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Vegetation Colonization of Dredge Spoil on Perdido Key, Florida

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ABSTRACT

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The vegetation colonizing dredge spoil is described from the first year following massive beach nourishment. Dredge spoil was deposited in late 1990 gulfward of mean high water on Perdido Key, a barrier island off the coast of the Florida panhandle, for a distance of 8 km and averaging 150 m in width. A grid of permanent plots was used to measure density and cover of the colonizing species. With a density of 997 plants per ha in Summer 1991, *Cakile constricta* was the most abundant of ten species colonizing the dredge spoil. Other species with a density of more than 50 plants per ha were *Uniola paniculata, Iva imbricata, Panicum amarum*, and *Oenothera humifusa*. Sand fencing 10–15 m below old mean high water increased the density of *U. paniculata*. Maps of *C. constricta* show that the highest densities were adjacent to and below the old mean high water. A new strand line of *C. constricta* that was establishing just above the new high water mark in May 1991 was lost following overwashing from late spring storms. Canonical Correspondence Analysis was used to compare species cover data from plots on the dredge spoil to cover data from permanent plots on the main island and above the old mean high water. Vegetation in the first year of colonization most closely resembled a species-rich strand or low density developing dune vegetation. The precarious nature of the vegetation colonizing onto the dredge spoil during the first year following deposition indicates that additional dredge spoil deposition is not advisable for several years.

ADDITIONAL KEY WORDS: *Barrier island, beach nourishment, Canonical Correspondence Analysis, primary succession*, Cakile constricta, Uniola paniculata.

INTRODUCTION

Beach nourishment is a common coastal management tool used in both the disposal of dredge spoil and the replenishment of beach sediment lost through erosion (DAVISON *et al.*, 1992). While there has been much concern as to the geomorphological impact and success of beach nourishment projects (PILKEY, 1990), virtually nothing is known about the subsequent ecological impacts on the coastal vegetation. Indeed, the Monitoring Completed Coastal Project established in 1981 by the U.S. Army Corps of Engineers to provide planners, designers and builders with an evaluation of coastal projects makes no mention of the ecological impact of beach nourishment projects (HEMSLEY, 1990). A review and annotated bibliography by DAVISON *et al.* (1992) contains no reports on the effect of beach nourishment on coastal vegetation. Exceptions to this apparent lack of plant ecological interest in nourishment projects in the past have included COULTAS *et al.* (1978) and LANDIN's (1985) studies of planting success and habitat development on dredge spoil (but not beach nourishment projects), and SYLVIA and WILL's 1988 study of soil fungi on a beach replenishment site. Coastal dune managers in Europe have also considered the importance of incorporating an ecological perspective into evaluating the success of beach nourishment (*e.g.*, VAN DER MEULEN and VAN DER MAAREL, 1989).

The 1990 Pensacola Naval Air Station Homeporting Project was one of the largest ever beach nourishment projects in the eastern U.S. and involved the nourishment of 8 km of the Gulf beach on the eastern end of Perdido Key, Florida, by the deposition of approximately 5.4 million m^3 of beach quality sand (LEONARD *et al.*, 1990; ZIMMERMAN, 1990). The plant species colonizing the dredge spoil have been monitored since deposition of the dredge spoil as a part of a comprehensive monitoring program established by the U.S. National Park Service (WORK *et al.*, 1991).

In this report, the plant species colonizing the dredge spoil in the first year after deposition are reported and plant communities compared with those that existed on the barrier island prior to nourishment. The spatial pattern of the first and most abundant species to colonize the dredge spoil in the first year, *i.e.*, *Cakile constricta*, is described to allow the processes and dynamics of primary succession to be followed.

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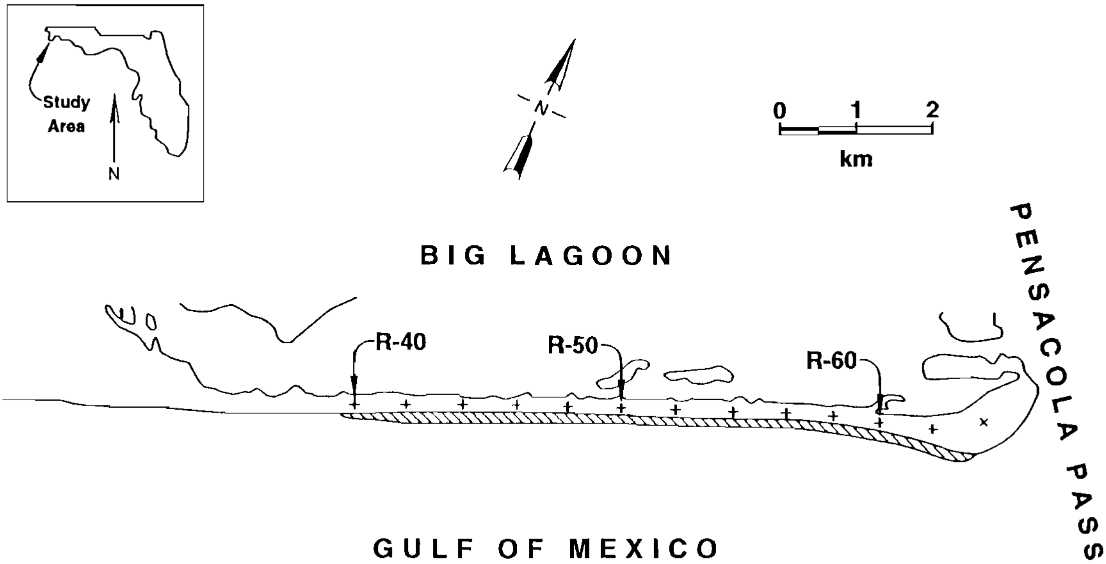


