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Coast 2050 Region 2

TIMBALIER ISLAND PLANTINGS DEMONSTRATION (TE-18)

First Priority List Vegetative Plantings Project of the
Coastal Wetlands Planning, Protection, and Restoration Act
(Public Law 101-646)

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Acknowledgments

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Abstract

This comprehensive report concludes a 5-year examination of sediment fences and plantings on Timbalier Island, Louisiana. The goal of the project was to stabilize portions of bare beach and overwash areas on Timbalier Island by utilizing sediment-trapping fences, vegetative plantings, or a combination of both. The project area consists of sand fencing, vegetative plantings, or both at seven treatment sites totaling approximately 7,390 linear ft (2252 m) of the Gulf of Mexico shoreline of Timbalier Island. Each fence site consisted of a primary fence oriented parallel to the gulf shoreline with perpendicular spurs every 50 ft (15.2 m) that extended 25 ft (7.6 m) bayward from the primary fence. Fence construction was completed in July 1995. However, numerous tropical storms damaged the fences, and repairs were conducted prior to planting *Spartina patens* (marshhay cordgrass) and *Panicum amarum* var. *amarulum* (Atlantic panicgrass) at some locations in 1996. The specific goals of the project were: (1) to increase the percent cover of emergent vegetation behind the sediment-trapping fences and (2) to increase the elevation of areas enclosed by the sediment-trapping fences. To measure these goals, aerial photography, elevation surveys, and vegetation sampling were conducted to determine changes in habitats, acreages, elevations, volumes, and vegetation cover and composition. Fences and plantings did build dunes as in other projects previously reported, including one on Timbalier Island. However, treatment locations were impacted throughout the project life and after 5 years only one site remained unimpacted by shoreline erosion. Dunes in fenced and planted sites grew at an annual rate of 0.4 ft/yr, while associated reference plots grew at an average rate of 0.3 ft/yr over the 5-year period. However, reference areas exhibited 9% higher volume gains than fenced areas surveyed after 5 years. We feel the small sample size and location of most reference plots to the west of the fence sites probably contributed to these volume and elevation results, because of the dominant direction of longshore sand movement from southeast to northwest. Vegetation exhibited high survival rates (98% at 1 year post-planting) and covered dunes well (44% at 1 year post-planting). However, after 5 years, cover values were the same as at the time of initial planting in the one remaining treatment, and the two planted species contributed less cover and occurred less frequently than they did after initial planting. The authors believe that the sampling method biased these results and that cover was better than pre-construction where treatments survived. Overall, fences and plantings did build dunes. However, even well-established dunes cannot prevent the natural transgression of the shoreline and will eventually erode as the shoreline retreats. This is evidenced by the fact that all treatments, other than at Site A, have eroded from east to west, as the barrier island's natural process of northwestward migration occurs. One-time applications of fences and plantings cannot stabilize the beach and will continue to show similar results on Louisiana's highly transgressive shorelines. Based on these conclusions, an overall programmatic approach of sand management is recommended, including: 1) placing features parallel to the shoreline since they are effective and more cost efficient per linear foot of beach; 2) containing minimal gaps such that they build as continuous a dune as possible; 3) building dunes to appropriate elevations that will maintain regional balance in collisions and overwash regimes (islands should not be built so high that they will never be overwashed); 4) regular maintenance; 5) expanding the program as dunes form, to provide multiple dunes; 6) responding quickly to storm impacts; and 7) utilizing biodegradable materials as appropriate, to ensure that the use of sand fencing and vegetative plantings will positively contribute to Louisiana's restoration program.

INTRODUCTION

The Timbalier Island Plantings Demonstration (TE-18) project is a 5-year demonstration of sediment trapping fences in conjunction with vegetative plantings to build dunes. The project is located along the Gulf of Mexico shoreline of Timbalier Island, in Terrebonne Parish, Louisiana (figure 1). The project was sponsored by the United States Department of Agriculture, Natural Resources Conservation Service (USDA/NRCS), and the Louisiana Department of Natural Resources, Office of Coastal Restoration and Management (LDNR/OCRM), under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA, Public Law 101-646, Title III). The project area consists of sand fencing, vegetative plantings, or both at seven treatment sites totaling approximately 7,390 linear ft (2252 m) of the gulf shoreline of Timbalier Island.

Timbalier Island is part of the chain of barrier islands, the Timbalier Islands, which border Timbalier Bay in Terrebonne Parish, Louisiana, and part of the Caminada-Moreau Headland system. The island has decreased in size by 58% over the last century (Hester and Mendelssohn 1992), and the island's average width has decreased from 2,789.5 ft to 1,361.9 ft (850.2 m to 415.1 m) between 1978 and 1988 (Williams et al. 1992). McBride and Byrnes (1997) projected island disappearance by the year 2046, based upon long-term (1887–1988) average gulfside and bayside shoreline change rates of -23.0 ft/yr (-7.0 m/yr) and -46.3 ft/yr (-14.1 m/yr), respectively.

The dunes of Timbalier Island are not well developed as a continuous dune line and are generally less than 6.6 ft (2.0 m) above mean sea level (MSL) (Mendelssohn and Hester 1988). These factors leave the island highly susceptible to erosion, storm overwash, and breaching. Stabilized sand dunes reduce the likelihood of island breaching and erosion from wave action, storm waves, and surges (Mendelssohn and Hester 1988; Mendelssohn et al. 1991). Plants accumulate sand and can colonize overwash areas after storm events, providing a stabilizing effect on island sands.

The goal of the Timbalier Island Plantings Demonstration (TE-18) project is to provide a catalyst to hasten the development of dunes on Timbalier Island by utilizing sediment-trapping fences, vegetative plantings, or a combination of both to trap and stabilize aeolian and *in situ* (overwash) sediments (Raynie 1998). The specific goals of the project are: (1) to increase the percent cover of emergent vegetation behind the sediment-trapping fences and (2) to increase the elevation of areas adjacent to the sediment-trapping fences.

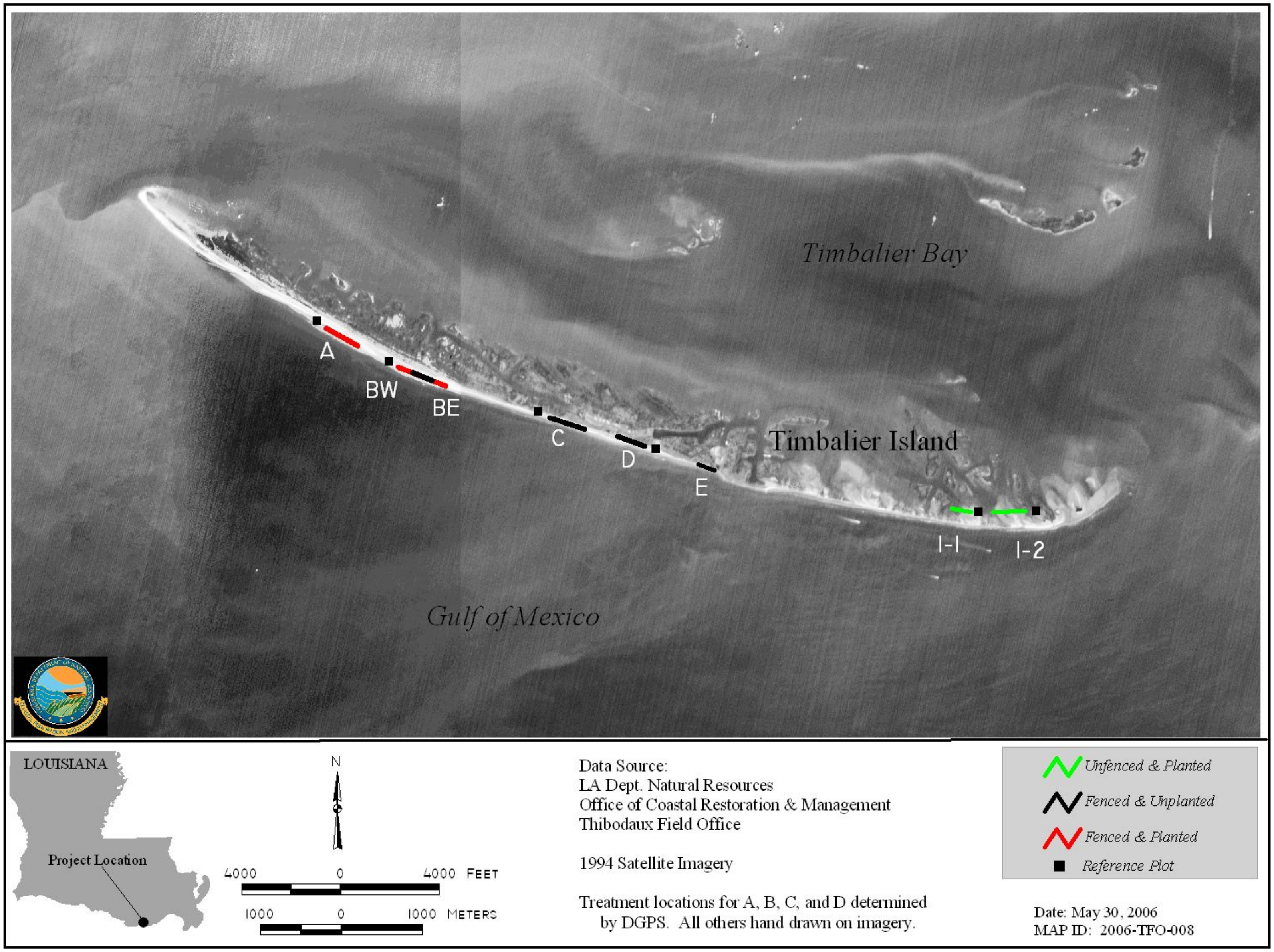


Figure 1. Timbalier Island Plantings Demonstration (TE-18) project features.

METHODS

Project Features

Project goals were to be accomplished by the construction of approximately 7,390 linear ft (2252 m) of sand fencing at seven sites along the length of the island, parallel to the Gulf of Mexico shoreline (figure 1). Each fence site had a primary fence oriented parallel to the gulf shoreline with perpendicular spurs every 50 ft (15.2 m) that extended 25 ft (7.6 m) bayward from the primary fence (figure 2).

Fence construction was completed in July 1995. However, numerous tropical storms damaged the fences, and repairs were conducted in October 1995 to sections at Sites A through D. Fence sections at Sites E, I-1, and I-2 were damaged beyond repair. Fence sections at Sites B through D were repaired again due to additional storm damage immediately prior to planting in July 1996.

Spartina patens (marshhay cordgrass) and *Panicum amarum* var. *amarulum* (Atlantic panicgrass) were planted on the bay side of the remaining fences (Sites A – D) between the perpendicular fence spurs, as indicated by the planting scheme (figure 3). Minor changes were made in the planting design at the time of planting, which occurred under the supervision of NRCS in July 1996. Site A was planted as prescribed. No plantings occurred in Sites C and D, since vegetation was naturally colonizing the site or it was destroyed. Site B was planted on the

Figure 2. Typical sand fencing with perpendicular spurs at Timbalier Island Plantings Demonstration (TE-18) project (photo taken at Site A, July 1996, looking northwest).

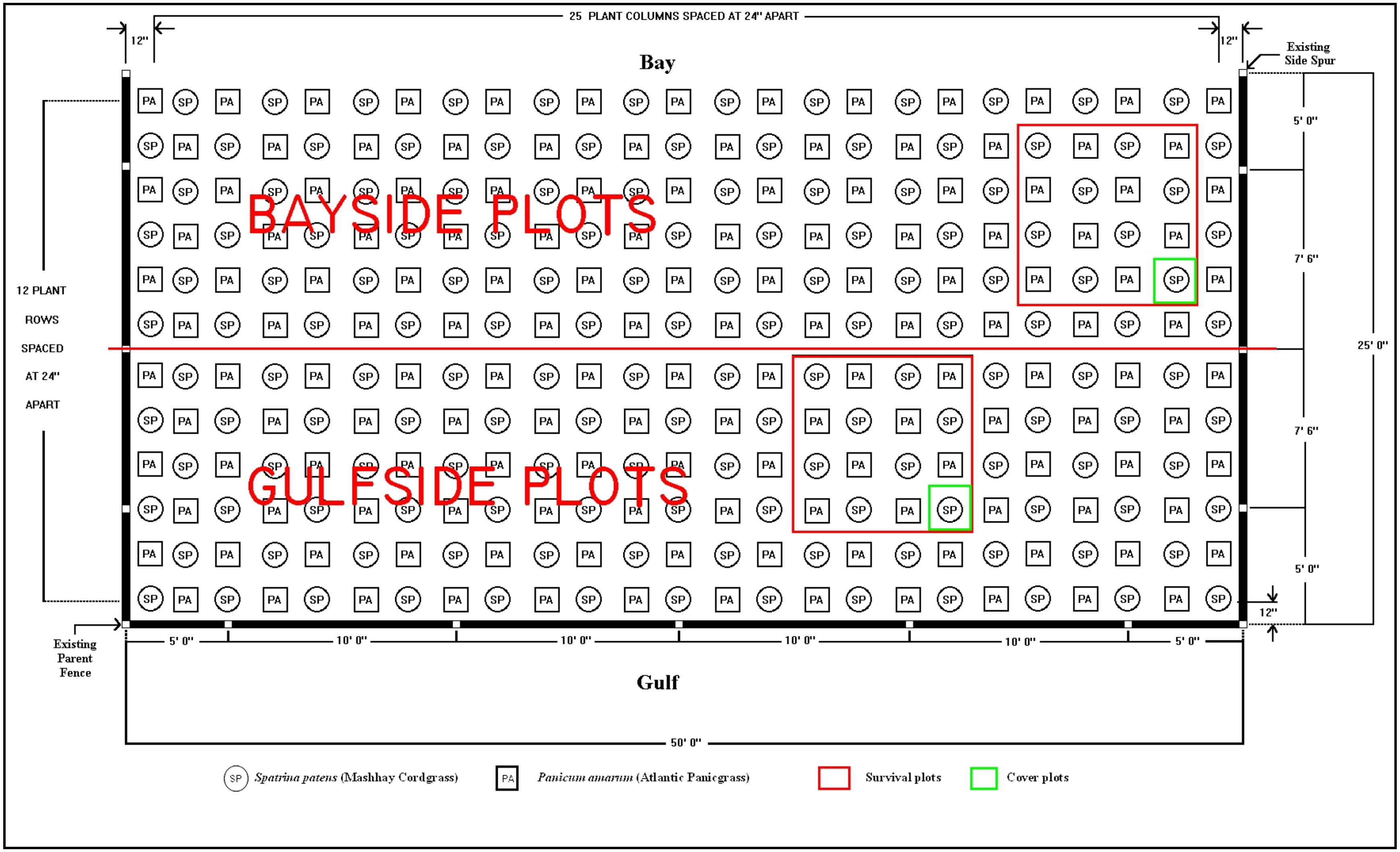


Figure 3. Typical layout for vegetation planting within a 50-ft (15.2-m) segment (fenced or unfenced), including examples of randomly placed 2.0-m x 2.0-m vegetation survival plots and 0.5-m x 0.5-m vegetation cover plots for the Timbalier Island Plantings Demonstration (TE-18) project.

eastern and western ends, referred to as BE and BW respectively, while the middle section of the site was not planted since it was naturally vegetating. Sites I-1 and I-2 were planted on overwash areas bayward of the fence sites damaged in the aforementioned storms, and Site E was abandoned, as mentioned previously.

Monitoring Design
Raynie (1998) provides a detailed description of the monitoring design over the entire life of the project which includes:

Aerial Photography: The National Wetlands Research Center (NWRC) in Lafayette, LA, obtained 1:12,000 scale near-vertical color-infrared (CIR) aerial photography of the Timbalier Island Plantings Demonstration (TE-18) project area on November 21, 1993, and November 19, 2001 (figure 4). This pre-construction (1993) and post-construction (2001) photography was checked for flight accuracy, color correctness, and clarity. The original film was archived and duplicate photography was indexed and scanned at 300 dots per inch. Using ERDAS Imagine®, an image processing and geographic information systems (GIS) software package, individual frames of photography were geo-rectified and combined to produce a mosaic of the island, which was classified to determine the project's land-to-water ratios and the total acreage of the island. A classified GIS land-water layer at 1 meter resolution was produced.

The GIS land-water analysis of the 1993 photography classified the island into three categories: water, land, and unvegetated sand (figure 5). The water class includes all open water and submerged land. The sand class includes all areas of dry, unvegetated sand (i.e., beaches and ephemeral landforms) exposed at the time of photography. The remainder of the island falls into the land category. The sand class was added to the classification system in an attempt to minimize the effects of daily tidal fluctuations on land-water ratios. Together, the land and sand categories make up the total land area exposed at the time of photography. Due to a CWPPRA programmatic monitoring budget reduction, future land-water analysis was eliminated from the project budget in 1998. This decision was based on the short project life and limited relevance of land-water changes to the specific goals of the project.

Additional funding sources provided 1:24,000 CIR aerial photography of Timbalier Island in May and November 2002 (figure 6). The University of New Orleans - Coastal Research Laboratory (UNO/CRL) acquired the May 2002 photography during the 2002 CWPPRA Adaptive Management process and then photographed the island following Tropical Storm Isidore and Hurricane Lili in November 2002, to assess damage to the barrier islands by the back-to-back storms. The November 2002 photography was used to develop a habitat map at 2 m resolution (figure 7). The habitat analysis classified the island into beach, bare land, marsh, and barrier vegetation. Acreages of intertidal habitat were also provided. LDNR personnel collapsed the classified habitats into land (marsh and barrier vegetation habitats), sand (beach and bare land habitats), and water (water and intertidal habitats) classes for comparisons to the 1993 NWRC land-water analysis.

