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Coastal Dynamics Monitoring at Padre Island National Seashore, Texas

2017–2025 Data Summary

View of vegetated foredune near South Sprint Pass at Padre Island National Seashore.
NPS / JANE CARLSON

Coastal Dynamics Monitoring at Padre Island National Seashore, Texas: 2017–2025 Data Summary

Science Report NPS/SR—2025/370

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Abstract

In the spring of every other year, the National Park Service's (NPS) Gulf Coast Network conducts geomorphology monitoring at Padre Island National Seashore (PAIS) using standardized methods developed by the NPS Vital Signs Monitoring Program.

In 2025, a shoreline position survey was completed for the entire length of the park's gulf shore, and a fixed set of 23 cross-shore topographic transects distributed along the Gulf shore were surveyed for elevations. This report presents results for the 2025 season and evaluates changes across time.

Some of the key findings presented include that a relatively high number of high tide events occurred at Padre Island National Seashore during 2024, with prolonged inundation periods occurring in late summer and early fall. The mean rate of sea level rise at the park, based on nearby tide stations, averages 4.5 mm per year. From 2017 to 2025, the shoreline position at Padre Island National Seashore has retreated at an average rate of 0.7 meters per year. Topographic monitoring transects generally indicate slight increases in dune crest elevation, retreat of the dune crest position, and decreases in profile area. Notable trends in topographic change include profile area losses near Closed Beach and mile marker 54, increases in dune crest elevation near mile markers 5 and 14, and dune crest retreat near the Mansfield Channel.

Although this project employs a well-established and tested methodology for measuring features and reporting changes, the study's duration (2017–2025) is still short in the context of understanding long-term geomorphological dynamics and trends. Future surveys will be beneficial for gaining insights into the influence of slight changes in survey timing and other environmental variations.

Summary and Key Findings

In the spring of every other year, the Gulf Coast Network conducts geomorphology monitoring at Padre Island National Seashore as a part of the NPS Vital Signs Monitoring Program.

Monitoring is conducted following methods detailed in the Protocol Implementation Plans for Coastal Topography (Bracewell 2017a) and Shoreline Position (Bracewell 2017b). This report presents results for the 2025 season and evaluates changes across time. In 2025, a shoreline position survey was completed for the entire length of the park's gulf shore, and a fixed set of 23 topographic transects distributed along the Gulf shore were surveyed for elevations.

Key findings from this effort are as follows:

- A relatively high number of high tide events occurred at Padre Island National Seashore during 2024, punctuated by prolonged inundation periods in late summer and early fall.
- Mean sea level rise for the park using nearby tide stations averages to 4.5 millimeters (mm)/year.
- From 2017 to 2025 the shoreline position at Padre Island National Seashore has retreated at a rate of 0.7 meters (2.3 feet [ft])/year.
- The Network's topographic monitoring transects generally show slight increases in dune crest elevation, retreating dune crest position, and decrease in profile area.
- Significant trends in topographic change include profile area losses at or near Closed Beach and mile marker 54; dune crest elevation increases near mile markers 5 and 14; and dune crest retreat near the Mansfield Channel.

Although this project employs a well-established and tested methodology for measuring features and reporting changes, the study's duration (2017–2025) is still short in the context of understanding long-term geomorphological dynamics and trends. Future surveys will be beneficial for gaining insights into the influence of slight changes in survey timing and other environmental variations.

Introduction

Coastal barrier islands are dynamic physical foundations for ecosystems. Winds, tides, and currents continuously shape island landforms, while extreme weather events, sea-level change, and human activities exert significant influence on island geomorphology. In coastal regions where change is constant, effective resource management and protection require an understanding of geomorphic change rates, severities, and potential causes.

To address this need, the Gulf Coast Network conducts coastal geomorphology monitoring at two National Seashores, using methods established by the Northeast Coastal and Barrier Network (Psuty et al. 2010, 2012). The Network records coastal topography—i.e., the beach/dune elevation profile—and shoreline position using Global Navigation Satellite System (GNSS) surveys conducted in the spring of alternate years (Bracewell 2017a, 2017b).

This document reports the Network's most recently collected geomorphology data for Padre Island National Seashore, within the context of the park's long-term shoreline position and topographic change datasets. Data and findings from previous surveys are available through the Network's Shoreline and Coastal Topography Monitoring Projects on the Integrated Resource Management Applications (IRMA) Portal.

Study Area

Padre Island National Seashore, established in 1962, encompasses approximately 52,609 hectares (130,000 acres) of land and water. The National Seashore includes most of North Padre Island, which is separated from South Padre Island by the Port Mansfield Channel. At 113 kilometers (70 miles) in length, Padre Island National Seashore is the longest stretch of undeveloped barrier island in the world, with a width ranging from 0.8 to 4.8 kilometers (0.5 to 3.0 miles; Cooper et al. 2005). Except for the 4.5-mile (7.2 kilometer) stretch of Closed Beach (also known as Malaquite Beach), the beaches of Padre Island National Seashore are open to vehicular traffic. The authorized boundary of the seashore includes not only the barrier island itself but also portions of the Gulf of Mexico and the Laguna Madre. North Padre Island contains 41% of Texas's total sediment volume in beach and foredune systems above 1 meter (3.3 ft) in elevation (Paine et al. 2025).

Figure 1 shows the extent of the Network's shoreline monitoring effort at Padre Island National Seashore, which begins at the northern Gulf-side boundary at North Beach and extends south to the Port Mansfield Channel. The figure also identifies the locations of topographic transect survey sites.

Padre Island National Seashore contains a variety of aquatic and terrestrial ecosystems. From the Gulf-side westward to the Gulf Intracoastal Waterway, the park includes nearshore waters; the foreshore (swash zone) and backshore (from the high-tide line to the dunes); foredunes; vegetated flats behind the dunes with shallow fresh or brackish ponds and marshes; back-island dunes in some areas; wind-tidal flats; and shallow, hypersaline seagrass beds in the lagoon. The interplay of climate, physiography, and geomorphology results in a landscape that is largely shaped by wind (Withers et al. 2004).

This document reports the Network's most recently collected geomorphology data for Padre Island National Seashore within the context of long-term (2017 to 2025) changes in shoreline position and topography. Data and findings from previous surveys are available at the Network's Shoreline and Coastal Topography Monitoring Projects on the Integrated Resource Management Applications (IRMA) Portal.