Figure 1. Map of the eastern end of Perdido Key, Florida, showing the extent of beach nourishment (hatched area) and even-numbered DNR markers used in the placement of cross-island line transects and permanent sample plots.

MATERIALS AND METHODS

Study Area

The study was conducted in the Gulf Islands National Seashore (GINS) on the eastern 11 km of Perdido Key, a barrier island off the northwest coast of Florida (87°24′W, 30°18′N) (Figure 1). The island consists of coastal dunes dominated by *Uniola paniculata*. Three hundred and twenty-three species of vascular plants have been reported for the GINS portion of Perdido Key (LOONEY *et al.*, in press) in a variety of habitats ranging from coastal strand just above mean high water (MHW) to several types of *U. paniculata* dunes, wet and dry swales and a *Juncus roemerianus* dominated marsh at the back of the island (GIBSON and LOONEY, 1992). The area is largely undeveloped except for the ruins of a WWII artillery battery on the extreme eastern end of the island. Off-road vehicle use has been banned since 1983. The only major recent disturbance was Hurricane Frederic in September 1979 which extensively overwashed the island flattening as much as 90% of the dunes (COUSENS, 1988).

To counteract shoreline erosion (0.5 m per year from 1859–1985 [STONE *et al.*, 1992] and to dispose of spoil from the dredging of Pensacola Pass, the U.S. Army Corps of Engineers nourished approximately 8 km of the GINS in late 1990 with 5.4 million m^3 of beach quality sand (WORK *et al.*, 1991). Beach nourishment almost doubled the width of the barrier island in some places (Figure 1). In late 1990, 50 m long sand fences 10–15 m below the old MHW were erected on the dredge spoil to facilitate the dune building process and arrest the landward, wind borne movement of the dredge spoil. Each sand fence was constructed of 50 m long × 0.61 m high plastic mesh buried to a depth of 5–7 cm. The fences were placed in groups of three with different groups being a slightly different distance from the old MHW. Gaps were left between some adjacent groups of sand fences to compare dune establishment and vegetation colonization in the absence of sand fences. Plantings have not been carried out, and vegetation is being allowed to colonize the dredge spoil naturally.

Data Collection and Analysis

In Autumn 1990, permanent plots were established along thirteen transects on the dredge spoil (Figure 1). The transects were located along even-numbered Department of Natural Resource (DNR) profiles R-40 through R-64 and were a continuation of transects established in 1989 to monitor the vegetation on the barrier island above the old MHV (GIBSON and LOONEY, 1992). Two sizes of permanent plots were established: 2 × 5 m plots established every 12 m at and below the old MHW for species cover estimates, and contiguous 12 × 5 m plots running from 36 m above the old MHW to the new MHW for density counts. The smaller 2 × 5 m plots were established to be consistent with the plots used in an ongoing vegetation monitoring program on the barrier island above the old MHW (GIBSON and LOONEY, 1992). Up to twelve plots were established across the width of the dredge spoil (depending on the distance to the new MHW) and twelve plots were established off the dredge spoil above the old MHW. Within each plot, the vegetation was sampled in Spring (May), Summer (July), and Autumn (November) 1991, by estimating cover of all species according to the Daubenmire scale (DAUBENMIRE, 1959) within 25 permanently located 0.1 m^2 quadrats that were randomly located within the permanent plot for the first sampling. Within the 12 × 5 m plots, the density of all *Cakile constricta* plants (mature plants and seedlings) was counted in December 1990 and Spring 1991, the presence/absence of all vascular plants was recorded in Spring 1991, and the density of all vascular plants was counted in Summer and Autumn 1991.

The effect of sand fencing upon the establishment of vegetation on the dredge spoil was investigated by comparing the density of species in the 12 × 5 m plots in July 1991, through which the sand fence passed ($n = 14$) with the density in plots at the same distance below old MHW in which a sand fence was absent ($n = 11$) using Analysis of Variance (ANOVA) of square root transformed density data. Possible differences in the density of plants in plots above ($n = 13$) or below ($n = 13$) the line of sand fencing were also tested in the ANOVA.

