



Vegetation Monitoring at Padre Island National Seashore: Results for 2023

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Summary and Key Findings

- In the fall of 2023, the Gulf Coast Inventory and Monitoring (I&M) Network completed the second round of vegetation monitoring in long-term plots at Padre Island National Seashore. Although the park is best known for its 66-mile stretch of beach, teeming with wildlife and recreational opportunities, the bulk of the park lies behind the dunes in an immense coastal grassland. To monitor these grasslands, the I&M network distributed 32 400 m² plots over the interior landscape, with eight plots in each of four evenly-spaced panels between mile markers 0 and 40. These targeted panels were dominated by six different vegetation classes, which varied as a function of the island's elevational and hydrologic gradients.
- The total number of species recorded during the 2023 sample was 113, and there was only one non-native species, Bermudagrass, recorded in a small area within a single plot. The park's plant communities stand out for their near absence of non-native species and their relatively low species richness as compared to similar habitats on the mainland.
- The most abundant community type in the I&M sample was Coastal Grasslands with Pocket Wetlands, in 14 of 32 plots. This community type also had the two highest-richness plots in 2023, with 35-36 species each (class average = 22 species per plot). With almost half of the I&M plots featuring this community, it is clear that small, ephemeral wetlands are widespread throughout the park's grasslands, and they support distinct species within the dry grassland environment.
- Of the remaining 18 plots, there was an even split between plots in wetlands and plots in relatively dry uplands. For the nine upland plots, seven were in Coastal Grasslands and two were in Coastal Grasslands on Fore-Island Dunes. The Coastal Grassland class was dominated by seacoast bluestem (*Schizachyrium littorale*) and gulf dune paspalum (*Paspalum monostachyum*) and had low richness.
- For the nine wetland plots, four were in Umbrella Sedge Wetlands, four were in Swale Wetlands, and one was in Vegetated Salt Flats. Among these, Umbrella Sedge Wetlands had the highest average species richness, at 29 species per plot. This class represents a plant association only known to occur in coastal Texas, and it contains a rare species, the coastal plains umbrella sedge (*Fuirena longa*). All three wetland classes had fairly high cover of wetland obligate species in 2023, occupying 21-31% of sampled areas.
- When findings from 2023 were compared to those from 2019, there were notable differences in both richness and cover. For example, most plots had fewer species in 2023 than in 2019, averaging four fewer species per plot. Between-year differences were most likely linked to a minor drought in 2023. Similar non-permanent losses and gains were recorded during the park's vegetation community mapping project several years earlier.
- The recency of fire also differed between sample years, and this may have caused some differences in plant communities over time as well. In 2019, all plots had burned within the last two years, whereas in 2023, four or five years had passed since the last fire. Other studies have shown that plant species richness increases in the first few years after a fire, which is consistent with higher richness during the 2019 sampling event. Continued monitoring and future analyses of trends will help unravel the different drivers that shape the park plant communities. Understanding the park's baseline condition and the sources of both natural and problematic change is key to informed park management.

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ON THE COVER: Seacoast bluestem (*Schizachyrium littorale*) at Padre Island National Seashore. Photo by NPS /Jane E. Carlson

Project Background

Throughout the National Park Service, plant communities and other key natural resources are monitored as indicators of environmental health by a nationwide program of 32 Inventory and Monitoring (I&M) Networks. The [Gulf Coast I&M Network](#) covers eight National Park Service (NPS) units in the southeastern U.S. and Texas. The network's [terrestrial vegetation monitoring program](#) is carried out in all eight parks, with the goal of measuring the health and condition of key plant communities repeatedly over time. Specific objectives include documenting status and change in (1) richness of native and non-native species; (2) percent cover and frequency of key species, groups or growth forms (e.g., grasses or shrubs); and (3) the health and regeneration of forests. The network's vegetation monitoring program follows a [published protocol](#) (Carlson et al. 2018) that is largely consistent with other I&M networks in the eastern U.S.

The Gulf Coast I&M Network conducts vegetation monitoring fieldwork once every four years in each park. This article presents a project overview and key findings from the 2023 I&M vegetation monitoring event in [Padre Island National Seashore](#), Texas, which was the second round of sampling for the park (see [Carlson \[2020\]](#) for initial summary report). The report's five appendices (A-E) include the full species list as well as several supporting tables and figures. All current and past reports, as well as raw data exports, can be found through the online [project repository](#).

Study Area

Padre Island National Seashore is located along the Texas coast, on the longest barrier island in the U.S. The island is 180 km (113 miles) long and up to 5 km (3.1 miles) wide, and the National Seashore covers most of its land area north of Mansfield Pass. The park is perhaps best known for its 106 kilometer-long (66 mile) coastline, providing sandy beaches for recreation and critical habitat for shorebirds, sea turtles, marine fish, and many other wildlife species. But the bulk of the park lies behind the dunes, in an immense coastal grassland. Spanning over 13,000 hectares (32,124 acres) across flats, wet depressions, and secondary dunes, the park's grasslands stabilize the deep sands on which they grow and reduce the dynamism of

these landforms, relative to the highly active beach and dune systems. Although less often visited by the public, the island's interior is an essential component of the National Seashore, with its diverse habitats, vast sand storage, and its role in buffering the Texas coast from storms. Long-term monitoring of the interior grassland communities therefore provides a direct window into the island's ecological health, to inform management decisions that benefit the park, the public, and the coastline as a whole.

General Vegetation Features

The island's vegetated landscapes generally begin where the beach ends, over the rise of the dunes and into the gently undulating interior. Figure 1 shows a representative transect from dune ridge to western shore, crossing several different vegetation communities. These communities, introduced below in bold, are adapted from Diamond et al. (2017), which classified vegetation using the U.S. National Vegetation Classification (USNVC) system. The vegetated back side of the **fore-island dunes** support characteristic dune stabilizers like sea oats (*Uniola paniculata*) and bitter panicum (*Panicum amarum*) as well as the hardy dominants of the **coastal grassland**: seacoast bluestem (*Schizachyrium littorale*) and gulfdune paspalum (*Paspalum monostachyum*). Approaching the island's center, coastal grasslands occur in a matrix with freshwater and brackish wetlands ranging in size from small **pocket wetlands in coastal grassland** that are intermittently flooded, to larger **swale wetlands**, marshes or ponds that can hold water year-round. The park is widest at the northern end of the park, and this section supports the largest interior ponds as well as a unique **umbrella sedge wetland** community characterized by species of umbrella and beak sedges, in an association only known to occur in coastal Texas (Diamond et al. 2017). Further south, grasslands intermix with **vegetated salt flats** that regularly experience overwash and contain salt marsh elements. Collectively, these six broadly-defined communities encompass most of the park's grasslands and are targets of this long-term project (See Appendix A for detailed class descriptions).

Outside of the focal grasslands and marshes, most other plant communities are either sparsely vegetated or infrequent on the landscape. Approaching the hypersaline Laguna Madre to the west, the grasslands break up into occasional back-island dunes followed by increasingly