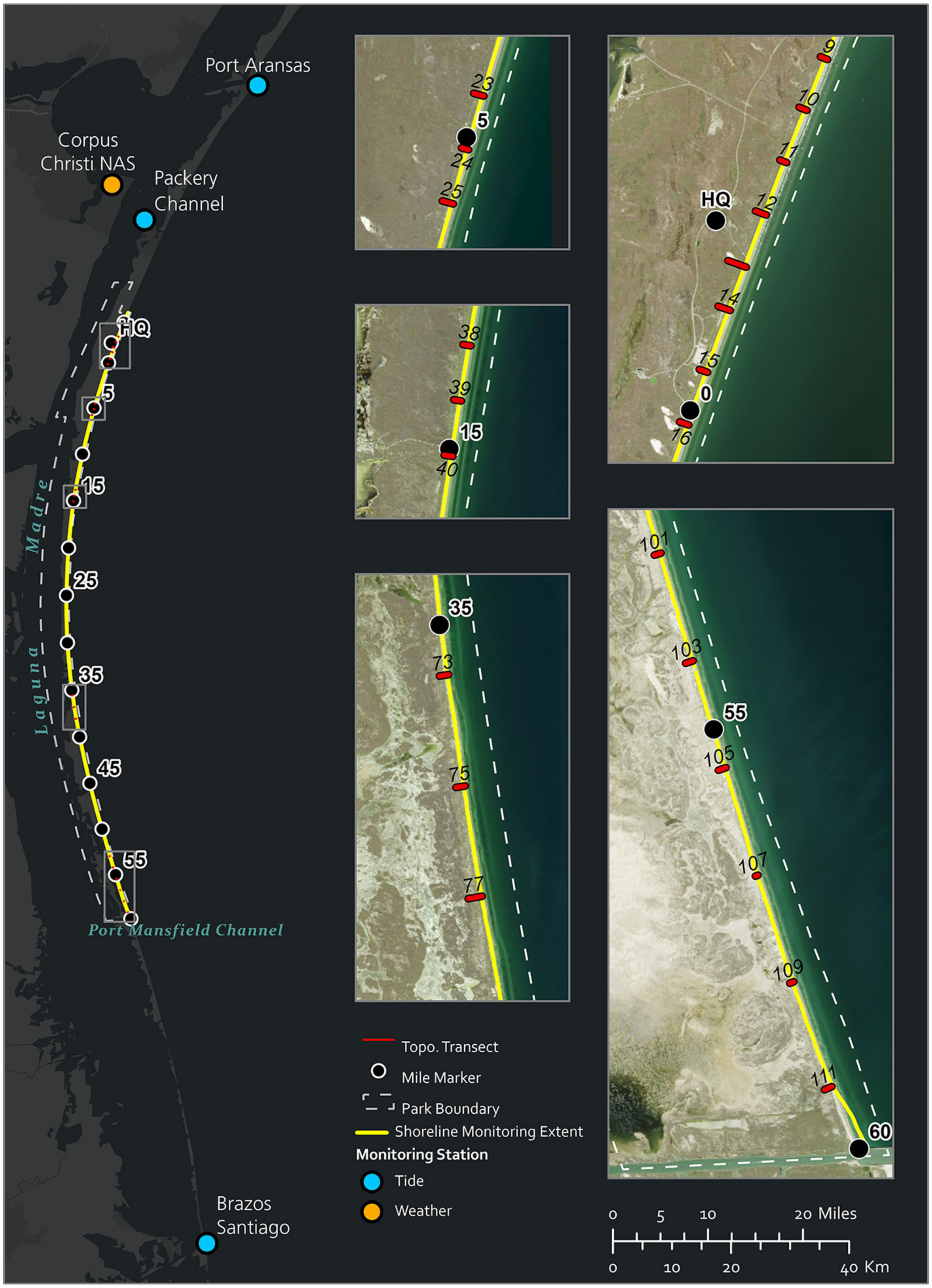

Figure 1. The 23 Gulf Coast Network coastal topography survey transects at Padre Island National Seashore (red lines) and extent of shoreline monitoring (yellow line). The locations of weather and water level monitoring stations are indicated with orange or blue circles.
NPS / GULN

Water Levels and Weather

Shoreline position and dune topography are influenced by regular variations in weather and tidal conditions, in addition to the more extreme conditions brought on by hurricanes or other storms. To track the high tide occurrences that cause accelerated changes, the Network considers three proximal tide stations to represent variation in water levels at the Seashore (station locations shown in Figure 1). Figure 2 reports the count of high tide days (events), averaged from the stations, from April 2015 to April 2025. Particularly noteworthy in this report is the elevated number of high tides in 2024/25, following several years of relatively few occurrences.

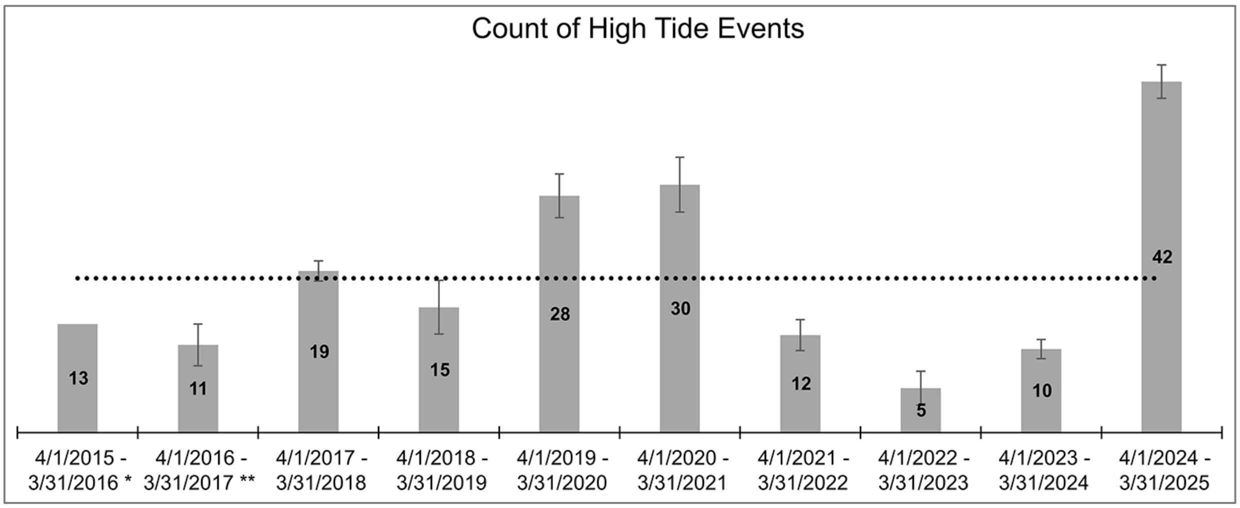

Figure 2. Number of high tide events by study period at up to three water-level monitoring stations near Padre Island National Seashore (station locations shown in Figure 1). The overall average number of high tide events per year is indicated by the dotted line. The Network's survey window begins in April, and counts are binned from April 1 of one year through March 31 of the following year. High tide events are defined as those high water levels falling above the 95th percentile, measured in NAVD 88 meters (Packery = 0.66, Brazos Santiago = 0.48, Port Aransas = 0.69). Due to variation in the start dates of each tide station, * excludes Port Aransas and Brazos Santiago; ** excludes Brazos Santiago. When multiple stations are available for a given year, the average count across stations is presented; otherwise, the count from a single station is shown.

NPS / GULN

High tide events are known to occur in response to tropical storms or hurricanes, but perhaps surprisingly, they are more often linked to unnamed conditions, as demonstrated for the Port Aransas tide station in Figure 3. In 2024, there were five named storms that likely influenced water levels at Padre Island National Seashore, while the survey window for 2024/2025 included 42 high tide events (Figure 2). These other high-tide occurrences were likely the result of one or more phenomena acting alone or in combination, including moon phase, water temperature, and prolonged periods of wind blowing onshore from a fixed direction, known as onshore flow. These factors often combine to create seasonal patterns, like a tendency for high tides in late summer and early fall. Of the 42 high water events in 2024/2025, 28 occurred in October and November over multi-day periods. For example, in November, there were 11 consecutive “flood” days, those that exceeded 0.69 meters (2.3 ft; NAVD 88), at the Port Aransas tide station.

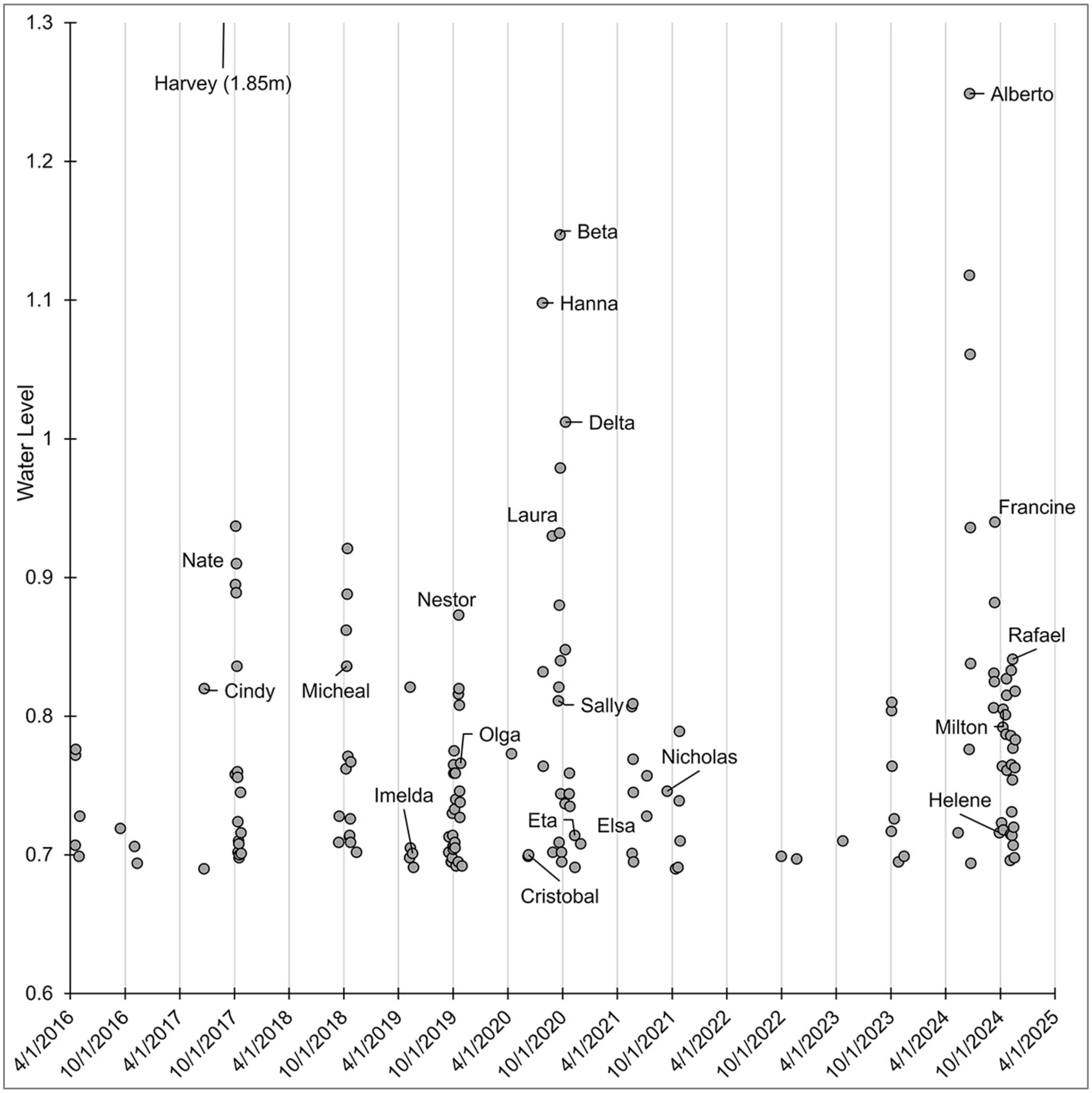

Figure 3. Scatterplot of high tide events at the Port Aransas tide station where water levels exceed the 95th percentile, or 0.69 meters (2.3 ft; NAVD 88). For instances where high tide conditions occur concurrently with tropical storms or hurricanes in the Gulf, points are labelled with the storm’s name. *NPS / GULN*

