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Recovery of vegetation following a wild fire on the margins of tidal flats, Padre Island National Seashore, Texas

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Abstract.--Recovery of halophytic vegetation on the margin of tidal flats following a wildfire at Padre Island National Seashore, Texas, was studied for 26 months. Species richness, species diversity, species importance, evenness and vegetation abundance were evaluated. Species richness and diversity were restored within 108 days after the fire. Sporobolus virginicus was the dominant species on both burned and non-burned transects. Vegetative cover was slow to recover. It took 19 months for cover of burned areas to equal or exceed cover of non-burned areas. Biomass also was slow to recover and it did not equal biomass of non-burned transects in 26 months. Species colonizing the burned transects were mostly species in nearby non-burned areas. Only one exotic species (Polypogon monspeliensis) appeared in the burned transects. The principal way that fire affected the tidal flats community was in the reduction of standing dead plants and surface litter.

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Fires naturally occurred in the Rio Grande Plains of southern Texas with a frequency of 5 to 30 years prior to European settlement (Wright & Bailey 1982), and fires caused by humans or lightning occur annually on North Padre Island (Drawe & Kattner 1978). Drawe & Kattner (1978) investigated the effects of prescribed burns in February and September in the midgrass prairie of the Padre Island National Seashore (PINS). Their report represents the only information available on the effects of fire on Padre Island vegetation. Drawe & Kattner (1978) concentrated on the effect of fire on litter and green plant biomass in the secondary dunes and vegetated flats topographic zone. They list the number of species present before and after the fires in the secondary dunes and vegetated flats zone, but they do not identify the species involved. They enumerate species that recovered soon after the fires, but they do not present data on the recovery of halophytic vegetation following fire on the margins of tidal flats of the barrier island.

Secondary succession following fire in the halophytic vegetation on the margins of tidal flats on Texas barrier islands has not been described. Consequently, a wild fire that occurred 22 December 1999 at PINS, Kleberg County, Texas, provided an opportunity to fill this gap in our knowledge. This study documents the recovery of halophytic vegetation following fire on the margins of tidal flats at PINS over a 26 month period. Species richness, diversity, importance and biomass are compared between burned and nearby non-burned areas.

MATERIALS AND METHODS

Study area.--Weise & White (1980) refer to the barren flats on the periphery of the Laguna Madre that are subject to wind-blown tides as wind-tidal flats. Tidal flats replace salt marshes along the semi-arid coastal zone of southern Texas where freshwater inflow is curtailed (White et al. 1983; Withers 2002). This unique topographic feature occupies over 900 k[m.sup.2] of surface area (Brown et al. 1976; Tunnell 2002). Wind-tidal flats are typically less than 0.9 m above mean sea level and are often flooded by the hypersaline waters of the Laguna Madre following high spring tides or heavy rainfall. However, flooding from high tides has been curtailed at sites examined during this study due to the construction of an elevated gravel road that parallels the Laguna Madre. Dunes do not form because the sites are depauperate of vegetation in loose sand. Vascular plants are usually absent from this topographic zone, but mats of cyanobacteria (Lyngbya confervoides = Microcoleus lyngbyaceus) are conspicuous on the wind-swept flats (Pulich & Rabalais 1986; Withers 2002). Salt tolerant species occur only in a narrow belt on the margins of the tidal flats adjacent to the vegetated flats (Judd 2002).

Long-term precipitation at Corpus Christi adjacent to PINS shows a peak of rainfall that occurs in September (NOAA 2002). Almost two-thirds (65%) of the rainfall occurs in the six month period from May through October, and 36% of the annual rainfall occurs from August through October. This pattern corresponds closely to the "rainy season" that prevails in the tropical region of eastern and central Mexico (Davis 1942).

Mean monthly temperature is lowest in January and reaches a peak in August (NOAA 2002). Mean monthly temperature is above 22.5[degrees]C from April through October (7 months), and winters are short and mild.

Fire.--A fire of undetermined origin burned 890.4 ha of barrier island midgrass prairie at the northern end of PINS on 22 December 1999. The fire spread westward from the primary dunes facing the Gulf of Mexico to the wind-tidal flats adjacent to the Laguna Madre leaving an irregular patchwork of burned and non-burned areas.

Census methods.--Two 30 m transects were established in burned and non-burned tidal flat margins. Study sites were located 50 m east and 75 m north of the terminus of Bird Island Basin road adjacent to the shoreline of the Laguna Madre. Transects were oriented east to west and marked with stakes at 10 m intervals.