In addition to overall trends in island habitats, specific areas affected by fenced treatments (A – D) were isolated to compare habitat trends at each location. An area of the same width and

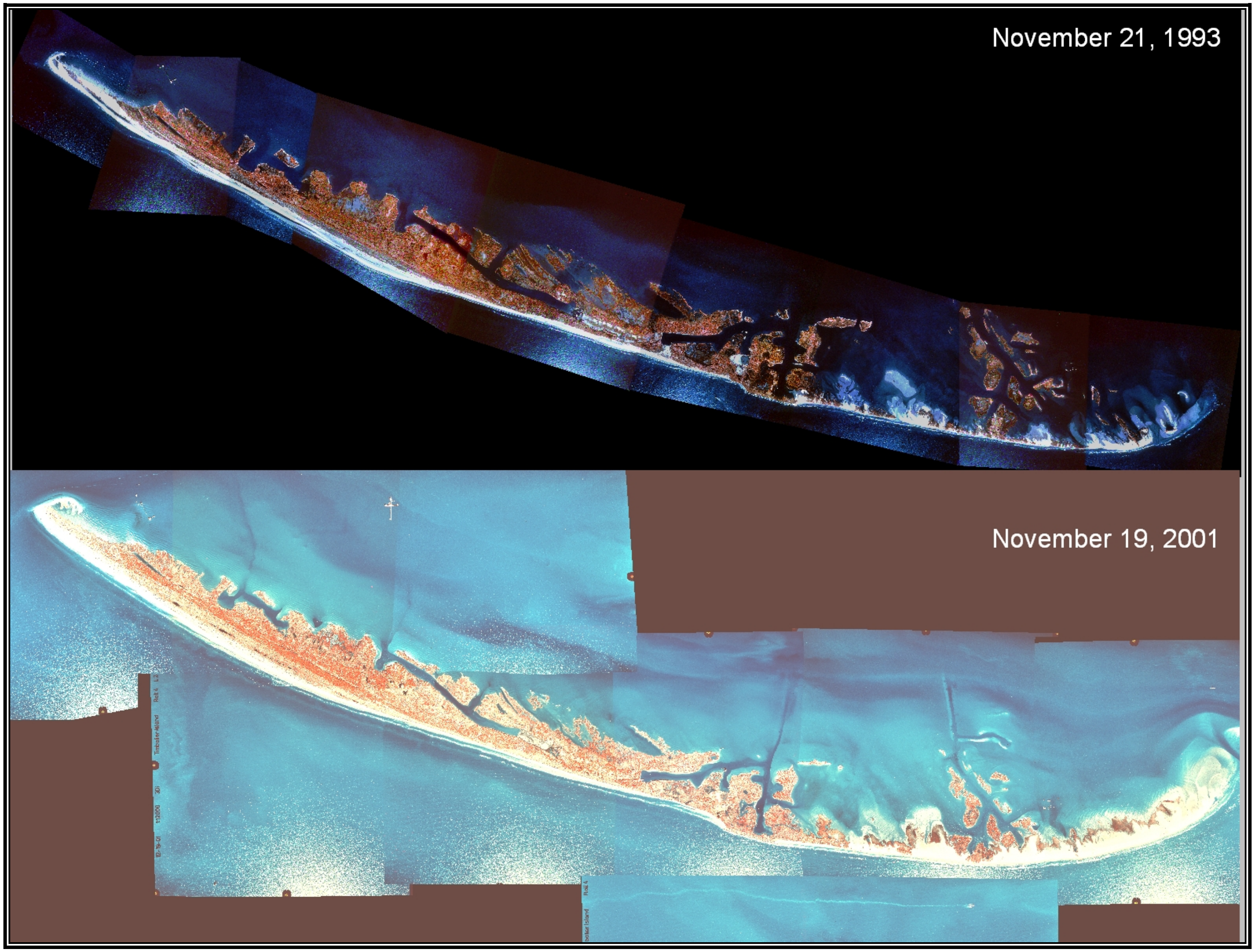


Figure 4. **Mosaic of the November 1993 and 2001 CIR aerial photography of the Timbalier Island, produced by USGS/NWRC, Lafayette, LA.**

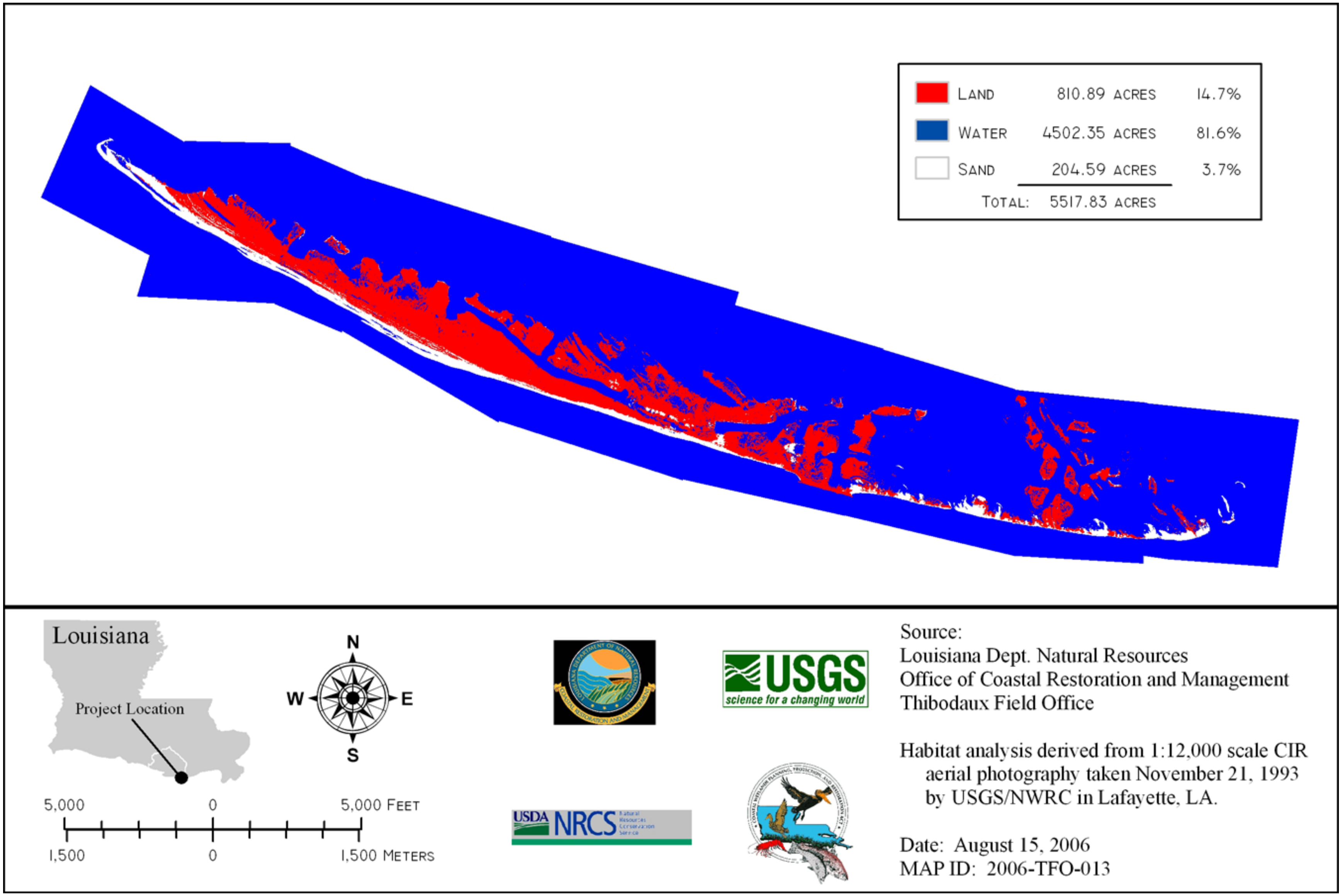


Figure 5. USGS/NWRC land-water analysis from the 1993 CIR aerial photography of the Timbalier Island Plantings Demonstration (TE-18) project.

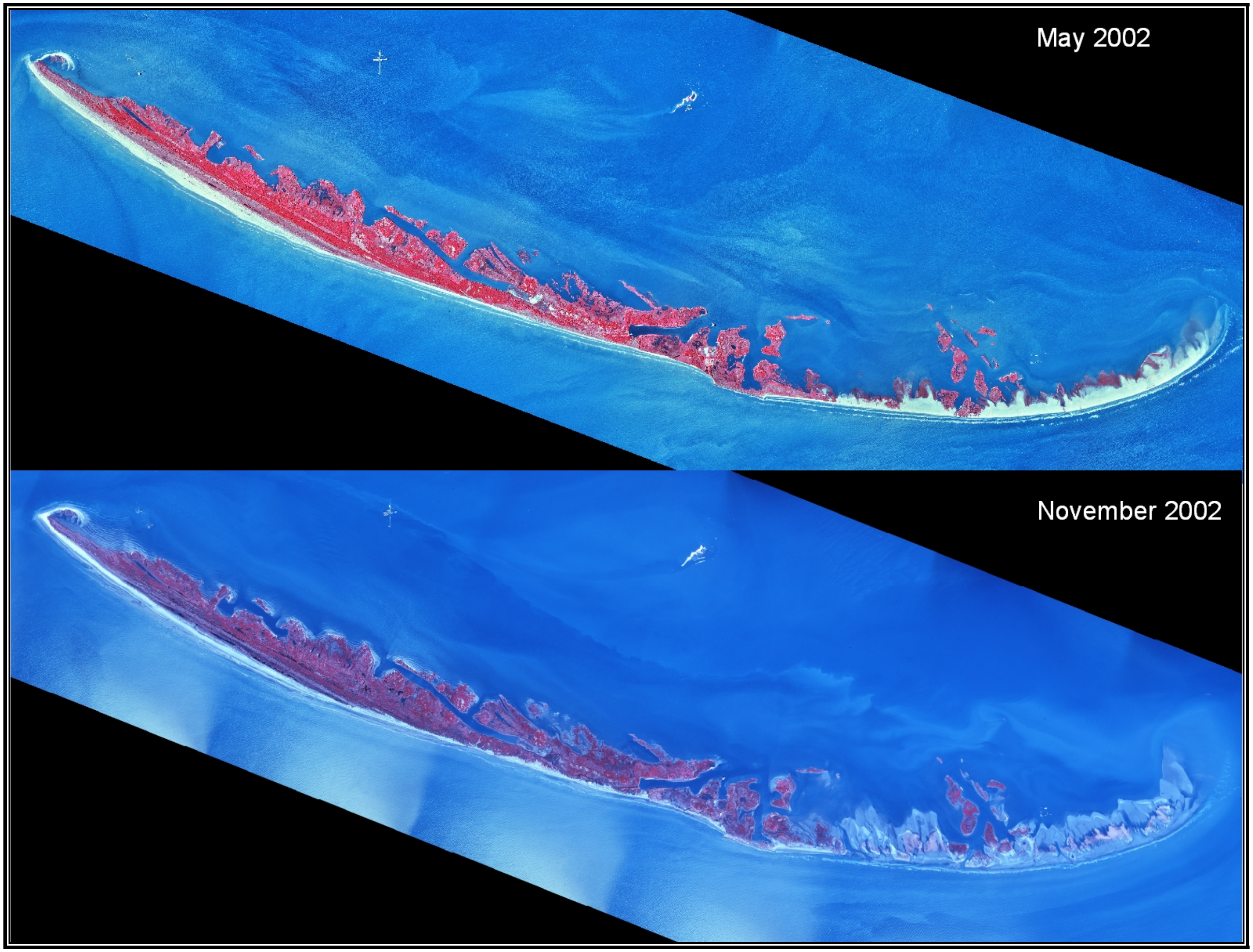


Figure 6. **Mosaic of the May 2002 and November 2002 CIR aerial photography of Timbalier Island, produced by the University of New Orleans-Coastal Research Lab, New Orleans, LA.**

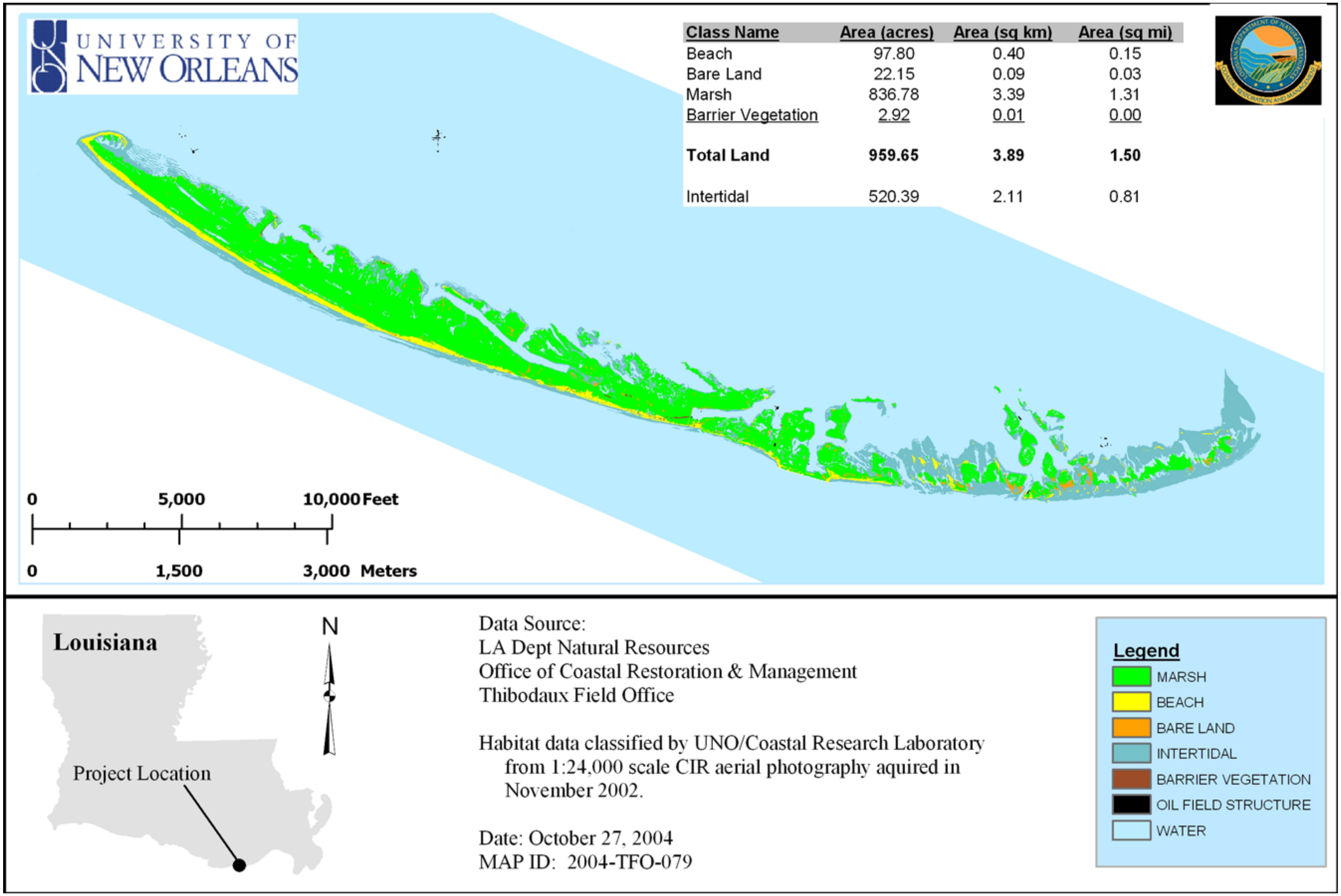


Figure 7. Habitat analysis from the November 2002 CIR aerial photography of Timbalier Island.

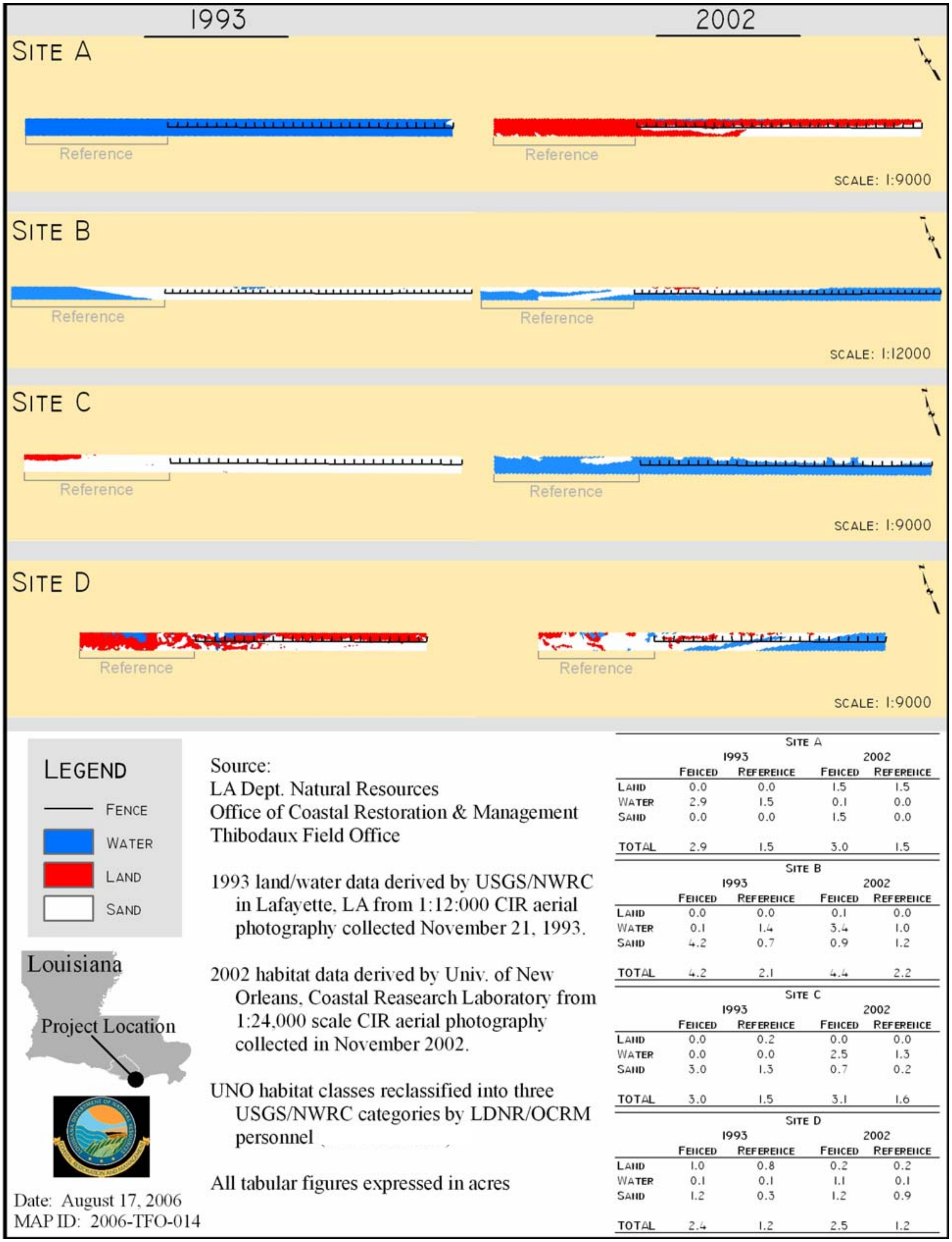
placement as the elevation surveys (90.0 ft [27.4 m]) was used to analyze site-specific changes in habitats over approximately 9 years. In addition, a reference area immediately west of each treatment site was analyzed. The reference area was the same width but half the distance of the fence at each treatment (figure 8).

