National Park Service
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Natural Resource Stewardship and Science

Shoreline Change at Gulf Islands National Seashore, Florida and Mississippi

2018–2022 Data Summary

Natural Resource Data Series NPS/GULN/NRDS—2022/xxxx

ON THE COVER
Erosional beach on the north shore of Horn Island. NPS photo / GULN staff.

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible and technically accurate.

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Summary and Key Findings

In May and June 2018, April 2021, and April 2022 the Gulf Coast Network (GULN) surveyed shoreline position at Gulf Islands National Seashore (GUIS) as a part of the NPS Vital Signs Monitoring Program. Monitoring was conducted following methods detailed in Monitoring Shoreline Position at Gulf Coast Network Parks: Protocol Implementation Plan (PIP; Bracewell 2017). Shoreline change was calculated using the Digital Shoreline Analysis System developed by USGS (Theiler et al. 2008).

Key findings from this effort are as follows:

- In Florida, the mean shoreline change rate from 2018 to 2022 was -5.14 meters/year (-17.75 feet[ft]/year) with a standard deviation of 4.57 meters (14.99 ft). Approximately 91% of transects exhibited landward retreat.
- In Mississippi, the mean change in island width from 2018 to 2022 was -7.46 meters/year (-24.5 ft/year) with a standard deviation of 12.49 meters (41.0 ft). Approximately 73% of transects exhibited a loss in width.
- The 2020 hurricane season was extremely active, causing high shoreline retreat rates from 2018 to 2021. The 2021 hurricane season was much calmer in comparison, and concordantly, rates of shoreline retreat were generally lessened or reversed to shoreline advance between 2021 and 2022.
- A beach nourishment project on the eastern end of Perdido Key advanced the shoreline an average of 42.2 meters (138.5 ft) within the project area.
- This report expands on the previous GULN Shoreline Position report (Bracewell 2022a), to document "storminess" and current sea level rise trends.

This project is in the early phases of implementation and will benefit from future surveys to better understand the influence of slight changes in survey timing and other environmental variations.

Introduction

As stated by Psuty et al. (2010)

> *Changes in shoreline position are recognized as interacting with many other elements of the ocean beach-dune ecosystem and are thus both driving and responding to the variety of natural and cultural factors active at the coast at a variety of temporal and spatial scales. The direction and magnitude of shoreline change can be monitored through the application of a protocol that tracks the spatial position of the neap-tide, high tide swash line under conditions of temporal sampling.*

The Gulf Coast Network monitors shoreline position at Gulf Islands National Seashore (GUIS) and Padre Island National Seashore (PAIS) using modified procedures developed for the Northeast Coastal and Barrier Network (NCBN). Handheld and utility task vehicle (UTV)-mounted Global Positioning Systems (GPS) or Global Navigation Satellite Systems (GNSS) are used to record shoreline position by walking or driving the high tide swash line. The Gulf Coast Network's monitoring objective is to identify the biennial and long-term trends and variability of shoreline position in network seashore parks.

The purpose of this document is to report the most recently collected data from within the park as part of an ongoing long-term shoreline-change monitoring program. This report focuses on change between 2018 and 2022, but also makes comparisons between 2018 and 2021 as well as 2021 to 2022. Surveying in 2020 was moved to 2021 because of COVID-19 travel restrictions. Other data collected during this and other related surveys are available at https://irma.nps.gov/DataStore/Reference/Profile/2238503.

Study Area

Gulf Islands National Seashore (GUIS) consists of several park units in Florida and Mississippi. The Mississippi district (GUIS-MS) is five islands and a small mainland headquarters area. The authorized boundary includes not only the barrier islands themselves, but portions of the Gulf of Mexico and Mississippi Sound. From the west to east, the islands of GUIS-MS are: Cat, Ship, Horn, West Petit Bois, and Petit Bois Islands. These islands are only accessible by boat. Horn Island is the largest and Cat is the most recently acquired. Davis Bayou is the only mainland area in the GUIS-MS park district.

The Florida district (GUIS-FL) is portions of two islands (Santa Rosa Island and Perdido Key) and two small mainland areas. Three park units are located on Santa Rosa Island: Fort Pickens, Santa Rosa Area, and Okaloosa Area. The Naval Live Oaks Reservation is on a peninsula forming part of the eastern mouth of Pensacola Bay. Unlike the GUIS-MS park district, all areas of the GUIS-FL park district, including the islands, are accessible to vehicles. Water bodies surrounding the Florida district include Santa Rosa Sound, Big Lagoon, Pensacola Bay, Choctawhatchee Bay, and the Gulf of Mexico (Cooper et al. 2005).

There are a number of aquatic and terrestrial ecosystems in Gulf Islands National Seashore, including gulf, bay, dunes, salt marsh, maritime forest, barrier islands, seagrass beds, and other marine systems. Hydrology and water-related issues are of central importance because 80% of the park is submerged land (Anderson et al. 2005). The mainland portion of the GUIS-FL park district consists of live oak, sandhill, and marsh communities; the mainland portion of the GUIS-MS park district consists of pine/palmetto flatwoods, mixed pine/hardwood, lowland hardwood, and tidal marsh.

Hurricanes are one of the biggest concerns for the park, as they can have devastating effects on biological communities as well as park structures and facilities. They can also cause rapid morphological shoreline changes through erosion and overwash of the islands. Hydrologic alternations (e.g., jetties and navigation channels) alter sediment input and transport, limiting the ability of these systems to recover on their own between storms. To combat erosion, the beaches of Gulf Islands National Seashore have been regularly nourished with sand, which generally comes from the dredging of navigation channels. Although these nourishment projects are beneficial for the reduction of erosion, there is concern regarding the rates of revegetation, adverse effects on macroinvertebrates, and reduction of the vegetative seed bank (Cooper et al. 2005).

Methods

The GUIS shoreline position is mapped in the spring of every other year using methods developed by the National Park Service Northeast Coast Barrier Network (NCBN; Psuty et al. 2010) and adapted by the Gulf Coast Network (GULN; Bracewell 2017). Figures 1–3 show the extent of the shoreline mapping effort at Gulf Islands National Seashore.

The high tide swash line is mapped using a GNSS (GPS) unit, then differentially-corrected results are exported into a standard GIS format. Digital Shoreline Analysis System (DSAS; Theiler et al. 2008) is used to analyze the shoreline change along spatially fixed cross-shore transects distributed every 20 meters (65.6 ft). Annual shoreline change rates are calculated for the GUIS-FL units using the End Point Rate (EPR) method, which addresses the change in shoreline by determining the distance between the initial and current shoreline positions and dividing the distance by the time between the shoreline surveys (Figure 4). At GUIS-MS, island width rate is calculated instead of EPR because of large amounts of variation in shoreline position on both Gulf and Sound sides of these islands. Figure 5 describes how the island width rate is calculated.

Figure 1. Shoreline Position monitoring extent—Horn Island.

Figure 2. Shoreline Position monitoring extent—West Petit Bois Island, Petit Bois Island.

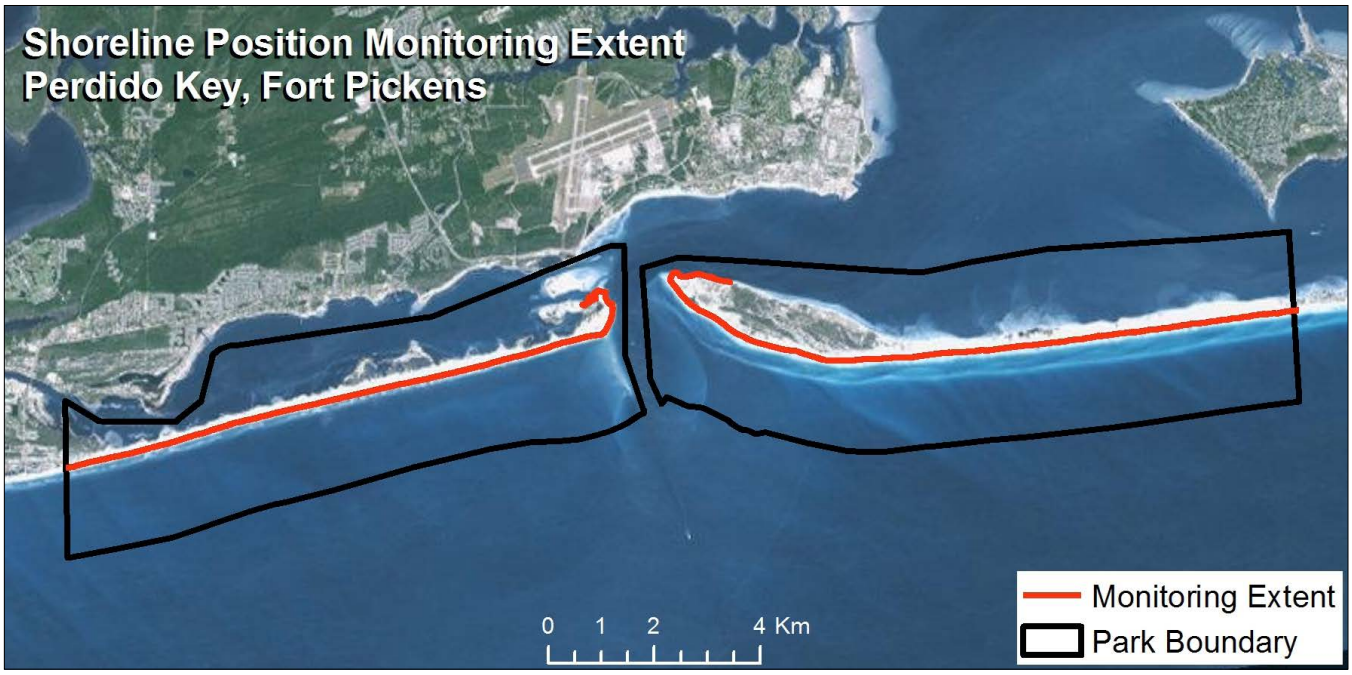

Figure 3. Shoreline Position monitoring extent—Perdido Key, Fort Pickens.

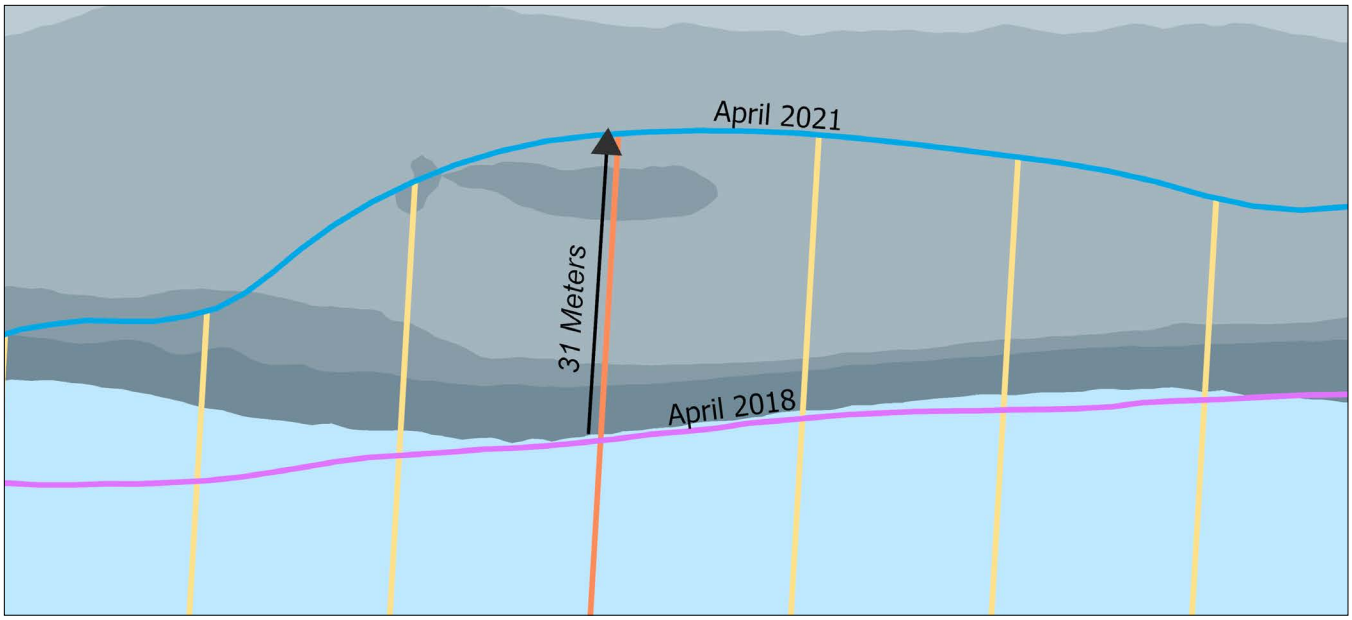

Figure 4. End Point Rate (EPR) calculation is performed on distance between the first year and the current year. The result is then divided by the time interval between surveys. In the case of the transect measured in this figure, the shoreline retreated 31 meters (101.7 ft), or 10.3 meters (33.8 ft) per year.

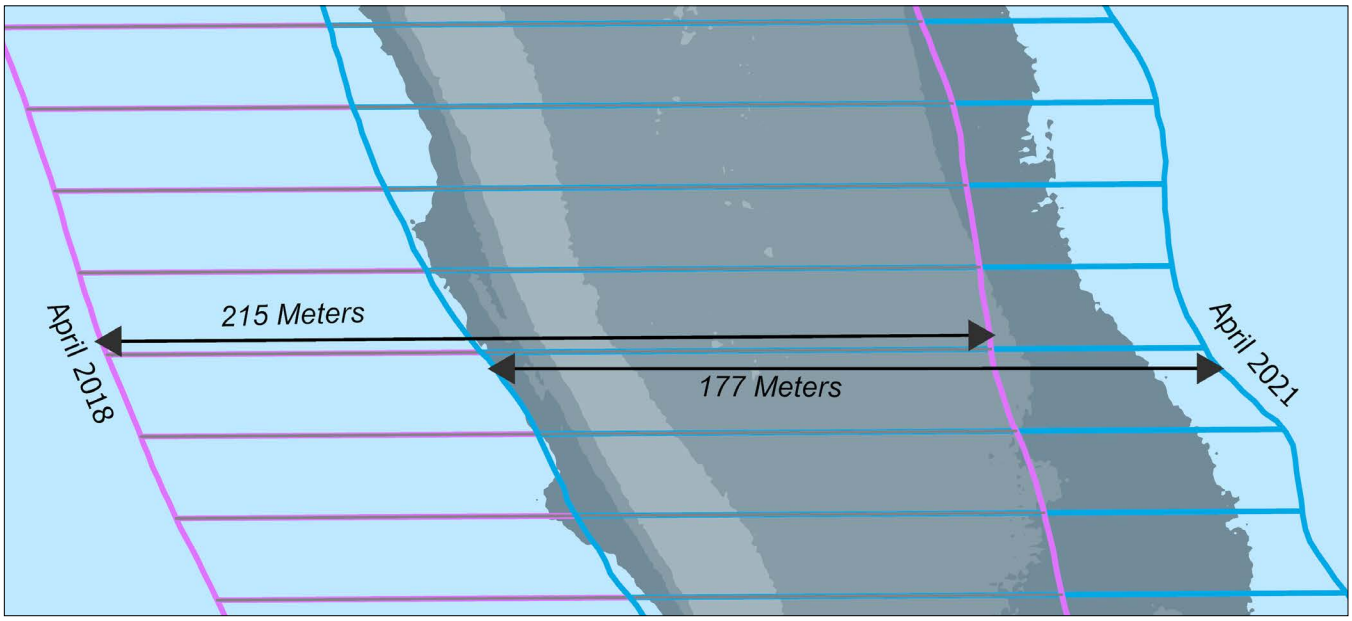

Figure 5. Island width rate calculation is performed on cross-shore width. The first year is subtracted from the current year, then the difference is divided by the time interval between surveys. In this figure, the island narrowed 38 meters (124.7 ft) or 12.7 meters (41.7 ft) per year.

Standard Operating Procedures

Table 1 presents the standard operation procedures considered critical to maintaining continuity between datasets across many surveys, so results are comparable. No significant changes were made to SOPs between 2017 and 2022, and version numbers in the table apply to all datasets.

Table 1. Standard operating procedures used for shoreline position data collection, processing, and reporting.

SOP number	SOP title	SOP version
SHR03	Survey Timing and GPS Mission Planning	1.0
SHR04	Basic GPS Settings for Position Collection	1.0
SHR05	Conducting the Survey	1.0
SHR06	Initial Post Survey Processing	1.0
SHR07	Change Calculation, Data Analysis and Reporting	1.0

Timing of the Shoreline Position Survey

Shoreline surveys of the high tide swash line are conducted during neap tides in April and May. Neap tides are the two periods per month when high and low tides are least different. For a given survey season, these neap tide periods are determined based on predicted water levels using the closest NOAA monitoring stations: 'Pascagoula NOAA Lab MS' in Mississippi and 'Pensacola FL' in Florida (NOAA 2022a). The verified water levels occurring before or during the 2022 surveys are listed in Table 2. Graphs of verified versus predicted water levels for the survey periods and the prior week are presented in Figures 6 and 7. Water level data for 2018 and 2021 can be found in the project's previous report at https://irma.nps.gov/DataStore/Reference/Profile/2293103.