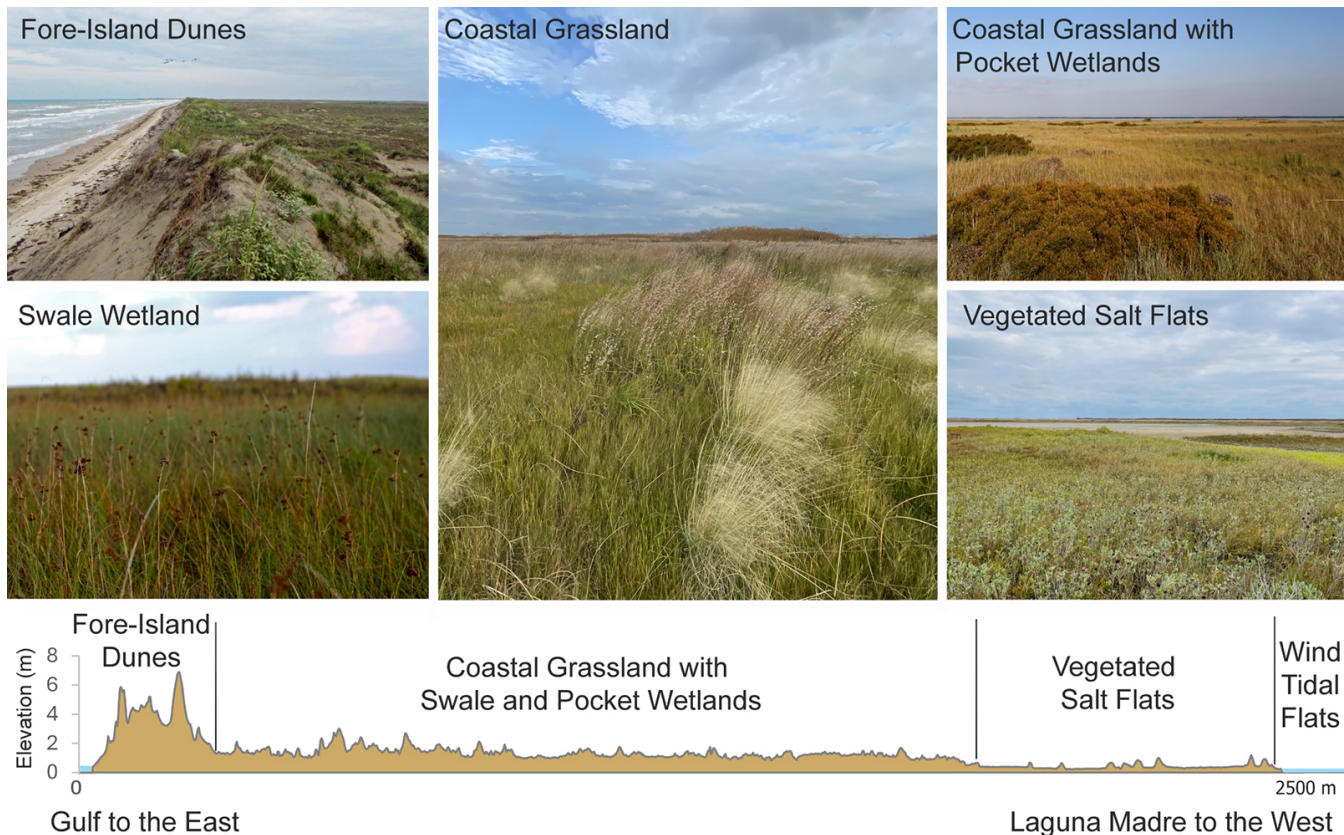


Figure 1. Dominant vegetation communities at Padre Island National Seashore and their approximate locations along a representative 2,500-meter long elevational profile from the east to the west shore. The elevation profile is from a location 2 km north of Yarbrough Pass, using data from a 2018 lidar-based digital elevation model. Photo credits NPS/Jane Carlson

barren salt flats that slope into the algal wind-tidal flats (Figure 1). There are also a few areas of natural shrubland and oak mottes on the island, mainly in the extreme north and extreme south of the park. Although these vegetation communities are not part of the current study, they have been described in the USNVC map and report produced by Diamond et al. (2017). Other descriptions and studies of the park's vegetation communities are in Drawe et al. (1981), Nelson et al. (2000), and Nelson et al. (2001).

Overall, the park's grassland and marsh communities are relatively species-poor, particularly in comparison to nearby grasslands on the mainland (Nelson et al. 2001). Even so, they have many fewer non-native plants, likely due to the park's sandy, harsh growing conditions. Over 500 plant species have been documented during botanical surveys on the island thus far (Negrete et al. 1999; Sassine 2014; Diamond et al. 2017), and less than 10% of species are non-native. Most non-natives are associated with human infrastructure in the park, with very minimal presence in the grassland interior.

Agents of Vegetation Change

Environmental conditions at Padre Island National Seashore are dynamic and can often be extreme. When plant communities are exposed to extreme events, they can change rapidly. Most native plants are adapted to the island's natural disturbances regimes of drought, storms, and fire, yet the recovery trajectory depends on the species and the intensity and rate of events. Unnatural disturbances, such as by non-native animals and livestock, have also shaped the island's plant communities. These included herds of cattle in the past, and more recently, feral hogs. Documenting the agents of vegetation change, both current and historical, provides essential context for long-term monitoring data. As described below, each type of disturbance impacts vegetation communities differently, and they also vary in spatial extent and frequency.

Hurricanes and tropical storms are major forces that shape plant communities on barrier islands, through landform change, flooding, and washover events. Vegetation on the beach and dunes can be swept away,

whereas saltwater overwash harms plants on the island's interior. Many species quickly regrow and recolonize, but in the short term, impacts can be catastrophic. The park's most damaging weather events in recent years have been Hurricane Harvey in 2017, Hurricane Hanna in 2020, and Tropical Storm Alberto in 2024. In general, major hurricanes are infrequent (~1 per decade) and patchy in their damage. The I&M Coastal Dynamics monitoring project explores how major weather events and other processes cause park landforms to change along the beach and foredune (e.g., Bracewell and Carlson 2024, Bracewell 2025), and these results complement vegetation monitoring data, with its focus on the island's interior.

Natural and human-ignited fires are frequent events at Padre Island National Seashore, both now and historically. Coastal Texas grasslands likely burned once every 1 to 5 years prior to European settlement in the late 1700s and early 1800s (Stambaugh et al. 2014). Fire frequency remained high through the 1940s, as farmers burned prairies to improve cattle forage and remove woody brush. Coastal grasslands benefit from fire in several ways. For example, Lonard et al. (2004) showed that up to two years after fire, burned areas within the grasslands at Padre Island National Seashore had higher live plant cover and

greater species richness than nearby unburned areas. Total biomass, including litter, remained lower in burned areas, leaving openings for new plants to colonize. Other studies showed increased abundance in certain plant species following fire, but that the responses often depended on the season when burned (Hansmire et al. 1988; Britton et al. 2010). Prescribed fire is currently used at Padre Island National Seashore as a habitat management and fuel reduction tool, and staff are actively developing a fire management plan that best accommodates the federally endangered black rail (Butler and Olsen 2025). Long-term monitoring data can support these efforts by demonstrating vegetation response to prescribed fire in relation to management objectives. Information on recent burn history at whole-park and plot-level scales is provided in Appendix B.

Vegetation disturbance by non-native animals has a long history on the island, first by cattle, and more recently by feral hogs. Cattle grazing began in the early 1800s and ended in 1971, shortly after NPS took ownership. By this time, the combination of overgrazing and several extreme droughts had turned large expanses of grassland into barren dune fields (Brezina 2005, KellerLynn 2010; Figure 2A,B; see Appendix B for plot-level assessments). Over the

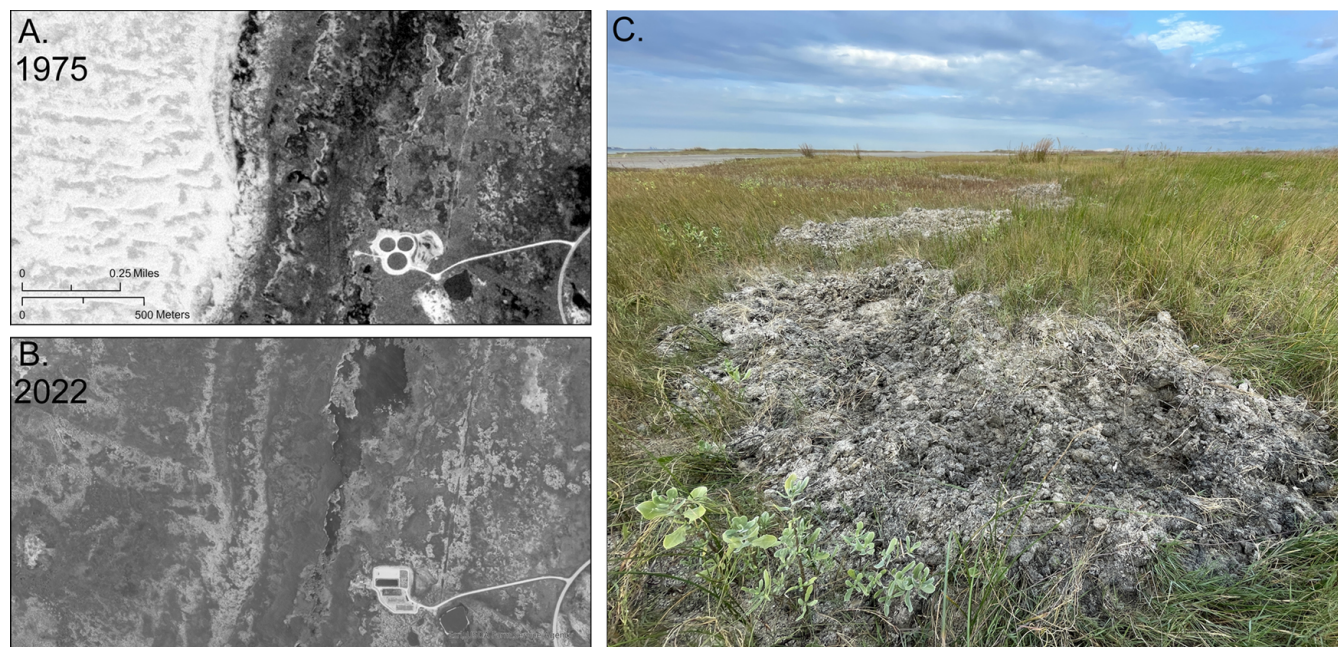


Figure 2. Evidence of past and current disturbance events at Padre Island National Seashore. (A) Aerial image from 1975 near current-day park headquarters, depicting one of the many barren, active dune fields that were present when the park was fully acquired in 1969. These barren areas were attributed to overgrazing combined with severe droughts. (B) Aerial image from 2022 in the same location. Over the 60 years since cattle were removed from the park, grasses and wildflowers have recolonized most barren areas. (C) soil disturbance by feral hogs near Bird Island Basin boat launch, recorded in fall 2024. Image credit: NPS/Jane Carlson