Due to differences in resolution and classification methods, comparisons should be viewed with some caution, but because they are available they are presented to provide an overview of the land-water trends for the island and treatment sites.

Vegetation: Vegetation sampling was conducted by LDNR/CRD and NRCS personnel 1 month post-planting in August 1996, 1 year post-planting in August 1997, 3 years post-planting in August 1999, and 5 years post-planting in September 2001. Vegetation was sampled at two randomly placed 2.0-m x 2.0-m permanent plots, one bayside and one gulfside, within each segment of the planted sites (figure 3). Plots were given the treatment designation of "bayside" or "gulfside," based on the location of the plants with respect to the center line of the fence segment and the Gulf of Mexico (figure 3). From all 126 plots, percent survival of the planted individuals was determined and two plants within each plot were randomly selected to determine tiller number and tiller length. In addition, percent cover of plants and plant species composition were determined in a 0.5-m x 0.5-m sub-plot, located in the southeast corner of the 2.0-m x 2.0-m survival plot. The small size of the species composition plot may have biased initial results due to the placement of the plot over one of the planted species. The initial cover estimates were high due to the plot being filled by the plantings, and covers may appear reduced in the future as plantings were outcompeted; plants filled in bare areas and cover was reduced in the small plots. Reference plots were established adjacent to each treatment to provide comparisons of cover values for unplanted areas.

Typically, vegetation data collected in 1996, 1997, 1999, and 2001 at the Timbalier Island Plantings Demonstration (TE-18) project would be combined for analysis. Since the data set was unbalanced due to loss of numerous segments and complete sites at various times, data comparisons were made within the set for each year using an unbalanced block design. The assumptions of parametric analysis were tested using Statistical Analysis System (SAS) univariate procedure. When the univariate procedure indicated that data were not normally distributed, square root transformation ($x^{1/2}$) of the data was conducted, which resulted in a near-normal distribution. Percent cover, tiller number, and tiller spread were square-root transformed for analysis. Data were analyzed with the SAS Analysis of Variance (ANOVA) procedure and the least significant difference (LSD) procedure at the 95% confidence level to determine differences among treatments. Based on the small p-values produced by the ANOVA, the effect of transforming non-normal data should not diminish the overall conclusions drawn from the analyses. Data were de-transformed for presentation.

Importance values (IV's) were calculated by adding the relative percent cover to the relative frequency for each species (Barbour et al. 1998; Courtemanche et al. 1999). Relative percent cover is the total percent cover of a species in each plot divided by the summed total percent cover of all species in each plot. Relative frequency for each species is the sum of each species occurrence divided by the total number of plots in a treatment. Based on these definitions, the potential maximum sum of any species' IV is 200. Importance values provide a



Site A

	1993 Fenced	1993 Reference	2002 Fenced	2002 Reference
Land	0.0	0.0	1.5	1.5
Water	2.9	1.5	0.1	0.0
Sand	0.0	0.0	1.5	0.0
Total	2.9	1.5	3.0	1.5

Site B

	1993 Fenced	1993 Reference	2002 Fenced	2002 Reference
Land	0.0	0.0	0.1	0.0
Water	0.1	1.4	3.4	1.0
Sand	4.2	0.7	0.9	1.2
Total	4.2	2.1	4.4	2.2

Site C

	1993 Fenced	1993 Reference	2002 Fenced	2002 Reference
Land	0.0	0.2	0.0	0.0
Water	0.0	0.0	2.5	1.3
Sand	3.0	1.3	0.7	0.2
Total	3.0	1.5	3.1	1.6

Site D

	1993 Fenced	1993 Reference	2002 Fenced	2002 Reference
Land	1.0	0.8	0.2	0.2
Water	0.1	0.1	1.1	0.1
Sand	1.2	0.3	1.2	0.9
Total	2.4	1.2	2.5	1.2

Figure 8. **Comparison of 1993 and 2002 land-water analysis for each fenced location included in the Timbalier Island Plantings Demonstration (TE-18) project.**

useful and more realistic measure of dominance. Mean IV's were determined by categorizing plant species into planted (i.e., *S. patens* or *P. amarum*), present via natural recruitment or re-colonization, and bare ground. Species were further separated into habitat niches determined by where they were commonly located: foredune, dune, back swale, bare ground, and other (multiple habitat niches) (figure 9). These categories were selected from a review of several sources (Mendelssohn *Unpublished*; Tiner 1993; Courtemanche et al. 1999) and personal experience.

<u>*Elevation*</u>: The pre-construction elevation survey was conducted by NRCS in May 1995 and tied into the Louisiana South Zone Coordinate system in the National Geodetic Vertical Datum of 1929 (NGVD) from a permanent benchmark as listed on 1996 monitoring survey drawings (USDA/NRCS 1996). The second survey was conducted with the one-month post-planting vegetation sampling in July/August 1996. The third survey was completed in July/August 1997 and the fourth survey was completed in August 1999. The latest survey was completed in September of 2001. All elevation surveys were conducted by NRCS using the conventional leveling rod survey technique. All surveys used the same control points and are not tied to the Louisiana Coastal Zone GPS Network (USDA/NRCS 1996, 1997, 1999, 2001).

Vertical elevations were collected along transects located within the sixth segment from the eastern end of Sites A, B, C, and D (figure 10). Elevation data in 1999 and 2001 were collected only from Sites A and C and their associated reference plots, because the fence segments were still identifiable. Beginning 5 ft (1.5 m) from the side spur of the plot, to reduce direct influence of the side spur, five transect lines were established at 10-ft (3.0-m) intervals. The two outermost lines extended 45 ft (13.7 m) past the fencing onto the beach towards the Gulf of Mexico. Along

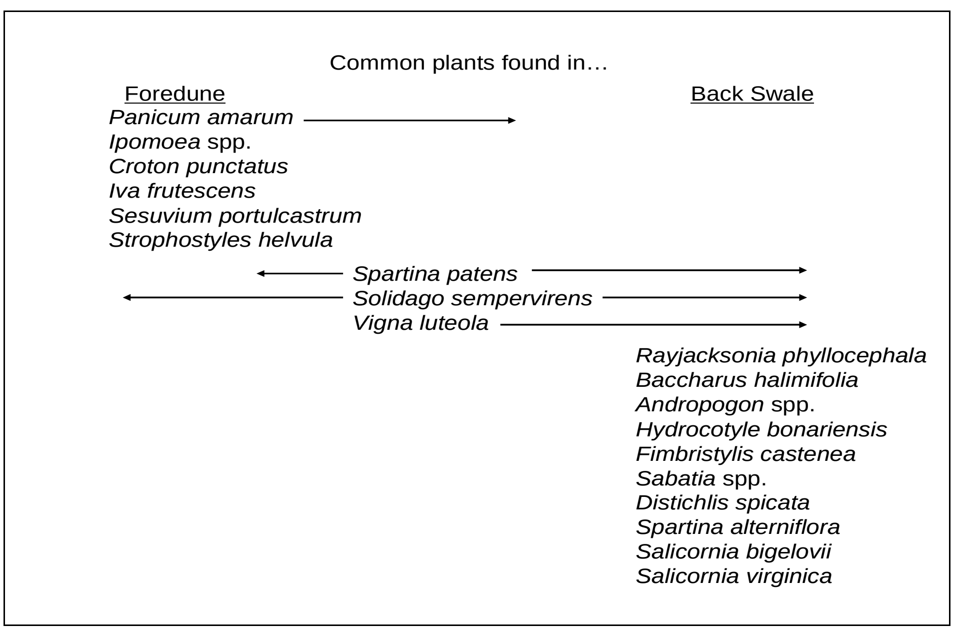


Figure 9. Classification of plant species found at the Timbalier Island Plantings Demonstration (TE-18) project for habitat shift analysis.

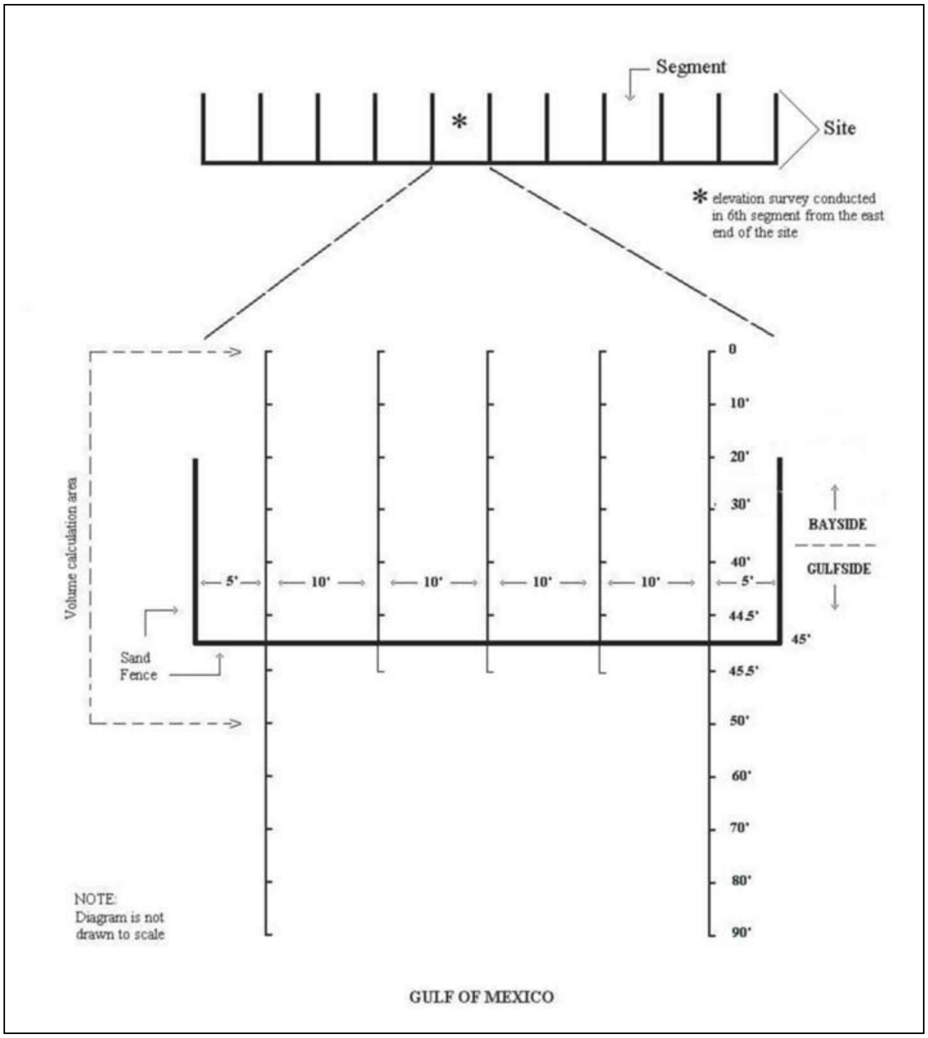


Figure 10. Typical elevation survey schematic within a segment at the Timbalier Island Plantings Demonstration (TE-18) project.

each transect, elevation measurements were taken at 10-ft (3-m) intervals with additional points at 44.5 ft (13.6 m) and 45.5 ft (13.9 m) to avoid the fence (figure 10). The raw data and blue line drawings from the elevation survey were provided to LDNR/CRD personnel (USDA/NRCS 1996, 1997, 1999, 2001). Associated with each site, an unfenced reference plot, the same dimensions as the sampled fenced segment, was established by NRCS and surveyed in the same manner as the fenced segments (figure 1). These reference plots were selected to allow comparisons of sand accumulation in the fenced treatments to that in unfenced reference areas. Reference plots were established on various sides of the fences and at various distances from the treatment area. However, an attempt was made to establish reference plots far enough from fenced treatments to eliminate any influence yet remain within the same shoreline area.

A Triangulated Irregular Network (TIN) model was created from the elevation data for each of the elevation plots using ESRI ArcView® and ArcGIS®, geographic information system (GIS) software packages. A surface was interpolated from the elevation data collected for each of the four fenced segments (90.0 x 40.0 ft [27.4 x 12.2 m] including the fence) and their associated reference plots (figure 11). Each TIN model was converted to a grid model, and area calculations, volumes, and volume changes were determined by using the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center's Light Detection And Ranging (LiDAR) Data Handler ArcGIS® extension. All volumes were calculated above a base elevation of zero NGVD and the software's grid subtractor and cut/fill calculator functions were utilized to subtract the earlier surface from the later surface and calculate areas and volume losses or gains (figures 11, 12, 13 and 14).

In addition, a typical dune profile was developed for each plot for each sample period. The typical dune profile was the average elevation at each interval along all transects in the 90 x 40-ft (27.4 x 12.2-m) plot, including the fence (i.e., all measurements across each transect were averaged to obtain the average dune elevation at each transect interval). Average change in dune height was then calculated from the typical dune profiles by calculating the difference between the highest point on each typical dune profile at time *i* and time *i+1* for each 90 x 40-ft (27.4 x 12.2-m) plot (figure 10). These data will be used to compare the effects of sand fences on sand trapping and dune development over time.

A LiDAR topographic survey of the Timbalier Islands was conducted in March 2000 by John Chance Land Surveys, Inc., with funding from other CWPPRA projects. The survey acquired subaerial elevation data along East Timbalier Island, Timbalier Island, East Island, Trinity Island, Whiskey Island, and Raccoon Island. The helicopter-mounted LiDAR system (FLYMAP II®) was selected as a preferred method for topographic data collection over traditional ground surveys because it provides a cost-effective means for acquiring large amounts of elevation data over relatively large areas, and presently LDNR/OCRM has several barrier island restoration projects currently under way on the Timbalier and Isles Dernieres barrier islands.

Also, additional funding sources provided two additional LiDAR surveys during September 2001 and November 2002. USGS conducted airborne LiDAR topographic surveys of Timbalier Island using NASA's Airborne Topographic Mapper (ATM) system (Krabill et al. 1995; Sallenger et al. 1999; Stockdon et al. 2002; Sallenger et al. 2003).

LDNR/OCRM personnel created a grid model of Timbalier Island from the 2000 LiDAR data in the same manner as described above for the NRCS elevation surveys. USGS provided grid models for the 2001 and 2002 LiDAR data sets, and LDNR/OCRM personnel created unedited 1-ft (0.3048-m) contour lines from all LiDAR grids using ESRI ArcView® Spatial Analyst extension. Additionally, grid models were subtracted as described above for the NRCS elevation surveys to determine overall elevation changes. These data are useful in determining overall island geomorphic changes that may affect sand fence effectiveness and longevity.

Since fence construction in July 1995, numerous storm events have impacted the project (Townson and Gaudet 1998) (figure 15). By the 2001 sampling period, Site A was the only treatment which remained undamaged and from which all data could be collected.

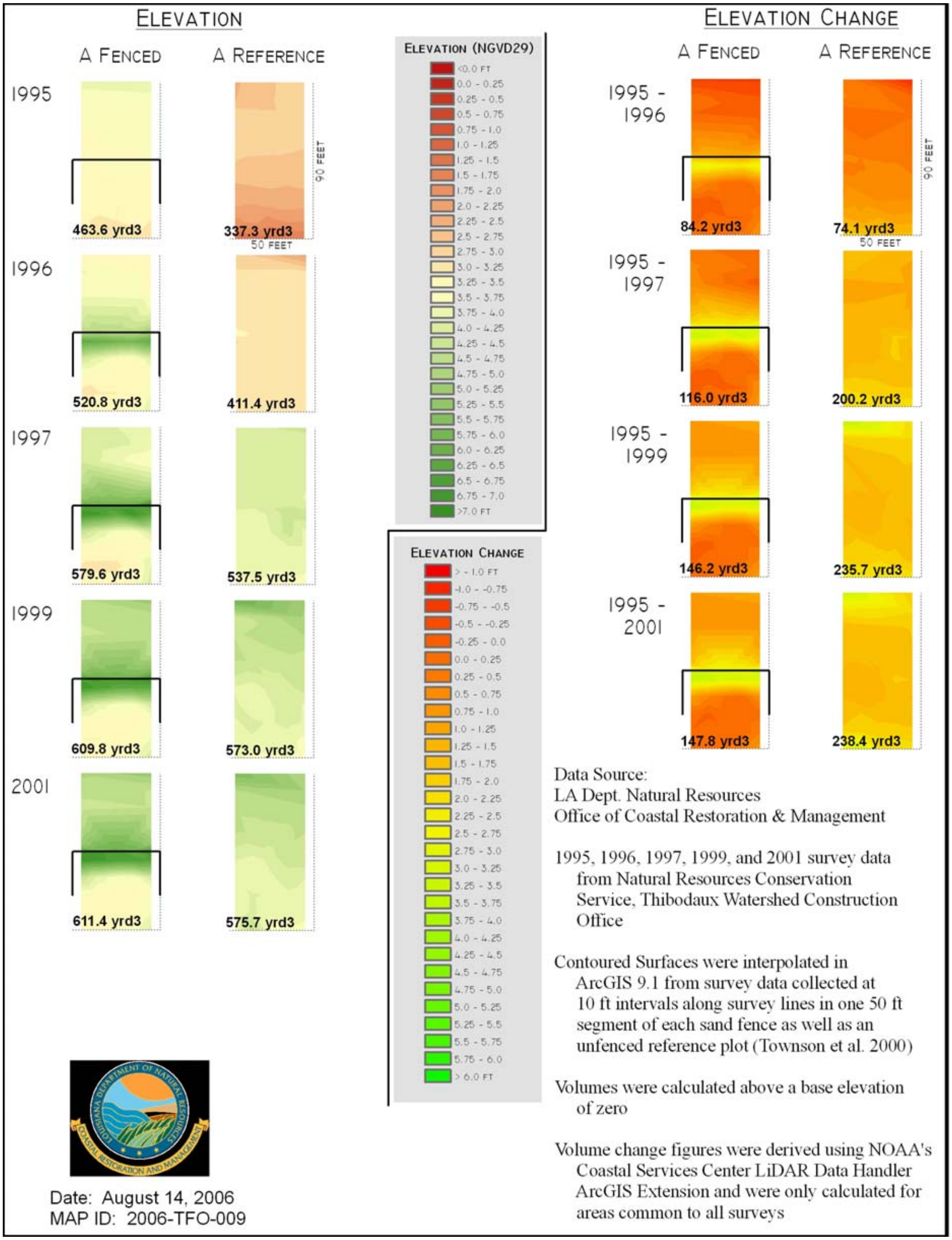


Figure 11. Elevation and elevation change contours from NRCS survey data, with volumes and volumetric changes, for Site A at the Timbalier Island Plantings Demonstration (TE-18) project.

