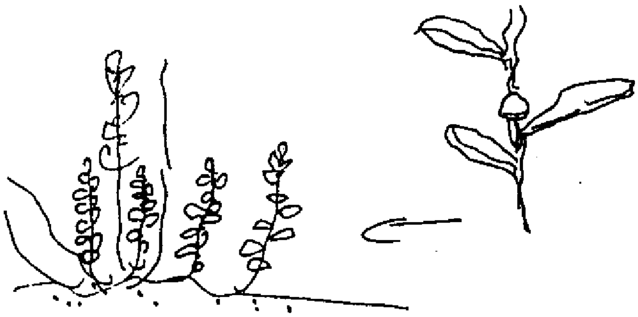


Serona repens **Saw Palmetto**
Palm Family
Similar in appearance to the dwarf palmetto, the saw palmetto is also a shrub form of the palm tree. It has stems that run along the ground, forming new plants a short distance from the parent plant. This palm can grow to 6 m tall with stems protruding upwards from ground level. It is common to dry habitats like pinelands and pine-deciduous hardwood forests. It is native from Louisiana through South Carolina. A visually significant seed cluster occurs from March through July.

Sabal minor **Dwarf palmetto**
Palm Family
A shrub, the dwarf palmetto has similar leaves to the cabbage palm. The stem is often entirely underground. This palm is native to Louisiana and Texas and will grow to 6 m tall. It is commonly found along rivers and in wet woodlands. Indians used the palm fronds for baskets and shelter roofs. It produces a visually dominant seed head from May through July.

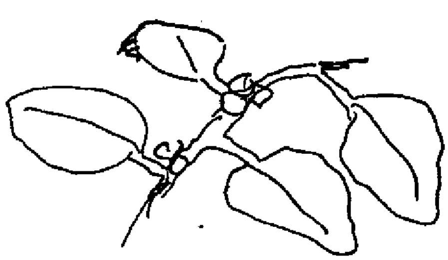


Myrica cerifera **Wax Myrtle**
Wax-myrtle Family
This small evergreen tree has alternate, simple leaves. It is an aromatic shrub with sexes almost always on separate plants. It has been said cut branches of wax myrtle placed indoors will rid a shelter of fleas. Fruit is a small greenish berry found in clusters. The fragrant berries are covered with wax which can be collected through boiling the berries. Colonists at Fort Frederica, Georgia, an early outpost-settlement for the Colonies made candles from wax myrtle. The plant is found scattered in primary dunes, on stable dunes, and at the edges of marshes. Flowers bloom from April through June.

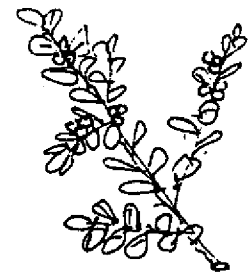


Batis Maritima **Saltwort**
Saltwort Family
These are trailing, arching and sometimes erect plants that are located in dense masses. Leaves are succulent and very fleshy. Stems older than one year are woody in nature and brownish in color. Oblong leaves are pale to yellow green, and flowers small and insignificant. Flowers occur from May through July. Plants are 50 cm tall and unisexual, that is, sexes are on separate plants. Fruit is purple in color. The unusual shrub-like plant is common in marsh areas, on salt flats, and drift zones.

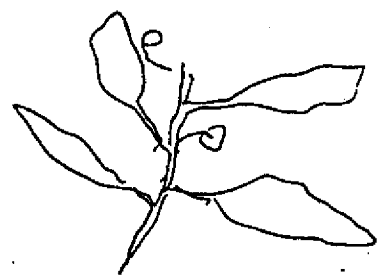
Rubrus argutus **Blackberry**
Rose Family
This low arching rose is commonly found in dry places. It blooms in April and May and produces fruit during early summer. Many first year leaves have 5 leaflets and second year leaves have 3 leaflets.