The line intercept technique was used to sample vegetation (Canfield 1941). Transects were divided into 10 m intervals and data were recorded along the length of each interval. Each species intercepted by the line was rated individually and recorded without separation into strata. Foliar cover and frequency of occurrence were recorded. From these data, relative cover, relative frequency and importance value (IV) were calculated. The IV is the sum of the relative frequency and relative cover and was used to determine dominant species.

Initial sampling of vegetation in the burned and non-burned sites was conducted 5 March 2000, 73 days after the fire was extinguished. The burned transects were sampled monthly (8 April, 17 May, 15 June, 31 July and 18 to 19 August 2000) for five months. Sampling was conducted bimonthly after August 2000 (21 October, 15 December and 25 February 2001 and then quarterly in 2001-2002 (13 April, 27 July, 4 November and 2 February 2002). The non-burned transects were censused 5 March 2000, 18 to 19 August 2000, 25 February 2001, 27 July 2001 and 2 to 3 February 2002.

Biomass.--Biomass samples were obtained 25 February 2001, 4 August 2001 and 22 February 2002 for each of the burned and non-burned sites by clipping 10, 0.25-[m.sup.2] quadrats. Standing dead and green plant material was clipped at ground level and loose dead material on the surface was removed with the sample. Samples were sorted in the laboratory into dead (litter) and live material, dried at 42.5[degrees]C for 13 days in a herbarium convection dryer, and weighed on an electronic balance to the nearest 0.1 g.

Comparisons between burned and non-burned sites.--Similarity of floristic composition between the burned and non-burned sites was calculated using Sorensen's Coefficient of Community (Krebs 1999). Species importance value was used as the measure of abundance for calculating species diversity indices. Species diversity was assessed using the Shannon diversity index (Brower et al. 1998; Krebs 1999). Evenness was determined as the ratio of heterogeneity (H') to maximum heterogeneity (H' max) (Brower et al. 1998; Krebs 1999). Means for biomass, species richness, species diversity, and evenness were compared between burned and non-burned sites using Student's t-tests (Sokal & Rohlf 1981). Nomenclature follows Jones et al. (1997), Hatch et al. (1999), and Negrete et al. (1999).

RESULTS

Species richness, species diversity and evenness.--Species richness was similar in the burned and non-burned transects in the first census (March 2000), 73 days after the fire (Table 1). Four species were common to the burned and non-burned transects. The coefficient of community was 61.5%. Culms of the rhizomatous S. virginicus and stoloniferous M. littoralis were in early stages of emergence from the ashes.

In April 2000, 108 days after the fire, species richness of the burned transects (10 species) exceeded mean species richness of the non-burned transects (Table 1). Stunted culms of S. virginicus and M. littoralis were partially covered by sand in the burned areas. Species common to both burned and non-burned transects included S. virginicus and M. littoralis, Suaeda linearis (Chenopodiaceae) and Borrichia frutescens (Asteraceae). With the exception of B. frutescens, all species were in vegetative condition. Species richness of the burned transects declined in the subsequent censuses in 2000 to a low of five species in December 2000.

Twelve species were recorded in the burned transects and 13 species were present in the non-burned transects

in February 2001, 431 days after the fire (Table 1). The floristic composition of the burned and unburned transects was similar (Coefficient of Community = 72%). Nine species were common to both sites. There were more species in the burned transects due to the emergence of several ephemeral annuals, e.g., Coreopsis tinctoria (Asteraceae), Spergularia marina (Caryophyllaceae) and unidentified dicot and grass seedlings. Apparently, the dominant species had not yet reached densities that would exclude some of the rare to infrequent species.

In April 2001, 477 days after the fire, 11 species were present in the burned transects. Cool season annuals, e.g., C. tinctoria, Plantago hookeriana (Plantaginaceae) and the only exotic species encountered in the study, Polypogon monspeliensis (Poaceae) occurred on the burned transects and the largely barren wind-tidal flats.

In July 2001, 582 days after the fire, seven species were present in the burned transects and 11 species were recorded in the non-burned transects. Six of the species in the burned transects also occurred on the non-burned transects (Coefficient of Community = 67.7%). Species richness increased to 12 species on the burned transects in November 2001, 682 days after the fire. A portion of the increase was due to the appearance of Sesuvium portulacastrum (Aizoaceae), Sesuvium sp. and Sporobolus coromandelianus (Poaceae) for the first time after the fire. Species richness in the burned transects exceeded species richness in the non-burned transects in the final census in February 2002, 772 days after the fire (Table 1). Floristic composition was relatively similar (Coefficient of Community = 63.6%).

Species diversity and evenness showed patterns of variation similar to that for species richness (Table 1). There was no significant difference in mean species richness ($t = 0.659$, 16 df, $P > 0.5$), mean species diversity ($t = 0.905$, 16 df, $P > 0.3$), or mean evenness ($t = 0.881$, 16 df, $P > 0.3$) between the burned and non-burned transects.

