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Recovery and Stability in Barrier Island Plant Communities

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ABSTRACT

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As a habitat for plants, barrier islands are characterized by constant salt spray and desiccation stress, punctuated by periodic storm events. This combination of chronic and stochastic effects of abiotic factors leads to the development of unique plant communities, with some species endemic to the habitat. Two hurricanes made landfall on Santa Rosa Island, Florida in 1995. A storm surge from one resulted in overwashes of many areas of the barrier island. These areas were scoured by water and sand, denuding them of vegetation. Plant community dynamics of a heavily impacted area and an area of secondary dunes that received minor damage were monitored over a three-year period. The data suggest a stable endpoint in the unaffected area characterized by constant species richness, species evenness and vegetative coverage despite year to year changes in species composition. The storm surge area revegetated rapidly to an average plant coverage equal to the undisturbed area, yet the recovery was the result of high abundance of relatively few species. The dune building plants Sea oats (*Uniola paniculata*), Blue stem (*Schizachyrum maritima*), and Bitter Panicum (*Panicum amarum*) were dominant components of the rapid recovery community, and many appeared to grow from colony fragments dispersed in the storm surge-leveled sand. Substantial species turnover of rare species was observed for both areas. It is anticipated that the storm surge area will continue to change as dunes rebuild creating microhabitats and as more species colonize from distant areas of the island.

ADDITIONAL INDEX WORDS: *Hurricane, storm surge, coastal, dune vegetation, recovery, Gulf of Mexico.*

INTRODUCTION

Barrier islands are the predominant landforms along the east and Gulf coasts of North America covering eighty-five percent of the shoreline (STAUBLE, 1989). These coastal barriers are elongated, narrow beach and dune systems that may shelter maritime forests, lagoons, wetlands, and salt marshes from direct wave and wind action (YOUNG, 1996). In absorbing the energy from wind and waves, these barriers experience a high degree of disturbance, making the systems geologically dynamic. During severe storms, the beach and the associated dunes may be overtopped by storm surges, a combination of locally elevated sea level and high waves. This water levels dunes and carries sediment across the island. This sediment transport transforms and shapes the island, yet the total sediment mass is mostly conserved (STAUBLE, 1989). Contrary to the leveling action of water, winds scour sand down to the water table creating wetlands or swales (COUSENS, 1988) in some locations, while piling up sand dunes in others. Many of the plant species on the islands have become well adapted to this high disturbance regime.

Areas subject to repeated storm surges have plant community compositions that reflect this periodic disturbance. Severe storm surges can scour the island free of vegetation, but seed banks and vegetative growth from fragments of plants will quickly recolonize such areas (COUSENS, 1988). Indeed, qualitative assessments often point to incredibly prolific growth of some species such as Sea Oats (*Uniola paniculata*), Coastal Blue Stem (*Schizachyrum maritima*), and Bitter Panicum (*Panicum amarum*) following storm surge scouring.

This physical disturbance is overlaid on a constant backdrop of stress from shifting sand, salt, and desiccation. Blowing sand and dune accretion requires plants to colonize bare droughty sand and to grow to keep pace with the accumulation of sand once established. Salt stress results from a gradient of surf spray blown inland, creating a gradient of salt tolerance in plant assemblages and resulting in salt spray sculpting of woody species. Desiccation stress in the sandy, droughty "soil" is accentuated by a lack of water retention and high evaporation rates. Some plant species of the secondary dune areas are shared with inland xeric habitats such as Long Leaf Pine sandhills (WOLFE *et al.*, 1988).