Table 2. List of verified high tide water levels occurring before shoreline position surveys were conducted [m—meters; *— NAVD 88].

Survey Collection Date and Time	Survey Area	High-Tide Height* (m)	High-Tide Date and Local Time
4/13/2022, 08:26–13:47	Perdido Key	0.407	4/12/2022, 20:24
4/14/2022, 12:00–14:27	Fort Pickens	0.327	4/14/2022, 11:00
4/26/2022, 13:26–18:00	Horn Island (West)	0.255	4/26/2022, 14:24
4/27/2022, 08:50–14:00	Horn Island	0.300	4/27/2022, 10:18
4/27/2022, 15:26–16:08	West Petit Bois Island	0.300	4/27/2022, 10:18
4/28/2022, 09:46–16:12	Petit Bois Island*	0.292	4/28/2022, 10:00

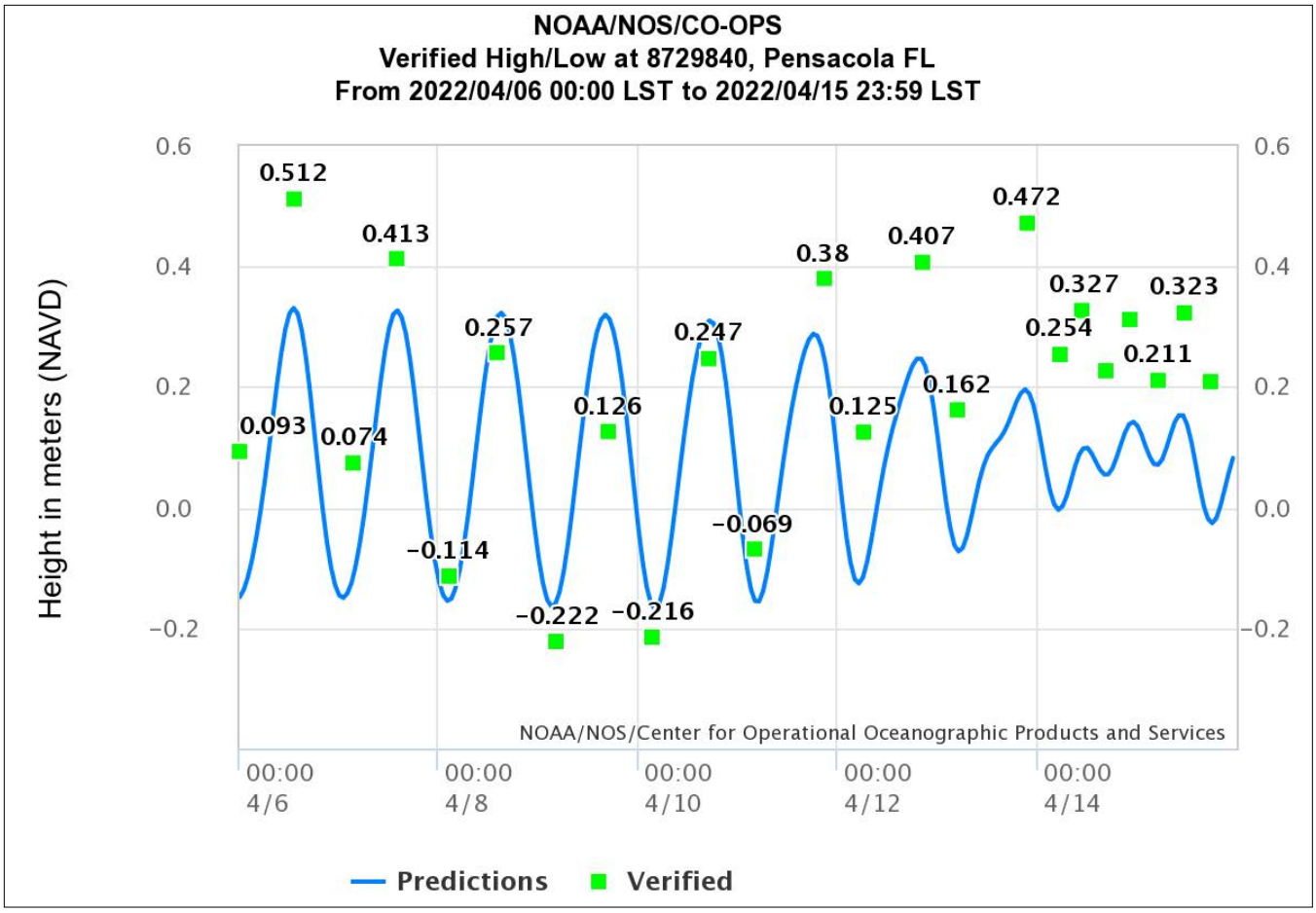

Figure 6. Water levels recorded at Pensacola FL NOAA monitoring station before and during the 2022 GUIS-FL shoreline survey (completed 4/13 and 4/14).

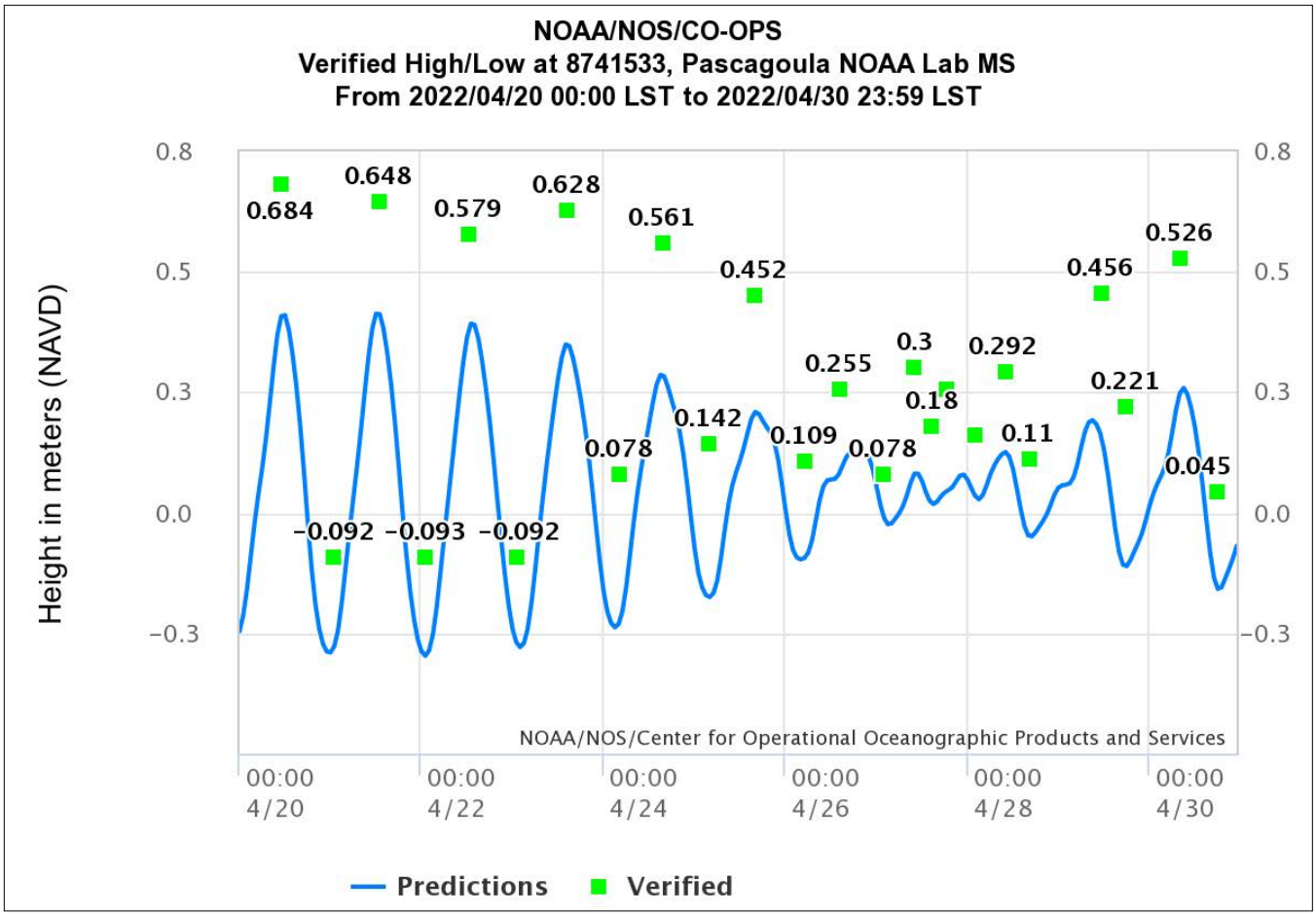

Figure 7. Water levels recorded at Pascagoula NOAA Lab MS before and during the 2022 GUIS-MS shoreline survey (completed 4/26, 4/27, and 4/28).

Weather and Water Levels Affecting Shoreline Position

Weather is the primary driver of abrupt changes in Gulf region shorelines so this report includes a section on major weather or high-water events. Figure 8 shows tracks for named tropical storms landing on the northern Gulf region starting in 2017. A single tropical storm or hurricane tends to primarily effect a single GUIS district, but some bigger storms have impacted both districts. In addition to named storms, several other high-water level or wind events occur throughout the year, altering physical landscapes and damaging park infrastructure. Measurements for water level and wind are taken at NOAA 'Tides and Currents' and 'Climatological' stations near each park district. Their locations are shown in Figure 8 (NOAA 2022a, NOAA 2022b). The wind and water-level variables from these datasets were combined into an *ad hoc* 'storminess' metric, allowing for cross-year comparisons of the number of major natural events that could impact shoreline position. To calculate this metric for each year between 2017 and 2022, the number of high-water events were summed with the number of high wind events. High-water events were defined as those where the local tide gauge measured at least 0.7 meters (2.3 ft) above NAVD88. High wind events were defined as those where wind speed exceeded 25 knots (28.8 mph). The three highest water level events at GUIS-MS included Hurricane Nate on 10/8/2017 (2.16 meters [7.1 ft]); Hurricane Cristobal on 6/8/2020 (1.36 meters [4.5 ft]); and Hurricane Zeta on 10/29/2020 (2.39 meters [7.8 ft]) (Figure 9). At GUIS-FL the highest water level events included Hurricane Nate on 10/8/2017 (1.21 meters [4.0 ft]); Hurricane Cristobal on 6/7/2020 (1.04 meters [3.4 ft]) and Hurricane Sally on 9/16/2020 (1.97 meters [6.5 ft]; Figure 10).

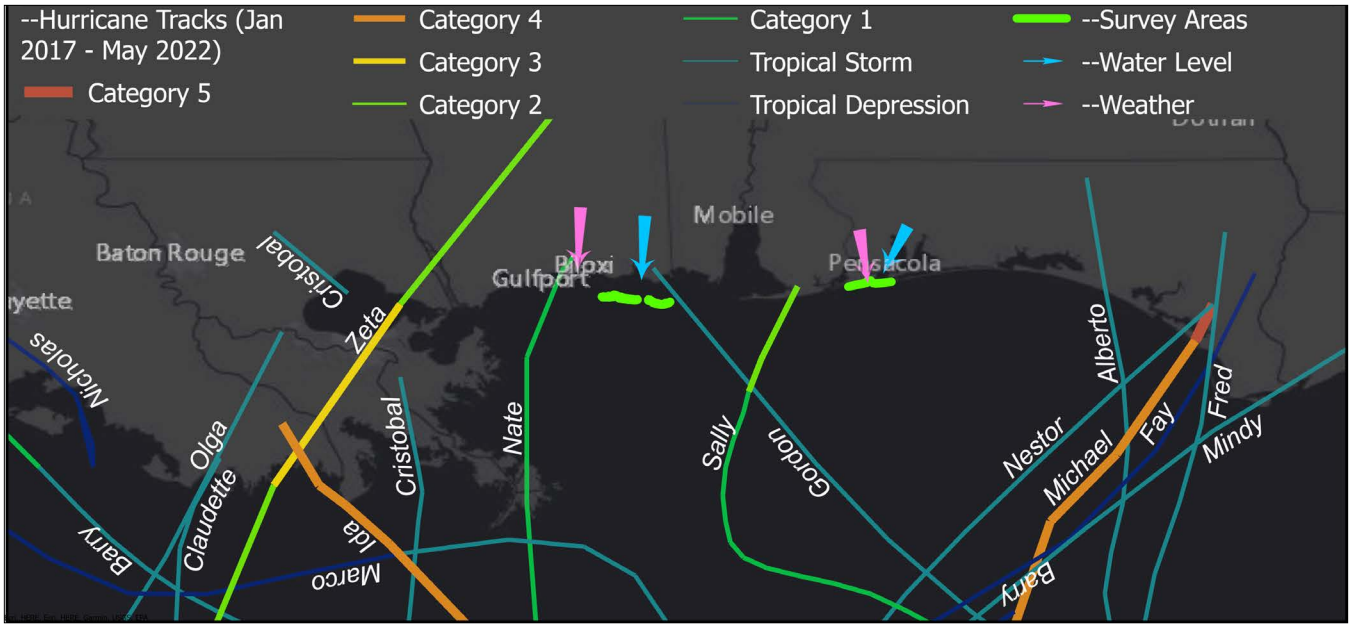

Figure 8. Map showing tropical storms making landfall near Gulf Islands National Seashore from January 2017 through May 2022. Weather and water level stations used for this report are also shown.

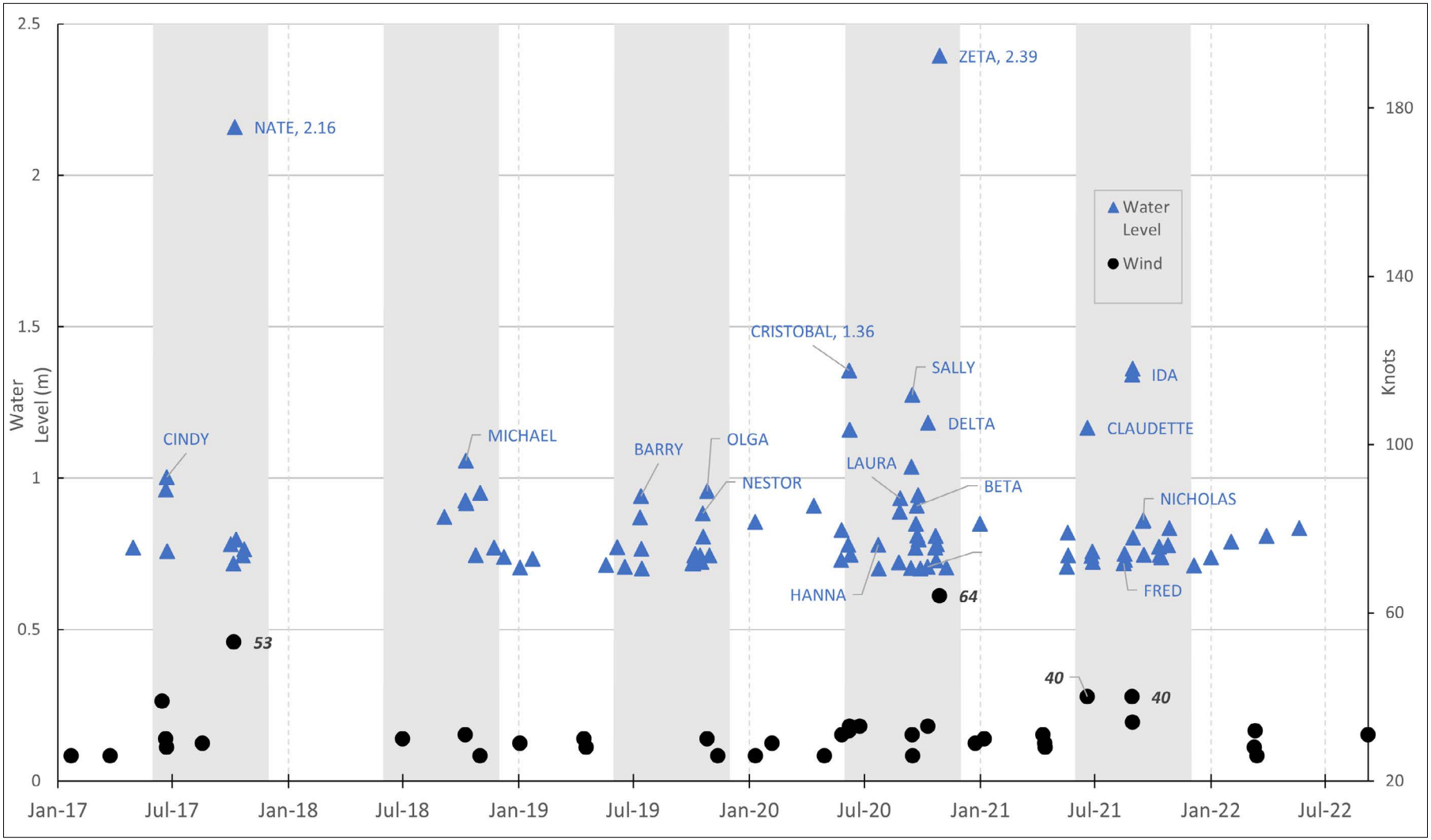

Figure 9. GUIS-MS combined scatterplot showing water level events that exceed 0.7 meters (2.3 ft) NAVD88 and wind speeds that exceed 26 knots (28.8 mph). Water level is depicted with triangles, and circles represent wind speed. All named storms for the period are labeled on the water level plot and the three highest water level event labels include the recorded water level. Likewise, the three windiest events are labeled with wind speed. Grey columns define the Atlantic hurricane season, June 1 through November 30.