Cover and biomass.--Foliar cover of living plants was 10.7% in the burned transects in the initial census 73 days after the fire (Table 2). The first three species in importance comprised 93.1% of the relative cover. Total cover in the non-burned transects was 84.9% of the surface area in the first census (Table 2). The top three species in importance made up 97.2% of the relative cover.

The cover of living plants increased incrementally on the burned transects from March to July 2000 and reached 33.8% in July 2000 (Table 2). A small quantity of litter (0.25%) was noted for the first time after the fire in July 2000. The litter was derived from annuals that had completed their life cycles in spring. Cover on the burned transects varied slightly from 30 to 36% in August, October and December 2000, then increased markedly to 46% in February 2001 (Table 2). At this time, cover of live plants on the non-burned transects was 78.2% (Table 2). The increase in cover on the burned transects occurred in January 2001 when temperature and rainfall were near the long-term means for these parameters (NOAA 2002).

Cover of live plants remained at 45% on the burned transects in April 2001 (Table 2). No litter was detected. Cover of live plants increased to 56.0% on the burned transects in July 2001. At the same time, live plant cover on the non-burned transects was 49.8% (Table 2). Thus, 582 days after the fire live plant cover on the burned transects exceeded live plant cover on the non-burned transects. Litter cover, however, was markedly greater on the non-burned transects (46.58%) than on the burned transects (0.45%).

Total biomass on the burned transects in February 2001 was about one-third of that of the non-burned transects (Table 3). However, the most striking difference was in litter biomass. Litter biomass on the burned transects was only 13.4% of the litter biomass on the non-burned transects. In August 2001, biomass (live, litter and total) was greater on the non-burned transects than on the burned transects (Table 3). Most of the biomass in both the burned and non-burned transects was in live plants, but in February 2002 the relationship was reversed in both the burned and non-burned transects, most of the biomass was in litter (Table 3). Litter biomass on the burned transects increased rapidly during the year and at the end of the study in February 2002 it was 85.2% of that of the non-burned transects.

Species importance.--Sporobolus virginicus was the dominant species in each of the 13 censuses conducted of the burned transects (Table 2), and it was the dominant species in four of the five cenuses of the non-burned transects (Table 2). Monanthochloe littoralis was the dominant species in the July 2001 census of the non-burned transects.

Suaeda linearis ranked second in importance in the burned transects from March 2000 through February 2001. It

was replaced as second in importance in April 2001 by M. littoralis. Subsequently, M. littoralis was the second most important species in November 2001 and the final census in February 2002 (Table 2).

Monanthochloe littoralis was the second most important species in the non-burned transects from March 2000 through February 2001 (Table 2). It was first in importance in July 2001. In the final census (February 2001) it ranked third in importance but it was numerically close to the species (C. tinctoria an ephemeral annual) that ranked second.

DISCUSSION

The vegetation of Padre Island is primarily herbaceous and is typically zoned in relation to topographic features (Judd et al. 1977; Carls et al. 1990). The spatial impact of the wild fire at PINS was extensive. The fire spread over all topographic facets except the sparsely vegetated foredunes adjacent to the Gulf of Mexico. The blaze was halted on the margins of the tidal flats where moisture levels were high or where the vegetation was too sparse to sustain the fire.

Species richness and species diversity were restored within three and a half months on transects in the burned tidal flats. Vegetative cover, however, took 19 months to equal (or exceed) that of unburned transects. Likewise, biomass (live and litter) was slow to recover and it never equaled biomass on the non-burned transects in the 26 months of this study.

Fire has been a regular component in the evolutionary history of Padre Island (Drawe & Kattner 1978). Thus, it is not surprising that the Padre Island tidal flats community is resilient to fire. Drawe & Kattner (1978) studied the effects of prescribed fires in September and February in the secondary dune and vegetated flats topographic zone on Padre Island, but they did not examine vegetation of the tidal flats. However, they report that there were no differences in plant species after burns. Drawe & Kattner (1978) do not state how long it took for burned areas to return to pre-burn condition, but they report that burning in February depressed grass and forb production the first growing season after treatment. They do not present data for the second growing season.

Drawe & Kattner (1978) report that burning effectively removes litter on Padre Island. This was certainly true for the tidal flats and in two years litter on burned transects still had not completely recovered (i.e., litter biomass on burned transects was 85.2% of the litter biomass of non-burned transects). Drawe & Kattner (1978) recommended burning litter during winter or late summer to increase total production, to increase plant vigor and to suppress detrimental accumulations of litter. These factors were not examined in this study, but burning did not increase species richness, species diversity or evenness. Similarly, species importance (community structure) was relatively unaffected by the burn, but it took 16 months to be fully restored. Sporobolus virginicus was the dominant species in the tidal flats throughout the study on both burned and non-burned transects. The principal way in which fire affected the tidal flats community was in the reduction of litter. However, it appears likely that litter biomass may be restored in three years.