For some areas of barrier islands, successional endpoints are determined by not only the xeric conditions and constant salt spray, but also periodic overwash and wind blown sand. Other areas, while still subject to xeric conditions and salt

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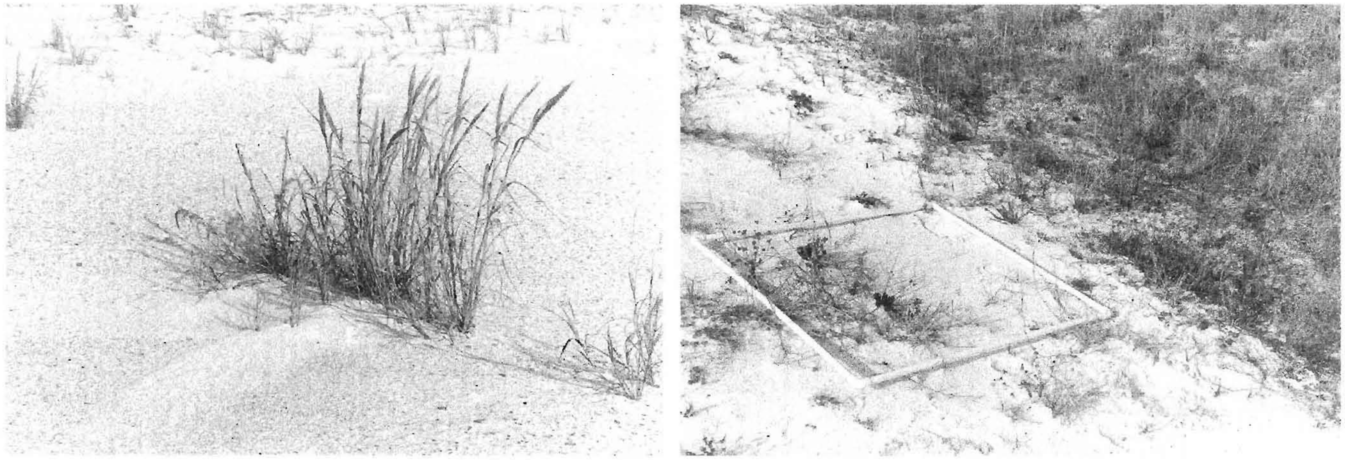

Figure 1. Representative images of the east (left) and west (right) transect areas. The east transect area was scoured by storm surge, denuding it of vegetation and leaving a shell hash. Rapid colonial growth of dune building grasses like *Panicum amarum* (pictured) was evident after one year. The west transect area was characterized by well developed secondary dunes largely unaffected by the storm surge. An ecotone between the dune and swale habitat, with a m^2 sampling quadrat, is shown. Photos by Dr. H.G. Stopp.

spray, may experience less disturbance due to distance from the shoreline or the protection of dunes and elevation of the island above the reach of storm surges. These areas may show changes in species and dominance with both distance/protection from salt spray and age over long time periods (JOHNSON, 1997). Thus, stability for barrier island plant communities involves the ability of species to resist harsh conditions and resiliency after periodic disturbance.

In 1995, hurricanes Opal and Erin both made landfall on Santa Rosa Island, Florida. Hurricane Erin (August 3) was a category one storm with wind gusts up to 65 mph with a 1–2 meter tidal surge. Hurricane Opal (October 4) was a category 4 hurricane (nearly category 5) having sustained winds of 95 miles per hour and a 4–5 meter storm surge. Sand dunes 5 meters high were entirely removed or significantly decreased in height. Severe overwashing occurred along Santa Rosa Island from Pensacola Pass to Destin, Florida. Sediment transport from the Gulf side to the Bay or Sound side was significant. Much of the island vegetation was washed away, covered with debris, or killed from standing salt water.

Recovery of barrier island vegetation post-disturbance is important for dune building, island stabilization, and providing food and shelter for the wildlife. A short-term revegetation study of an overwash area was conducted for three years beginning in the fall one year after the storms to document the natural recovery and dynamics of plant communities on Santa Rosa Island.

MATERIALS AND METHODS

Two transects in Fort Pickens area of the Gulf Islands National Seashore, Santa Rosa Island, were selected for the study. The two transects sustained different degrees of damage from the storms. The east transect was in an area flattened and scoured clean by the hurricane storm surges, leaving a shell hash surface (Figure 1). The west transect was relatively protected in a well-developed secondary dune and swale field (Figure 1). Although no pre-huricane data was available for the plant communities at these two specific sites, the plant species found in the west transect were typical of the secondary dune field plant communities over large areas of the island, including the east transect site. The transects were representative of the site, habitat, and plant communities in their respective immediate areas after the storm event. Elevation profiles were made with a plane table, alidade and stadia rod, and mean low water (MLW) determined from nearby benchmarks.