Exacerbating seasonal high-water levels during this flood period, Hurricane Rafael entered the Gulf on November 6, 2024, after making landfall in Cuba, where it strengthened to a Category 3 storm with peak winds of 120 mph (Figure 4). This intensity made Rafael one of the two strongest storms to ever occupy the Gulf in the month of November. Interestingly, Rafael diminished over 300 miles

(483 kilometers) off the southern Texas coast but nevertheless had a noteworthy impact on the park, causing coastal flooding as reported by the National Weather Service's Marine Forecasts (Iowa State 2025).

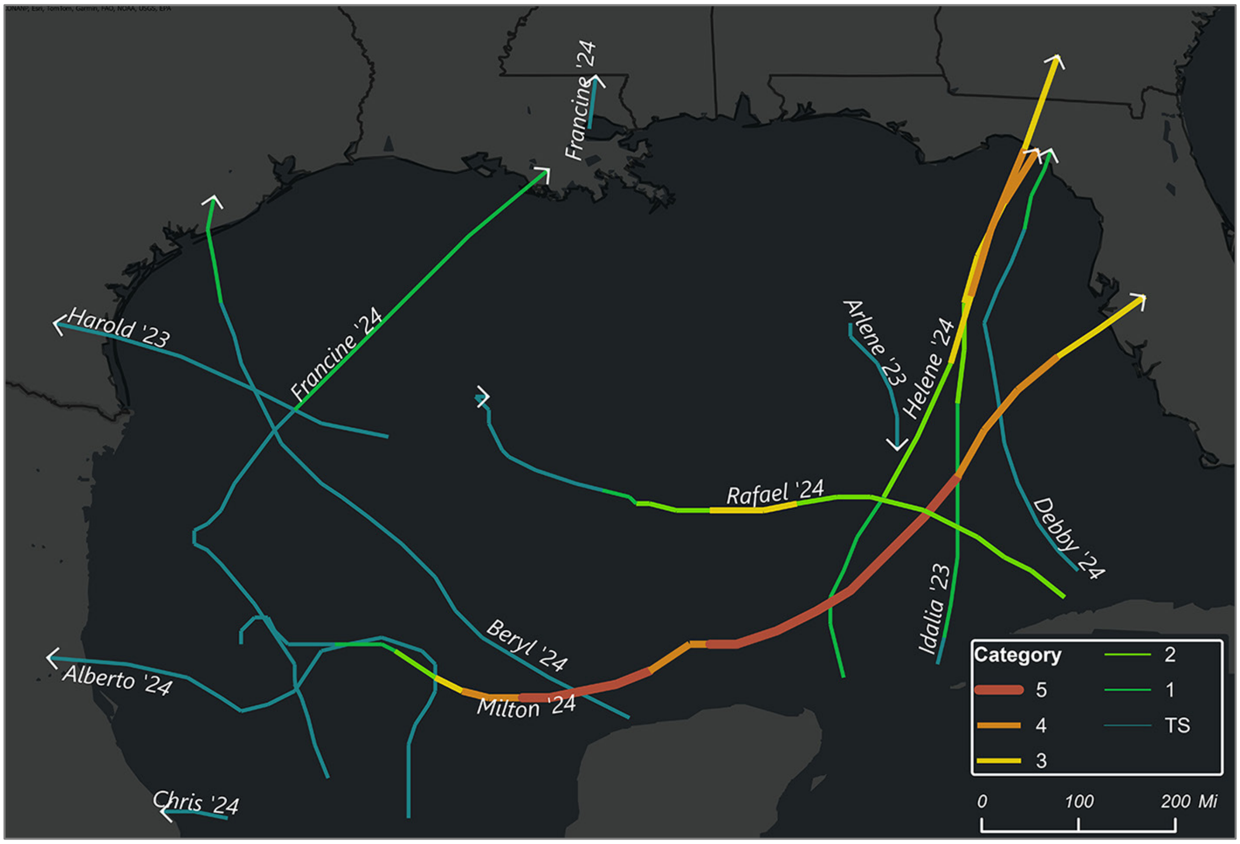

Figure 4. Map of hurricane and tropical storm (TS) tracks along the Gulf Coast from May 2023 through May 2025. Minimum wind speeds based on the Saffir-Simpson scale (in mph): TS – 39, Category 1 – 74, Category 2 – 96, Category 3 – 111, Category 4 – 130, Category 5 – 157.
NPS / GULN

Earlier, in June of the 2024 hurricane season, Tropical Storm Alberto brought a much shorter, but higher intensity flood period to Padre Island National Seashore. This storm had a broad area of tropical-storm-force winds that caused water levels to swell to 1.2 meters (3.9 ft; NAVD 88) at the Port Aransas tide station and closed access to the park's beaches for several days (Figure 5).

Figure 5. Photo of beach access road at South Beach taken on June 20, 2024, while Tropical Storm Alberto churned off the Mexican coast (see storm track in Figure 4).
NPS / GULN STAFF

Along with tides and currents, the other dominant force shaping coastal geomorphology is wind. The most recent Network survey was preceded by a relatively average number of windy days from April 2023 to April 2025, as shown in Figure 6, which graphs weather data from the Corpus Christi Naval Air Station (NOAA 2025b). Windy days are those where the average daily wind speed exceeded 19.6 mph, or the 95th percentile of all daily averages.

While peak high-tide occurrences typically happen in late summer and early fall, an average of wind speeds by month across a ten-year period shows a peak in the spring (Figure 7). This seasonal offset reduces the overall likelihood of peak wind and water levels overlapping. In 2024, there was only one instance where high wind and high water coincided—during Tropical Storm Alberto. Additional details about other weather and tide extremes can be found in previous series reports (Bracewell 2021; Bracewell and Carlson 2022, 2024).

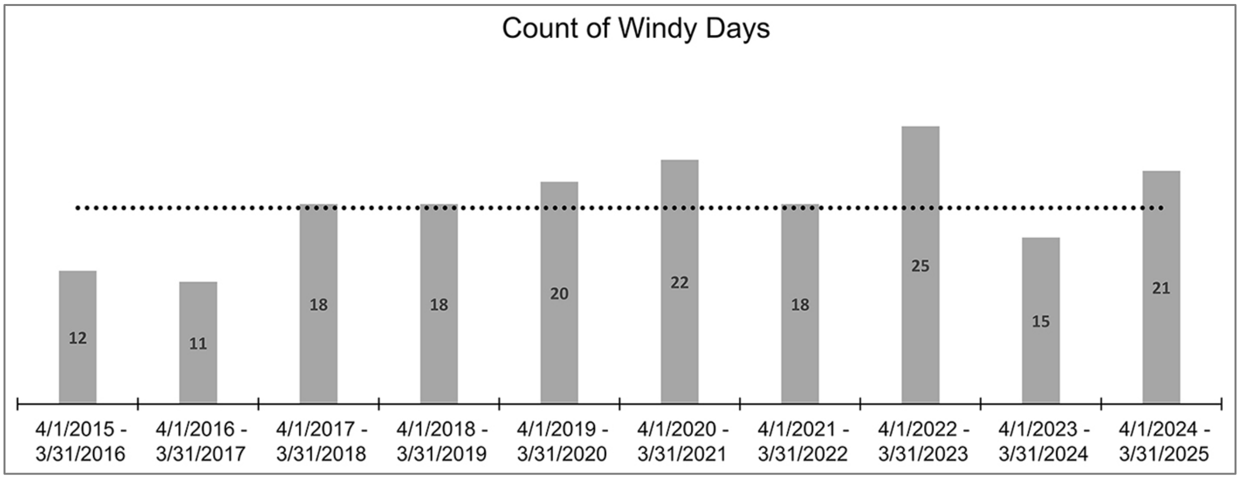

Figure 6. The number of windy days recorded at the Corpus Christi Naval Air Station. The average count for the reporting period is 17.7 windy days per year, represented by the dotted line.
NPS / GULN

