Galveston Island State Park Geoenvironmental Atlas

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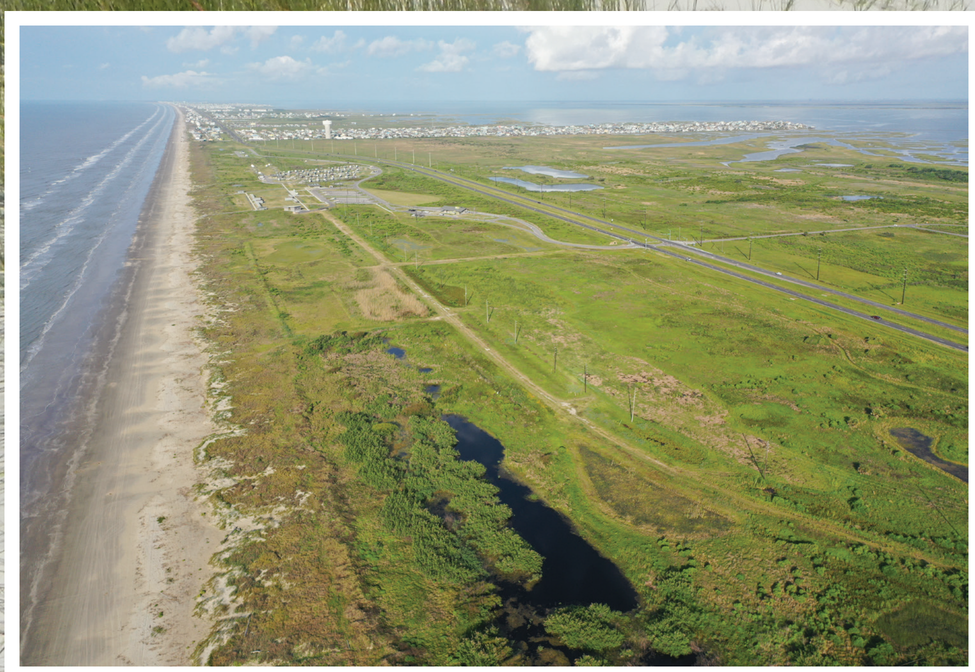

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by

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Geoenvironmental Atlas

Researchers at the Bureau of Economic Geology at The University of Texas at Austin (Bureau) have created a geoenvironmental atlas of Galveston Island State Park that highlights the geologic, geomorphic, and wetland features, and coastal hazards unique to the park. This atlas is comprised of products that help park visitors, staff, and coastal resource managers visualize and define the geologic and geomorphologic characteristics that make Galveston Island State Park unique. The atlas enables visitors of the park to learn more about its natural environment or about hazards that impact the park. This atlas is built on concepts presented in the Padre Island National Seashore guidebook (Weise and White, 1980); Down to Earth at Mustang Island, Texas (Raney and White, 2002) and the Powderhorn Ranch Geoenvironmental Atlas (Paine and others, 2018).

The atlas also allows park staff and coastal resource managers to assess coastal natural hazards like shoreline change and susceptibility to storms and sea-level rise. It can be used to help understand the natural framework of the park and surrounding area, for example, how wetland environments have changed through time. They support the Texas Parks and Wildlife Department's mission to ensure that coastal parks are responsibly managed and conserved to ensure that all visitors will be able to enjoy the park for generations to come.

Galveston Island

Galveston Island is a sandy barrier island that is approximately 30 miles long and up to 3 miles wide (Fig. 1). Barrier islands are long narrow islands parallel to a mainland coast that are built up by the deposition of sand. Barrier islands protect the mainland and estuary (body of water between the island and mainland) from erosion and storms. Galveston Island separates the Gulf of Mexico from West Bay, which is part of the Galveston Bay system. The island was formed through processes related to waves, tides, storms, and sea-level rise, and these forces continue to change it today. The types of environments on the island are controlled by the height above or below sea level and whether they are on the Gulf or bay side of the island.

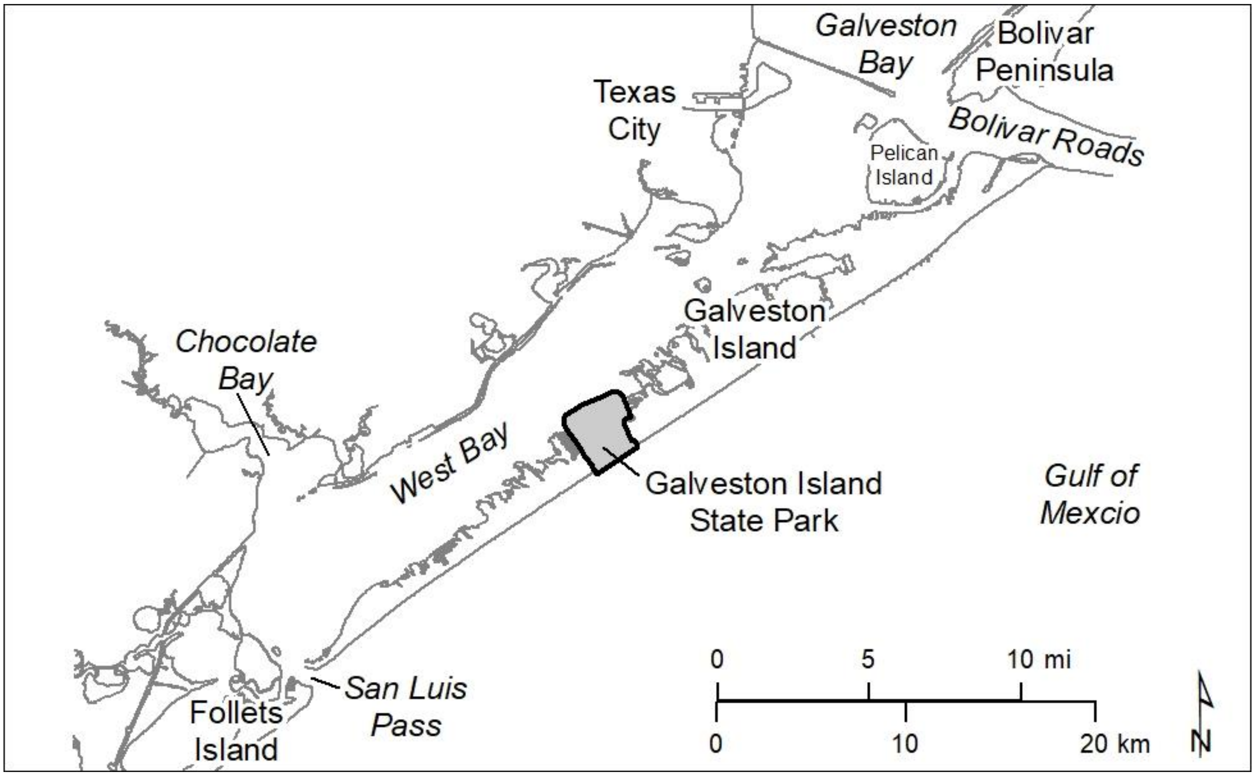

Figure 1. Galveston Island State Park location map.

Galveston Island State Park is a 2,000-acre section of the barrier island that opened for public use in 1975 (Figs. 1 and 2). It provides visitors with a variety of recreational activities from enjoying Gulf of Mexico beaches to paddling trough wetlands at the margin of West Bay. The park also protects the natural habitat found on the island, providing a place where visitors can safely explore and learn about these valuable resources.

Galveston Island State Park 3D Virtual Field Trip

Bureau researchers used a DJI Mavic 2 Pro quadcopter unmanned aerial vehicle (UAV) to collect imagery along the Gulf (including the beach and foredune system) and bay shorelines at Galveston Island State Park. Twenty-one missions were flown on May 1 and 2, 2023 for a total of 4,817 bayside and 541 shoreline images captured, resulting in 530 and 55 ha imaged. GPS points were collected throughout the park, including 35 on the bay side and 11 on the shoreline, to improve registration of the images. A digital terrain model (DEM) and orthomosaics were produced from this UAV survey. The imagery and DEM were used to create a three-dimensional (3D) model and virtual field trip that highlights the habitats found within the park (Fig. 2). The 3D field trip can be found at: https://www.beg.utexas.edu/txcoastalsp3d/.

Figure 2. Galveston Island State Park map with virtual field trip stops labeled.

STOP 1. DUNE & SWALE: This view to the southwest looks along the sandy beach, dunes, and swales (Fig. 3). Landward of the main dune ridge in Galveston Island State Park are linear, low lying depressions, called **swales**, that lie between older dune ridges. The ridges and swales run parallel to the shoreline. Brackish water ponds and wetlands are commonly found in the swales.

Figure 3. View looking southwest along the dune ridge. The Gulf of Mexico is to the left and a water-filled swale is visible landward (right) of the dune ridge.

STOP 2. BEACH & DUNE: Along the Gulf of Mexico is the sandy beach where waves and currents interact the island and the dunes that collect windblown sand. A **beach** is the gently sloping shore of a body of water that is washed by waves or tides. The lower part of the beach that is regularly covered and uncovered by the rise and fall of tides is called the **forebeach**. The **backbeach** lies between the high-water line and the upper limit of shore-zone processes (start of dune vegetation). This zone is dominated by wind-driven processes but can be affected by waves or covered by water during severe storms or unusually high tides.

Dunes start at the landward edge of the beach. The **foredune** is a coastal dune at the landward margin of a beach, typically stabilized by vegetation. **Coppice dunes** are small dunes formed by the accumulation of wind-blown sand on the backbeach and anchored by vegetation (Fig. 4). With an adequate sediment supply these mounds can grow larger, become continuous, and form a new foredune system.

Figure 4. Vegetated coppice dunes forming at the landward edge of the beach.

STOP 3. VEGETATED BARRIER FLAT: The **vegetated barrier flat** is the low-relief plain that extends from landward of the fore-island dune system to the bay margin on a barrier island (Fig. 5). It is covered with coastal prairie vegetation, mostly grasses and other low vegetation with sparse groves of live oak (mottes). There are several depressions scattered across the barrier flat that host freshwater to brackish water ponds and marshes. The barrier flat is the most extensive geoenvironment present on Galveston Island, and is where most development has occurred. Galveston Island State Park preserves the vegetated barrier flat in its natural state, allowing visitors to observe its flora and fauna.

Figure 5. Fresh to brackish water pond on the vegetated barrier flat. An oak motte is visible in the distance.

STOP 4. TRANSITION ZONE: Transition zone from the barrier flat to the low-lying bay margin wetland environments (Fig. 6). The **bay margin** is the area adjacent to the bay or other body of estuarine waters that is influenced by tidal waters. Estuaries and bay margin habitats provide a safe haven and protective nursery for small fish, shellfish, migrating birds, and coastal shore animals. Bay margin environments protect our health and well-being by improving water quality (filtering nutrients for the bay waters) and reducing mainland flooding and erosion by absorbing the impact of coastal storms. Because water depths are so shallow and relief is so low, a small change in water level may cause a large change in the amount of land that is either covered by water or exposed to the air. Winds, tides, and storms can cause water levels to rise or fall by a few feet.

Figure 6. Transition zone from the vegetated barrier flat with ponds (upland) on the right of the image to the lower lying bay margin.

STOP 5. BAY MARGIN: Wetland habitats found within the bay margin include salt marsh, tidal flats, bay beaches and berms, and grassflats (Fig. 7). **Salt marsh** is a saturated, poorly drained area, intermittently or permanently flooded with salt water and having salt-tolerant vegetation. **Tidal flats** are nearly horizontal barren tracts of unconsolidated sediment that are alternately covered and uncovered by the tide. Sometimes tidal flats are covered by a layer of algae called an algal mat. Algal mats develop on flats that alternate between emergent (a falling sea level) and submergent (a rising sea level) in fairly regular cycles. **Grassflats** are areas adjacent to the bay shoreline where submerged aquatic vegetation grows.

Figure 7. View of tidal flats (barren areas) and salt marsh on the bayside of Galveston Island State Park.