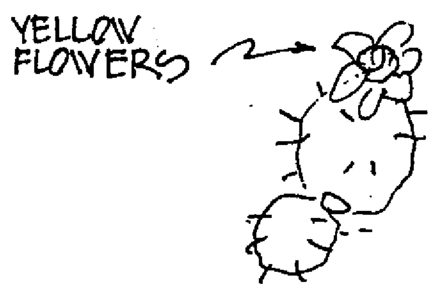
Croton punctatus
Silver-leaf Croton, Black-tea
Spruge Family
This striking 1.2 m tall plant is common on dunes, sand flats, and in loose, deep sands. It is found in large numbers on Ship Island. Leaves are a pale green in color, and hairy. Blossoms occur nearly all year long and are a cream color, and very subtle in appearance. The plant attracts many bees.



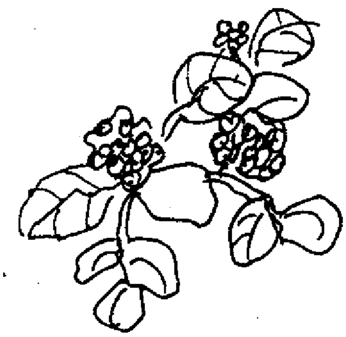
Ilex vomitoria **Yaupon Holly**
Holly Family
This striking small tree and shrub-like plant grows to 8 m tall and is evergreen with red berries that persist from fall through spring. It is common in swamps, wet woods, on stable dunes, sand flats, and at the edges of brackish and salt marshes. Tiny white flowers in March and June, produce green berries that turn red and fleshy by fall. Indians used to drink the juice from the berry to purge themselves during body cleansing ceremonies, thus the species name vomitoria.



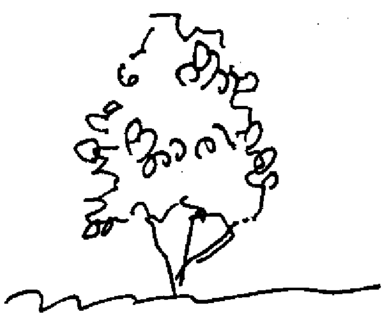
Ilex glabra **Inkberry, Bitter Gallberry**
Holly Family
This small evergreen shrub is common in grassland savannahs, wet thickets, and on sandy flats. Berries are purple in color.



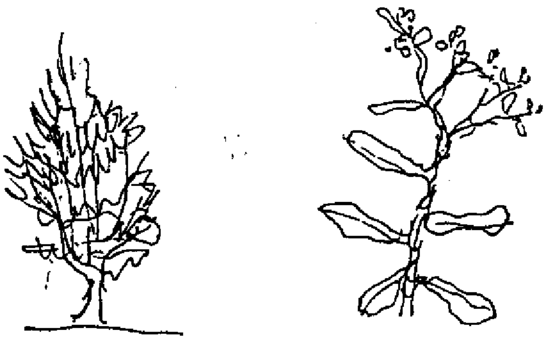
Opuntia humifusa **Eastern Prickly-pear**
Cactus Family
This visually attractive cactus is a perennial and common to sandy flats on the upper beach landscape. It blooms yellow flowers from April through June. Thorns on this cactus are needle like and up to 25 mm long. Small clusters of thorns about 4 mm long are spaced on plant leaves in clusters throughout the plant, rendering a double dose of ill comfort to those who handle this plant.



Lantana camara **Shrub-verbena, Lantana**
Vervain Family
This attractive shrub is evergreen and will grow to 1.6 m in height. Cold weather with repeated frosts will kill the plant back to its root system and, if not thoroughly mulched, will kill the entire plant. Blossoms appear from May thorough September, followed with clusters of purple berries that contain seeds. Blossoms are a combination of small flowers that range in color from white, to cream, to pink and yellow. Many people call the blooms of the native lantana, ham and eggs color.



Baccharis halimifolia
Silverling, Groundsel-tree
Composite Family
This is a very show evergreen shrub that will grow to 5 m tall. It is unisexual with male plants having a dull-yellow cast, and female plants being a satiny white color with a profusion of white blossoms from August through October. It is found along the edges of salt marshes.