Table 1. Comparison of species richness, species diversity and evenness between burned and non-burned transects on the margins of tidal flats at Padre Island National Seashore.

Census	Burned			Unburned		
	Number of Species	Evenness		Number of Species	Evenness	
	Species	Divers.		Species	Divers.	
Mar 2000	6	.778	.752	7	.845	.797
Apr 2000	10	1.000	.689			
May 2000	9	.954	.732			
Jun 2000	8	.903	.755			
Jul 2000	7	.845	.720			
Aug 2000	6	.778	.743	9	.954	.778
Oct 2000	6	.778	.740			
Dec 2000	5	.699	.771			
Feb 2001	12	1.079	.786	13	1.114	.813
Apr 2001	11	1.041	.785			
Jul 2001	7	.845	.786	11	1.041	.818
Nov 2001	12	1.079	.806			
Feb 2002	13	1.114	.741	9	.954	.859

Table 2. Comparison of the relative importance of species occurring on the burned and non-burned tidal flats. F = frequency, Rf = relative frequency, C = cover (%), Rc = relative cover, Iv = importance value (sum of Rf and Rc), and R = rank.

Mar. 2000
Burned

Species	F	Rf	C	Rc	Iv	R
Sporobolus virginicus	83.3	33.3	8.17	76.1	109.4	1
Suaeda linearis	50.0	20.0	1.40	13.0	33.0	2
Salicornia bigelovii	50.0	20.0	0.43	4.0	24.0	3
Monanthochloe littoralis	33.3	13.3	0.58	5.4	18.7	4
Borrichia frutescens	16.7	6.7	0.08	0.8	7.5	5
Iva texensis	16.7	6.7	0.07	0.6	7.3	6
Blutaparon vermiculare						
Sesuvium portulacastrum						
Coreopsis tinctoria						
Salicornia virginica						
Limonium carolinianum						
Machaeranthera phyllocephala						
Dicot:seedlings						
Spergularia marina						
Poaceae:seedlings						
Sesuvium sp.						
Spartina patens						
Polypogon monspeliensis						
Plantago hookeriana						
Atriplex pentandra						
Batis maritima						
Sporobolus coromandelianus						
Total live plant cover 10.73						
Total litter cover						

Apr. 2000
Burned

Species	F	Rf	C	Rc	Iv	R
Sporobolus virginicus	33.3	26.3	20.83	85.0	113.3	1
Suaeda linearis	50.0	15.8	2.00	8.2	23.5	2
Salicornia bigelovii	50.0	15.8	0.18	0.7	16.5	3
Monanthochloe littoralis	16.7	5.3	0.27	1.1	6.4	6
Borrichia frutescens	16.7	5.3	0.20	0.8	6.1	7
Iva texensis	16.7	5.3	0.50	2.0	7.3	5
Blutaparon vermiculare						
Sesuvium portulacastrum						
Coreopsis tinctoria						
Salicornia virginica	33.3	10.5	0.40	1.6	12.1	4
Limonium carolinianum	16.7	5.3	0.05	0.2	5.5	8
Machaeranthera phyllocephala	16.7	5.3	0.05	0.2	5.5	9
Dicot:seedlings	16.7	5.3	0.03	0.1	5.4	10
Spergularia marina						
Poaceae:seedlings						
Sesuvium sp.						
Spartina patens						
Polypogon monspeliensis						
Plantago hookeriana						
Atriplex pentandra						
Batis maritima						
Sporobolus coromandelianus						
Total live plant cover 24.51						
Total litter cover						

May 2000
Burned

Species	F	Rf	C	Rc	Iv	R
Sporobolus virginicus	100.0	30.0	21.00	76.1	106.1	1

Suaeda linearis 50.0 15.0 1.95 7.1 22.1 2
Salicornia bigelovii 33.3 10.0 0.12 0.4 10.4 6
Monanthochloe littoralis 33.3 10.0 3.00 10.9 20.9 3
Borrichia frutescens 16.7 5.0 0.30 1.1 6.1 8
Iva texensis 16.7 5.0 0.43 1.6 6.6 7
Blutaparon vermiculare
Sesuvium portulacastrum
Coreopsis tinctoria
Salicornia virginica 33.3 10.0 0.38 1.4 11.4 4
Limonium carolinianum 33.3 10.0 0.37 1.3 11.3 5
Machaeranthera phyllocephala 16.7 5.0 0.05 0.2 5.2 9
Dicot:seedlings
Spergularia marina
Poaceae:seedlings
Sesuvium sp.
Spartina patens
Polypogon monspeliensis
Plantago hookeriana
Atriplex pentandra
Batis maritima
Sporobolus coromandelianus
Total live plant cover 27.60
Total litter cover

