



Shoreline Position Monitoring at Fire Island National Seashore

2007-2012 Trend Report

Natural Resource Report NPS/NCBN/NRR—2017/1403



ON THE COVER

Beach and dune zone, Fire Island Pines, August 30, 2011

Photo by J. Raphael

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2007-2012 Trend Report

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Norbert P. Psuty

Elizabeth Haussner

Andrea Spahn

Jordan Raphael

New Jersey Agricultural Experiment Station
Rutgers – The State University of New Jersey
74 Magruder Road
Highlands, New Jersey 07732

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Executive Summary

The Shoreline Position Trend Report summarizes the results of surveys conducted from Spring 2007 through Spring 2012 at the ocean-facing shoreline of Fire Island National Seashore. Data sets include a spatial depiction of annual changes in shoreline position as well as statistical data describing annual and 5-year changes, all following the model presented by Psuty et al. (2010). Both the mean change for the entire ocean-facing shoreline and the linear trend in shoreline displacement are smaller than margins of error associated with data. Generally, the middle portion of Fire Island had greater variations in shoreline gains and losses during this period. The most mobile portions of shoreline are at either end of the island, particularly at Democrat Point where the shoreline downdrift of the jetty is extending westward. This is the first Trend Report for the Fire Island National Seashore produced for the Northeast Coastal and Barrier Network in accordance with the protocol for shoreline position monitoring. It benefits from the outstanding cooperation in data gathering and report preparation contributed by members of the Fire Island National Seashore. This 5-year trend report is augmented by a more detailed seasonal and annual report covering the period between Spring 2011 - Spring 2012 as an appendix.

Acknowledgments

The field survey team is a critical component in the gathering of the field data and the subsequent processing of the data sets. Particular recognition is given to Dennis Skidds (Data Manager, Northeast Coastal and Barrier Network) and Jason Flynn (Park Ranger, Fire Island National Seashore) for conducting shoreline position surveys and ably assisting Jordan Raphael (Park Biologist, Fire Island National Seashore) in conducting shoreline position surveys and cleaning the collected data files. The shoreline monitoring could not have occurred without the logistical assistance of Park personnel and Michael Bilecki (Chief of Resources Management, Fire Island National Seashore) in providing onsite support and encouragement. Robin Baranowski, Northeast Coastal and Barrier Network, provided constructive and valuable assistance in the final production of this report. A special note of appreciation is extended to Thom Curdts and Courtney Schupp of the National Park Service for their constructive reviews and suggestions for improvement of an earlier version of this report.

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Introduction

This is the first Trend Report documenting the changing position of the ocean-facing shoreline of Fire Island National Seashore (FIIS). This report follows the protocols described in the NCBN Geomorphological Monitoring Protocol for ocean shoreline position (Psuty et al., 2010) to track the spatial position of the neap tide high-tide swash line. The protocol was applied consistently for the first time at FIIS in Spring 2007 and the results were described in the first annual report (Psuty et al., 2013). Subsequent surveys were conducted semi-annually throughout most of Fire Island in Spring 2007 through Spring 2011 by members of the Fire Island National Seashore, reported in Psuty et al., 2011a; 2011b; 2011c; and 2013. Together with surveys in Fall 2011 and Spring 2012, these collected shoreline position data provided the basis for this Trend Report.

As prescribed in Standard Operating Procedure (SOP) #7 of the monitoring protocol (Change Calculation, Data Analysis, and Reporting (Psuty et al., 2010)), the goal of the Trend Report is a summary of the full database of shoreline positions, with an emphasis on the previous five years. It is a compilation of annual analyses that synthesize and characterize shoreline change data and interpret trends revealed by the numerical analyses. These longer-term comparisons of shoreline position changes reveal trends created by variation in sediment availability and in the intensity of formational processes.

Site and Situation

Fire Island is a barrier island along the southern coast of Long Island (Fig. 1). The barrier is approximately 50 km (31.07 miles) alongshore from Fire Island Inlet at the western end to Moriches Inlet at the eastern end. Each of the inlets is controlled by one or more jetties that border federally-maintained navigation channels. The Moriches Inlet terminus of Fire Island is relatively stable in position because both sides of the channel are defined by jetties. In contrast, the westernmost terminus of Fire Island, known as Democrat Point, extends into Fire Island Inlet considerably beyond the single jetty at the western margin of Fire Island and the shoreline position is quite mobile. The primary direction of sediment transport along the ocean-facing shoreline of Fire Island is from east to west.

In addition to land managed by the National Park Service, Fire Island is occupied by 17 private communities that share presence on the island as well as Robert Moses State Park and Smith Point County Park (Fig. 1). The variation in administration is reflected by differences in shoreline management practices and some of the effects will be examined in this report. The effects of hard structures, such as the jetties at either end of the island and groins extending from the ocean-facing shoreline, are also represented by the results of the monitoring data in this report.

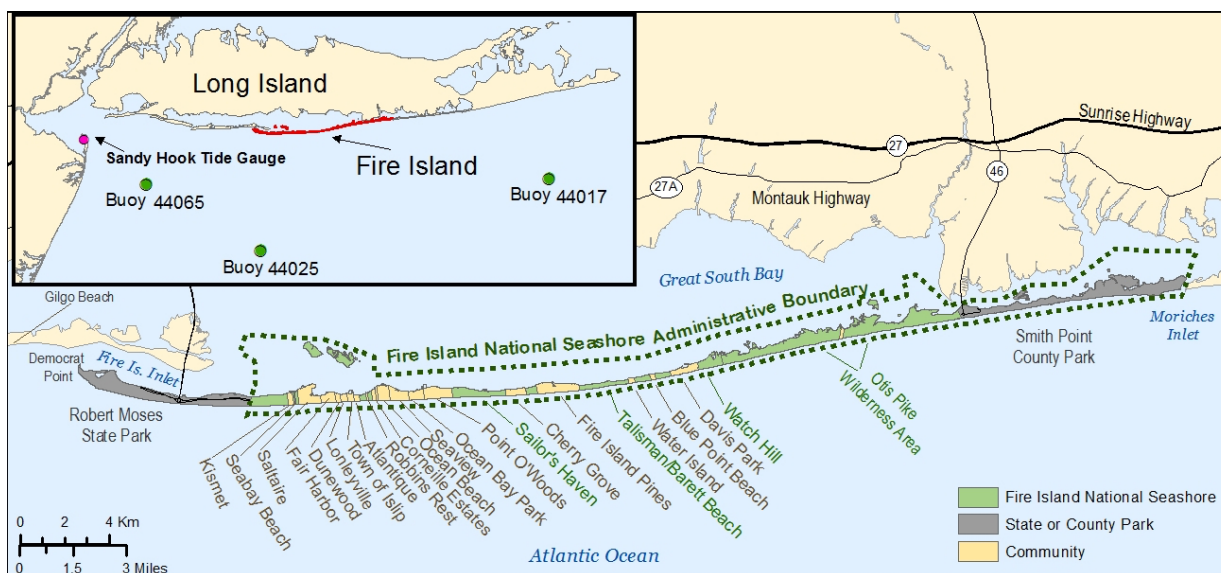


Figure 1. Fire Island and environs, including the Fire Island National Seashore Administrative Boundary, the state and county park administrative units, and the private communities. The inset includes locations of the buoys and tide gauge cited in the report.

Timing of Shoreline Position Surveys

Shoreline position is collected at Fire Island semi-annually and the seasonal variation is examined in annual reports. For this Trend Report, only the six spring shorelines from 2007 – 2012 are compared to elucidate trends and patterns in shoreline position change (Table 1). The high-tide shoreline positions compared in this report were all collected during the predicted neap-tide period to ensure that water level elevations were similar.

According to protocol (Psuty et al., 2010), water level elevations should be determined prior to survey by utilizing the nearest NOAA tide gauge. At Fire Island, there are tide gauges in the Great South Bay between Fire Island and the south shore of Long Island, and at the inland margins of the two inlets on either side of Fire Island. These tide gauges, however, are located in zones of restricted tidal amplitude compared to the ocean tidal range and thus are not good indicators of the water position on the ocean beach. The nearest gauge that portrays the ocean condition is at the northern end of Sandy Hook, NOAA National Ocean Data Center, Station #8531680) (<http://tidesonline.nos.noaa.gov/>). This gauge is used to reference water level positions and the timing of high water levels in this report. The Sandy Hook tide gauge is also used to predict water level variation for the general Fire Island area by the NOAA National Ocean Data Center.

Table 1. Spring shoreline surveys and recorded elevations of previous neap tide high-tides

Season	Date of survey	Previous High Tide	
		Height* (m)	Time
Spring 2007	14 March 2007	1.350	02:42 AM
Spring 2008	17 March 2008	1.527	04:06 AM
Spring 2009	23 March 2009	1.428	05:18 AM
Spring 2010	19 April 2010	1.531	11:18 AM
Spring 2011	26 May 2011	1.476	02:24 AM
Spring 2012	30 April 2012	1.252	02:00 AM

* Tide elevation values are referenced to Mean Lower Low Water (MLLW) Source: NOAA tide gauge (#8531680) Sandy Hook, NJ

Natural and Cultural Events Affecting Shoreline Position

Storms are important drivers of coastal change at the ocean beach. Shoreline position is affected during storm events by the high-energy mobilization and transportation of beach and dune sediment. Generally, the winter season is considered a time of increased storminess characterized by higher energy levels and considerable sediment transport. The summer season is conversely characterized by lower energy levels and more opportunity for sediment retention. Shoreline position surveys are scheduled at six-month intervals to provide insight into the comparison between the conditions of winter and summer seasons (though not to identify the effects of any specific storm). The seasonal signal, however, is often complicated by additional variables affecting ocean shorelines. Structures at inlets and along the shoreline lead to localized sites of accumulation and loss; human activities manipulate sediment availability and pathways; inshore circulation cells create local sediment sequestering; alongshore transport can include pulses of sediment; etc.

Natural Events

To characterize the annual and 5-year sediment balances at the ocean shoreline, an understanding must be developed for each year of the net shoreline change after seasonal stormy and non-stormy conditions. The monitoring protocol (Psuty et al., 2010) recommends utilizing a tide gauge to identify stormy conditions. Although the Sandy Hook tide gauge is an adequate resource for the determination of neap-tide occurrence and elevation at Fire Island, it does not respond to the full range of ambient wave directions and storm surges that approach and affect the island, specifically waves and surges from the southwest and west. In an effort to identify the full range of coastal storms that affect the Fire Island shoreline, wave data from offshore buoys have been reviewed to describe conditions of storminess, including relative intensity and duration. These wave data are derived from the NOAA National Data Buoy Center station #44025 supplemented by data from station #44017 when needed and then from #44065 to fill any additional data gaps (<http://www.ndbc.noaa.gov/>). The combined data from the three stations provided near-continuous wave data from January 2007 through May 2012 with only one major gap of approximately one month of data in the fall of 2011 (Fig. 2).

Wave data are often described by values such as wave height, wave length, wave period, etc. A common wave description is ‘significant wave height,’ which is the mean of the highest one-third of the waves measured during some time interval. In the case of NOAA stations #44025, #44017, and #44065, significant wave heights were determined for successive 20-minute intervals and plotted to describe the sequence of wave conditions from January 2007 through May 2012 (Fig 2). Periods of large significant wave heights were associated with storm events and the wave data were screened to establish threshold conditions. It was determined that a minimum significant wave height of 3 m (9.84 ft) would be used to identify the number and duration of storm events.

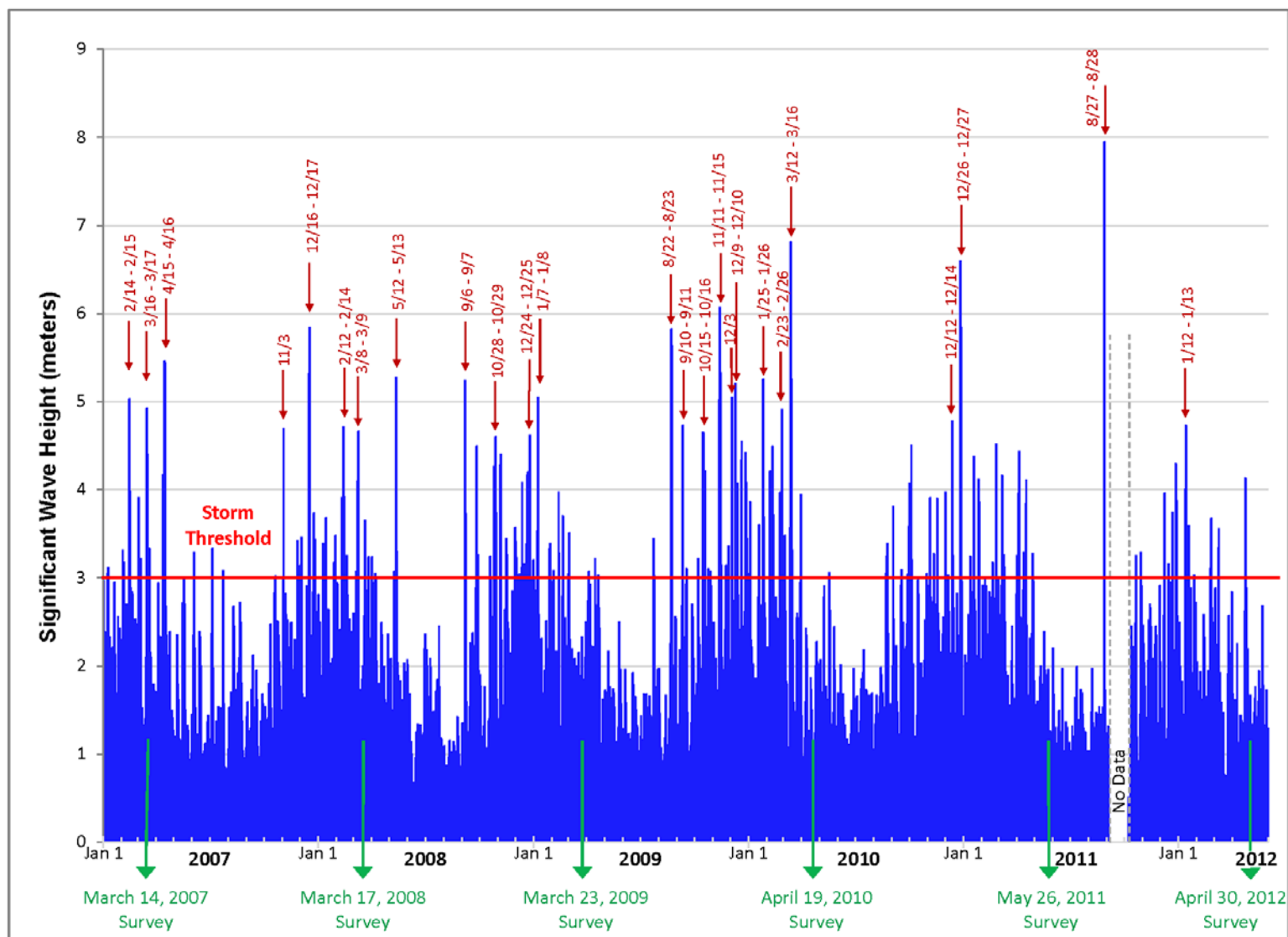


Figure 2. Distribution of significant wave heights from January 2007 through May 2012; all significant wave heights that surpass the threshold value of 3.0 m indicate storm events. Dates of the top 25 wave height storm events are noted, as well as the spring survey dates. Source: NOAA National Data Buoy Center stations #44025, #44017, and #44065 (<http://www.ndbc.noaa.gov/>).

Using this method, 127 storms have been identified as occurring between January 2007 and May 2012. The 25 storm events with the highest significant wave height values are identified and labeled in both Figure 2 and Table 2. Storm durations were established by noting consecutive dates with greater than 3 m (9.34 ft) significant wave height for the 20-minute periods, describing storms 1-60 hours in duration. In addition to wave height, NOAA offshore buoys also record wave direction in azimuth degrees, from which waves are arriving (Table 2). Station #44017 only began collecting wave direction data in May 2008, and did not collect wave direction information during 2010 and 2011, therefore all storms recorded by this station during these times are subject to unreported wave direction data.

Table 2. Frequency and magnitude of 25 highest significant wave height values above 3.0 m, Fire Island, 2007-2012.

Major Storms	Maximum Significant Wave Height (m)	Average Wave Direction* (Quadrant)	Duration (Hours)	Number of High Tides
2007, February 14-15	5.03	SE	24	2
2007, March 16-17	4.92	E	19	1
2007, April 15-16	5.46	SE	32	3
2007, November 3	4.69	-unreported-	22	2
2007, December 16-17	5.84	-unreported-	32	3
2008, February 13-14	4.71	S	23	1
2008, March 8-9	4.66	S	21	2
2008, May 12-13	5.27	E	25	2
2008, September 6-7	5.24	S	9	1
2008, October 28-29	4.60	W	13	1
2008, December 24-25	4.62	S	11	1
2009, January 7-8	5.05	S	27	2
2009, August 22-23	5.82	SE	14	2
2009, September 10-11	4.73	SE	36	3
2009, October 15-16	4.65	E	23	1
2009 November 11-15	6.07	SE	81	7
2009, December 3	5.05	SE	14	1
2009, December 9-11	5.21	S	37	2
2010, January 25-26	5.25	SE	22	2
2010, February 23-26	4.91	S	35	2
2010, March 12-16	6.81	SE	60	4
2010 December 12-14	4.78	SE	39	3
2010, December 26-27	6.60	SW	30	2
2011, August 27-28	7.95	S	16	1
2012, January 12-13	4.73	SE	34	3

Source: NOAA National Data Buoy Center (station #44025 supplemented by station #44017 and #44065).

* The direction from which waves approach.

The data illustrated in Figure 2 and Table 2 portray the seasonality of frequent storm events; storms occur more frequently during the winter and spring than in the summer. The maximum significant wave height was measured during Hurricane Irene (7.95 m (26.08 ft)) in August 2011 and the storm of greatest duration occurred in March 2010 (60 hours). The Fall 2009 to Spring 2010 season has notably high frequency of stormy wave conditions.

Cultural Events

Community residents of Fire Island, the National Park service, and the state and county parks are governed by different sets of rules and regulations in managing their beaches. During this reporting period, artificial emplacement of sediment, or beach nourishment projects, was prohibited on the land managed by the National Park Service (Table 3). However, these projects were allowed on land managed by the private communities. Once placed, alongshore currents can transport the sediment downdrift to contribute to the local sediment supply at federal and state lands. In addition to beach nourishment projects, the private communities applied additional approaches to erosion control including beach scraping and the placement of sandbags and sand fences at the base of the ocean-beach dunes. A listing of the major beach nourishment projects is available at:

<http://beachnourishment.wcu.edu/>.