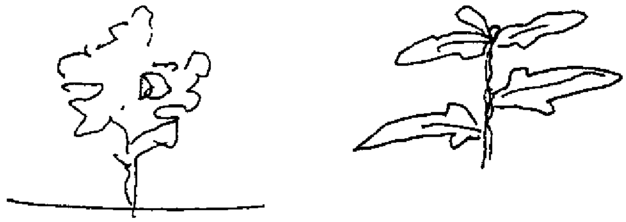


Iva frutescens **Marsh-elder**

A medium evergreen shrub that is found in brackish or saltwater habitats, uphill from emergent plants and above the mean tideline. It is commonly found along ditches and in sloughs and blooms from June through October.

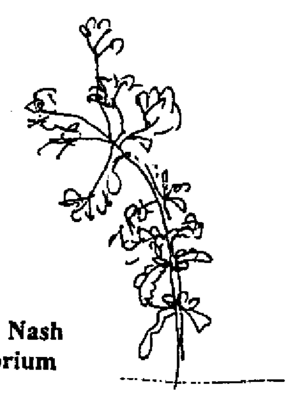
Helianthemum corymbosum
Rock-rose, Sun-rose

This evergreen shrub grows to 35 cm in height and has arching stems terminating in a cluster of yellow flowers that bloom in February through May. Blossoms attract many bees and butterflies. Rock-rose grows in dense colonies and has thick, tuberous roots, and coarse textured medium leaves. It is found occasionally on dunes.

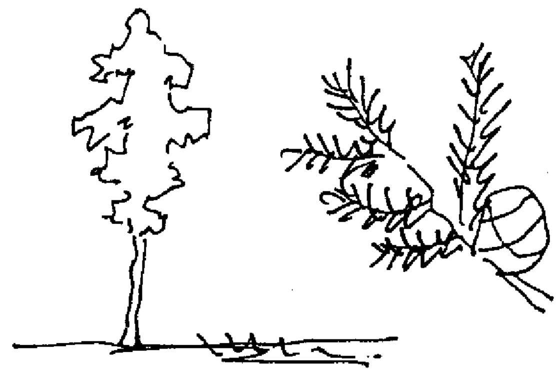


Quercus virginiana **Live Oak**
Beech Family
Live oaks in a beach environment range from scrubby plants to trees having trunks over 1 m in diameter. These monarchs of the Deep South forest prefer dry, sandy soils. Live oaks are infrequently seen in the sand dune environment.

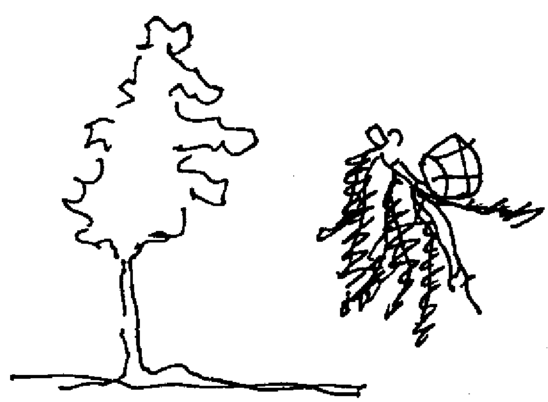
Froelichia floridana **Cottonweed**
Amaranthaceae Family
Usually found with a solitary, erect stem with cotton-like white flowers and fruit that are unusual looking. This is only found occasionally on sandy soils, stable dunes, and on pinelands. It blooms from June through October.



Eupatorium anomalum **Nash**
Narrow-leaved Eupatorium
Composite Family
This perennial grows to 1.5 m tall and has a whorl of leaves in groupings of from 2 to 4 leaves. White flowers appear in July through October. It is found only occasionally in wet places such as swales, meadows, and wet pinelands.



Taxodium distichum
Common Bald Cypress
Taxodiaceae Family
This tree will tolerate a wide range of soil conditions and levels of soil moisture. It prefers moist soil where it will achieve maximum growth. This tree has a shallow, fibrous root system, and is susceptible to heat and droughts.