Diversity and evenness (the distribution of abundance among species in a community) were calculated from the mean cover and density of each species on the dredge spoil for Spring, Summer, and Autumn 1991. Diversity was calculated as the exponent of Shannon's H' (HILL, 1973), and evenness was calculated according to Hill's ratio (HILL, 1973). Calculations were performed using programs provided in LUDWIG and REYNOLDS (1988).

Detrended Canonical Correspondence Analysis (CCA; TER BRAAK, 1986, 1987) was used to ordinate cover data summarized per permanent plot (mean species cover per plot) collected from the new beach in Spring, Summer, and Autumn 1991. CCA is a multivariate method of direct gradient analysis that seeks to order samples along gradients such that the corresponding species abundances follow a unimodal distribution. In addition, the ordination axes are constructed so that the axes are linear combinations of environmental variables. For this analysis, species cover data from 178 plots above the old MHW surveyed in May 1990 prior to deposition of the dredge spoil were used to construct the ordination axes. Two hundred and twelve plots surveyed in Spring, Summer and Autumn 1991 from at and below the old MHW (*i.e.*, on the dredge spoil) were held "passive" in the construction of the ordination (*i.e.*, did not contribute to the extraction of the ordination axes) and added to the ordination afterwards (TER BRAAK, 1988; see SCHMALZER and HINKLE, 1992, for an example). This procedure was followed so that the ordination portrayed the relationship of the vegetation in plots on the dredge spoil (*i.e.*, at and below the old MHW) to vegetation in plots on the main part of the island (*i.e.*, the plots above the old MHW). Thus, the analysis revealed how the vegetation on the dredge spoil related to the vegetation on the rest of the island prior to the deposition of the dredge spoil.

Previous analyses (GIBSON and LOONEY, 1990) had shown that the vegetation on Perdido Key was strongly related to location on the island. Consequently, sample scores on the CCA axes were constrained to be linear combinations of environmental variables; specifically in this case, plot elevation above datum, distance from MHW, transect number, and sand loss. Elevation above datum and distance from MHW for each plot were taken from data presented by WORK *et al.* (1990). Transect numbers identified the Florida Department of Natural Resource profile line along which the plot lay (see Study Area) and allowed possible east–west gradients to be identified. Loss or accumulation of sediment in each permanent plot, referred to as sand loss, was estimated by measuring the height of permanent marker stakes above the ground level at each sample date. The difference between the heights on two subsequent sample dates indicated whether sediment was accumulating or being lost from the plot. When stakes had been removed or obviously disturbed, a measurement was not taken. Sand loss data were expressed as + or − depending on whether the

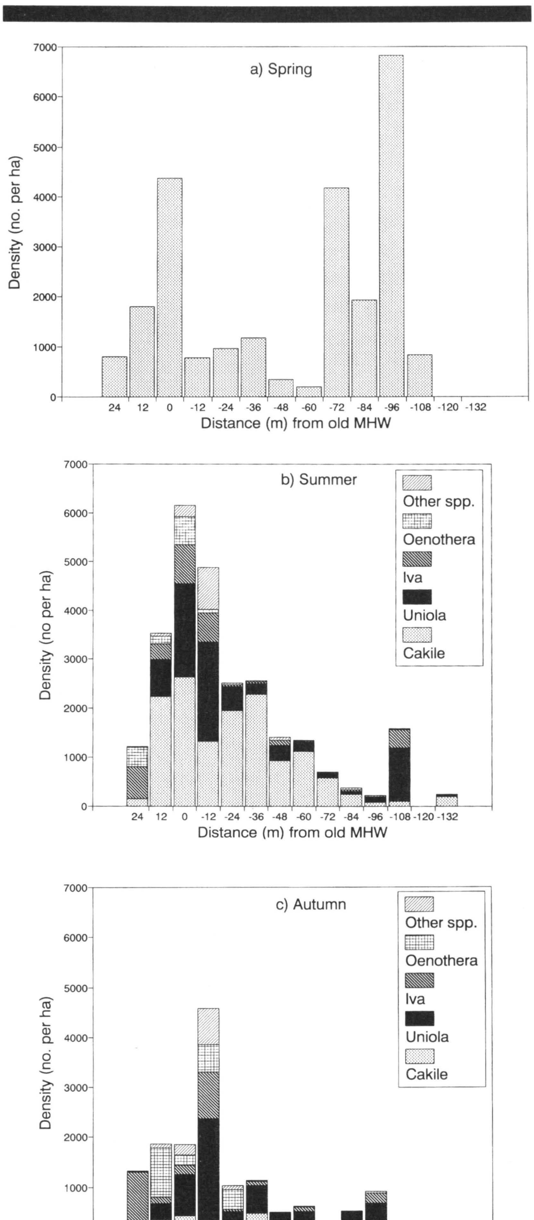


Figure 2. Density of plant species across the new beach in (a) Spring, (b) Summer, and (c) Autumn 1991 with respect to distance from old MHW. Counts of only *Cakile constricta* were made in Spring 1991. Negative distances refer to plots on the dredge spoil, whereas positive distances refer to plots above the old MHW.

elevation of the plot had increased or decreased over the previous six months.