past 60+ years, those areas have largely returned to grassland, although a legacy of overgrazing may persist in terms of community composition (e.g., Nelson et al. 2000). Although cattle are no longer impacting park vegetation, feral hogs have recently become more common in the park, and they damage vegetation by uprooting plants and disturbing soil (Figure 2C). Nilgai antelope are also present in the park and can harm vegetation as well. Natural resource management staff are actively removing these non-native animals to reduce harm and prevent them from becoming more widely established in the park. As of this report's writing, hog damage has not yet been observed where monitoring occurs, but in the event that they expand on the island, vegetation monitoring data can help document their spread and impacts over time.

Given this wide range of stressors, fluctuations in the park's plant communities are inevitable. Some changes will reflect natural, cyclical processes, but others could indicate sustained declines. Distinguishing between these alternatives requires an in-depth understanding of park processes and vegetation change. In this first comprehensive summary of results, the goal is to provide an overview of the types of plant communities sampled and present their status in terms of composition, richness, and percent cover. Spatial patterns, environmental effects, and change between 2019 and 2023 are also examined informally, with more in-depth analyses planned after two more rounds of data collection.

Methods

Padre Island National Seashore has 32 permanently-marked vegetation plots that are sampled by the Gulf Coast I&M Network. Plot locations were selected as a random draw of eight plots within each of four 200-hectare panels. Panels were distributed at a fixed interval from north to south along the island and were also used for the network's Coastal Dynamics Monitoring Project. Within each panel, potential sampling locations included all terrestrial areas with the exceptions of active dunes, wind-tidal flats and permanently flooded ponds. The 32 plots were first visited during the summer of 2019 to install plot markers and conduct the first round of sampling (details in [Carlson 2020](#)). Crews returned in 18-22 September and 17-18 October 2023 to sample plots for the second time. Both sampling events followed the methods published by Carlson et al. (2018), in the protocol "[Monitoring Terrestrial Vegetation in Gulf Coast Network Parks](#)" and its [11 standard operating procedure documents](#). All plant species were identified in each 400-meter² (20 x 20 meter) plot, and their coverages and relative frequencies were recorded in nested sampling frames (e.g., Figure 3).

Key Findings

Vegetation Communities Sampled

The majority of I&M plots at Padre Island NS were classified as Coastal Grassland with Pocket Wetlands, at

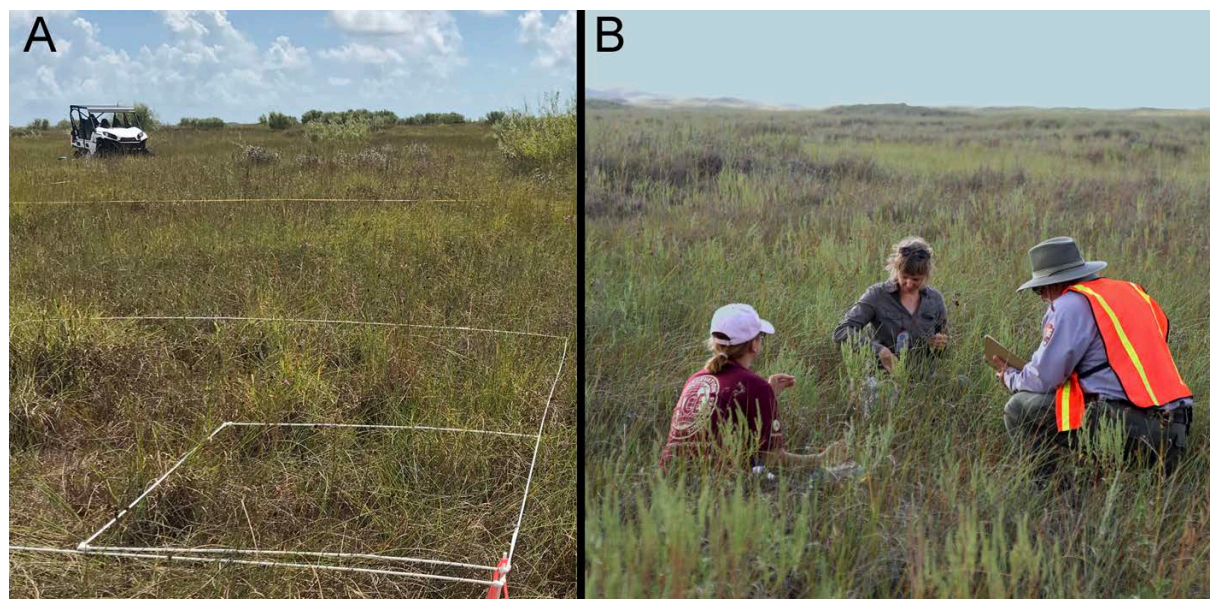


Figure 3. Vegetation plot sampling at Padre Island National Seashore. (A) Sampling frames consisting of a 1m² quadrat nested within a 10m² microplot placed in the corner of the 400m² plot. (B) Crew members identifying plants in a plot. Photo credits NPS/Jeff Bracewell.

14 of 32 plots (Figure 4). All four panels had at least two plots in this class, highlighting the prevalence of small, ephemeral wetlands as a regular component of the park's grasslands. The second most frequent class was Coastal Grassland, which generally had drier soils and few to no pocket wetlands. These drier sites were typically at higher

elevations, and in fact, five of the seven Coastal Grassland plots were in the highest elevation panel of the sample, panel 18. The mean elevation in panel 18 was 2.6 meters, whereas the remaining three panels were between 1.7 and 1.9 m. Elevations also tended to be high for the two plots in the Coastal Grassland on Fore-Island Dunes class. These