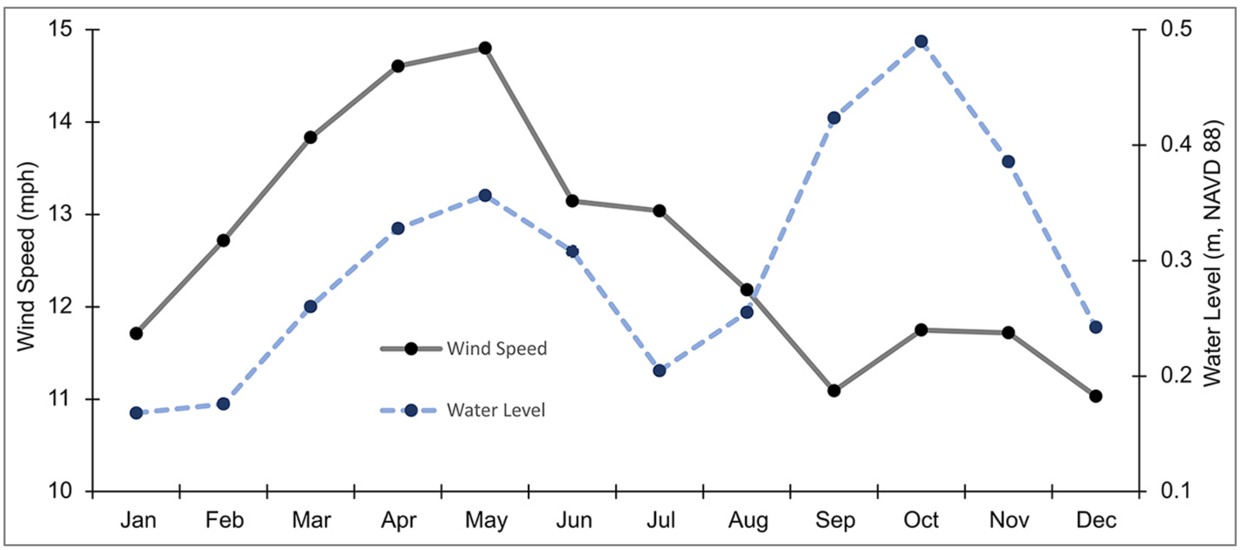

Figure 7. The ten-year average of wind speeds and water levels by month recorded at Corpus Christi Naval Air Station and Port Aransas tide station for the period between April 2015 and April 2025.
NPS / GULN

Wind, tides, and storms drive stochastic landscape changes that can interfere with public use and threaten park infrastructure. An additional concern for long-term management planning is sea level rise. Table 1 presents 2022 and 2024 estimates of relative sea level trends from NOAA (2025a) for the three stations closest to the park. In all cases, the values are positive, indicating that water levels are rising, the land surface is subsiding, or a combination of both is contributing to increased inundation. Across the three stations, the average estimated rate of sea level rise for Padre Island National Seashore is 4.5 mm/year.

Table 1. Relative sea level trends at three stations near Padre Island National Seashore from NOAA (2025a). Mean Sea Level is presented as gain in mm/year with 95% confidence interval.

Station ID	Station Name	Last Year	First Year	Mean Sea Level Trends (mm/year)
8775870	Corpus Christi	2022	1983	5.48 (±0.98)
8778490	Port Mansfield	2024	1963	3.75 (±0.61)
8779748	South Padre Island	2024	1958	4.19 (±0.46)

At a beach with a 4° slope—such as much of Closed Beach—this rate of sea level rise would result in approximately 6.4 meters (21.1 ft) of horizontal shoreline displacement over a 10-year period. A more detailed explanation of the relationship between slope and horizontal displacement is provided in the Results section of this report.

Human Impacts

As a protected area, the Seashore's landforms are minimally affected by direct human modification. Although the National Park Service generally prioritizes natural processes, there are occasions when the park undertakes projects—either independently or in collaboration with partners—to modify landforms in beneficial ways. These include beach nourishment using dredged material and restoration efforts such as installing sediment fencing or planting stabilizing vegetation.

Currently, the Willacy County Navigation District has dredging projects planned for the Port Mansfield harbor and the wyes (intersections) between the Port Mansfield Channel and the Gulf Intracoastal Waterway. Additional dredging is also planned in the Channel south of the park. While much of the dredged sediment is expected to be deposited in containment cells adjacent to the pass, preparations are underway to use a portion of this material to nourish the southernmost Seashore beach (M. Ford, personal communication, July 24, 2025).

In alignment with these dredging efforts, the Texas General Land Office and the Willacy County Navigation District—through the Coastal Erosion Planning and Response Act (CEPRA)—contracted Stantec Consulting Services in the summer of 2024 to provide engineering and project design templates for beach nourishment at Padre Island National Seashore, south of Mile Marker 58 (Texas General Land Office [TX GLO] 2024). The timeline for these nourishment activities remains uncertain, as they are contingent on non-NPS funding sources and must be coordinated with broader dredging operations and schedules.

Methods

Sampling Schedule and Field Methods

All the Network's coastal geomorphology surveys, including the most recent event, follow the sampling schedule and methods outlined in Bracewell (2017a, 2017b). All fieldwork is scheduled to coincide with neap tide periods in April and May of every other year. Neap tides occur twice monthly and are characterized by the smallest difference between high and low tides. For each survey season, these periods are determined using predicted water levels from the nearest NOAA monitoring station at Port Aransas (NOAA 2025a).

The neap tide period is especially important for shoreline position surveys, as it helps reduce variability in the location of the high tide swash line. While topographic surveys are not dependent on neap tides to produce comparable results, surveying low elevations is more efficient when those areas are not inundated.

To measure topography, groups of cross-shore virtual transects are projected along the seashore at areas of high park management interest or where they coincide with other Network monitoring projects. A crew member walks along each transect recording elevation, longitude, and latitude at topographic inflections in the beach and primary dune complex on precision Global Navigation Satellite System (GNSS) equipment. These x, y, and z coordinates are plotted as profiles for documentation and comparison over time (Bracewell 2017a).

To record shoreline position, a crew member walks or drives along the high tide swash line using a handheld or UTV-mounted GNSS unit. The swash line is typically marked by a wet/dry boundary in the sand, shell hash, or other debris. Positional data are differentially corrected either in real time or during post-processing, and results are exported into a standard GIS format. Shoreline position data are then compared across time to determine change (Bracewell 2017b).

For the 2025 field season, coastal topography data were collected from April 7–9, and shoreline position data were collected from April 8–9. The previous high tide occurred at 3:00 p.m. on April 7 at Port Aransas. Horizontal accuracy for the shoreline survey was 0.016 meters (pre-survey) and 0.014 meters (post-survey). For the topographic survey, horizontal and vertical accuracies were equal to or better than 0.047 meters and 0.024 meters, respectively.

Shoreline Change Rate Calculations

Shoreline position change is assessed using the Digital Shoreline Analysis System (DSAS; Himmelstoss et al. 2024). This geospatial tool evaluates temporal changes in shoreline location by analyzing spatially fixed cross-shore transects, spaced at 50-meter (164-ft) intervals. Annual rates of shoreline change are calculated using the Linear Regression Rate (LRR) method, which applies least squares regression to determine the slope of distances from a fixed baseline to successive shoreline positions along each transect. Also, the length between starting shoreline distance and final shoreline distance—Net Shoreline Movement (NSM)—is presented to a lesser degree in the results section

(Figure 8). A default positional uncertainty of 5 meters (16.4 ft) is incorporated to account for GNSS error and variability in the swash zone due to wind and tidal influences.