Table 3. Beach nourishment and dredging projects at Fire Island, Spring 2007 – Spring 2012.

Sediment Placed	Sediment Source	Time Period	Total Sediment Placed (m ³)
Smith Point County Park	offshore borrow area	Mar - Apr, 2007	172,000
Gilgo Beach	Fire Island Inlet	Mar, 2008	474,024
Smith Point County Park	Moriches Inlet	Dec 2008 - Jan 2009	238,000
Davis Park	upland source	Nov 2007 - Feb 2008	19,466
Saltaire	offshore borrow area	Jan - Feb, 2009	159,881
Fair Harbor	offshore borrow area	Jan - Feb, 2009	107,015
Dunewood	offshore borrow area	Jan - Feb, 2009	65,488
Lonleyville	offshore borrow area	Jan - Feb, 2009	64,478
Corneille Estates and Summer Club	offshore borrow area	Mar - Apr, 2009	52,020
Ocean Beach	offshore borrow area	Mar - Apr, 2009	101,547
Seaview (TOI)	offshore borrow area	Mar - Apr, 2009	121,444
Seaview (TOB)	offshore borrow area	Mar - Apr, 2009	57,761
Fire Island Pines	offshore borrow area	Mar, 2009	375,996
Davis Park	offshore borrow area	Mar, 2009	222,755

During the period of data collection for this Trend Report, three minor beach nourishment projects and one major beach nourishment project took place. Sediment for nourishment projects was most often dredged from offshore borrow sites but in a few cases, was excavated from Fire Island Inlet and from Moriches Inlet. These inlets are dredged on a periodic basis to maintain a safe depth for watercraft navigation. Sediment dredged from Fire Island Inlet was placed on the barrier island

immediately west of Fire Island at Gilgo Beach (Fig. 1), a location downdrift of the northwest boundary of Fire Island Inlet. Additionally, smaller dredging and other sediment transport events took place during the span of this report; these projects were poorly documented in comparison with larger projects and smaller sediment volumes have less impact on shoreline changes.

Changes to the Protocol

There are no documented changes to the protocol used in the data collection cited in this report. The early work on development of the protocol was in collaboration with data collection on Fire Island before final publication of the protocol, and the general application of the 1-D shoreline position monitoring protocol was followed throughout the shoreline surveys. Further, this first FIIS Trend Report is following the format described in the protocol and is generating a model for reporting as well as for interpretation of the archived data.

Methods for Portraying Metrics of Change in Shoreline Position

After field collection of shoreline data, each shoreline surveyed for this Trend Report is registered to an offshore baseline along transects that extend perpendicular to the baseline toward the shore, at 10 m (32.8 ft) intervals, following the Digital Shoreline Analysis System (DSAS) program created and maintained by the U.S. Geological Survey (Thieler et al. 2009) (see SOP # 7, Psuty et al., 2010). Shoreline change analysis is accomplished by first plotting the offshore baseline, the transects, and the measured shoreline position, then measuring the distance between the offshore baseline and shoreline at 10 m intervals along each transect (Fig. 3). The distance between the offshore baseline and shoreline position for each transect is recorded in a table of measurements available from the NCBN data manager in GIS format (Table 4).

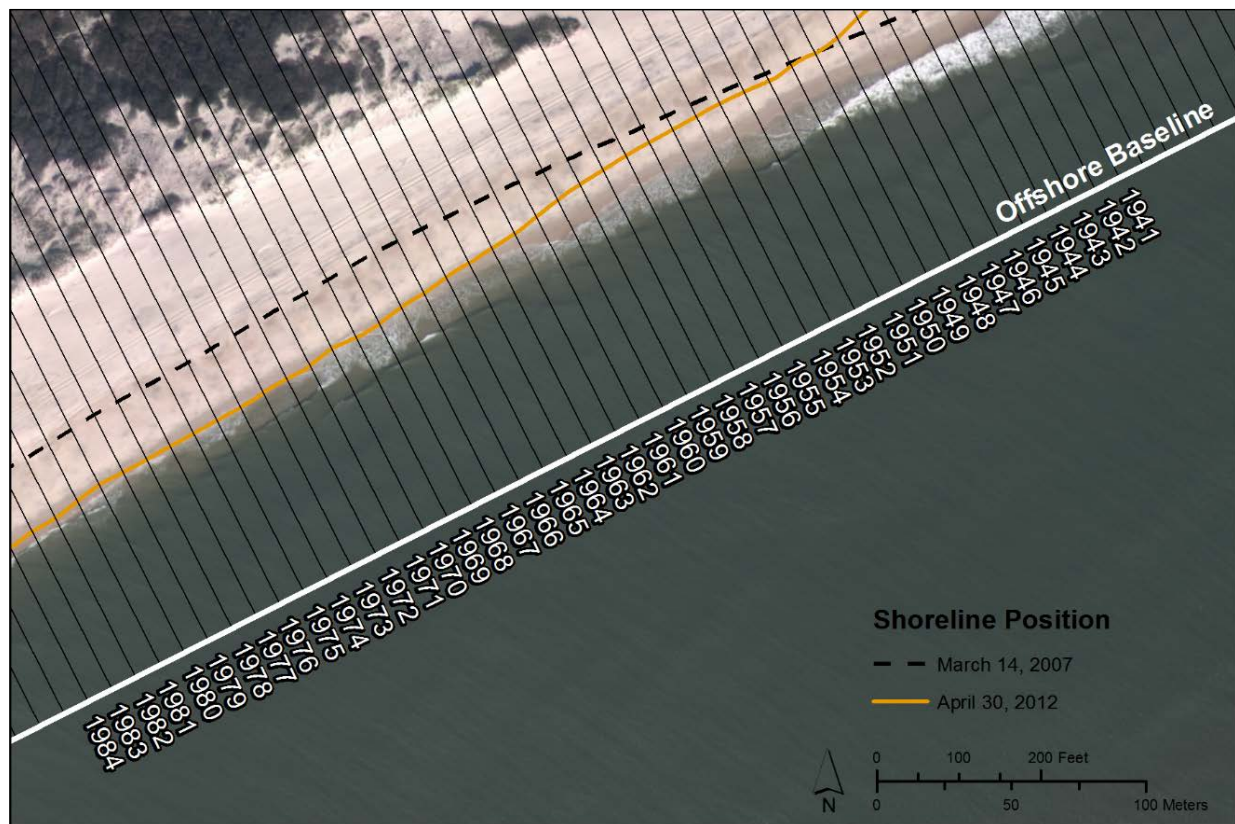


Figure 3. Relationship between offshore baseline, numbered transects, and selected shorelines for a sample of the Spring 2007 and Spring 2012 shorelines at Fire Island. The distance between the baseline and shorelines is measured at each transect position.

Table 4. Measured distances between offshore baseline and each surveyed shoreline for a sample of transects; comparative displacement of shoreline between surveys for same transects.

Transect Numbers	Distance (m)		Change (m)
	Spring 2007	Spring 2012	Spring 2007 – Spring 2012
1955	437.83	413.93	24.46
1956	437.25	413.35	24.13
1957	436.57	413.89	24.1
1958	436.02	411.95	24.1
1959	435.48	411.47	24.19
1960	434.86	410.65	23.79
1961	434.17	409.72	23.13
1962	433.5	439.19	23.82
1963	433.08	408.99	24.84
1964	432.81	408.72	25.35
1965	432.52	408.33	27.5

Despite every effort to accurately document changes in shoreline position while surveying, there is inherent error and uncertainty associated with the collected line position. These include: 1) the recording instrument is a GPS unit with sub-meter accuracy; its variation is about 0.3 m (0.98 ft); 2) there is variation (as much as 3 m (9.84 ft)) in the wave runup to create the neap high-tide swash line; 3) there is some variation (as much as 1 m (3.28 ft)) in the elevation of the high-tide water level on the beach face; and 4) there is some small variation (about 0.5 m (1.64 ft)) in the operator's tracking of the swash line on the beach face. Combined, these factors create an uncertainty in the position of the ocean shoreline as much as +/- 5 m (16.4 ft) and any comparison between two survey lines would have a statistical uncertainty of +/- 7 m (22.97 ft) (calculated as the square root of the sum of the squares of the two measures of uncertainty).

The distribution and dimensions of shoreline change are displayed through the utilization of Shoreline Change Mapper, a software application that works within ESRI's ArcGIS software and was developed by Aaron Love of the Sandy Hook Cooperative Research Programs for the purpose of this protocol (Psuty et al., 2010). The application generates a series of lines, each of which corresponds to a sampling transect (Figure 4). The lines represent dimension or magnitude of change between two shoreline position datasets in a manner similar to a bar graph, with the offshore baseline as an x-axis. Longer lines represent greater magnitude of change, either in the positive (seaward) direction or in the negative (landward) direction at the location of any particular transect, whereas shorter lines represent a lesser magnitude of change at the location of a particular transect. Differences in line color promote ease of interpretation of the direction and magnitude of change between the two shoreline position datasets. Shoreline displacement of less than 10 m (32.81 ft), either seaward (+10 m) or landward (-10 m) at any transect location, are represented as gray. Seaward shoreline displacement greater than +10 m is represented by shades of blue and indicates accretion or gain (Fig. 4). Landward shoreline displacement greater than -10 m is represented by shades of red and indicates erosion or loss.

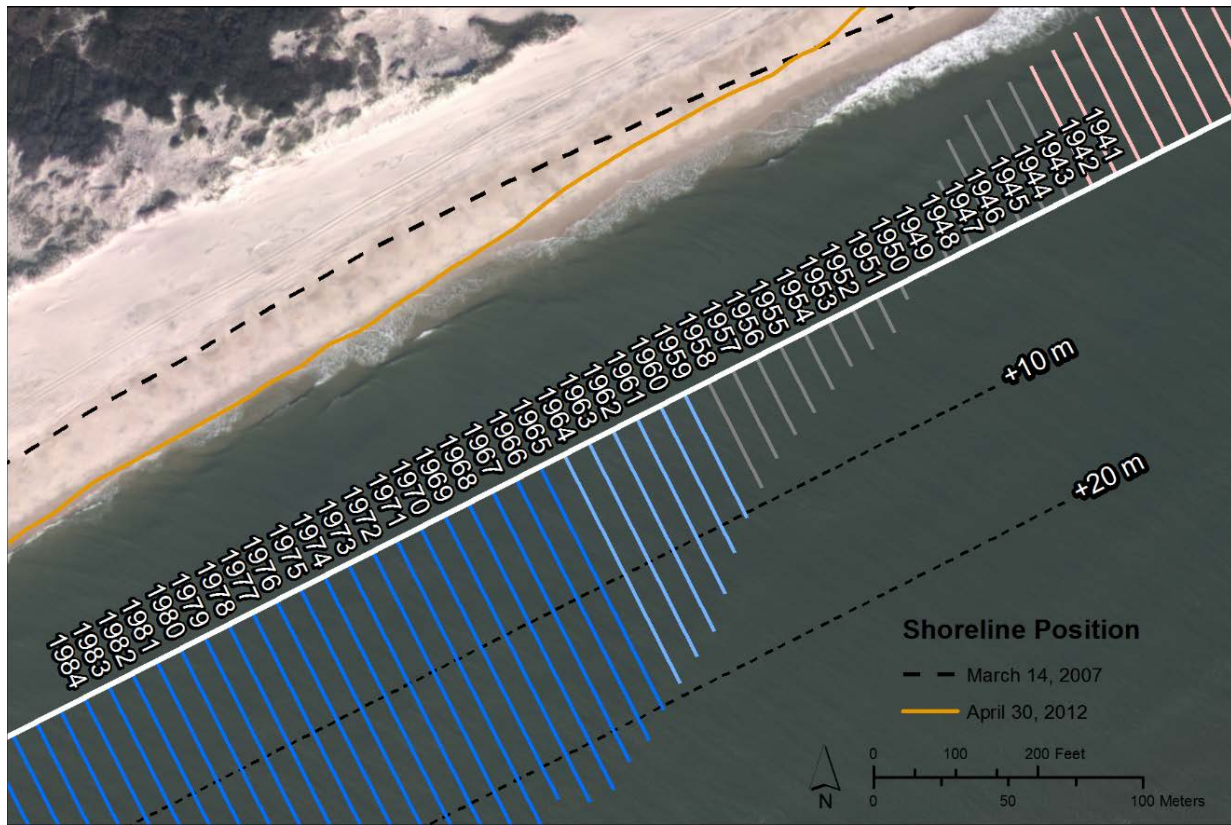


Figure 4. Sample of vectors of change produced by Shoreline Change Mapper to represent magnitude and dimensions of shoreline change for a sampling of transects at Fire Island, Spring 2007 - Spring 2012.

For this 5-year Trend Report, annual changes in spring shoreline position, as well as 5-year change from spring 2007 – spring 2012, are portrayed spatially in a series of 8 map panels of the ocean shoreline of Fire Island. The difference measurements between shoreline positions for all map panels are subjected to statistical analysis to determine the mean and standard deviation of annual and trend comparisons. The difference measurements for the 5-year trend comparison are also represented as a histogram of the frequency of individual magnitudes of change to identify modal characteristics of the dimensions of change.

Results of Shoreline Monitoring

The sequence of 8 map panels (Figs. 5 - 12) illustrates the annual and 5-year surveyed shoreline displacement along Fire Island from 2007-2012. An additional map (Fig. 13) provides an overview of annual and 5-year surveyed shoreline displacement and vectors of change for the entire island. These vectors of change are represented in a histogram to examine the distribution of change values (Fig. 14). Statistical analyses of the metrics of shoreline change are derived for all of Fire Island (Table 5) and for each land jurisdiction (Appendix B, C).

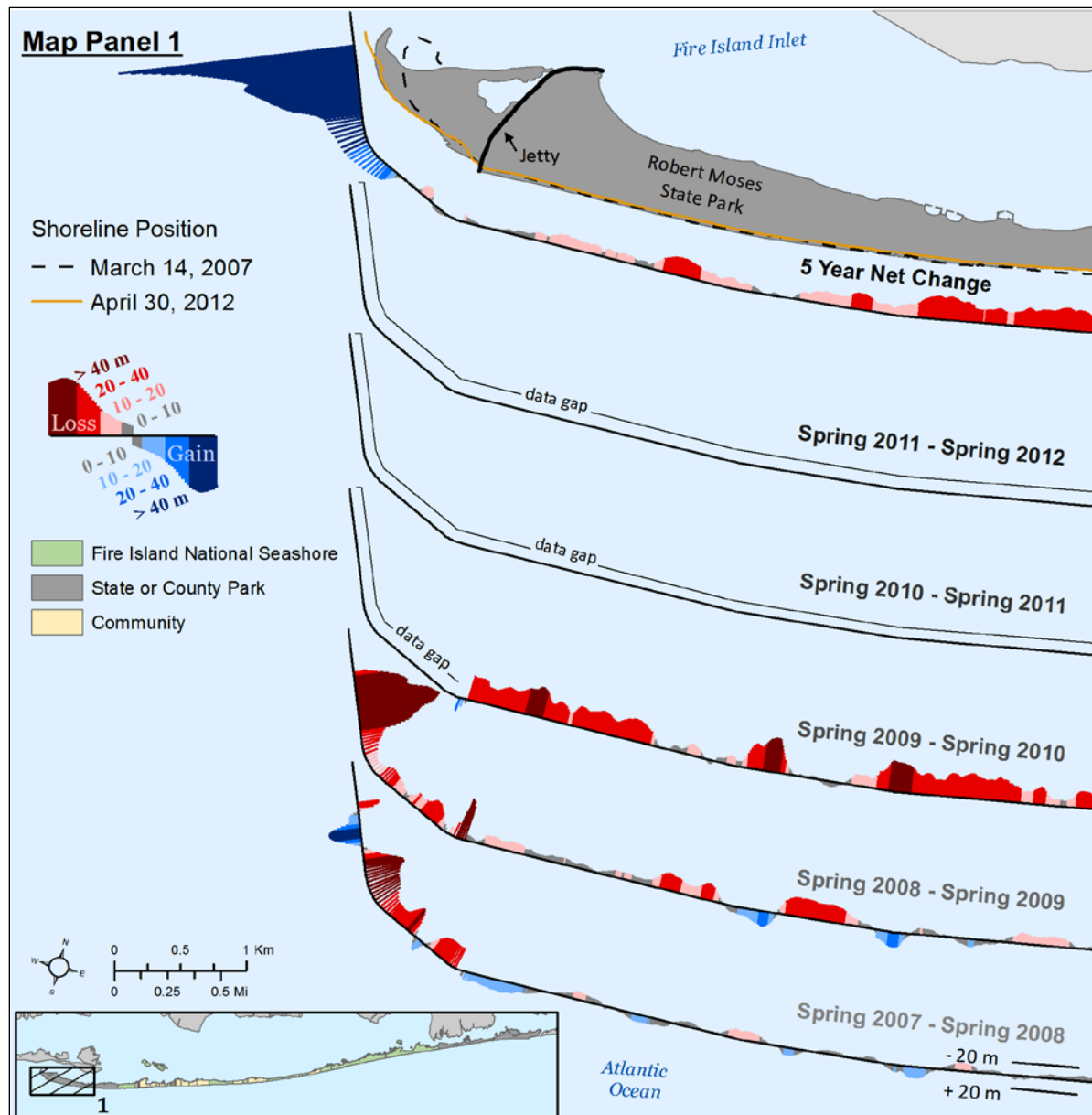


Figure 5. Distribution of annual and 5-year shoreline position change at Fire Island; Map Panel 1. The scale for all vectors of change is incorporated on the Spring 2007 – Spring 2008 comparison. Data gap in Spring, 2011 shoreline and smaller data gap in Spring 2010 shoreline produce gaps in Spring 2009 – Spring 2010, Spring 2010 – Spring 2011, and Spring 2011 – Spring 2012 shoreline comparisons.