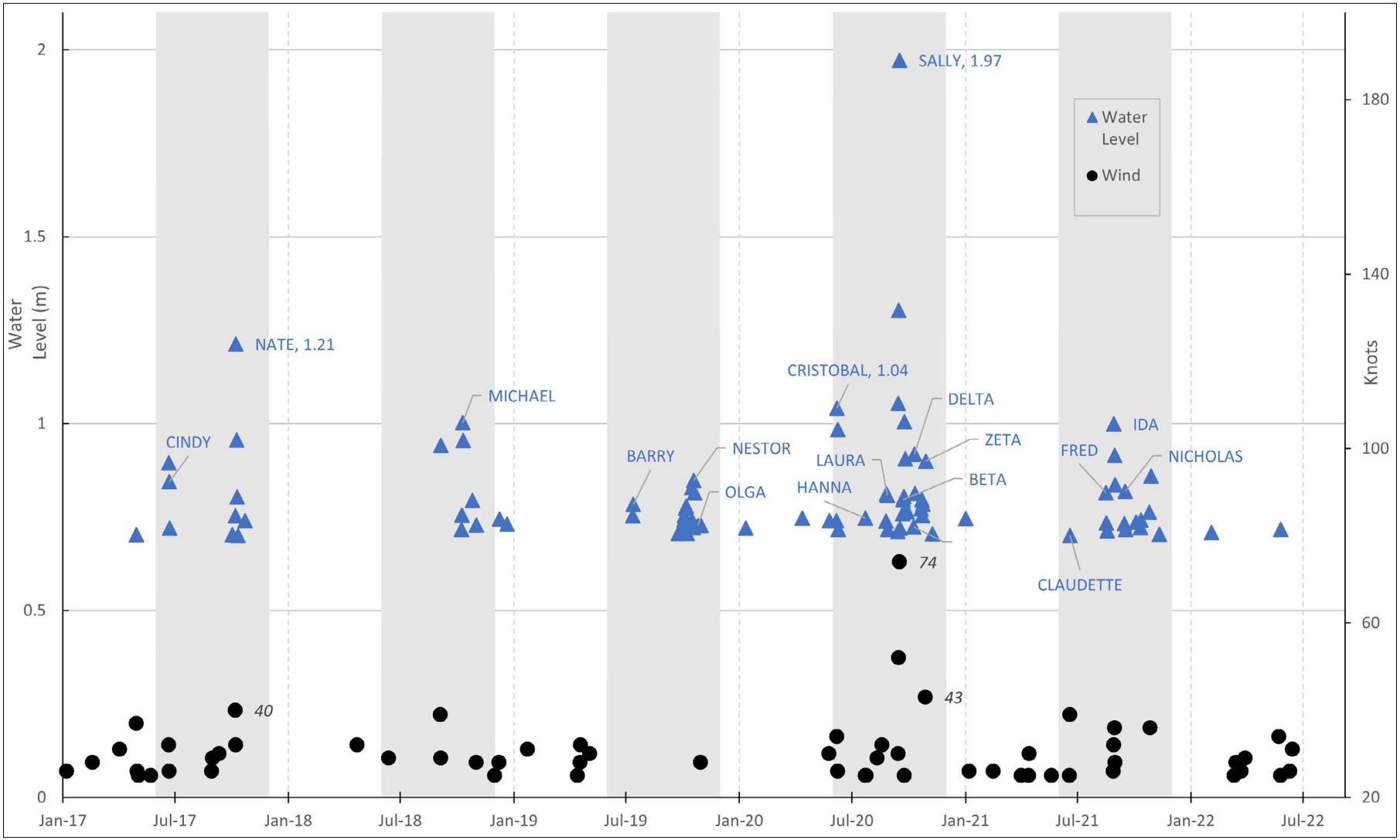

Figure 10. GUIS-FL combined scatterplot showing water level events that exceed 0.7 meters (2.3 ft) NAVD88 and wind speeds that exceed 26 knots (28.8 mph). Water level is depicted with triangles, and circles represent wind speed. All named storms for the period are labeled on the water level plot and the three highest water level event labels include the recorded water level. Likewise, the three windiest events are labeled with wind speed. Grey columns define the Atlantic hurricane season, June 1 through November 30.

Table 3 shows that GUIS-FL has experienced more frequent storm-like conditions than GUIS-MS over the past six years, with 28 more high water or high wind events. However, GUIS-MS was particularly hard hit by Hurricanes Nate and Zeta, where water levels exceeded 2 meters (6.6 ft) and wind speeds exceeded 50 knots (57.5 mph; Figure 9). At GUIS-FL, Hurricane Sally was the most damaging storm for the six-year period, with water levels near 2 meters (6.6 ft) and wind speeds at 74 knots (85 mph; Figure 10). For both park districts, 2020 was ranked as the stormiest year. Most recently, Hurricane Ida made landfall south of New Orleans, LA, in late August of 2022. Maximum wind speeds and gusts recorded on August 30 by nearby NOAA Co-ops stations were 34 and 46 knots (39.1 and 52.9 mph) at GUIS-MS, and 25 and 31 knots (28.8 and 35.7 mph) at GUIS-FL (NOAA 2022a).

Table 3. Water level and wind events exceeding 0.7 meters (2.3 ft) NAVD88 and 26 knots (28.8 mph) are counted by year and then combined to estimate "storminess." Rank is given in the Year column, 2020 was the stormiest year in both park districts. *2022 only includes data up to the writing of this report, September 2022, and is therefore incomplete and not ranked.

Year (Rank)	MS-Water Level	MS-Wind	MS-Total	FL-Water Level	FL-Wind	FL-Total
2017 (4)	11	7	18	10	14	24
2018 (5)	9	3	12	8	7	15
2019 (3)	16	5	21	19	6	25
2020 (1)	34	12	46	32	12	44
2021 (2)	17	7	24	22	13	35
*2022	2	4	6	4	8	12
Total	**89**	**38**	**127**	**95**	**60**	**155**

Table 4 presents current relative sea level trends assembled from NOAA (2022a) for three stations close to the park. In all cases, the values are positive, indicating that water levels are rising, the land surface is subsiding, or some combination of the two variables that causes land to become increasingly inundated.

Table 4. Relative sea level rates for NOAA tide stations close to GUIS.

Location	Station ID	Rate (mm.year)
Dauphin Island, AL	8735180	4.25
Pensacola, FL	8729840	2.59
Panama City Beach, FL	8729210	4.9

Dredging and Beach Nourishment

In spring 2022, GUIS-FL began a beach and dune nourishment project that added about 180,962 cubic yards (CY; 138,355 cubic meters) of sand near the eastern end of Perdido Key (A. Warren, Personal Communication, October 2022). The nourishment project was underway when the Gulf Coast Network conducted its shoreline position survey at Gulf Islands National Seashore on April 13, 2022, but only about 25% of the project was complete at that time. Mild weather followed the GULN visit, and construction was finished before the end of the month. The network digitized a post-construction shoreline using cross-shore topographic survey data of the project area collected by project contractors. The digitized shoreline was created from topographic points that fell close to 0.0 elevation (NAVD88). A summary comparing the digitized post-construction shoreline with the spring 2021 shoreline reveals that the restoration project advanced the shoreline position by an average of 42.2 meters (138.5 ft). This position is seaward of the 2018 shoreline position for most of the project area (Figure 11).

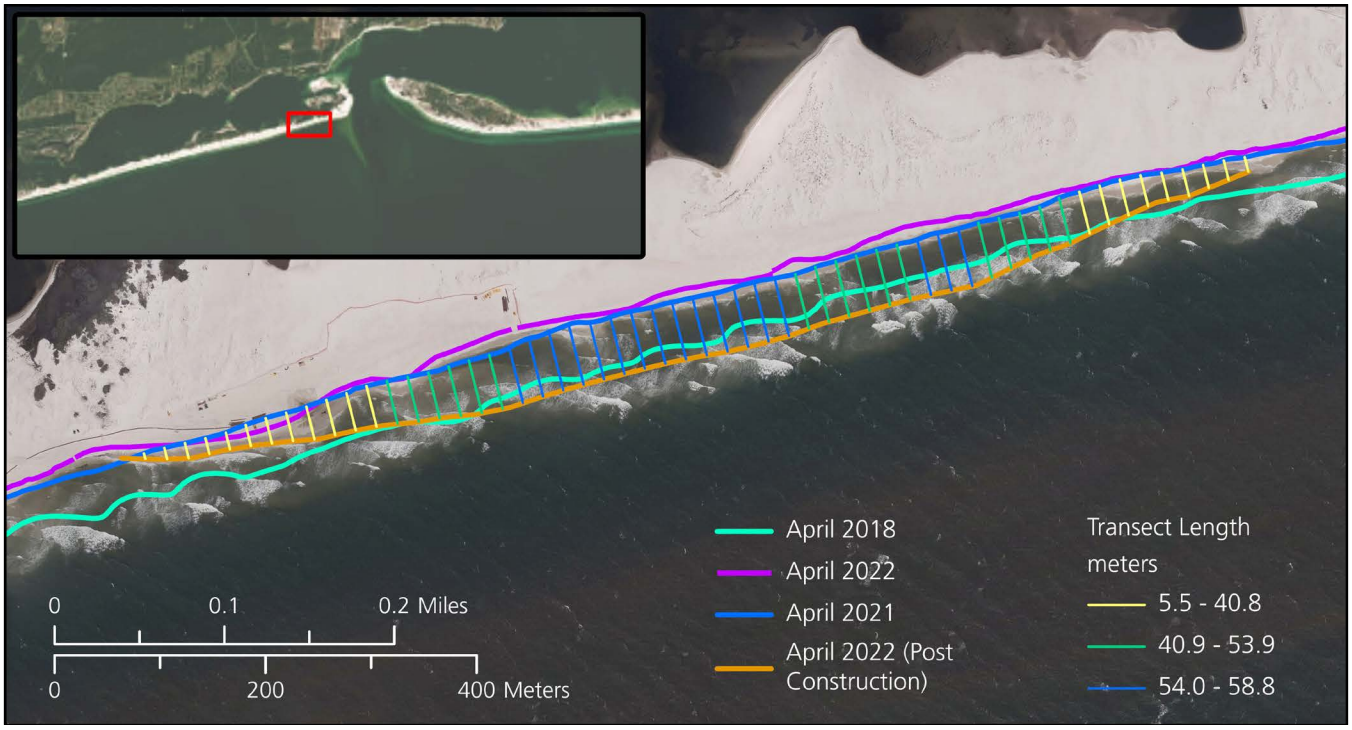

Figure 11. Graph showing distribution of shoreline advance distances in meters for the GUIS restoration project at Perdido Key. Summary statistics for project area include Range: 5.5 to 58.8 meters (18 to 192.9 ft), Mean: 42.2 meters (138.5 ft), and Standard Deviation: 15.3 meters (50.2 ft).

Results

Shoreline Position Data Quality

Shoreline position was recorded in the spring of 2018, 2021 and 2022. The average post-processed horizontal precision remained near or below 10 centimeters (3.9 inches; Table 5). There were two gaps in data coverage in 2021 on the western Gulf shoreline of Horn Island due to equipment operator error that totaled approximately 3.8-kilometers [2.4 miles] (Figure 12). This loss in coverage reduces sample size and spatial distribution of island width transects for 2018 to 2021 and 2021 to 2022 comparisons, but the impact is limited to Horn Island.

Table 5. Summary of End Point Rate (EPR) for the Florida Units. Distances are reported in meters per year. Positive numbers indicate an advance seaward and negative numbers indicate landward retreat.

Area	Year	Average Horizontal Accuracy (centimeters)
GUIS-FL	2018	1.5
GUIS-MS	2018	4.2
GUIS-FL	2021	4.8
GUIS-MS	2021	13.0
GUIS-FL	2022	1.9
GUIS-MS	2022	12.6

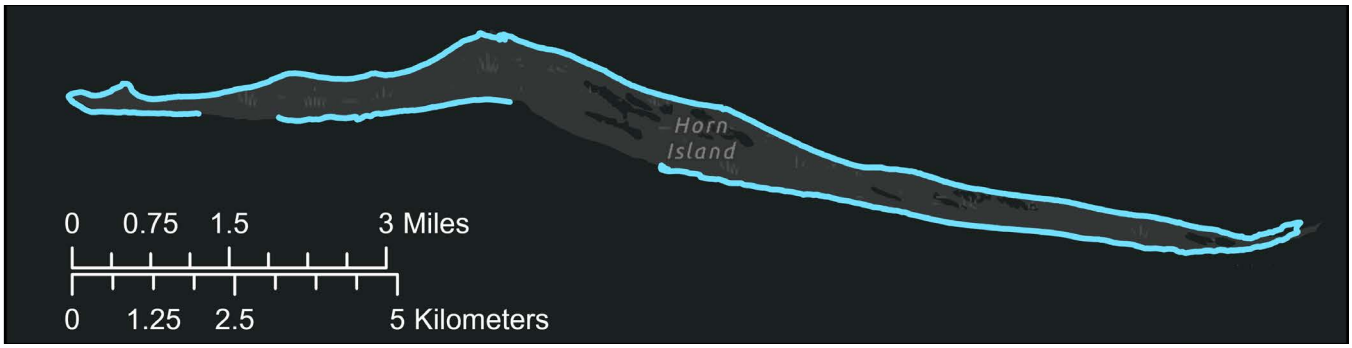

Figure 12. Data gaps on Horn Island totaling approximately 3.8 kilometers or 2.4 miles.

Table 6 and Figure 13 present grouped summary statistics for the 2018, 2021 and 2022 shoreline position change rates and include: transect count, minimum, maximum, average, and standard deviation. Although the focus was on comparing the temporal endpoints of 2018 and 2022, short-term comparisons were also made using 2018 and 2021 as well as 2021 and 2022. All groups showed overall landward retreat or island narrowing as indicated by the end-point comparisons. That said, short-term accretion was noted at West Petit Bois Island and Fort Pickens. The accretion in Mississippi is likely the outcome of a spring 2021 Horn Island Pass dredging project that disposed of 159,233 cubic yards (121,742 cubic meters) of sand on West Petit Bois Island (Bracewell 2022b). The Santa Rosa County beach updrift from Fort Pickens was last nourished in 2016 with over 1.8 million cubic yards (1.4 million cubic meters) of sand (FDEP 2020). Although Perdido Key and Petit Bois showed shoreline retreat in both short-term time steps, the retreat was less between 2021 and 2022 than it was from 2018 to 2021.

A notable observation for Horn Island is that the overall shoreline retreat (2018 to 2022) is less than the retreat between 2018 to 2021 or between 2021 and 2022. The most likely explanation is that accretion occurred in the zones where no data were collected in 2021.

Overall, the shift from highly erosional to less erosional or accretional shorelines for the two short-term time steps is likely the outcome of a very active 2020 hurricane season followed by a much quieter 2021 hurricane season (Table 4). End point and island width rate histograms, grouped by unit, are presented in Appendix A and related change rate maps are presented in Appendices B and C.

Table 6. Summary of End Point Rate (EPR) for the GUIS-FL units: distances are reported in meters per year. Positive numbers indicate an advance seaward and negative numbers indicate landward retreat. Summary of Island Width Rate (IWR) for the GUIS-MS units: change in width is reported in meters per year. The negative numbers indicate island narrowing, while positive numbers indicate island widening over the three-year interval. *These two sample sizes are smaller than 2018 to 2022 sample sizes because of a data gap on Horn Island in 2021. [a] Bolded values indicate mean shoreline advance.