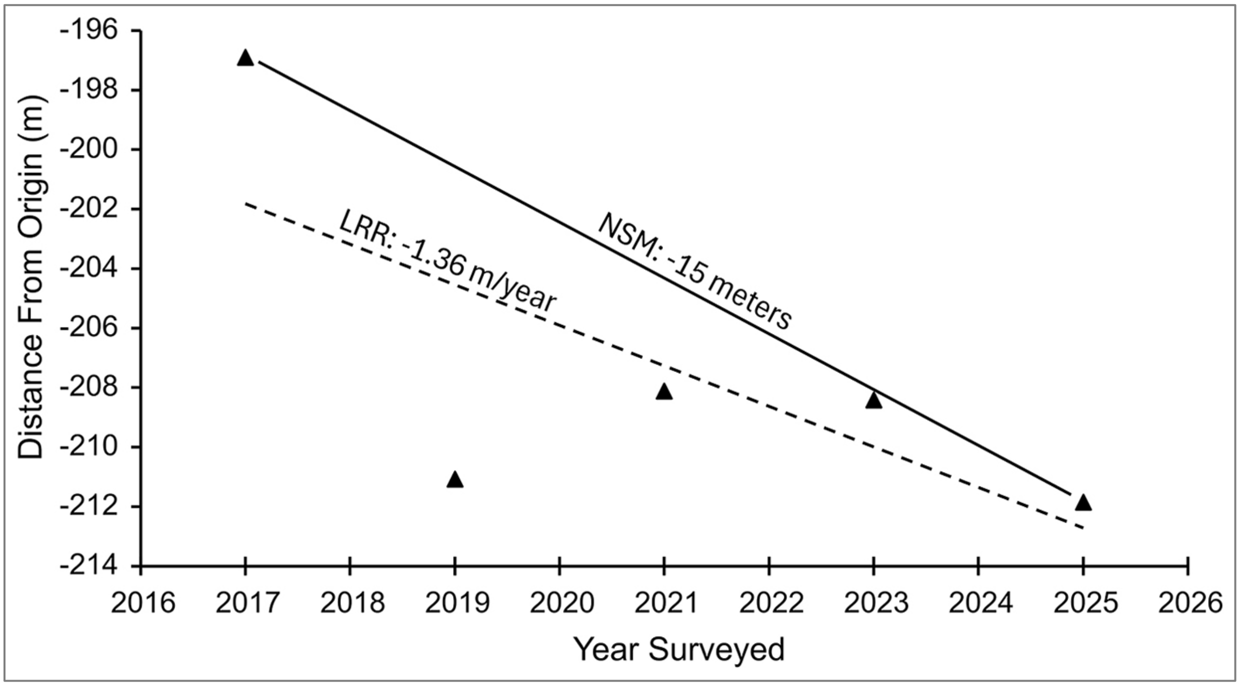

Figure 8. Graph comparing shoreline change as Net Shoreline Distance (NSM, solid line) and Linear Regression Rate (LRR, dashed line). Individual distances measured along a spatially fixed transect from an offshore origin are shown as triangles.

NPS / GULN

To facilitate interpretation of regional trends, shoreline change metrics are averaged across contiguous five-mile segments. This report primarily focuses on long-term shoreline change (2017–2025), with additional notes on recent change between 2023 and 2025.

Topographic Measurements and Change Calculations

Topographic monitoring profiles originate at a physical or virtual benchmark (0.0 meters horizontal), located landward of the foredune complex. Measurements are taken across the active portion of the beach-dune system and do not always extend back to their origin. To quantify dune features and assess change, four primary metrics are derived from each profile: Distance to Dune Crest (referring to the foredune crest), Dune Crest Elevation, Distance to 0.0 (meters, NAVD 88), and Profile Area (see examples of each metric in Figure 9). Profile Area refers to the two-dimensional area beneath the profile curve, measured down to 0.0 NAVD 88.

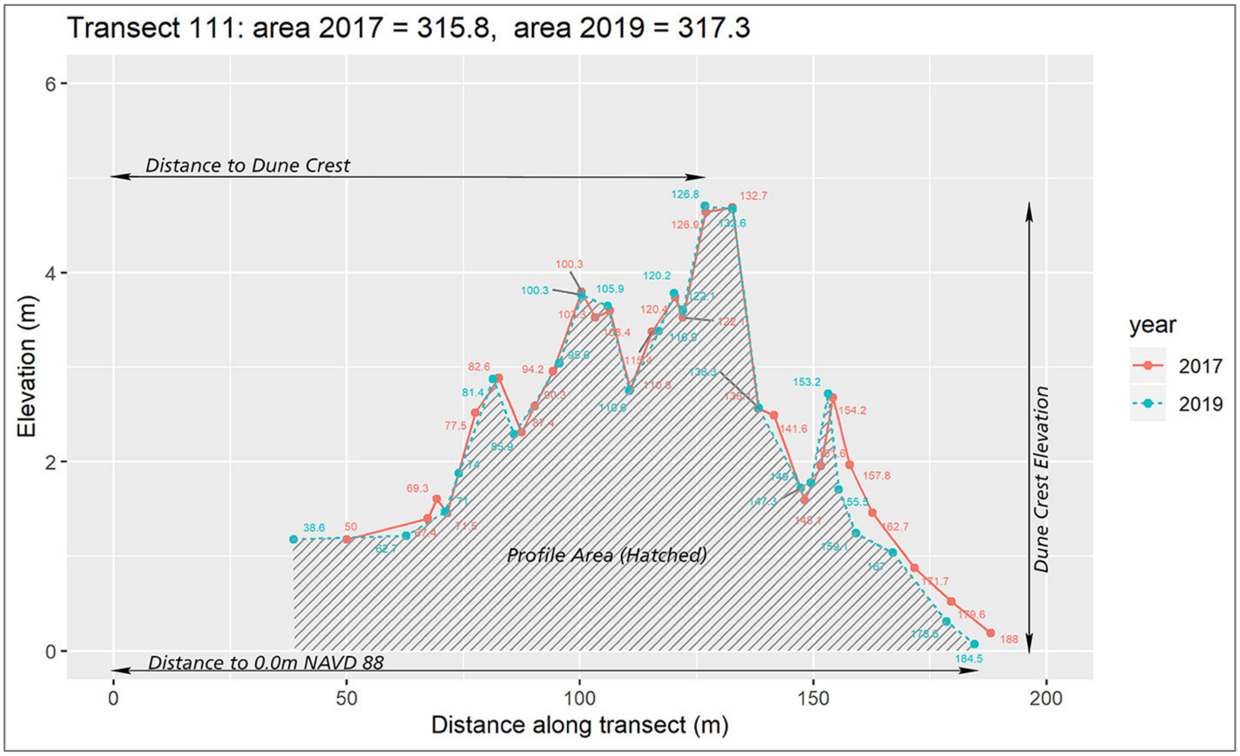

Figure 9. Example graph showing key profile dimensions. Arrows indicate: Distance to dune crest, Dune crest elevation, and Distance to 0.0 meters NAVD 88. The hatched portion under the 2019 profile represents the area calculated for Profile area. Each topographic measurement point is labeled with "distance from benchmark" for each year. All elevation measurements are referenced to NAVD 88, Geoid 12B.

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Comparisons and summaries of these metrics were conducted within and among seven panels spanning the full length of the National Seashore, with each panel containing 3–5 transects. These groupings included: Closed Beach; panel 08 near the Visitor Center; panel 18 near mile marker 5; panel 28 near mile marker 14; panel 37 near mile marker 35; a northern group of transects near Mansfield Pass; and a southern group of transects near Mansfield Pass. Graphical depictions of individual transect profiles are provided in the supplemental materials (SM 1).

For each focal topographic variable, change was assessed within and across panels using repeated measures linear mixed-effects models in R version 4.2.3 (lme4 package; Bates et al. 2015). Year, panel, and their interaction were treated as fixed effects, while transect was included as a random effect. Post hoc Tukey-adjusted tests of slopes within each panel were used to determine whether individual panels exhibited significant temporal change for a given topographic metric.

Results

Positional Change

Results from the Network's shoreline monitoring project up to the spring of 2025 are presented below. Given the potential for variation in shoreline position relative to beach slope and water level, the conservative estimate of shoreline change rate uses the Linear Regression Rate (LRR) model, but Net Shoreline Movement (NSM) is also presented with overall change for additional scale and context.

Overall, the Padre Island National Seashore Gulf shoreline retreated at a rate of 0.7 meters (2.3 ft)/year (±0.37, LRR), while the NSM for the same period was −10.9 meters (−35.8 ft), with 95% of transects retreating. The LRR estimate aligns with the historical shoreline retreat rate for the park's Gulf shoreline, which averaged −0.69 meters (−2.3 ft)/year (SD = 1.09) over a period between the 1930s and 2007 (TX BEG 2012).

Group-level LRR averages for shoreline change ranged from a loss of 1.3 meters (4.3 ft)/year at Closed Beach to a gain of 1.0 meter (3.3 ft)/year near the Port Mansfield Channel (mile markers 55 to 60, Figure 10A). The elevated rates of change within these two sections of the park are attributed to different causes. At Closed Beach, complex natural processes are likely in play, whereas at Port Mansfield, the shoreline advance is primarily the result of beach nourishment occurring between 2019 and 2021 (see Bracewell and Carlson 2022). In other areas of the park, the shoreline position changed very little over time. For example, the section between mile markers 20 and 25 exhibited the slowest retreat rate. The relative stability in this area is consistent with previous reports in this series, as this zone tends to have a steep beach slope (Bracewell and Carlson 2022).