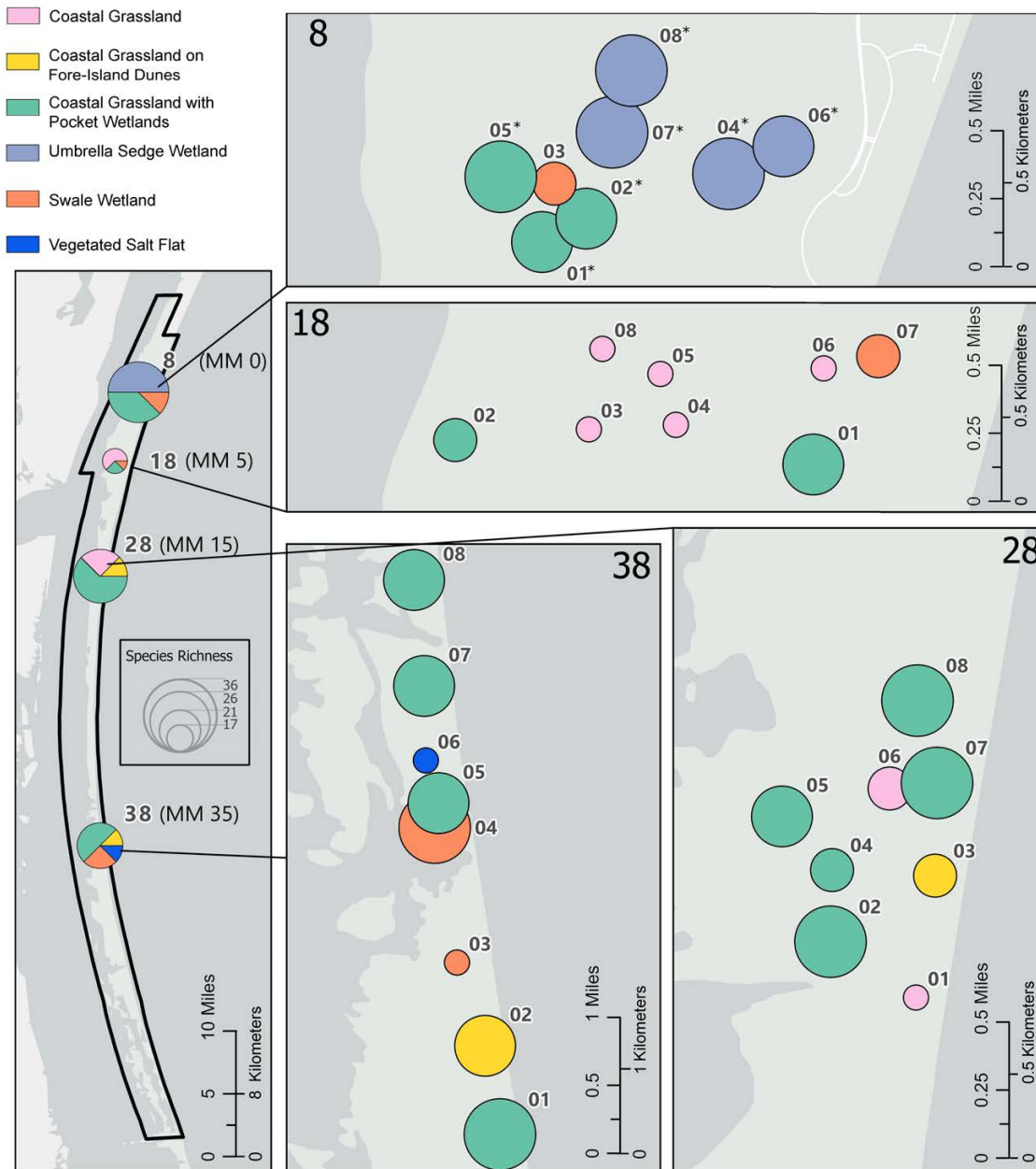


Figure 4. Monitoring plots at Padre Island National Seashore, with the map on the left showing the full park extent with the locations of the four target panels (named 8, 18, 28 and 38), and the inset boxes showing plot locations within each panel. Plot locations are labeled and marked with circles scaled by species richness and colored to indicate their broad vegetation class. Asterisks indicate the presence of species characteristic of the Umbrella Sedge Wetland class, even if in trace amounts. Plots were assigned to a given class if characteristic species occurred in more than half the plot; see Appendices A-B for more information. The full park extent map shows the relative proportion of each broad vegetation class per panel, scaled to show mean richness per plot. The nearest Mile Marker (MM) to each panel is included in parentheses.

mixed communities were distinguished by their proximity to the dune ridge and the presence of sea oats (*Uniola paniculata*) along with the usual Coastal Grassland species.

At the wetter end of the spectrum for I&M plots, there were four plots in each of the Swale Wetland and Umbrella Sedge Wetland classes. The Umbrella Sedge Wetland class aligned with a single USNVC association that was first documented in the park in 2016, as part of the vegetation community mapping process (Diamond et al. 2017). Umbrella Sedge Wetland plots were restricted to the northernmost panel, where characteristic members could be found either in larger patches or as minor elements within pocket small wetlands (Figure 4). The northern sections of the park also feature a soil type –Novillo– that underlies the large interior ponds and swale wetlands that cross through panel 8 and areas to the north. Novillo soils have an organic surface horizon above the deep sands, whereas most other soil types in the park lack an organic horizon (Haile and Brezina 2012).

The Swale Wetland class was no more frequent in the sample than Umbrella Sedge Wetland, yet Swale Wetland plots were much more widely distributed, found in three of the four target panels (Figure 4). In the vegetation community map by Diamond et al. (2017), the closest equivalent to Swale Wetland was the Brackish/Fresh Herbaceous Wetland map class, which encompassed two main USNVC associations: one dominated by marshhay cordgrass (*Spartina patens*) and another dominated by common threesquare (*Schoenoplectus pungens*). Although the Swale Wetland class contained the most frequently-inundated plots within the I&M sample, there were deeper waterbodies in the island’s interior, as well as large expanses of tidal flats on the western shore. These wet areas were excluded from the I&M sampling frame for logistical reasons.

There was just one I&M plot classified as Vegetated Salt Flats, and it had the sparsest plant cover and the most salt-tolerant species of all sampled plots. It belonged to a vegetation class more typically associated with tidally-influenced flats along the Laguna Madre. In the narrower, southern portions of the island, however, Vegetated Salt Flats were more common throughout the island (Diamond et al. 2017). Salt-tolerant succulents, sea lavender (*Limonium carolinianum*), and shoregrass (*Monathochloe*

littoralis) were characteristic species of this community type.

Park-Wide Richness Summaries and Notable Species

Across all 32 plots sampled in 2023, I&M staff recorded 113 plant taxa (See Appendix C for full species list). Of the total, 24 were classified as wetland obligates on the National Wetland Plant List for the Gulf Coastal Plain (U.S. Army Corps of Engineers 2022). The two dominant growth forms were graminoids –a group containing all grasses, sedges and rushes– and forbs, which are often referred to as wildflowers. These two groups encompassed 42% and 52% of species, respectively. Among the remaining six species there were two vines, two trees or shrubs, and two cacti. Ninety-seven percent of the total species list could be identified to species level, leaving three taxa as unknown or genus only, due to a lack of distinguishing features and non-reproductive plants.

The 2023 sample added one new species to the park species list: the coastal plain umbrella sedge (*Fuirena longa*). This species was not on the Negrete et al. (1999) plant inventory of 456 species, nor had it been seen during other vegetation surveys in the park, including the 2019 I&M event. This species has a very limited range in Texas, found in only a few coastal counties, but is also known from wet flatwoods or wetlands in coastal Mississippi, Alabama, Florida and Georgia. Although this species is among five others in the park listed as Vulnerable by NatureServe (2025; Appendix C), none of the park’s plant species are classified as threatened or endangered on state or federal lists.

The two most frequently-recorded species in the I&M sample were the well-known codominants of the park’s Coastal Grasslands: gulfdune paspalum (*Paspalum monostachyum*; 31 plots) and Seacoast bluestem (*Schizachyrium littorale*; 30 plots). Six more species were fairly frequent, found in 20 to 26 plots in the 2023 sample. These were dayflower (*Commelina erecta*), whitetop sedge (*Rhynchospora colorata*), Texas marshelder (*Iva texensis*), narrow-leaved panicgrass (*Dichanthelium aciculare*), red lovegrass (*Eragrostis secundiflora*), and common threesquare (*Schoenoplectus pungens*). All of these frequently-recorded species were native, and out of the top eight, six were grasses or sedges. Only one of the top eight, common threesquare, was a listed as a wetland obligate

species for the Gulf Coastal Plain (U.S. Army Corps of Engineers 2022).

The only non-native species identified in an I&M plot in 2023 was Bermudagrass (*Cynodon dactylon*). This species is often planted in cattle pastures or lawns, and its presence in a single grassland plot may be a legacy of the park's ranching history. Many more non-natives are known to occur in the park; 47 have been recorded so far, according to the vegetation inventory by Negrete et al. (1999) and subsequent observations. The park's non-native species are generally found along roadsides, on spoil islands, near park infrastructure, and in other disturbed sites. Within the park's native grassland and wetland habitats, however, non-natives are rare. Bermudagrass was recorded in just one of the 32 I&M plots, and within that plot, its cover values were fairly low, averaging to 16% cover across four 10-m² microplots. A later section of this report includes more information on percent cover of the dominant species within plots.

Plot-Level Richness Summaries

Overall: Long-term monitoring plots at Padre Island NS each contained 22 plant species on average, with a range of 11 to 36 species (Table 1, Figure 4). There were more species of forbs than graminoids in 15 of the 32 plots. Of the remaining ~half, three plots had equal counts of the

two growth forms and 13 were richer in graminoids than forbs (see Appendix D for plot-level metrics). Six plots were strongly skewed towards forbs, with a ≥ 6 species difference, and these were from diverse vegetation classes in panels 28 and 38. The nine plots with a ≥ 6 species bias towards graminoids were also from diverse classes, but all were located in panels 8 or 18.

Plot-level species lists consisted mainly of species that were not dependent on wetland conditions, i.e., upland or wetland facultative species. Wetland obligates accounted for 15% of plot species, on average. The plot with the highest proportion of wetland obligate species, reaching 31%, was the single Vegetated Salt Flats plot (38_06). The second highest proportion was an Umbrella Sedge Wetland plot (08_04), and it reached 30%. There were only three plots with no wetland obligates: two were Coastal Grassland plots (28_01 and 18_06) and one was on Coastal Grassland on Fore-Island Dunes (28_03).