The distribution of plots with respect to the CCA axes was summarized by constructing Gaussian confidence ellipses (ELM procedure in SYSTAT [Wilkinson, 1990]). Confidence ellipses circumscribed plots prior to dredge spoil deposition in May 1990 according to vegetation types identified by Gibson and Looney (1992). Plots surveyed on the dredged spoil were circumscribed according to sample date (Spring, Summer or Autumn).

Isoline maps showing the distribution of *Cakile constricta* plants on the dredge spoil in December 1990, Spring, Summer or Autumn 1991, were constructed using a Kriging procedure in the software package SURFER (Golden Software, Inc., Golden, CO). Kriging is a spatial interpolation procedure that provides a means of estimating values for points not physically sampled (Legendre and Fortin, 1989). With this procedure, it was possible to estimate the density of *C. constricta* across the whole dredge spoil area throughout the first year of colonization using the density counts in a 195 element grid.

RESULTS

Plant Communities

Ten species colonized the new beach in 1991 (Table 1). Of these, *Cakile constricta* was the most abundant both in terms of cover and density, except in the Autumn. *Uniola paniculata* and *Iva imbricata* were also important colonizers with the former being the most abundant species in the Autumn. The maximum density of plants and the largest number of species were associated with the old MHW, and there was a decline in density of plants from the old MHW across the new beach to the new MHW (Figure 2). A secondary peak of plant density occurred close to the new MHW associated with higher densities of *U. paniculata*.

During 1991, there was little change in the total cover of the colonizing species, especially between Summer and Autumn (Table 1). Mean cover of all species remained below 0.4%. Over the period from Spring to Autumn 1991, the cover of *C. constricta* decreased while other species such as *U. paniculata* and *I. imbricata* increased. Changes in density (Table 1) led to marked seasonal differences in the composition of the vegetation across the new beach (Figure 2). In Spring 1991, *C. constricta* had the highest cover; but in the succeeding Summer and Autumn, the other colonizing

Table 1. *Density and cover[1] of plant species colonizing the dredge spoil below old MHW on Perdido Key in Spring, Summer, and Autumn 1991.*

	Spring		Summer		Autumn	
Species	Density no·ha⁻¹	Cover %	Density no·ha⁻¹	Cover %	Density no·ha⁻¹	Cover %
Cakile constricta	1,742	0.37	997	0.20	184	0.13
Uniola paniculata	*	0.07	465	0.05	541	0.13
Iva imbricata	*	0.07	131	0.02	170	0.05
Panicum amarum	*	+	102	+	94	0.02
Oenothera humifusa	*	0.01	9	+	119	+
Chamaesyce ammannioides	*	+	6	+	9	+
Schizachyrium maritimum	*	0.01	11	0.01	8	0.01
Ipomoea stolonifera	*	+	6	+	3	+
Heterotheca subaxillaris	*	+	2	+	2	+
Froelichia floridana	*	+	—	—	—	—
Total	—	0.53	1,723	0.28	1,130	0.34

* Indicates species present in the density plots; only *C. constricta* numbers were counted in the Spring

\+ Indicates species that occurred in the density plots but were absent from the plots used to assess cover

[1] Cover was calculated as the mean cover from plots containing vegetation, whereas density values are based on all plots surveyed

species became proportionally more abundant in terms of density and more widespread across the new beach. These changes were reflected in an increase in diversity and a decrease in evenness even though the number of species did not markedly change (Table 2).

The occurrence of sand fencing significantly increased the density of *U. paniculata* (Table 3). The density of *Oenothera humifusa* was also higher in areas of sand fencing, although the effect was not significant ($P = 0.06$). The density of *Cakile constricta* and *Iva imbricata* and other less abundant species was not affected by the establishment of sand fences. The density of none of the species was significantly different above or below the line of sand fencing.