STOP 6. MARSH RESTORATION: The bay shoreline in Galveston Island State Park has retreated significantly over the last 100 years, leading to loss of critical bay margin wetlands. Several marsh restoration projects have taken place to mitigate wetland loss. A terrace-style marsh restoration project was completed in 2000. The terraces were created by dredging bay sediments and forming open square shaped berms with intertidal elevations (waffle like appearance, Fig. 8). The berms were then planted with marsh plants by hand. In 2017 another wetland restoration project took place replacing the terrace grids with “marsh mounds" (Fig. 8). These mounds (circular structures) create an ideal elevation for various marsh vegetation to thrive. A breakwater was also constructed to protect the new marsh restoration project and the state park shoreline. Breakwaters are a rock structure that is placed in open water to protect the shoreline by diminishing the effects of tides, currents, waves, and storms.

STOP 7. WEST BAY: A bay is a body of water that is partly enclosed by land with open access to an ocean. An **estuary** is a type of bay, a body of water partly enclosed by land that receives freshwater from rivers and streams and saltwater from the ocean. The mixing of freshwater and saltwater is the key to defining an estuary. West Bay (Fig. 8) is part of an interconnected estuary system that is composed of Galveston, Trinity, East, and West Bays and other minor bays. Saltwater enters the estuary through Bolivar Roads (between Galveston Island and Bolivar Peninsula) and San Luis Pass (between Galveston Island and Follets Island). Freshwater is supplied by the Trinity River at the head of Trinity Bay and San Jacinto River in the upper reaches of Galveston Bay. Compared to the river that flows into the estuary or the open ocean, the bay environment is typically very calm, except during storms.

Figure 8. Marsh restoration projects along the West Bay shoreline of Galveston Island State Park.

Hurricane Ike

Bureau scientists study beach and dune systems to understand how major storms like hurricanes affect barrier islands. Working with students from Ball High School, data is collected from sites on Galveston Island, including one in the state park, that documents changes to the beach and dune system due to tropical cyclones and post-storm recovery. This type of data is vital for scientists, decision makers, and coastal planners in understanding beach and dune dynamics on Galveston Island and elsewhere along the Texas coast. The state park provides an opportunity to examine the beach and dune system in a natural setting with minimal human impact compared to the developed parts of the island.

Hurricane Ike struck the upper Texas coast on September 13, 2008. Ike made landfall on the eastern end of Galveston Island as a large and powerful category 2 hurricane. Sustained winds were nearly 110 mph, and storm surge reached at least 4 m (13 ft) inundating the barrier island and pushing water miles inland. The storm surge associated with Hurricane Ike caused erosion around the entire Gulf of Mexico. Galveston Island experienced significant beach and dune erosion, as well as extensive damage to property and infrastructure. Before Ike's landfall, Galveston Island State Park had a wide beach and healthy vegetated dune (Fig. 9A). After Ike's landfall the dune system at Galveston Island State Park was completely destroyed, the shoreline moved 53 m (174 ft) landward at the monitoring site, and the vegetation line moved 56 m (184 ft) landward (Fig. 9B).

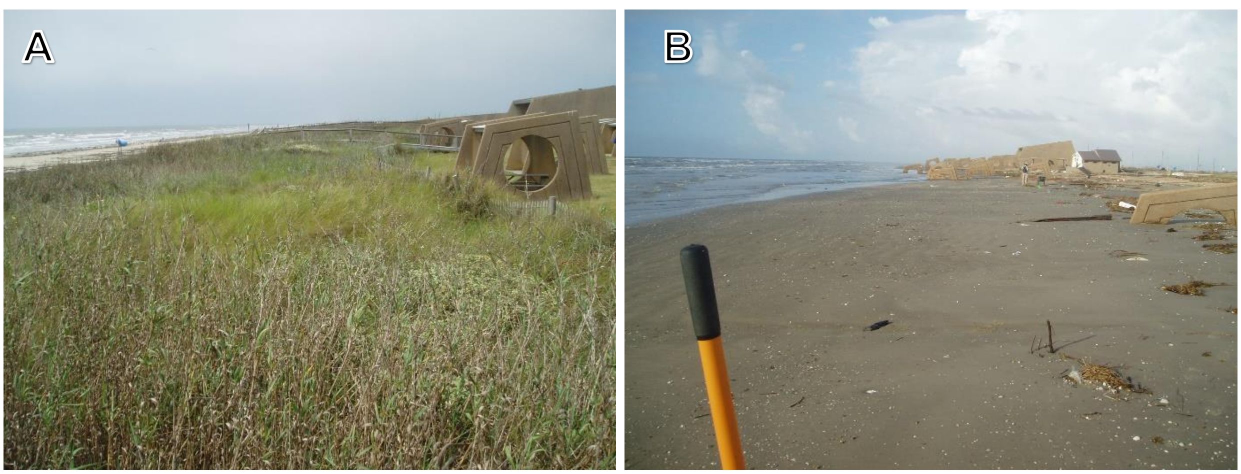

Figure 9. A) Foredunes and vegetation in Galveston Island State Park on April 23, 2008. View is toward the southwest with the Gulf of Mexico along the left edge of photo. B) Galveston Island State Park after Hurricane Ike. The photo was taken on October 7, 2008. Notice that the dune system has been completely destroyed and the damage to the picnic pavilions, restroom structures, and Visitor's Center.

An interactive 3D model developed for the Texas High School Coastal Monitoring Program (THSCMP) demonstrates two manners in which scientists interpret beach and dune changes and recovery from tropical cyclones. One manner is using beach profile data collected by students participating in THSCMP. The second approach is using elevation data to visualize shoreline and volume changes. The interactive 3D coastal model created to examine erosion and recovery on the Texas coast following Hurricane Ike in 2008 can be accessed at https://www.beg.utexas.edu/visualizations/3d-coastal-model/.

Geoenvironmental Atlas Interactive Data Viewer

Bureau researchers have collected and created several datasets for the web-based data viewer component of the geoenvironmental atlas. The state parks map viewer is a custom-made Angular framework web app. It uses the ArcGIS JavaScript API to provide the map-related user interface elements. The map datasets are served by ArcGIS Enterprise 10.8.1 in a series of map and imagery services. The user interface allows the user to view data related to each park in a 3D viewport similar to that of Google Earth. It allows the user to toggle individual layers on and off for clearer viewing, and displays the terrain in true 3D, using data collected and processed by the Bureau (https://coastal.beg.utexas.edu/glostateparks/).

Datasets compiled for this atlas include:

1. Texas Parks and Wildlife Department (TPWD) State Park boundary.
2. Aerial photography from 1930, 1956, 2020 and 2022.
3. High-resolution topographic data from multiple Bureau lidar surveys, 2015 data captured by Surveying And Mapping, LLC (SAM) for Galveston Island State Park, and 2018 lidar data collected for the Texas StratMap program.
4. Historical and current bay and Texas Gulf coast shoreline positions mapped from georeferenced aerial photography and base maps.
5. Long-term and recent shoreline movement rates for the Gulf of Mexico and bay shorelines.
6. Beach and dune volumetric data from a 2019 Bureau lidar.

7. Geologic map.
8. Historical and current wetland status mapping.
9. Maps of environmental geology, physical properties, environments and biologic assemblages, and active processes from the Bureau's Environmental Geologic Atlas of the Texas Coastal Zone publication.
10. Shoreline and vegetation line positions, beach profiles, and photography from Texas High School Coastal Monitoring Program field trips.

The purpose of the online data viewer and this atlas is to convey historical and current knowledge of the surface at Galveston Island State Park to the public so that the best and most complete data can be used to educate visitors about the environments present at the park and to influence management decisions that ensure responsible stewardship and future use.

Park Boundary

The boundary of Galveston Island State Park was adapted from a geographic information system (GIS) shapefile containing statewide polygon boundary data representing lands owned or managed by the State Parks Division of Texas Parks & Wildlife Department (TPWD, https://tpwd.texas.gov/gis/). The park boundary file was used to clip larger datasets (topography, shoreline database, wetland maps, etc.) so that the data presented in the viewer and this guide only pertain to Galveston Island State Park.

Historical and Recent Photography

The Bureau has Tobin Research, Inc. 1930s and 1950s quadrangle photomosaics as part of their historical aerial photo collection. The United States Geological Survey (USGS) subdivides the United States by using latitude and longitude lines to form the boundaries of four-sided figures called "quadrangles". A common quadrangle size for mapping purposes is the 7.5-minute quadrangle, meaning 7.5 minutes of latitude by 7.5 minutes of longitude. Galveston Island State Park falls within the 7.5-minute quadrangle called Lake Como. A photomosaic is several images pieced together to create an image of a larger area, in this case 7.5-minute quadrangles. For this project, Bureau researchers scanned the 1930 and 1956 Lake Como quadrangle at 600 dpi to create a digital image which was then georeferenced to the NAD83 coordinate system. Newer imagery acquired for the project, and used to georeference the photomosaics, includes U.S. Department of Agriculture (USDA) National Agricultural Inventory Program (NAIP) digital imagery photographed during the agricultural growing seasons in 2020 and 2022 (USDA, 2022).

Lidar Data

Numerous topographic lidar datasets were collected to include in the state park atlas, the 3D field trip, and to develop other datasets. Lidar, light detection and ranging, is a remote sensing technique that uses a pulsed laser to measure distance from the instrument to the Earth’s surface. The Bureau owns and operates an airborne lidar system that has been used to collect precise elevations from the Texas coast. Some of the Bureau lidar datasets include the entire island from the Gulf of Mexico shoreline to the bay shoreline, but most only include a swath along the beach/dune system. The Bureau has lidar data Galveston Island State Park from 2000, 2001, 2002, 2003, 2005, 2008, 2010, 2011, 2012, 2017, and 2019. Additional lidar datasets include 2015 data captured by Surveying And Mapping, LLC (SAM) for Galveston Island State Park and an airborne lidar survey flown by Fugro USA Land, Inc. in 2018 as part of the Texas Strategic Mapping (StratMap) program. The SAM and StratMap data were downloaded from the Texas Geographic Information Office (TxGIO, formerly TNRIS) Data Hub (https://data.tnris.org/). A high resolution (1-m) digital elevation model constructed from the airborne lidar data collected for StratMap is included in the data viewer (Fig. 10). A digital elevation model, or DEM, is a representation of the Earth’s surface at the time a dataset has been collected. The 2018 StratMap dataset is the most recent that covers the entire park. The Bureau recently completed a full coast lidar survey that covers the entirety of Galveston Island from the Gulf shoreline to West Bay. The 2024 DEM will be added to the online viewer once the data has been processed.