Unit	2018 to 2021 Count	2018 to 2021 Min, Max	2018 to 2021 Mean	2018 to 2021 St Dev	2021 to 2022 Count	2021 to 2022 Min, Max	2021 to 2022 Mean	2021 to 2022 St Dev	2018 to 2022 Count	2018 to 2022 Min, Max	2018 to 2022 Mean	2018 to 2022 St Dev
Horn	*764	-44.9, 34.5	-7.0	11	*768	-68.7, 84.2	-6.8	19.1	954	-37.9, 64.2	-4.2	14.6
W Petit Bois	74	-69.0, 61.6	-18.8	23.3	74	-122.5, 241.7	**10.0**[a]	73.1	76	-67.1, 45.5	-11.6	22.2
Petit Bois	485	-28.5, 22.6	-7.7	9.2	485	-45.4, 92.3	-7.5	16.9	489	-25.8, 29.6	-7.5	7.9
Perdido Key	539	-23.1, 12.7	-8.3	4.4	539	-36.4, 35.3	-2.6	12.6	582	-19.0, 26.5	-6.0	5.3
Fort Pickens	538	-20.8, 3.8	-6.8	4.2	587	-43.1, 66.9	**4.0**[a]	13.4	587	-17.5, 17.7	-3.5	4.9

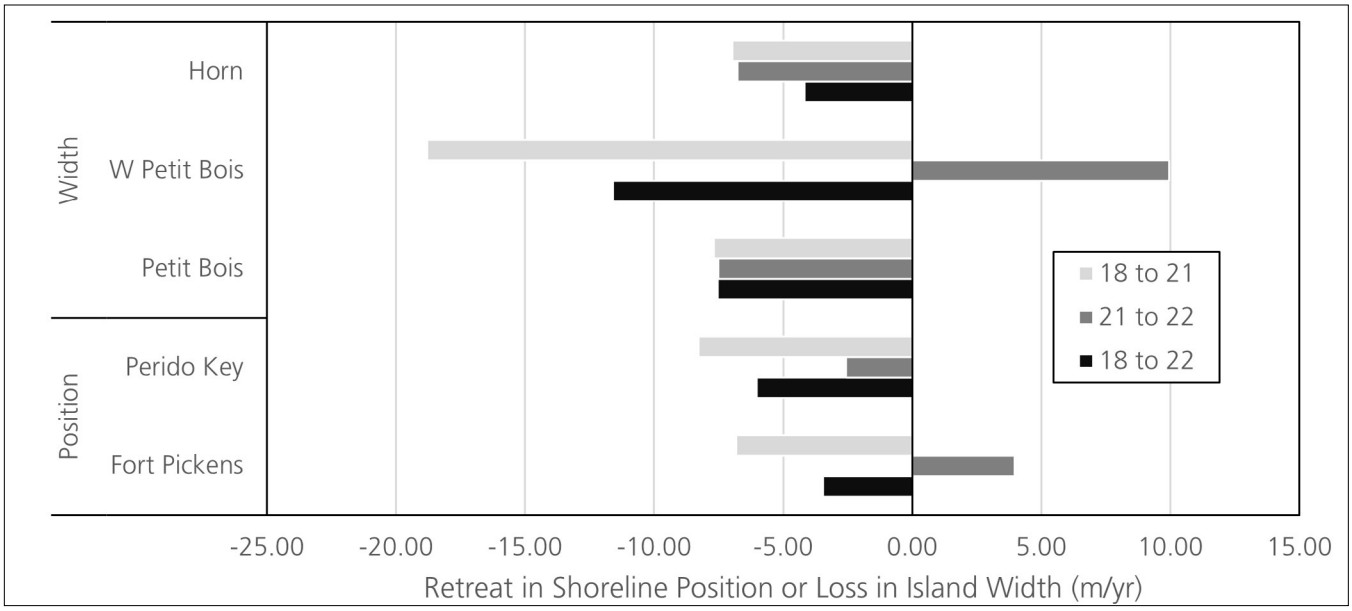

Figure 13. Grouped summary statistics for changes in shoreline position and shoreline width. Note in 2021, a data gap occurred on the western, Gulf side of Horn Island that reduces the sample size and limits the spatial distribution of island-width transects.

Annual Shoreline Change Analysis

End-point shoreline change rates were strikingly high for both GUIS-FL and GUIS-MS (Table 6, Figure 13). The average rates of retreat at Fort Pickens and Perdido Key are about three times higher than the losses reported in Kratzmann et. al (2021) between 1978 and 2018. In that report, Perdido Key retreated 2.14 meters/year (7.0 ft/year) and Fort Pickens retreated 0.93 meters/year (3.1 ft/year), compared to the rates found here of 6.02 meter/year (19.8 ft/year) at Perdido Key and 3.45 meter/year (11.3 ft/year) at Fort Pickens.

Results of EPR used at GUIS-FL are not directly comparable to Island Width Rates used at GUIS-MS because EPR only accounts for change on one shoreline. Even so, the changes reported for the GUIS-MS islands in Table 6 likely parallel the pattern of increased rates of retreat shown at GUIS-FL. Himmelstoss et al. (2017), which does not include West Petit Bois Island, reports rates of -2.88 meters/ year (-9.4 ft/year) at Petit Bois Island and -1.69 meters/year (-5.5 ft/year) at Horn Island from 1966 to 2001.

Areas of Special Interest

During scoping meetings for this project, GUIS Resource Management staff expressed targeted interest in the areas adjacent to Pensacola Pass. The most western 1-kilometer (.62 miles) stretch of Fort Pickens retreated 4.5 meters/year (14.8 ft/year) while the most eastern 1-kilometer (.62 miles) stretch of Perdido Key lost 9.2 meters/year (30.18 ft/year). Unsurprisingly, these rates of loss are higher than the unit averages of 3.45 meters/year (11.32 ft/year) and 6.02 meters/ year (19.75 ft/year; Table 6).

Problems and Concerns

A 440-meter (1444-ft) stretch of shoreline at the east end of Perdido Key, associated with the 2022 restoration project, was not surveyed because it fell within a limited access construction zone. This area had heavy equipment and discharge pipes present during the survey and posed a safety concern for access (Figure 14). To bridge the data gap, this short length of shoreline was digitized from 2022 NOAA Pre-storm imagery (NOAA 2022c), as shown in Figure 11.

When interpreting change in shoreline position, it is important to consider the influence of beach slope on horizontal displacement of shoreline position. Even slight changes in water level will expose or inundate large areas where the slope is shallow. A technical report summarizing the influence of slope and tidal variation can be found in Appendix B of Bracewell (2017). What may seem like a dramatic change in shoreline position could be attributed to a slight beach slope and tidal variation between surveys. It is anticipated that linear regression models presented in future trend reports will lessen the impact from tidal variation.

Figure 14. Heavy equipment and enclosure fencing associated with restoration work at Perdido Key.

Protocol Changes

No major changes occurred to the GULN PIP (Bracewell 2017) between its initial publication in 2017 and composition of this report.

Additional Information

For data and information related to this report please visit https://irma.nps.gov/DataStore/Reference/Profile/2237508.

For information about the GULN's complementary coastal dynamics project on topographic change, visit the Gulf Coast Network Coastal Topography Monitoring Project at https://irma.nps.gov/DataStore/Reference/Profile/2238503.

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Appendix A. End Point and Island Width Rate Histograms

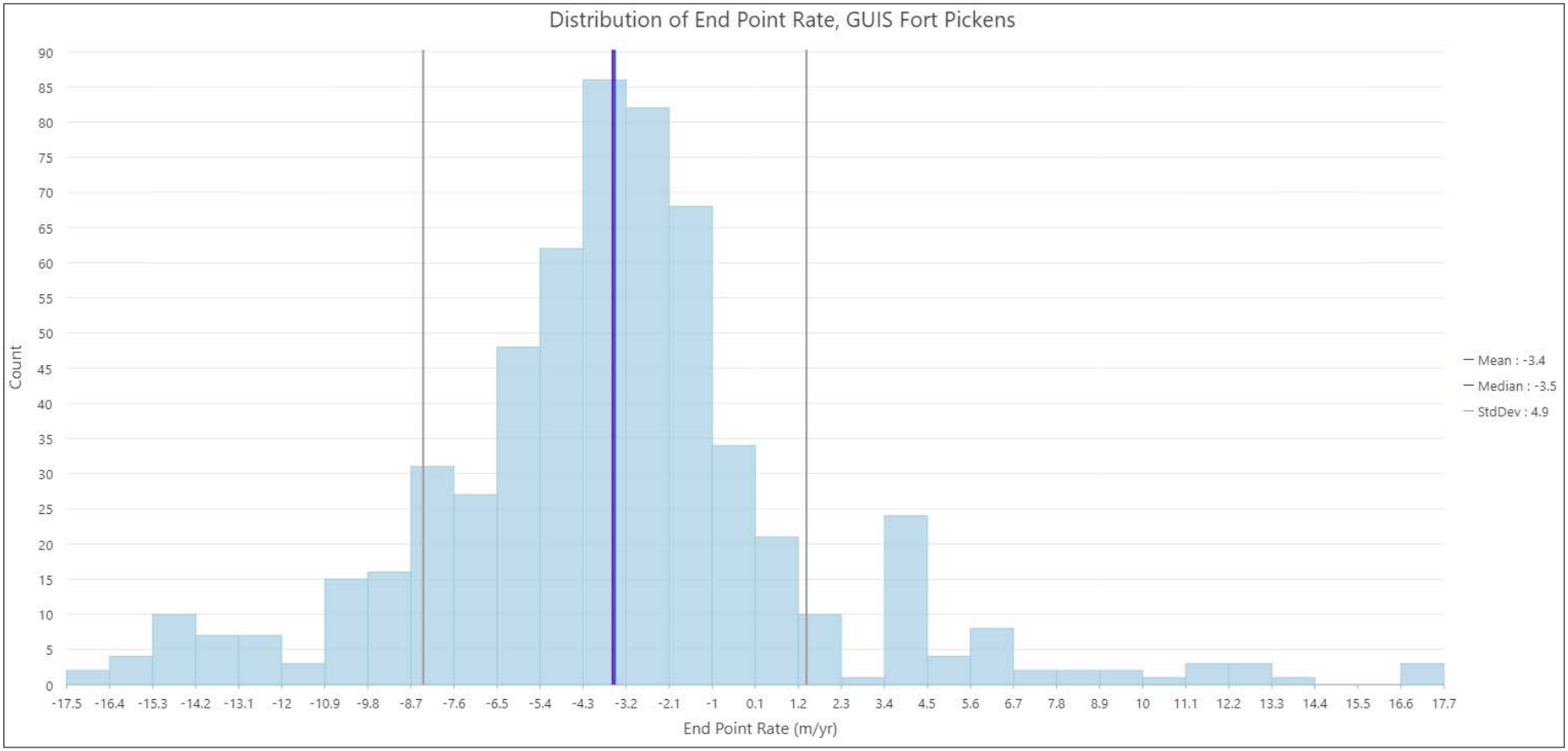

Figure A-1. Distribution of the End Point Rates (2018 to 2022) calculated for transects at Fort Pickens.

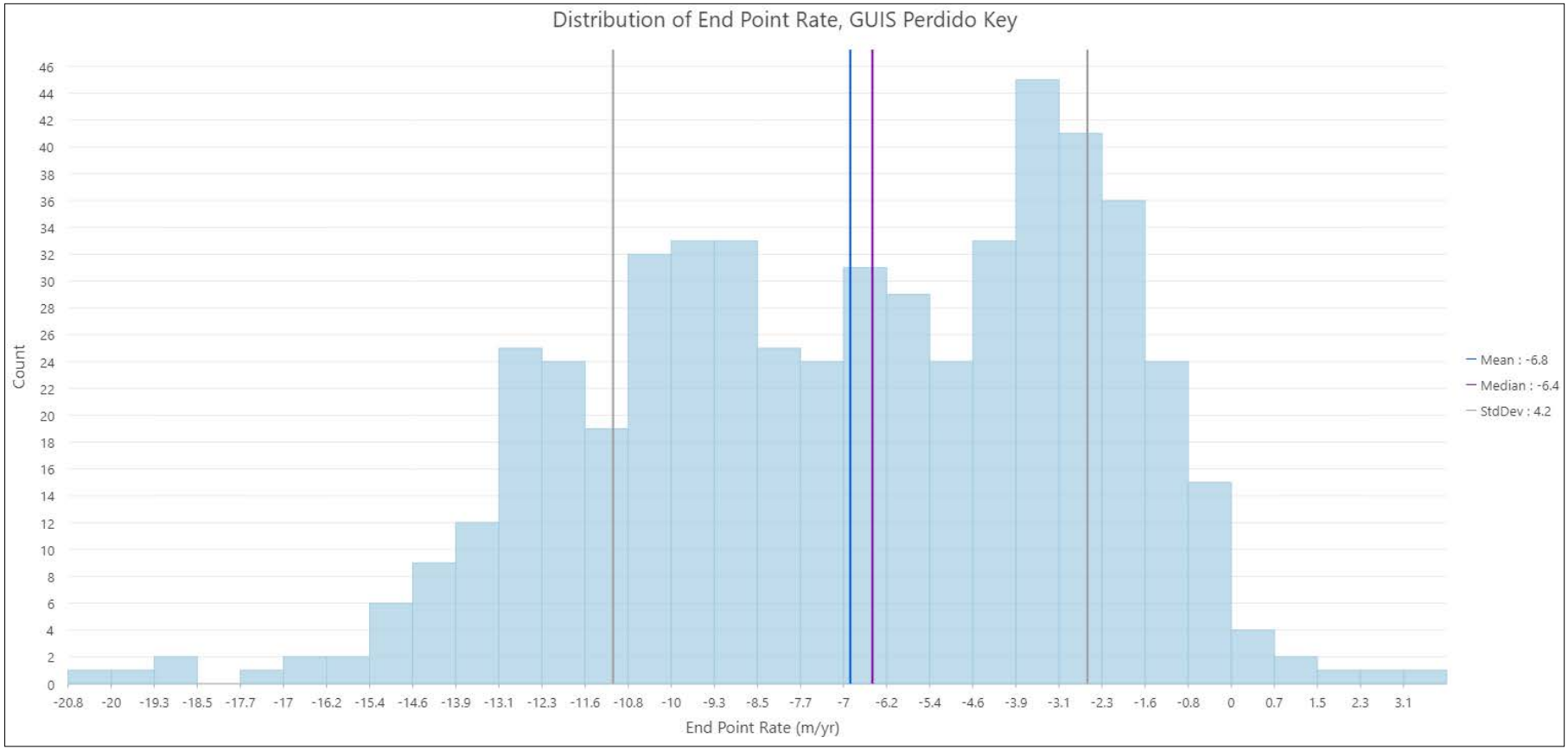

Figure A-2. Distribution of the End Point Rates (2018 to 2022) calculated for transects at Perdido Key.

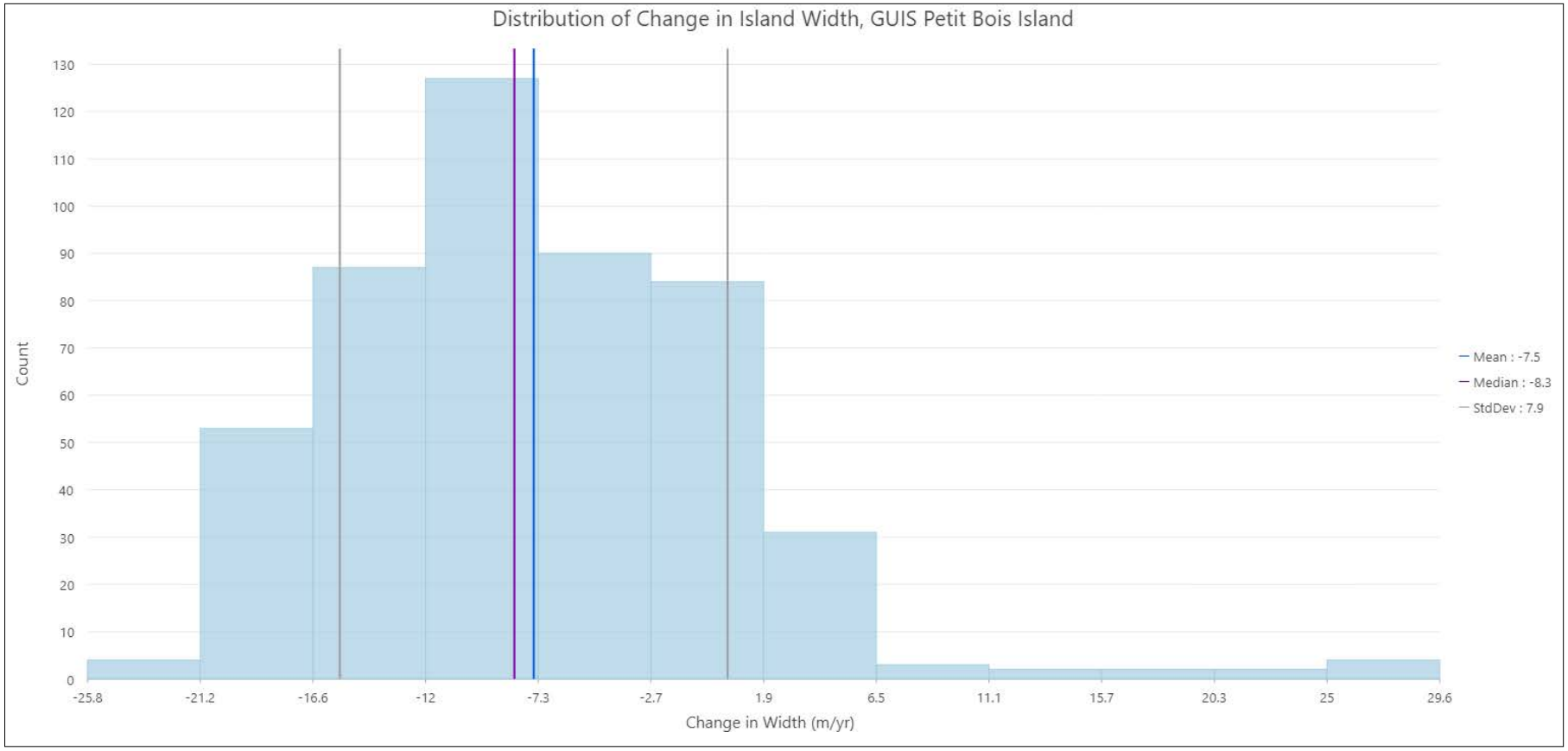

Figure A-3. Distribution of the End Point Rates (2018 to 2022) calculated for transects at Petit Bois Island.