The west transect, approximately 180 m length, was located south of Battery 234 before entry into the Fort. The southern terminus was the shoreward face of a primary dune on the Gulf of Mexico beach. The northern terminus was near a paved road. This transect was characterized by a series of dunes and swales. The west transect area did not have any dune breaches or scouring washovers, but storm debris was deposited on the primary dunes, and many dead pine tree saplings were found in the swales where salt water had ponded.

The east transect was located approximately 100 feet east of the first parking lot upon entering the seashore area. The transect extended from the first line of vegetation near the Gulf of Mexico (near where the primary dunes would have been), across the island and ending with the last line of vegetation near Santa Rosa sound. This area was overwashed and scoured from storm surge and was densely covered with shell pieces (hash). The transect intersected the main road in the park, which was excluded from the data.

The surveys were conducted during the summer and fall when the vegetation growth was maximal. A quadrat size 1.0 m^2 was used for continuous sampling along the transect (Figure 1; CHAMBERS AND BROWN, 1983). Transects were marked approximately every 20 m with PVC pipes from beginning to end. A twine was laid along the transect connecting the PVC pipes as a guide during surveys. The 1.0 m^2

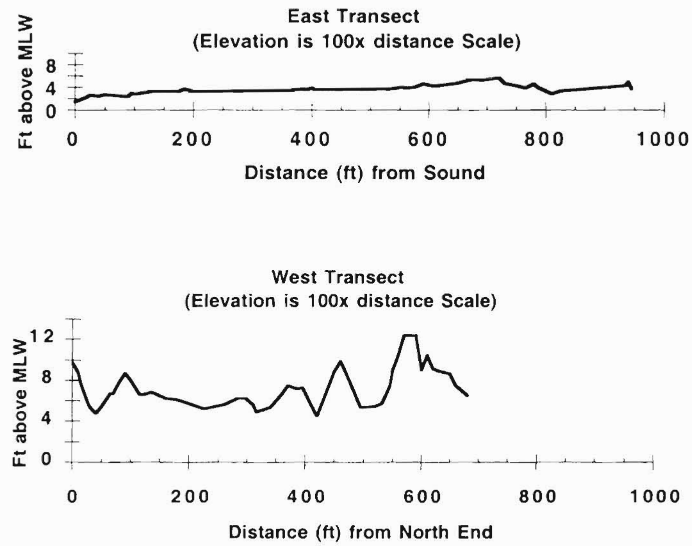

Figure 2. Elevation profiles of the two transects analyzed for this study.

quadrat was placed on the ground to the west of the line and the vegetation inside the quadrat was identified and percent vegetation cover estimated by eye. The quadrat was then flipped to the adjacent area along the transect line and repeated for the total length. The quadrat number, the percent cover, the type of habitat (dune, sand flat, swale), and the plant species found in each transect were recorded. Plant species in the two transects were identified using taxonomic keys and checked against reference specimens in the UWF herbarium. Published references used for this purpose included Clewell (1985), Duncan and Duncan (1987), Godfrey and Wooten (1979a,b), Taylor (1992), and Tiner (1993). Data were entered into the Microsoft Excel(TM) spreadsheet program for reduction and statistical analyses. The graphics package Kaliedagraph(TM) (MacIntosh) was used for data presentation.

Analyses included percent cover, dominance-diversity curves, Simpson's index for a species richness and evenness estimate, and Sorenson's similarity coefficient for comparisons between transects and years (Brower *et al.*, 1998). Dominance-Diversity curves were plotted from transect data sorted by the frequency of occurrence for each species. These data were Log transformed and fitted to linear models by the program Microsoft EXCEL for comparison of slope and intercept estimates by the program STATVIEW.