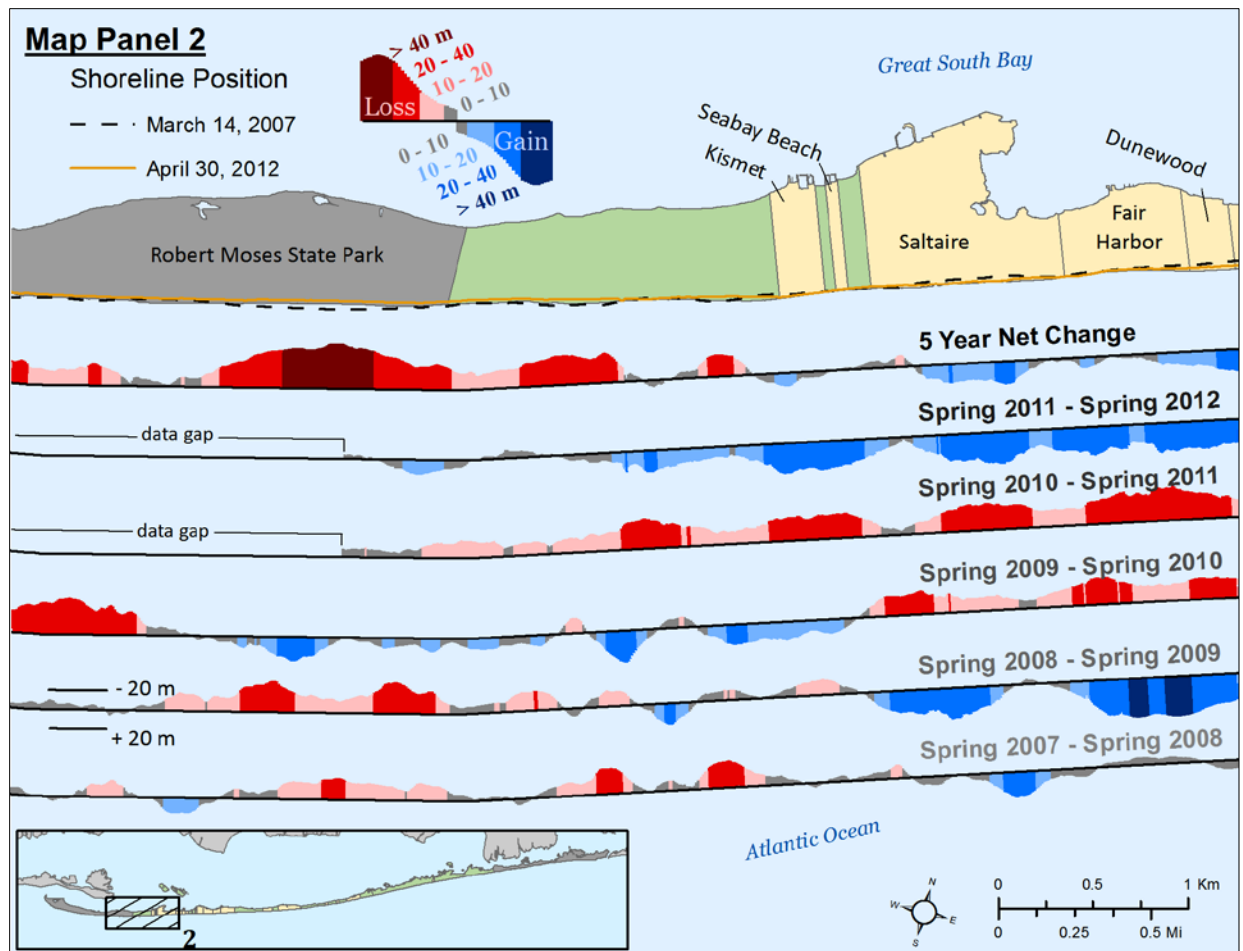


Figure 6. Distribution of annual and 5-year shoreline change at Fire Island; Map Panel 2. The scale for all vectors of change is incorporated on the Spring 2008 – Spring 2009 comparison. Data gap in Spring 2011 shoreline produced gaps in Spring 2010 – Spring 2011 and Spring 2011 – Spring 2012 shoreline comparisons.

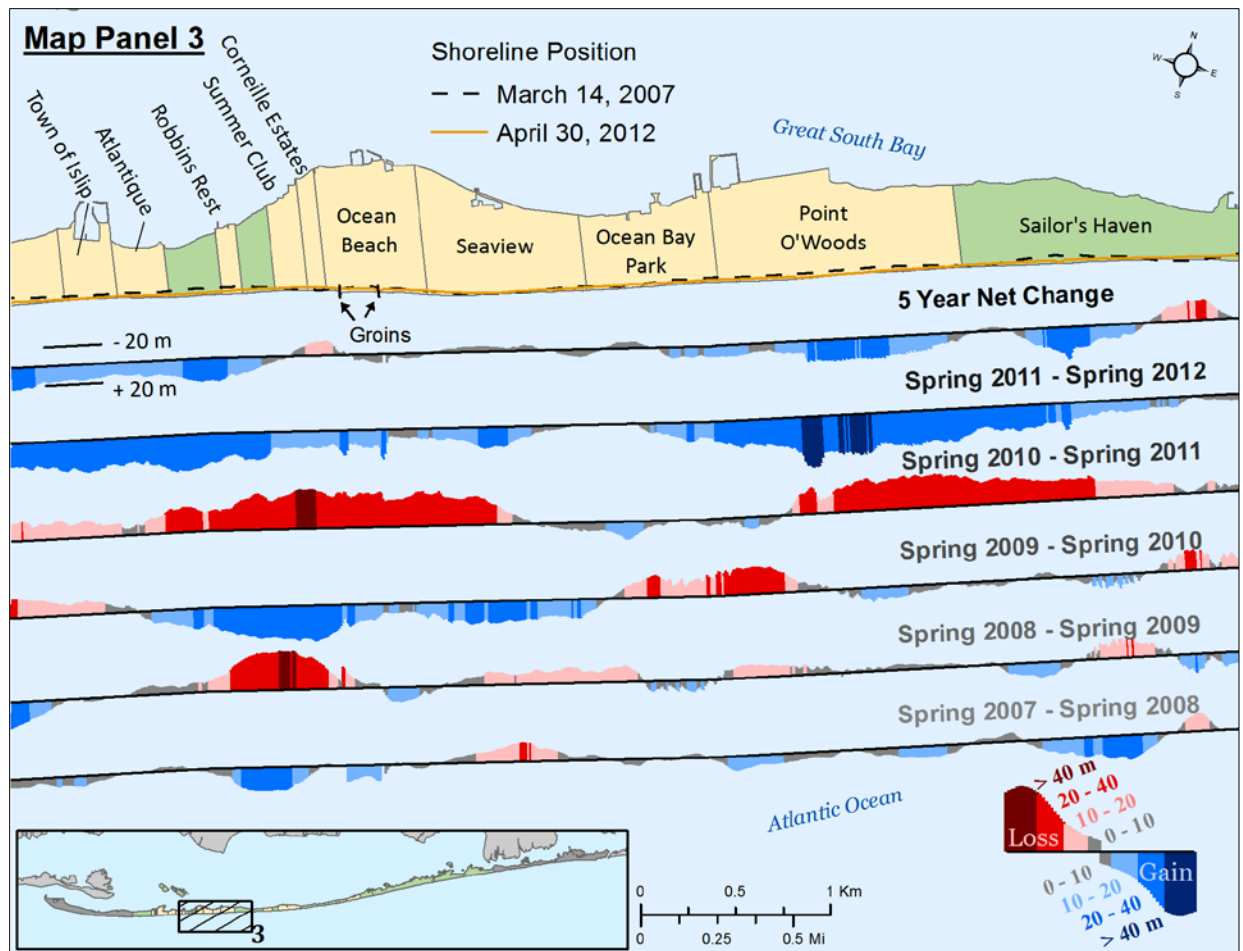


Figure 7. Distribution of annual and 5-year shoreline change at Fire Island; Map Panel 3. The scale for all vectors of change is incorporated on the 5-year net change comparison.

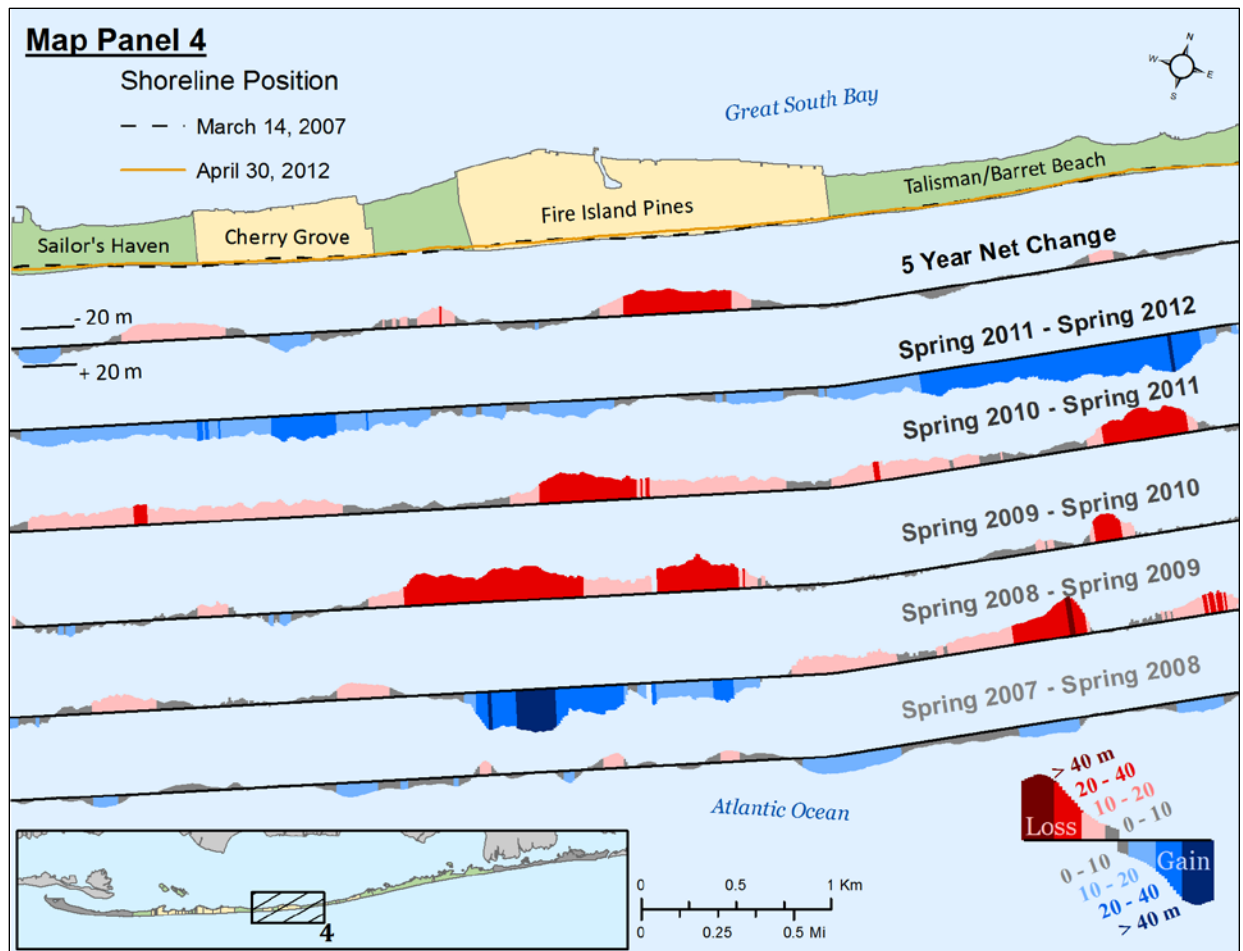


Figure 8. Distribution of annual and 5-year shoreline change at Fire Island; Map Panel 4. The scale for all vectors of change is incorporated on the 5-year net change comparison.

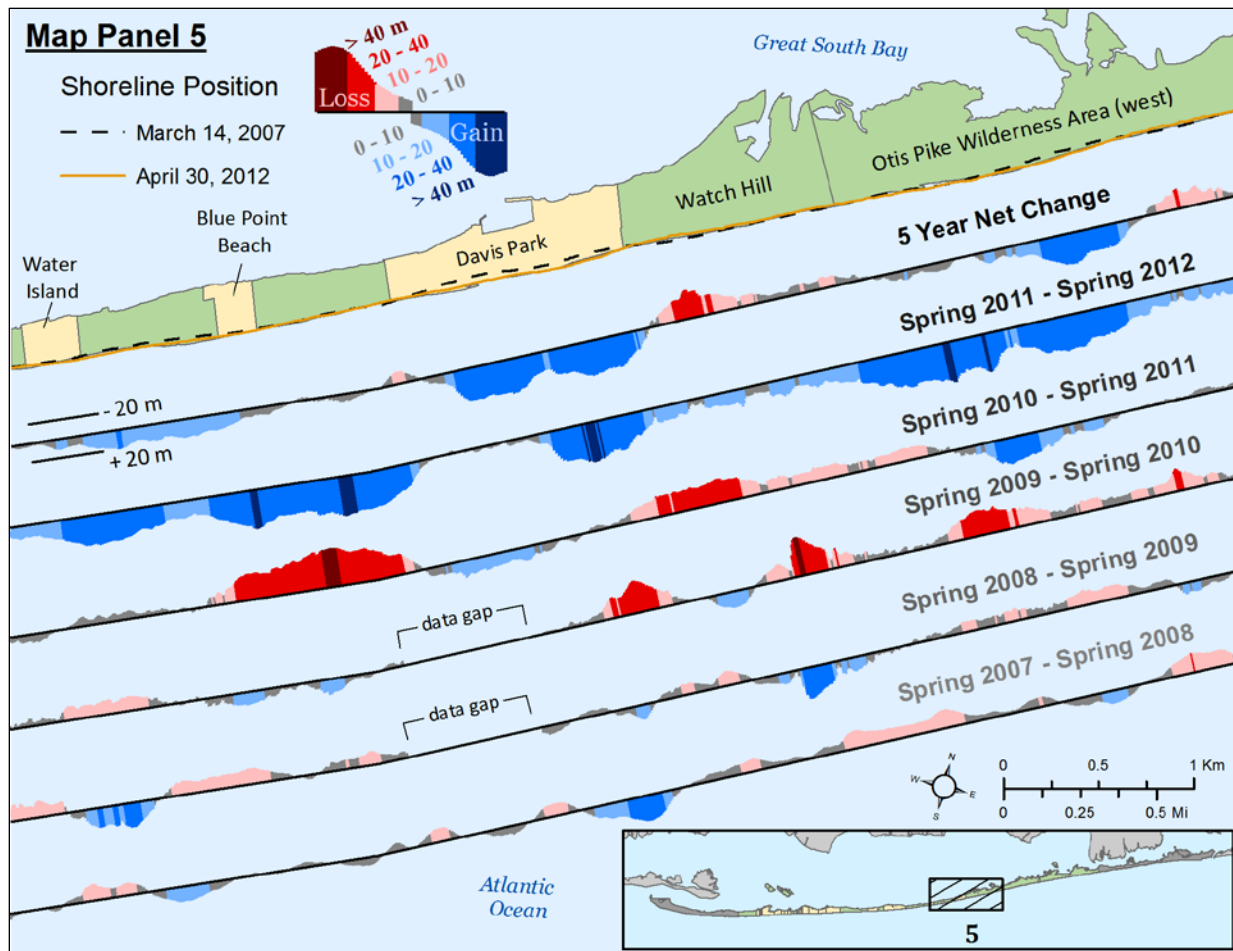


Figure 9. Distribution of annual and 5-year shoreline change at Fire Island; Map Panel 5. The scale for all vectors of change is incorporated on the 5-year net change comparison. Data gap in Spring 2009 shoreline produced gaps in Spring 2008 – Spring 2009 and Spring 2009 – Spring 2010 shoreline comparisons.

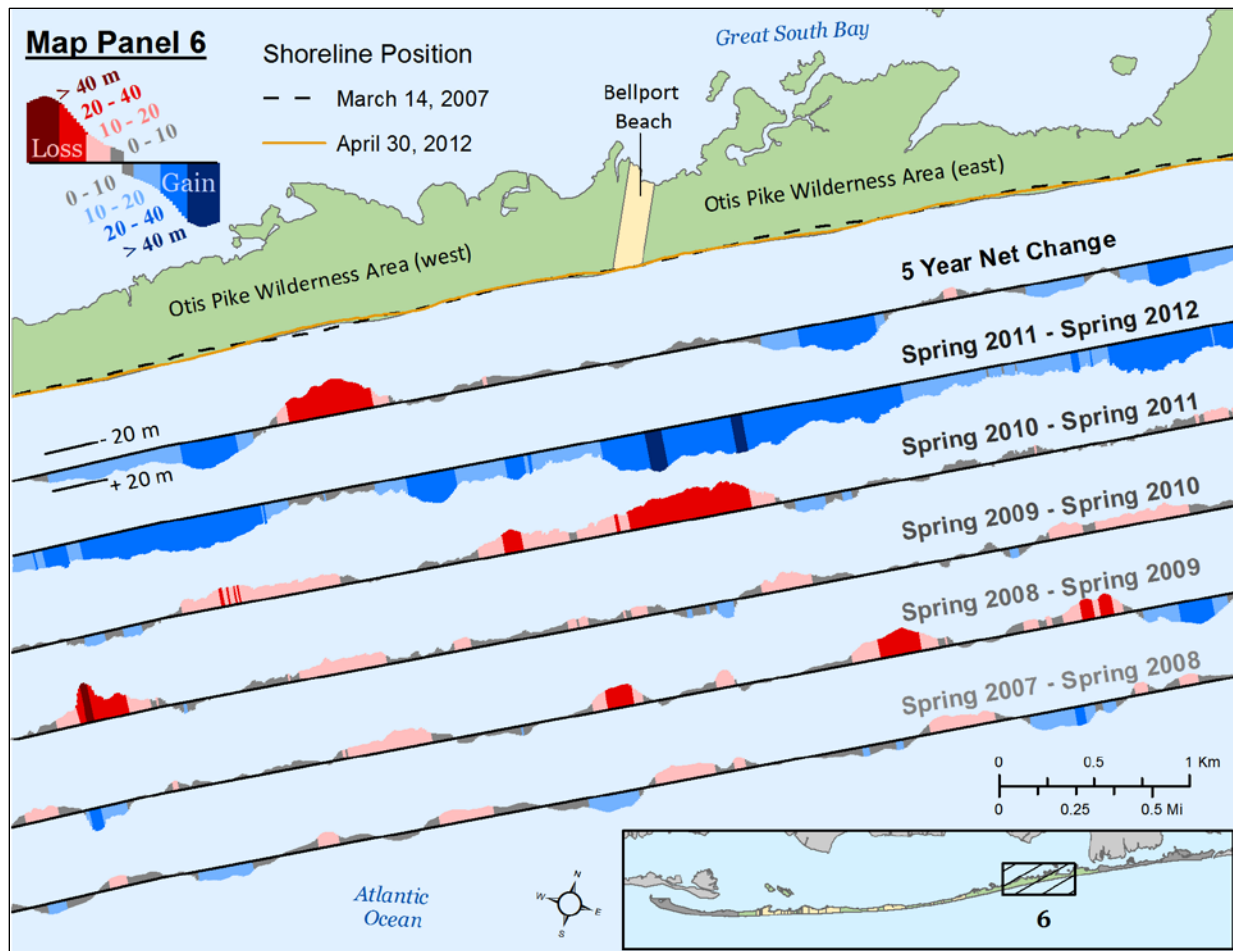


Figure 10. Distribution of annual and 5-year shoreline change at Fire Island; Map Panel 6. The scale for all vectors of change is incorporated on the 5-year net change comparison.