Vegetation Class: Of the six vegetation classes, mean species richness was highest in the Umbrella Sedge Wetland class followed by the Coastal Grassland with Pocket Wetlands class (Table 1, Figure 4). The latter class contained the park's two richest plots in 2023: 28_08 with 36 species and 28_02 with 35 species. For both classes, high richness was likely a function of individual plots capturing

Table 1. Species richness metrics per plot in 2023, summarized by vegetation class and panel. Species counts include all species recorded in each plot, and includes plants that are rooted in, overhanging, or prostrated across the plot.

Broad Vegetation Class (Number of Plots)	Plot Mean Elevation in meters	Mean Richness Per Plot, All Species	Range in Mean Richness Per Plot	Mean Graminoid Richness Per Plot	Mean Forb Richness Per Plot	Proportion that are Wetland Obligates
Coastal Grassland (7)	2.6	15	11-20	8	6	12%
Coastal Grassland on Fore- Island Dunes (2)	2.5	20	18-22	8	12	5%
Coastal Grassland with Pocket Wetlands (14)	1.7	26	19-36	12	13	14%
Umbrella Sedge Wetland (4)	1.7	29	22-34	17	11	21%
Swale Wetland (4)	1.5	20	14-30	11	9	21%
Vegetated Salt Flat (1)	1.3	13	13	4	9	31%
Panel 08 (8)	1.8	26	18-34	15	10	19%
Panel 18 (8)	2.5	17	11-23	9	7	15%
Panel 28 (8)	1.9	24	19-36	10	13	9%
Panel 38 (8)	1.5	22	13-30	9	13	17%
Average	1.9	22	11-36	11	11	15%

a variety of wetland species as well as grassland species in adjacent patches.

Swale Wetland and Coastal Grassland on Fore-Island Dunes exhibited intermediate species richness (Table 1, Figure 4). Unlike plots in the two most species-rich classes, Swale Wetland plots were typically fully contained within larger wetland patches and did not have as many grassland species in close proximity. The two plots abutting fore-island dunes were also spatially separated from contrasting vegetation classes, but they did capture four dune species not found elsewhere within I&M plots.

The two most species-poor classes were Coastal Grassland and Vegetated Salt Flats (Table 1, Figure 4). The single Vegetated Salt Flats plot was the least similar to any other I&M plot, with six of its 13 species exclusive to that plot. The total species list was nevertheless short. Many of the park’s widespread species were likely excluded from that plot by its saline conditions and its higher flooding frequency. Two plots in the Coastal Grassland had even lower richness than the Vegetated Salt Flats Plot, at 11 or 12 species each. The low richness of these plots, and for the class on average, was likely related to their relatively high elevations and the absence of pocket wetlands.

Panel: The four monitoring panels differed in mean species richness in 2023 (Table 1, Figure 4), and these cross-panel differences were largely driven by the

vegetation classes they contained. For example, the panel with the highest mean richness, 08, also contained the high-richness Umbrella Sedge Wetland plots. Likewise, panel 18 had the lowest mean richness and contained five of the seven low-richness Coastal Grassland plots. Another difference among panels was their elevation profiles, which appeared to underpin the dominant community types they represented. The higher elevations of panel 18 tended to support Coastal Grassland, whereas the other units averaged lower in elevation and were less dominated by a single class. Interestingly, these differences in vegetation composition emerged in spite of relatively low variation in elevation among plots: ranging from 1.15 m to 3.02 m. In other words, small changes in elevation have a large impact on the dominant plant species.

Elevation: There was a negative relationship between richness and elevation across I&M vegetation plots in 2023, but this varied between coastal grassland classes and wetland classes (Figure 5). Across plots in the three coastal grassland classes, richness was higher at lower elevations (Figure 5A). Across plots in the wetland-dominated classes, in contrast, there was no apparent association between richness and elevation, although elevation also varied less in that group (Figure 5B). A possible explanation for differing relationships with elevation is that at least for the 2023 sampling season, many wetland species were excluded from the higher elevations of the park due to

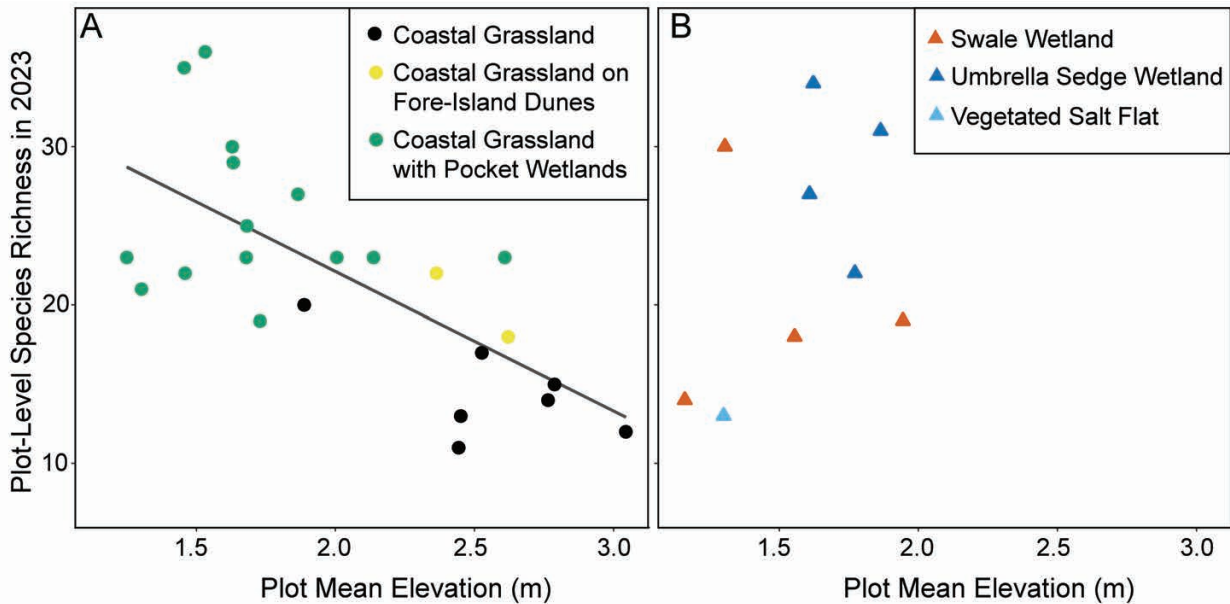


Figure 5. Plot of mean elevation in relation to species richness in 2023 for the (A) three coastal grassland vegetation classes and (B) the three wetland classes. The trend line in A is the least squares regression line.

overly dry conditions, whereas at lower elevations, both the grassland and wetland species could co-occur.

Percent Cover

Percent cover was estimated in each plot for each species within four 10-m² microplots, based on all foliage and stems up to 5 m above ground level. These data were used to measure density of different plant species within plots. To examine patterns within and among classes, percent cover of each species was averaged for all microplots within each class, and the top 15 species were graphed. The resulting patterns in percent cover generally reflected overall habitat and vegetation type. For example, all six classes were strongly dominated by graminoids (Figure 6),

as expected for these types of grasslands. The sum graminoid cover was 50-86% for the top 15 species per class, while forbs had just 3-23% cover in each class. There was only one shrub species present on the list, wax myrtle (*Morella cerifera*) with 2% mean cover in the Umbrella Sedge Wetland. The three highest-cover forb species were camphorweed (*Heterotheca subaxillaris*; 14%), frogbit (*Phyla nodiflora*; 13%) and Texas marshelder (*Iva texensis* 10%; Figure 6).