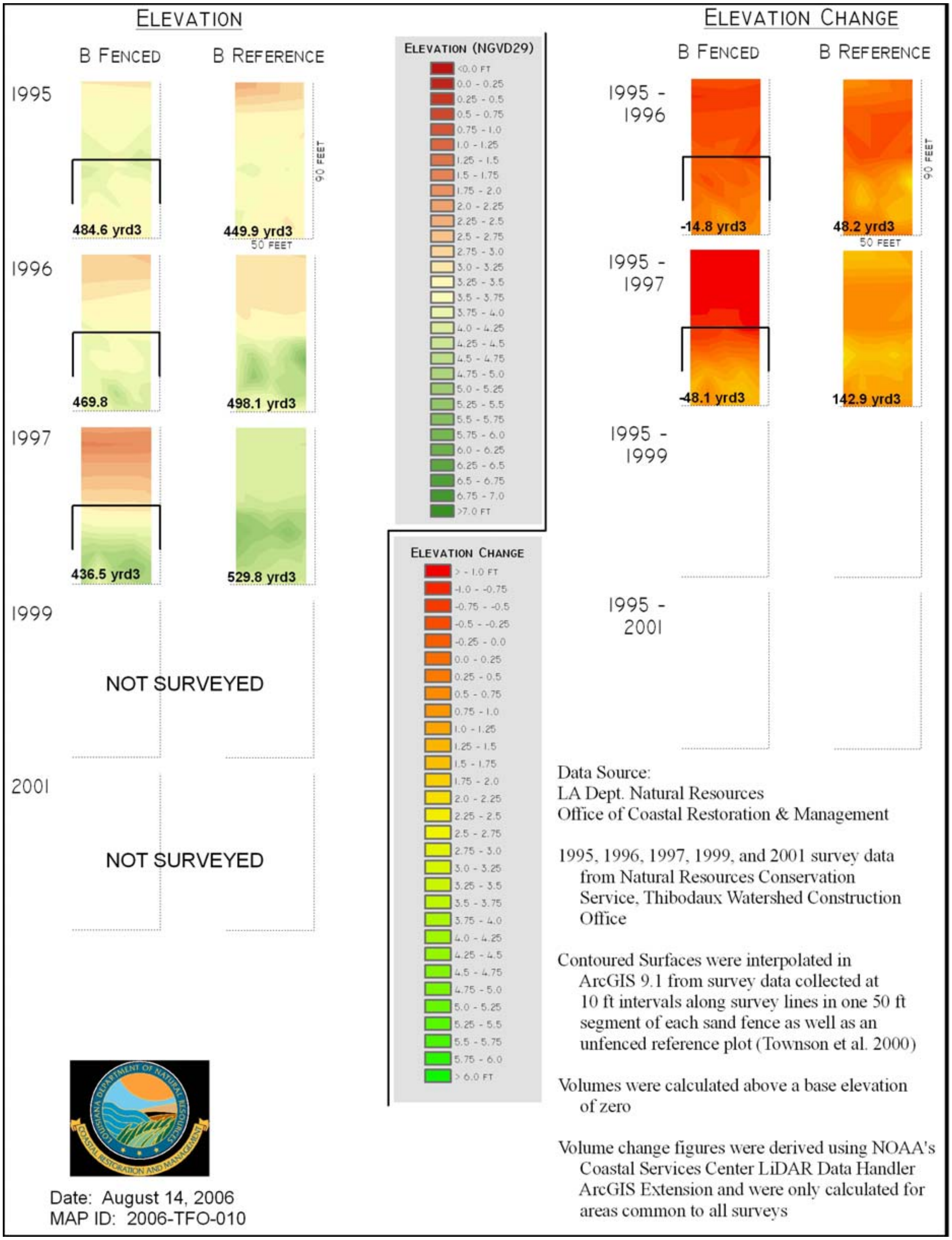


Figure 12. Elevation and elevation change contours from NRCS survey data, with volumes and volumetric changes, for Site B at the Timbalier Island Plantings Demonstration (TE-18) project.

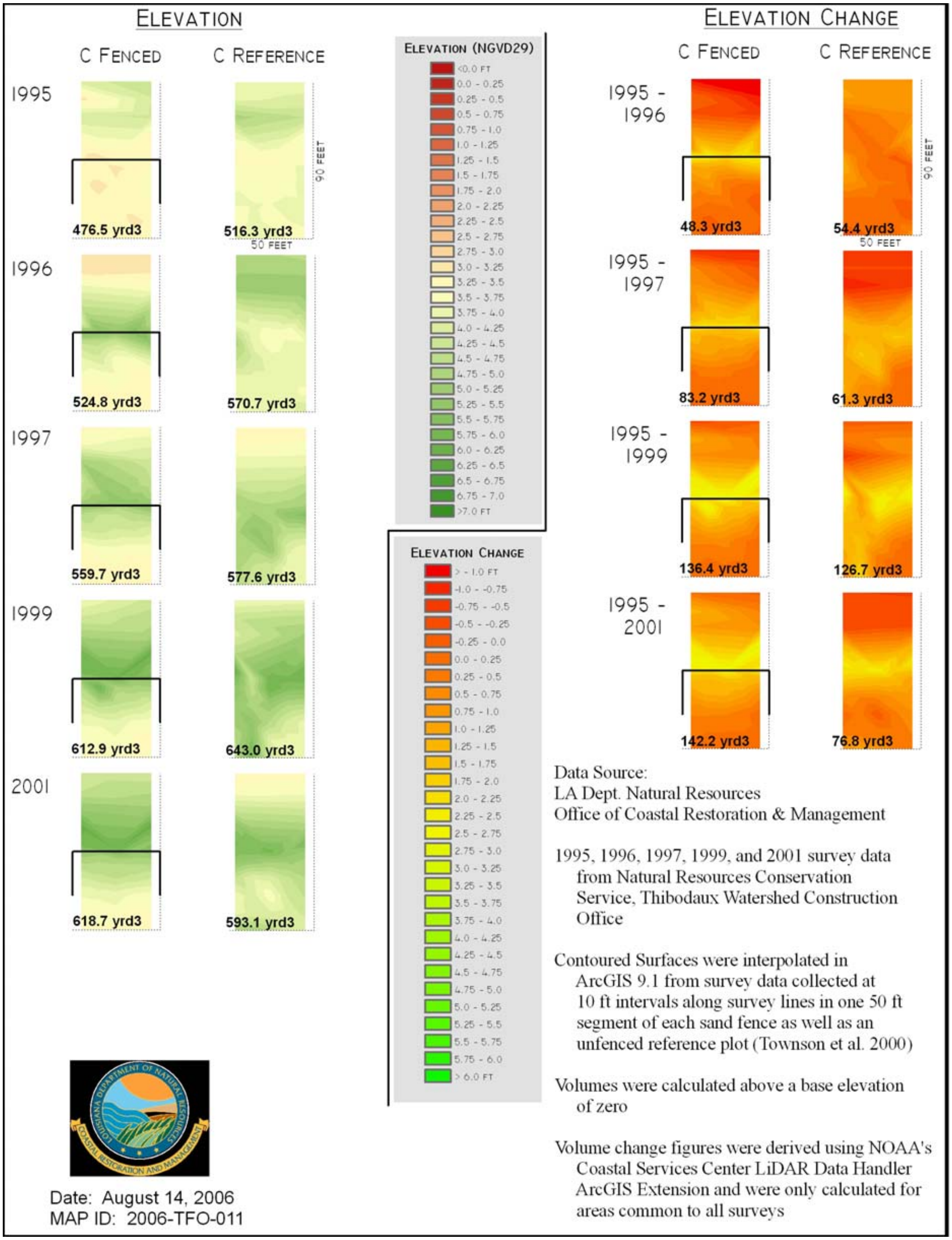


Figure 13. **Elevation and elevation change contours from NRCS survey data, with volumes and volumetric changes, for Site C at the Timbalier Island Plantings Demonstration (TE-18) project.**

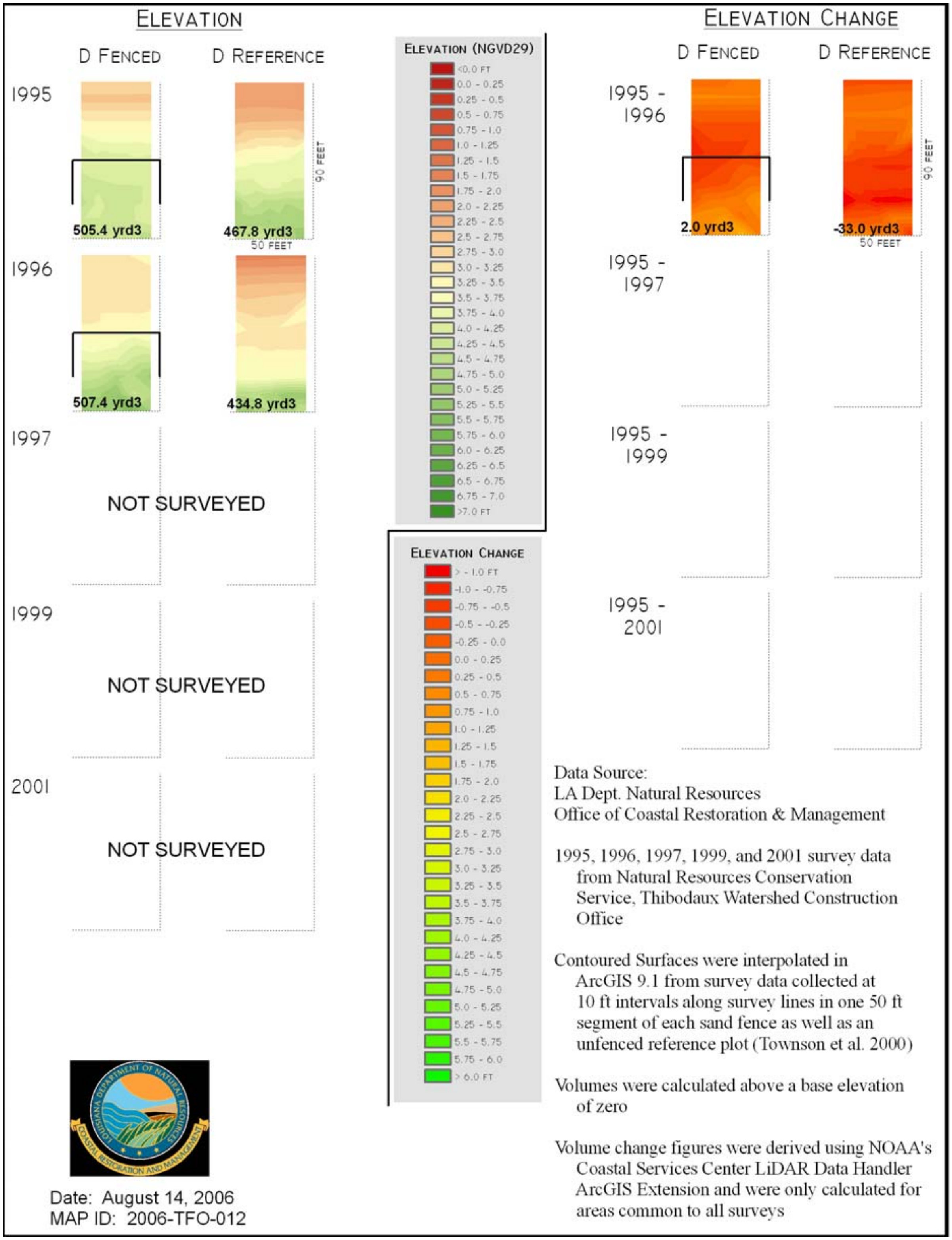


Figure 14. Elevation and elevation change contours from NRCS survey data, with volumes and volumetric changes, for Site D at the Timbalier Island Plantings Demonstration (TE-18) project.

Figure 15. Eastern end of fence at Site B after impacts from storm waves and debris at the Timbalier Island Plantings Demonstration (TE-18) project (LDNR photo, taken September 2001).

RESULTS

Aerial Photography: According to the GIS land-water analysis, at the time of the 1993 USGS/NWRC photography, the island was composed of 810.89 ac (328.16 ha) of land and 204.59 ac (82.80 ha) of unvegetated sand (figure 5). Combining these two classes results in a total area of 1,015.48 ac (410.95 ha). No analysis of the 2001 USGS/NWRC photography was conducted due to the monitoring program budget adjustments in 1998, so the next data set available was the November 2002 habitat data from the UNO/CRL flight.

The November 2002 habitat classification showed the island was composed of 97.80 ac (39.58 ha) of beach, 22.15 ac (8.96 ha) of bare land, 836.78 ac (338.63 ha) of marsh, and 2.92 ac (1.18 ha) of barrier vegetation for a combined total of 959.65 ac (388.36 ha) (figure 7). This may indicate a net loss of approximately 55.83 ac (22.59 ha) from the 1993 data and an overall loss of approximately 5.5% of the total land.

Also, the comparison of unvegetated sand in 1993 to beach and bare land in November 2002 may indicate the dramatic loss of sand on the island. The data indicate that the overall loss of 84.64 ac (34.25 ha) of sandy areas, accounting for the majority of the overall loss, was a factor in land change on the island. This is an approximate 41.37 % loss of beach/sand on the sub-aerial portion of the island during the previous nine years.

However, when looking at USGS's land category versus UNO's marsh, a gain of 25.89 ac (10.48 ha) occurred. This difference in gain versus overall loss may indicate that classification differences (UNO intertidal class) could be responsible for the large differences in the land change results. Taking the opposing results into account, it seems the data indicate a somewhat stable island overall (only approximately 5% change), with the majority of any changes apparently in the sandy areas, but the extent of the changes are difficult to determine definitively due to different data sets.

Specific change analysis for each treatment site experiences the same issues as discussed above, but it seems to indicate the trend of land to water conversions over time (figure 8). All sites, other than Site A, increased in the amount of water (includes UNO intertidal class) over time. Site A had significant increases in coverage of land, from all water to 100% land, but it was the only site to show this trend. Additionally, the two treatments that had land in 1993 exhibited transition from the land into the sand or water categories by 2002. Even Site B, which did show a minor gain of land (0.1 ac [0.04 ha]), had an overall change of 4.2 ac (1.3 ha) of sand to 0.9 ac (0.27 ha) of sand in 2002. Additionally, the reference areas showed the same trends in changes from land to sand or water as the treatments to which they were compared. The specific changes reported should be viewed with caution due to differences in classification methods, but the overall trends seem representative of other studies that showed shoreline erosion (Beall et al. 2004; Connor et al. 2004) with concomitant changes in habitats as land changed to sand and then water along the shoreline.

Vegetation: As stated previously, wave impacts on various treatments at various times made testing treatment location effects on survival difficult. However, previous reports (Townson and Gaudet 1998; Townson et al. 2000) stated that location effects on survival were significant both

1 month and 1 year post-construction. After the 1-year post-construction sampling, no treatment location effects on survival could be tested due to destruction of all but the fenced treatment at Site A. The destruction of treatments, however, seems to be an obvious confirmation of continuing the study of the effect of treatment location on survival (Townson and Gaudet 1998, Townson et al. 2000).

Survival data were analyzed to determine differences in bayside versus gulfside plantings. Previous monitoring reports (Townson and Gaudet 1998; Townson et al. 2000) stated that where sampled, bayside plots had significantly higher percent survival in the entire first three sample

Table 1. Mean percent survival and mean percent cover for August 1996 (1 month post-planting), August 1997 (1 year post-planting), August 1999 (3 years post-planting), and September 2001 (5 years post-planting) vegetation sampling at Timbalier Island Plantings Demonstration (TE-18) project (n = number of plots).

		Mean % Survival				Mean % Cover			
Site	Treatment	1996	1997	1999	2001	1996	1997	1999	2001
A	Bayside	99	99	64	---[a]	51	54	55	53
	Gulfside	87	89[b]	41	---[a]	22	34	48	21
BW	Bayside	95	94	---[c]	---[c]	34	44	---[c]	---[c]
	Gulfside	86	83	---[c]	---[c]	26	43	---[c]	---[c]
BE	Bayside	100	---[c]	---[c]	---[c]	42	---[c]	---[c]	---[c]
	Gulfside	100	---[c]	---[c]	---[c]	51	---[c]	---[c]	---[c]
I-1	Bayside	99	---[c]	---[c]	---[c]	15	---[c]	---[c]	---[c]
	Gulfside	57	---[c]	---[c]	---[c]	2	---[c]	---[c]	---[c]
I-2	Bayside	97	---[c]	---[c]	---[c]	11	---[c]	---[c]	---[c]
	Gulfside	95	---[c]	---[c]	---[c]	4	---[c]	---[c]	---[c]
Mean	**Bayside**	**98** (n = 63)	**98**[d] (n = 39)	**64**[d] (n = 29)		**31** (n = 62)	**49**[d] (n = 39)	**49**[d] (n = 29)	**53**[d] (n=29)
	Gulfside	**87** (n = 63)	**88**[d] (n = 39)	**41**[d] (n = 29)		**21** (n = 63)	**39**[d] (n = 39)	**48**[d] (n = 29)	**21**[d] (n= 29)

[a] Planted vegetation was indistinguishable from individual plants.

[b] Dune movement may have resulted in shifting of plot and/or vegetation within the plot resulting in an increased number of plantings within the plot.

[c] Although vegetation may have been present, data could not be collected due to inability to relocate vegetation plots within damaged fences.

[d] 1997 mean includes only the sites sampled, A and BW; 1999 and 2001 means include the only site sampled, A.

periods (1996, 1997, 1999) when compared to gulfside plots (table 1). These differences could not be examined in 2001, due to the inability in distinguishing individual plantings at Site A.