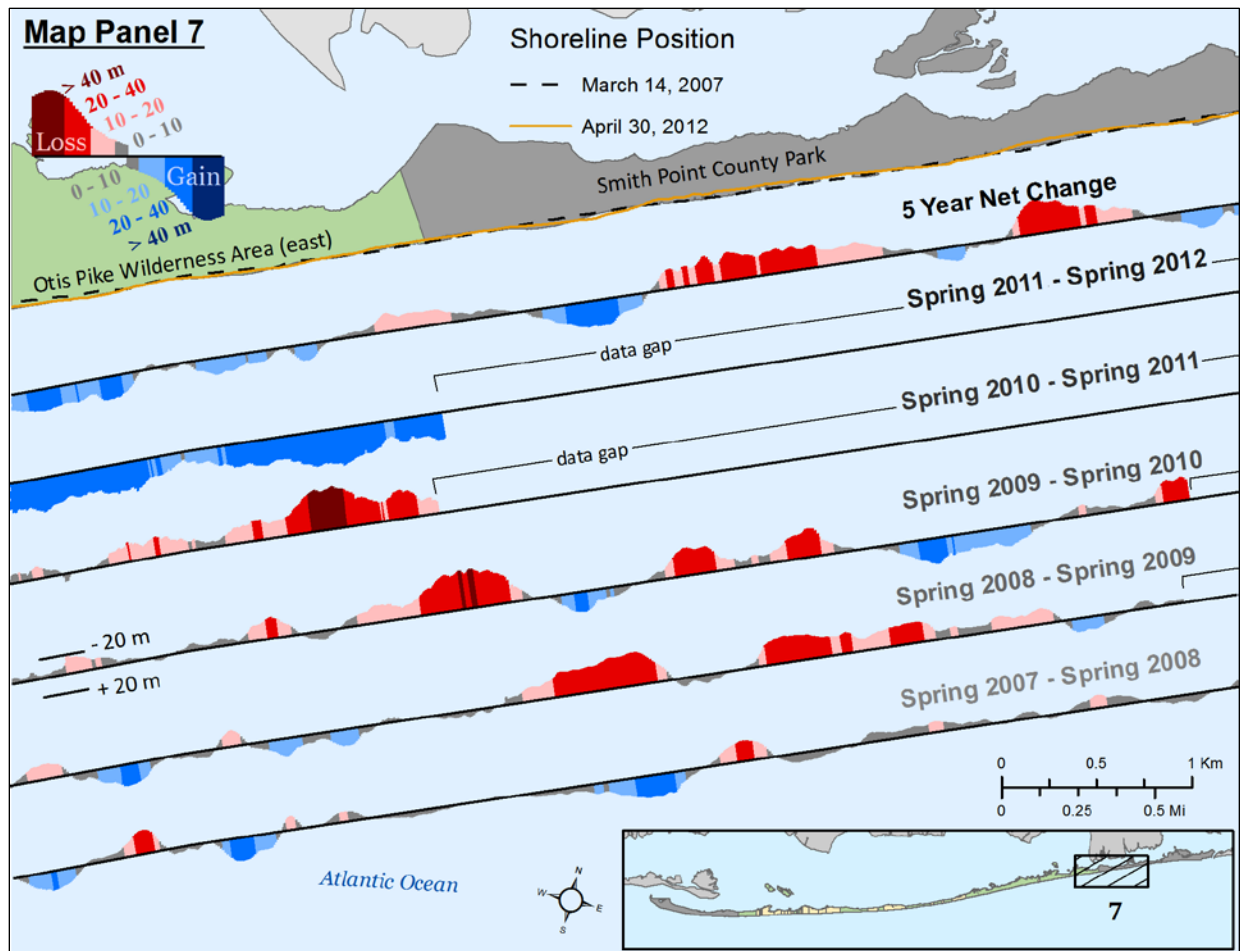


Figure 11. Distribution of annual and 5-year shoreline change at Fire Island; Map Panel 7. The scale for all vectors of change is incorporated on the Spring 2009 – Spring 2010 comparison. Data gap in Spring 2011 shoreline produced gaps in Spring 2010 – Spring 2011 and Spring 2011 – Spring 2012 shoreline comparisons.

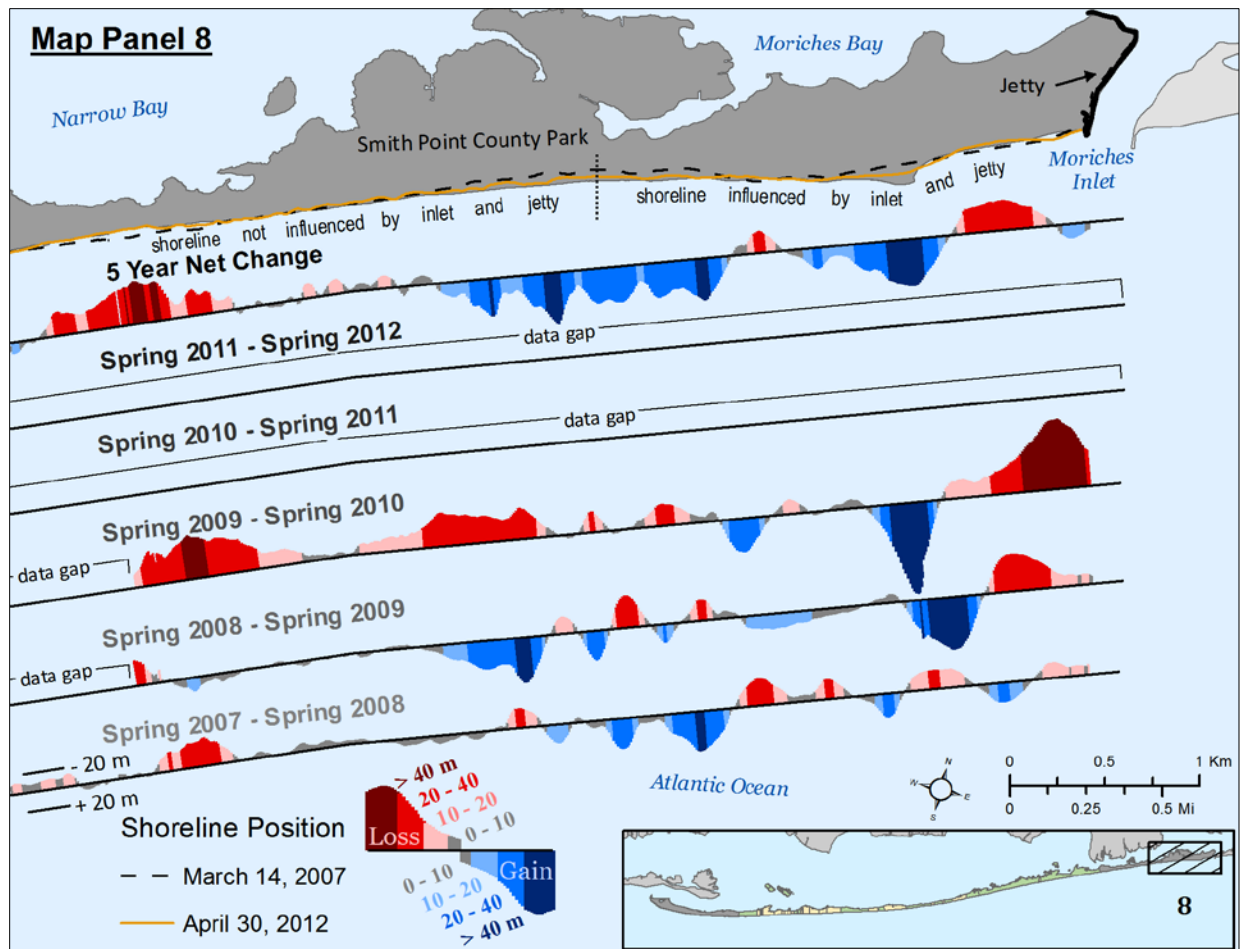


Figure 12. Distribution of annual and 5-year shoreline change at Fire Island; Map Panel 8. The scale for all vectors of change is incorporated on the Spring 2007 – Spring 2008 comparison. Data gap in Spring 2011 shoreline and smaller data gap in Spring 2009 shoreline produce gaps in Spring 2008 – Spring 2009, Spring 2009 – Spring 2010, Spring 2010 – Spring 2011, and Spring 2011 – Spring 2012 shoreline comparisons.

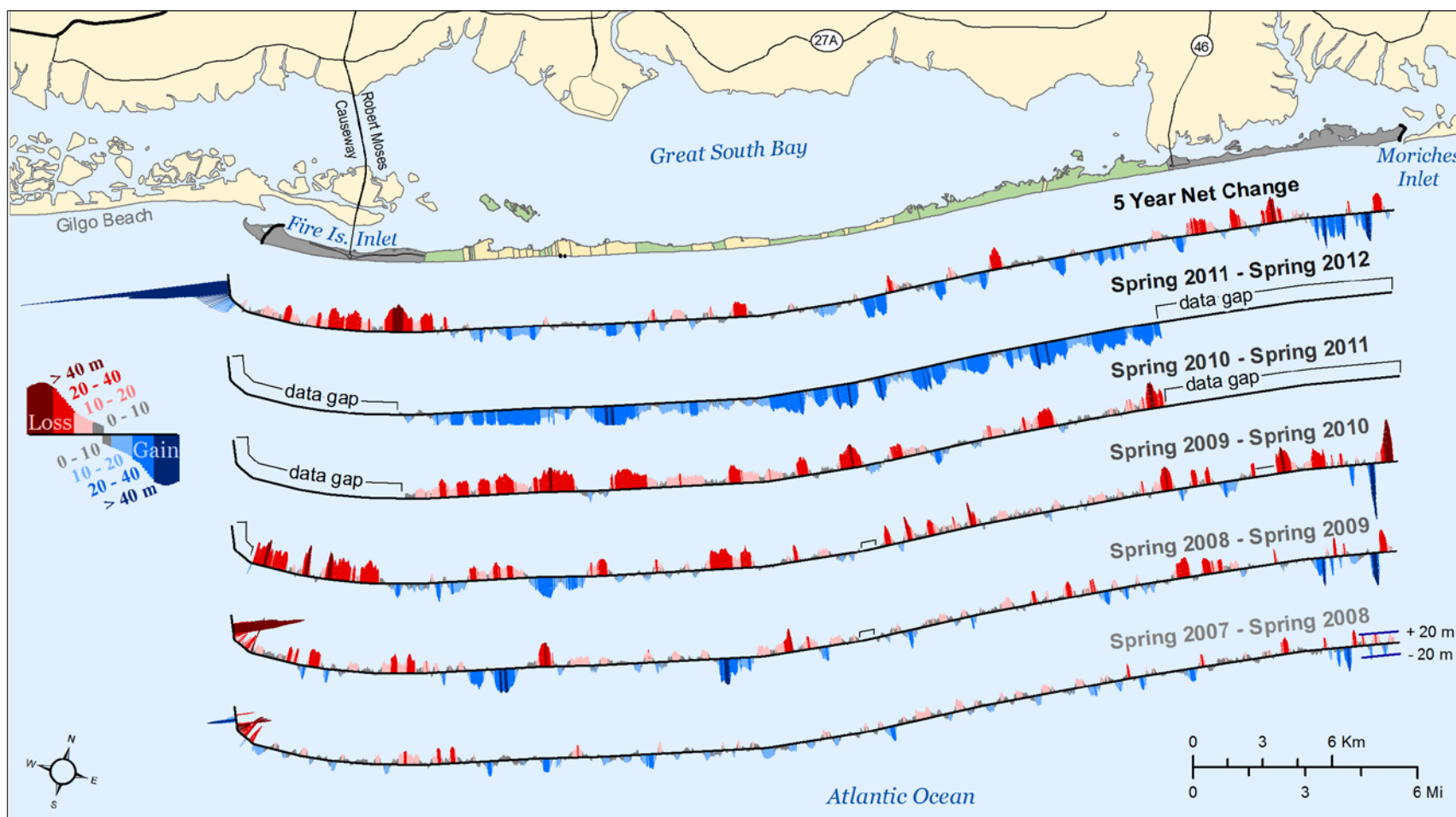


Figure 13. Distribution of annual and 5-year shoreline change along the ocean-facing shoreline of Fire Island.

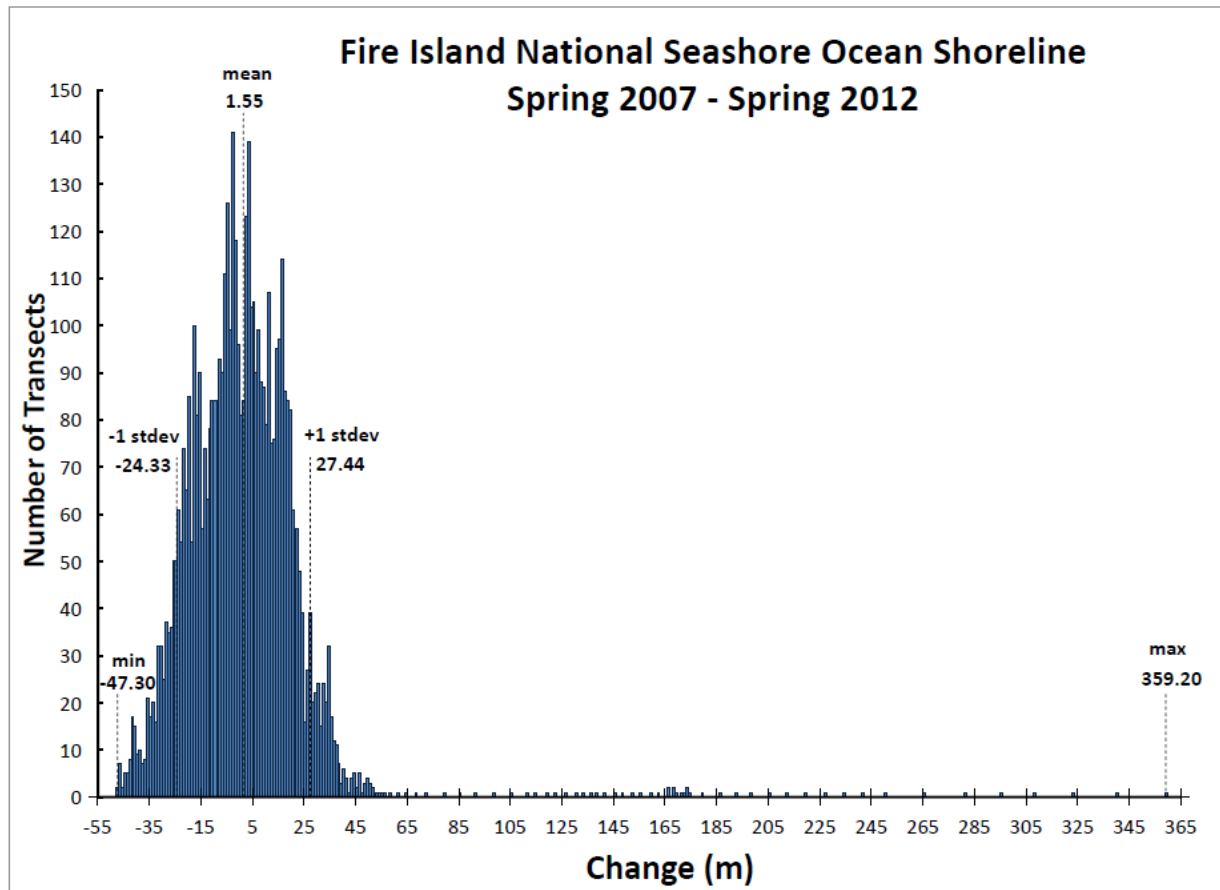


Figure 14. Histogram of vectors of shoreline change, 5-year trend from Spring 2007 to Spring 2012.

Table 5. Statistical values of seasonal, annual, and 5-year shoreline changes for the Fire Island total ocean shoreline, 2007 – 2012.

Time Period	Mean (m)	1 St Dev	Max Accretion	Max Erosion	Net Mean Change from Spring 2007 +	
Seasonal Changes						
Spring 2007 - Fall 2007	-9.75	14.56	64.63	-171.13	Fall 2007	-9.75
Fall 2007 - Spring 2008	9.51	15.95	202.10	-80.52	Spring 2008	-0.18
Spring 2008 - Fall 2008	-7.59	19.61	80.00	-88.48	Fall 2008	-7.64
Fall 2008 - Spring 2009	4.07 *	22.18 *	69.49 *	-130.31 *	Spring 2009	---
Spring 2009 - Fall 2009	3.76 *	18.43 *	58.08 *	-90.38 *	Fall 2009	---
Fall 2009 - Spring 2010	-12.42 *	19.39 *	67.55 *	-63.08 *	Spring 2010	---
Spring 2010 - Fall 2010	-0.73 *	11.70 *	42.71 *	-38.65 *	Fall 2010	-11.95
Fall 2010 - Spring 2011	-8.82 *	10.21 *	26.22 *	-33.35 *	Spring 2011	---
Spring 2011 - Fall 2011	15.85 *	9.08 *	44.55 *	-9.06 *	Fall 2011	0.48
Fall 2011 - Spring 2012	1.16	12.90	116.32	-70.49	Spring 2012	1.55
Annual Changes						
Spring 2007 - Spring 2008	-0.18	11.65	48.95	-60.84	Spring 2008	-0.18
Spring 2008 - Spring 2009	-3.66 *	17.54 *	56.12 *	-125.67 *	Spring 2009	---
Spring 2009 - Spring 2010	-7.45 *	17.21 *	96.47 *	-73.67 *	Spring 2010	---
Spring 2010 - Spring 2011	-12.62 *	12.92 *	27.52 *	-45.18 *	Spring 2011	---
Spring 2011 - Spring 2012	20.65 *	10.66 *	54.06 *	-8.69 *	Spring 2012	1.55
5 Year Change						
Spring 2007 - Spring 2012	1.55	25.88	359.20	-47.30	Spring 2012	1.55

* indicates that there is a gap in the shoreline data during the specified time period

+ shorelines with missing data were not used to calculate this statistical value because missing data reduces the comparability to the 2007 shoreline

Annual Shoreline Change

Annual displacements along the ocean-facing shoreline of Fire Island generally followed a spatial pattern of alternating gain and loss along the island (Fig. 13). The storminess of the early period was reflected in the net negative shoreline displacement until Spring 2011. However, the annual change from Spring 2011 to Spring 2012 was primarily shoreline gain along the entire island, rather than the previous annual comparisons of alternating gains and losses (Fig. 13). The alternating spatial pattern of gains and losses does not appear to be affected by the slight change in orientation of the ocean-facing shoreline at Fire Island, from generally west-east on the western half of the island to southwest-northeast on the eastern half of the island (Fig. 13). Although the orientation of the shoreline does not appear to affect the spatial pattern of shoreline displacement, vectors of shoreline change at either end of the island are larger and more dramatic than in the center (Fig. 13). In a seeming paradox to storminess producing erosion, the post-Irene shoreline, Fall 2012, had a seaward displacement. This outcome may have been the product of erosion of the upper beach and recovery of the shoreline low on the profile, a condition of storm-related sediment displacement often noted at other survey locations (Psuty et al., 2014)

The Fire Island shoreline near Moriches Inlet is downdrift of the jetty and that structure may affect the distribution of the natural sediment supply (Figs. 12 and 13). During the span of this report, 238,000 m³ (311,300 yds³) of sediment was dredged from Moriches Inlet between December 2008 and January 2009 and placed at Smith Point County Park (Table 3). The shoreline immediately downdrift of the jetty reflected greater displacement between Spring 2008 to Spring 2010, following the dredging episode (Figs. 12 and 13).