The first two ordination axes extracted by the CCA procedure accounted for 76% of the variation in the May 1990 species abundance data set. CCA axis 1 explained 67% of the variation in the data set and separated marsh and swale vegetation from dune vegetation (Figure 3). Wooded dunes and back slopes were assigned intermediate positions along this compositional gradient while strand and developing dunes were associated with dunes. All four environmental variables included in the analysis were significantly associated with the first CCA axis (t-values of regression coefficients with CCA all > 2.1, $P < 0.05$) with plot elevation and distance to MHW having the strongest relationships (canonical coefficients with CCA 1 = 0.64 and −0.50, respectively; transect and sand loss coefficients both less than ±0.2). Thus, the marsh to dune gradient in vegetation composition above MHW in May 1990 is best related to distance above MHW and plot eleva-

Table 2. *Diversity (exponent of Shannon's H′) and evenness (Hill's ratio) based on cover and density estimates of plant species colonizing the dredge spoil below old MHW on Perdido Key, in Spring, Summer, and Autumn 1991*

	Spring	Summer	Autumn
	Cover		
Number of species	5	4	5
Diversity	2.55	2.35	3.62
Evenness	0.26	0.36	0.20
	Density		
Number of species	10	9	9
Diversity	1.43	3.13	4.38
Evenness	0.81	0.77	0.77

Table 3. *Density (number per 60 m² plot) of plants colonizing dredge spoil in July 1991 in plots with and without sand fencing*

	With fencing		Without fencing		
Species	Mean	se	Mean	se	P[1]
Cakile constricta	11.6	4.2	13.4	6.5	0.98
Uniola paniculata	20.4	4.8	2.5	1.5	0.003
Iva imbricata	7.4	3.9	1.4	0.9	0.15
Oenothera humifusa	3.6	2.4	0		0.06
Other species (n = 6)	6.0	4.0	0.3	0.3	0.11
Total	48.2	11.1	17.5	6.8	0.03

[1] P = probability level (ANOVA) testing the effect of sand fencing (presence or absence) upon density

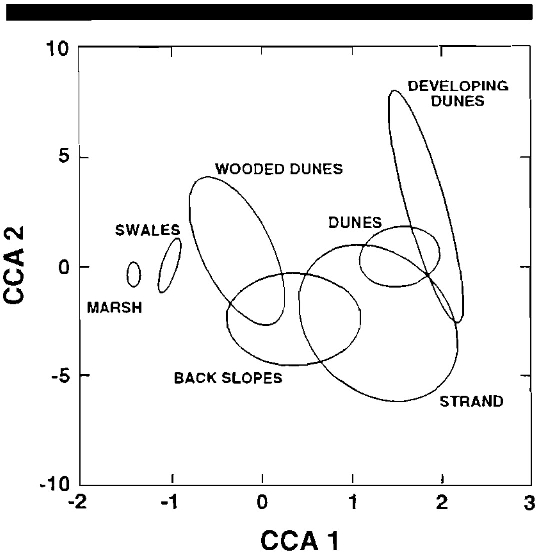


Figure 3. Canonical Correspondence Analysis of 178 plots surveyed on Perdido Key in May 1990. Confidence ellipses circumscribe the distribution of plots (not shown for clarity) according to their assignment to vegetation types in GIBSON and LOONEY (1992).

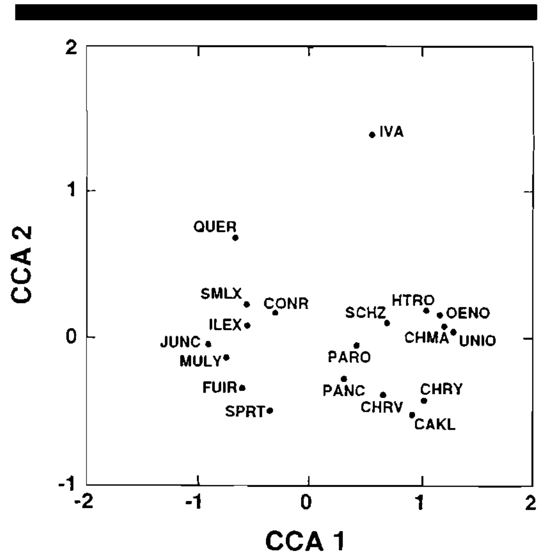


Figure 4. Plot of species scores for Canonical Correspondence Analysis of 178 plots surveyed on Perdido Key in May 1990. Only species given species weightings (TER BRAAK, 1988) greater than 50 shown. CAKL = *Cakile constricta*, CHMA – *Chamaesyce ammannioides*, CHRY = *Chrysopsis godfreyi*, CHRV = *C. godfreyi* f. *viridis*, CONR = *Conradina canescens*, HTRO = *Heterotheca subaxillaris*, ILEX – *Ilex vomitoria*, IVA = *Iva imbricata*, OENO – *Oenothera humifusa*, PARO – *Paronychia erecta*, QUER = *Quercus geminata*, JUNC = *Juncus roemerianus*, MULY – *Muhlenbergia capillaris*, PANC = *Panicum amarum*, SCHZ = *Schizachyrium maritimum*, SMLX = *Smilax bona-nox*, SPRT – *Spartina patens*, UNIO = *Uniola paniculata*.