Within the three coastal grassland classes, seacoast bluestem (*Schizachyrium littorale*) and gulfdune paspalum (*Paspalum monostachyum*) were among the top three species for percent cover (Figure 6). For the three wetland

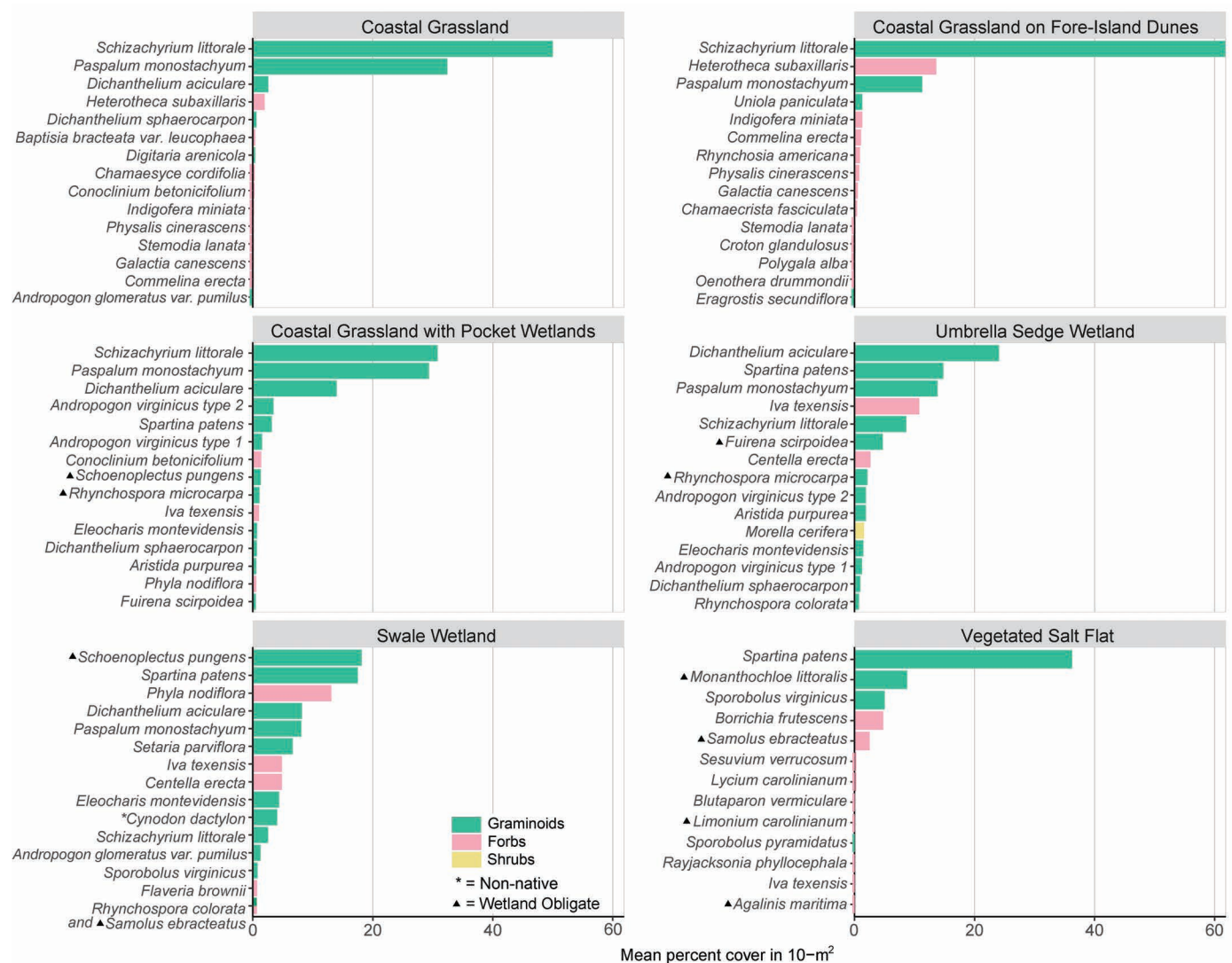


Figure 6. Percent cover of the top 15 plant species at Padre Island National Seashore, organized by vegetation class and color coded by growth form. Percent cover is the per-species average within four microplots per full plot. For species with cover values below 1%, bars were extended below the y-axis so the growth form color class was visible.

classes, marshhay cordgrass (*Spartina patens*) had either the highest or second highest percent cover value in each class. The other dominant graminoids in the wetland classes included narrow-leaved panicgrass (*Dichanthelium aciculare*) for Swale Wetland and Umbrella Sedge Wetland, common threesquare (*Schoenoplectus pungens*) in Swale Wetland, and shoregrass (*Monathochloe littoralis*) in the Vegetated Salt Flat class. Among these, only common threesquare and shoregrass were classified as wetland obligates (U.S. Army Corps of Engineers 2022). Two or more wetland obligates were present within the top 15 of all classes except the two driest grassland types (Figure 6), again highlighting the presence of wetland species throughout most of the park's landscapes.

Vegetation and Environmental Conditions Compared Between 2019 and 2023

Given that 2023 was the second round of sampling for the park, some context may be gained from informal comparisons with the 2019 summaries. Differences in richness and cover between years can also be compared with variation in weather conditions and other

environmental factors, to explore possible drivers. Even so, such assessments remain preliminary, awaiting additional years of data collection and the statistical analyses of trends that also account for key environmental covariates.

Species Richness and Percent Cover

The 32 plots sampled each year had a combined richness of 129 species in 2019 and 113 species in 2023. Of the cumulative list of 143 species, 69% were recorded both times. For wetland obligate species, there were 28 on the cumulative list: 25 were recorded in 2019, and 24 were recorded in 2023. Twenty-one of these wetland obligates (75%) were recorded both times.

At the plot level, average richness was 26 species in 2019 and 22 in 2023. The range in richness was 15-37 species per plot in 2019 and 11-36 species per plot in 2023. For the two dominant growth forms, plots had two fewer forbs and one fewer graminoid, on average, in 2023.

The loss of species from plots was not equal across vegetation classes. Plots in Coastal Grasslands lost more species, on average, than those in any other class (Figure 7A), while the least impacted classes were the three

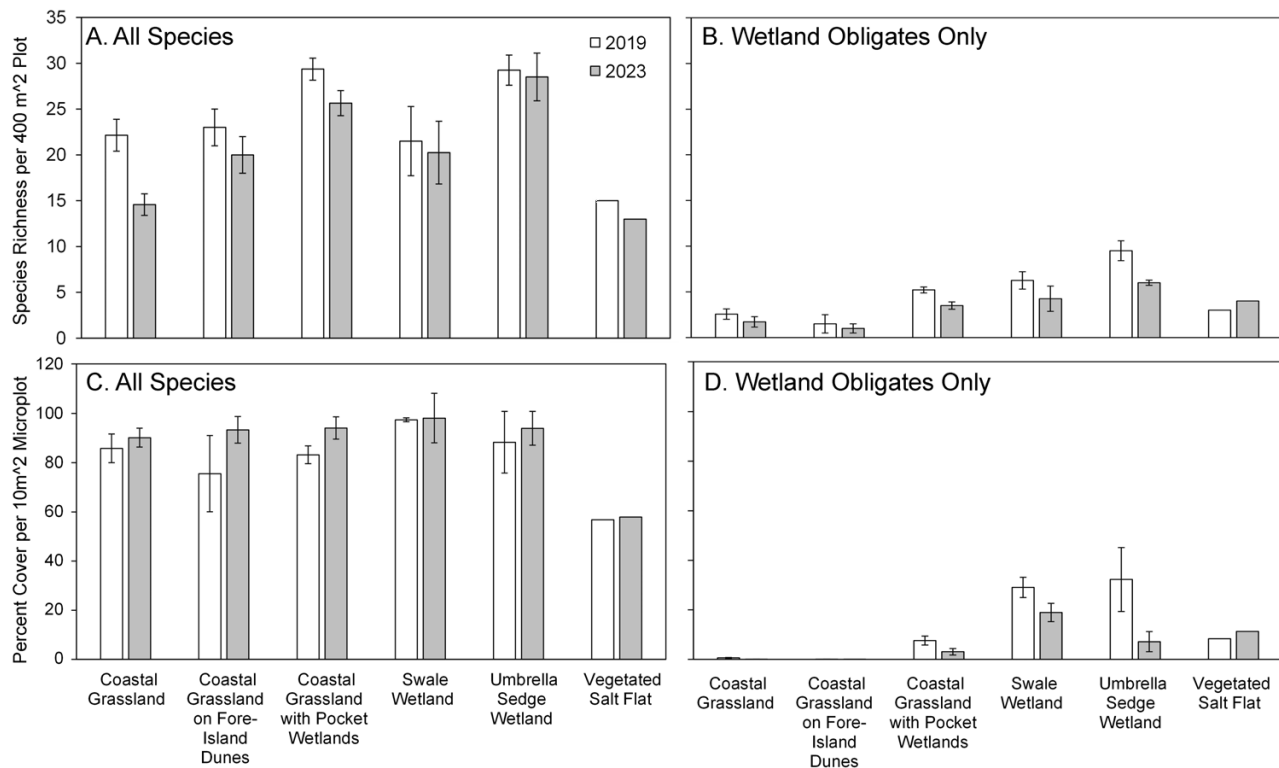


Figure 7. Mean species richness (A,B) and percent cover (C,D) in 2019 and 2023 for the six vegetation classes in monitoring plots at Padre Island NS. Error bars are +/- 1 standard error, except for Vegetated Salt Flat, which had only one plot. Coastal Grassland on Fore-Island Dunes had only two plots, and remaining classes had ≥ four plots.

wetland classes (Figure 7A). That said, for wetland obligate species alone, the Swale and Umbrella Sedge Wetland classes had greater declines in richness than the three Coastal Grassland classes (Figure 7B).