Near Democrat Point, the jetty affected natural sediment supply updrift of the jetty and downdrift of the jetty differently (Figs. 5 and 13). In March 2008, 474,024 m³ (620,000 yds³) of sediment were dredged from the Fire Island Inlet and placed downdrift of the inlet at Gilgo Beach (Table 3). The largest vectors of negative shoreline displacement at the mobile portion of Democrat Point, downdrift of the jetty, occurred between Spring 2008 and Spring 2009, although missing data obscures annual displacement of this portion of shoreline from Spring 2009 through Spring 2012.

5-Year Shoreline Change

Similar to annual changes in shoreline position at Fire Island National Seashore, the 5-year change comparison of the Spring 2007 and Spring 2012 shorelines is primarily characterized by alternating gain and loss along the length of the island (Fig. 13), a product of the seasonal variation rather than that caused by specific events. When plotted on a histogram, these vectors of change have a unimodal distribution about a relatively small mean value of +1.55 m (5.1 ft) (Fig. 14). As with annual comparisons, variations in shoreline position at Smith Point County Park and Robert Moses State Park are greater than the center of the island.

The most dramatic change in shoreline position between Spring 2007 and Spring 2012 is at the western end of the island. The shoreline updrift (east) of the jetty at Fire Island Inlet and along Robert Moses State Park experienced negative shoreline displacement (erosion) over the course of the 5 years. Conversely, the shoreline downdrift (west) of the jetty experienced positive shoreline growth, with sediment building the highly mobile shoreline in a westward direction (Figs. 5 and 13).

The vectors of shoreline change at the western terminus of the island are responsible for the relatively high max value of +359.20 m (1,178.48 ft) of shoreline change represented in the histogram (Figure 14).

Summary Statistics Tables and Trends of Change

In addition to annual and 5-year changes in shoreline position, the analysis of shorter-term summary statistics were calculated seasonally for the 2007 – 2012 period to provide the advantage of investigating shoreline displacements with increased detail. For this reason, summary statistics for seasonal changes were also calculated over the 5-year period. Therefore, seasonal, annual, and 5-year statistics were calculated for the total shoreline of Fire Island (Table 5) as well as for each of the administrative units along the ocean-facing shoreline of Fire Island from west to east (Tables B1 and C1). These administrative units are further combined and divided (Tables B2 and C2) to investigate the potential impact of managerial practices on shoreline position. For example, annual and 5-year shoreline change statistics for the total land managed by the National Park Service can be compared with annual and 5-year shoreline change statistics for total land managed by private communities, or with statistical values for the ocean-facing shoreline of the island as a whole. The statistical calculations for each portion of shoreline and each temporal span are represented by a mean value of change, one standard deviation, and vectors of maximum shoreline gain (accretion) and maximum shoreline loss (erosion) (Tables 5, B1 - B2, C1 - C2). For analyses of the total ocean shoreline of Fire Island, the net mean change from the Spring 2007 shoreline was calculated for each successive temporal span (Table 5). Gaps in shoreline position data during specific surveys reduce the comparability of the statistics calculated for each data set. Therefore, shorelines with data gaps have not been compared with the Spring 2007 shoreline (Table 5).

Net mean displacement is an additive statistical value that can assist in elucidating patterns of shoreline fluctuation and recovery. It is calculated by adding the mean value of annual shoreline change to the previous year's displacement; however, it requires comparable data sets with no gaps in shoreline position data. To apply net mean displacement analysis to the ocean shoreline of Fire Island, only vectors of change that are present in every shoreline comparison were incorporated in the analysis. Therefore, Smith Point County Park, Robert Moses State Park, and the western half of Davis Park are not incorporated in this analysis because shoreline position data are missing for these locations during at least one of the shoreline surveys incorporated in this report (Fig. 13).

The advantage of calculating net mean displacement is the application of a best-fit line to a scatterplot of net mean displacement values to describe linear trends in shoreline change (Fig. 15). To best understand the effects of shoreline displacement and recovery on the overall linear trend, seasonal displacement values (Table 5) were selected over annual displacement values because they encompass the net stormy, and non-stormy seasons and provide more detail. Over the 5-year period, seasonal changes in shoreline position for the combined federal and community land at Fire Island (not including the western half of Davis Park) indicate a linear trend of -0.14 m (0.46 ft) per year (Fig. 15).

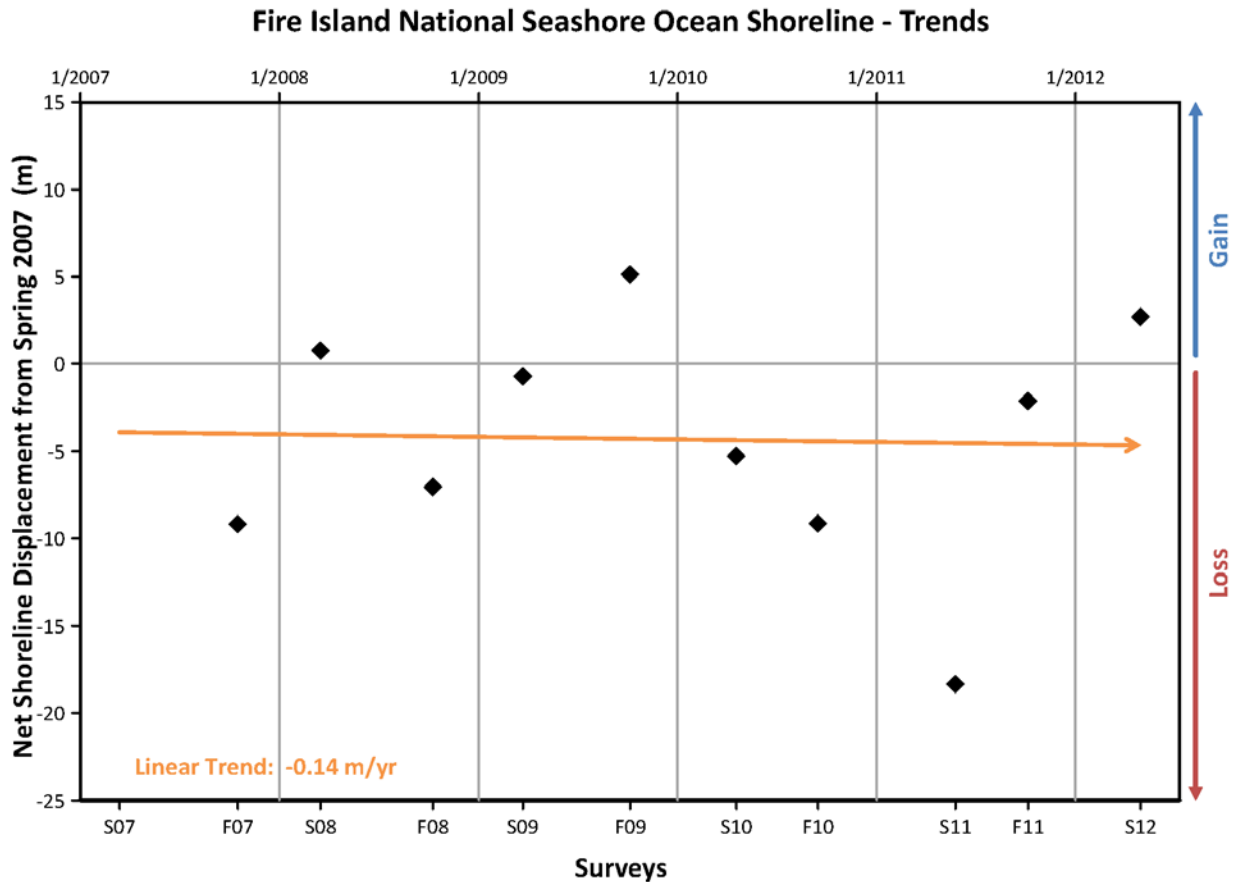


Figure 15. Trend of mean seasonal shoreline net displacement for federal and community lands at Fire Island ocean shoreline (not including the western half of Davis Park), Spring 2007 – Spring 2012. Seasonal survey dates are represented on lower x-axis with respect to timeline on upper x-axis.

Both natural storminess and artificial beach nourishment projects impacted the trend value during the period covered in this report (Fig. 2, Tables 3, 4). In the spring of 2007, sediment was placed at Smith Point County Park from an offshore source. In the winter of 2008-2009 sediment was dredged from Moriches Inlet and again placed at Smith Point County Park. A major beach nourishment project at 10 private communities added sediment from an offshore source both before and during the Spring 2009 survey. The winter season between Fall 2010 and Spring 2011 (Fig. 2) was a particularly stormy year. Combined, these events would have impacted the linear trend of net mean displacement of shoreline change at the federal and community lands of Fire Island (Fig. 15).

Interpretation of Trends

Though inherent temporal variation in shoreline position renders 5 years to be a relatively short period of measurement, analysis of the Fire Island shoreline change from 2007 to 2012 provides a preview for future patterns and trends of change. Natural fluctuations in the sediment budget along the long and continuous ocean shoreline of Fire Island produce the alternating patterns of growth and loss (Figs. 5 – 13) described above. The largest vectors of shoreline change are produced by natural events such as storms, by human-induced cultural events such as beach nourishment and dredging, and by anthropogenic structures.

In accordance with National Park Service policy during the span of this report, during beach nourishment projects, sediment is only placed on private community land rather than on park-managed shoreline. Though some of this sediment is transported downdrift and contributes to the sediment budget of park land, calculated mean shoreline displacement values for all park service land and all community land (Table B2) indicate that community lands experienced greater positive shoreline change (5.68 m (18.64 ft)) than park lands (1.78 m (5.84 ft)) during the 5-year period. This difference is likely a product of beach nourishment projects.

The largest mean shoreline gain for all of Fire Island occurred Spring 2011 – Fall 2012, following prior large shoreline losses (Figs. 5-13, 15). Some shoreline gain is likely the natural recovery of the beaches after the prior extreme losses (Psuty et al., 2016). The shoreline position growth can also be attributed to Hurricane Irene, August 2011, as sediment eroded from dunes and other areas higher in the beach profile accumulate lower on the beach profile and displace the shoreline seaward.

Information for Management and Recommendations

The majority of the private communities on Fire Island experienced mean positive shoreline growth larger than the ± 7 m (22.97 ft) margin of error during the span of this report, though Corneille Estates experienced shoreline loss of 13.98 m (45.87 ft) and Fire Island Pines a loss of 8.16 m (26.77 ft) (Table B1). Some tracts of National Park land experienced similarly large shifts in shoreline position. The larger tracts of National Park land, however, such as the Wilderness Area (+ 1.58 m (5.18 ft)), Talisman/Barett Beach (+ 0.50 m (1.64 ft)), and Sailor's Haven (+ 0.99 m (3.25 ft)) experienced very small mean change values in the 5-year comparison (Table B1). In contrast, the Fire Island Lighthouse tract has a mean shoreline loss of 14.81 m (48.59 ft) during the 5-year comparison (Table B1). The largest vectors of change occur at the terminal ends of the island (Fig. 13); gaps in shoreline position data prevent strong interpretation of trends at these localities and additional monitoring should take place. As presented in the suite of data collected thus far, there is an opportunity to evaluate the impacts of beach nourishment within the communities and their associated downdrift effects. Seasonal surveys would provide more detail on these impacts. They would allow for identification of the responses to storminess in the variety of land holdings along Fire Island.

Problems/Concerns

The gaps in shoreline position data during certain surveys, caused by limitations in access to portions of the beach, analyzed in this report reduce the comparability of shoreline position data from season to season and year to year. Improved communication on timing of beach nourishment efforts and nesting restrictions could reduce the occurrence of survey gaps. Statistics calculated with incomplete data sets are either flagged (Tables 5, B1-B2, C1-C2), or portions of the shoreline represented in every survey must be extracted from the full data sets for analysis (Fig. 15). Despite these efforts, gaps in shoreline position data result in a skewed analysis that must be taken into consideration when viewing the results of this report.

Additional concerns include the poor documentation of beach nourishment activities at Fire Island, particularly smaller sediment transfers and sediment transfers funded by private communities. Despite best efforts to fully represent all sediment transfers in this report (Table 3), incomplete documentation of these events prevents this report from fully quantifying the impact of these actions on shoreline position change at Fire Island.

Data Archives

The lines that represent the shoreline position for each of the surveyed periods are stored as features in a Geodatabase along with the Transects and Baseline used in the shoreline change analysis, and the spreadsheet with the results from the DSAS analysis. This information and data are available from the Data Manager for the National Park Service, Inventory and Monitoring Program, Northeast Coastal and Barrier Network:

Data Manager, Northeast Coastal and Barrier Network
URI Dept. Natural Resources Science
1 Greenhouse Rd
Kingston, RI 02881
401-874-4305 (phone)
401-874-4561 (fax)
<http://science.nature.nps.gov/im/units/ncbn/>

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Appendix A. Annual Shoreline Change 2011-2012 at Fire Island National Seashore

Unlike previous years, there is no independent 2011-2012 Fire Island Annual Report on shoreline displacement. All of the Spring 2011 – Spring 2012 data are incorporated in the maps and statistics that describe the trends. This appendix reports on the shorter-term seasonal shoreline change as well as the net annual change at Fire Island for 2011-2012.

Timing of Surveys

In accordance with protocol (Psuty et al., 2010), the shoreline surveys were collected during a period of neap tide to reduce the variation in swash line position (Table A-1). The surveys were run at high-tide twice per year to capture the seasonal variation of the higher energy winter period contrasted with the lower energy summer (Fig. A-1). As with previous FIIS annual shoreline change reports, water levels and the timing of high tides was determined based upon the Sandy Hook tide gauge, which provides the nearest representation of ocean conditions (Fig A-1). The location of the Sandy Hook tide gauge, however, prevents the identification of storms that would approach Fire Island from the southwest and western directions. Therefore, in accordance with previous annual reports and this trend report, data from offshore wave buoys has been employed to determine the full range of storms that may have impacted the ocean-facing shoreline of Fire Island (Fig. A-2).

Table A-1. Seasonal shoreline surveys and recorded elevations and timing of previous neap-tide high-tides, 2011-2012.

Season	Date of survey	Previous High Tide	
		Height* (m)	Time
Spring 2011	26 May 2011	1.476	02:24 AM
Fall 2011	6 October 2011	1.365	02:54 AM
Spring 2012	30 April 2012	1.252	02:00 AM

* Tide elevation values are referenced to Mean Lower Low Water (MLLW) Source: NOAA tide gauge (#8531680) Sandy Hook, NJ

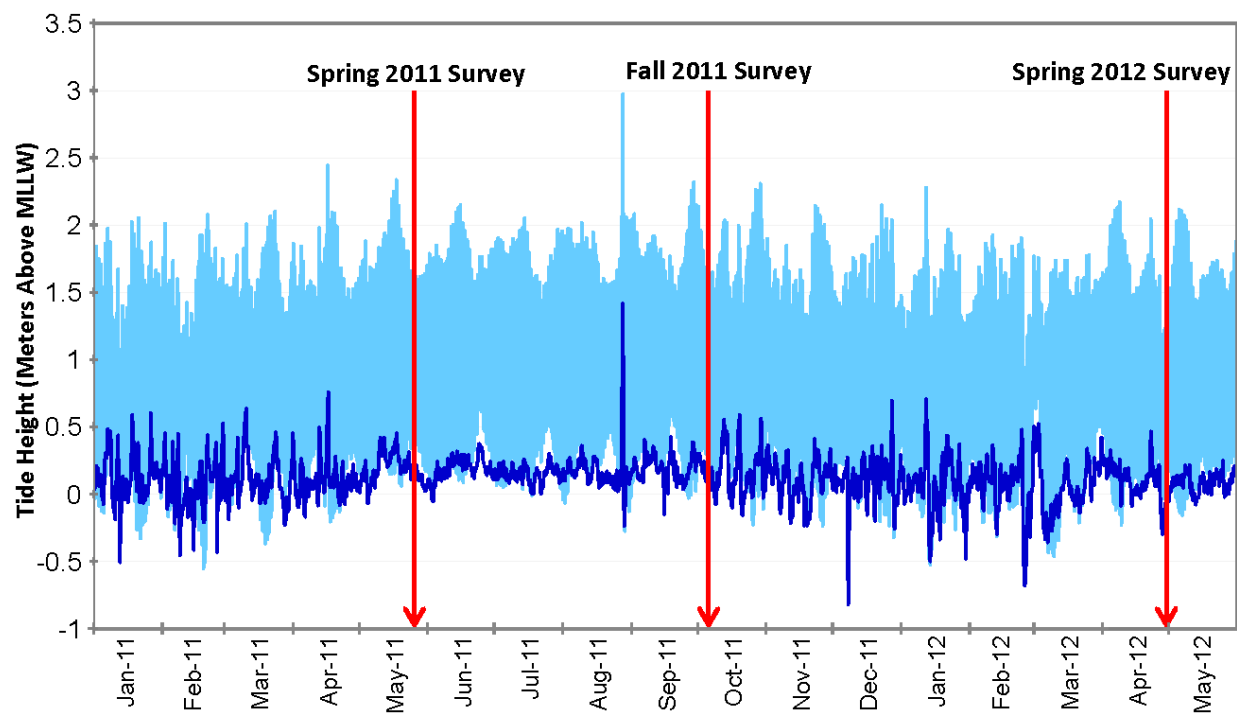


Figure A-1. Daily water level variation at Sandy Hook tide gauge from January 2011 through May 2012; dates of seasonal surveys indicated. Dark blue elevations represent surge values (difference of actual water level relative to predicted value). Source: NOAA tide gauge (#8531680) Sandy Hook, NJ (<http://tidesandcurrents.noaa.gov/>).