Taxodium ascendens **Pond Cypress**
Taxodiaceae family
The pond cypress will tolerate a wide range of soil conditions and levels of soil moisture. It prefers moist soil where it will achieve maximum growth. This tree has a shallow, fibrous root system, and is susceptible to heat and droughts.

An article by writer Glenn Himebaugh in the Images of Biloxi magazine provides a brief history and mission of the project.

It's just a five-acre patch on a 26-mile-long beach, but it sticks out like a sore—no, make that a healthy--thumb.

Supported by the Biloxi Bay Chamber of Commerce among others, the Natural Beach Landscape at Miramar Road proves we can enjoy healthy beaches if we'll let Mother Nature have her way.

We'll save big bucks, too, adds Dr. Pete Melby, professor of landscape architecture at Mississippi State

University and director of the restoration project.

Melby says it's costing about $10 million every eight years to renourish Biloxi's beach [replace sand lost to wind and erosion] with sand pumped from the Mississippi Sound, the 12-mile-wide body of water between the mainland and the barrier islands.

"The sand on the rest of the beach has been washing out to sea and blowing onto Highway 90 for years," says Melby, noting such problems don't exist on the restoration site.

High school students and Mississippi State landscape architecture students kick started nature by planting more than 4,000 sea oats and smooth cord grass plants.

"The sea oats are creating sand dunes which store the sand," Melby explains. "If there were a hurricane, the dunes would absorb the energy from the waves and thereby help protect the mainland."

Fifty-seven native plant species have established themselves. Seed-eating birds have flocked to the site, as have butterflies and other insects.

Posted with signs saying "Beach Goers Welcome," the Natural Beach Landscape is more visually diverse and interesting for people, Melby notes.

All this has been accomplished with volunteer labor and a "shoestring" $40,000 budget over the last seven years.

Besides the Chamber, key backers have been the Harrison County Sand Beach Department, the Mississippi Department of Marine Resources, the Mississippi Tidelands Trust Fund, and the Mississippi/Alabama Sea Grant Consortium.

"This project never would have lasted had it not been for the optimism and support of the Chamber over the years," says Melby. "It's something that is good for the city, the people, the water, and the wildlife."

This month and next Mississippi State students will create a neighboring one-acre marsh to filter highly polluted mainland runoff before it goes into the Mississippi Sound. The marsh will provide habitat for aquatic plants and animals, including shrimp and blue crabs.

"Ultimately," says Melby, "this ongoing project will create a model for management of the entire 26 miles of sand beach."

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The Salt Marsh that was, and Hope for a Future Marsh

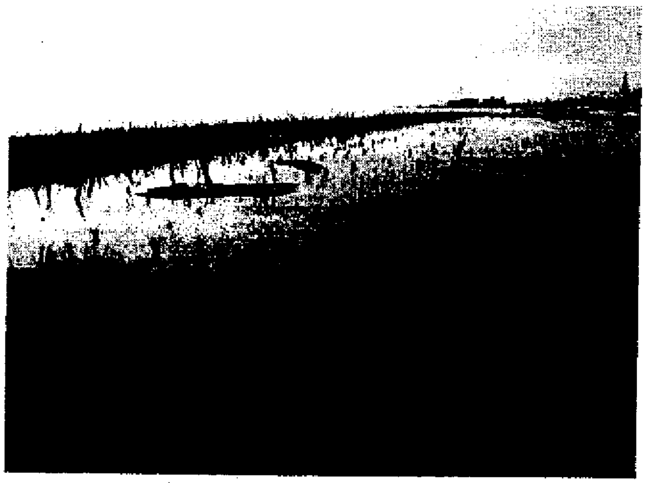

Figure 2 Salt Marsh Built in 2001-2002

This salt marsh was built adjacent to the natural beach landscape during the winter of 2000 and planted in the spring of 2001. The protection the sand spit gave the quiet waters of the salt marsh allowed for growth of both smooth cord grass and black needle rush. However, the wave energy was too strong for the vegetated sand spit and the spit eroded. While in place though, the protected marsh was teeming with blue crabs and small fish. Larger fish would visit the marsh to feed on the abundant aquatic life. Bird life including ducks were attracted to the quiet and rich waters of the marsh. The following paper explains the value of marshes to the coastal edge. Over 80% of the original marshes along the Mississippi coast are gone. It would be fitting to restore and recreate marshes along the coastal edge.