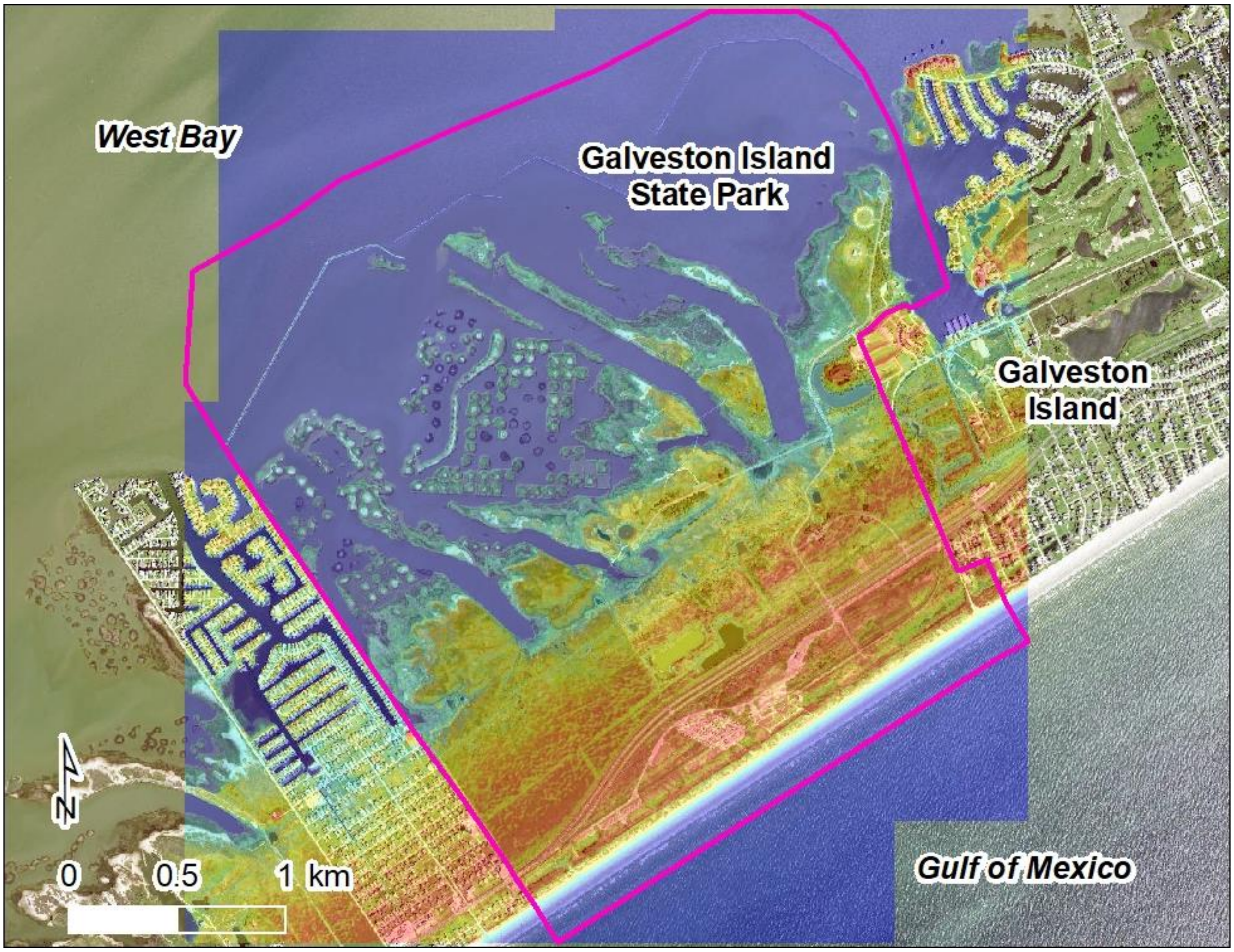

Figure 10. High-resolution (1-m grid cell size) digital elevation model (DEM) of Galveston Island State Park, created from the 2018 StratMap lidar data. The pink line is the state park boundary that was modified from TPWD and used to clip larger datasets.

Shorelines

Shorelines are the dynamic boundary between land and water. The Bureau maintains a digital database that contains numerous shoreline positions for the Gulf of Mexico coastline and select Texas bays that are used to calculate rates of shoreline change. These shorelines come from numerous sources including photography, GPS, and lidar. Shorelines used in older Bureau studies were mapped directly on aerial photomosaics (quadrangles) then optically transferred to 1:24,000 scale, 7.5-minute USGS topographic base maps (Caudle and Paine, 2024; Paine, Caudle, and Andrews, 2021). With the advent of ArcGIS, those paper maps were scanned to create a digital file, then imported into ArcGIS, georeferenced in NAD27 (datum of the USGS topographic maps), and transformed into the NAD83 coordinate system. The shoreline positions were then digitized in ArcGIS. The 1995, 2007, parts of the 2016, 2020, and 2022 shorelines were mapped digitally within GIS by digitizing the wet beach/dry beach boundary as depicted on high-resolution, georeferenced aerial photographs. The 1996 Gulf shoreline was surveyed using differentially corrected GPS data acquired from a GPS receiver mounted on a motorized vehicle. Shoreline positions were extracted from lidar data collected in 2000, 2010-2012, parts of 2016, and 2019.

For this project, the original paper maps were again scanned at 600 dpi to create a digital image, georeferenced in NAD27, and transformed into the NAD83 coordinate system. The shoreline positions on the paper maps were compared with the shorelines that were contained in the Bureau database. In some instances, particularly along the bay shorelines, positions were revised if they did not match with the database. In other instances, older shorelines that were notated on the paper maps were not included in the digital database. They were digitized and added to the data for the park. The georeferenced 1930 and 1956 photos were also used to verify shoreline positioning. In areas where there were differences between the paper maps and the georeferenced photographs, the shoreline position from the photomosaics were digitized in ArcGIS. By using directly georeferenced imagery, errors can be eliminated that can be introduced through the transfer to paper maps, georeferencing in the older NAD27 coordinate system, and transformation to the newer NAD83 coordinate system. Table 1 lists the shoreline vintages that have been assembled to include in the data viewer.

Galveston Island State Park has approximately 2.6 km of Gulf of Mexico shoreline. These shorelines are highly susceptible to erosion by non-storm waves, storm surge and storm waves, and relative sea level rise. The West Bay shoreline in Galveston Island State Park is characterized by back-barrier marsh and tidal flats. Bay-margin marshes and tidal flats have low elevation, minimal slope, muddy sand or sandy mud substrate, and dominant marsh vegetation with interspersed tidal flats. These shorelines are highly susceptible to erosion by non-storm waves and to land loss by submergence related to relative sea level rise. They have a low susceptibility to erosion related to storm surge and storm waves because they are inundated before storm passage. The position of the bay shoreline has experienced significant erosion between the 1850s and 2022 (Fig. 11).

Table 1. Shorelines included in the data viewer. GOM stands for Gulf of Mexico shoreline and Bay stands for West Bay shoreline

Shoreline Type	Year	Source
GOM & Bay	1851	U.S, Coast Survey Topographic Map (NOAA)
Bay	1930	black & white mosaiced photography (Tobin Research, Inc.)
GOM	1934	black & white mosaiced photography (Tobin Research, Inc.)
GOM & Bay	1956	black & white mosaiced photography (Tobin Research, Inc.)
GOM	1965	black & white aerial photography (GLO)
GOM	1974	black & white aerial photography (GLO)
GOM & Bay	1982	false-color infrared aerial photography (GLO)
Bay	1995	aerial photography (USGS)
GOM	1996	GPS
GOM	2000	Bureau lidar
Bay	2002	Bureau lidar
GOM	2007	TOP imagery
GOM	2010	Bureau lidar
GOM	2011	Bureau lidar
GOM	2012	Bureau lidar
GOM	2016	USACE lidar & NAIP imagery
GOM	2019	Bureau lidar
GOM & Bay	2022	NAIP imagery

Shoreline Movement

Texas coastal shorelines include bay and Gulf of Mexico frontage along the barrier islands and mainland shores. In Galveston Island State Park, these shorelines include Gulf beaches, marshes, tidal flats, and bay beaches. Common coastal processes that include wind-driven waves, storm surge and storm waves, and relative sea-level rise contribute to the dynamic nature of these coastal boundaries, leading to shoreline retreat or advance through removal or addition of sediment, or by submergence and emergence. It is important to monitor the movement of these coastal boundaries, determine coastal land loss and gain, and characterize shoreline movement and its potential impact on the varied activities, uses, and functions of coastal land, vegetation, and habitat.

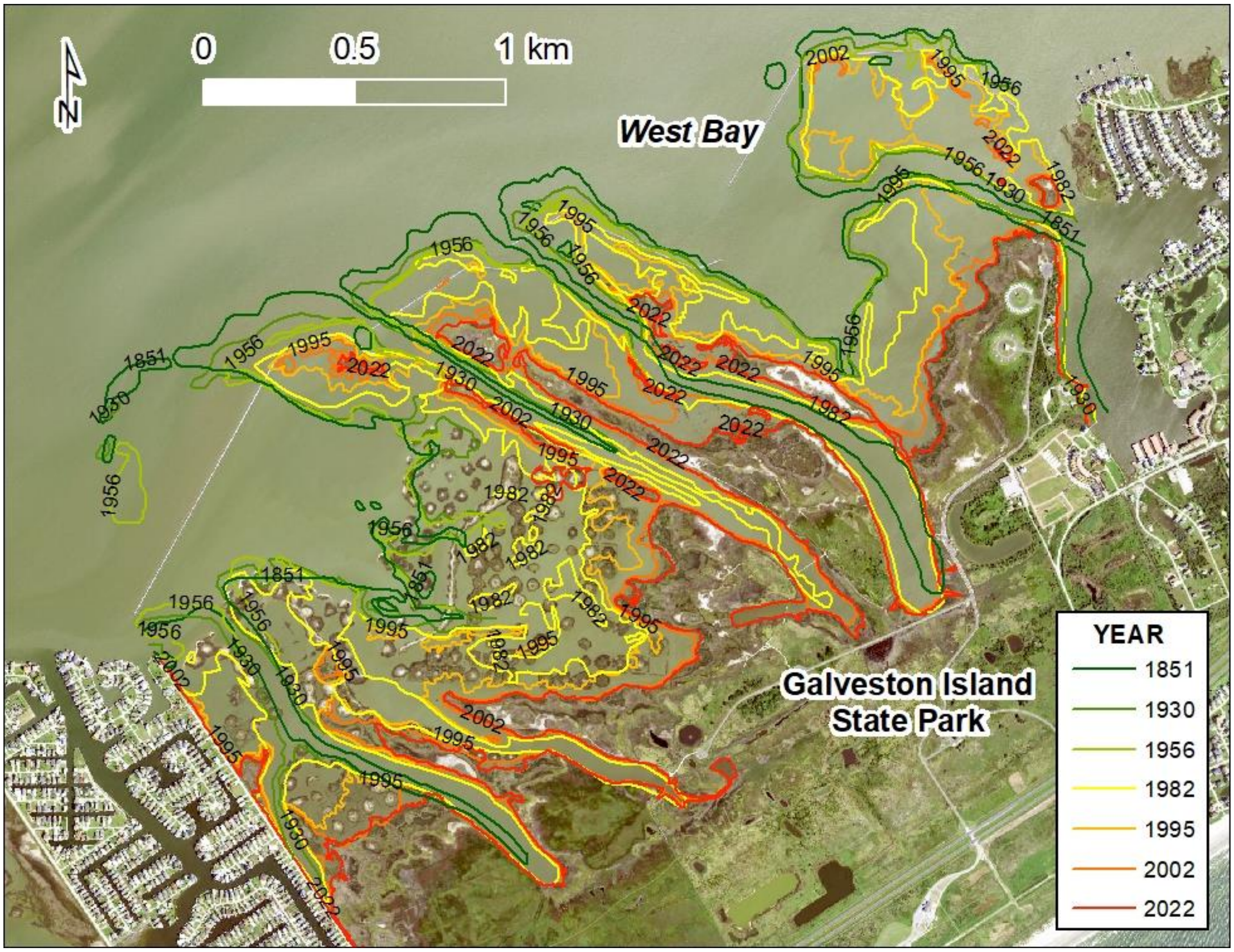

Figure 11. Position of West Bay margin shorelines in Galveston Island State Park between 1851 and 2022. The 2022 shoreline position is mapped along the continuous coastline. It does not include the shoreline positions around the wetland restoration marsh mounds.

Bureau researchers conduct studies that update rates of shoreline movement; characterize shoreline types; and access shoreline vulnerability to sea-level rise, non-storm waves, and storm surge and waves. The most recent update to Gulf of Mexico shoreline movement for the entire Texas coast was completed through 2019 (Paine, Caudle, and Andrews, 2021). The Galveston Bay system (including West Bay) was the subject of a recently completed study that determined longer-term net movement rates by comparing shoreline positions from 1930 and 1956 with those from 2022, and a more recent net shoreline movement rate by comparing shoreline positions from 1982 to those from the 2022 data (Caudle and Paine, 2024). For this project, long-term and short-term Gulf shoreline change rates were calculated based upon the shorelines assembled for this project. The bay shoreline movement rates included in the data viewer are from the Galveston Bay study (Caudle and Paine, 2024).

Calculating rates of shoreline movement starts with importing shorelines into an ArcGIS geodatabase, then creating a baseline from which to cast shore-parallel transects using the GIS-based extension software Digital Shoreline Analysis System (DSAS v. 5.1; Himmelstoss and others, 2021). Transects were cast at 25-m intervals along Gulf of Mexico shorelines and 50-m intervals along the bay shoreline. Rates of change and associated statistics for the 1934 to 2022, 1956 to 2022, and 2000 to 2022 periods were calculated using the transect locations and the selected shorelines for the Gulf shoreline. Rates of change and associated statistics for the 1930-2022, 1956-2022, and 1982-2022 periods were calculated for the bay shorelines. The intersection of the transect lines with the latest shoreline was used to create GIS shape files containing the rates, statistics, and period of shoreline change measurements and the measurement transects bounded by the most landward and seaward historical shoreline position for each measurement site. For additional information and details regarding Texas Gulf and bay shorelines and calculating shoreline change rates, see Paine, Caudle, and Andrews, 2021; Caudle and Paine, 2024; as well as the Bureau's Texas shoreline change websites (https://www.beg.utexas.edu/research/programs/coastal/the-texas-shoreline-change-project or https://www.beg.utexas.edu/research/programs/coastal/texas-bay-shoreline-change).