tion (marsh plots being far from MHW and at a low elevation; dune plots being the opposite). This primary gradient in species composition was related to the abundance of *Juncus roemerianus* in the marshes, *Muhlenbergia capillaris*, *Ilex vomitoria*, and *Smilax bona-nox* in the swales, and *Uniola paniculata*, *Chamaesyce ammannioides*, *Oenothera humifusa*, and *Schizachyrium maritimum* in the dunes (Figure 4). The second CCA axis explained 9.6% of the variation in the data set after extraction of first CCA axis and provided a distinction between developing dunes, dunes, and strand vegetation (Figure 3). This gradient was significantly related to transect number, distance to MHW, and sand loss (regression coefficient t-values > 2.1, $P < 0.05$), but not elevation ($P > 0.05$). Transect number had the largest canonical coefficient (-1.06) with distance to MHW (0.74) and sand loss (-0.47) having smaller coefficients. These relationships indicate that developing dunes, characterized by *Iva imbricata* (Figure 4), were more common to the west of the study area (lower numbered transects). By contrast, strand vegetation, characterized by *Cakile constricta*, was closer to the front of the island (smaller distance to MHW) and associated with sand loss.

Plots surveyed on the new beach were all assigned high CCA axis 1 values (Figure 5) reflecting a high degree of similarity with strand, dune and developing dune vegetation types. Plots on the new beach surveyed in the Spring and Summer were associated with strand vegetation; but by Autumn, the plots were more diverse and showed an overlap in distribution on the ordination with developing dunes as well as strand. Plots surveyed above the old MHW in May 1991 were placed on the ordination in the same place as these same plots when they were earlier surveyed in May 1990 and assigned to the dune vegetation type.

Colonization Pattern of *Cakile constricta*

The spatial pattern of *C. constricta* on the dredge spoil indicated that colonization was not a random process (Figure 6). In December 1990, two main invasion fronts were present: the largest associated with transects 50 through 58, and a smaller associated with transect 46 (Figure 6A).

The larger colonization front was still present in May 1991 (Figure 6B), but several new foci were forming a new strand line just above the new MHW. In July 1991, the distribution pattern (Figure 6C) was similar to that from the previous December (Figure 6A) following the loss of the plants associated with the new strand line in May (Figure 6B). The pattern of distribution of *C. constricta* was similar in November 1991 (Figure 6D) to the preceding July (Figure 6C) except that the overall densities were lower. The new strand line evident in May (Figure 6B) had not reestablished.

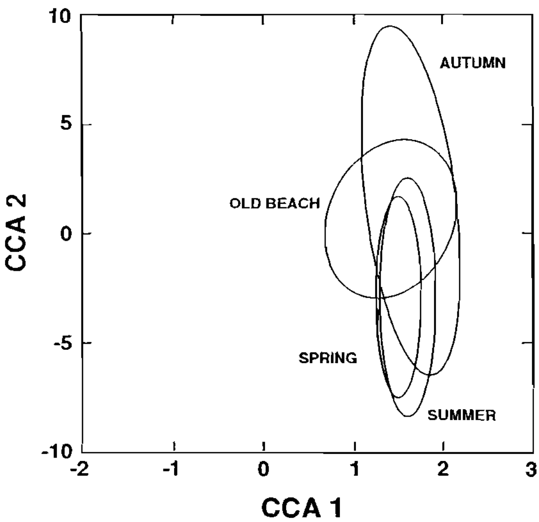


Figure 5. Confidence ellipses circumscribing the distribution of plots surveyed on the new beach in Spring, Summer and Autumn 1991, and plots on and up to 144 m above old MHW in May 1991 (*i.e.*, old beach) with respect to Canonical Correspondence Analysis axes 1 and 2 of plots surveyed above MHW in May 1990 (Figure 3).