Tiller number and lateral spread were also analyzed in previous monitoring reports (Townson and Gaudet 1998; Townson et al. 2000). Tiller numbers and lateral spread 1 month post-planting were both reported to be significantly higher ($p = 0.001$ and $p = 0.0038$, respectively) in bayside plots than gulfside plots, but after one year post-planting only the lateral spread bayside remained significantly higher ($p = 0.02$) (Townson and Gaudet 1998). Tiller numbers and lateral spread measurements for the vegetation plantings 3 and 5 years post-plantings were not analyzed. The number of plants from which data could accurately be determined was too small to be tested. It was impossible to determine which tillers were associated with particular plants due to growth patterns (figure 16).

Vegetative cover differences bayside versus gulfside were compared for all sampling periods in previous reports. Townson et al. (2000) reported higher percent cover in bayside plots 1 month post planting, but found that by 1 and 3 years post-planting there was no longer a difference (table 1). However, 5 years post-planting at Site A, mean percent cover of vegetation within the bayside plots had again become significantly higher than in gulfside plots ($p = 0.0001$). Mean percent cover in the bayside plots was approximately 152% higher than in gulfside plots (table 1).

Figure 16. Bayside of dune, exhibiting extensive growth of planted and natural vegetation at fenced treatment, Site A, Timbalier Island Plantings Demonstration (TE-18) project (photo taken September 2001, looking west).

Vegetative survival and cover data were also analyzed by year to determine vegetative differences over time. The analysis of vegetation data by year includes only Site A, since this was the only site intact during all sample periods. Townson et al. (2000) reported that the fenced treatment at Site A exhibited the same survival pattern as the other treatments, in that the overall percent survival of plantings declined after 1 year post-planting (1997) and could not be accessed in 2001. Also, percent cover increased significantly from 1 month post-planting to 1 year post-planting, but remained similar between 1 year post-planting and 3 years post-planting (1999) (Townson et al. 2000). Additional analysis at 5 years post-planting (2001) indicated that mean percent cover significantly decreased between 3 years and 5 years post-planting ($p = 0.0057$), with mean cover decreasing from 51.35 to 36.64%, respectively. This is a return to mean cover values similar ($p = 1.00$) to 1 month post-planting cover of 36.76% (figure 17). However, the authors believe that these cover similarities are an artifice of the sampling design, which uses a too small a plot and places that plot directly over an initial planting (figure 3). We believe this technique artificially causes a higher percent cover value initially and does not account well for cover in other portions of the fenced area between plantings (figures 2 and 16).

Also, reference plots were so few in number ($n = 6$) that statistical comparisons were deemed useless. Reference plots did show increases in cover, as did planted areas with initial covers of approximately 14% that increased to 24% by 1 year post-planting and then appeared similar to the planted plots at 30% in 2001, at 5 years post-plantings. Again, these values are presented to compare trends with plantings, but no statistical testing was done due to the extremely unbalanced sampling of project to reference plots (126 project and 6 reference plots in 1996, respectively).

Species richness was also determined for Site A, as it was the only site sampled in all periods (Barbour et al. 1998). Species richness increased throughout the sample periods, indicating changes in species composition over time. Cover plots sampled averaged 1.3 species per plot at the time of initial sampling, but had increased to an average of 4.1 species per plot by 3 years post-planting. At 5 years post-planting in 2001, species richness had decreased slightly from 1999 to 3.7 species per plot, indicating that colonization of the fenced area may have stabilized. Also, species richness in bayside and gulfside plots were compared. Initially bayside and gulfside plots showed similar species richness values of 1.4 and 1.2 species per plot, respectively. However, within 1 year post-planting, bayside plots averaged 4.1 species per plot, while gulfside plots averaged 2.6 species. This higher species richness in bayside plots continued throughout the sample periods, with species richness at 5 years post-planting averaging 4.7 and 2.7 in bayside and gulfside plots, respectively.

Importance Values (IV) were calculated to show trends in dominance of species both throughout time and in bayside and gulfside areas. Importance Values for the two planted species, *P. amarum* and *S. patens*, both initially increased in importance after 1 year post-planting, but declined during all subsequent sample periods, ending with IV's less than those recorded at 1 month post-planting (figure 18). During the same time period, the IV's of all the naturally colonizing species showed an overall increase, in all cases exhibiting more importance than the two species planted.

Lastly, to further investigate cover and species composition changes, we classified all species found into four habitat niches: foredune, dune, back swale, and other

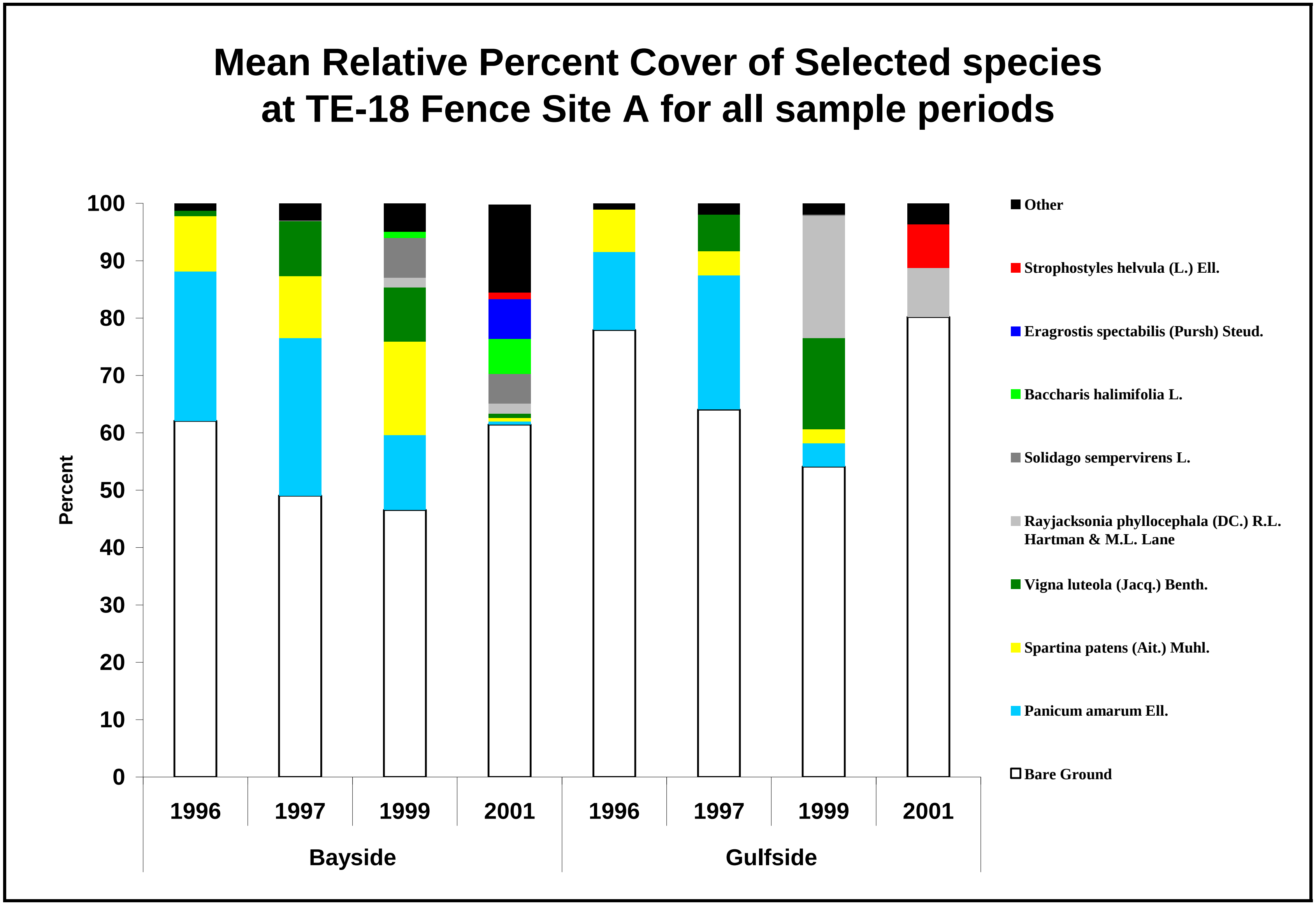


Figure 17. **Mean relative percent cover of vegetation bayside and gulfside, for all sample periods, at fenced treatment, Site A, Timbalier Island Plantings Demonstration (TE-18) project.**

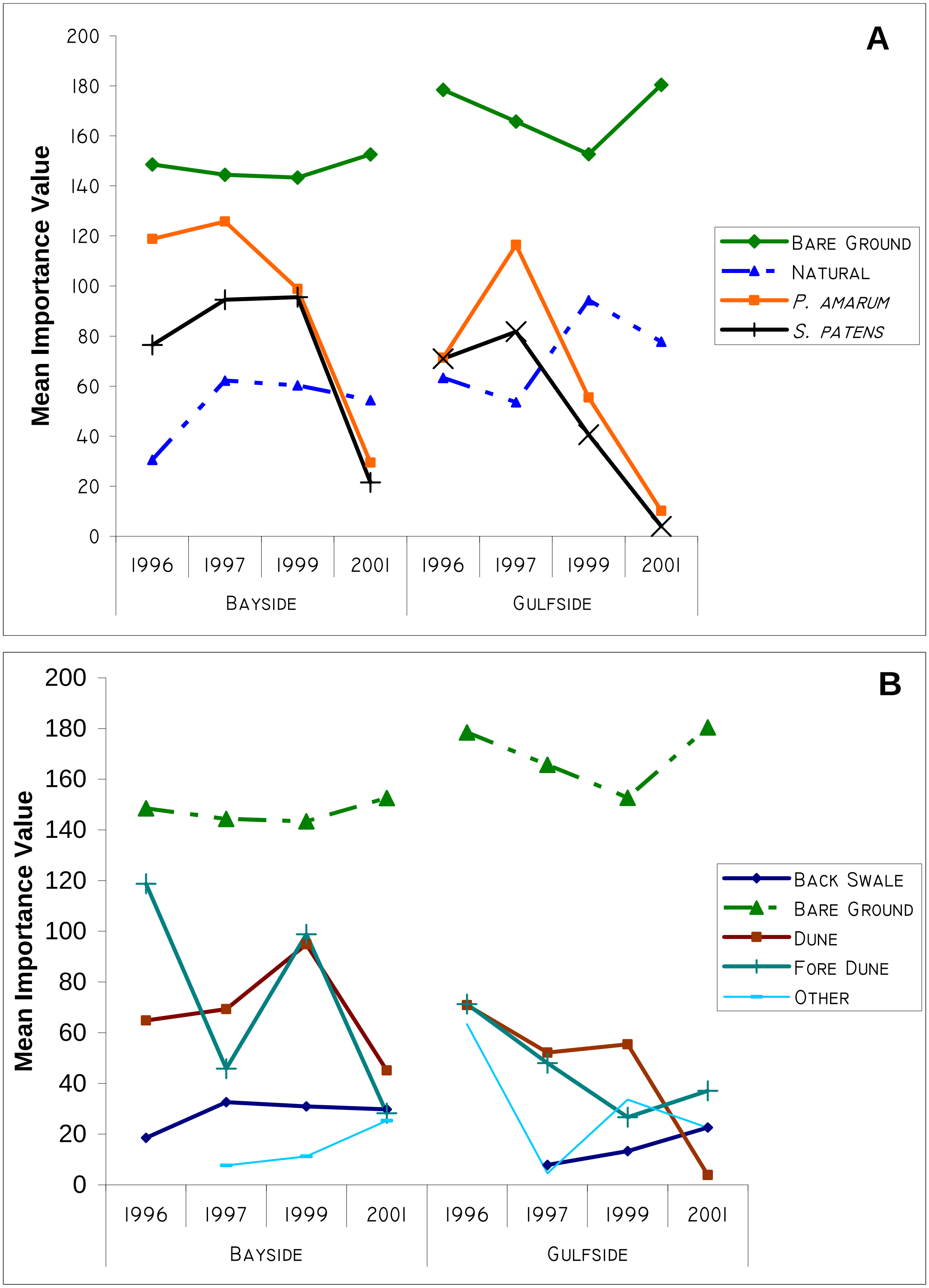


Figure 18. Importance values during each sample period of: A) planted versus naturally colonizing species, and B) species classified by habitat niche at fenced treatment, Site A, Timbalier Island Plantings Demonstration (TE-18) project.

(multiple habitat niches). Importance values were calculated for each habitat niche and results indicated that, although variable, foredune and dune species declined in both bayside and gulfside plots over the whole project period, while back swale species and those categorized as other increased in importance (figure 18).

Elevation: Previous monitoring reports (Townson and Gaudet 1998; Townson et al. 2000) stated that the reference plots showed the greatest cumulative increase in volume of sediment, but in fenced plots that survived (Sites A and C) there were greater increases in average height as desired. Additionally, the greatest volumes and heights were exhibited at Sites A and B on the western end of the island.

The 2001 NRCS elevation survey sampled only Sites A and C, fenced and reference, and the fence at Site A was the only one remaining totally intact during all sampling periods (figure 1). The data showed that Site A reference had the greatest total accumulation during the 6-year period (6438.25 ft^3 [182.31 m^3]), as well as a greater annual accumulation since the 1999 sampling (36.42 ft^3/yr [1.03 m^3/yr]), than its fenced counterpart (21.86 ft^3/yr [0.62 m^3/yr]). Final project sampling in 2001 showed that the fenced treatment at Site A had 38% less total volume accumulated than its reference, and was similar to Site C's fenced treatment (figure 19) (table 2).

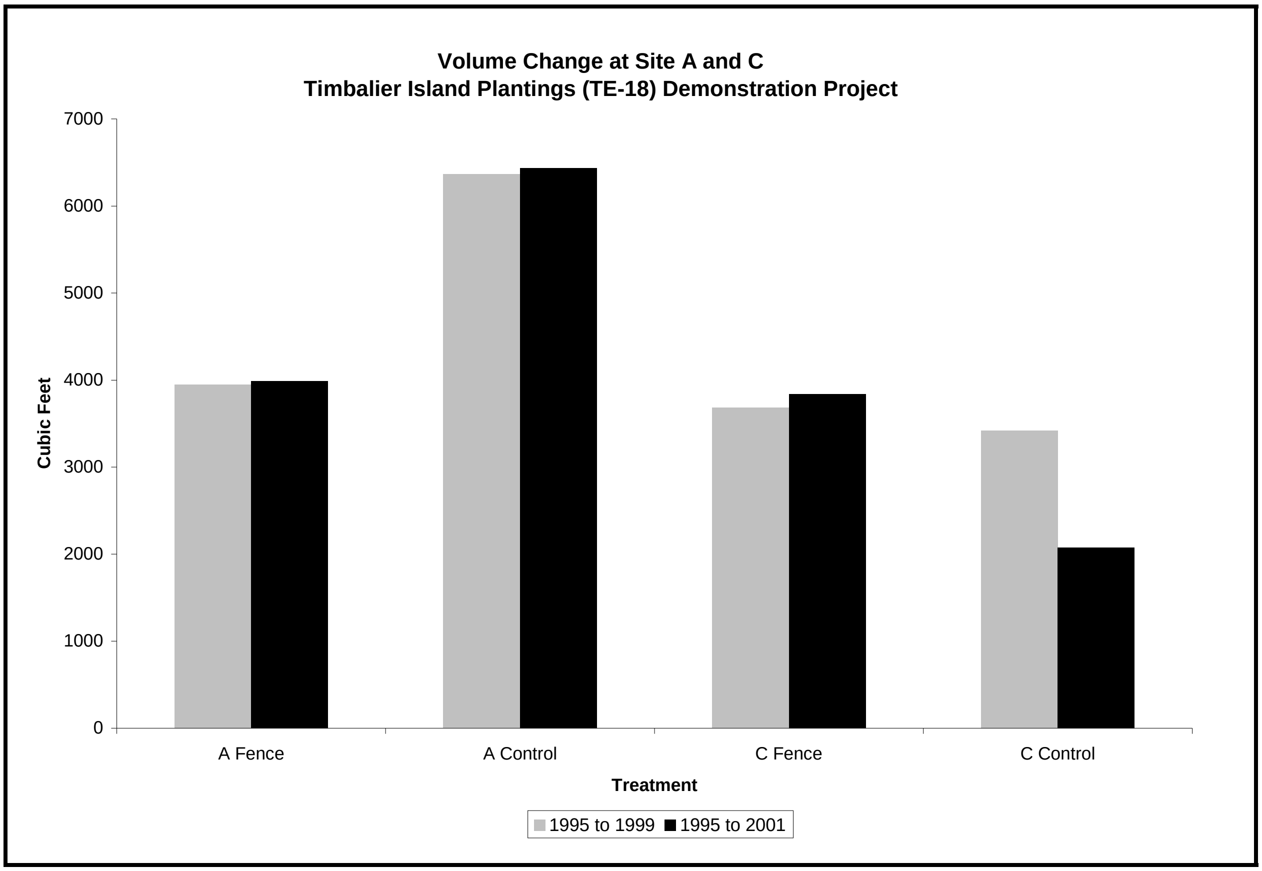


Figure 19. Volume changes in NRCS survey elevation plots between 1995, 1999, and 2001 at Sites A and C, Timbalier Island Plantings Demonstration (TE-18) project.

Table 2. Change in mean dune height and volume of sediment per year determined through NRCS elevation surveys (1995–1999) at Timbalier Island Plantings Demonstration (TE-18) project.

		Mean Dune Height Change (ft /yr)					Volume Change (ft^3 /yr)				
Site	Treatment	1995 to 1996	1996 to 1997	1997 to 1999	1999 to 2001	1995 to 2001	1995 to 1996	1996 to 1997	1997 to 1999	1999 to 2001	1995 to 2001
A	Fenced/ Planted	2.2	0.5	0.0	0.0	**0.51**	1324	1560	192	22	**633**
A	Reference	0.4	1.0	0.1	0.0	**0.25**	1714	3350	225	36	**1021**
B	Fenced/ Planted	0.1	0.8	---[a]	---[a]	---[a]	-343	-886	---[a]	---[a]	---[a]
B	Reference	0.8	0.6	---[a]	---[a]	---[a]	1115	2515	---[a]	---[a]	---[a]
C	Fenced/ Unplanted	1.8	-0.2	0.2	-0.1	**0.36**	1117	928	338	76	**609**
C	Reference	0.2	1.0	0.5	-0.2	**0.30**	1259	185	415	-666	**329**
D	Fenced/ Unplanted	0.7	---[a]	---[a]	---[a]	---[a]	46	---[a]	---[a]	---[a]	---[a]
D	Reference	0.0	---[a]	---[a]	---[a]	---[a]	-764	---[a]	---[a]	---[a]	---[a]
Mean	**Fenced**					**0.4** [b]					**621** [b]
	Reference					**0.3** [b]					**675** [b]

[a] Data could not be collected due to inability to reestablish elevation transect lines within damaged fences.
[b] Mean includes only the sites sampled in 1996, 1997, 1999, and 2001 (A and C).