The density of vegetation, as measured by percent cover, also changed between sample years (Figure 7C). For most vegetation classes, total cover for all species combined was slightly higher in 2023 than in 2019. The strongest increase was observed in Coastal Grassland on Fore-Island Dunes, and the least change was in Swale Wetlands. For wetland obligate species alone, percent cover declined for Swale and Umbrella Sedge Wetlands, as well as for Coastal Grassland with Pocket Wetlands (Figure 7D). For the drier grassland classes, in contrast, wetland obligates made up almost no cover in either year and showed no detectable change.

Changes in richness and cover reflected shifting composition within plots between the two years. For example, several species were fairly widespread among plots in 2019 but then much less common to nearly absent

in 2023. These included American bluehearts (*Buchnera americana* Figure 8A), which was found in 24 plots in 2019 but dropped to 14 in 2023. Similarly, beach false foxglove (*Agalinis fasciculata* Figure 8B) declined from 13 to two plots between events. Several wetland obligate species also showed notable declines, including manyspike flatsedge (*Cyperus polystachyos* Figure 8C; seven to one plot) and saltmarsh umbrella sedge (*Fuirena breviseta* Figure 8D; nine to three plots). The smaller subset of species that increased in plot occupancy included purple lovegrass (*Eragrostis spectabilis*; Figure 8E; zero to five plots) and Virginia bluestem (*Andropogon virginicus* type 1, Figure 8F; two to nine plots. For type 2, it was zero to eight plots).

Environmental Conditions

It is unsurprising that plant composition within plots changed over time, given that plant populations are dynamic, and both annual and perennial species can shift locations through recruitment, mortality, and rhizomatous spread. Some of these changes are non-directional and stochastic—even under uniform conditions, composition

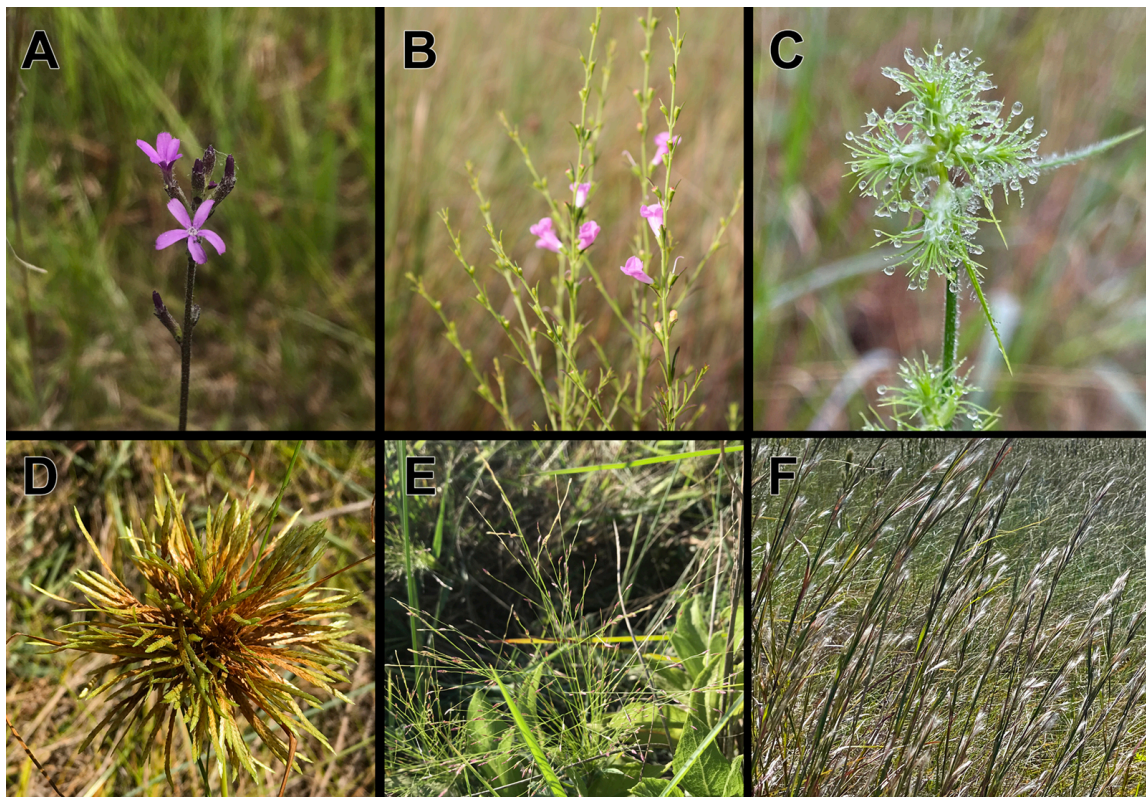


Figure 8. A subset of plant species in vegetation monitoring plots at Padre Island NS that showed notable patterns of change, in terms of plot occupancy between 2019 and 2023. Species that declined include (A) American bluehearts (*Buchnera americana*); (B) beach false foxglove (*Agalinis fasciculata*); (C) umbrella sedge (*Fuirena breviseta*) and (D) manyspike flatsedge (*Cyperus polystachyos*). Species that increased included (E) purple lovegrass (*Eragrostis spectabilis*) and (F) Virginia bluestem (*Andropogon virginicus*, morphotype 1).

would eventually change through random variation within demographic processes. But more immediately, weather, spatial heterogeneity in the landscape, and fire combine to drive variation in plant composition among plots and through time.

Weather in the park can often be extreme, including high winds, storms, and drought. Between the two sampling events for the park, Hurricane Hannah hit in 2020, which eroded shoreline and changed dune topography (Bracewell and Carlson 2024). Plants growing in overwash areas or where sand was eroded were heavily impacted, but away from this active zone, storm effects were presumed greatly diminished. Indeed, the landforms of the grassland interior, where nearly all plots are located, have changed very little over the past 15 years (see Appendix E for example elevational profiles).

Apart from major storms, the two sampling years had notably different rainfall patterns, which would be expected to impact vegetation. Based on gridded monthly rainfall data for the park (NPS Historical Water Balance Datasets; AppEEARS Team 2025), cumulative rainfall by the end of August was slightly higher in 2023 (42 cm) than in 2019 (35 cm). Just prior to and during sampling, however, only 3 cm of rain fell in September 2023, as compared to 12 cm in 2019. Water deficit values, which more accurately depict drought stress for plants (Tercek et al. 2021), showed a smaller deficit in September 2019 (11 mm) than September 2023 (25 mm; Figure 9A). Consistent with the short-term differences, field crews observed wetter conditions and more standing water in wetlands during the 2019 sampling event, relative to that of 2023.

These observations suggest that drier conditions likely led to reduced plant growth in 2023. This was apparent in the shorter species list that year, lower overall richness in individual plots, and declines in richness and cover in wetland obligate species in the communities where they were most common. Similar drought-related fluctuations in plant assemblages have been observed before in the park. During the park's USNVC mapping project by Diamond et al. (2017), the first two years of fieldwork in 2012 and 2013 were substantially drier than the project's final year in 2016. The combination of wetter conditions and more-intensive fieldwork in 2016 produced 36 new species for the park list (13 wetland obligates) and four previously-undetected

wetland associations, including the Umbrella Sedge Wetland (USNVC Association CEG004952).

In addition to differences in weather, the two sample years were associated with different stages in the grassland fire cycle. In September 2019, all plots were nearing the end of their second growing season after fire. In September 2023, however, four or more growing seasons had passed since any plot had burned (See Appendix B for plot-level fire history). The recent fire in 2019 may have boosted richness values in plots, relative to 2023 values. Indeed, previous work in the park showed that mean species richness was higher in burned versus unburned grassland plots in the first year after a fire, and richness was even greater in burned plots in the second year after fire (Lonard et al. 2004). A similar pattern of a richness peaking in the second year after fire has been detected in grasslands elsewhere in the U.S. (e.g., Collins and Steinauer 1998). Several more years of monitoring data will be required to disentangle the relative importance of rainfall patterns and fire recency on species richness within plots.