Intertidal Marshes

With an Emphasis on the Mississippi Gulf Coast

by Pete Melby, ASLA, Landscape Architect
Co Director, Center for Sustainable Design
Mississippi State University
1 February 2001

Introduction

Intertidal marshes exist at the water-logged fringe of land over which waters inundate and recede from the force of wind and tide. Marsh vegetation is very productive but not very diverse. Marshes provide food and cover for juvenile stages of shrimp, blue crabs, red drum, and spotted seatrout. Marshes also reduce damage from storms by attenuating the energy of waves, winds, and storm surges. Marshes affect water quality by cleansing water, and they contribute significantly, to the food supply for the web of life in the estuary. Marshes trap and stabilize sediments, thereby reducing turbidity and increasing water clarity in coastal waters. This affects the presence of seagrass beds which depend on light through the water column. Without water clarity, seagrass beds would die. Seagrass beds also help to stabilze sediments, protect from storms, and they serve as habitat for many aquatic animals. The intertidal marshes are a part of the image of the coast line and they stimulate many to tour and live along the coastal landscape.

Marsh Value Summary

Shoreline Protection

Habitat-Food and Cover for animals
Water Quality Buffer
Attractive Coastal Image

Basic Energy Sources of the Salt Marsh

Sunlight
Wind
Tide
Rain
Rivers

Major Components of the Coastal Ecosystem

Water column
Subtidal bottom
Intertidal marsh
Upperbeach-Maritime forest

Cities are the main consumer of the coastal marsh. The marsh produces fish, crabs, and shrimp for commercial and recreational fishing, it contributes to tourism and land developments, and it recycles nutrients from domestic and industrial wastes.

Marshes will grow in a narrow band known as the intertidal zone, but if suspended sediments are in great supply, the marsh may expand seaward. Coasts that receive a lot of silt and clay from rivers often have extensive marshes. Sediment starved coastal areas do not have barrier islands. Sea level along the Florida coast has risen 25 cm per century and has accelerated in the past century. As sea levels rise, marshes will move inland.

Intertidal Marsh Ecosystem Processes

The hierarchy of tidal channels results from the interaction of tidal energy, sediments, and marsh vegetation. Just like mechanical tilling and fertilizing of industrialized agricultural crops, the energy of the wind and tide subsidize the growth of marsh vegetation. Vegetation grows taller near the edges of the tidal creeks, due to the combination of greater tidal energy, nutrient availability, and soil-water exchange. The dominant marsh vegetation is black needlerush (Juncus roemerianus). The greener smooth cordgrass (Spartina alterniflora) occurs near the water's edge where tidal flooding and draining are frequent. Cordgrass often forms a narrow border at the edges of the creeks. The marsh food web is dominated by vascular plant detritus and soil microalgae. The algae are very productive, they grow in the shade of the vascular plants, and they contribute as much to the food web as the vascular plant detritus. Consumers include microscopic animals, snails, fiddler crabs, shrimp, minnows, oysters, and juvenile fish. These animals, then, are food for transient fish, birds, and mammals.

Plants that occur above the mean high water include the maritime forest plants of wax myrtle, red cedar junipers, cabbage palms, and live oaks. The maritime forest could also be a flatwoods forest with pines, palmettos, gallberry, and other scrub vegetation. The area above the marsh is also know as the high marsh landscape.