Finally, at Site C, the reference plot showed similar volume accumulations (3421.29 ft^3 [96.88 m^3]) to its fenced counterpart (3682.37 ft^3 [104.27 m^3]) during the first 4 years of the project, but then lost volume during the last 2 years, ending up well below its fenced counterpart in volume accumulated (figure 19). The lost volume at Site C's reference treatment in the last 2 years of the project indicated that shoreline retreat had begun to impact the ability of this area to capture sand from shoreface processes, while Site C's fenced segment maintained itself (5.8 ft^3 [0.16 m^3]).

The annual volume accumulation rates at all sites showed dramatic decreases, when comparing rates during the first 4 years with the final accumulation rates (table 2). This may indicate that both the fenced and reference areas were filled and vegetated, or are now out of the zone where active sand transport occurs (table 2). Additionally, of the Site C reference treatment became located in a zone of erosion and volume loss. Overall, fenced and reference areas showed similar average annual volume changes, with an average of 621 and 675 ft^3 (18 and 19 m^3), respectively, in 2001 (table 2).

Dune heights in 2001 were similar to those reported earlier (Townson and Gaudet 1998; Townson et al. 2000), with only a slight decrease in average annual dune height, a change of -0.06 ft/yr since 1999 (figure 20; table 2). However, during the total project time period, fenced treatments showed annual dune height changes of 0.4 ft/yr, and reference plots averaged dune height changes of 0.3 ft/yr. Overall, changes in annual dune heights seem to correspond with volume changes, in that there was an overall slowing of elevation change at both fenced and reference sites over time.

LiDAR data showed that as of October 2002, all the fences except that at Site A had some portion of their footprint below the 2.0-ft (0.6-m) contour (figure 21). Also, only Site A showed that the shoreline position was prograding since 1993, and that all the other fence locations were now in the active surf zone (figure 21). Additional analysis of a small area at the fenced treatment at Site A showed elevation changes averaged +1.0 ft (+0.31 m) between March 2000 and October 2002, even including the elevation loss along the shoreline after Hurricane Lili (figure 22). Also, note that the pattern of elevation gain is in front of the fences, with very little gain within the fenced area, again indicating that the fences were now away from the shoreline and out of the active sediment transport zone. This was in direct contrast to Site C, which shows erosion throughout the treatment area (figure 23). Comparisons with each reference area could not be done due to a lack of information on the areas' exact locations.

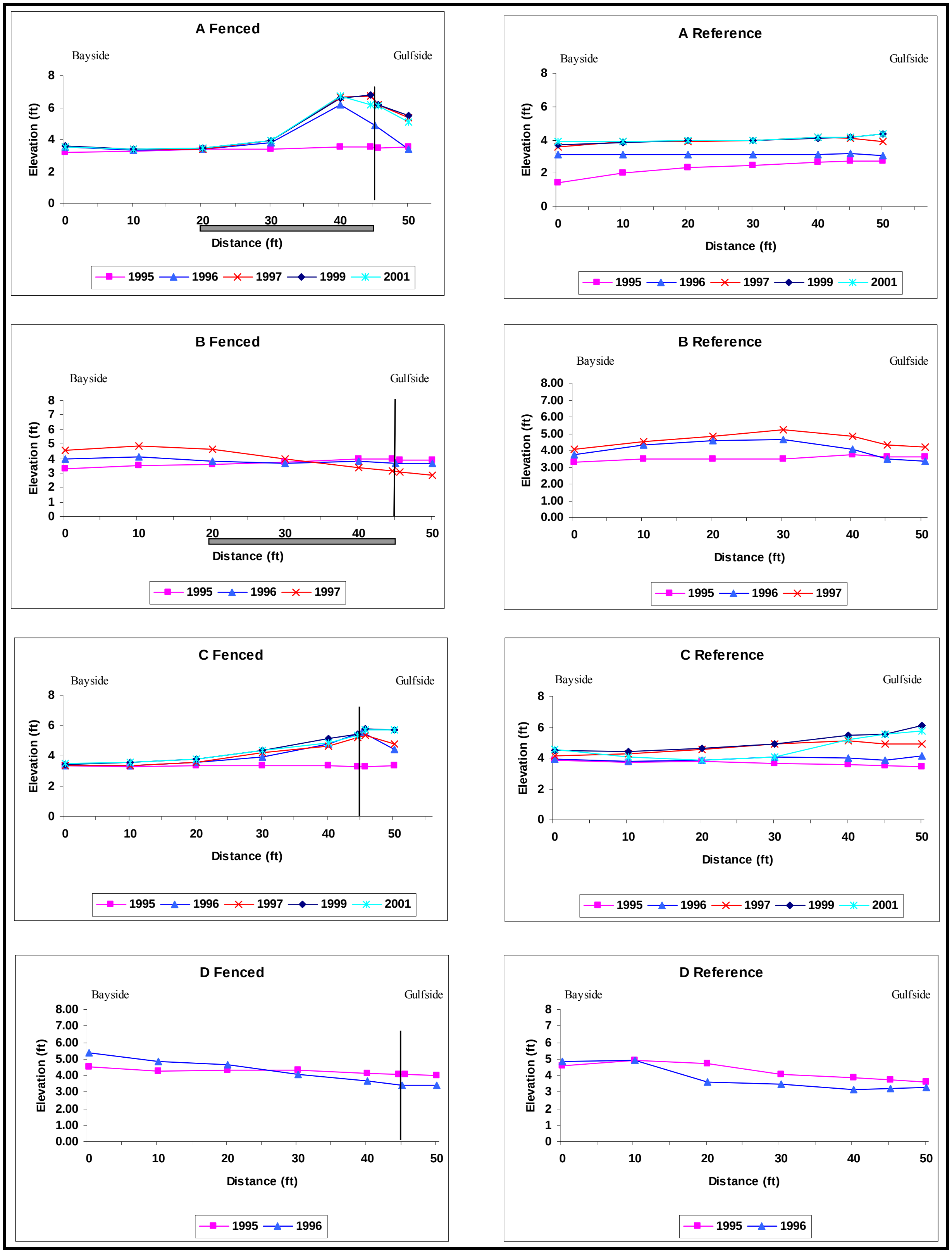


Figure 20. Average elevation profiles for each sample period in one segment and reference plot per treatment at Timbalier Island Plantings Demonstration (TE-18) project (note – line indicates position of fence, and gray area denotes area planted).

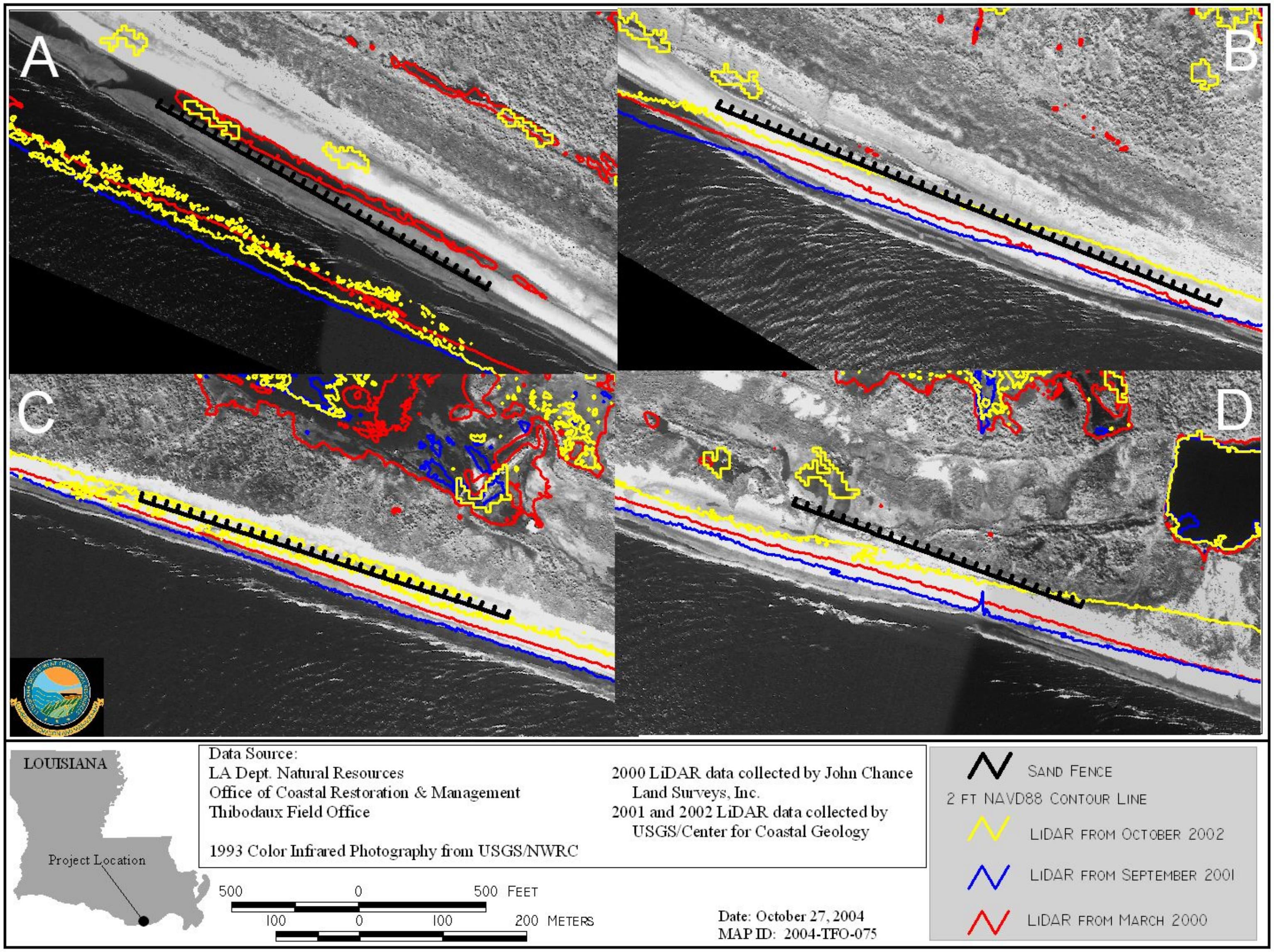


Figure 21. **Sand fence locations in relation to the 1993 aerial photo and the 2000, 2001, and 2002 LiDAR-derived 2.0-ft (0.6-m) elevation contour at Timbalier Island Plantings Demonstration (TE-18) project.**

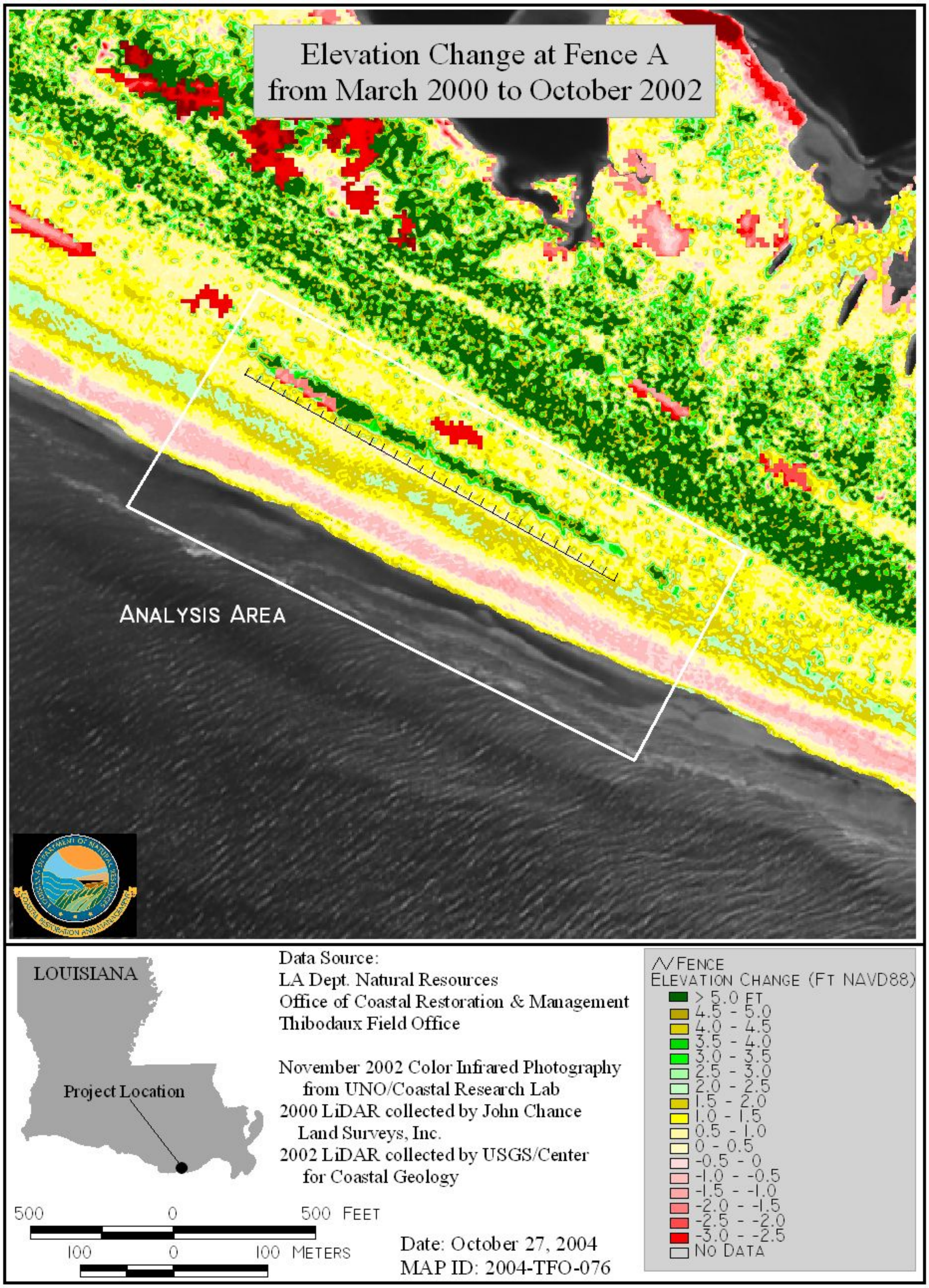


Figure 22. LiDAR survey elevation change models from 2000 to 2002 at Site A, Timbalier Island Plantings Demonstration (TE-18) project.

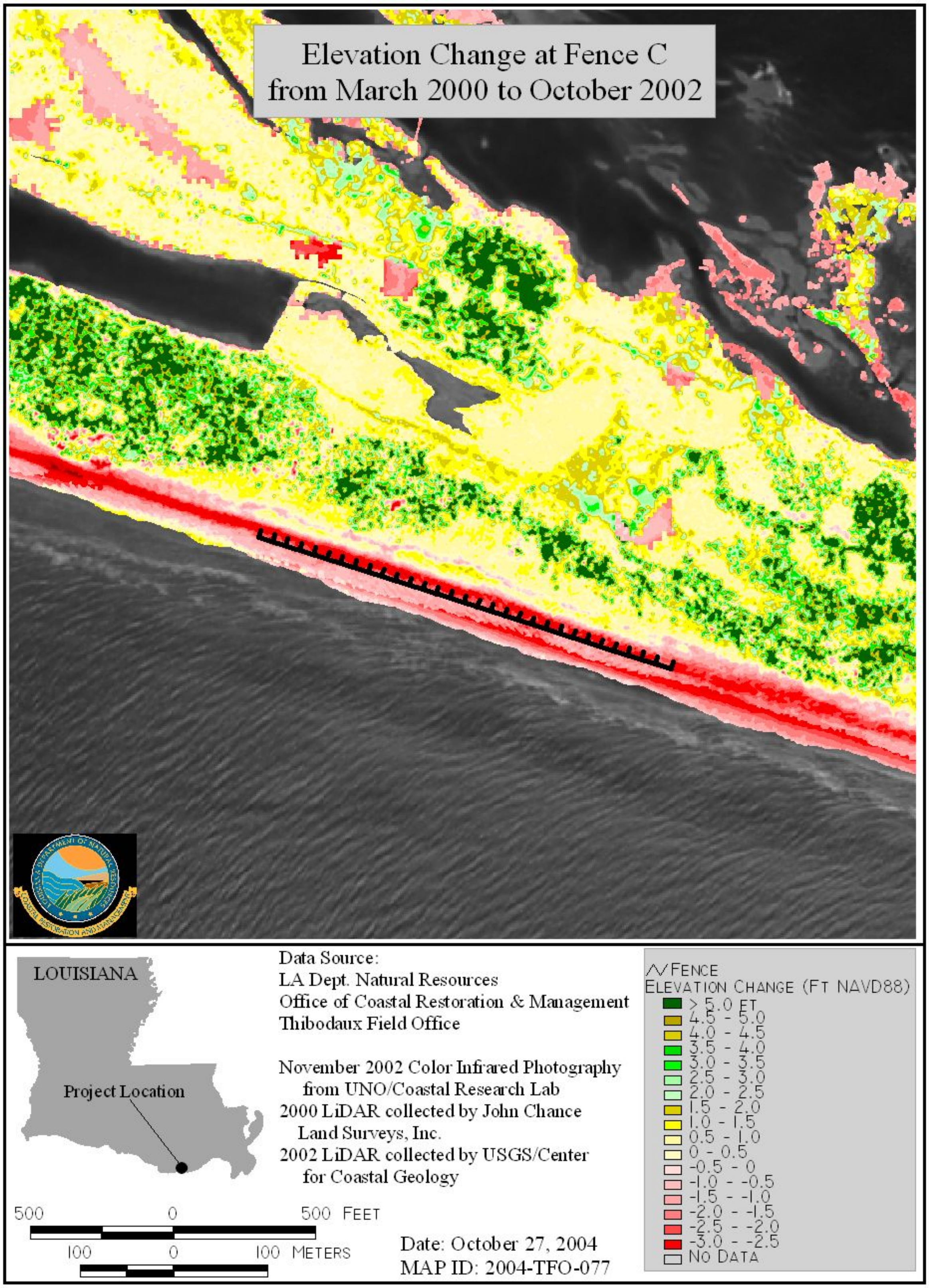


Figure 23. LiDAR survey elevation change models from 2000 to 2002 at Site C, Timbalier Island Plantings Demonstration (TE-18) project.