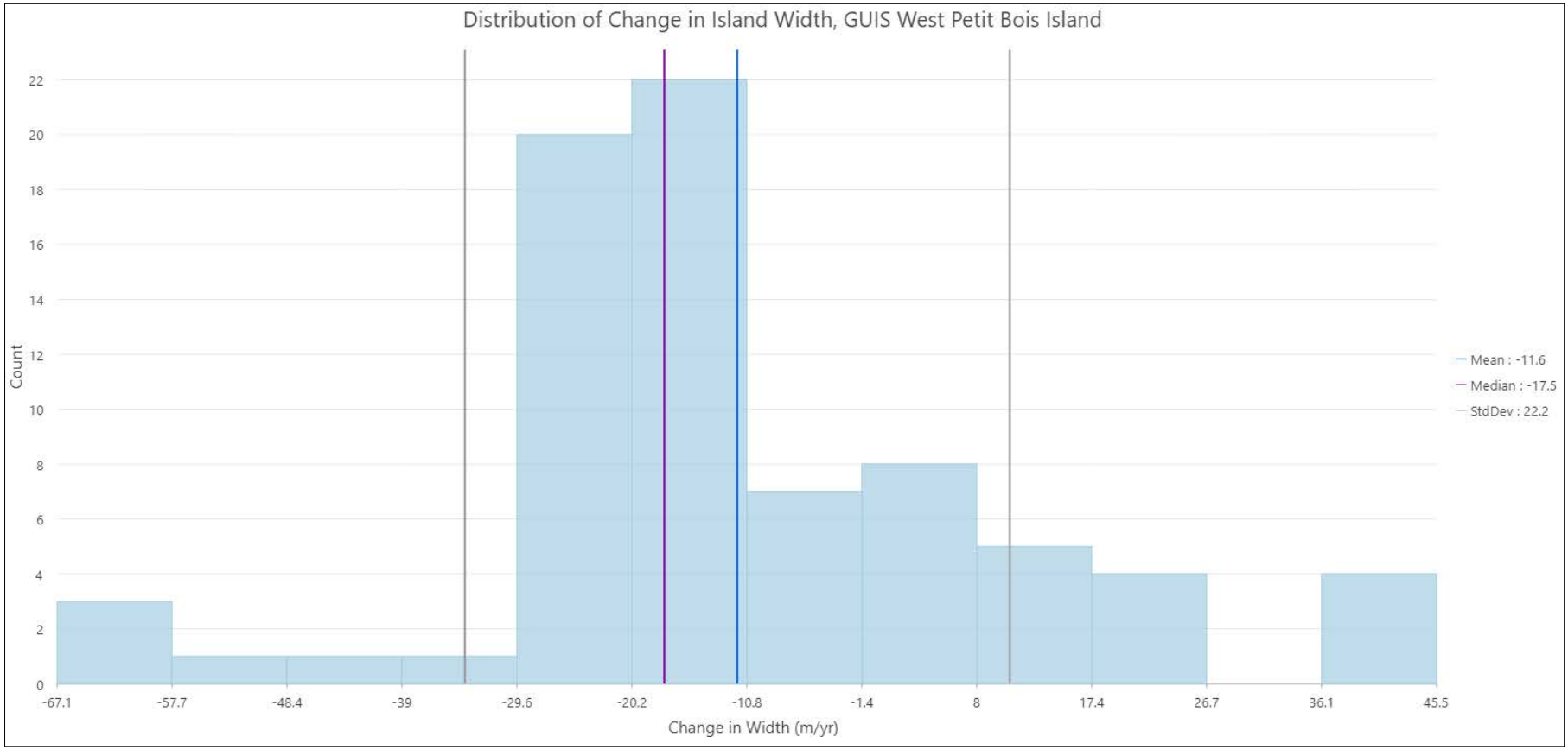

Figure A-4. Distribution of the End Point Rates (2018 to 2022) calculated for transects at West Petit Bois Island.

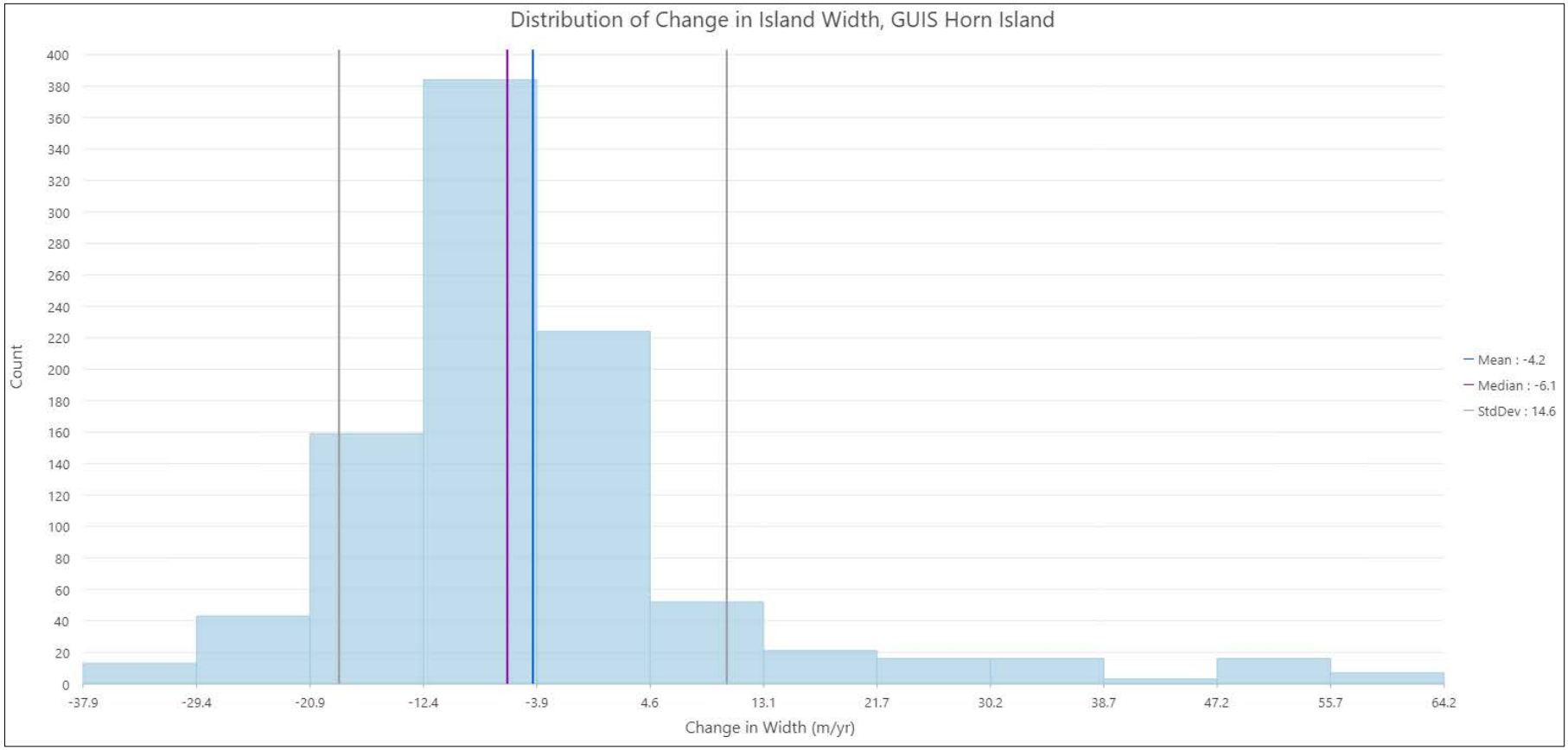

Figure A-5. Distribution of the End Point Rates (2018 to 2022) calculated for transects at Horn Island.

Appendix B. Shoreline Distance Change Rate Maps (Florida)

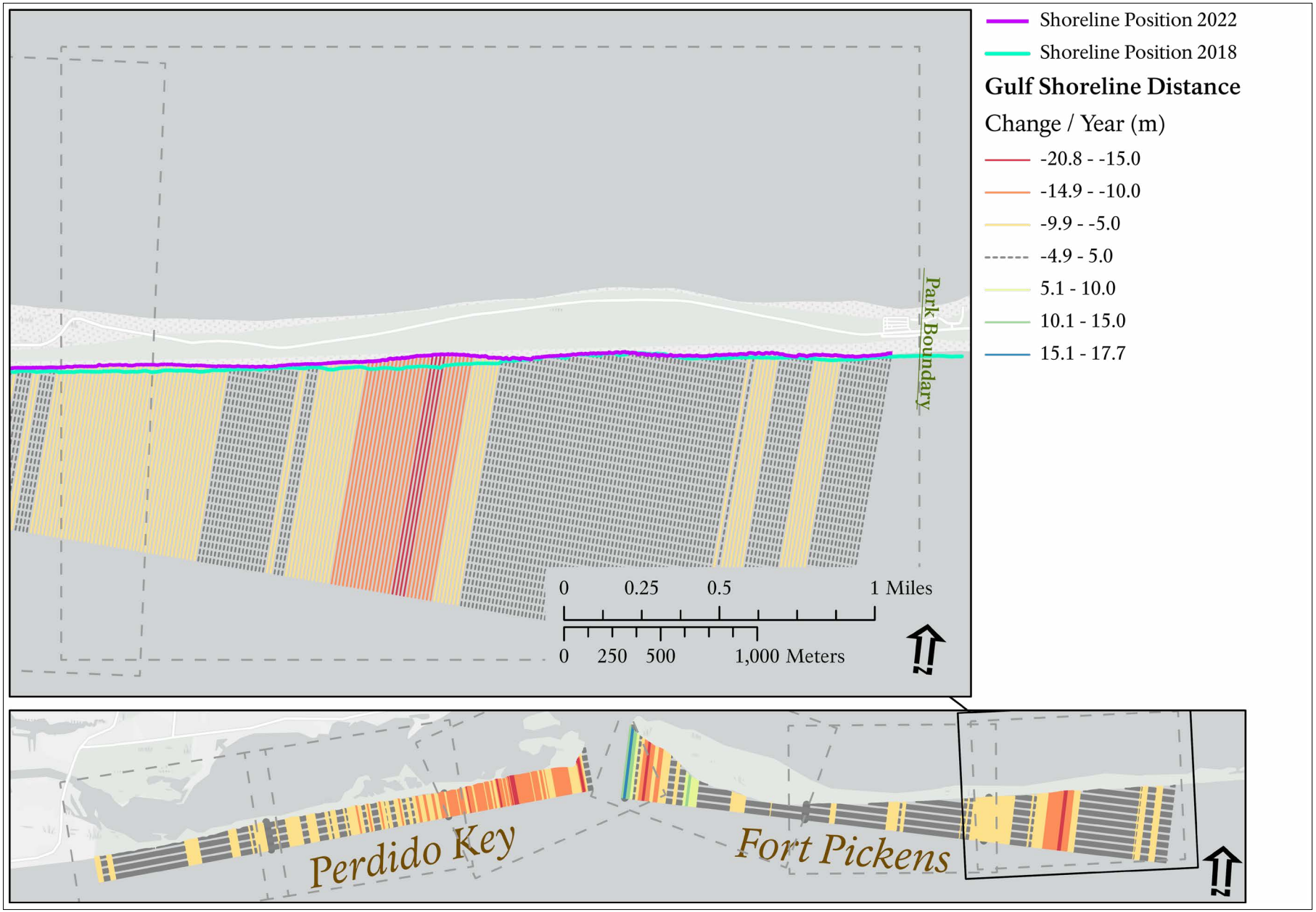

Figure B-1. Island Width Rate (2018 to 2022) for Fort Pickens and Perdido Key 1 of 6.

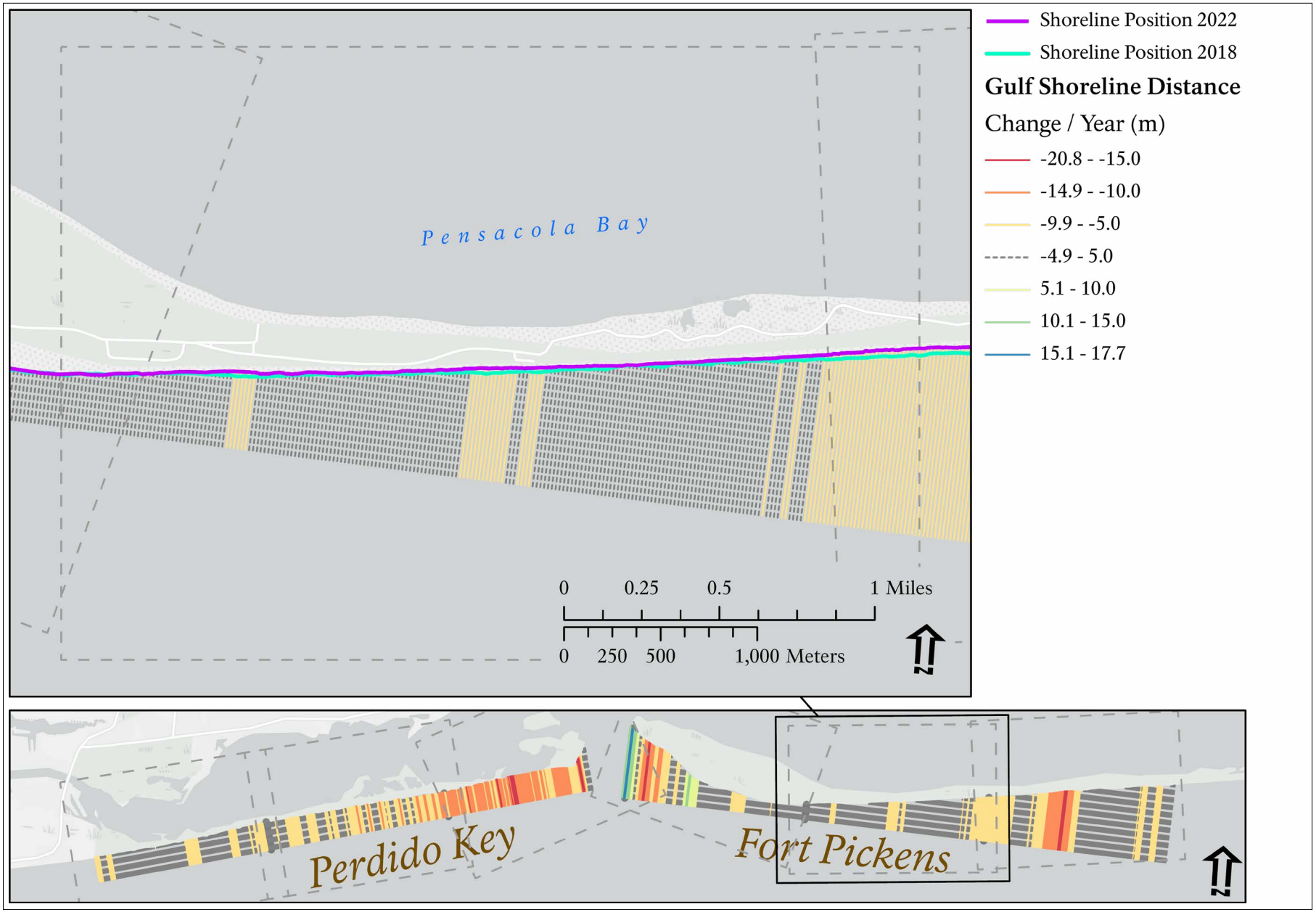

Figure B-2. Island Width Rate (2018 to 2022) for Fort Pickens and Perdido Key 2 of 6.