The marsh attracts a large and diverse arthropod community which helps in controlling mosquitoes. The marsh functions to receive and treat wastes and to protect the coast from storms. Natural processes thus contribute to the public welfare with out requiring taxes. Distichlis spicata is attracted to sulphur conditions in sea water along with Juncus and Spartina. Juncus produced more above ground biomass in low marsh conditions than it did in high marsh conditions. In low marsh it produced 949 g/m2/year, middle marsh produced 595 g/m2/year, and high marsh 243 g/m2/year. Below ground biomass ranged from 4063 g/m2/year to5140 g/m2/year in the high marsh. Spartina alterniflora is higher in protein and breaks down to provide more detritus to more organisms.

Marsh Vegetation

Salt marshes occur behind protective beaches and on the leeward shorelines of barrier islands. Its topography consists of a gently inclined plane. The salt marsh begins at or just below sea level. The inner edge of the marsh might lie one to three meters above the mean sea level. There are four typical vegetational zones:

Spartina alterniflora – smooth cordgrass
Juncus roemerianus – black needlerush
Salt flats including salt barrens
High marsh

Most plant species in a salt marsh landscape belong to a few genera. There are the glassworts (Salicornia), cord-grasses (Spartina), rushes (Juncus), plantains (Plantage), and the sea-lavenders (Limonium). The cord-grasses and sea-lavenders are restricted to saline habitats while the rushes, plantains, and glassworts are also native to non-saline habitats.

Low tidal amplitudes along the Mississippi Gulf Coast has created only a narrow band of of Spartina along the creek banks and a vast zone of Juncus roemerianus. The Spartina zones are typically flooded daily by tides. In Mississippi, Lionel Eluterious determined that Spartina occupied an elevational range from 0.24m below to 0.54 m above mean low water. Tidal flooding in the Spartina zone occurred from 87-100% if the year. The Juncus zone occupied elevations that were inundated intermittently by the tides. Spartina alterniflora that is shorter is usually located back from the edges of the creeks, and it is shorter because it is away from the larger infusion of nutrients provided by the daily tides. The short form of Spartina alterniflora has fewer nutrients within the plant tissue than the plant located near the tidal creeks. The short form is probably a result of nitrogen deficiency. Spartina leaves live 14 – 22 months. Juncus plants cannot tolerate salinity levels in excess of 30% indefinitely. Spartina patens plants occupies aerated soils with low salinities. Juncus can be planted in any month, but best performance occurs when planted in February and March. Juncus plugs with 12 shoots had grown to 300 shoots after 22 months in a planting in Mississippi. Complete coverage occurred within a 5 year period when planting on a 1.2 meter spacing in the Mississippi marsh.

Spartina seeds germinate best in areas like sand or mud flats where the water is more freshwater than seawater. Seeds will germinate in two weeks if soaked in freshwater, and in a month or two of soaking in seawater. The salt marsh will not grow, though, unless the water has some salt in it.

Spartina is dependent on the nutrients in flowing water and will grow vigorously when located near the flowing water of a tidal creek. When located away from tidal currents, the Spartina alterniflora will be stunted and nearly one-half the height of Spartina near the tidal currents. Spartina cannot grow submerged continuously. It requires exposure to air. Over time, it has been determined Spartina marshes grow higher in elevation because of the trapping of sediment and contribution of plant detritus the marsh plants make. Eventually, a Spartina alterniflora marsh becomes a Spartina patens upland beach planting. The gradual buildup of the Spartina marsh due to sediment and plant detritus contributes to this elevation change.

The salt marsh is the most productive landscape in the world. A salt marsh will produce up to 10 tons of biomass per acre per year while the open ocean produces less than one ton and a productive agricultural field will produce up to 7.5 tons per year.

Spartina patens is a fine textured, small grass no taller than two feet in height. It forms an even carpet on the upper beach and can tolerate infrequent high tides and salt spray. Because of the density of growth of patens, the soil beneath is usually moist and very shaded year round.