June 2000
Burned

Species F Rf C Rc Iv R

Sporobolus virginicus 100.0 27.3 23.30 71.2 98.5 1
Suaeda linearis 83.3 22.7 4.83 14.8 37.5 2
Salicornia bigelovii 50.0 13.6 0.20 0.6 19.7 4
Monanthochloe littoralis 33.3 9.1 2.95 9.0 18.1 3
Borrichia frutescens
Iva texensis 16.7 4.5 0.58 1.8 6.3 6
Blutaparon vermiculare
Sesuvium portulacastrum
Coreopsis tinctoria
Salicornia virginica 33.3 9.1 0.30 0.9 10.0 5
Limonium carolinianum
Machaeranthera phyllocephala 16.7 4.5 0.30 0.1 4.6 7
Dicot:seedlings
Spergularia marina
Poaceae:seedlings
Sesuvium sp.
Spartina patens
Polypogon monspeliensis
Plantago hookeriana
Atriplex pentandra
Batis maritima
Sporobolus coromandelianus
Total live plant cover 32.71
Total litter cover

Jul. 2000
Burned

Species F Rf C Rc Iv R

Sporobolus virginicus 100.0 31.6 25.90 76.5 108.1 1
Suaeda linearis 83.3 26.3 4.37 12.9 39.2 2
Salicornia bigelovii 33.3 10.5 0.07 0.2 10.7 5
Monanthochloe littoralis 33.3 10.5 2.53 7.5 17.5 3
Borrichia frutescens 16.7 5.3 0.12 0.3 5.6 7
Iva texensis 16.7 5.3 0.22 0.6 5.9 6
Blutaparon vermiculare
Sesuvium portulacastrum
Coreopsis tinctoria
Salicornia virginica 33.3 10.5 0.67 2.0 12.5 4
Limonium carolinianum
Machaeranthera phyllocephala

Dicot:seedlings
Spergularia marina
Poaceae:seedlings
Sesuvium sp.
Spartina patens
Polypogon monspeliensis
Plantago hookeriana
Atriplex pentandra
Batis maritima
Sporobolus coromandelianus
Total live plant cover 33.88
Total litter cover 0.25

Aug. 2000
Burned

Species F Rf C Rc Iv R

Sporobolus virginicus 100.0 35.3 22.58 73.2 108.5 1
Suaeda linearis 66.7 23.5 3.42 11.1 34.6 2
Salicornia bigelovii
Monanthochloe littoralis 50.0 17.6 3.67 11.9 29.5 3
Borrichia frutescens 16.7 5.9 0.12 0.4 6.3 6
Iva texensis 16.7 5.9 0.33 1.1 7.0 5
Blutaparon vermiculare
Sesuvium portulacastrum
Coreopsis tinctoria
Salicornia virginica 33.3 11.8 0.73 2.4 14.2 4
Limonium carolinianum
Machaeranthera phyllocephala
Dicot:seedlings
Spergularia marina
Poaceae:seedlings
Sesuvium sp.
Spartina patens
Polypogon monspeliensis
Plantago hookeriana
Atriplex pentandra
Batis maritima
Sporobolus coromandelianus
Total live plant cover 30.85
Total litter cover

Oct. 2000
Burned

Species F Rf C Rc Iv R

Sporobolus virginicus 100.0 33.3 22.38 75.7 109.0 1
Suaeda linearis 83.3 27.8 2.45 8.3 36.1 2
Salicornia bigelovii 50.0 16.7 0.78 2.6 19.3 4
Monanthochloe littoralis 33.3 11.1 3.80 12.9 24.0 3
Borrichia frutescens 16.7 5.6 0.05 0.2 5.8 6
Iva texensis 16.7 5.6 0.10 0.3 5.9 5
Blutaparon vermiculare
Sesuvium portulacastrum
Coreopsis tinctoria
Salicornia virginica
Limonium carolinianum
Machaeranthera phyllocephala
Dicot:seedlings
Spergularia marina
Poaceae:seedlings
Sesuvium sp.
Spartina patens
Polypogon monspeliensis
Plantago hookeriana
Atriplex pentandra
Batis maritima
Sporobolus coromandelianus
Total live plant cover 29.56