Simpson's Index was calculated as:

$$I = \frac{\sum n_i(n_i - 1)}{N(N - 1)}$$

where:

n_i = the abundance of the i^{th} species
N = the total number of individuals (all species)

Sorenson's similarity index was calculated as:

$$CC_s = \frac{2c}{s_1 + s_2}$$

where:

c = species in common between two communities
s_n = total number of species found in community "n"

RESULTS & DISCUSSION

Elevation changes over the transects are shown in Figure 2. The east transect was washed flat with very little relief and a total elevation that never exceeded 6 ft above MLW. The highest point was just seaward of the paved road where the primary dune line would have been. Little to no vegetation existed in many areas of the east transect when the study began. After Opal's storm surge washed the island flat, winds from Hurricane Danny (1997) aided in the rebuilding of the dunes in this area by redistributing the sand leveled by Opal. By the end of the study, dune formation was occurring where *Uniola paniculata* and *Panicum amarum* had become reestablished. The west transect covered an established dune field, as indicated in the elevation changes along its length (Figure 2). Here again the highest elevation encountered was nearest the Gulf in the area of primary dunes.

Seventy one plants were identified from both transects and all years (Table 1). The transects were good representatives for the dune, swale and sandy habitats, but were not inclusive of all plants on the island. Most species in the east transect increased in occurrence within m^2 plots over time, like Coastal Bluestem and Bitter (seaside) Panicum. A notable exception was Sea Oats, which increased only slightly after two years, and did not increase in frequency of occurrence in the third year of the study. This may be due to vegetative propagation being the primary means of dispersal and growth in this species, with little addition of new genetic stock via

Table 1. *List of plant species recorded.*

- *Panicum portoricense*
- *Schizachyrium maritimum*—coastal blue stem
- *Chrysopsis godfreyi* f. *godfreyi*—Godfreyi's golden aster
- *Helianthemum nasii*—rock rose
- *Balduina angustifolia*—yellow buttons
- *Polygonella polygama*—bushy jointweed
- *Paronychia erecta*—square flower
- *Polygonella gracilis*—wireweed
- *Fuirena scirpoidea*—leafless fuirena
- *Polypremum procumbens*—rust weed
- *Chrysopsis godfreyi* f. *viridis*—octopus plant
- *Ceratiola ericoides*—beach rosemary
- *Centella asiatica*—coinwort
- *Juncus scirpoides*—needle rush
- *Cyperus retrorsus*—flat burr sedge
- *Hypericum gentianoides*—pineweed
- *Smilax auriculata*—dune greenbrier
- *Cyperus lecontei*—flat sedge
- *Galactia microphyla*—sand pea
- *Uniola paniculata*—sea oats
- *Spartina patens*—saltmeadow cordgrass
- *Chrysoma pauciflocculosa*—woody goldenrod
- *Lachnathes caroliniana*—red root
- *Panicum repens*—torpedo grass
- *Asclepias humistrata*—sandhill milkweed
- Sand vine
- *Hydrocotyle bonariensis*—seaside pennywort
- *Physalis angustifolia*—sand ground-cherry
- *Strophostyles helvola*—wild bean
- *Dactyloctenium aegyptium*—crowfoot grass
- *Panicum* sp.
- *Baccharis halimifolia*—silverling
- *Polygala ramosa*
- *Rumex orbiculatus*—water dock
- *Ludwigia alata*
- *Rubus trivialis*—dewberry
- *Rhexia cubensis*—meadow beauty
- *Euthamia minor*—flat-topped goldenrod
- *Linum medium*—wild flax
- *Hypericum cistifolium*—St. Peter's wort
- *Heterotheca subaxillaris*—camphorweed
- *Eragrostis refracta*—purple love grass
- *Cuscata gronovii*—love vine
- *Panicum erectifolium*
- *Hypericum reductum*—St. John's wort–Atlantic
- *Smilax bona-nox*—fringed greenbrier
- *Juncus dichotomous*—path rush
- *Eupatorium mohrii*—narrow leaved Eupatorium
- *Chamaesyce ammannoides*—sand dune spurge
- *Stipulicida setacea*—skeleton plant
- *Drosera capillaris*—pink sundew
- *Paspalum notatum*—bahia grass
- *Panicum amarum*—seaside panicum
- *Cakile constricta*—sea rocket
- *Oenothera laciniata*—beach primrose
- *Ludwigia virgata* slender seedbox
- *Lachnocaulon engleri*—bog-button
- *Iva imbricata*—beach elder
- *Aristida intermedia*
- *Pluchea rosea*
- *Proserpinaca pectinata*—mermaid weed
- *Pinus elliottii*—slash pine
- *Solidago sempervirens*—seaside goldenrod
- *Stellaria* sp.
- *Limonium carolinianum* sea-lavender; marsh-rosemary
- *Hedyotis uniflora*—oldenlandia
- *Hypericum hypercoides*—St. Andrew's-cross
- *Panicum aciculare*
- *Panicum chamaelonche*
- *Syngonanthes flavidulus*—bantam-button
- *Myrica cerifera*—wax-myrtle