When shoreline position transects are considered individually across the length of the island, an additional spatial pattern emerges. This pattern divides the park into northern and southern sections, with the dividing point just south of the 30-mile marker. In the northern section, there is relatively little variability in shoreline positional change from one transect to the next. For group-level averages, this is reflected in the narrow error bars for groups up to mile marker 30 in Figure 10A, compared to the wider error bars for groups south of 30. This indicates shoreline changes in the north are generally uniform across transects, whereas those in the south exhibit markedly greater spatial variability, with substantial gains and losses occurring in close proximity.

Figure 10B highlights the top and bottom 5% of LRR values, illustrating the southern section's elevated variability. This pattern is consistent with field observations from the southern reaches of the seashore, where soft, shifting sands and geomorphic pinch points constrain the space between the shoreline and the toe of the dune, often denying vehicular access. To clarify these points and explore additional patterns of shoreline change, an indexed map series and DSAS summary statistics are provided in the supplemental materials (SM 2).

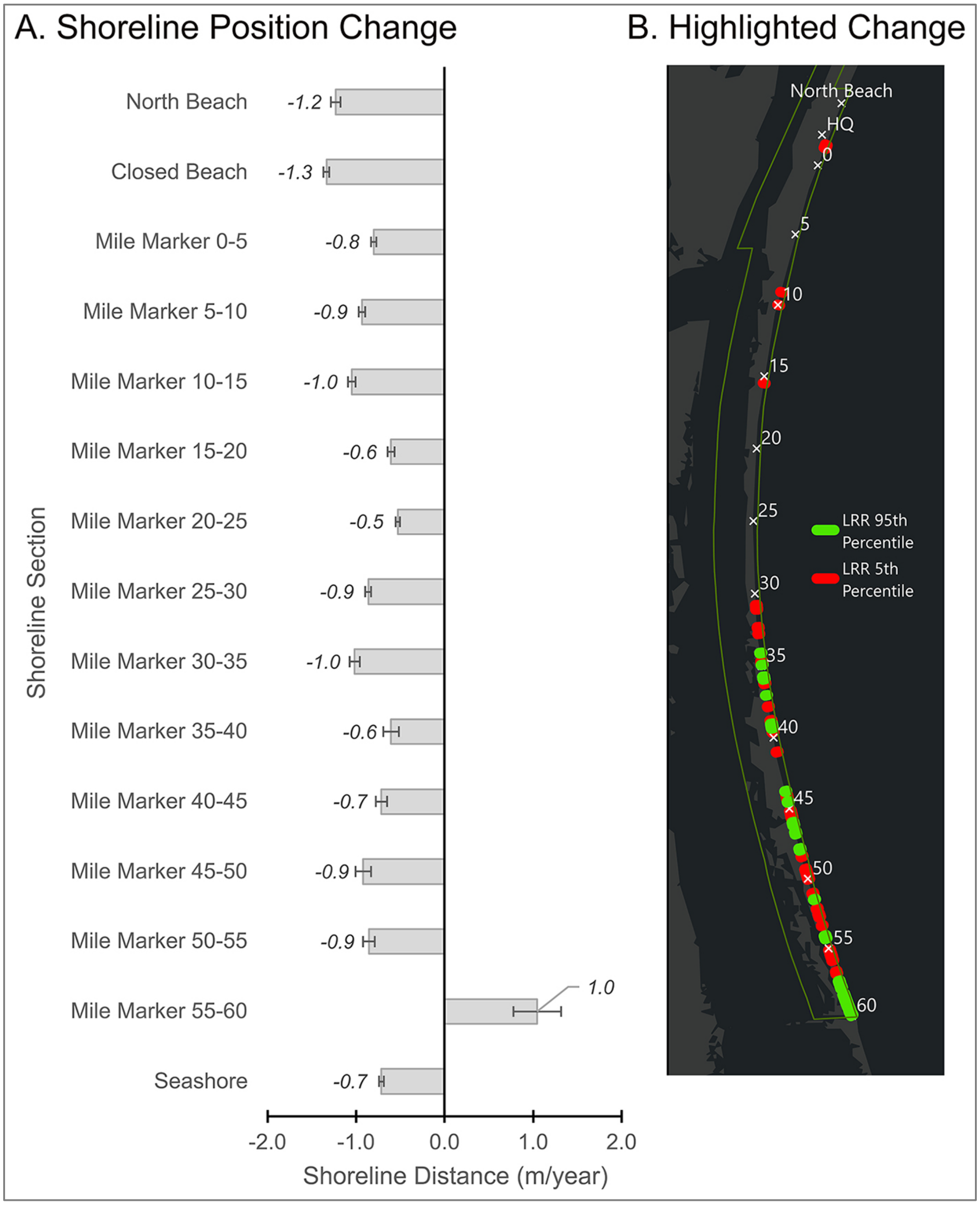

Figure 10. Combined figure showing shoreline positional change in five-mile sections as a bar chart, and a map showing transects with the highest rates of change. A: Average change in shoreline position, measured in meters of retreat or advance per year. Change is measured as the linear regression rate of change in shoreline distance to a spatially fixed benchmark. Negative values indicate shoreline retreat and positive values indicate shoreline advance. Standard error is shown with brackets and related values at the tails of each bar. B: Percentile ranks for LRR transects with green representing transects with change rates at the 95th percentile (0.69 meters [2.3 ft]/year) or higher and red representing transects with change rates at the fifth percentile (-2.0 meters [-6.6 ft]/year) or lower.

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Topographic Change

Like shoreline positional change, topographic change along the seashore also varies. In terms of dune crest elevation, distance to dune crest, and profile area, some groups experienced directional changes—either gains or losses—some of which were statistically significant.

By 2025, nearly all groups showed an increase in dune crest elevation relative to their 2017 values (Figure 11A). The only exception was the southernmost transect group near the Port Mansfield Channel, which exhibited greater variability over time. Among the groups that increased, only Panels 8 and 18 showed a statistically significant positive slope in dune crest elevation (asterisks in Figure 11A; statistical results in SM 3).

In contrast, most groups showed a reduction in profile area over time, except for Panel 38 and the southern Port Mansfield group (Figure 11B). Significant losses in profile area were observed at Closed Beach, Panel 8, and the northern Port Mansfield group (SM 3).

For distance to dune crest, there was little variation over time, again apart from the southernmost Port Mansfield group (Figure 11C). Of all groups, Panel 38 appeared the most stable across the three metrics, showing minimal variation and no significant trends.

Much of what was previously reported in Bracewell and Carlson (2024) regarding topographic changes remains relevant to the 2025 findings. Notably, incipient—or formative—dunes have been slow to re-form—or have not yet re-formed—following the 2020 tropical storm season (see profile graphs in SM 1). This morphological shift is evident in the profile graphs, which show slightly taller dunes with reduced profile areas, indicating sediment redistribution.

The overall retreat of the distance to dune crest is heavily influenced by transects 107 and 109, which are part of the southern Port Mansfield group and located on the margins of washover cuts. The impact of washovers on geomorphic variability in this group is likely representative of the entire southern third of the park, where such events are common (Keller-Lynn 2010).