DISCUSSION

The results from the fencing and plantings in the Timbalier Island Planting Demonstration (TE-18) project produced results similar to those previously published on Timbalier Island (Mendelssohn et al. 1991; Townson and Gaudet 1998; Townson et al. 2000) with initially high dune creation and then a reduction in fill rates as the fences were filled. NRCS topographic survey data from 1995 to 2001 continued to indicate a decrease in the rate of dune height gain for both fenced and reference plots (table 2) throughout the project. LiDAR data from 2002 also indicated a slowing of sediment trapping bayward of the fences (figures 22 and 23).

Volumetric changes were also reduced in the treatment areas over the years, similar to changes observed in dune heights (table 2). These results indicate that initial filling of the fences was rapid, followed by a decline in sand accumulation. However, decreases in the accumulation rates in the reference areas seem to indicate that other factors were involved, such as reduced sediment availability and shoreline erosion. Although volumes increased at Sites A and C, they were even greater in the reference area for Site A. NRCS survey results from 2001 indicated that volumes remained above the initial 1995 survey, but Site C's reference area volume was beginning to decline, whereas treatments A and C were still accumulating sediment (figure 19). This observation was consistent with the conclusions of Townson et al. (2000), suggesting that Site A benefited from being on the western end of the island, where natural progradation of the shoreline occurred (figure 24).

Townson et al. (2000) reported much lower volume accumulations per linear foot of beach than previous studies (table 3) (Savage and Woodhouse 1969; Dahl et al. 1975; Woodhouse et al. 1976; Myer and Chester 1977; Knutson 1980). We expected this trend to continue, since total volumes have not changed substantially since 1999, and accumulation rates are lower than at most other areas studied. Townson et al. (2000) found that the sand supply was limited, making it difficult to compare Timbalier Island with East Coast projects where sand supplies may be greater. The continued decline in annual accumulation in 2001 indicates three possible mechanisms: 1) the redistribution of the sand after the dunes attain a particular height; 2) the continuing decrease in the sand supply as a result of the erosion on the eastern end of the island; or 3) the movement of some areas (Site A) out of the active sand transport zone since the beach has prograded.

Mendelssohn and Hester (1988) found that fences accumulated an average of 78% more sediment than unfenced references on Timbalier Island, whereas this project showed 168% less accumulation in the fenced treatments than in the reference plots through the 1997 sampling period, but by 2001 at Site A, there ended up being only 61% less volume in the fenced plot (figure 11). The small sample size and location of most reference plots to the west of the fence sites (figure 1) probably contributed to the results, because of the dominant direction of sand movement from southeast to northwest (Meyer-Arendt and Wicker 1981).

Timbalier Island has historically exhibited accretion at the western end, while eroding from the east (Meyer-Arendt and Wicker 1981), as confirmed by the CIR aerial photography and LiDAR data sets (figures 21-24). Although we expected that an increase in dune height would correspond with increased volume of sediments, the data indicate a different relationship. The dune height

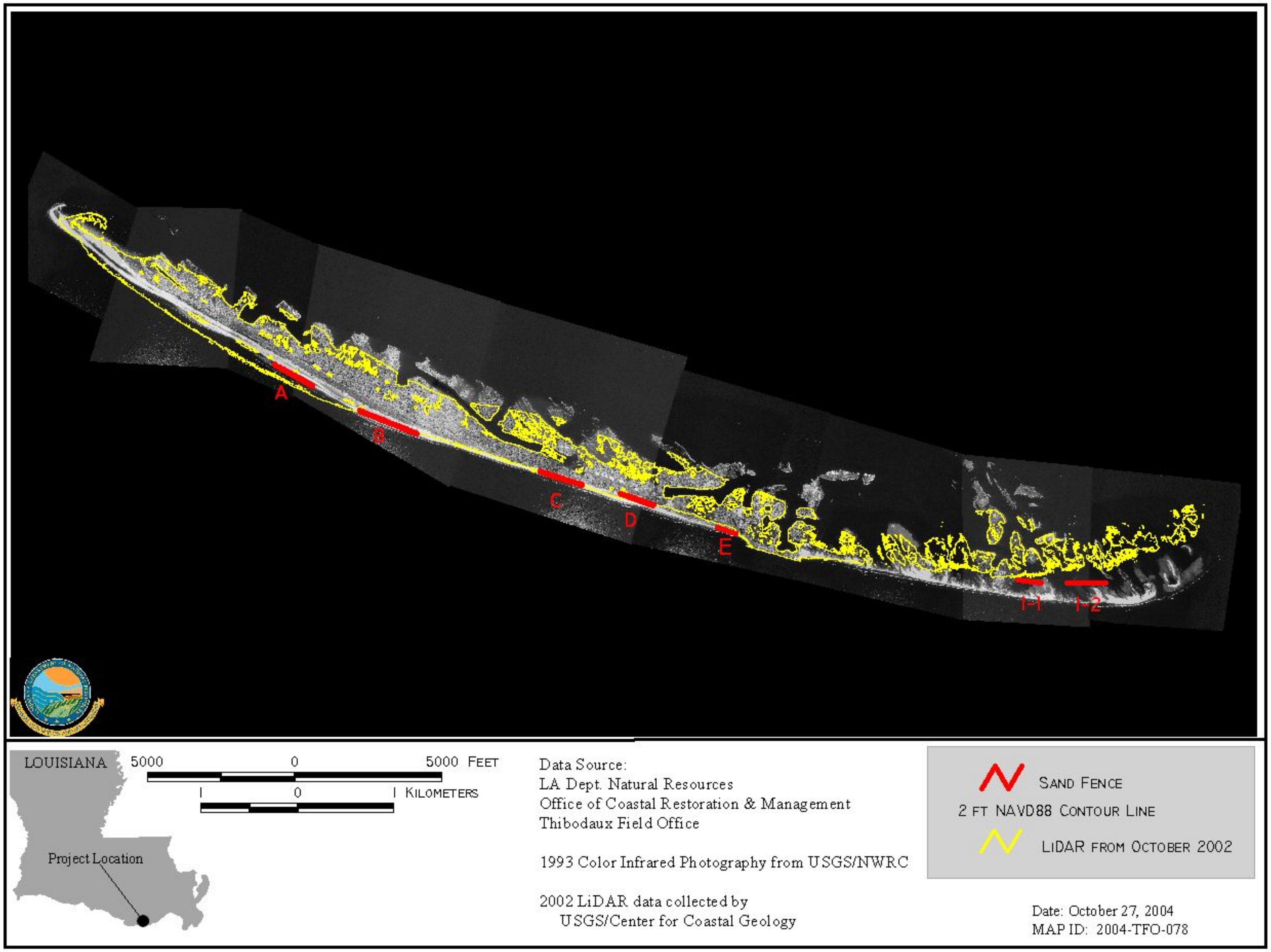


Figure 24. **October 2002 LiDAR-derived 2.0 ft (0.6-m) elevation contour, overlain on 1993 CIR aerial photography to show shoreline change differences between eastern and western portion of Timbalier Island over the last 9 years.**

Table 3. Comparison of annual sand accumulation in Massachusetts, North Carolina, Louisiana, Texas, and Oregon sediment fencing projects.

Location	Investigators/Growth Duration	Sand Accumulation	
		ft^3/ft	m^3/m
Nauset Beach, Cape Cod, Massachusetts	Knutson (1980) – 7 yrs growth	89.4	8.3
Ocracoke Island, North Carolina	Woodhouse et al. (1976) – 3 yrs growth	90.5	8.4
Timbalier Island, Louisiana	Mendelssohn and Hester (1988) – 3 yrs growth	7.5 - 45.2	0.7 - 4.2
Timbalier Island, Louisiana	Townson et al. (2000) – 3 yrs growth	16.2	1.5
Padre Island, Texas	Dahl et al. (1975) – 4 yrs growth	116.3	10.8
Clatsop Plains, Oregon	Myer and Chester (1977) – 30 yrs growth	147.5	13.7
Santa Rosa Island, Florida	Miller et al. (2001) – 3 yrs growth	-41.2 – 91.3	-3.83 – 8.48

increased in the immediate area of the fence, which accounted for only a small area of the total plot. In the reference plots, sand seems to have accumulated throughout the plot, resulting in greater accumulation for the plot (figures 11 – 14). The latest changes in dune height from the 2001 survey continue to show less drastic increases or decreases, but rather indicate a change in position of the highest points. This trend suggests a shift, generally gulfward, of the material deposited, as confirmed by the LiDAR data at Site A (figure 22). In comparison to earlier observations, the volume of sediment accumulated per year decreased for both fenced and reference plots for all sites. This volume change rate may be due to: 1) a general shifting of material; 2) a lack of additional sand being put into the system from natural processes; or 3) removal of sand deposited earlier as locations move below the 2.0-ft contour. However, since only one segment of a site was sampled, no definitive conclusions can be made.

The average annual dune growth within the fences, based upon measurements in one segment, was within the range of dune growth reported by Mendelssohn et al. (1991) for the Timbalier Island fencing project, but less than other coastal sand fencing projects reported in the literature (Savage and Woodhouse 1969; Dahl et al. 1975; Woodhouse et al. 1976; Myer and Chester 1977; Knutson 1980). Average annual dune growth in this study was 0.4 ft/yr (0.15 m/yr) (table 2), whereas Mendelssohn et al. (1991) reported annual dune growth of 0.16 - 0.85 ft/yr (0.05 - 0.26 m/yr) on Timbalier Island. Again, the small sample size and location of most reference plots to the west of the fence sites (figure 1) probably contributed to the results, because of the dominant direction of longshore sand movement from southeast to northwest (Meyer-Arendt and Wicker 1981).

Federal Emergency Management Agency (FEMA) funding was used in 1999 by LDNR/OCRM to place additional sand fencing on Timbalier Island. The location of this fencing was not recorded and its effects on Sites A and C are difficult to access. NRCS personnel reported that fencing was placed directly within Site C's fenced and reference areas and was placed approximately 30 ft (9 m) gulfward of Site A's fence and approximately 106 ft (32 m) gulfward of the Site A reference. The impacts of FEMA fences on project results are difficult to access, but they must be incorporated into our interpretations of any results.

The percent survival values of vegetation transplants within the undamaged portion of the project were reported by Townson et al. (2000) to be higher than those reported by Mendelssohn and Hester (1988). Mendelssohn et al. (1991) found *Panicum amarum* var. *amarulum* had a 73% survival after 15 months, while Townson et al. (2000) reported 93% survival after 12 months for *Panicum amarum* var. *amarulum* and *S. patens* transplants combined, and 53% survival after 3 years (table 1). Percent survival of the vegetation transplants was significantly different by site (table 1) during the Timbalier Island Plantings Demonstration (TE-18) project, as was also reported in the Mendelssohn et al. (1991) study.

The conditions at the time of planting may have improved the survival rate of the plantings at Timbalier Island Plantings Demonstration (TE-18) project. Within the 6-month period up to and including planting in July 1996, a near normal amount of precipitation was recorded for the area according to the National Drought Mitigation Center's Standardized Precipitation Index (SPI), whereas the 1-month period between planting and the first sampling in August 1996 was moderately wet (figure 25) possibly contributing to the 93% survival rate of plantings (National Drought Mitigation Center 1996a, 1996b, 1997, 1999) Additionally, the 1997 SPI data showed a near normal precipitation for the 12 months prior to sampling, which would indicate potentially favorable conditions for planting survival. However, the SPI for January to August 1999 indicated moderately dry conditions, which could have affected the lower survival rate (53%) found 3 years post-planting (figure 25).

Soil nutrients were not measured during this study, but Mendelssohn and Hester (1988) did report that soil nutrient status may affect transplant survival. Project planting did receive a slow-release fertilizer tablet at the time of planting. Also, differences in herbivory by site were noted to affect percent survival during the Mendelssohn and Hester (1988) study. Lower survival rates (73% after 15 months) reported by could have been due to extensive herbivory during their study period. Mendelssohn and Hester (1988) reported total decimation of *Panicum amarum* var. *amarulum* transplants, and reduction in cover of *S. patens* and *Heterotheca subaxilaris* (camphorweed) of approximately 30% when compared to vegetation in 16.1-ft^2 (1.5-m^2) exclosures. Herbivore impacts appeared minimal among the plantings in the present project study. It is possible that herbivore populations may have been significantly impacted by the effects of Hurricane Andrew in 1992, thus making herbivory less of a factor.

The higher survival rate of planted vegetation within the bayside plots, as compared to gulfside plots, may be due to: 1) rapid accumulations of sand in the fences; or 2) reduced soil moisture in dune areas. Sand aggradation near the fence may have exceeded the transplants' ability to grow

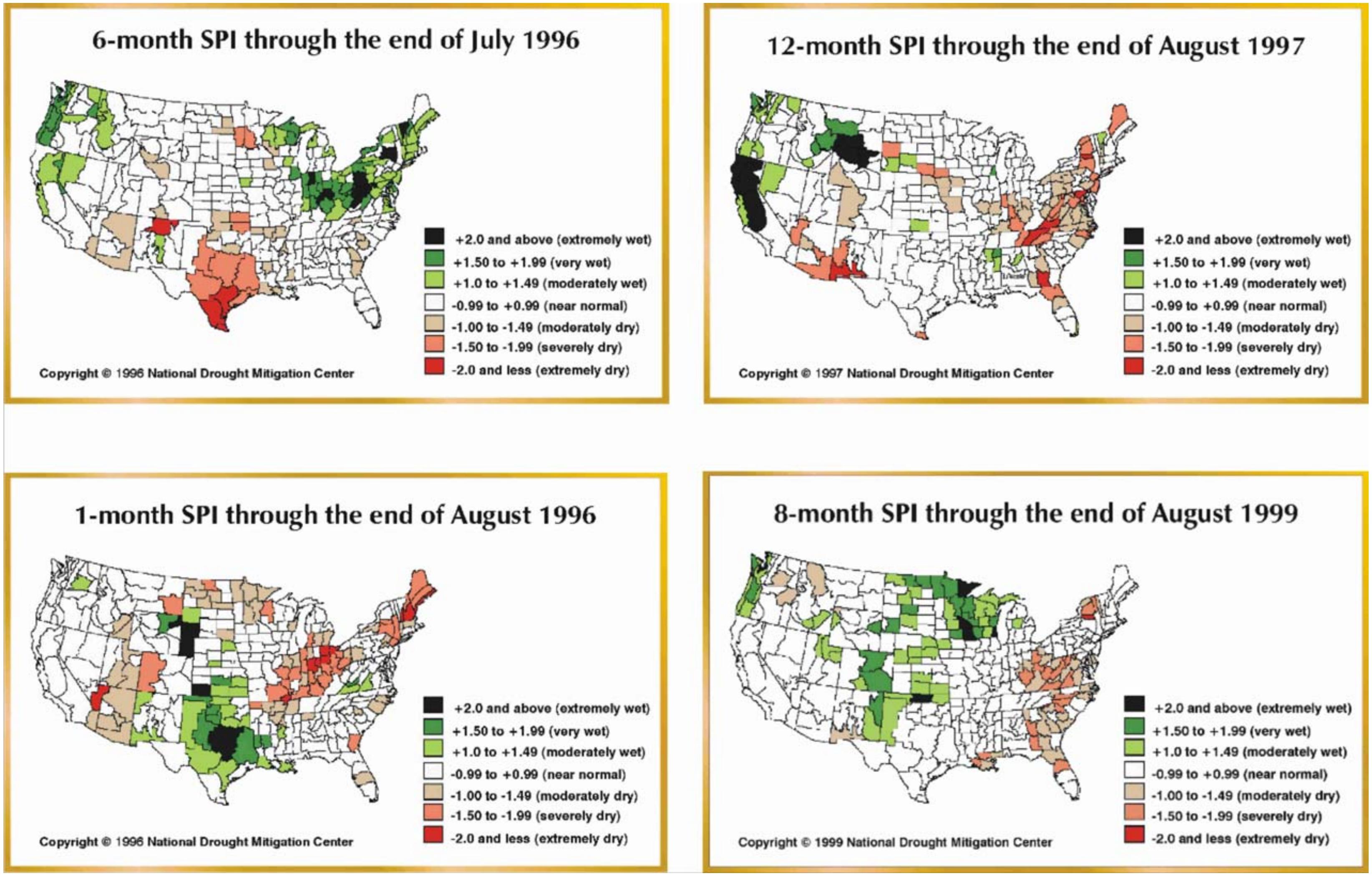


Figure 25. Standard Precipitation Index (SPI) for various time periods during the sampling at the Timbalier Island Plantings Demonstration (TE-18) project (National Drought Mitigation Center 1996a, 1996b, 1997, 1999) (from Townson et al. 2000).

in the gulfside segments, although this is unlikely due to fences having built dunes before planting (figure 2). According to Mendelssohn and Hester (1988), the sand fence design used in the Timbalier Island Plantings Demonstration (TE-18) project (figure 2) tends to accumulate the most sand during the first year of construction, compared to other designs tested. However, a straight fence design, without spurs, collected 164% more sand than the fence with spurs after 3 years (Mendelssohn and Hester 1988). Also, soil moisture may be reduced as dune height increases (Mendelssohn and Hester 1988). Survival was also a function of location because the western sites—A, BE, and BW in 1996 and A in 1997—had higher survival rates than the eastern sites (table 1).

Total plant coverage increased between the 1996 and the 1999 sample measurements as transplants grew (table 1) and additional species colonized the area (appendix). However, by 2001, the total percent cover at Site A was similar to the 1-month post-planting cover, with planted species contributing less cover and occurring less frequently than they did in initial samples (figures 17 and 18). This seems to indicate that even though volumes were similar at Site A between 1999 and 2001, and survival was highest at Site A, the treatment area underwent a change from dune habitat to back swale habitat, with a corresponding change in species composition and cover (figures 17 and 18). Drought conditions, which prevailed between late 1999 and early 2001, may have also had an effect on species composition and cover (National Drought Mitigation Center 2000) (figure 26). However, the IV analysis shows a clear change from dune species to back swale species, suggesting that the changes were more than drought related. Additionally, the problems with the cover sampling method mentioned earlier must be taken into account when drawing conclusions.