Table 2. *Coverage, Simpson's Index, and Species richness in the two transects. Coverage estimates with the same letter are not significantly different.*

	# Species	Coverage (%)			Simpson's Index		
		Average	Std. Dev.	Sig.	Average	Std. Dev.	Sig.
All Data							
East							
1996	16	9.110	16.224	A	0.175	2.84E-02	A
1997	20	18.019	26.947	B	0.263	6.23E-02	B
1998	23	29.628	25.256	C	0.166	4.48E-03	A
West							
1996	51	32.470	27.841	C	0.068	1.06E-03	C
1997	54	32.486	29.882	C	0.071	8.59E-04	C
1998	51	26.438	24.176	C, D	0.062	6.79E-04	C
Dune and Sand Flat							
East							
1996	14	8.422	14.892	A	0.148	1.29E-03	A
1997	13	12.119	20.969	A, B	0.106	8.23E-05	A, B
1998	13	29.058	23.140	D	0.089	7.42E-05	D
West							
1996	30	21.333	17.313	E	0.066	8.00E-06	E
1997	31	23.438	23.700	C, E	0.071	8.59E-06	C, E
1998	32	18.731	17.670	B, E	0.062	6.79E-06	B, E
Swale							
West							
1996	41	63.6	28.2	F	0.0432	6.79E-06	F
1997	41	67.7	25.1	F	0.0369	4.87E-06	F
1998	42	53.7	22.6	G	0.0433	7.91E-06	G

seed germination. In the west transect, most species were stable, while others decreased or increased without an obvious pattern.

The total number of species found in the east transect was lower than the total number found in the west transect, for all three years (Table 2). Total species increased with time for the east transect (Table 2), but remained constant for the west Transect (Table 2). The increase in the east transect was attributable in part to the development of a bayside "wetland" affected by spring tides and storm waves providing infrequent inundation. This habitat accounted for 11, 31, and 21 m^2 area of the north end of the east transect for years 96, 97 and 98 respectively. Despite the variability in the area affected, the number of unique species (from the total of both transects) found in this habitat increased from 2 in year 96, 5 in year 97, to 6 in year 98. Of these, only 2, *Baccharis halimifolia* and *Limonium carolinianum*, would not normally be found within the secondary dune field, and only the latter is restricted to habitats regularly saltwater-flooded.

At year three, total species richness in the west transect was about double the total species richness for the entire east transect. A comparison of sand flat and dune habitat between the two transects was accomplished by excluding the swale habitat which was only found in the west transect, road margins and the bay shore area of the east transect. For dune and sand flat only, species richness was constant over the three year period for both transects, but the west transect still had approximately twice the species richness that the east transect (Table 2). These figures indicate that for short-term revegetation of the overwash area, all of the species within this three year period were already present after the first year. This implies that this short term recovery following storm surge scouring is accomplished by either a seed bank in the scoured sand or vegetative growth from plant fragments buried in the sand. The swales in the west transect were the most stable communities encountered, with 41, 41, and 42 species in years 96, 97, and 98 respectively.