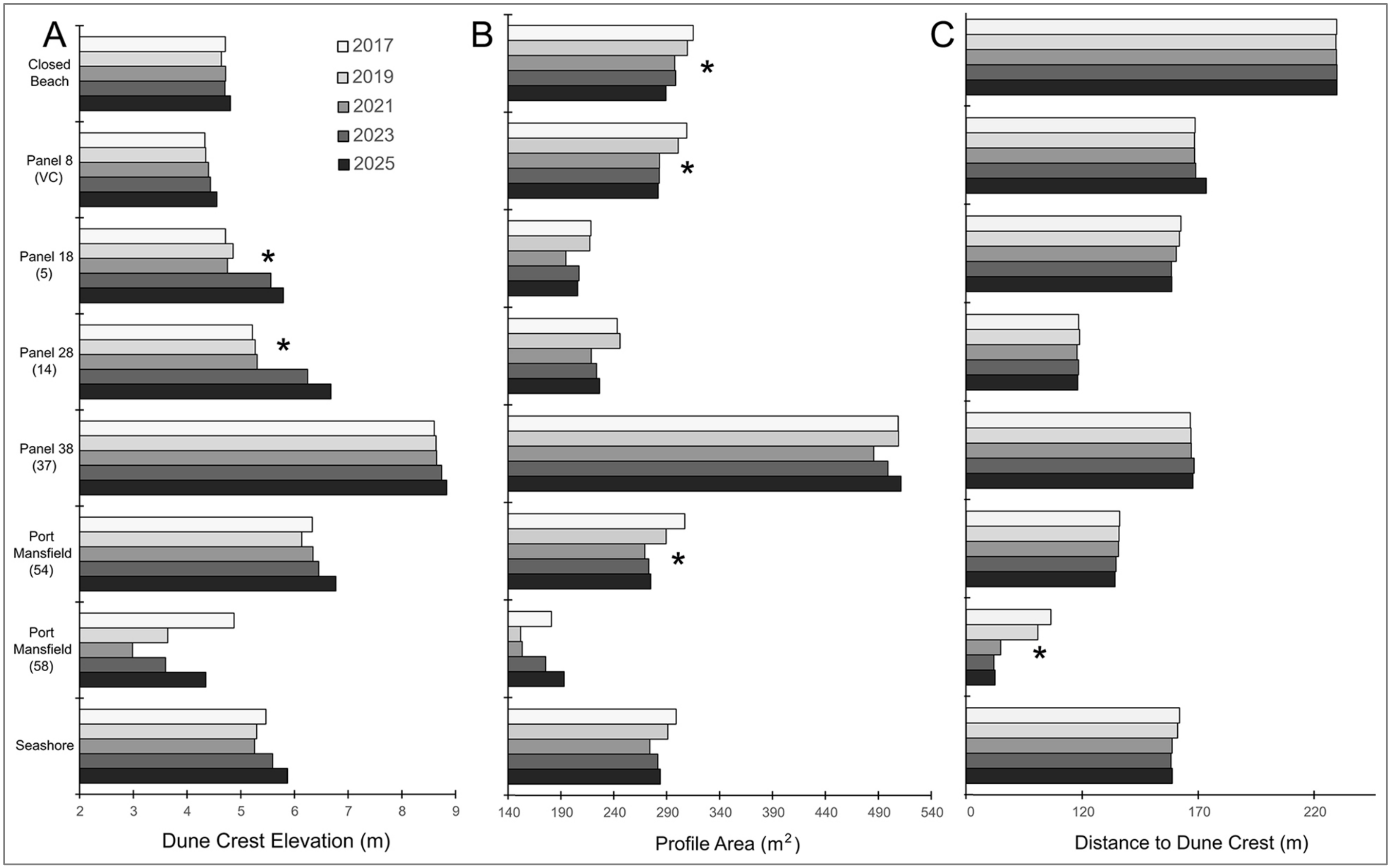

Figure 11. Graph showing group averages by year for: Dune crest elevation, Distance to dune crest, and Profile area. All measurements are in meters and height values are referenced to NAVD 88. The group label is related to the Network's monitoring panels, e.g., "Panel 8", while the other group names are related to park areas of high interest. The most centrally located mile marker among the group is in parenthesis. An asterisk is shown for groups demonstrating a significant change. Note that results for Distance to 0.0 are not included in this figure due to the co-presentation of a continuous shoreline position summary.

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Relationship between Distance to 0.0 and Shoreline Position Measurements

The Network measures shoreline position and dune topography during each geomorphology sampling event, and although the results for each are reported separately, these two datasets are fundamentally related. Specifically, the rates of change calculated for Distance to 0.0 from the topography dataset should correspond to shoreline positional change at those locations along the shoreline survey. Therefore, rates of change calculated for Distance to 0.0 should correspond to shoreline positional change. To evaluate this, a pairwise comparison was performed between the average LRR for shoreline transects located within 100 meters (328 feet) of topography transects, and the LRR for Distance to 0.0. As expected—given the similarity in measurement types—a strong linear relationship was observed (Figure 12). This suggests the LRR rate derived from shoreline data can serve as a relatively continuous proxy for Distance to 0.0 for the entire seashore.

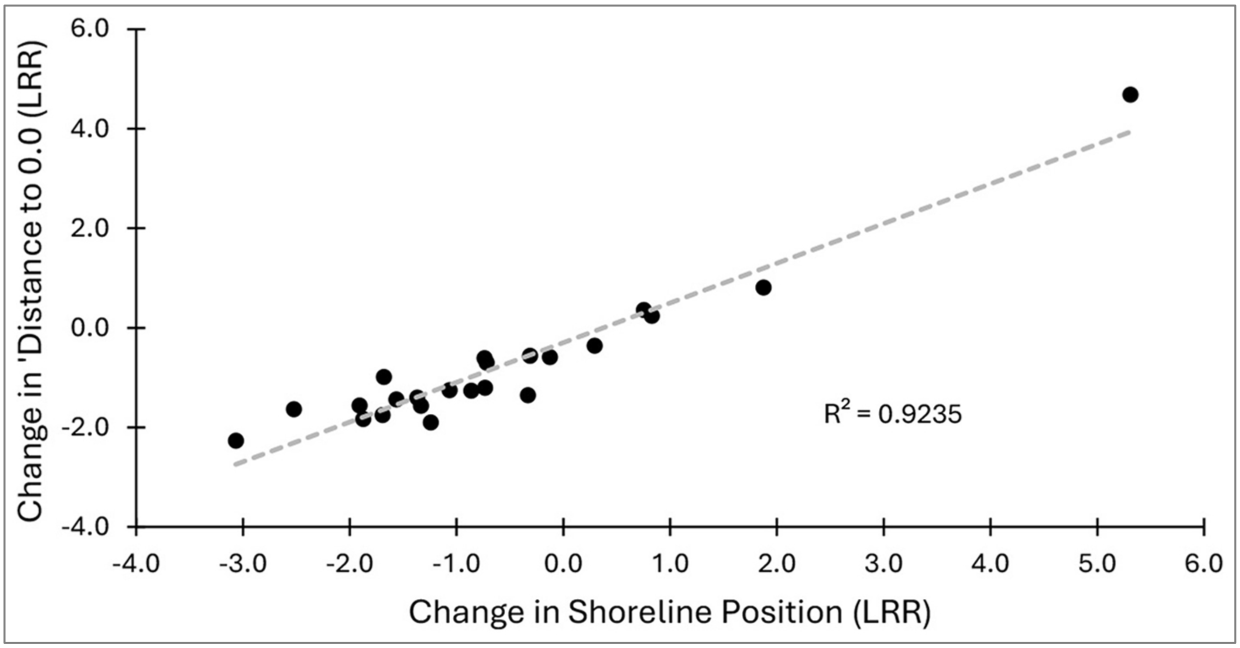

Figure 12. Scatterplot comparing Change in Distance to 0.0 (LRR) and Change in Shoreline position (LRR).
NPS / GULN

Statistics on Distance to 0.0 revealed a significant negative slope of −1.4 meters (−4.6 ft)/year at Closed Beach and a positive slope of 1.6 meters (5.2 ft)/year in the lower Port Mansfield group (SM 3).

Context for Interpreting Shoreline Positional and Topographic Change

As stated in the previous report by Bracewell and Carlson (2024), much of the variation in shoreline change rates can be attributed to beach slope. The beaches are relatively flat at the northern and southern ends of the seashore—specifically at Closed Beach and Port Mansfield—while the central section of the island features significantly steeper slopes (Figure 13A).

As shown in Figure 13B, maximum dune elevations within the foredune complex range from just over 1 meter (3.3 ft) to 13 meters (42.7 ft). The highest foredunes are located between Mile Markers 20 and 25, where the average maximum height approaches 8 meters (26.2 ft). In contrast, the lowest dunes are found at Closed Beach (USGS 2020).

Beaches adjacent to high foredunes generally exhibit steeper slopes, reflecting the interrelated nature of the foredune ridge, beach, and nearshore bathymetry. An exception to this pattern occurs between Mile Markers 5 and 15, where the island narrows from the north and features a high foredune ridge and gently sloping beaches.

The relationship between beach slope and shoreline position is important for interpreting change, as small fluctuations in water level can significantly impact the horizontal displacement of the high tide swash line—particularly where beach slopes are shallow. To accurately illustrate the range of beach slopes along the seashore, slope values from a digital elevation model were sampled into regularly spaced points along shoreline monitoring transects. The results were summarized to produce 0.01, 0.5, and 0.99 percentile values, which correspond to slopes of 1.7°, 3.1°, and 8.4°, respectively (Figure 14; USGS 2020). In Figure 14, we observe that a 0.5-meter (1.6 ft) change in elevation on a shallow 1.7° slope results in approximately 16.8 units of horizontal displacement, while the same change on the steeper 8.4° slope results in only 3.4 units.