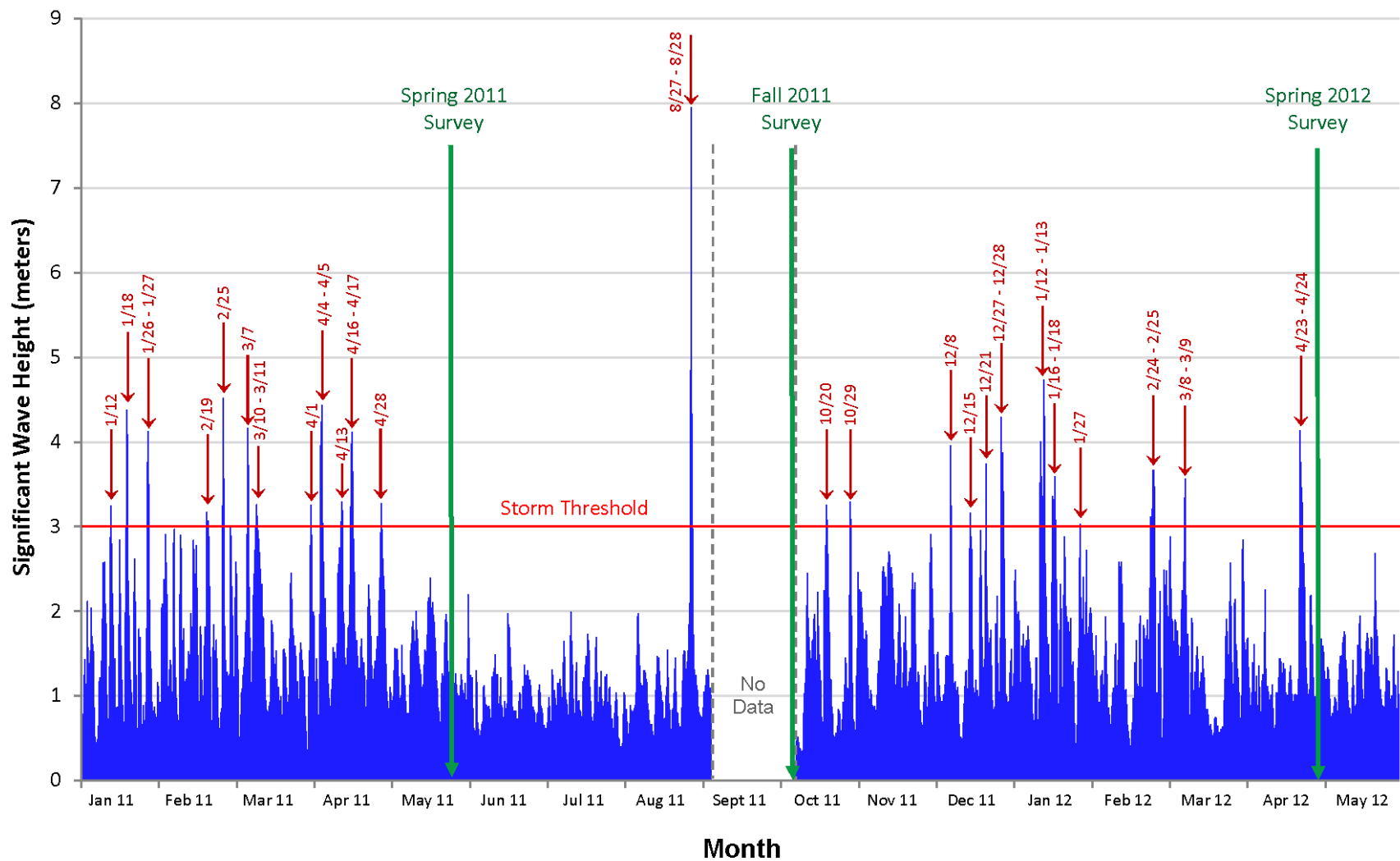


Figure A-2. Distribution of significant wave heights from January 2011 through May 2012; all significant wave heights surpassing the threshold value of 3.0 m indicate storm events. Dates of seasonal survey indicated. Source: NOAA National Data Buoy Center stations #44025, #44017, and #44065 (<http://www.ndbc.noaa.gov/>).

As previously determined for FIIS annual reports, buoys that record a significant wave height above 3 m (9.84 ft) are considered storm events; the duration of significant wave height above 3 m (9.84 ft) is noted as well as the dominant wave direction during this time and the number of high tides that occur throughout the storm event (Table A-2). Stormy and non-stormy conditions, according to wave buoy data, support expected seasonal trends, though the less stormy summer season is punctuated by Hurricane Irene in late August (Fig. A-2). Despite the combination of three wave buoys (station #44025, supplemented by #44017, and then by #44065), there is a gap in wave data of approximately 1 month when none of the buoys recorded wave information.

Table A-2. Frequency and magnitude of 25 highest maximum significant wave height values above 3.0 m, Fire Island, 2011-2012.

Period	Maximum Significant Wave Height (m)	Average Wave Direction* (Quadrant)	Hours	Number of High Tides
January 12, 2011	3.24	W	2	0
January 18, 2011	4.38	SE	12	1
January 26-27, 2011	4.12	E	13	1
February 19, 2011	3.17	W	3	1
February 25, 2011	4.52	S	12	1
March 7, 2011	4.16	SE	12	1
March 10-11, 2011	3.26	SE	7	1
April 1, 2011	3.25	E	4	0
April 4-5, 2011	4.43	S	17	1
April 13, 2011	3.29	E	8	1
April 16-17, 2011	4.11	SE	22	2
April 28, 2011	3.27	S	4	1
August 27-28, 2011	7.95	S	16	1
October 20, 2011	3.25	SE	5	0
October 29, 2011	3.29	E	3	0
December 8, 2011	3.96	W	5	0
December 15, 2011	3.16	S	2	0
December 21, 2011	3.74	S	2	0
December 27-28, 2011	4.29	S	26	2
January 12-13, 2012	4.73	SE	34	3
January 16-18, 2012	3.59	S	15	1
January 27, 2012	3.03	W	1	0
February 24-25, 2012	3.67	W	19	2
March 8-9, 2012	3.56	S	7	0
April 23-24, 2012	4.13	SE	20	2

Source: NOAA National Buoy Center (stations #44025 supplemented by station #44017 and #44065).

* The direction from which waves approach.

Shoreline Change

Investigation of seasonal and annual changes between Spring 2011 and Spring 2012 at Fire Island provides additional detail about short-term shoreline position change and is a complement to the previously produced Fire Island National Seashore annual reports on shoreline position (Figs. A-3 through A-11).

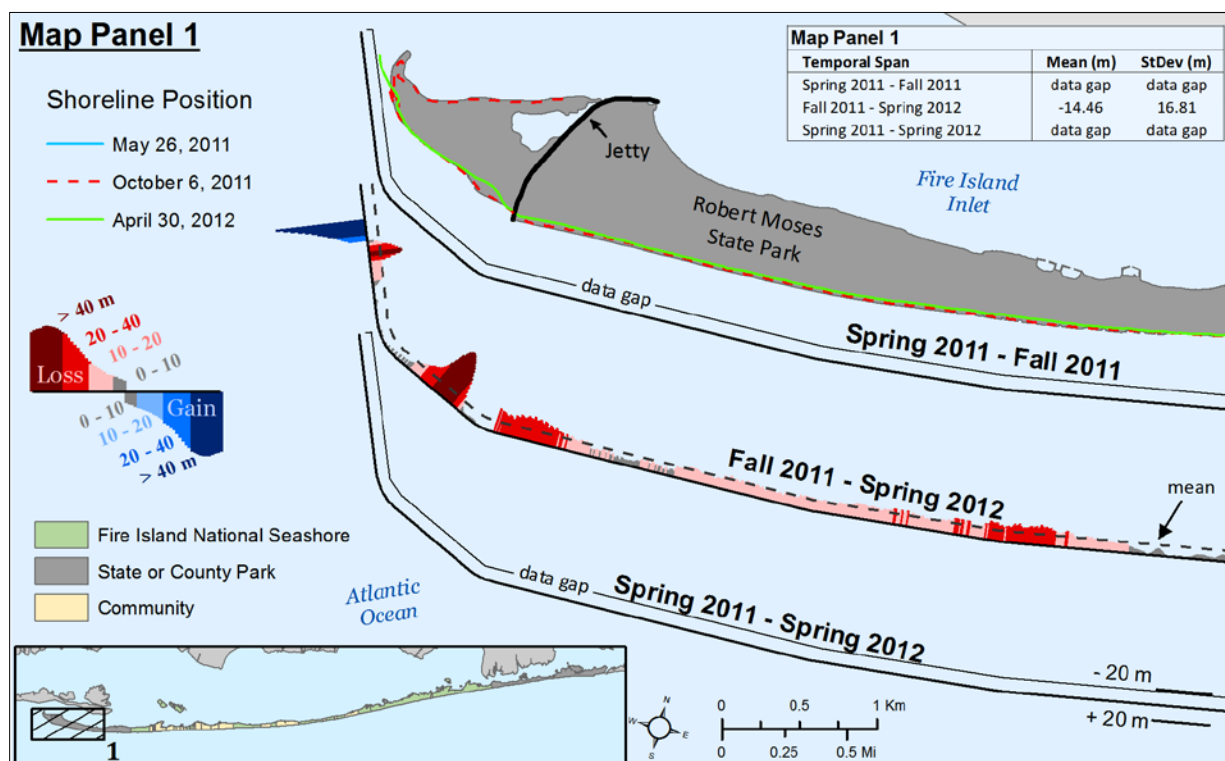


Figure A-3. Distribution of annual and seasonal shoreline change at Fire Island from Spring 2011 to Spring 2012; Map Panel 1. Mean change is portrayed as dashed line near baseline. The scale for all vectors of change is incorporated on the Spring 2011 – Spring 2012 comparison. Statistical calculation and mean line relate only to the change depicted in this map panel.

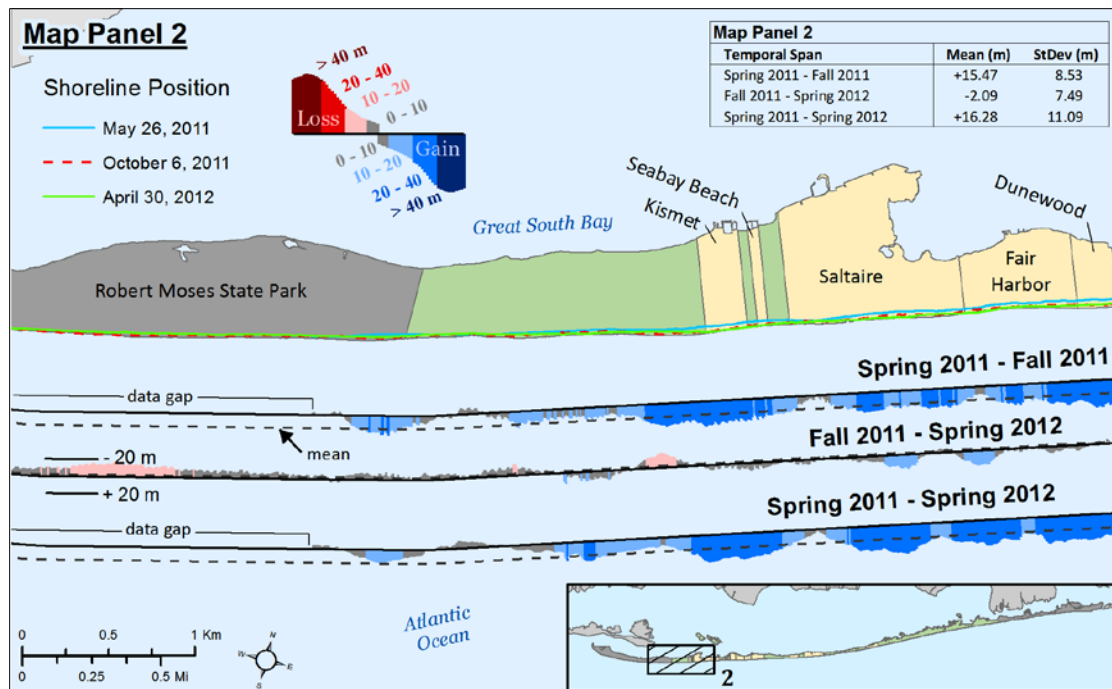


Figure A-4. Distribution of annual and seasonal shoreline change at Fire Island from Spring 2011 to Spring 2012; Map Panel 2. Mean change is portrayed as dashed line near baseline. The scale for all vectors of change is incorporated on the Fall 2011 – Spring 2012 comparison. Statistical calculation and mean line relate only to the change depicted in this map panel.

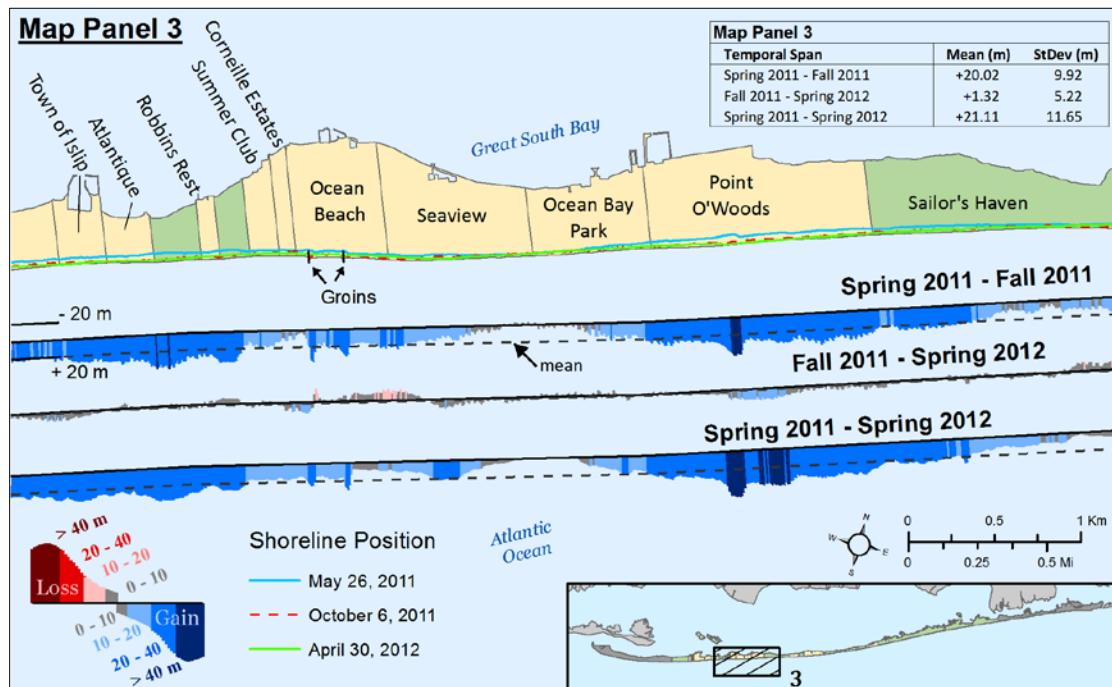


Figure A-5. Distribution of annual and seasonal shoreline change at Fire Island from Spring 2011 to Spring 2012; Map Panel 3. Mean change is portrayed as dashed line near baseline. The scale for all vectors of change is incorporated on the Spring 2011 – Fall 2011 comparison. Statistical calculation and mean line relate only to the change depicted in this map panel.

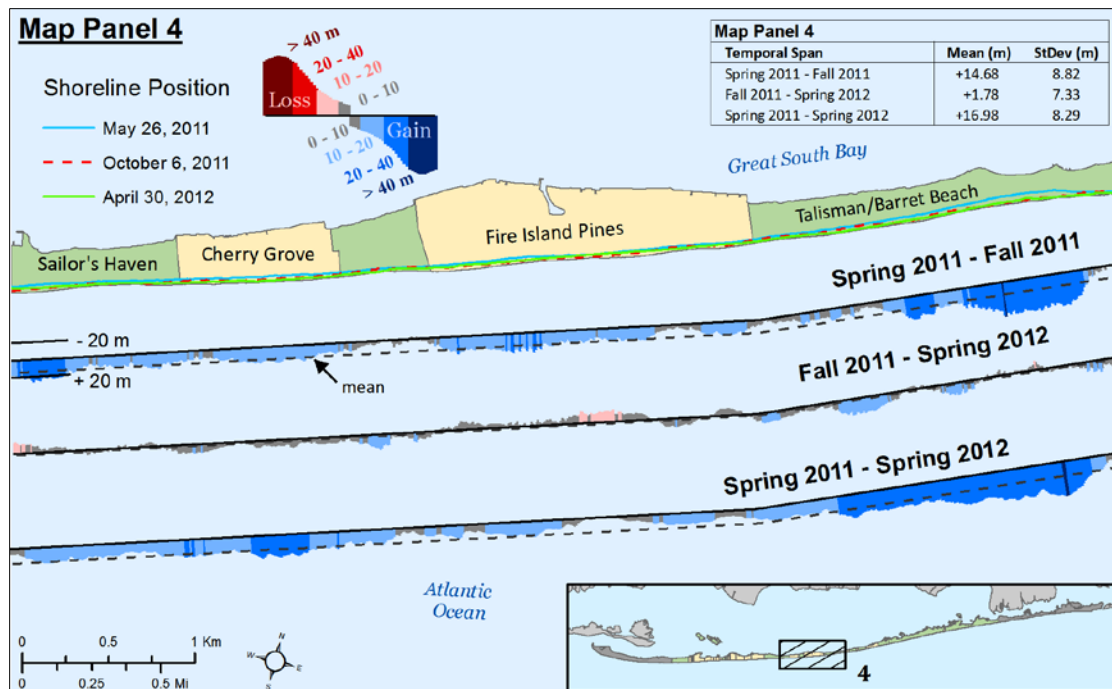


Figure A-6. Distribution of annual and seasonal shoreline change at Fire Island from Spring 2011 to Spring 2012; Map Panel 4. Mean change is portrayed as dashed line near baseline. The scale for all vectors of change is incorporated on the Spring 2011 – Fall 2011 comparison. Statistical calculation and mean line relate only to the change depicted in this map panel.