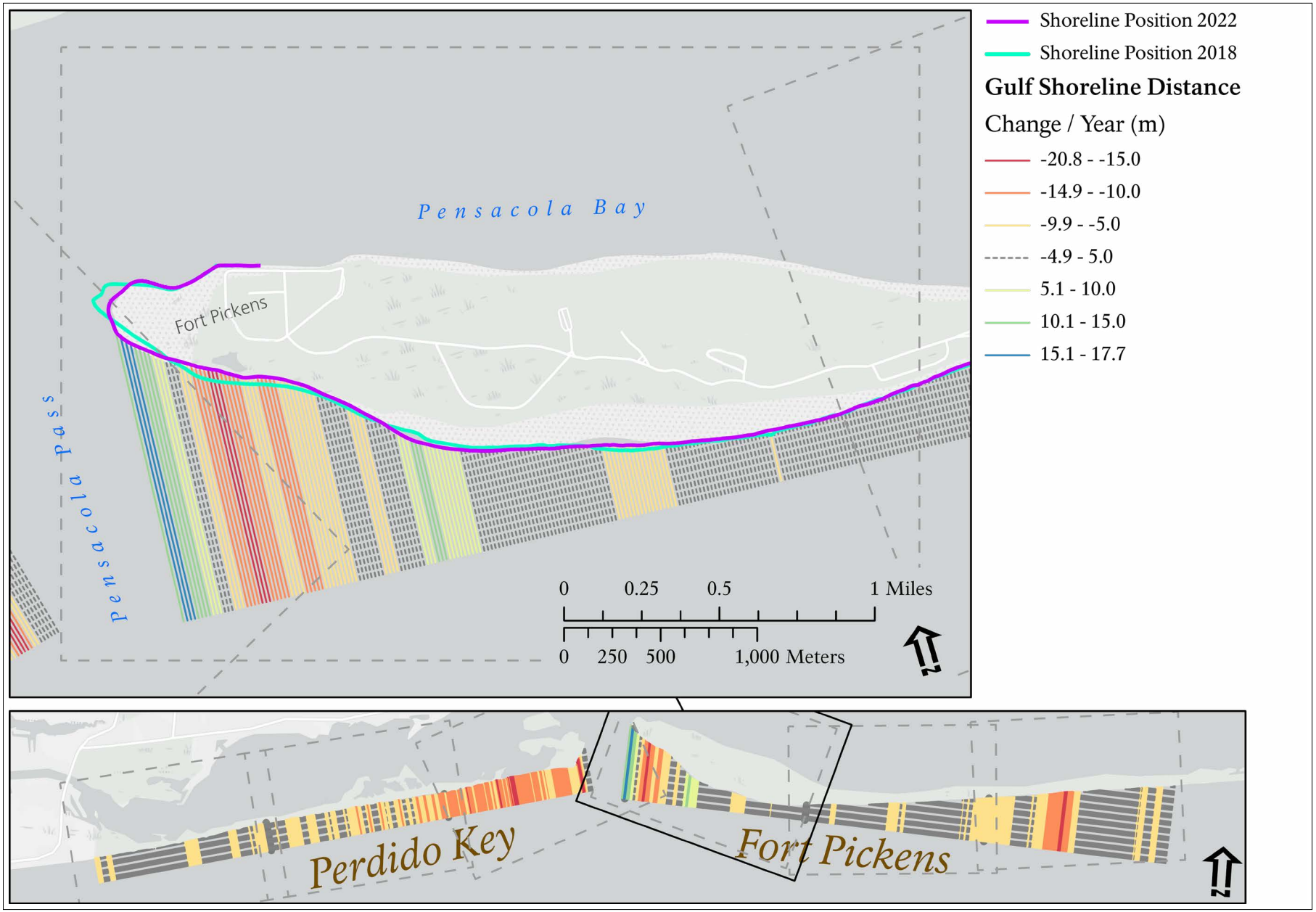

Figure B-3. Island Width Rate (2018 to 2022) for Fort Pickens and Perdido Key 3 of 6.

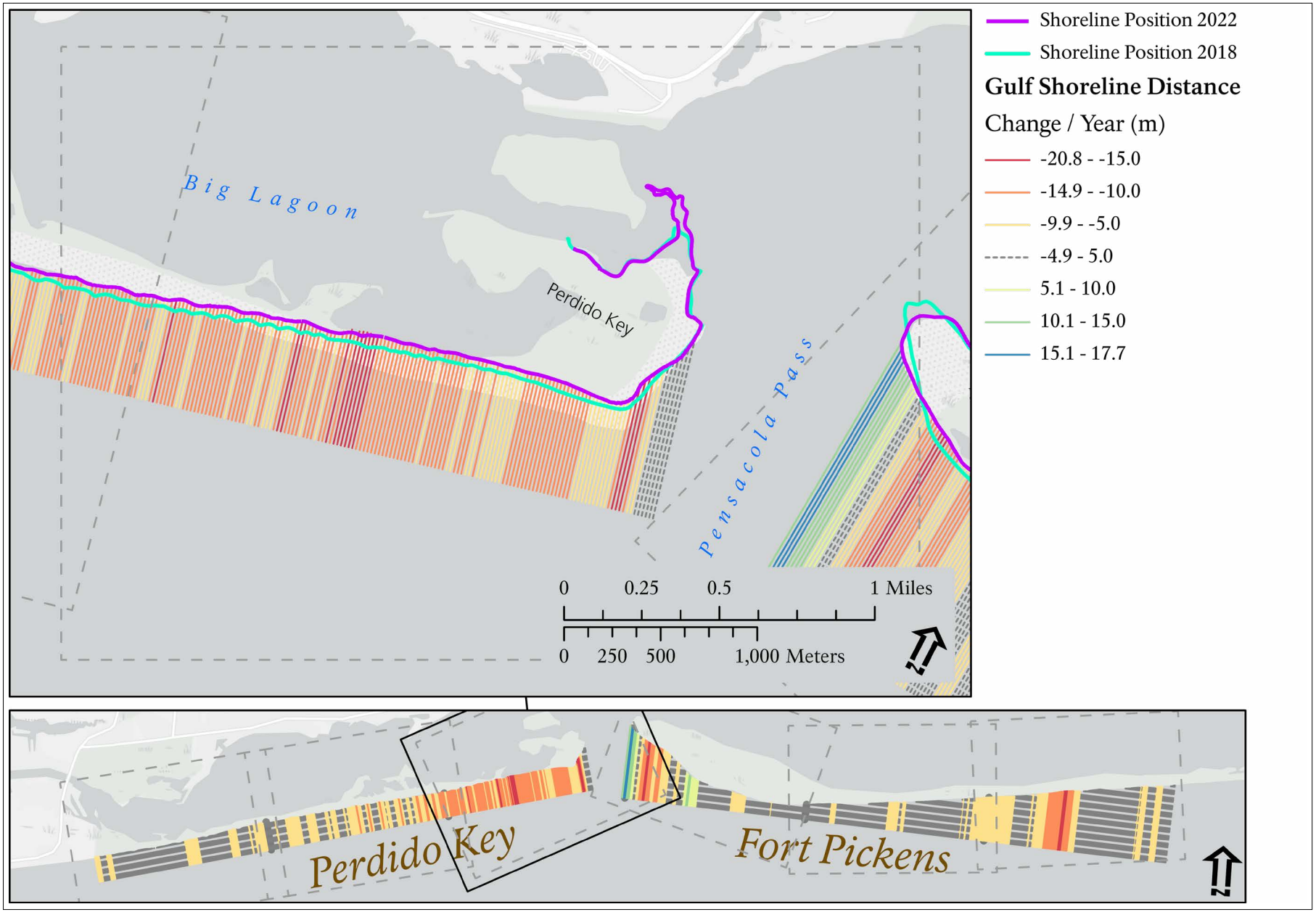

Figure B-4. Island Width Rate (2018 to 2022) for Fort Pickens and Perdido Key 4 of 6.

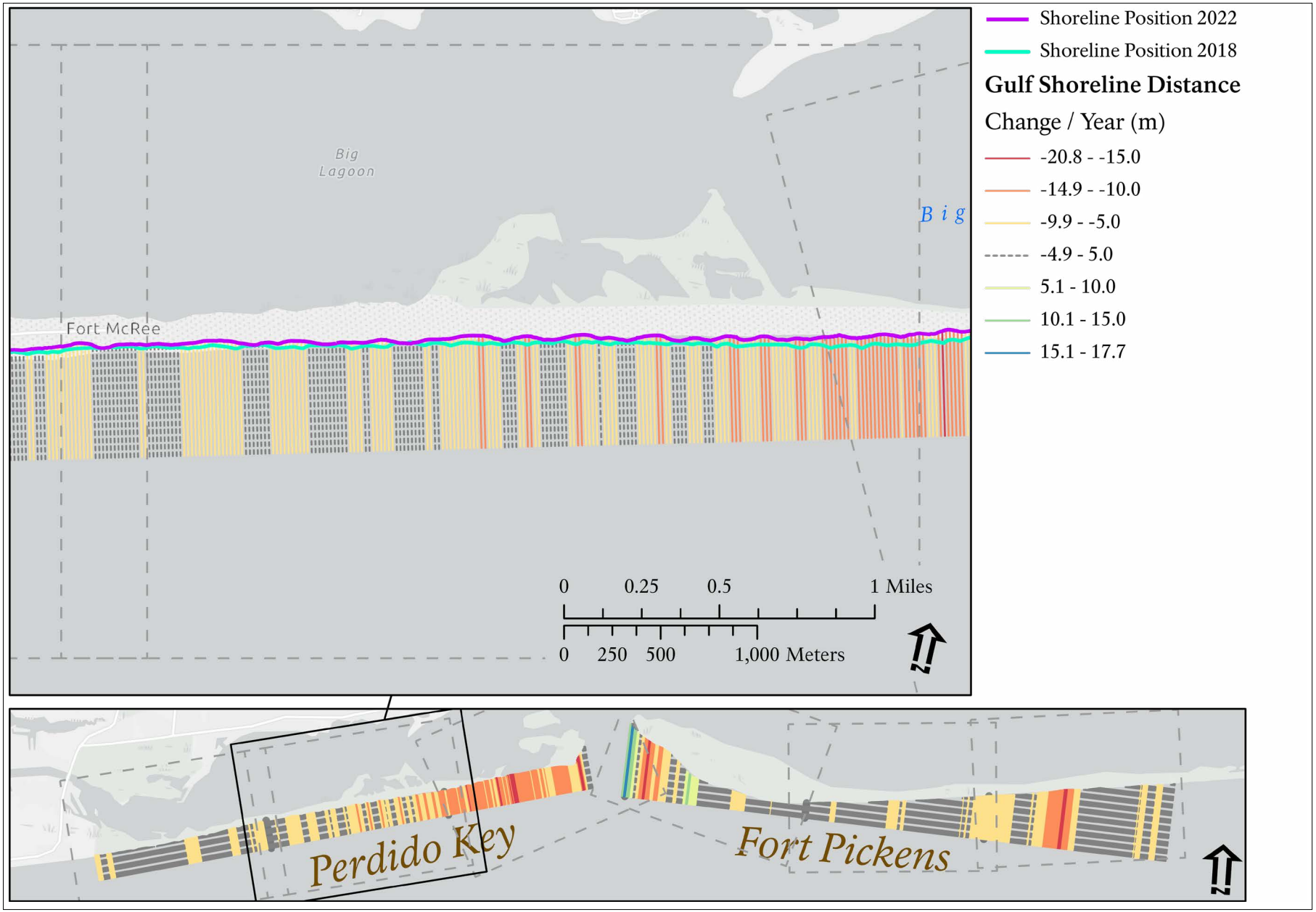

Figure B-5. Island Width Rate (2018 to 2022) for Fort Pickens and Perdido Key 5 of 6.

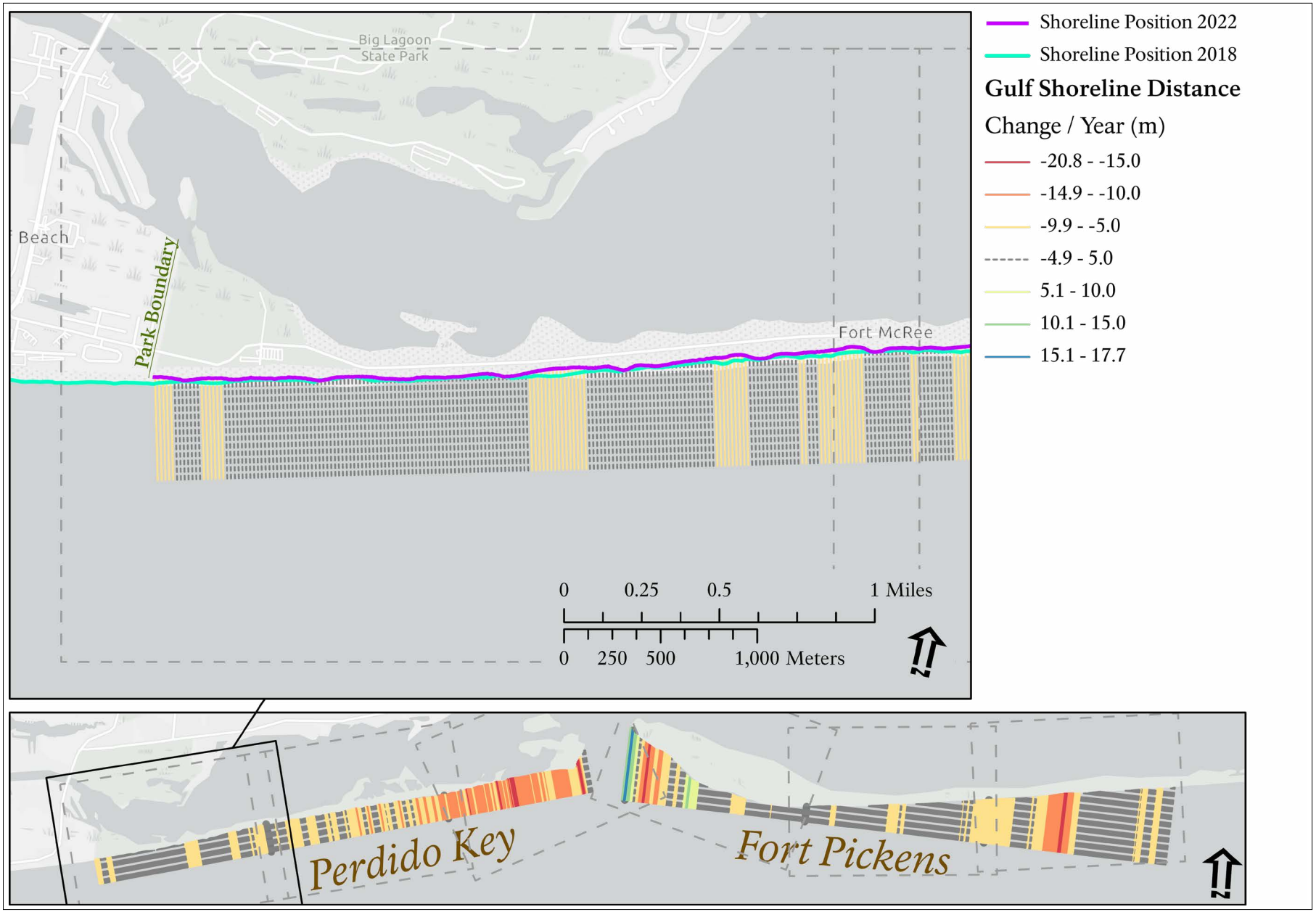

Figure B-6. Island Width Rate (2018 to 2022) for Fort Pickens and Perdido Key 6 of 6.