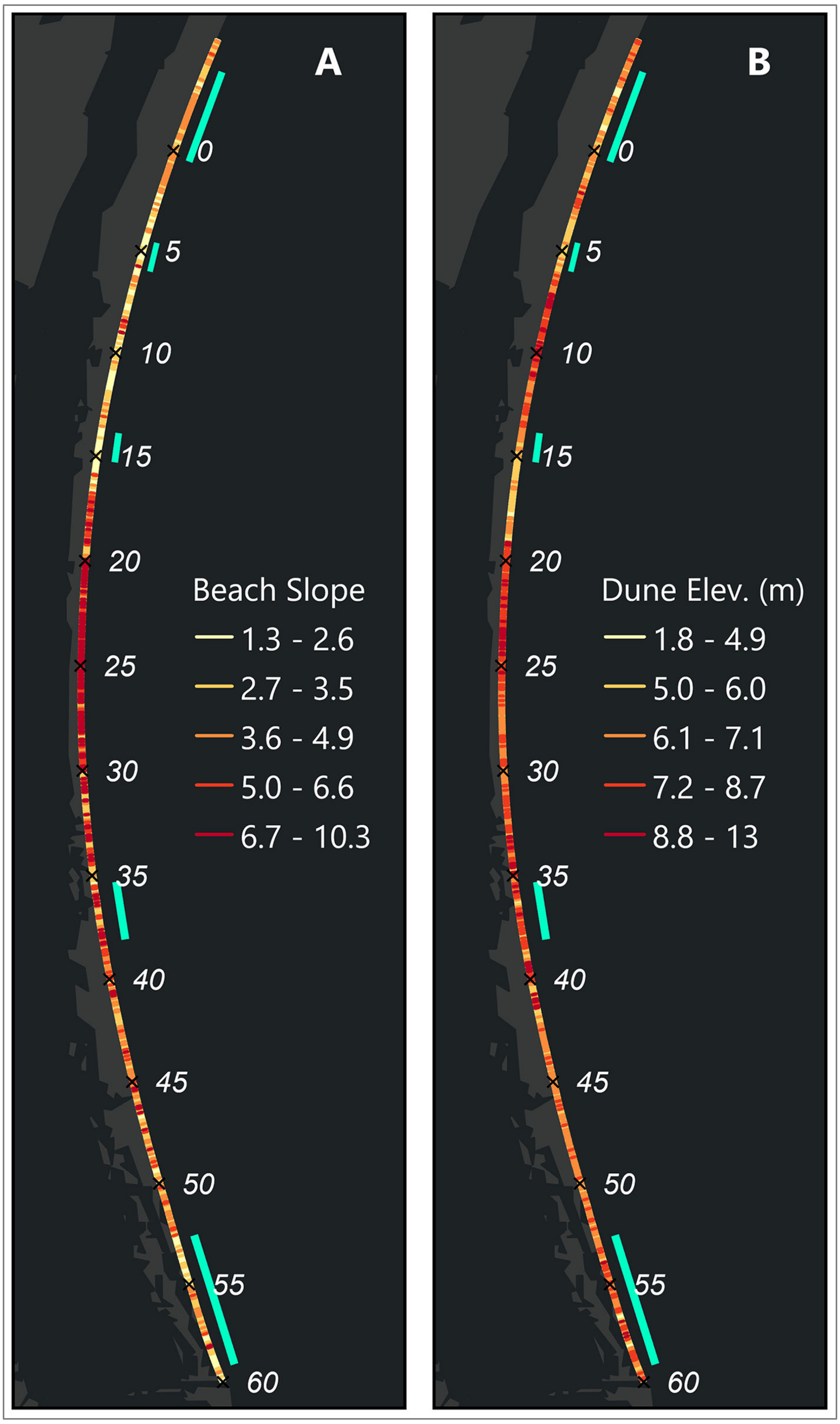

Figure 13. Panel A shows beach slope and Panel B shows foreshore dune elevations; these figures use the same virtual cross-shore transects as the shoreline position datasets. The cyan block that is seaward of the transects shows the extent of topographic monitoring transects. Both slope and elevation were calculated using a 2018 LiDAR Digital Elevation Model (DEM) for the Padre Island National Seashore Gulf seashore (USGS 2020). The darker/redder hues represent a steeper slope in A or taller foredunes in B.

NPS / GULN

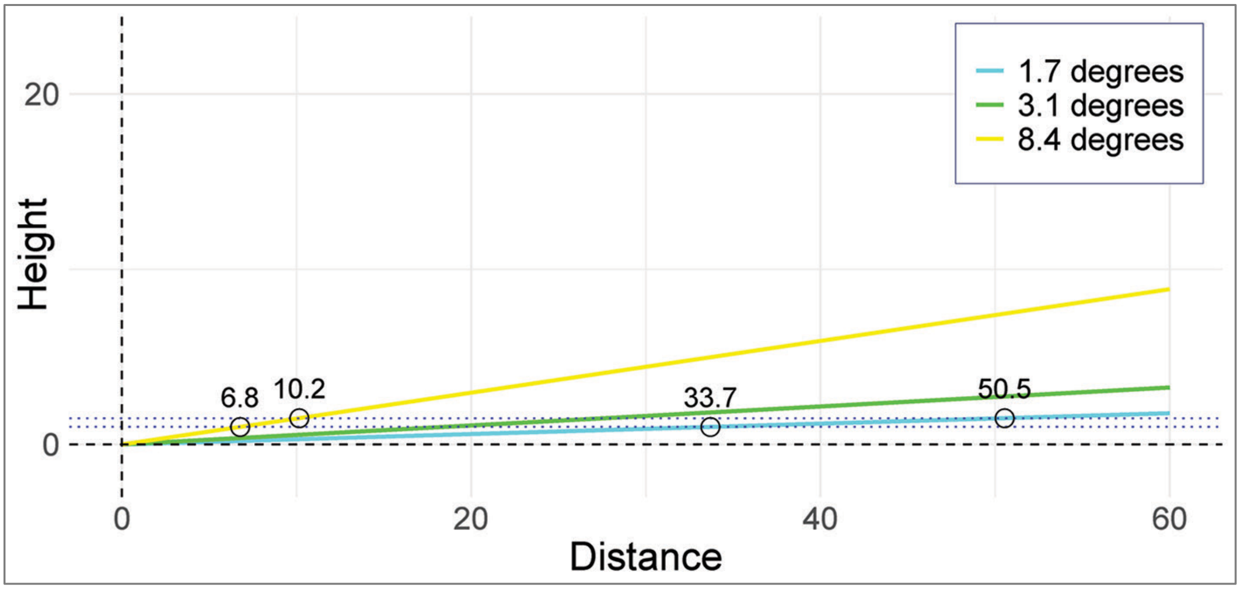

Figure 14. Graph shows the relationship between horizontal displacement associated with variation in water level. The two horizontal dotted lines at 1 and 1.5 height units represent a change in water level of 0.5.

NPS / GULN

Conclusions

Over the relatively short duration of the Network's geomorphology monitoring project at Padre Island National Seashore, dunes have increased in height while simultaneously losing profile area. Shoreline position has retreated at a slightly higher rate than long-term historical averages. A significant trend in profile area loss is evident among transect groups at Closed Beach, where much of the park's infrastructure—such as the headquarters buildings and the Visitor Center—is located. The rate of shoreline retreat in this area is also relatively high, occurring on a beach with a shallow slope, where even small changes in water level can result in high horizontal displacement distances.

Despite notable losses in both profile area and shoreline position at Closed Beach, dune crest elevations and positions have remained stable, suggesting the persistence of a robust geomorphic barrier to storm impacts.

To help offset rapid shoreline retreat at the far southern end of the seashore, a beach nourishment project conducted between late 2019 and early 2021 placed over 1 million cubic yards of sediment within approximately 0.5 miles (0.8 kilometers) of the northern Mansfield Jetty. Although the placement zone was discrete, longshore currents have transported sediment farther north, resulting in general shoreline advance within the southernmost 2.5 miles (4.0 kilometers) of the park.

Recommendations for Future Work

A great deal of systematic work has been conducted to assess shoreline position changes over many decades (TX GLO 2024; Himmelstoss et al. 2017). However, the long-term context for topographic monitoring remains limited, despite the availability of high-resolution digital elevation models (DEMs) derived from LiDAR data since 2000. This underscores a specific need to harness existing elevation datasets to extend the temporal record of topographic change, enabling recent findings to be placed within a broader geomorphic context and interpreted more accurately.

A longer time series would also support topical investigations into key processes such as variations in foreshore dynamics, the formation and loss of incipient dunes, and the cycles, migrations, or other geomorphic mechanisms that create pinch points along the beach.

In the spring of 2027, we plan on adding topographic monitoring transects both updrift and downdrift of Closed Beach to provide further insight and to better contextualize the geomorphic processes affecting park infrastructure. Monitoring transects might also be added in areas where pinch points are a recurring concern for down-island access as this is a perennial concern for park managers.

This is the fourth report in a series of biennial assessments focused on monitoring shoreline and topographic change at Padre Island National Seashore. Geomorphology surveys and reporting at Padre Island National Seashore will resume in 2027. It is anticipated that future reports will benefit from the accumulation of datasets, enabling improved interpretation of measurement variability attributed to geomorphic differences (e.g., slope), as well as weather, seasonal, and tidal influences.

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