In addition to changes in richness, accumulation of live and dead biomass is also known to vary over the years following a fire. In I&M plots, total cover increased between 2019 and 2023 (Figure 7C), but this estimate did not discriminate between new growth and older, partially dried stems and leaves. The higher cover in 2023 may be evidence of a longer period of biomass accumulation, i.e., four or five years in 2023 versus two years in 2021, although the difference may also be weather-related. Live plant cover in these grasslands can return to or even surpass pre-fire levels within the first two years, yet the accumulation of less productive or dead biomass may require up to eight years to match pre-fire levels, according to Lonard et al. (2004). The park's fire management program aims to keep this buildup to a minimum, particularly near buildings and other infrastructure, because heavy fuel loads can lead to excessively hot and hard-to-control fires (Padre Island National Seashore 2005).

Prescribed fire has long been considered an important tool in grassland management for cattle in Texas, because fires stimulate more nutritious regrowth as forage (Avila et al. 2020, Wanchuk et al. 2024). There are general benefits to the ecosystem as well, such as increased plant growth,

stimulus for successional change, and faster nutrient cycling (Lonard et al. 2004, Brockway et al. 2002). Although the timing of data collection for this study generally precludes the direct assessment of fire effects, remote-sensing data provide evidence of a productivity boost in the first years after fire.

Satellite-based measurements of Enhanced Vegetation Index (EVI, MOD13Q1-016; AppEEARS Team 2025) can serve as a proxy for productivity. Between 2018 and 2024, EVI values for targeted panels were highest in the second

growing season after fire, as opposed to the first or later seasons (See Figure 9B-D for panels 8 and 18). Even so, the strength of this increase was not equal across all panels (see Figure F1 in Appendix F for all four panels and a longer time sequence). Cross panel differences in both plant community responses and EVI suggest that additional factors are at play. Site-level characteristics such as soil type, surrounding plants, flooding regime, and elevation can also influence plot composition over time and shape how plants experience drought or other weather events.

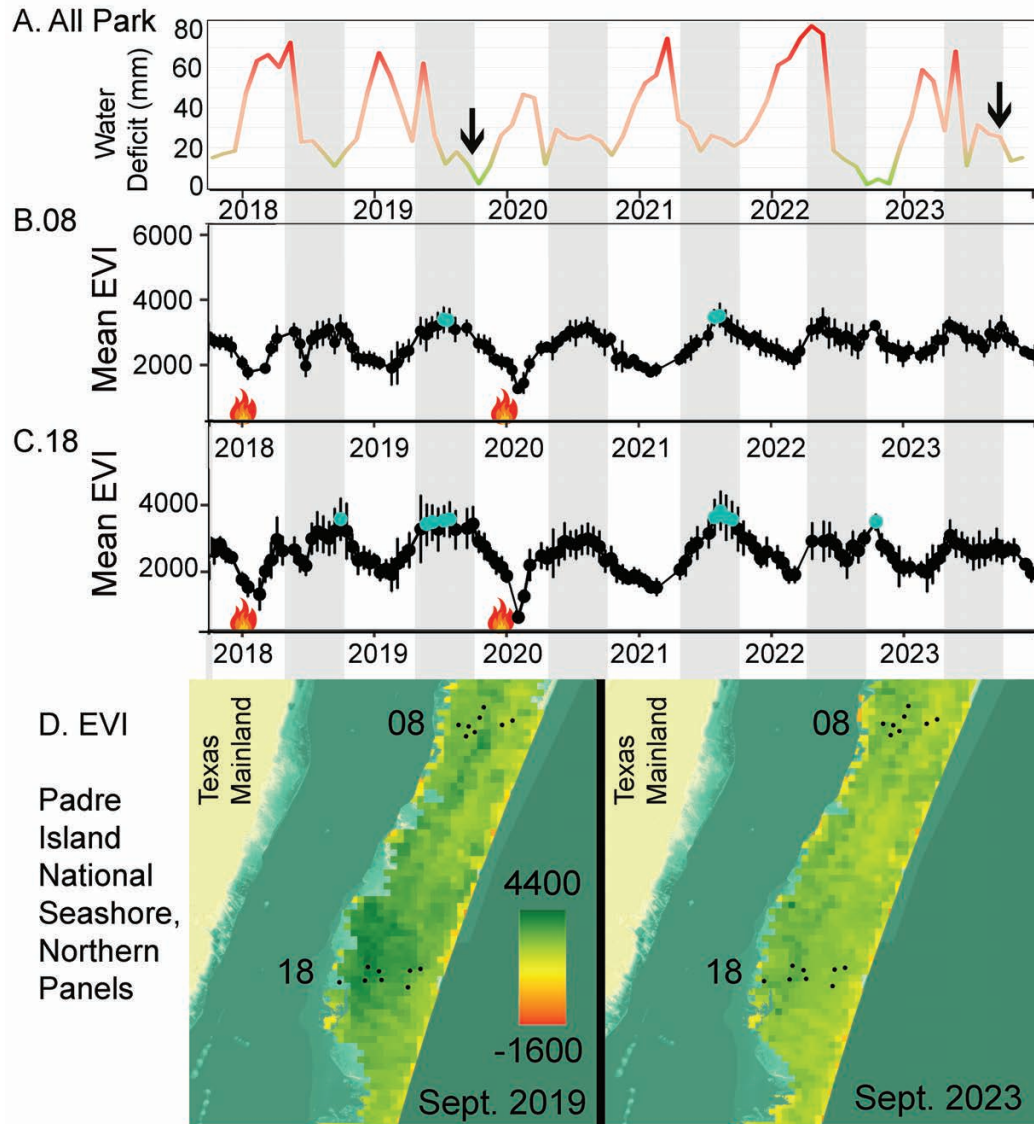


Figure 9. Temporal sequences of (A) monthly water deficit; (B) Panel 8 or (C) Panel 18 mean Enhanced Vegetation Index (EVI) for 16-day periods, which measure vegetation greenness as a proxy of productivity; grey bars span May-September; (D) map of EVI values for September 2019 and 2023 for the area around panel 8 and 18. Black dots show plot locations. The color ramp shows the range in EVI, from high values (max=4400) indicating greener vegetation, to low values (min=-1600) where the landscape is less green. Black arrows in (A) indicate sampling events. Fire icons indicate timing of fires. Blue dots in B and C are above the 95th percentile for that panel; error bars are ± 1 standard deviation. Both water deficit and EVI datasets were downloaded with NASA AppEEARS software online (AppEEARS Team 2025).

Conclusions

The status of park vegetation in 2023 and the changes observed between 2019 and 2023 provide a compelling picture of a dynamic park. With few invasive plant species, relatively frequent fire, and large, continuous, undeveloped tracts surrounded by water, the park's grasslands are strikingly intact and undisturbed. Their floristic composition may have been altered to some extent by historic overgrazing, but half a century post-cattle, the park's grasslands and wetlands are likely closer to pristine, reference conditions than most similar properties nearby. The high quality of the park's flora is further supported by the presence of the unique Umbrella Sedge Wetland and its rare coastal plain umbrella sedge (*Fuirena longa*) in the northern portions of the park.

The recent invasion of feral hogs across the park's northern boundary poses a new threat. The species was confirmed present in the park in 2021, and initial removal activities began that same year (NPS 2024). A Draft Management Plan for Feral Exotic Species was finalized in spring 2025, which also included plans to remove the other exotic ungulate from the park, the Nilgai antelope. Feral hogs are a particular concern because they destroy habitat and will predate nests of endangered and threatened bird and sea turtle species (NPS 2024). They are also likely to harm sensitive plant communities that occur throughout the park by trampling, uprooting plants, and creating wallows.

No signs of feral hog activity were observed during the 2023 vegetation monitoring event, but during a non-sampling visit to the park in late 2024, I&M staff observed areas of uprooted vegetation within 5 km of panel 8 (Figure 2C). With an approved management plan now in place, the park has a range of removal techniques at their disposal. Given the limited means of reentry, sustained eradication of hogs from Padre Island NS is more feasible than it would be on the mainland.

The current vegetation monitoring program supports the park's exotic management plan and other management efforts in several ways. First, crews check for signs of feral hogs or other agents of disturbance in and around plots and then report findings to park staff. Second, I&M collects baseline data and analyzes changes in park plant communities to provide a clearer picture of the park's natural ecological cycles, which is essential for recognizing

when change is atypical or unnatural. When problematic declines are detected, I&M data can then help inform appropriate management actions to return to baseline conditions whenever possible. In these ways, long-term monitoring serves the park both now and into the future.

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