Appendix C. Island Width Change Rate Maps (Mississippi)

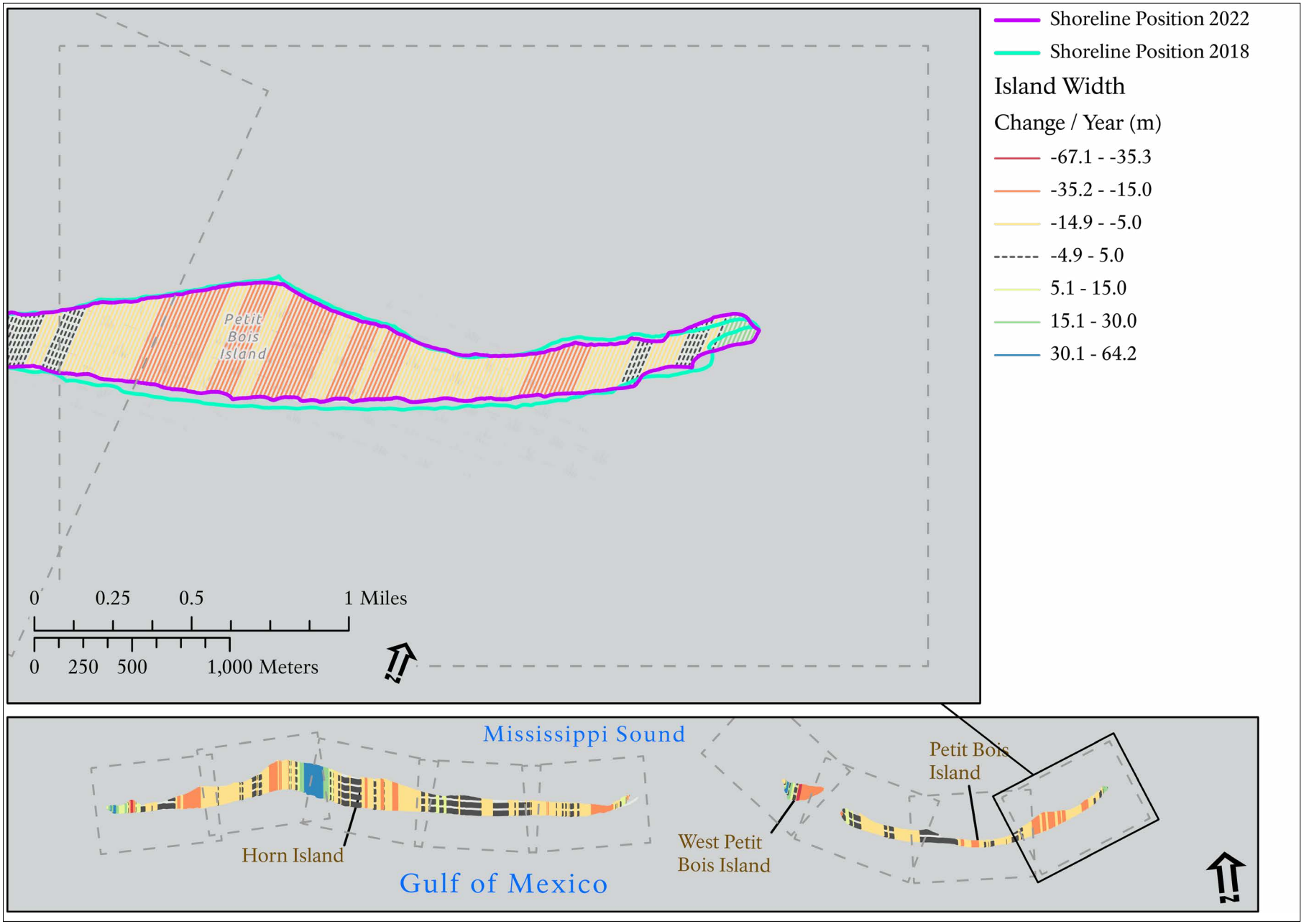

Figure C-1. Island Width Rate (2018 to 2022) for Fort Pickens and Perdido Key 1 of 9.

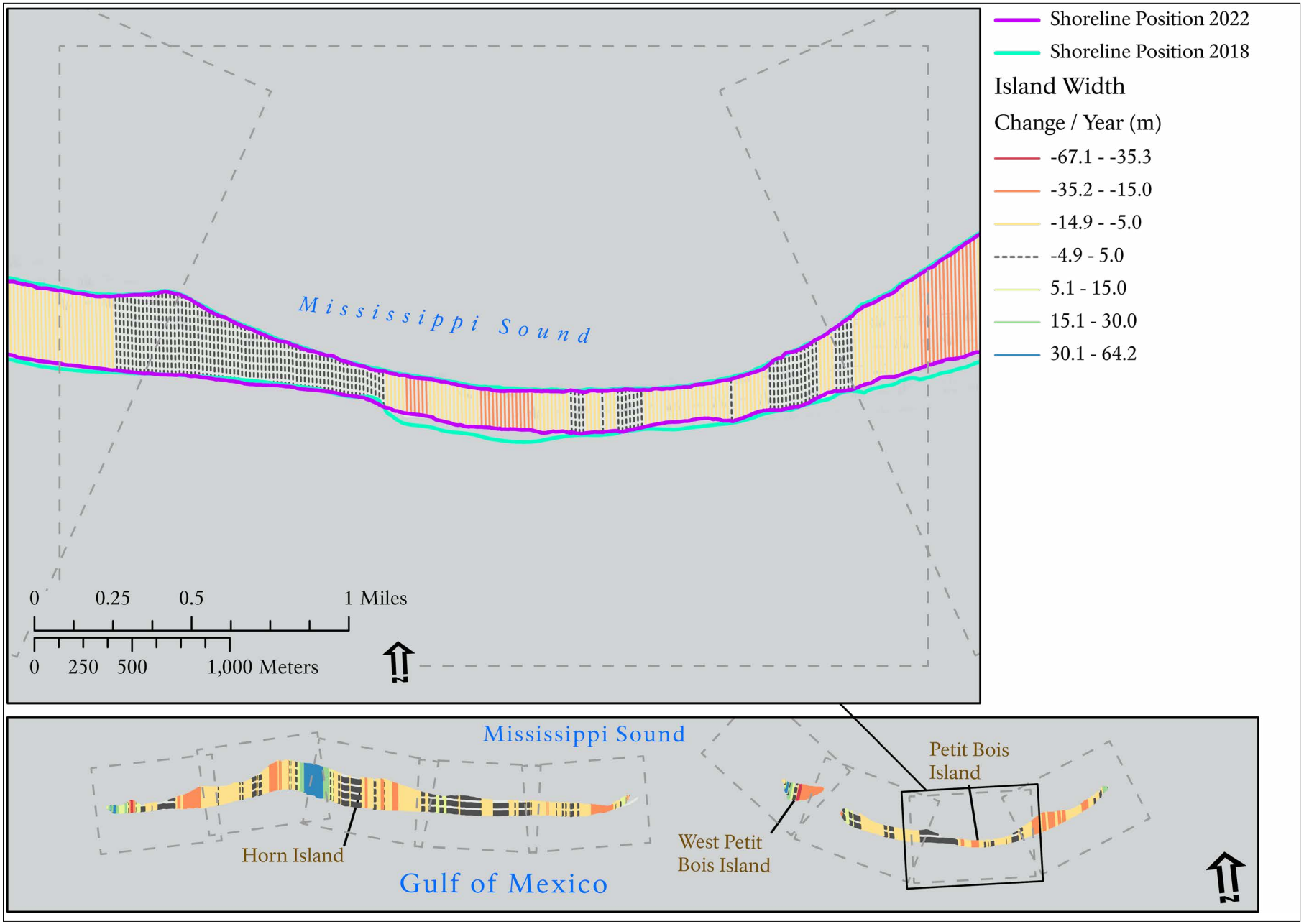

Figure C-2. Island Width Rate (2018 to 2022) for Horn Island, West Petit Bois, and Petit Bois Island 2 of 9.

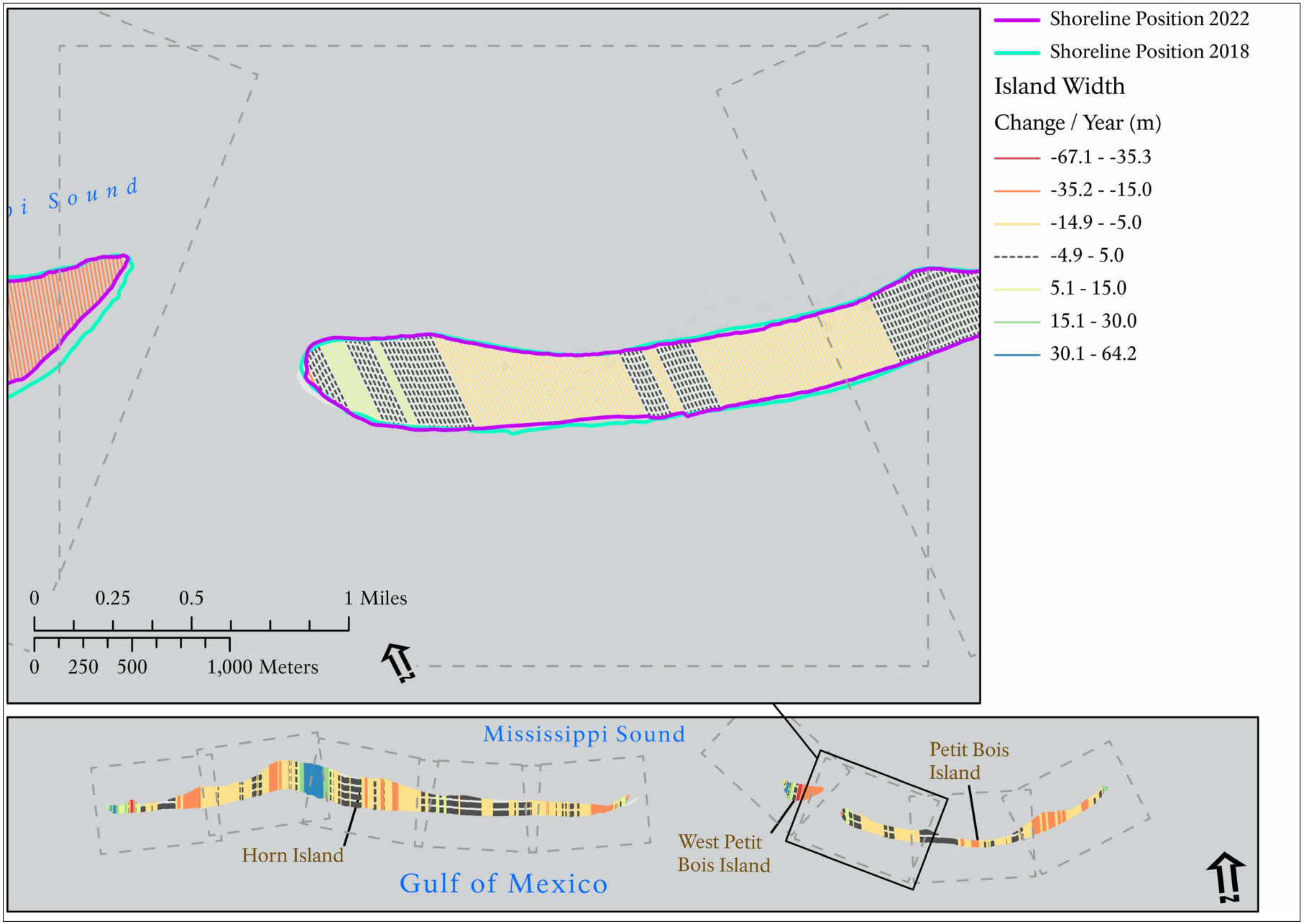

Figure C-3. Island Width Rate (2018 to 2022) for Horn Island, West Petit Bois, and Petit Bois Island 3 of 9.

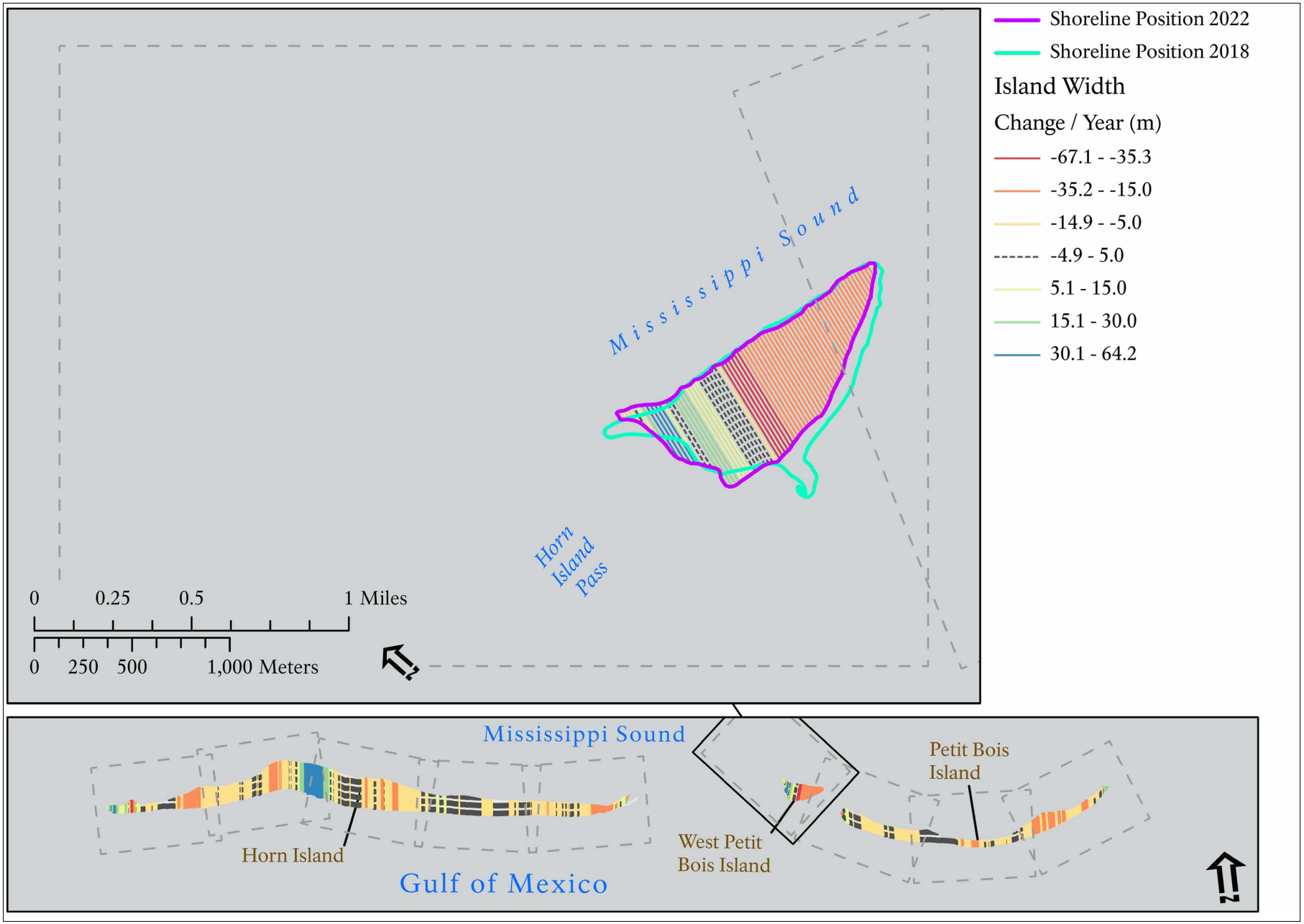

Figure C-4. Island Width Rate (2018 to 2022) for Horn Island, West Petit Bois, and Petit Bois Island 4 of 9.

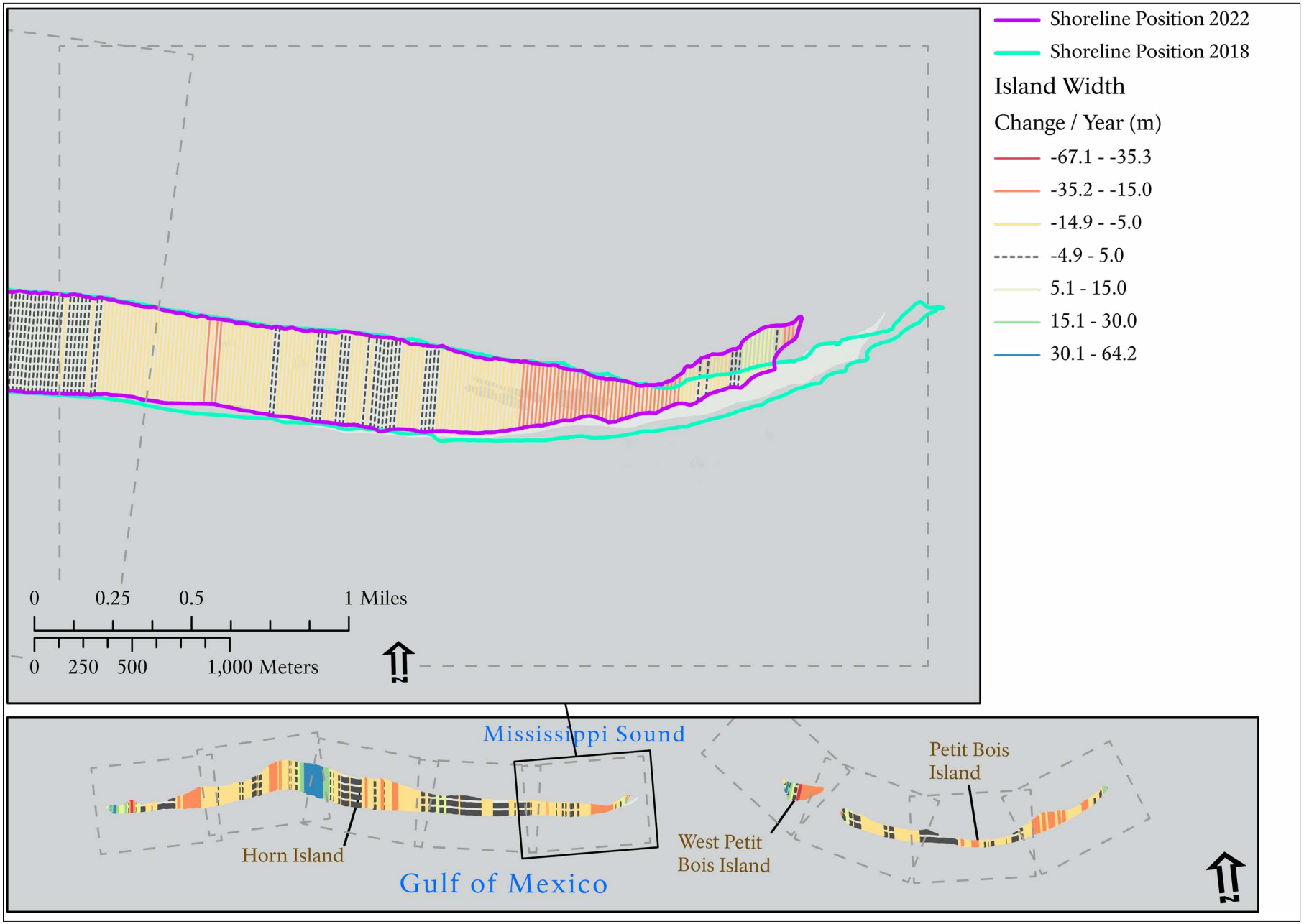

Figure C-5. Island Width Rate (2018 to 2022) for Horn Island, West Petit Bois, and Petit Bois Island 5 of 9.