Salt flats are inundated infrequently, usually less than once a month. High salinity causes ion toxicity. Plants that are able to withstand salt flats include the

Aster tenuifolius,
Batis maritime (saltwort),
Borrichia frutescens (sea ox-eye),
Distichlis spicata (saltgrass),

Limonium carolinianum (sea lavender),
Salicornia bigelovii (annual glasswort), and
Salicornia virginica (perennial glasswort).

Upland forests adjacent to a salt marsh is either a pine-palmetto flatwoods or a hydric hammock dominated by live oaks. These forests can tolerate salt in the form of aerosols and plants that can withstand hurricane force winds. Saltwater inundation during hurricanes is diluted by rainwater and runoff which protects plant roots from salt related root damage. The pine-palmetto flatwoods contain:

Pinus elliottii
Serona repens
Sabal palmetto (cabbage palm)

The hydric hammock contains:

Live oaks
Cabbage palm
Red cedar (Juniperus silicicola)

The strip of sand above the salt marsh is usually very saline and can support sparse plant growth including species such as:

Atriplex pentandra,
Cakile constricta,
Chenopodium berlandieri
Sesuvium portulacastrum,
Suaeda linearis

Above the salt barrens is located Spartina patens. Above the spartina is the area known as the high marsh, where shrubs like Iva, Baccharis, and Lycium exist at a slightly higher elevation. At elevations about one meter above mean sea level there could establish a stand of coastal hammock consisting of red cedar, cabbage palm, and live oak. In some areas there are meadows of Distichlis spicata (salt spikegrass). The soil surfaces of salt marshes are covered with algae in the form mainly of diatoms and blue-green algae. The algae help to hold pieces of vascular plants to the ground where pieces then decompose and nutrients are released by the algae that absorbed them.

Productivity

Most organisms in the marsh are either detrivores or predators. The benthic and planktonic microalgae form the basis of the food chain for the fish and invertebrates in a Spartina marsh. Shrimp and crabs (invertebrates) are transient residents whose presence varies with their life history and the tidal fluctuations. Pink shrimp spawn offshore and larve use tidal currents and salinity gradients to guide them to marsh and tidal creek nursery areas that provide protection and food. Young adults emigrate from marshes to offshore breeding grounds as water temperatures decrease in the fall. The pink shrimp (Penaeus duorarum) are most abundant in marsh zones in late spring and summer. Inshore yields of animals are directly related to the area of estuarian vegetation. Brown shrimp are more abundant in the flooded marsh than in adjacent bare bottoms. Blue crabs mate in the marsh. About 75% of Florida's recreational and commercial fishes are dependent upon marsh habitats for at least a portion of their lives. The red drum spawn offshore and the spotted seatrout spawn in the estuary. Both of these game fish use the marsh and estuary as nursery areas. A total of 90 species of fish have been reported from the open waters of Juncus marshes.

Wetlands provide an environmental service called environmental quality that also has considerable economic value. Wetlands help maintain water quality and improve degraded waters by doing the following:

Removing nutrients
Processing chemical and organic waste
Reducing sediment loads of water
Wetlands also reduce turbidity of flood waters
They reduce biochemical oxygen demand

They are significant converters of solar energy into biomass
Dead plant matter becomes detritus and a major food source
Shrimp and mullet eat detritus and graze on bacterial, fungi, diatoms, and protozoa growing on detritus surfaces.
Wetlands temporarily store flood waters and slowly release it
Wetlands buffer land areas from wave damage during storms
Wetland areas provide for recreational activities such as hunting and fishing

Major Wetland Values

Fish and Wildlife
Fish and shellfish habitat
Waterfowl and other bird habitat
Furbearer and other wildlife habitat

Environmental Quality Values
Water Quality Maintenance
Pollution filter
Sediment removal
Oxygen production
Nutrient recycling
Chemical and nutrient absorption
Aquatic productivity
Microclimate regulator
(The Brillion Marsh in Wisconsin has been used to process domestic sewage since 1923.)