Total plant coverage followed similar trends as species richness (Table 2). The mean plant coverage for the east transect increased two fold from 1996 to 1997 (9.11% to 18.02%) and increased further (18.02% to 29.63%) from 1997 to 1998. The west transect total coverage was constant from 1996 to

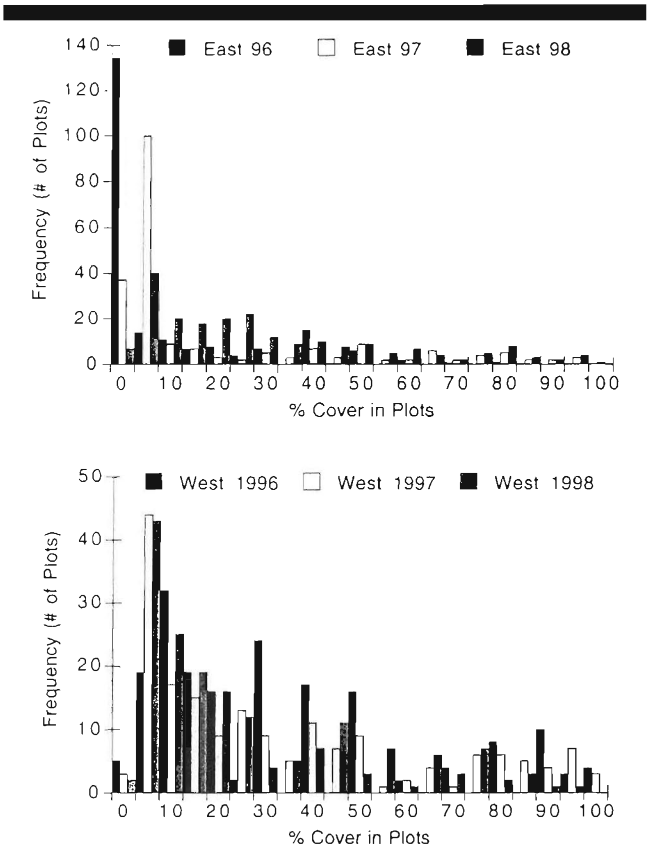

Figure 3. Frequency of percent cover estimates within quadrats of the east (top) and west (bottom) transects by year.

1997 but dropped from 32.49% to 26.44%) in 1998, presumably due to drought conditions experienced that summer. Total coverage of plant material for dune and sand flat habitat increased in the east transect all three years with a constant species number (Table 2). Total coverage estimates for the west transect swale were the highest recorded (63.6%, 67.7%, and 53.7%).

The frequency of occurrence for coverage estimates within quadrats is presented in Figure 3. The east transect had 135 plots with no coverage in 1996. In 1997, there was a greater number of plots with 5% coverage (100) than in 1996 (10) and a decrease in 0% coverage (135 to 35) was observed. The trend in 1998 shows less 0% coverage than 1996 and 1997 and less 5% coverage than in 1997, but more coverage between 5%-30%, and more 60%, 80% and 95% coverage than any of the previous years. As with species richness and coverage averages, the frequency distributions of coverage for the west transect were relatively stable, but higher frequencies of lower percentage coverage occurred in both 97 and 98.

Simpson's Index calculated from the data reflect the dominance of relatively few species in the east transect, even when only sand flat and dune habitats are compared (Table 2). Swale habitats, in addition to having the greatest species richness, also had Simpson Index values significantly different than the sand flat and dune or total transect data form either transect (Table 2).

Dominance-Diversity curves graphically illustrate differences in species richness and evenness between years and between habitats. Figure 4 (top two graphs) shows these curves for the total data from east and west transects for the three year study period. For the east transect, the increase in species number was the result of addition of rare species, with the community increasingly dominated by less than 10 species, providing the increased coverage noted above. Curves for the west transect did not appreciably change during the study period, but were quite different from the east transect curves reflecting the greater species richness and evenness of the west transect habitats. This suggests that the topography of the west transect may be providing microhabitats necessary for the survival of some sand and dune species. The east transect community should continue to change as more species colonize and dunes begin to emerge until a stable endpoint is reached, as reflected in the west transect data. Figure 4 (bottom two graphs) shows the west transect sand flat and dune habitat data in comparison to the west transect swale data. Both of these habitat types of the west transect reveal the interannual stability previously mentioned, but are very different communities. The dune and sand community had a greater abundance of fewer species and the swales had the highest diversity and greatest evenness of the habitats encountered, in addition to the highest percent coverage.