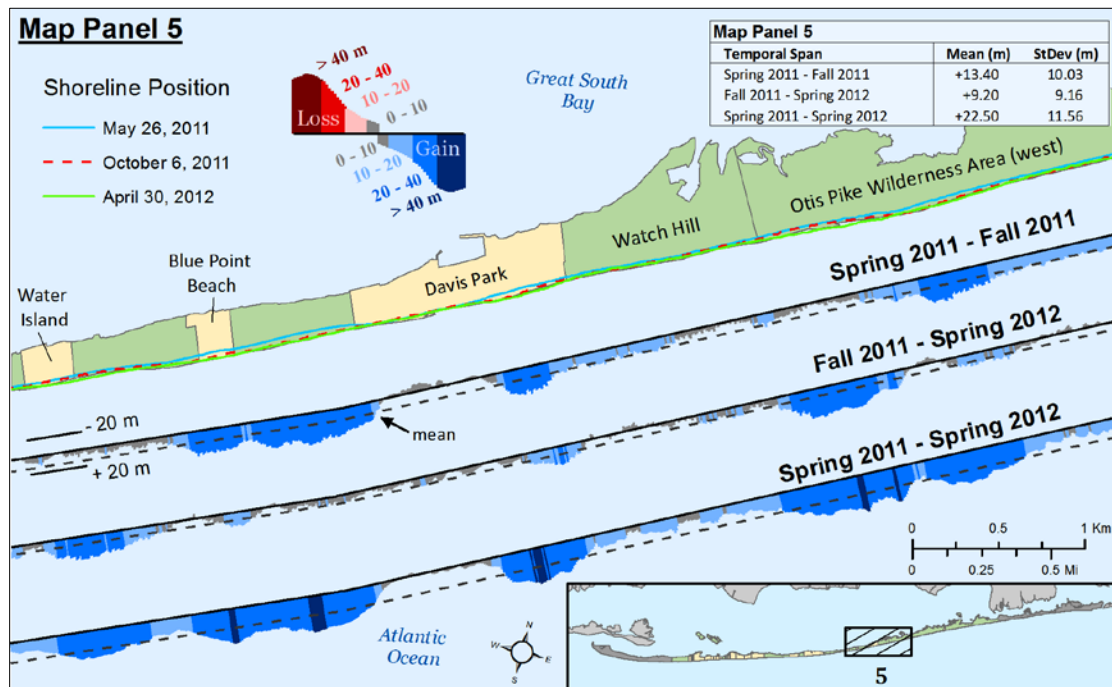


Figure A-7. Distribution of annual and seasonal shoreline change at Fire Island from Spring 2011 to Spring 2012; Map Panel 5. Mean change is portrayed as dashed line near baseline. The scale for all vectors of change is incorporated on the Spring 2011 – Fall 2011 comparison. Statistical calculation and mean line relate only to the change depicted in this map panel.

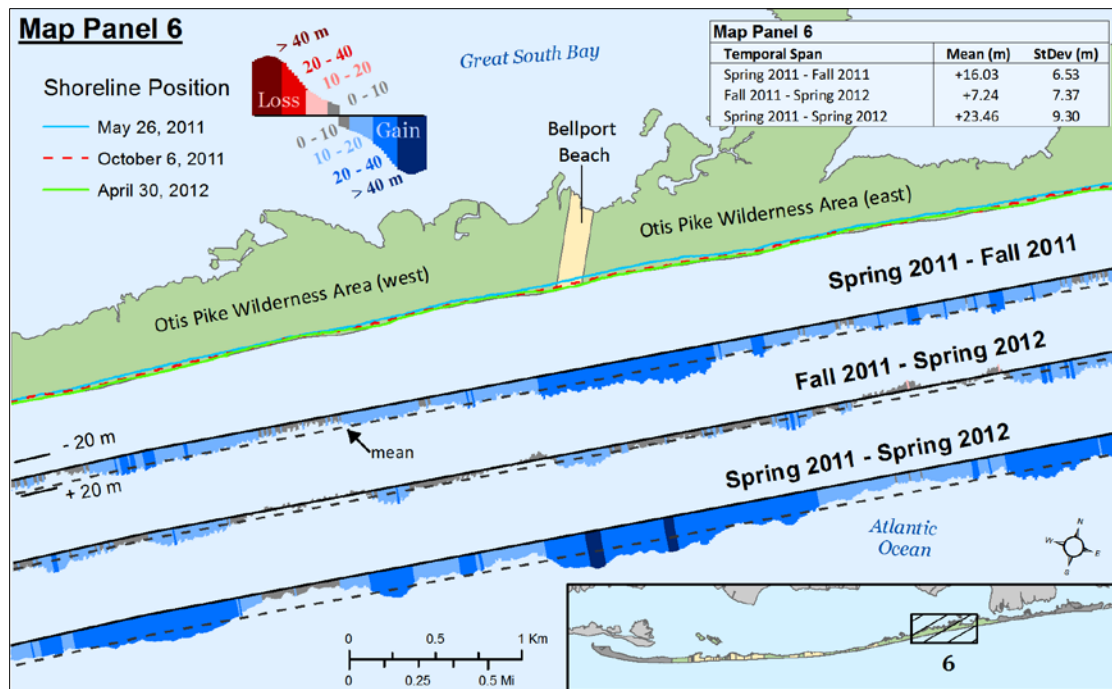


Figure A-8. Distribution of annual and seasonal shoreline change at Fire Island from Spring 2011 to Spring 2012; Map Panel 6. Mean change is portrayed as dashed line near baseline. The scale for all vectors of change is incorporated on the Spring 2011 – Fall 2011 comparison. Statistical calculation and mean line relate only to the change depicted in this map panel.

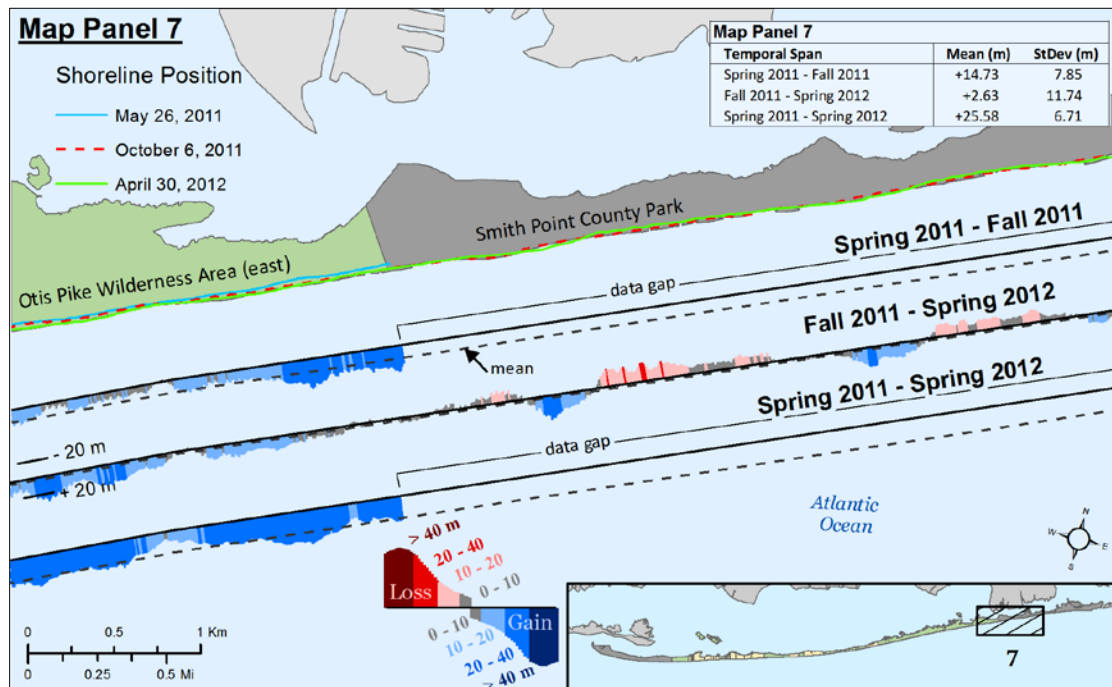


Figure A-9. Distribution of annual and seasonal shoreline change at Fire Island from Spring 2011 to Spring 2012; Map Panel 7. Mean change is portrayed as dashed line near baseline. The scale for all vectors of change is incorporated on the Fall 2011 – Spring 2012 comparison. Statistical calculation and mean line relate only to the change depicted in this map panel.

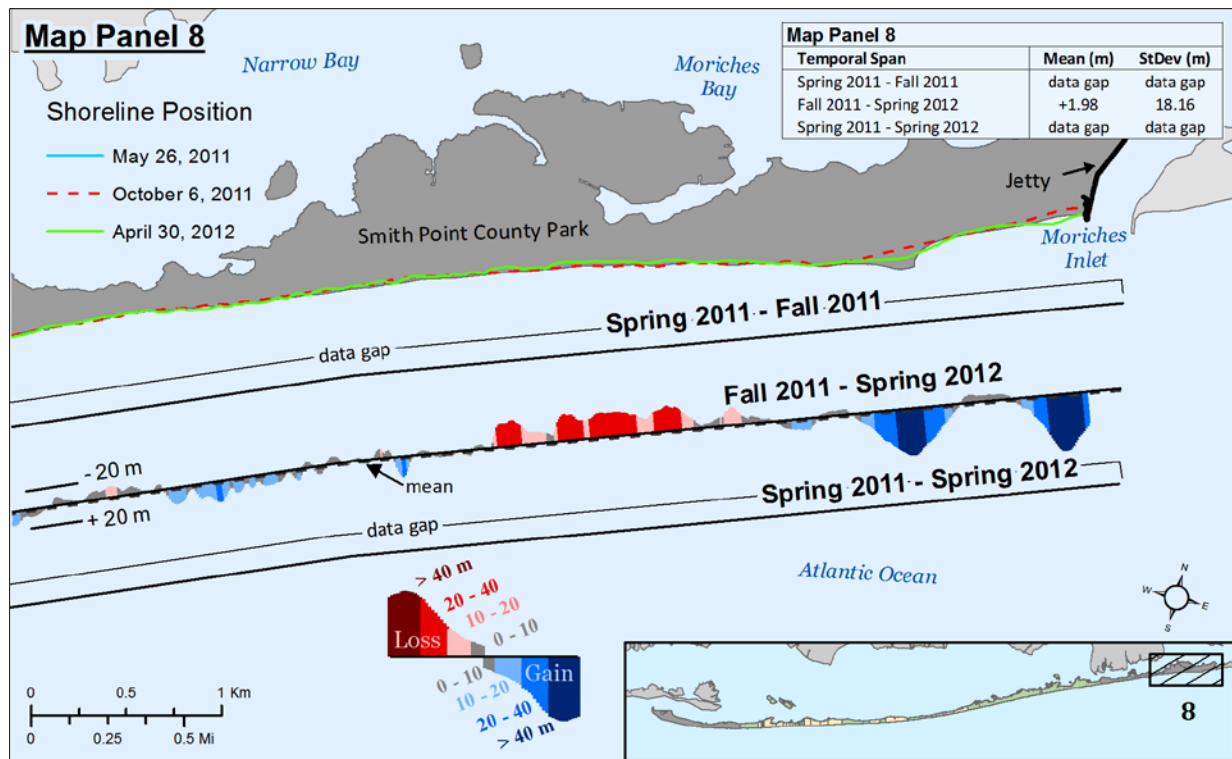


Figure A-10. Distribution of annual and seasonal shoreline change at Fire Island from Spring 2011 to Spring 2012; Map Panel 8. Mean change is portrayed as dashed line near baseline. The scale for all vectors of change is incorporated on the Fall 2011 – Spring 2012 comparison. Statistical calculation and mean line relate only to the change depicted in this map panel.

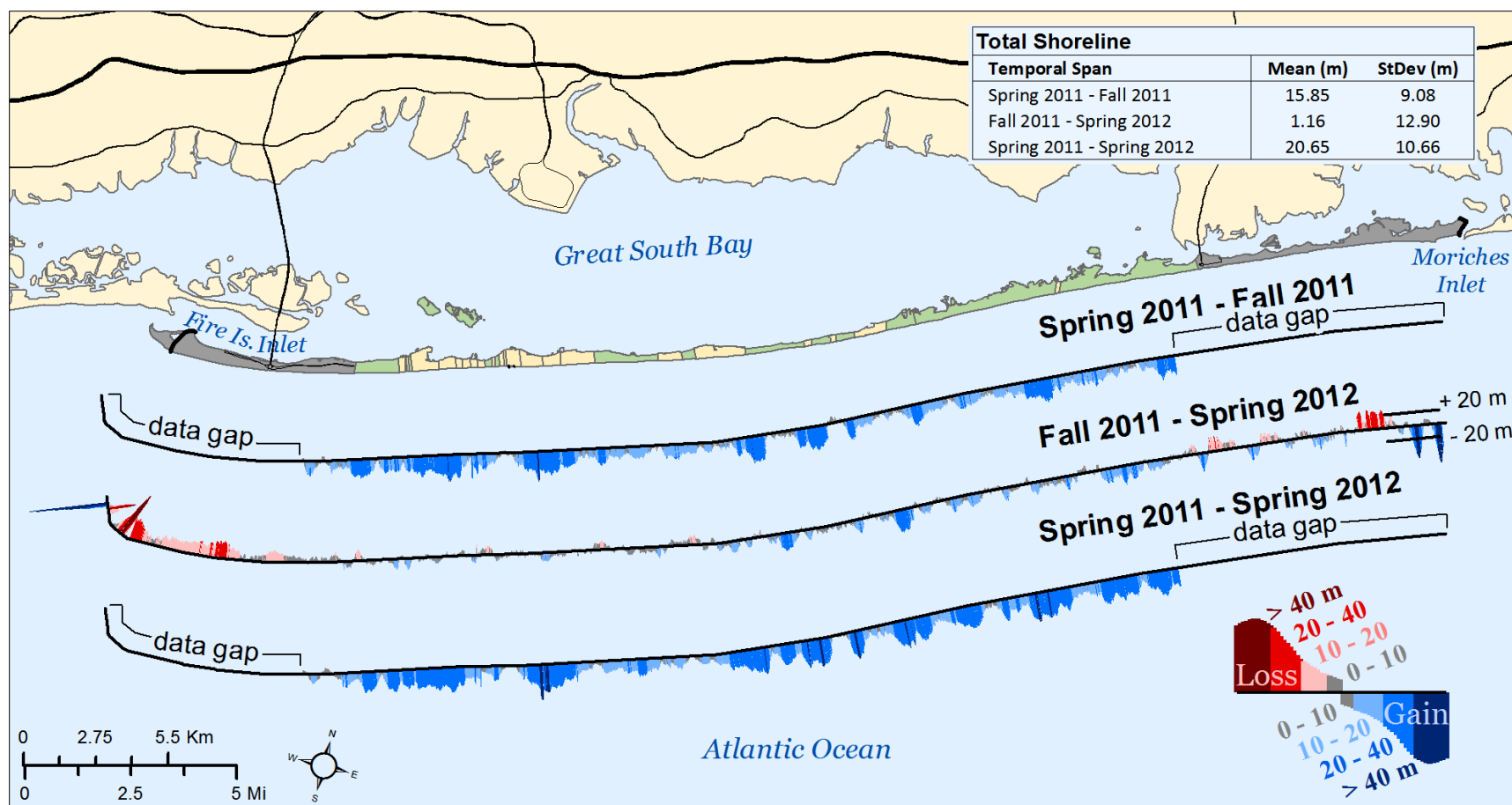


Figure A-11. Distribution of annual and seasonal shoreline change at Fire Island from Spring 2011 to Spring 2012. Statistical calculations relate to total ocean shoreline.

The seasonal shoreline comparisons at Fire Island indicate shoreline growth from Spring 2011 – Fall 2011 and an alternating pattern of shoreline growth and loss along the length of the island from Fall 2011 – Spring 2012 (Figs. A-3 through A-11). Histograms depicting the frequency of values of seasonal change along each transect have a unimodal normal distribution (Figs. A-12 and A-13). Though both seasonal comparisons reveal a positive mean growth in the total ocean shoreline, the stormier winter season (Fall 2011 – Spring 2012) experienced a lower value of mean growth of +1.15 m (3.77 ft) compared with the less stormy summer (Spring 2011 – Fall 2011) seasonal mean growth of +15.85 m (52 ft) (Figs. A-12 and A-13).

Only the Fall 2011 – Spring 2012 shoreline comparison includes vectors of change at Smith Point County Park and Robert Moses State Park where vectors of shoreline change tend to be higher. These vectors of change are responsible for the relatively large maximum and minimum values when compared with other seasonal and annual vectors of change during this period (Fig. A-13). The western growth of Democrat Point is indicated by the largest positive vector of change of 116.32 m (381.63 ft) whereas the shoreline immediately downdrift of the jetty experienced the largest negative vector of change of -70.49 m (231.27 ft) during this season. The shoreline updrift of the jetty at Robert Moses State Park also experienced negative shoreline displacement (Figs. A-3, A-11, A-13). The shoreline immediately downdrift of the jetty at Smith Point County Park experienced positive shoreline growth, though further downdrift the shoreline reveals both positive and negative vectors of shoreline growth (Figs. A-10, A-11, A-13).

The annual shoreline comparison from Spring 2011 to Spring 2012 indicates net shoreline growth (Figs. A-3 through A-11). The histogram depicting the distribution of annual vectors of change from Spring 2011 to Spring 2012 is somewhat bimodal with two positive peaks at approximately +16 m (52.5 ft) and + 28 m (92 ft) (Fig. A-14). The only negative vectors of shoreline change between Spring 2011 and Spring 2012 are at the eastern margin of Robert Moses State Park (Figs. A-3 through A-11). There were no documented sediment transfer events at Fire Island between Spring 2011 and Spring 2012 (Table 3).