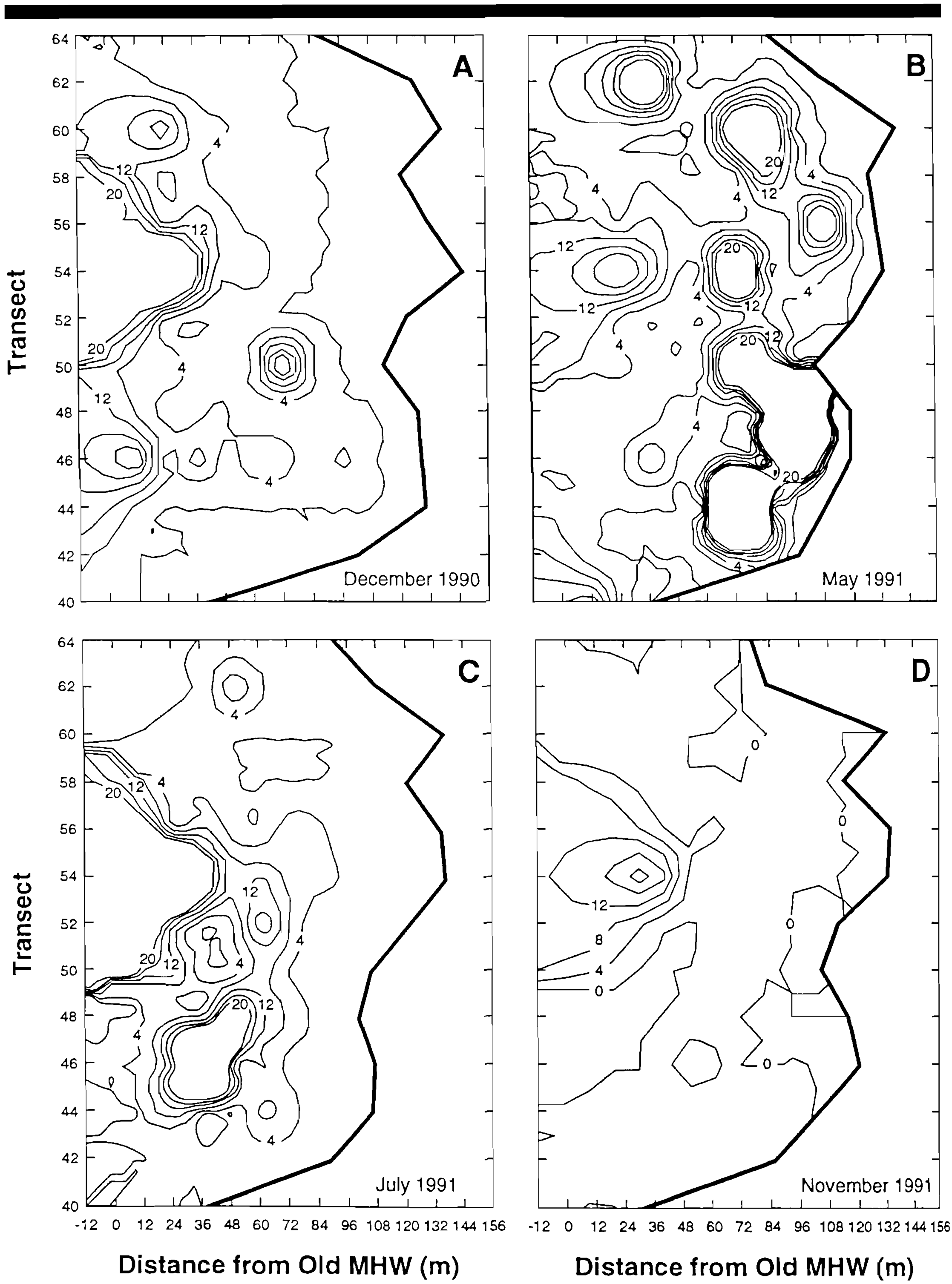
DISCUSSION

Primary Succession

The most abundant species on the dredge spoil during the first year following deposition was the annual, *Cakile constricta*. This species and its congeners from other coastal areas are coastal strand species that colonize open sand at or within a few meters above MHW (MAUN *et al.*, 1990). Colonization onto the dredge spoil was highly variable both spatially and seasonally (Figures 2 and 6) reflecting the annual habit of this species. Towards the end of the first season, other species such as *Uniola paniculata, Oenothera humifusa* and *Iva imbricata* were also colonizing the new beach (Figure 2). The continuing establishment of *U. paniculata* is particularly encouraging since it is the dominant foredune perennial grass along the Gulf of Mexico, and is involved in dune building and stabilization (WAGNER, 1964; WOODHOUSE *et al.*, 1968). Populations of *U. paniculata* are less likely than the annual species (*e.g., C. constricta*) to be extirpated by storms and washovers and the growth of seedlings of *U. paniculata* has been shown to be promoted by salt spray. However, sea water flooding can lead to salt stress (SENECA, 1972). *I. imbricata* and *O. humifusa* are perennial species that can also establish permanent populations, although *I. imbricata* seedlings have been shown to be sensitive to salt water inundation (COLOSI and MCCORMICK, 1978).

The sand fences were erected to arrest excessive landward movement of the dredge spoil and to encourage dune development and vegetation colonization. The higher densities of *U. paniculata* in plots associated with the sand fence (Table 3) reflect the short-term success of this policy. MENDELSSOHN *et al.* (1991) have shown that sand fences increase the survival rate of transplanted dune grasses, including *U. paniculata*.