Similarity estimates for the transects show that species composition changed from year to year, even where species richness and coverage were constant (Table 3). Sorensen's Coefficient for the east transect was never higher than 79.07% between years (97–98) and lowest between the first and last year of the study (66.67%) reflecting the re-growth of vegetation and continual change in this community. In contrast, the similarity figures between years for the west transect ranged from 87.62 to 91.43%, with the greatest similarity occurring between the first and last years of the study. These figures, while high, do reflect a constant change in community structure despite the relative stability of the west transect for species richness and coverage. Indeed, where the greatest difference in total coverage occurred, the highest similarity in composition was found (years '96 to '97). Low similarity estimates were obtained between the east and west transect data (20 to 40%), reflecting the very different nature of the two communities. When comparing the dune and sand flat habitats of the two transects, the similarity figures rise (33.73 to 36.57), but still reflect a successional endpoint of the west transect plant communities relative to the recovering east transect. Interestingly, for the dune and sand flat habitats only, the east transect similarity figures increase between years, but the west transect figures decrease, indicating that the community structure of the swale habitats of the west transect were more stable and the change in community structure was dominated by changes in the dune and sand flat areas despite their constant species number (30, 31, and 32) and coverage (21.33, 23.44, and 18.73%) between years.

The turnover (gain and loss) of species reflected in the similarity coefficients between years for each transect (Table 3) occurred with the most rare species in these plant assemblages. This species turnover requires either a seed bank, or