Socioeconomic Values
Flood control wave damage protection
Erosion control
Groundwater recharge
Timber and other natural products
Energy source (peat)
Fishing and shellfishing
Hunting and trapping
Recreation
Aesthetics
Education and scientific research

The salt marsh is the most productive landscape in the world. A salt marsh will produce up to 10 tons of biomass per acre per year while the open ocean produces less than one ton and a productive agricultural field will produce up to 7.5 tons per year. Of the twelve most important fish and shellfish taken in US waters, only tuna, haddock, yellowtail flounder, and ocean perch are not associated with estuarine waters. Menhaden is the leading commercial fish by weight, and it depends heavily on marshes in its juvenile stages. Shrimp is the most valued fish harvested from the sea, and it too spends much of its juvenile life in the salt marshes. Estuaries and marshes are about 10 times as productive as the open ocean waters. Fish that depend on plant matter are shrimps, oysters, menhaden, and mullet. These animals depend on a constant supply of detritus from Spartina, eelgrass, and turtle grass which grow in shallow waters near salt marshes. Animals, generally, must eat about 10 pounds of food to increase one pound in weight.

Dr. Lunz at the Bears Bluff Laboratory in South Carolina has shown that marsh ponds can produce 250-400 pounds of fish per acre, 100 pounds of crabs, and 300-400 pounds of shrimp. These amounts were harvested without special efforts at cultivation except for predator control in the case of shrimp.

Federal Regulation

Salt marshes are regulated by the Corps of Engineers under Section 10 of the Rivers and Harbors Appropriation Act of 1899, and by the Corps and EPA under Section 404 of the Clean Water Act of 1977. Factors that are considered when issuing a permit affecting a marsh include:

> Conservation, economics, aesthetics, environmental concerns, wetlands, historic properties, fish and wildlife values, flood hazards, floodplain values, land use, navigation, shore erosion, accretion of sand and sediment, recreation, water supply, energy needs, safety, food and fiber production, mineral needs, considerations of property ownership, and the needs and welfare of the people.

Salt marshes are inviolate and are sometimes sacrificed for more important public interest considerations, however destruction is usually very limited and mitigation is required. Creation and restoration of tidal wetlands is possible, but successful mitigation requires skill and commitment. Projects must be carefully designed and constructed. Failures must be corrected, and maintenance and monitoring are essential.

Marsh Management

Gulf coast salt marshes are a functioning ecosystem. An ecosystem is a community of animals and plants and their physical environment, which interact as an ecological unit. Resource management plans should relate to ecosystem processes. The complex network of management and regulation authorities should be encouraged to work together to effectively manage the marsh landscape. Management plans should include active,

on-site monitoring in order to meet management objectives and to continually update plans with new and current information and strategies. A large amount of planning must be undertaken to create successful marsh landscape management plans.

Many pollutants wash into marshes from the mainland. Heavy metals like chromium, zinc, mercury, lead, and copper are poisonous. They come from both natural sources like weathering rocks and from human activities such as automobile, copper piping, and fungicides and algaecides put in swimming pools.

Useful Resources

Ecology and Mangement of Tidal Marshes, A Model from the Gulf of Mexico by Charles Coultas and Yuch-Ping Hsieh, St. Lucie Press, Delray Beach, FL, 1977, ISBN 1-57444-026-8

Saltmarsh Ecology, by S.P. Long and C.F. Mason, Blackie Press, Glasgow and London, 1983, ISBN 0-412-00301-5

Live and Death of the Salt Marsh, by John and Mildred Teal, Little, Brown, and Company, USA, 1969

Shore Ecology of the Gulf of Mexico, Britton and Morton, University of Texas Press, 1989

Marine Resources and History of the Mississippi Gulf Coast, Department of Marine Resources, 1998

Marine and Estuarine Habitat Types and Associated Ecological Communities of Mississippi Coast by Ronald Wieland, Mississippi Department of Wildlife, Fisheries, and Parks 1994

Seaside Plants of the Gulf and Atlantic Coasts, by Wilbur H. Duncan and Marion B. Duncan, Smithsonian Institution Press, Washington, D.C., 1987