Total litter cover

Dec. 2000
Burned

Species F Rf C Rc Iv R

Sporobolus virginicus 100.0 35.3 29.27 81.6 116.9 1
Suaeda linearis 66.7 23.5 0.87 2.4 25.9 2
Salicornia bigelovii
Monanthochloe littoralis 33.3 11.8 4.35 12.1 23.9 3
Borrichia frutescens 33.3 11.8 0.10 0.3 12.1 5
Iva texensis
Blutaparon vermiculare
Sesuvium portulacastrum
Coreopsis tinctoria
Salicornia virginica 50.0 17.6 1.28 3.6 21.2 4
Limonium carolinianum
Machaeranthera phyllocephala
Dicot:seedlings
Spergularia marina
Poaceae:seedlings
Sesuvium sp.
Spartina patens
Polypogon monspeliensis
Plantago hookeriana
Atriplex pentandra
Batis maritima
Sporobolus coromandelianus
Total live plant cover 35.87
Total litter cover 0.43

Feb. 2001
Burned

Species F Rf C Rc Iv R

Sporobolus virginicus 100.0 15.8 31.20 68.2 84.0 1
Suaeda linearis 83.3 13.2 4.27 9.3 22.5 2
Salicornia bigelovii 16.7 2.6 0.02 <0.1 2.6 11
Monanthochloe littoralis 33.3 5.3 6.45 14.1 19.4 3
Borrichia frutescens
Iva texensis
Blutaparon vermiculare
Sesuvium portulacastrum
Coreopsis tinctoria 100.0 15.8 1.32 2.9 18.7 4
Salicornia virginica 50.0 7.9 0.97 2.1 10.0 6
Limonium carolinianum 33.3 5.3 0.17 0.4 5.7 8
Machaeranthera phyllocephala 16.7 2.6 0.07 0.1 2.7 10
Dicot:seedlings 50.0 7.9 0.23 0.5 8.4 7
Spergularia marina 83.3 13.2 0.70 1.5 14.7 5
Poaceae:seedlings 33.3 5.3 0.08 0.2 5.5 9
Sesuvium sp.
Spartina patens
Polypogon monspeliensis
Plantago hookeriana
Atriplex pentandra
Batis maritima
Sporobolus coromandelianus
Total live plant cover 45.78
Total litter cover
Apr. 2001
Burned

Species F Rf C Rc Iv R

Sporobolus virginicus 100.0 17.6 30.35 67.9 85.5 1
Suaeda linearis 83.3 14.7 3.78 8.5 23.2 3
Salicornia bigelovii
Monanthochloe littoralis 66.7 11.8 7.35 16.5 28.3 2
Borrichia frutescens 33.3 5.9 0.32 0.7 6.6 7

Iva texensis 16.7 2.9 0.10 0.2 3.1 11
Blutaparon vermiculare
Sesuvium portulacastrum
Coreopsis tinctoria 66.7 11.8 0.77 1.7 13.5 4
Salicornia virginica 50.0 17.6 1.28 3.6 21.2 4
Limonium carolinianum 33.3 5.9 0.22 0.5 6.4 9
Machaeranthera phyllocephala 50.0 8.8 0.22 0.5 9.3 6
Dicot:seedlings
Spergularia marina
Poaceae:seedlings
Sesuvium sp.
Spartina patens
Polypogon monspeliensis 33.3 5.9 0.23 0.5 6.4 8
Plantago hookeriana 33.3 5.9 0.07 0.1 6.0 10
Atriplex pentandra
Batis maritima
Sporobolus coromandelianus
Total live plant cover 44.68
Total litter cover

Jul. 2001
Burned

Species F Rf C Rc Iv R

Sporobolus virginicus 100.0 26.1 35.47 63.4 89.5 1
Suaeda linearis 83.3 21.7 9.70 17.3 39.0 2
Salicornia bigelovii
Monanthochloe littoralis 66.7 17.4 8.72 15.6 33.0 3
Borrichia frutescens 16.7 4.3 0.12 0.1 4.4 6
Iva texensis
Blutaparon vermiculare
Sesuvium portulacastrum
Coreopsis tinctoria
Salicornia virginica 50.0 13.0 1.68 3.0 16.0 4
Limonium carolinianum 16.7 4.3 0.07 0.1 4.4 7
Machaerthera phyllocephala 50.0 13.0 0.20 0.4 13.4 5
Dicot: seedlings
Spergularia marina
Poaceae:seedlings
Sesuvium sp.
Spartina patens
Polypogon Monspeliensis
Plantago hookeriana
Atriplex pentandra
Batis maritima
Sporobolus coromandelianus
Total live plant cover 55.96
Total little cover 0.45