Shoreline change rates for the Gulf of Mexico coast in Galveston Island State Park averages retreat (moving landward) at 1.37 m/yr (4.48 ft/yr) between 1934 and 2022. Between 1956 and 2022 that rate increases to 1.51 m/yr (5 ft/yr) of retreat (Fig. 12). For the most recent monitoring period, 2000 to 2022, the shoreline retreated at a much lower rate, 0.14 m/yr (0.5 ft/yr). According to the most up-to-date movement calculations for the entire Texas Gulf of Mexico shoreline (from Sabine Pass at the Texas/Louisiana border to the Rio Grande at the Texas/Mexico border), the average rate over the longer-term monitoring period (1930s to 2019) is retreat at 1.27 m/yr (4.2 ft/yr), over the intermediate-term monitoring period (1950s to 2019) is retreat at 1.42 m/yr (4.7 ft/yr), and for most recent, short-term monitoring period (2000 to 2019) is retreat at 1.25 m/yr (4.1 ft/yr) (Paine, Caudle, and Andrews, 2021). For these same time periods, Galveston Island shorelines retreated at a low net rate of 0.21 m/yr (0.7 ft/yr) between the 1930s and 2019, averaged a higher rate of retreat of 0.61 m/yr (2 ft/yr) between the 1950s and 2019, but averaged short-term net rates of advance of 0.77 m/yr (2.5 ft/yr) between 2000 and 2019 (Paine, Caudle, and Andrews, 2021). The shoreline in the state park showed higher rates of retreat in both of the longer-term and intermediate time periods than both the Texas coast and Galveston Island. For the most-recent time period, the state park shoreline was stable compared to the average advancement for the whole island and a retreat rate for the entire Texas coast that was similar to the long-term rate.

Shoreline change rates for the West Bay coastline in Galveston Island State Park was dominantly erosional over the three monitoring time periods. The back-barrier island shoreline averaged retreat (moving landward) at 4.28 m/yr (14 ft/yr) between 1930 and 2022. Between 1956 and 2022 the retreat rate increased to 6 m/yr (19.4 ft/yr), and for the most recent monitoring period (2000 to 2022) the shoreline retreated at 7.6 m/yr (25 ft/yr, Fig. 13). This trend mirrored the increasing retreat rates for each monitoring period for the entire Galveston Bay system—which includes Galveston, Trinity, East, and West Bays—although at much lower rates (Caudle and Paine, 2024). During the longest time period, 1930 to 2022, 83% of the measurement sites retreated at an average rate of 0.78 m/yr (2.56 ft/yr). Between 1956 and 2022, 82% of sites retreated at an average rate of 0.99 m/yr (3.25 ft/yr). During the more recent period (1982 to 2022), net shoreline retreat averaged 1.05 m/yr (3.45 ft/yr) for the Galveston Bay system. Along the back-barrier shoreline of Galveston Island shorelines retreated at 1.27 m/yr (4.2 ft/yr) during the longest-term 1930-2022, 2.07 m/yr (6.8 ft/yr) during the intermediate-term of 1956 to 2022, and 1.99 m/yr (6.5 ft/yr) between 1982 and 2022. While the trend in shoreline movement in the entire Galveston Bay system is erosional, with increasing rates of retreat as the monitoring periods get shorter, the shoreline retreat rates in Galveston Island State Park are exceptionally high. This is due to rising sea level flooding the low-lying bay margin environments and the lack of armoring in the state park. The adjacent shorelines have been heavily modified to decrease land loss in those communities.

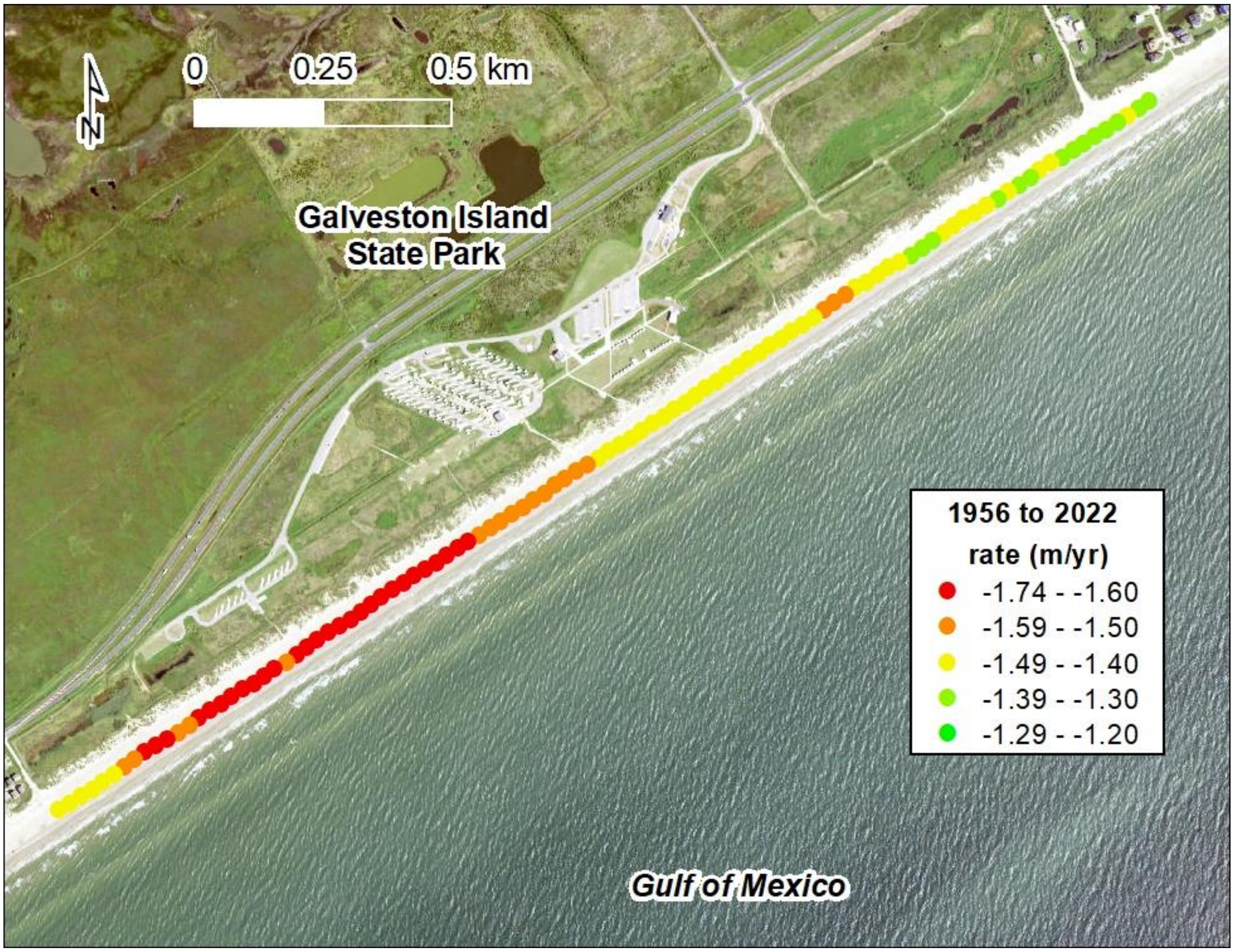

Figure 12. Net rate of intermediate-term movement for the Gulf of Mexico shoreline in Galveston Island State Park calculated from shoreline positions from 1956 and 2022.

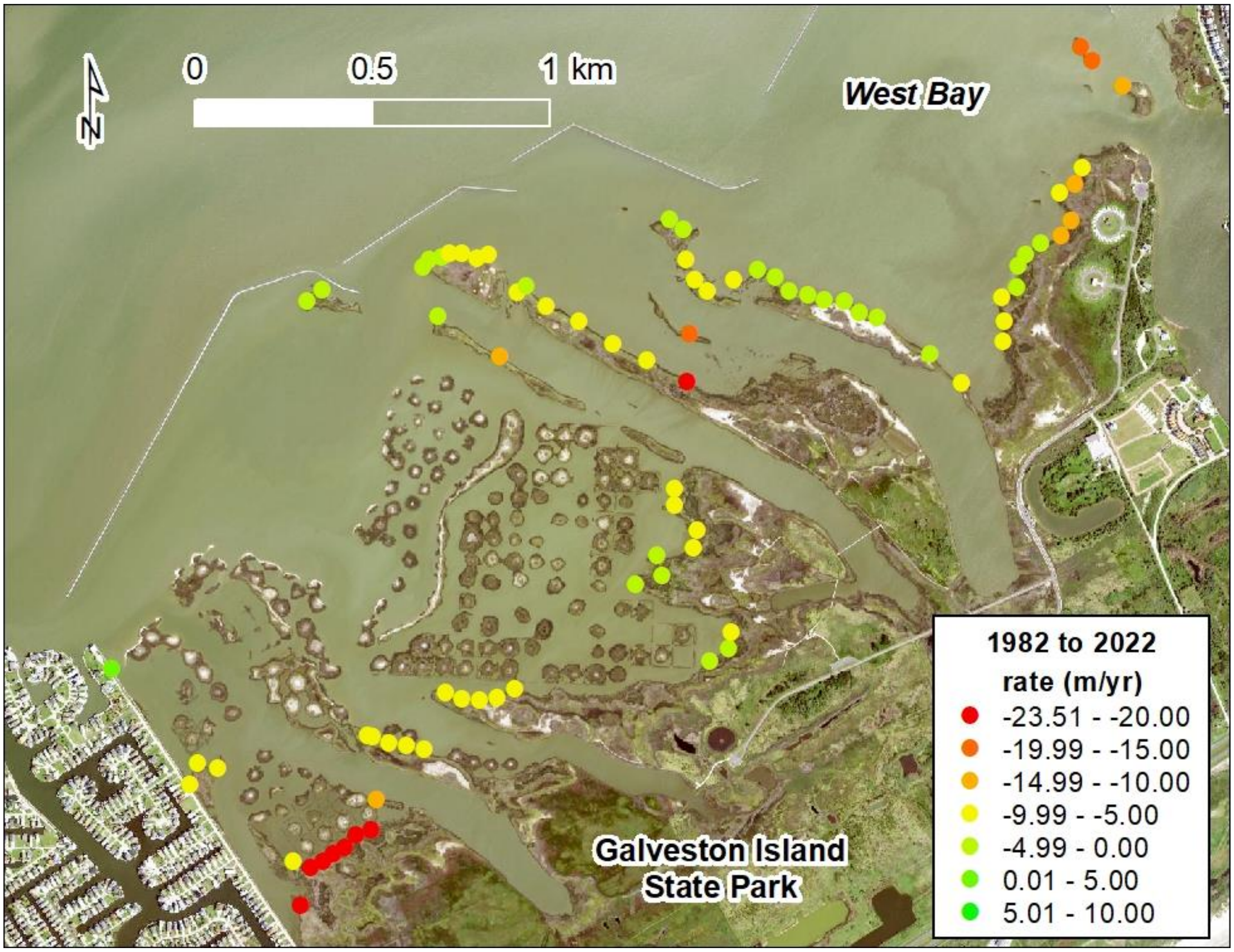

Figure 13. Net rate of short-term movement for the West Bay shoreline in Galveston Island State Park calculated from shoreline positions from 1982 and 2022.

Volumetrics

Volumes and their relationship to elevation help identify areas where sediment has accumulated, as well as areas where little sediment is stored near the shoreline. Peak elevations along the foredunes help identify areas susceptible to breaching and overwash during tropical cyclone passage. The Bureau calculated volumetrics data from the 2019 lidar data which is presented as peak elevations along the Texas Gulf shoreline and as volumes above threshold elevations ranging from 1 to 9 m (3 to 30 ft) relative to the NAVD88 elevation datum (Paine, Caudle, and Andrews, 2021). These volumes can be cast as total volume above a threshold elevation for a given shoreline segment, or as “normalized” alongshore volume above a threshold elevation, calculated by dividing the volume within the shoreline segment by the alongshore length of the segment. Peak elevations and normalized volume above 1 m elevation along the shoreline are presented in the state park online viewer. To view shoreline movement rates and volumetrics data for the entire Texas coast, visit the Bureau's Texas shoreline change project interactive map (https://coastal.beg.utexas.edu/shorelinechange2019/).