Planting took place in July just prior to the seed production/maturation period of the plants (Radford et al. 1968; USDA/SCS 1981), which may have contributed to the limited amount of growth or coverage produced during the first growing season. In 1996, bayside plant cover was greater than gulfside cover, possibly due to reduced soil moisture in developing dunes or the sheltering effect of the fencing and corresponding dunes. After the second growing season, the effect of location (site) and treatment (bay versus gulf), diminished with no significant differences. Final sampling in 2001 again showed bayside plots having greater cover than gulfside plots. As the decline of *Panicum amarum* var. *amarulum* and *S. patens* occurred in the plots, two species, *V. luteola* and *R. phyllocephala*, flourished on the dunes in 1999, therefore maintaining cover (figure 17). By 2001, cover had decreased, but additional species such as *Solidago sempervirens* L., *Baccharis halimifolia* L., *Eragrostis spectabilis* (Pursh) Steud., and *Strophostyles helvola* (L.) Ell. began to contribute more to the total cover (figure 17).

Our results support work from Mendelssohn and Hester (1988), which showed that, with time, percent cover was less dependent on transplant survival, as other species colonized the site. Mendelssohn and Hester (1988) found coverage of >75% in areas with transplant survival of <1% at 9 months post-planting. Fertilization, a factor positively affecting percent coverage in their study, could affect natural colonization by vegetation without transplants (Mendelssohn and Hester 1988). Because only Site A was remaining in 2001, our conclusions are limited.

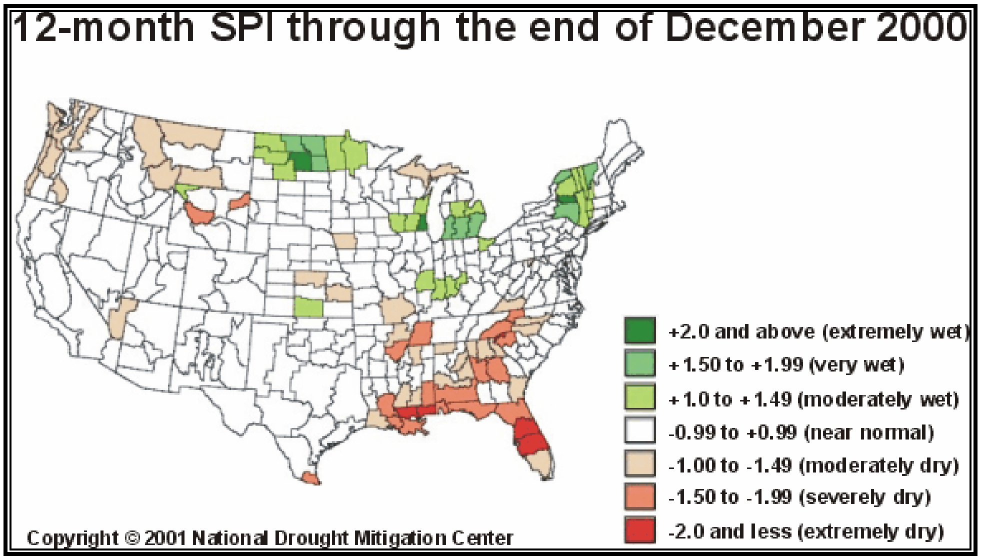


Figure 26. Standard Precipitation Index (SPI) for 2000 at the Timbalier Island Plantings Demonstration (TE-18) project (National Drought Mitigation Center 2000).

CONCLUSIONS

Destruction of all but one fence site after 3 years should not be considered failure in a transgressive barrier shoreline system such as Timbalier Island. Results confirm that sand fencing and vegetative plantings, as in numerous other studies, can be used to trap sand and build dunes (Savage and Woodhouse 1969; Dahl et al. 1975; Myer and Chester 1977; Woodhouse et al. 1976; Knutson 1980; Mendelssohn and Hester 1988; Hotta et al. 1991; Mendelssohn et al. 1991; Hester and Mendelssohn 1992; Miller et al. 2001). However, results at 5 years post-construction also appear to confirm Mendelssohn and Hester's (1988) conclusion that the only way to maintain a vegetated dune on Louisiana's barrier islands is to maintain a beach wide enough to dissipate wave energies. With short-term shoreline change rates of approximately -179.4 ft/yr (54.7 m/yr) on the eastern end of Timbalier Island (Beall et al. 2004), and beach habitat acreages reduced by 41% over the past 9 years, it is apparent that not only is natural maintenance of a beach wide enough to dissipate wave energies not taking place, but sands are extremely limited in this area. A well-established dune cannot prevent the natural transgression of the shoreline and will eventually erode as the shoreline narrows. This is evidenced by the fact that all treatments in this study, other than that at Site A, have eroded from east to west, as the barrier island's natural process of westward erosion occurs (Meyer-Arendt and Wicker 1981).

The project's vegetative plantings confirmed the ability of these plants to grow and cover the sand as reported in earlier studies (see previous citations above). Interestingly, the species planted were appropriate for initial plantings as per the literature, but other species may need to be considered, depending upon overall expectations of shoreline movement and habitat development. Both *S. patens* and *P. amarum* var. *amarulum* covered the planted areas quickly, but neither contributed to cover significantly after Site A changed from dune habitat into back swale. Temporary colonization and then succession may be enough, as we may only need to cover and hold sands temporarily as dunes develop. Additionally, Miller et al. (2001) reported that survival of plantings was negatively correlated with sand accumulation at the time of planting, and this may need to be considered in future fencing projects, since gulfside plots closer to the fences showed lower survival and cover than bayside plots. Other restoration projects in Louisiana have had some success with less dense planting schemes and placement of those plantings adjacent to the dunes, but again, location, timing and expectations for habitat development need to be considered in planting designs (figure 24). More work needs to be done on approaches to cover dunes quickly and efficiently, and on how this will affect the long-term community development as dunes are eroded or shorelines move and habitat conditions change.

The fencing and vegetative planting treatments built dunes and vegetated the newly accreted sands rapidly (figures 17, 20, and 27). This project demonstrated, as have others, that sand fencing and plantings are an integral part of an overall sand management program. The project has helped to formulate better management practices concerning the placement of fences and the vegetation species to be considered in an overall program of sand management.

Figure 27. East Island Restoration (TE-20) project sand fencing and *P. amarum* plantings: a) immediately after planting, and b) 4 years after planting. Note the single row of plantings adjacent to the dune toe and the subsequent colonization of *Panicum amarum* on the dunes (LDNR photos, taken June 1999 and April 2003).

RECOMMENDATIONS

Although the majority of treatment areas at Timbalier Island lasted less than 1 year, the incomplete results still indicate that vegetative plantings and sand fencing projects do have important roles to play in maintenance and establishment of dunes in appropriate areas. as the most likely sites for planting and fencing projects include newly placed sand, overwash areas of sufficient heights to resist consistent overwash in all but the highest events, and areas of natural shoreline transgression. The appropriate conditions can be subjective and location-specific conditions must be considered. We believe that employing a programmatic approach to sand fencing and planting would be a cost-effective way to manage sediments and habitats along Louisiana's barrier shoreline. Such an approach would offer the potential to maintain and restore dune habitats in areas quickly and cheaply as part of an overall shoreline restoration program.

The areas for fences or plantings need to be carefully selected and should exhibit conditions such that fences will only be affected during larger storm events. This would include areas such as the naturally prograding shoreline of western Timbalier Island, newly emplaced sediments of restoration projects, and areas with sufficient beach widths and heights to allow fences to only be impacted in storm conditions (Miller et al. 2001). Considerations need to be given to location, timing, and maintenance of fencing and plantings, or combinations of each.

We believe design considerations need to follow the literature (Woodhouse 1978, Craig 1984) and should institute these standard components: 1) placing features parallel to the shoreline since they are effective and more cost efficient per linear foot of beach; 2) containing minimal gaps such that they build as continuous a dune as possible; 3) building dunes to appropriate elevations that will maintain regional balance in collisions and overwash regimes (islands should not be built so high that they will never be overwashed); 4) regular maintenance; 5) expanding the program as dunes form, to provide multiple dunes; 6) responding rapidly to storm impacts; and 7) utilizing biodegradable materials as appropriate (i.e., no metal poles or plastic fencing, and as small a wooden post as can be used [figures 15 and 28]).

Additionally, monitoring changes need to be made based on observations mentioned in earlier portions of this report. Both the surveys and vegetation sampling experienced problems with a lack of replication and/or references. The sampling of one or two locations was insufficient and caused problems when the sample area was impacted but portions of the rest of the treatment remained intact (Site B after 1997). Sampling did not cover all the treatment types (fenced and unplanted) and the very unbalanced design (only 6 reference plots compared to 126 treatment plots) caused unnecessary analysis issues. Also, the percent cover plots were too small and caused problems with interpretation of the cover estimates. Lastly, sampling needs to better reflect sediment transport and to plan for differences in sediment accumulation rates based on natural processes, and should place reference sites appropriately (multiple references on each side of the treatment).

Observations of other projects—such as East Island (TE-20), Trinity Island (TE-24), Whiskey Island (TE-27), and East Timbalier Island (TE-25 and 30)—indicate that vegetative plantings as well as fencing can focus overwash, causing intensification of scour by focusing water into more channeled flows. Because of this, all construction features need to be parallel to shore (figure

29). Also, lack of simple maintenance can contribute to reduced dune building in areas (figure 30). It is also important that a response plan to storm events be developed so that bare

Figure 28. Metal support poles from sand fencing on Whiskey Island after impacts from tropical storms and hurricanes (LDNR photo, taken April 2003).

overwash terraces, such as those at Whiskey Island after Hurricane Lili, can be assessed and implemented quickly if deemed appropriate, to ensure that dune building can begin before sediments are removed through aeolian processes (figure 31). This response has not been the case in Louisiana's restoration program. It has been shown that fences are effective immediately after placement and vegetative plantings can rapidly cover sediments. Therefore a fast response to impacts can be accomplished with these techniques, but a programmatic approach to fencing, plantings, and combinations of these needs to be developed for Louisiana's barrier shorelines.

Finally, dunes are typically dependent upon beaches to supply sand necessary for their formation, and beaches are dependent upon dunes to provide sands held in reserve during high water. Dunes do serve as sand reservoirs, supplying sediment to the dynamic beach profile during high tides and waves (Van der Meulan and Gourlay 1969; Leatherman 1979a, b, c). However, dunes cannot accomplish the overall project goal of stabilizing portions of bare beach and overwash areas in sand-limited systems such as Timbalier Island. Dolan (1972) suggests that the dunes are response elements, not forcing elements of the system, and therefore will not provide for long-term stability. Beach stability is a function of sea level and the amount of sediment in the coastal system (Dolan 1972). Sand fences do not add sand, but simply stack available sand higher and hold it in reserve until released by storm waves, and data suggests that sand was extremely limited on the eastern two-thirds of Timbalier Island. A programmatic sand fencing and planting project can have impacts of its own, but additional sediment added to the system and managed with fences and vegetative plantings will ultimately be required to maintain barrier shorelines in this trangressive system.

Figure 29. Scour along a sand fence not parallel to shore, on Whiskey Island, LA (LDNR photo, taken April 2003).

Figure 30. Dune building approximately 1 year after fence installation at East Island Restoration (TE-20) project. Note lower dune in foreground due to bottom of the fence being above sediment surface allowing winds to continue to move sand. (LDNR photo, taken June 1999).

Figure 31. **November 2002 CIR aerial photography from UNO Coastal Research Lab, of Whiskey Island after Hurricane Lili in October 2002, showing the development of an extensive overwash terrace.**

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Appendix

Vegetation Sampling Species List

Scientific Name	1996 Bay % Stations	1996 Bay Mean Cover	1996 Gulf % Stations	1996 Gulf Mean Cover	1997 Bay % Stations	1997 Bay Mean Cover	1997 Gulf % Stations	1997 Gulf Mean Cover
Agalinis maritima (Raf.) Raf.								
Ambrosia artemisiifolia L.								
Andropogon gerardii Vitman								
Andropogon glomeratus (Walt.) B.S.P.								
Baccharis halimifolia L.								
Bare Ground	100.00	62.33	100.00	77.35	90.24	54.77	97.56	65.71
Batis maritima L.			1.52	60.00	2.44	0.50		
Cakile edentula (Bigelow) Hook.					2.44	0.50		
Conyza bonariensis (L.) Cronq.								
Croton punctatus Jacq.							7.32	15.00
Distichlis spicata (L.) Greene	3.03	25.00	1.52	5.00			2.44	4.00
Eleocharis R. Br.								
Eleocharis parvula (Roemer & J.A. Schultes) Link ex Bluff, Nees & Schauer								
Eragrostis secundiflora J. Presl								
Eragrostis spectabilis (Pursh) Steud.								
Erigeron procumbens (Houst. ex P. Mill.) Nesom								
Eustoma exaltatum (L.) Salisb. ex G. Don					14.63	1.58		
Fimbristylis castanea (Michx.) Vahl	1.52	2.00			17.07	2.50		
Heliotropium curassavicum L.	1.52	10.00	1.52	2.00				
Heterotheca subaxillaris (Lam.) Britt. & Rusby					14.63	0.67	4.88	11.00
Hydrocotyle bonariensis Comm. ex Lam.								
Ipomoea L.					2.44	1.00		
Ipomoea imperati (Vahl) Griseb.								
Ipomoea pes-caprae (L.) R. Br.								
Limonium carolinianum (Walt.) Britt.					4.88	0.50		
Morella cerifera (L.) Small								
Muhlenbergia capillaris (Lam.) Trin.								
Panicum amarum Ell.	66.67	37.41	48.48	27.22	87.80	30.25	87.80	26.11
Paspalum vaginatum Sw.	3.03	10.00			4.88	2.00	2.44	0.50
Phragmites australis (Cav.) Trin. ex Steud.								
Phyla nodiflora (L.) Greene								
Rayjacksonia phyllocephala (DC.) R.L. Hartman & M.L. Lane								

Scientific Name	1996 Bay % Stations	1996 Bay Mean Cover	1996 Gulf % Stations	1996 Gulf Mean Cover	1997 Bay % Stations	1997 Bay Mean Cover	1997 Gulf % Stations	1997 Gulf Mean Cover
Sabatia Adans.								
Sabatia stellaris Pursh					48.78	2.98		
Sacciolepis striata (L.) Nash								
Schizachyrium maritimum (Chapman) Nash								
Schizachyrium scoparium (Michx.) Nash								
Sesuvium portulacastrum (L.) L.					2.44	4.00	2.44	1.00
Solidago sempervirens L.					12.20	1.40	2.44	1.00
Spartina alterniflora Loisel.					2.44	15.00	2.44	5.00
Spartina patens (Ait.) Muhl.	45.45	20.40	50.00	16.58	82.93	12.81	78.05	6.48
Strophostyles helvula (L.) Ell.								
Symphyotrichum Nees								
Unknown					2.44	0.50		
Vigna luteola (Jacq.) Benth.	3.03	30.00			87.80	10.74	60.98	10.22

Scientific Name	1999 Bay % Stations	1999 Bay Mean Cover	1999 Gulf % Stations	1999 Gulf Mean Cover	2001 Bay % Stations	2001 Bay Mean Cover	2001 Gulf % Stations	2001 Gulf Mean Cover
Agalinis maritima (Raf.) Raf.	6.67	4.00						
Ambrosia artemisiifolia L.			3.33	3.00	6.67	0.30	6.67	1.25
Andropogon gerardii Vitman					20.00	14.17	3.33	10.00
Andropogon glomeratus (Walt.) B.S.P.	26.67	5.38	3.33	10.00	3.33	5.00		
Baccharis halimifolia L.	26.67	4.13			40.00	9.96		
Bare Ground	93.33	50.04	96.67	56.12	93.33	42.50	100.00	78.17
Batis maritima L.								
Cakile edentula (Bigelow) Hook.								
Conyza bonariensis (L.) Cronq.	13.33	1.13	6.67	7.50				
Croton punctatus Jacq.			3.33	15.00			3.33	0.10
Distichlis spicata (L.) Greene								
Eleocharis R. Br.	3.33	2.00						
Eleocharis parvula (Roemer & J.A. Schultes) Link ex Bluff, Nees & Schauer	3.33	10.00						
Eragrostis secundiflora J. Presl	10.00	1.50			3.33	2.00	3.33	5.00
Eragrostis spectabilis (Pursh) Steud.					56.67	7.85		
Erigeron procumbens (Houst. ex P. Mill.) Nesom	3.33	5.00			23.33	15.50	3.33	3.00
Eustoma exaltatum (L.) Salisb. ex G. Don								
Fimbristylis castanea (Michx.) Vahl	26.67	5.38			16.67	1.34		
Heliotropium curassavicum L.								
Heterotheca subaxillaris (Lam.) Britt. & Rusby								
Hydrocotyle bonariensis Comm. ex Lam.					6.67	0.50		
Ipomoea L.								
Ipomoea imperati (Vahl) Griseb.							6.67	12.75
Ipomoea pes-caprae (L.) R. Br.			3.33	3.00				
Limonium carolinianum (Walt.) Britt.								
Morella cerifera (L.) Small					6.67	17.50		
Muhlenbergia capillaris (Lam.) Trin.							16.67	6.70
Panicum amarum Ell.	83.33	15.70	46.67	8.79	20.00	1.75	6.67	0.10
Paspalum vaginatum Sw.								
Phragmites australis (Cav.) Trin. ex Steud.			3.33	2.00	3.33	10.00		
Phyla nodiflora (L.) Greene					6.67	0.30	3.33	0.50
Rayjacksonia phyllocephala (DC.) R.L. Hartman & M.L. Lane	10.00	16.67	83.33	25.62	26.67	4.25	83.33	9.92

Scientific Name	1999				2001			
	Bay		Gulf		Bay		Gulf	
	% Stations	Mean Cover	% Stations	Mean Cover	% Stations	Mean Cover	% Stations	Mean Cover
Sabatia Adans.	26.67	2.38						
Sabatia stellaris Pursh					20.00	0.85		
Sacciolepis striata (L.) Nash	6.67	2.75						
Schizachyrium maritimum (Chapman) Nash					3.33	0.10	3.33	5.00
Schizachyrium scoparium (Michx.) Nash					13.33	9.00	6.67	10.50
Sesuvium portulacastrum (L.) L.								
Solidago sempervirens L.	73.33	9.41	10.00	2.50	83.33	4.02		
Spartina alterniflora Loisel.			3.33	10.00				
Spartina patens (Ait.) Muhl.	73.33	22.27	33.33	7.30	16.67	2.52	3.33	0.50
Strophostyles helvula (L.) Ell.					30.00	2.52	93.33	7.98
Symphyotrichum Nees	3.33	5.00						
Unknown	3.33	1.00			3.33	5.00		
Vigna luteola (Jacq.) Benth.	96.67	9.83	96.67	16.47	13.33	3.28		