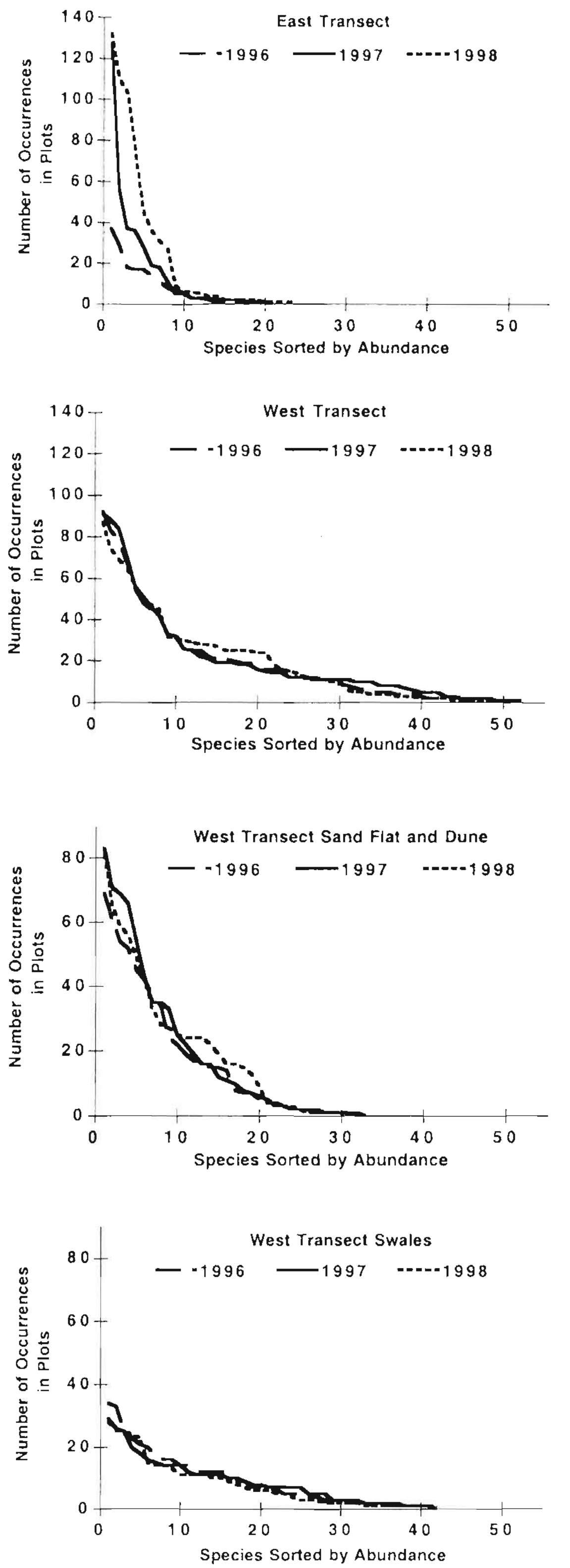

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Figure 4. Dominance diversity curves based on frequency of occurrence of species within quadrats along east and west transects for total data (top graphs), and for the west transect dune and west transect swale habitats (bottom two graphs).

Table 3. *Similarity matrixes and Sorensen's Similarity Coefficient for plant communities on the East and West Transects.*

	# Shared Species			# Different Species		
Diagonal is Species Richness in each Transect	East 96	East 97	East 98	West 96	West 97	West 98
East 96	16	14	13	8	7	7
East 97	9	20	17	12	11	11
East 98	12	9	23	13	12	12
West 96	52	48	49	51	48	46
West 97	57	52	53	11	54	46
West 98	54	49	50	11	13	51
Sorensen's Coefficient						
East 96	1.0000	0.7778	0.6667	0.2388	0.2000	0.2704
East 97		1.0000	0.7907	0.4000	0.2973	0.3099
East 98			1.0000	0.3514	0.3117	0.3243
West 96				1.0000	0.9143	0.9020
West 97					1.0000	0.8762
West 98						1.0000
Dune and Sand Flat Only						
East 96	14	11	10	5	7	6
East 97	7	13	11	6	8	8
East 98	9	4	13	5	7	7
West 96	34	31	24	30	21	24
West 97	33	28	30	19	31	24
West 98	35	29	31	14	15	32
Sorensen's Coefficient						
East 96	1.0000	0.8148	0.7407	0.2273	0.3111	0.3657
East 97		1.0000	0.8462	0.3243	0.3636	0.3556
East 98			1.0000	0.2326	0.3182	0.3111
West 96				1.0000	0.6885	0.7742
West 97					1.0000	0.7619
West 98						1.0000

more likely, a constant imigration source to maintain a stable species richness. The balance of local extinction and immigration of species to maintain an equilibrium species richness with constant species turnover is one of the features of the Island Biogeography Theory of community stability (MACARTHUR and WILSON, 1967). In order to preserve the species richness of these habitats, and to continue to increase species richness in recovering areas (east transect) until this endpoint is reached, source areas for these plant species should be identified. If these source areas are dependent on other areas of the barrier island as opposed to mainland sources, then preserve size and habitat diversity within preserve areas becomes critical for the maintainence of the more rare members of the plant communities.

CONCLUSIONS

This study has documented the plant community fluctuations in a relatively stable dune and swale system (west transect) and the recovery of vegetation on a storm surge scoured portion of the island (east transect). Swale vegetation was the most stable for all parameters, indicating the importance of water availability to plant community stability on the barrier island. Significant turnover of species occurred in the dune and sand flat communities of the west transect within the confines of stable species richness, evenness and coverage, indicating an equilibrium endpoint defined by the harsh conditions of the environment (drought, heat, salt). The east transect showed rapid revegetation after the storm surge, and the response was mainly due to the proliferation of relatively few species (<10). However, within these species were the major dune building plants Sea oats (*Uniola paniculata*), Blue stem (*Schizachyrum maritima*), and Bitter Panicum (*Panicum amarum*), which will trap sand and create microhabitats as the relief of the system increases. Further succession in the east transect plant communities is anticipated at a much slower rate controlled by the rate of geomorphologic change as described by JOHNSON (1997). The system should approach an equilibrium endpoint similar to that of the secondary dune and sand flat habitats of the west transect. This succession would continue unless interrupted by subsequent storm surges. Repeated overwashes would define a cycle of disturbance and regrowth quite different from the west transect. Geomorphologic evidence of past storm surges (not shown) suggests that certain areas of the island are more subject to such repeated disturbance than other areas of the island.

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