Beach and foredune elevations along most of the upper Texas coast between Sabine Pass and San Luis Pass are among the lowest on the Texas Gulf shoreline. Average dune elevation is 3.3 m (10.9 ft) on Galveston Island with peak elevations of 3.5 m (11.5 ft) or higher along almost 50% of Galveston Island (Paine, Caudle, and Andrews, 2021). The sites in the state park follow the same trend as the whole island of with average peak elevations of 3.3 m (10.9 ft) but with 58% of sites having peak elevations of 3.5 m (11.5 ft) or higher.

Normalized alongshore volumes above 1 m (3 ft) elevation are also very low on the upper Texas coast. Along the Texas Gulf shoreline, the average volume of sediment above 1 m (3.3 ft) elevation per meter alongshore is about 230 m^3/m (70 yd^3/ft, Paine, Caudle, and Andrews, 2021). For the entirety of Galveston Island, the average volume of sediment above 1 m (3.3 ft) elevation per meter alongshore is 56.5 m^3/m (22.6 yd^3/ft, Paine, Caudle, and Andrews, 2021). Along the state park shoreline, the average volume is 73.8 m^3/m (29.5 yd^3/ft), higher than the along Galveston Island but significantly lower than the Texas coast average.

Geologic Map

This layer of the interactive data viewer depicts the surficial geologic units found in Galveston Island State Park mapped from field investigations, digital elevation models, and 2022 aerial photography. This new geologic mapping has units similar to those found in the Environmental Geologic Atlas (later in atlas), but has been updated to follow mapping conventions developed through the Texas STATEMAP geologic mapping program (https://www.beg.utexas.edu/research/areas/geologic-mapping). In recent years, Bureau scientists have focused mapping on the Texas Gulf Coastal Plain to address a variety of needs, including planning and managing lands in sensitive coastal environments and studying erosion, habitat change and land loss, and geologic hazards. All units within the park are late Holocene in age (<5,000 years old) and represent bay-margin marsh, beach, and tidal flat and Gulf-margin beach, barrier flat, dune, ridge, and swale (Fig. 14). Geologically, the map units found in the state park are very young. To understand why the barrier island formed where it did, you have to go further back in time to understand how the Texas Coastal Plain developed.

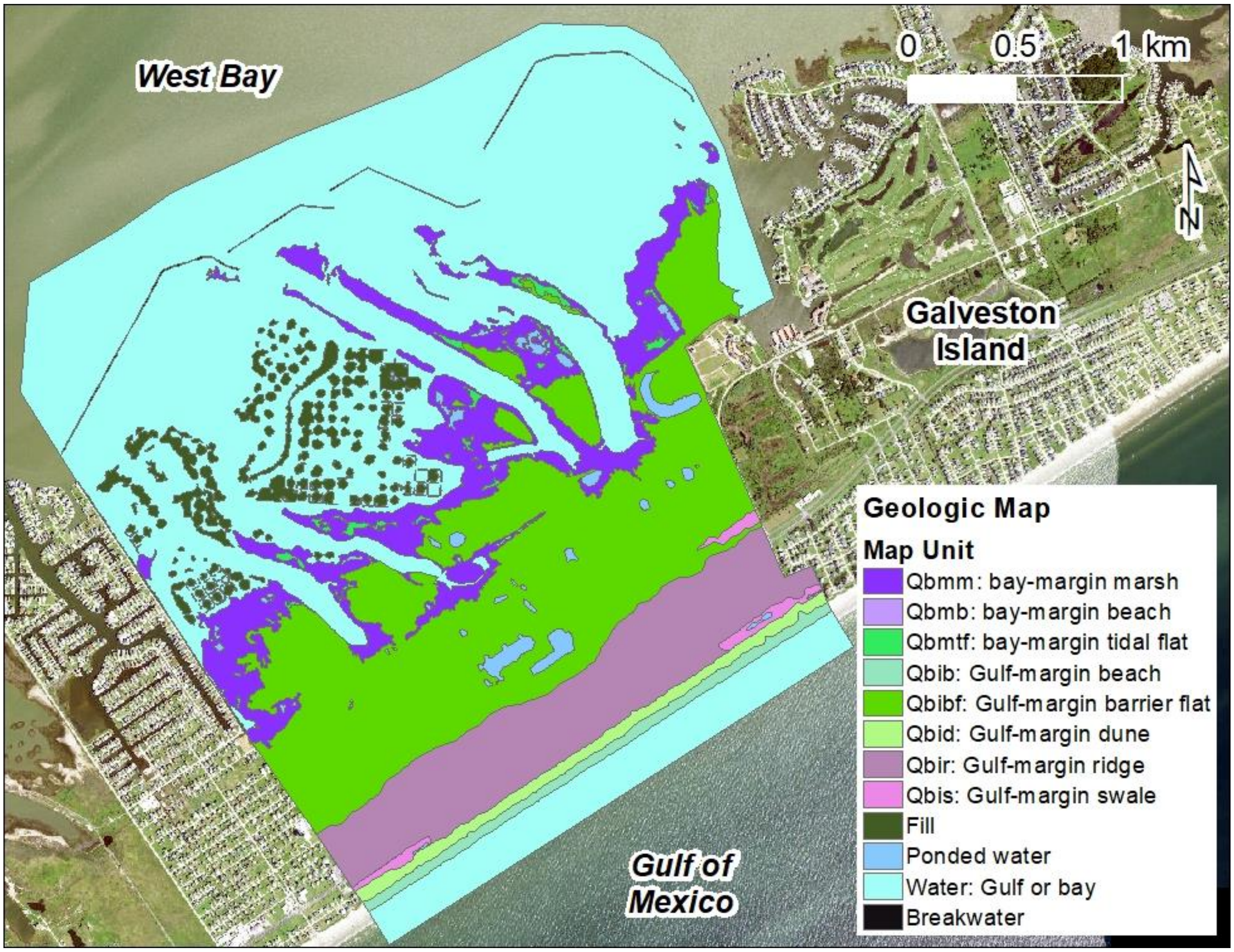

Figure 14. Geologic map Galveston Island State Park.

The last 2 million years of Earth's history was a time period called the Pleistocene, which fluctuated between periods of massive glaciation (cold periods where water was trapped in glaciers and sea level was lower) and interglacial stages. During the interglacial periods, climate was warmer and wetter. The melting glaciers and increased rainfall created large rivers that transported a huge amount of sand, silt, and mud to the coastal plain to be deposited at the edge of the Gulf of Mexico. As sea level fell during the cold glacier periods, the rivers carved deep channels through the sediments, creating wide river valleys.

About 18,000 years ago, the last glacial stage ended, and sea level was approximately 100-120 meters lower than today. As Earth warmed, the glaciers and ice sheets melted, causing large amounts of water to flow into the oceans and causing sea level to rapidly rise and fill the old river valleys. About 5,000 years ago, climate and sea level stabilized at near current levels (Fig. 15), although they are still rising. At the same time, the modern barrier islands of the Gulf coastline began to form. Sediments that were carried to the coast by rivers and eroded and deposited in the shallow nearshore were redistributed by wind, waves, currents, and storms. The stabilizing of sea level produced conditions that allowed for large barrier islands like Galveston Island to form.

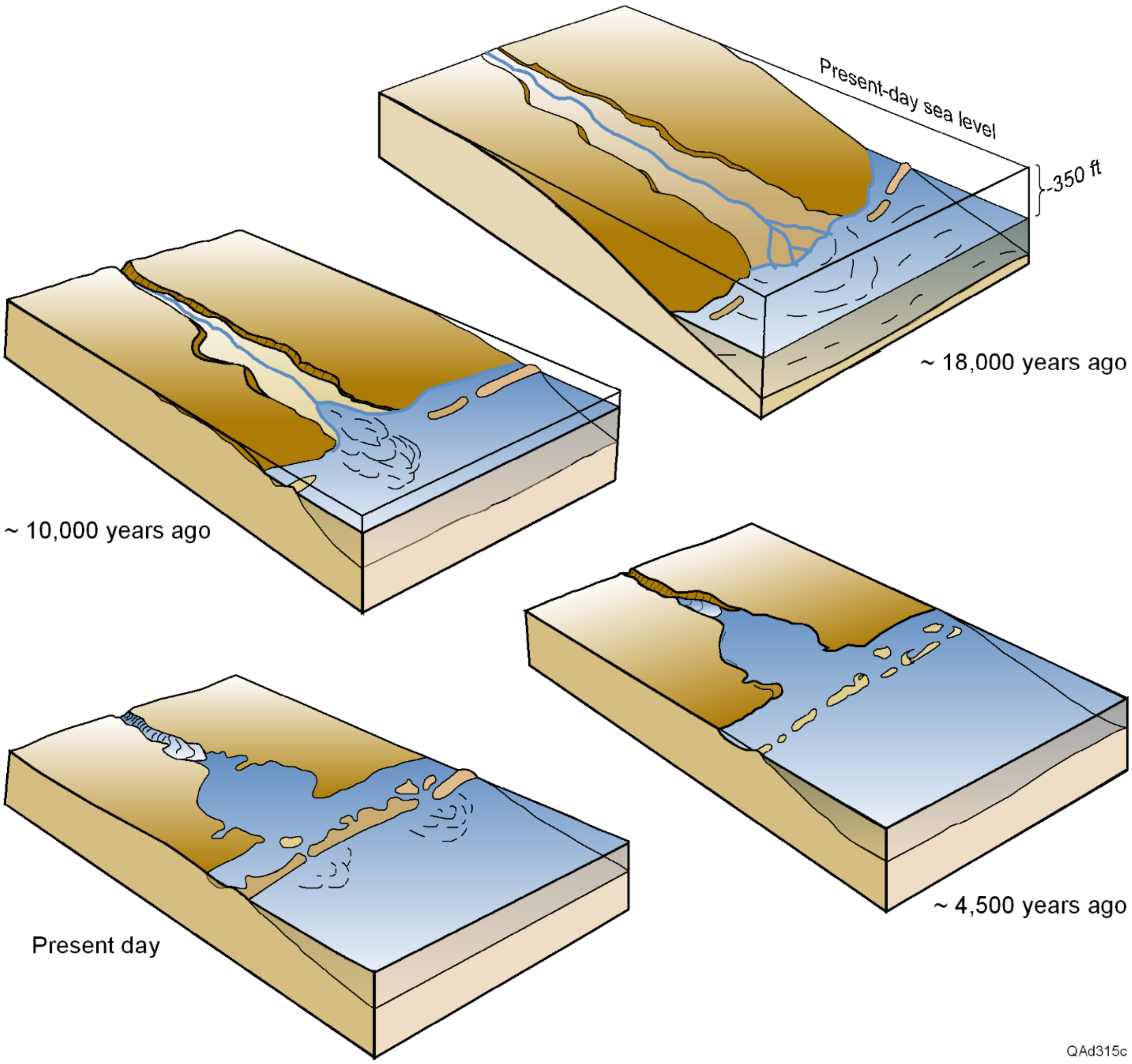

Figure 15. Schematic illustrations showing the effects of rising sea level on the evolution of ancient river valleys into the modern-day coastal environment.

Wetland Mapping

Coastal wetlands enhance water quality, provide flood protection, buffer against erosive storm surges, present unique recreational opportunities and provide high-quality habitats for fish and shellfish production and migratory waterfowl. Coastal wetland and aquatic habitats are essential components of inland and barrier island environments along the Texas coast. These valuable resources are highly productive biologically and chemically, and a variety of flora and fauna depend on part of this ecosystem. Scientific investigations of wetland distribution and abundance are needed to effectively manage the habitats and guide mitigation or restoration projects.