Nov. 2001
Burned

Species F Rf C Rc Iv R

Sporobolus virginicus 100.0 20.7 39.55 71.7 92.4 1
Suaeda linearis 83.3 17.2 1.33 2.4 19.6 3
Salicornia bigelovii
Monanthochloe littoralis 66.7 13.8 10.25 18.6 32.4 2
Borrichia frutescens 33.3 6.9 0.32 0.6 7.5 6
Iva texensis 16.7 3.4 0.15 0.1 3.5 9
Blutaparon vermiculare
Sesuvium portulacastrum 16.7 3.4 0.05 0.1 3.5 10
Coreopsis tinctoria 16.7 3.4 0.18 0.3 3.7 7
Salicornia virginica 50.0 10.3 1.87 3.4 13.7 4
Limonium carolinianum
Machaerthera phyllocephala 50.0 10.3 0.07 1.3 11.6 5
Dicot: seedlings
Spergularia marina
Poaceae:seedlings
Sesuvium sp. 16.7 3.4 0.17 0.3 3.7 8

Spartina patens
Polypogon Monspeliensis
Plantago hookeriana
Atriplex pentandra
Batis maritima
Sporobolus coromandelianus 16.7 3.4 0.02 <0.1 3.4 11
Total live plant cover 55.17
Total little cover 1.97

Feb. 2002
Burned

Species F Rf C Rc Iv R

Sporobolus virginicus 100.0 18.2 41.32 69.5 87.7 1
Suaeda linearis 66.7 12.1 0.85 1.4 13.5 4
Salicornia bigelovii
Monanthochloe littoralis 66.7 12.1 10.75 18.1 30.2 2
Borrichia frutescens 33.3 6.1 0.42 0.7 6.8 6
Iva texensis 16.7 3.0 0.35 0.6 3.6 9
Blutaparon vermiculare
Sesuvium portulacastrum 16.7 3.0 0.03 0.1 3.1 11
Coreopsis tinctoria 83.3 15.2 4.57 7.7 22.9 3
Salicornia virginica 50.0 9.1 0.63 1.1 11.0 5
Limonium carolinianum 33.3 6.1 0.18 0.3 6.4 8
Machaerthera phyllocephala 33.3 6.1 0.20 0.3 6.4 7
Dicot: seedlings 16.7 3.0 0.03 0.1 3.1 12
Spergularia marina 16.7 3.0 0.03 0.1 3.1 13
Poaceae:seedlings
Sesuvium sp. 16.7 3.0 0.12 0.2 3.2 10
Spartina patens
Polypogon Monspeliensis
Plantago hookeriana
Atriplex pentandra
Batis maritima
Sporobolus coromandelianus
Total live plant cover 59.48
Total little cover 1.52

Mar. 2000
Non-burned

Species F Rf C Rc Iv R

Sporobolus virginicus 83.3 27.8 52.62 62.0 89.8 1
Suaeda linearis 33.3 11.1 1.50 1.8 12.9 4
Salicornia bigelovii
Monanthochloe littoralis 50.0 16.7 24.90 29.3 46.0 2
Borrichia frutescens 33.3 11.1 0.17 0.2 11.3 6
Iva texensis
Blutaparon vermiculare 50.0 16.7 5.02 5.9 22.6 3
Sesuvium portulacastrum 33.3 11.1 0.52 0.6 11.7 5
Coreopsis tinctoria 16.7 5.6 0.17 0.2 5.8 7
Salicornia virginica
Limonium carolinianum
Machaerthera phyllocephala
Dicot: seedlings
Spergularia marina
Poaceae:seedlings
Sesuvium sp.
Spartina patens
Polypogon Monspeliensis
Plantago hookeriana
Atriplex pentandra
Batis maritima
Sporobolus coromandelianus
Total live plant cover 84.90
Total little cover

Aug. 2000
Non-burned

Species F Rf C Rc Iv R

Sporobolus virginicus 83.3 22.7 48.33 60.1 82.8 1
Suaeda linearis 50.0 13.6 2.23 2.8 16.4 4
Salicornia bigelovii
Monanthochloe littoralis 50.0 13.6 24.38 30.3 43.9 2
Borrichia frutescens 16.7 4.5 0.15 0.2 4.7 7
Iva texensis
Blutaparon vermiculare 66.7 18.2 4.07 5.1 23.3 3
Sesuvium portulacastrum 33.3 9.1 0.80 1.0 10.1 5
Coreopsis tinctoria
Salicornia virginica
Limonium carolinianum
Machaerthera phyllocephala 16.7 4.5 0.03 <0.1 4.5 9
Dicot: seedlings
Spergularia marina
Poaceae:seedlings
Sesuvium sp. 33.3 9.1 0.23 0.3 9.4 6
Spartina patens
Polypogon Monspeliensis
Plantago hookeriana
Atriplex pentandra
Batis maritima
Sporobolus coromandelianus 16.7 4.5 0.15 0.2 4.7 8
Total live plant cover 80.37
Total little cover