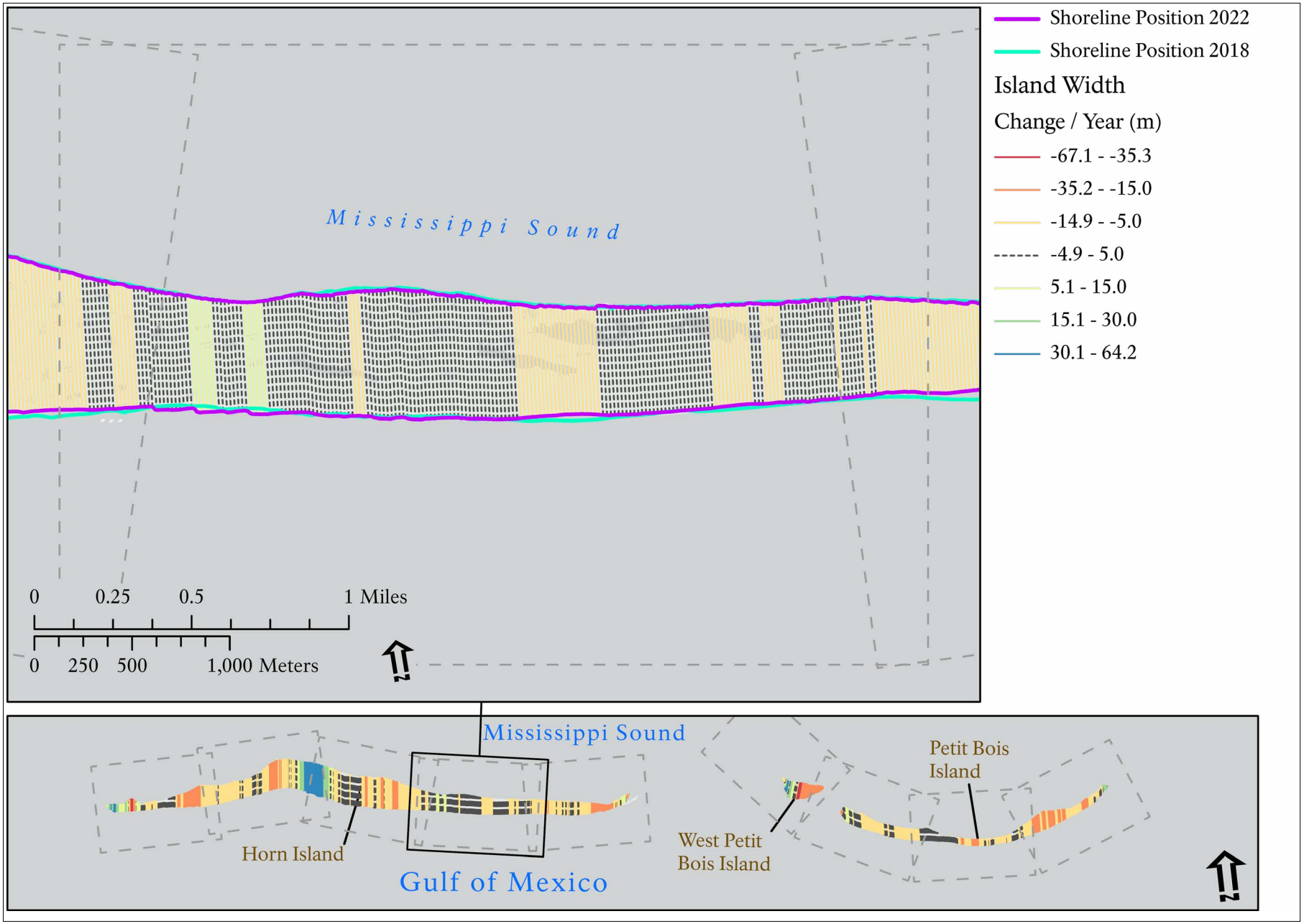

Figure C-6. Island Width Rate (2018 to 2022) for Horn Island, West Petit Bois, and Petit Bois Island 6 of 9.

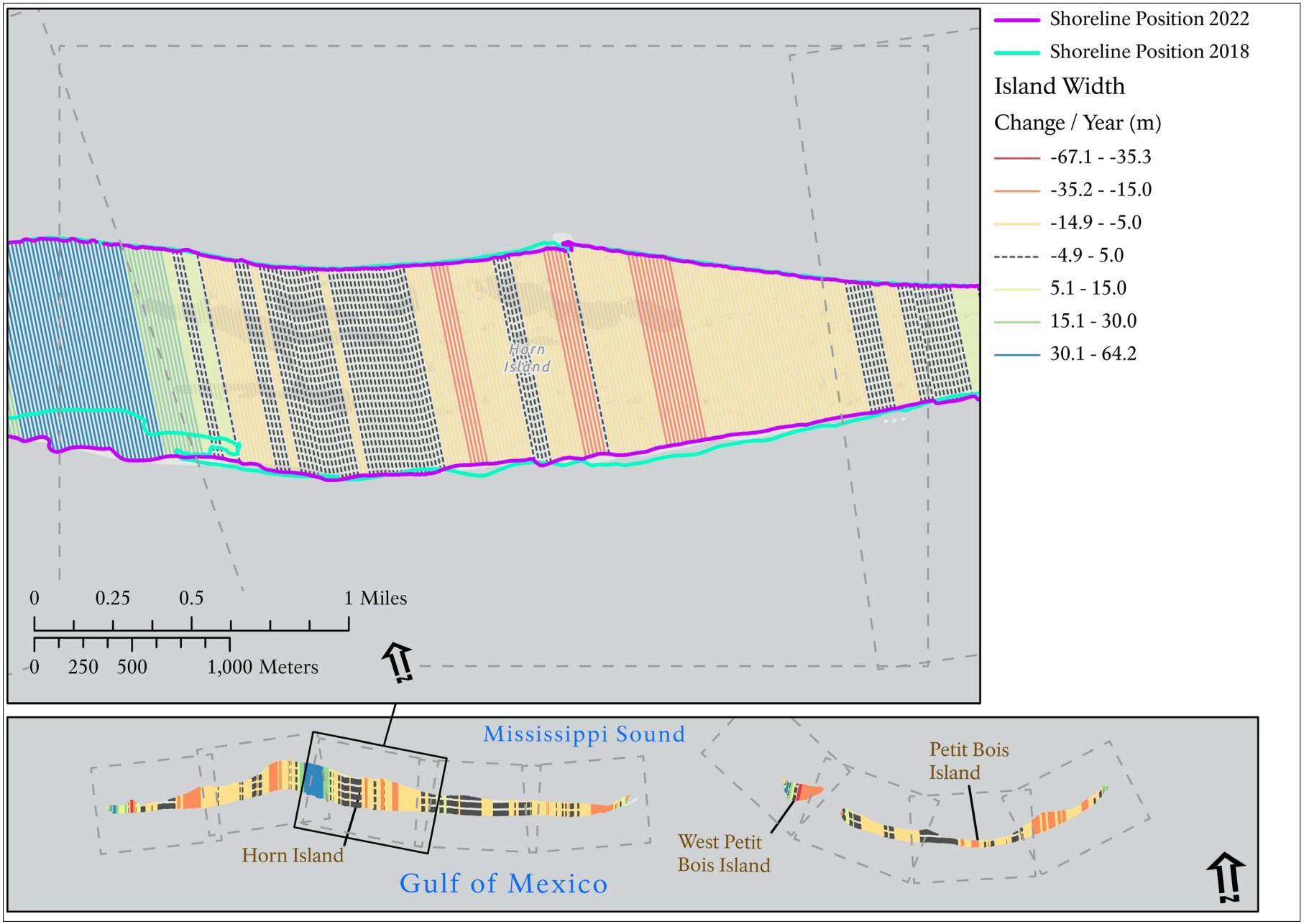

Figure C-7. Island Width Rate (2018 to 2022) for Horn Island, West Petit Bois, and Petit Bois Island 7 of 9.

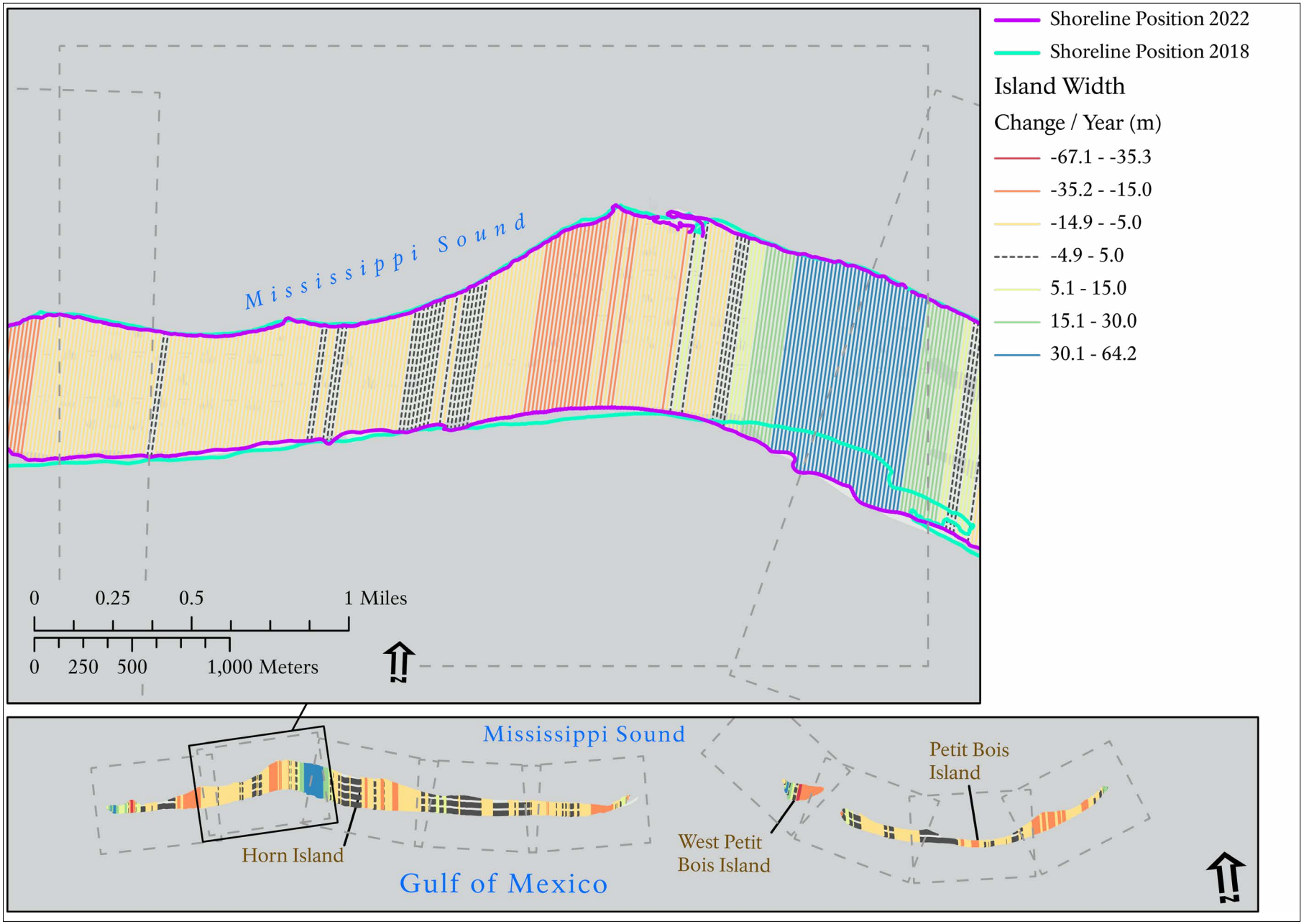

Figure C-8. Island Width Rate (2018 to 2022) for Horn Island, West Petit Bois, and Petit Bois Island 8 of 9.

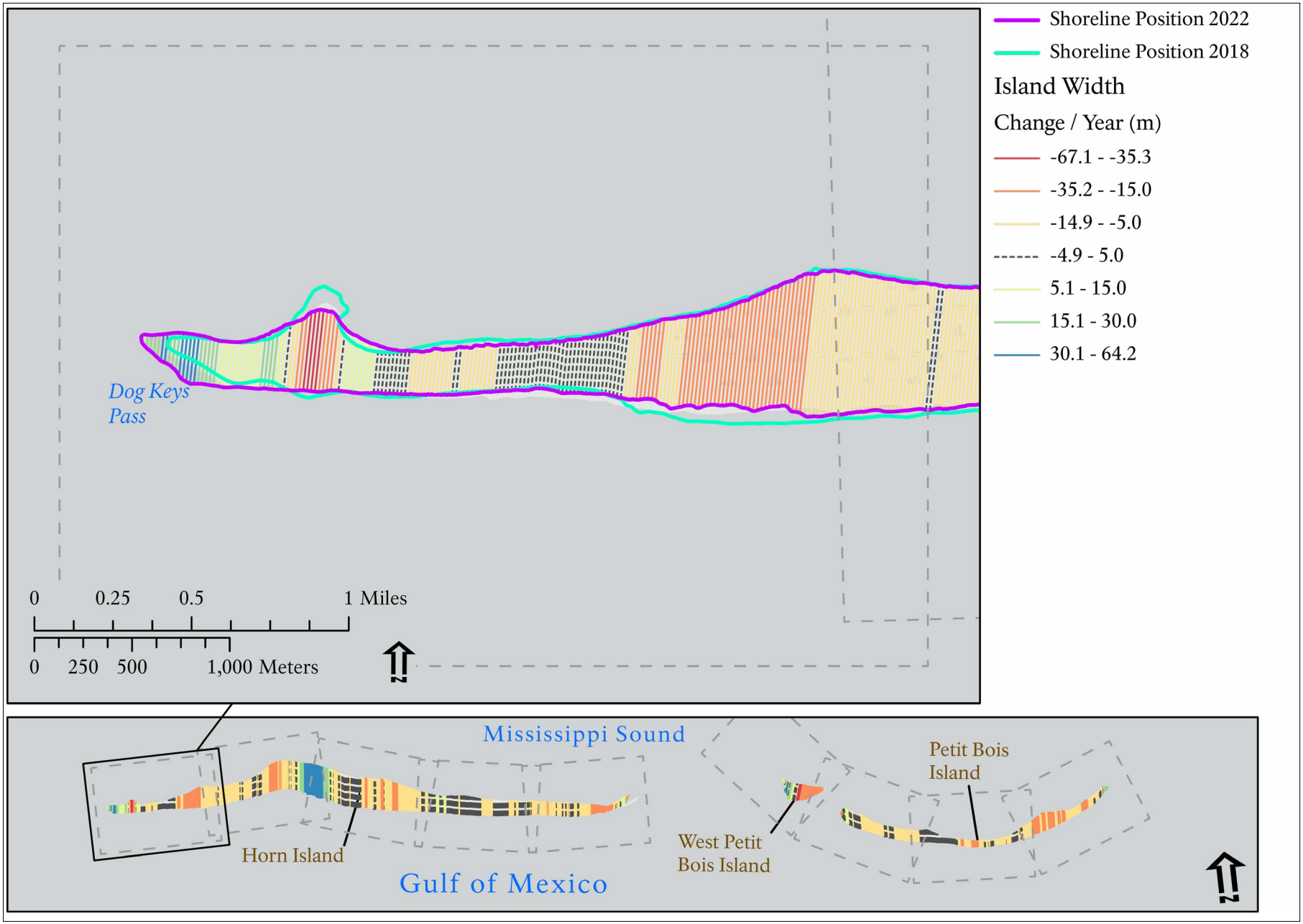

Figure C-9. Island Width Rate (2018 to 2022) for Horn Island, West Petit Bois, and Petit Bois Island 9 of 9.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS xxx/xxxxxx, December 2022

National Park Service
U.S. Department of the Interior

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