The Bureau has undertaken coast-wide studies of the status and trends of wetlands and aquatic habitats along the Texas portion of the Gulf of Mexico. Based on these studies, the Bureau produced a series of GIS datasets and reports designed to determine the status and historical trends of wetlands and associated aquatic habitats. These datasets are vital tools for coastal scientists, managers, planners, and decision makers. The study of status and trends are based on wetlands interpreted and mapped on recent and historical aerial photographs. The wetlands were mapped based upon the vegetation, hydrology, and geography at the time imagery was acquired. These datasets represent the extent, approximate boundary location, and type of wetland at time of imagery collection, the habitat boundaries and type may change through time.

The most recent Bureau wetland status study for Galveston Island State Park was determined by mapping wetlands on color-infrared (CIR) photographs taken in 2002 (White and others, 2004) with historical wetland distribution based on 1956 black-and-white and 1979 CIR photographs. For this project, wetland boundaries were updated using 2022 NAIP imagery and ground investigations. The U.S. Fish and Wildlife Service (USFWS, 1983, unpublished digital data of wetland maps) mapped historical wetland distribution using methods established through the National Wetlands Inventory Program. The Bureau obtained the 1956 and 1979 wetland map GIS files from USFWS and partly revised them to be more consistent with wetlands interpreted on the 2004 photographs (White and others, 2004). Mapping of the wetland and aquatic habitats was done by interpreting and delineating habitats onscreen in GIS at a scale of 1:5,000. This allowed for more detailed mapping. The 2002 maps were used to make comparisons with the historical mapping to determine habitat trends (White and others, 2004).

The wetland mapping by the USFWS and BEG follows the classification determined by Cowardin and others (1979) in *Wetlands and Deepwater Habitats of the United States*.

Wetlands are classified by system (marine, estuarine, riverine, palustrine, or lacustrine), subsystem (reflective of hydrologic conditions), and class (descriptive of vegetation and substrate). The systems represented in Galveston Island State Park include estuarine, palustrine, and marine (Table 2). The 1979 and 2002 maps were also classified by subclass (subdivisions of vegetated classes only), water regime (Table 3), and special modifiers (s=spoil, x=excavated). The 1956 wetlands were mapped only down to class.

Table 2. Wetland codes and descriptions from Cowardin and others (1979). Codes listed below were used in mapping the wetlands in the Galveston Island State Park area based upon the interpretation of 2002 and 2022 photography. The codes varied in some cases from the 1956 and 1979 maps.

NWI code (water regime)	NWI description	Common description
E1AB1	Estuarine, subtidal aquatic bed, algal	Estuarine seagrass
E1AB3	Estuarine, subtidal aquatic bed, rooted vascular	Estuarine seagrass
E1AB5	Estuarine, subtidal aquatic bed, unknown submergent	Estuarine vegetation
E1UB	Estuarine, subtidal unconsolidated bottom	Estuarine bay (West Bay)
E2AB1 (N, P)	Estuarine, intertidal aquatic bed, algal	Algal mat
E2EM1 (N, P, s)	Estuarine, intertidal emergent, persistent	Estuarine bay marshes, salt and brackish water
E2US (M, N, P, s)	Estuarine, intertidal unconsolidated shore	Estuarine bay, tidal flats, beaches
M1UB	Marine, subtidal, unconsolidated bottom	Gulf of Mexico
M2US (N, P)	Marine, intertidal, unconsolidated shore	Gulf beach
PEM1 (A, C, F)	Palustrine, emergent persistent	Freshwater marshes, meadows, depressions, or drainage areas
PSS	Palustrine, scrub-shrub, broad-leaved deciduous	Freshwater scrub-shrub wetland
PUB (Hx)	Palustrine, unconsolidated bottom	Pond
U	Upland	Upland

Table 3. Water-regime symbols and descriptions (Cowardin and others, 1979).

Nontidal	
A	Temporarily flooded: Surface water present for brief periods during growing season, but water table usually lies well below soil surface. Plants that grow both in uplands and wetlands are characteristic of this water regime.
C	Seasonally flooded: Surface water is present for extended periods, especially early in the growing season, but is absent by the end in most years. When surface water is absent, the water table is often near the land surface.
F	Semipermanently flooded: Surface water persists throughout the growing season in most years. When surface water is absent, the water table is usually at or very near the land surface.
H	Permanently flooded: Water covers land surface throughout the year in all years.
Tidal	
M	Irregularly exposed: Land surface is exposed by tides less often than daily.
N	Regularly flooded: Tidal water alternately floods and exposes the land surface at least once daily.
P	Irregularly flooded: Tidal water floods the land surface less often than daily.

A wetland trend analysis was completed by examining the distribution of wetland habitats as mapped in 1956, 1979, 2002, and 2022. Wetland classes were emphasized in the trend analysis over water regime and special modifiers, in part because wetland habitats were only mapped to the class level on the 1956 photography. Also, water regime classification can be influenced by local or shore-term events such as precipitation (for example, the 1950s Texas drought) and tidal cycles.

The estuarine system consists of many types of wetland habitats. Estuarine subtidal unconsolidated bottom (E1UB 2002 and 2022), or open water (E1OW 1956 and 1979), occurs in the bays and adjacent salt and brackish marshes. Unconsolidated shore (E2US 2002 and 2022) includes tidal flats (E2FL 1956 and 1979) and algal mats (E2AB 2022). The emergent areas around estuarine waters consist of low and high marshes (E2EM) that contain a variety of salt-tolerant and brackish-tolerant plants. The mapping of the boundaries between estuarine and palustrine systems is subjective based upon proximity to estuarine water bodies and vegetation types. A pond or emergent wetland is typically placed in the palustrine system if it is separated from the estuarine system by an upland break.

Mapped palustrine areas included the following classes: unconsolidated bottom or open water ponds (PUB 2002 and 2022, POW 1956 and 1979), emergent wetlands (PEM), and scrub-shrub (PSS 2002 and 2022). The palustrine emergent wetlands are fresh or inland marshes not inundated by tidal waters. The marine system consists of the Gulf of Mexico open water (M1UB 2002 and 2022, M1OW 1956 and 1979) and Gulf beaches (M2US 2002 and 2022, M2BB 1956 and 1979).

In 2022, wetland and aquatic habitats covered 162 ha (400 ac) within Galveston Island State Park (Fig. 16) and 318 ha (786 ac) were classified as uplands. A hectare (ha) is 10,000 square meters (100 m by 100 m) and equal to 2.47 acres (ac). The estuarine system is the largest of the wetland systems mapped covering 135 ha (333 ac), 83% of all wetland and aquatic habitats (Fig. 17). The estuarine intertidal emergent wetland habitat (E2EM, Fig. 18A) consists of 121 ha (299 ac) of salt or brackish marshes. This habitat makes up 75% of the study area, excluding the upland unit. Approximately 10 ha (25 ac) of estuarine tidal flats (Fig. 18B) and algal flats (E2US and E2AB) was mapped in the study area and 4 ha (9 ac) of aquatic beds (E1AB). The total mapped area of Gulf beaches (Fig. 19A) in Galveston Island State Park was 12 ha (30 ac), 7% of mapped wetland and aquatic habitats in 2022, palustrine marsh (Fig. 19B) was 6 ha (15 ac), 4% of habitats; and palustrine open water (fresh open water or ponds) was approximately 9 ha (21 ac), around 6% of mapped wetland and aquatic habitats in 2022.

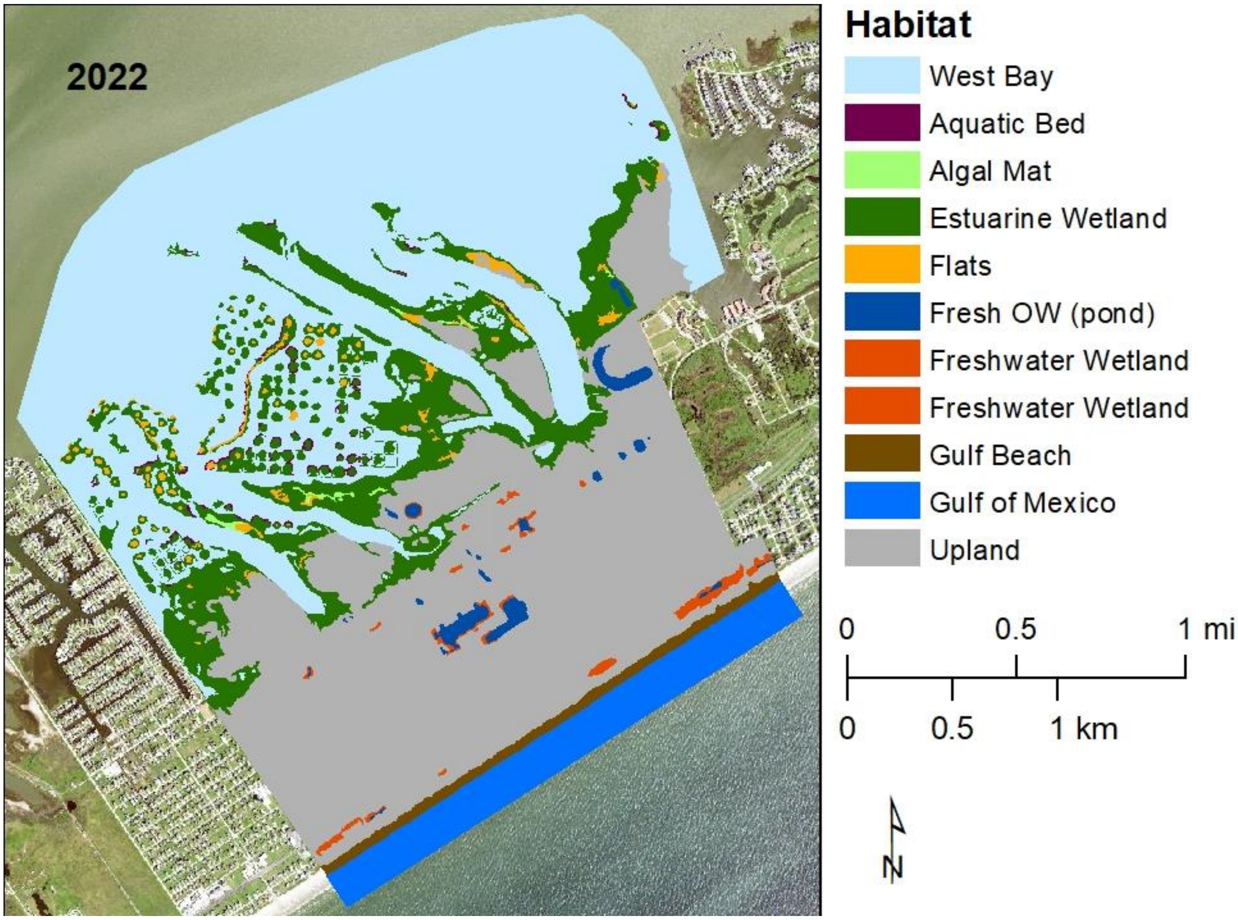

Figure 16. Areal distribution of habitats in Galveston Island State Park in 2022.

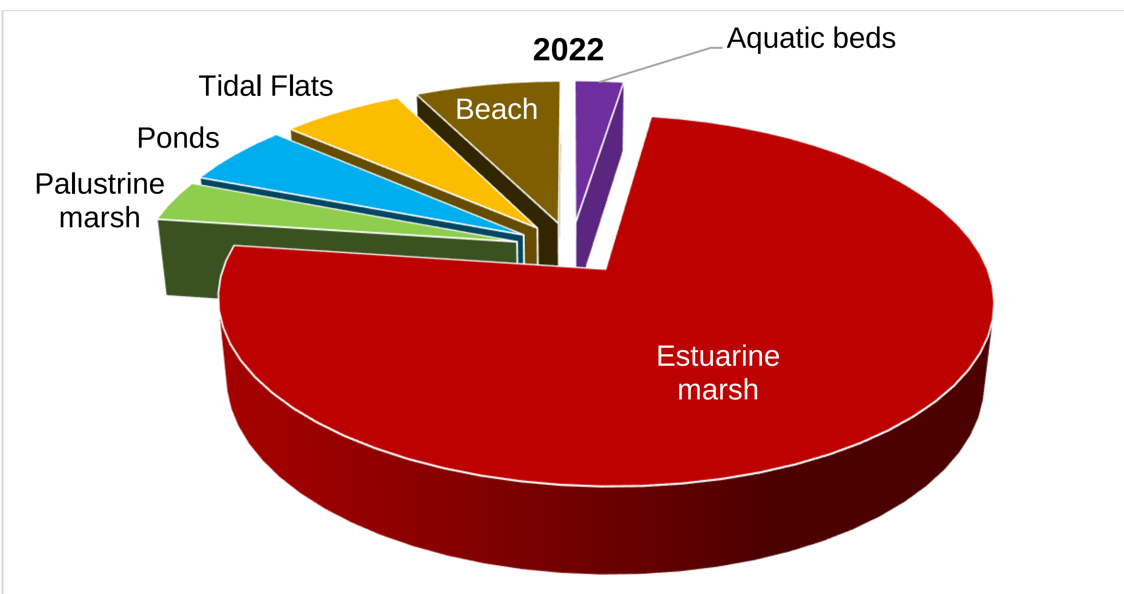

Figure 17. Areal extent of mapped wetland and aquatic habitats in 2022.