Feb. 2001 Non-burned

Species F Rf C Rc Iv R

Sporobolus virginicus 100.0 15.8 36.63 46.8 62.6 1
Suaeda linearis 83.3 13.2 1.13 1.4 14.6 5
Salicornia bigelovii
Monanthochloe littoralis 50.0 7.9 27.12 34.7 42.6 2
Borrichia frutescens 50.0 7.9 0.35 0.4 8.3 7
Iva texensis
Blutaparon vermiculare 66.7 10.5 3.28 4.2 14.7 4
Sesuvium portulacastrum 33.3 5.3 0.98 1.3 6.6 8
Coreopsis tinctoria 83.3 13.2 6.38 8.2 21.4 3
Salicornia virginica 33.3 5.3 0.38 0.5 5.8 10
Limonium carolinianum
Machaeranthera phyllocephala 50.0 7.9 1.05 1.3 9.2 6
Dicot:seedlings
Spergularia marina 16.7 2.6 0.03 <0.1 2.6 12
Poaceae:seedlings 16.7 2.6 0.07 0.1 2.7 11
Sesuvium sp. 33.3 5.3 0.77 1.0 6.3 9
Spartina patens 16.7 2.6 0.02 <0.1 2.6 13
Polypogon monspeliensis
Plantago hookeriana
Atriplex pentandra
Batis maritima
Sporobolus coromandelianus
Total live plant cover 78.19
Total litter cover 7.41

Jul. 2001 Non-burned

Species F Rf C Rc Iv R

Sporobolus virginicus 83.3 17.2 16.77 33.7 50.9 2
Suaeda linearis 66.7 13.8 1.57 3.1 16.9 3
Salicornia bigelovii
Monanthochloe littoralis 66.7 13.8 23.88 48.0 61.8 1
Borrichia frutescens 16.7 3.4 0.42 0.8 4.2 9
Iva texensis
Blutaparon vermiculare 33.3 6.9 0.58 1.2 8.1 8
Sesuvium portulacastrum 33.3 6.9 0.63 1.3 8.2 7
Coreopsis tinctoria
Salicornia virginica 66.7 13.8 1.55 3.1 16.9 4

Limonium carolinianum
Machaeranthera phyllocephala 50.0 10.3 3.20 6.4 16.7 5
Dicot:seedlings
Spergularia marina
Poaceae:seedlings
Sesuvium sp. 33.3 6.9 1.10 2.2 9.1 6
Spartina patens
Polypogon monspeliensis
Plantago hookeriana
Atriplex pentandra 16.7 3.4 0.07 0.1 3.5 10
Batis maritima 16.7 3.4 0.03 0.1 3.5 11
Sporobolus coromandelianus
Total live plant cover 49.80
Total litter cover 46.58

Feb. 2002 Non-burned

Species F Rf C Rc Iv R

Sporobolus virginicus 83.3 15.6 24.88 47.6 63.2 1
Suaeda linearis 16.7 3.1 0.15 0.3 3.4 9
Salicornia bigelovii
Monanthochloe littoralis 66.7 12.5 12.40 23.7 36.2 3
Borrichia frutescens 50.0 9.4 0.40 0.8 10.2 7
Iva texensis
Blutaparon vermiculare 66.7 12.5 1.65 3.2 15.7 4
Sesuvium portulacastrum
Coreopsis tinctoria 100.0 18.8 10.17 19.4 38.2 2
Salicornia virginica 50.0 9.4 1.43 2.7 12.1 5
Limonium carolinianum
Machaeranthera phyllocephala 50.0 9.4 0.63 1.2 10.6 6
Dicot:seedlings
Spergularia marina
Poaceae:seedlings
Sesuvium sp.
Spartina patens
Polypogon monspeliensis
Plantago hookeriana
Atriplex pentandra
Batis maritima
Sporobolus coromandelianus 50.0 9.4 0.25 0.3 9.9 8
Total live plant cover 52.31
Total litter cover 21.42

Table 3. Biomass estimates (g/0.25-[m.sup.2]) in burned and non-burned quadrats in the margins of the tidal flats of Padre Island National Seashore.

	Burned			Non-burned		
	Live	Litter	Total	Live	Litter	Total
Feb 2001	9.58	2.58	12.16	16.79	19.31	36.10
Aug 2001	67.00	15.92	82.94	108.78	42.72	151.50
Feb 2002	7.19	96.80	103.99	22.35	113.59	135.94

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