This study presents data from only the first year of primary succession on the nourished beach dredge spoil. Nevertheless, comparisons with the characteristics of succession and colonization in other dune systems are useful. GRUBB (1987) contrasts the pioneer species of coastal fore-dunes (developing dunes of GIBSON and LOONEY, 1992) and drift-lines (strand). Fore-dune pioneers are normally long-lived perennials, whereas drift-line pioneers are characteristically annuals. The difference between life forms in the two habitats reflects the continually wind-blown, sand disturbed and nutrient-poor fore-dunes and the nutrient-rich drift line that is disturbed by winter storms. The nourished beach on Perdido Key possesses characteristics of both of these habitats. Four of the ten colonizing species were annuals or biennials (*Cakile constricta, Chamaesyce ammannioides, Froelichia floridana* and *Heterotheca subaxillaris*), and many seedlings of *C. constricta* were observed in wrack (sea weed) washed up at the new MHW. This was reflected in the high density of *C. constricta* plants (mostly seedlings) just above the new MHW in May 1991 (Figure 6). KEDDY (1981) suggested that high nutrient levels beneath stranded wrack enhanced the re-


A
December 1990
B
May 1991
C
July 1991
D
November 1991
Transect
Transect
64
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-12 0 12 24 36 48 60 72 84 96 108 120 132 144 156
-12 0 12 24 36 48 60 72 84 96 108 120 132 144 156
Distance from Old MHW (m)
Distance from Old MHW (m)

productive output of the related *C. edentula*. By contrast, the other six colonizing species were perennials, which are longer lived and better able to withstand the disturbance of wind-blown sand movement and burial. The perennials consisted of both rhizomatous (*i.e., Iva imbricata, Panicum amarum*) and stoloniferous (*i.e., Uniola paniculata, Oenothera humifusa, Schizachyrium maritimum,* and *Ipomoea stolonifera*) life forms. MORENO-CASASOLA (1988) has emphasized the importance of these life forms in colonizing and stabilizing dune sand on Gulf of Mexico beaches. RANWELL (1960) demonstrated the importance of species of contrasting life forms in colonizing and hastening the accretion of sand on a dune system in Wales.

Relationships to Existing Vegetation

The vegetation above the old MHW was related to distance from MHW and elevation. More importantly, however, the CCA plot showed the relationship of the vegetation on the dredge spoil to the older vegetation above old MHW (Figure 5). Compositionally, the dredge spoil vegetation most closely resembled strand in the Spring and Summer and developing dune vegetation in the Autumn (GIBSON and LOONEY, 1992). These similarities occurred primarily because of the dominance of *Uniola paniculata* in a community with few other species. However, while there is the compositional similarity, the cover of vegetation between the new beach community and vegetation above the old MHW is very different. For example, the cover of *Uniola paniculata* on developing dunes was 4.3% in Autumn 1989 and 3.3% in Summer 1990 (GIBSON and LOONEY, 1992), whereas its cover on the dredge spoil in Autumn 1991 was <0.1% (Table 1). Nevertheless, by the end of 1991, there were a few scattered, small clumps of flowering *U. paniculata* on the dredge spoil. Total vegetation cover on the dredge spoil was less than 1% throughout 1991, considerably less than even strand vegetation (total cover approximately 4%), the most sparse vegetation type above old MHW. Even casual observations show that the nourished beach is, for the most part, open sand. The relative slowness of colonization of plants onto the dredge spoil is perhaps not surprising given the flat profile of the nourished beach, low nutrient availability (the dredge spoil sediment consists of almost pure quartz grains), continuous salt spray, desiccating effects of wind, and occasional inundation from storm overwash. Primary succession under such conditions is typically slow; indeed, COUSENS (1988) did not record vegetation cover over 5% until 1981 in an area on Perdido Key scoured by Hurricane Frederic in 1979. Cover did not exceed 10% until 1983. It is likely that it will be some years before the plant communities on the dredge spoil are comparable to those above the old MHW in terms of cover abundance.

CONCLUSIONS

Despite PSUTY *et al.* (1974) and REIMOLD's (1977) call for ecological assessments to be made of dredge spoil projects, there are few other studies with which to compare the results of this study. EHRENFELD (1990) showed that the pattern of succession on barrier islands was extremely variable depending on local topography, soil moisture and sand accretion or deflation. Comparable studies of colonization onto nourished beaches and dredge spoils are few. ART (1976) observed a large number of annual species two years after deposition on a dredge spoil island off Fire Island, New York. KRUCZYNSKI *et al.* (1978) found that natural invasion over a fourteen month period onto dredge spoil placed in a saline intertidal environment was insufficient to provide adequate ground cover. Certainly, the sparse and open nature of the vegetation on the nourished beach on Perdido Key twelve months after deposition of the dredge spoil indicates that an ecologically equivalent habitat to that above the old MHW has yet to form. Future deposition of dredge spoil above the tide line should not occur until the beach profile has better stabilized and vegetation cover has increased.

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Figure 6. Isoline map of the density (number of plants per 60 m^2 sample plot) of *Cakile constricta* on the dredge spoil on (A) December 1990, (B) May, (C) July, and (D) November 1991. The thicker solid line shows the position of the new shore line on the Gulf of Mexico. The old MHW is at 0 m. Transects are 600 m apart.

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