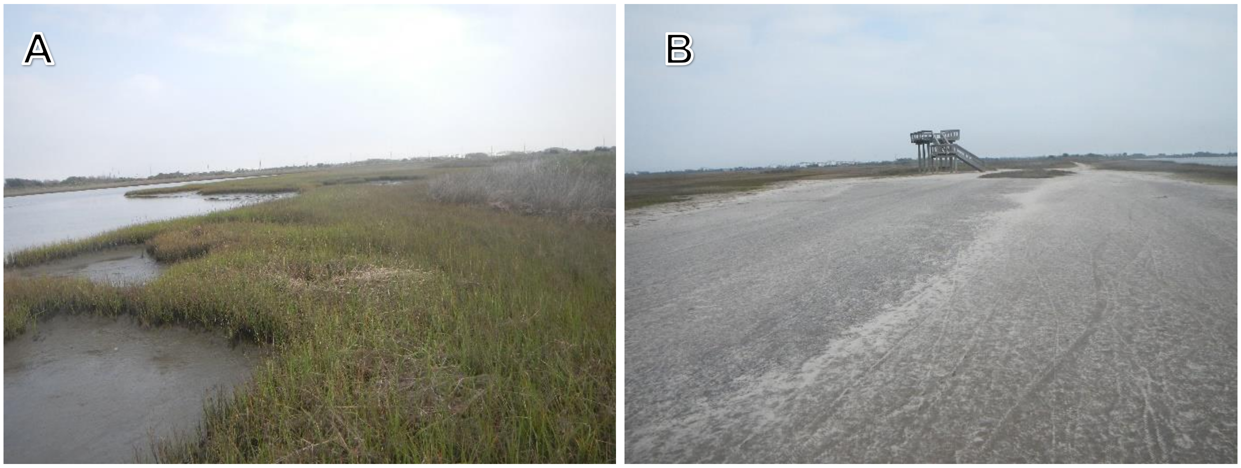

Figure 18. Examples of A) salt-water marsh, E2EM, and B) tidal flats, E2US, on the bay margin in Galveston Island State Park.

Figure 19. Examples of A) Gulf beach, M2US, and B) freshwater marsh and pond, PEM and PUB, in Galveston Island State Park.

Broad wetland classes were emphasized over water regimes in analyzing historical trends due to the limitations of the 1956 mapping. The total area of estuarine marshes decreased significantly between 1956 and 2022, from 274 ha (677 ac) in 1956 to 121 ha (299 ac) in 2022 (Table 4, Figs. 20 and 21). The total area of palustrine marsh was stable (16 ha, 39 ac) in 1956 and 1979, but decreased by almost 70% by 2002 (5 ha, 12 ac) and 2022 (6 ha, 15 ac). In Galveston Island State Park, tidal flats covered 51 ha (127 ac) in 1956, increased to 116 ha (287 ac) in 1979, decreased to 73 ha (180 ac) in 2002, and decreased to only 10 ha (25 ac) in 2022 (Table 4, Figs. 20 and 21).

Table 4. Total area (ha and acres) of major habitats, including uplands and open estuarine waters (West Bay), in 1956, 1979, 2002, and 2022. Modified from White and others, 2004.

	1956		1979		2002		2022	
Habitat	**ha**	**acres**	**ha**	**acres**	**ha**	**acres**	**ha**	**acres**
Open water	206	509	252	624	261	647	445	1099
Aquatic beds	26	65			108	267	4	9
Estuarine marsh	274	677	174	429	126	312	121	299
Tidal Flats	51	127	116	287	73	180	10	25
Palustrine marsh	16	39	16	38	5	12	6	15
Fresh OW	6	15	13	33	11	26	9	21
Beach	28	69	15	36	10	24	12	30
Uplands	351	868	355	877	334	825	318	785

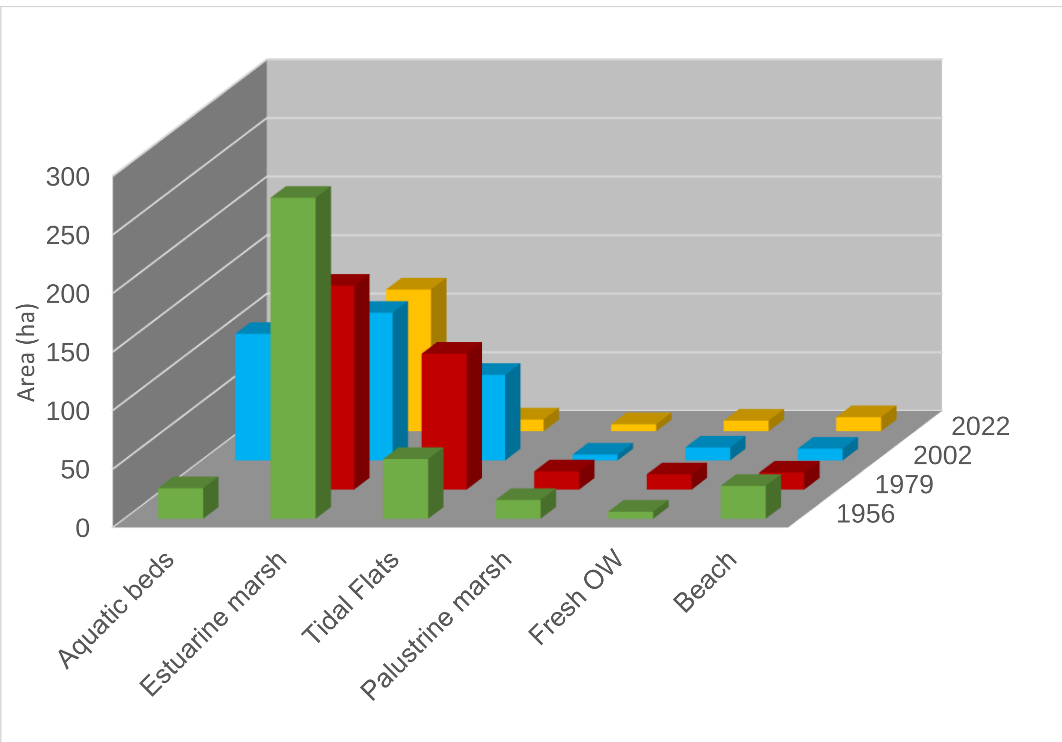

Figure 20. Areal distribution of habitats in Galveston Island State Park in 1956, 1979, 2002, and 2022. Modified from White and others, 2004.

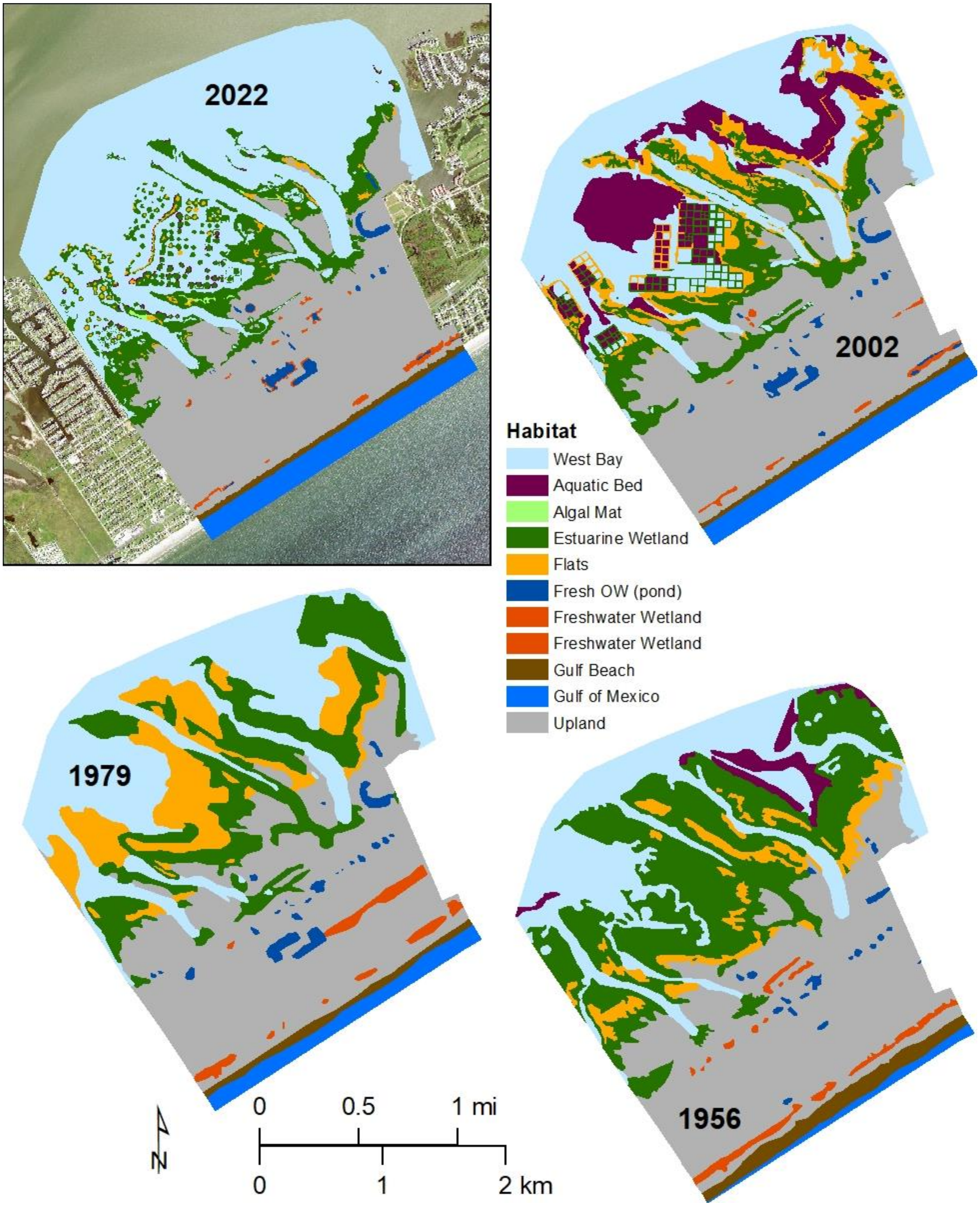

Figure 21. Maps showing distribution of major wetland and aquatic habitats in 2022, 2002, 1979, and 1956 in Galveston Island State Park. Modified from White and others, 2004.

Analysis of trends in wetlands and aquatic habitats in the Galveston Island State Park area show that there was a net decrease in marshes from 1956 through 2022. Emergent wetlands (both estuarine and palustrine) decreased from 290 to 127 ha (716 to 314 ac), a loss of more than half the area of emergent marshes (163 ha, 402 ac, Table 4, Figs. 20 and 21). The long-term (1956-2002) change rate of marsh was a loss of 3.5 ha/yr (8.5 ac/yr). Total emergent marsh habitat was stable between 2002 and 2022. A recurring trend in wetland habitat studies along the entire Texas coast is the loss of tidal flats through time (White and others 2004). Between 1956 and 1979, tidal flat area increased by more than double (Table 4, Fig. 20). Wetlands that were mapped as estuarine marsh in 1956 were mapped as tidal flats in 1979 (Fig. 21). The rate of change for tidal flats between 1979 and 2022 was a loss of 2.5 ha/yr (6 ac/yr). The decrease in estuarine marshes and tidal flats between 1956 and 2022, and the high rates of shoreline retreat, may be due to relative sea level rise flooding the low-lying areas along the bay margin areas of Galveston Island State Park (White and others, 2004, Caudle and Paine, 2024). The shorelines along the communities on either side of the state park have stabilized the shoreline position through bulkheads, fill, and rip-rap (rock walls). Restoration projects and a breakwater have been constructed in Galveston Island State Park in an effort to counteract some of the losses.

Environmental Geologic Atlas

The interactive viewer for Galveston Island State Park includes digitized maps detailing environmental geology, active processes, physical properties, and environments & biologic assemblages from the Bureau’s Environmental Geologic Atlas of the Texas Coastal Zone series for the Galveston-Houston area (Fisher and others, 1972). This historical publication series provides information that is still relevant for developing and managing the Texas coastal zone. As evidenced from the shoreline movement and wetland data layers, the boundaries for bayside units have moved since these maps were published in 1970s.

<u>Environmental Geology Map:</u> This layer delineates environmental geologic units found in Galveston Island State Park. The depositional units represented within the park

formed during the Modern-Holocene period (last 10,000 years) in a barrier-strandplain or offshore setting. The units represented by this map include beach (sand and shell), beach ridge and barrier flat (sand and shell, grass-covered), Marsh (salt-water, mud and locally sand substrate), tidal flat (sand), grass flat (muddy sand with shell), and bay (mud with oyster shell). The environmental geologic maps in this series is the basic map from which the special-use maps presented below were derived.

Physical Properties Map: This layer groups geologic, biologic, active processes, and man-made map units into groups that have common physical features and properties. Within Galveston Island State Park, two groups are represented.

> Group II: is made of the following geologic units: beach, foredunes, and barrier vegetated flats found on Galveston Island. This group is composed of dominantly sand with the following characteristics: high to very high permeability, low water-holding capacity, low compressibility, low shrink-swell potential, good drainage, low ridge and depressed relief, high shear strength, and low plasticity.

> Group VI: Geologic units on Galveston Island included in Group VI are tidal flats and salt marsh. This group has a permanently high-water table, very low permeability, high water-holding capacity, very poor drainage, very poor load-bearing strength, and is subject to frequent tidal inundations.

Environments and Biologic Assemblages Map: This layer characterizes the dominant collections of bottom-living plants and animals found in Galveston Bay and in the principal plant communities within the park. The collections are grouped by subaqueous environments of the bay and shoreface (grass flats, bay with reef, and fresh to brackish-water bodies) and subaerial environments (beach, barrier flat and dune, tidal flats, and salt-water marsh) defined by land vegetation.

> Grass flats: Occur in the shallow bay margin with dense grasses and a moderate variety of mollusks. Water depths in this environment are less than 1.5 m (5 ft).

> Bay with reef: The West Bay waters in Galveston Island State Park are designated as an enclosed bay with scattered clumps of oyster reefs. These

waters are away from tidal or river influence and are made of mottled mud, high species diversity, infauna, mollusks, and water depths of 1 to 2.4 m (3 to 8 ft).

Fresh to brackish-water bodies: These water bodies are land-locked ponds and lakes with variable substrates. In the barrier island environment, these ponds can be temporarily brackish or saline.

Beach: In Galveston Island State Park, the Environmental Geologic Atlas defines the beach as the area lying between low tide to 1.5 m (5 ft) above average sea level and includes the swash zone. It is a high energy composed of sand and shell debris where one can find back-beach sea-oats, halophytes, and ghost crabs.

Barrier flat and dune: The vegetated barrier flat, foredune ridge, beach ridge, and vegetated flat can have relief of 1.5 to 4.6 m (5 to 15 ft) above average sea level. Salt-tolerant grasses, vines, local freshwater marsh, ghost crab, rodents, snakes, and fowl dwell in these environments.

Tidal flats: The tidal flats are an undulatory sand surface only a few cm or inches above average sea level. The surface can be covered with blue-green algal mats or a thin halite film.

Salt-water marsh: Salt-water marshes are frequently inundated by tides and are comprised of sand to muddy sand or mud. Common flora and fauna found in Galveston Island State Park marshes include cordgrass, glasswort, seepweed, sea-oxeye, mammals, and fowl.

Active Processes Map: Outlines the major physical processes that are critical for determining land use. Main map features in Galveston Island State Park include areas that were inundated by Hurricanes Carla (1961) and Beulah (1967) and the active shoreline zones. Hurricane Carla made landfall as a category 4 hurricane near Port O’Connor, Texas in September 1961. Near the state park, still high water-mark elevation was measured at 3.4 m (11 ft) above average sea level. The entire west end of Galveston Island was inundated with Carla’s storm surge. Beulah reached category 5 strength while crossing the Gulf of Mexico before making landfall in September 1967 near the mouth of the Rio Grande as a strong category 3 hurricane. Even though Beulah made landfall far from Galveston Island, water levels were measured at 1.2 m (3.8 ft) above average sea level. The storm surge from Beulah inundated the wetlands and low-lying areas of Galveston Island. By examining historical hurricanes, coastal managers and planners can have a better understanding of how future storms might impact the coastal zone.

Texas High School Coastal Monitoring Program Data

The Texas High School Coastal Monitoring Program (THSCMP) is a research and outreach project led by the Bureau. The program is designed to help coastal residents develop a better understanding of dune and beach dynamics on the Texas coast. Bureau researchers work with high school and middle school students and teachers, training them to measure topography (Fig. 22A), map vegetation lines and shorelines, and observe weather and wave conditions (Fig 22B). As participants in a research project, students enhance their science education and provide coastal communities with valuable data on their changing shoreline. Eight schools participate in THSCMP, monitoring changes in beaches, dunes, and vegetation-line position along the Texas coast. The collected data has been used to investigate beach, dune, and vegetation-line recovery following tropical cyclones; monitor the effects of nourishment projects, beach maintenance practices, and jetty construction; and used in verifying shoreline positions for updates of Texas' long-term shoreline change rates. For more information about THSCMP and to view the data collected by the students, please visit the THSCMP website: https://www.beg.utexas.edu/thscmp/ (Caudle, 2023).

Figure 22. Students from Ball High School measuring A) a beach profile and B) wind speed at Galveston Island State Park for the Texas High School Coastal Monitoring Program.

Students and teachers from Ball High School have been working with Bureau scientists since 1997 collecting valuable data about the beach and dune system on Galveston Island. During the 25-years Ball students have participated in THSCMP, numerous storms with varying intensities have caused impacts to the beaches of Galveston Island including the following: Tropical Storms Frances (1998), Allison (2001), and Fay (2002) and Hurricanes Claudette (2003), Rita (2005), and Ike (2008). Ball High School data collection from a site in Galveston Island State Park documented how the beach and dunes changed after Ike (Figs. 9 and 23A) and the recovery of the beach and dune system through the years (Fig. 23B, Caudle, 2023). At the site, the foredune has re-established, and a wide vegetated zone with expanding coppice dunes developed between the seaward base of the foredunes and the landward extent of wave run-up. After the 2020 hurricane season, the beach was eroded landward and a washover feature was deposited in the coppice dune area (Figs. 23B and 24, Caudle, 2023).

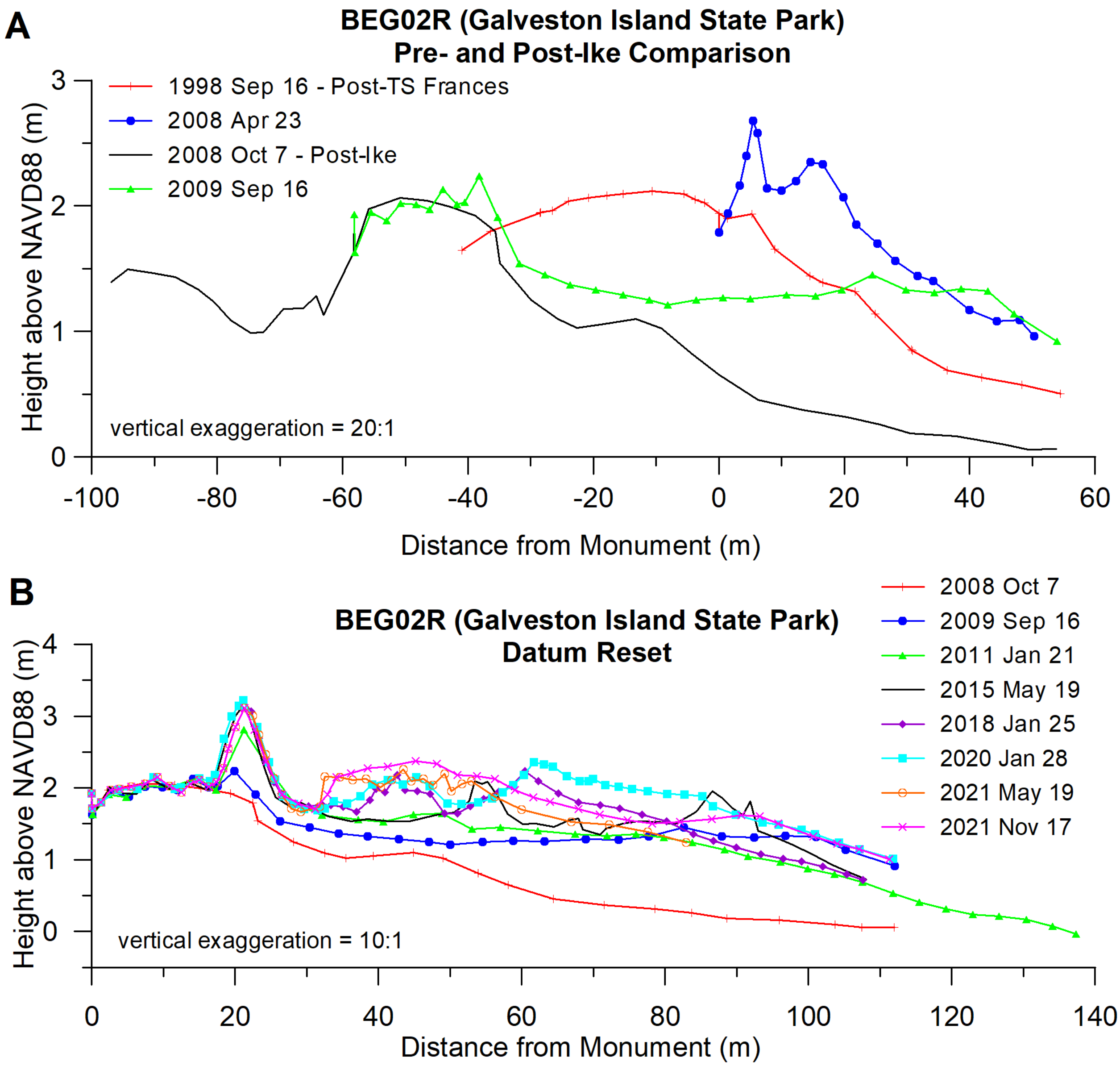

Figure 23. A) Beach-profile plots from BEG02 in Galveston Island State Park comparing the post–Hurricane Ike profile with a pre-storm profile from early 2008 and the post–Tropical Storm Frances profile from September 1998. Data from September 2009 (1-year post-storm) is also included. B) Beach profile plots from October 2008 through November 2021 showing the recovery of the beach and dune system and the impacts of the 2020 hurricane season.

Figure 24. Photo from November 17, 2021 looking northeast of the vegetated coppice dunes in the state park. Notice the toe of the washover feature (barren area). This is sand that was eroded from the beach and deposited on the coppice dunes during the 2020 hurricane season.

To learn more about Ball High School student participation in THSCMP and the data they collect, visit their webpage at: https://www.beg.utexas.edu/thscmp/schools/ball-high-school. The page includes photo galleries from field trips, information about their monitoring sites on Galveston Island, and a downloadable document that contains data and a summary of field trips from the past academic year. To view beach profiles and vegetation line and shoreline position data collected by Ball High School students on Galveston Island and at the state park, as well as data collected by students all along the Texas coast, please visit the THSCMP interactive data viewer at: https://maps.beg.utexas.edu/thscmp/.

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