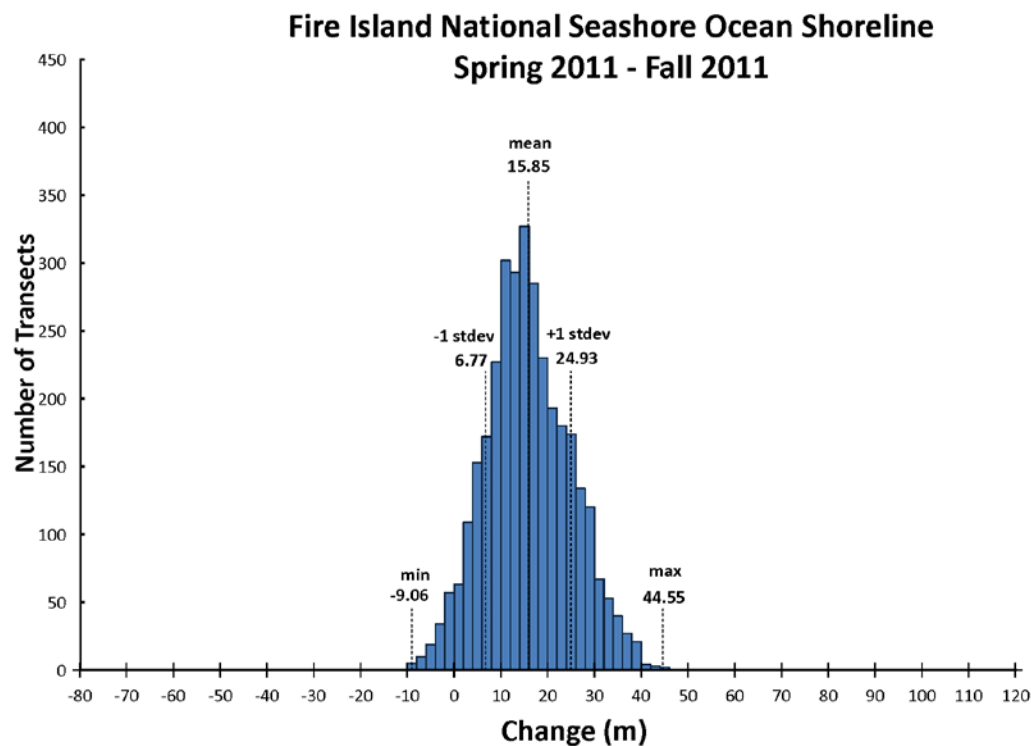


Figure A-12. Histogram of vectors of seasonal shoreline change from Spring 2011 – Fall 2011.

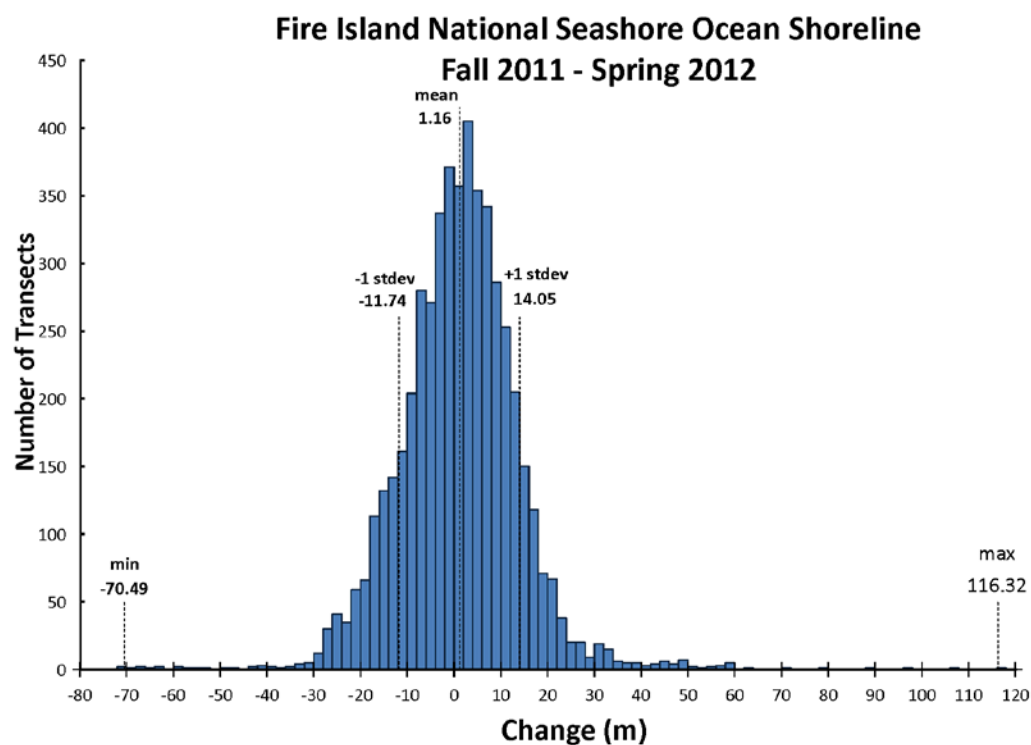


Figure A-13. Histogram of vectors of seasonal shoreline change from Fall 2011 – Spring 2012.

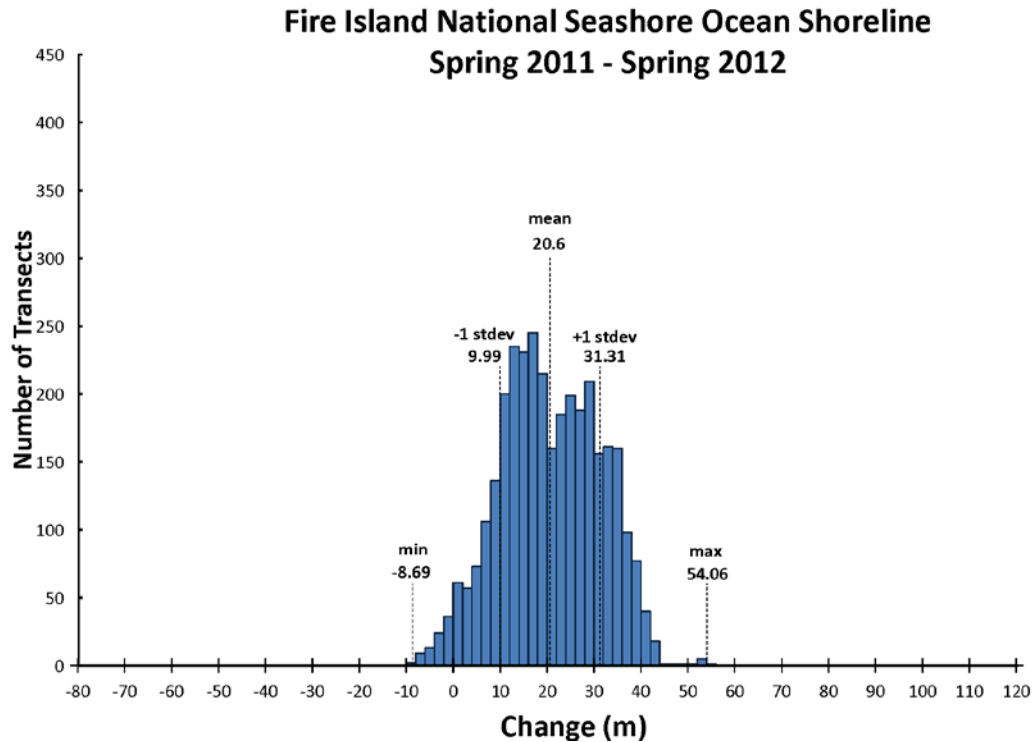


Figure A-14. Histogram of vectors of seasonal shoreline change from Spring 2011 – Spring 2012.

Conclusion

Between Spring 2011 and Spring 2012, the ocean-facing shoreline of Fire Island was displaced generally seaward. In accordance with seasonal storminess, the shoreline experienced greater growth over the summer season (Spring 2011 - Fall 2011) than during the winter from Fall 2011 to Spring 2012. Some of the seaward shoreline shift between Fall 2011 and Spring 2012 can be attributed to the relocation of sediment from higher on the beach profile to lower on the profile during Hurricane Irene, a trend visible at other coastal locations in the region following Hurricane Irene (Psuty et al., 2016). The most dynamic areas of Fire Island are at the state and county parks at either terminus of the island. Though the gap in data prevents analysis of annual shoreline change at these locations, the seasonal comparison between Fall 2011 – Spring 2012 indicates large vectors of change, including the growth of Democrat Point (Figs. A-3, A-10, A-11).

Appendix B. Tables of Annual Shoreline Change at Fire Island National Seashore

Statistical tables of shoreline changes were determined for annual changes between 2007 and 2012 (Table B-1 and Table B-2). These include mean, one standard deviation, and the values of vectors that experienced maximum shoreline accretion (growth) and maximum erosion (loss).

Statistical values of annual shoreline change were calculated for each administrative unit of Fire Island from west to east (Table B-1). Statistical values were also calculated for ‘zones of interest’ that include the combination and separation of administrative units to more closely investigate the impacts of either administrative policy on shoreline change mitigation or on the impact of hard structures on proximal shoreline change (Table B-2).

Table B-1. Statistical values of annual and 5-year shoreline changes for individual administrative units of Fire Island, 2007 – 2012.

Administrative Units		Spring 2007 to Spring 2008	Spring 2008 to Spring 2009	Spring 2009 to Spring 2010	Spring 2010 to Spring 2011	Spring 2011 to Spring 2012	Spring 2007 to Spring 2012
Robert Moses State Park	Mean (m)	-3.97	-14.89	-16.91 *	---	---	-4.89
	1 St Dev	14.61	21.64	18.26 *	---	---	51.74
	Max Accretion	48.95	23.72	26.39 *	---	---	359.20
	Max Erosion	-60.84	-125.67	-53.51 *	---	---	-47.30
NPS – Lighthouse	Mean (m)	-10.39	-4.98	8.97	-17.32	8.77	-14.81
	1 St Dev	8.91	10.44	11.28	5.57	9.19	12.49
	Max Accretion	7.26	23.05	34.15	-7.50	31.48	359.20
	Max Erosion	-27.85	-20.12	-16.11	-31.71	-8.69	-31.68
Kismet	Mean (m)	-1.09	-11.64	15.74	-24.02	29.39	7.81
	1 St Dev	4.30	3.71	3.26	1.32	1.67	3.73
	Max Accretion	5.03	-4.21	19.91	-21.47	32.33	14.18
	Max Erosion	-8.94	-16.49	10.78	-25.68	26.97	2.16
NPS	Mean (m)	-2.93	-14.84	14.03	-25.00	28.26	0.16
	1 St Dev	1.08	1.09	0.81	0.52	0.72	1.01
	Max Accretion	-1.10	-13.04	14.91	-24.37	29.33	1.73
	Max Erosion	-4.26	-16.09	12.61	-25.79	27.48	-1.24
Seabay Beach	Mean (m)	-4.80	-8.66	13.81	-25.92	26.17	-1.94
	1 St Dev	0.98	1.91	1.27	0.46	0.65	0.31
	Max Accretion	-2.94	-6.51	11.90	-25.09	27.33	-1.37
	Max Erosion	-5.59	-11.61	15.20	-26.45	25.48	-2.22
NPS	Mean (m)	-3.21	-0.52	2.87	-20.06	20.45	-4.76
	1 St Dev	1.30	4.53	5.64	2.89	2.42	2.26
	Max Accretion	-1.41	7.58	10.87	-15.82	24.27	-1.48
	Max Erosion	-5.16	-6.62	-6.08	-24.87	16.62	-7.41

* indicates that there is a gap in the shoreline data within the administrative unit during the specified time period

Table B-1 (continued). Statistical values of annual and 5-year shoreline changes for individual administrative units of Fire Island, 2007 – 2012.

Administrative Units		Spring 2007 to Spring 2008	Spring 2008 to Spring 2009	Spring 2009 to Spring 2010	Spring 2010 to Spring 2011	Spring 2011 to Spring 2012	Spring 2007 to Spring 2012
Saltaire	Mean (m)	7.35	16.04	-15.88	-18.53	21.07	9.79
	1 St Dev	10.72	11.24	4.43	4.43	8.46	10.73
	Max Accretion	27.06	33.86	-7.16	-7.16	34.06	24.47
	Max Erosion	-13.96	-4.86	-25.23	-25.23	2.49	-12.54
Fair Harbor	Mean (m)	-2.48	33.75	-20.98	-27.65	25.47	8.02
	1 St Dev	6.03	10.44	4.05	5.34	3.80	4.64
	Max Accretion	9.49	42.44	-16.44	-16.99	31.66	15.78
	Max Erosion	-8.74	8.65	-29.08	-35.84	17.34	-0.08
Dunewood	Mean (m)	4.36	33.70	-21.48	-24.13	27.07	19.35
	1 St Dev	4.77	3.34	1.11	2.99	1.79	3.13
	Max Accretion	9.41	39.88	-18.71	-19.10	29.60	23.78
	Max Erosion	-3.97	29.08	-22.92	-28.67	24.42	14.65
Lonleyville	Mean (m)	8.55	14.59	-16.46	-16.72	27.73	18.71
	1 St Dev	1.44	8.52	2.88	1.93	2.38	2.75
	Max Accretion	10.86	28.27	-10.99	-13.11	32.54	23.62
	Max Erosion	5.76	1.27	-21.16	-20.05	24.44	15.59
Town of Islip	Mean (m)	6.38	1.82	-11.05	-13.69	30.76	14.85
	1 St Dev	3.59	1.26	2.44	2.01	2.50	1.53
	Max Accretion	11.59	3.80	-5.69	-11.07	34.58	16.98
	Max Erosion	0.42	-0.27	-14.62	-17.41	27.15	12.24
Atlantique	Mean (m)	-2.00	39.34	-19.28	-29.49	28.62	15.30
	1 St Dev	1.84	3.21	2.29	3.18	0.91	1.65
	Max Accretion	0.50	42.44	-16.44	-25.12	30.52	19.12
	Max Erosion	-4.55	33.18	-22.92	-35.84	27.48	12.72
NPS	Mean (m)	2.19	-10.07	19.24	-22.98	33.57	22.97
	1 St Dev	4.03	3.25	2.51	2.34	4.14	1.80
	Max Accretion	8.15	-5.63	24.83	-19.23	38.43	24.97
	Max Erosion	-4.52	-16.73	15.03	-26.37	25.26	18.97
Robins Rest	Mean (m)	16.38	-25.53	26.72	-26.22	25.16	17.82
	1 St Dev	5.02	5.51	1.85	3.75	2.12	1.19
	Max Accretion	22.23	-17.14	29.09	-22.08	28.85	19.54
	Max Erosion	8.23	-32.63	24.29	-31.86	23.00	16.34
NPS	Mean (m)	23.90	-38.11	31.66	-33.62	24.60	9.02
	1 St Dev	0.43	1.82	1.41	3.02	5.08	3.95
	Max Accretion	24.39	-33.78	33.92	-29.40	29.39	15.66
	Max Erosion	22.86	-39.62	28.90	-38.21	16.39	3.57

* indicates that there is a gap in the shoreline data within the administrative unit during the specified time period

Table B-1 (continued). Statistical values of annual and 5-year shoreline changes for individual administrative units of Fire Island, 2007 – 2012.

Administrative Units		Spring 2007 to Spring 2008	Spring 2008 to Spring 2009	Spring 2009 to Spring 2010	Spring 2010 to Spring 2011	Spring 2011 to Spring 2012	Spring 2007 to Spring 2012
Summer Club	Mean (m)	17.37	-38.09	34.52	-37.45	17.48	-5.67
	1 St Dev	5.40	3.19	1.27	3.27	0.69	5.70
	Max Accretion	24.17	-32.68	37.19	-32.06	18.33	3.68
	Max Erosion	7.76	-41.11	32.38	-41.16	16.03	-13.14
Corneille Estates	Mean (m)	0.57	-28.22	36.21	-38.72	17.29	-13.98
	1 St Dev	3.34	4.72	1.41	2.34	1.12	1.16
	Max Accretion	6.28	-20.44	38.41	-34.53	18.60	-11.48
	Max Erosion	-2.84	-33.86	34.40	-41.45	15.18	-15.53
Ocean Beach	Mean (m)	6.19	0.21	16.04	-33.06	14.93	3.44
	1 St Dev	6.55	12.05	6.71	3.10	6.13	4.20
	Max Accretion	17.15	16.10	33.73	-26.84	31.92	9.84
	Max Erosion	-2.10	-23.42	8.57	-37.54	7.16	-8.88
Seaview	Mean (m)	-9.95	-9.56	19.52	-12.27	11.11	-1.20
	1 St Dev	6.07	5.91	2.75	15.62	7.18	4.43
	Max Accretion	2.17	7.95	24.51	9.49	22.93	7.97
	Max Erosion	-20.59	-17.01	11.26	-35.84	-0.23	-5.64
Ocean Bay Park	Mean (m)	0.92	-1.15	-11.69	7.66	9.84	4.03
	1 St Dev	3.62	10.63	10.49	5.34	8.37	7.03
	Max Accretion	7.26	12.46	13.90	19.69	24.31	12.33
	Max Erosion	-5.60	-17.69	-25.66	-1.05	-1.62	-6.66
Point O'Woods	Mean (m)	8.52	-6.29	-4.45	-18.31	35.02	15.10
	1 St Dev	3.80	4.11	14.57	16.69	6.73	5.63
	Max Accretion	15.76	4.03	15.69	12.56	54.06	22.92
	Max Erosion	0.44	-14.07	-28.40	-35.20	23.73	2.11
NPS - Sailors Haven	Mean (m)	4.24	-1.43	-0.12	-16.51	14.99	0.99
	1 St Dev	10.60	10.92	8.09	6.30	6.09	14.48
	Max Accretion	26.15	20.47	14.97	0.74	28.81	34.49
	Max Erosion	-19.69	-21.47	-22.31	-30.60	1.81	-20.73
Cherry Grove	Mean (m)	2.92	-5.65	-0.72	-13.56	20.25	3.24
	1 St Dev	6.64	5.50	7.99	3.95	3.16	9.43
	Max Accretion	16.01	3.47	13.51	-3.16	27.14	19.20
	Max Erosion	-6.83	-16.98	-16.10	-19.29	13.83	-14.91
NPS	Mean (m)	8.00	0.39	-25.19	-5.19	11.76	-10.90
	1 St Dev	2.00	7.59	6.93	2.03	4.26	5.01
	Max Accretion	10.61	15.62	-12.04	-1.83	19.08	-2.22
	Max Erosion	-0.49	-13.50	-33.91	-9.58	4.07	-20.31

* indicates that there is a gap in the shoreline data within the administrative unit during the specified time period

Table B-1 (continued). Statistical values of annual and 5-year shoreline changes for individual administrative units of Fire Island, 2007 – 2012.

Administrative Units		Spring 2007 to Spring 2008	Spring 2008 to Spring 2009	Spring 2009 to Spring 2010	Spring 2010 to Spring 2011	Spring 2011 to Spring 2012	Spring 2007 to Spring 2012
Fire Island Pines	Mean (m)	-0.62	18.08	-18.99	-16.59	9.85	-8.16
	1 St Dev	8.38	17.71	12.69	7.09	4.48	11.71
	Max Accretion	18.85	45.17	7.33	-4.36	19.04	10.04
	Max Erosion	-15.57	-19.38	-38.78	-31.73	-0.11	-25.92
NPS - Talisman/ Barrett Beach	Mean (m)	8.59	-14.49	-4.36	-12.87	23.63	0.50
	1 St Dev	5.28	9.16	7.25	10.07	8.47	5.02
	Max Accretion	18.90	3.65	5.43	8.96	40.62	10.00
	Max Erosion	-2.27	-41.13	-28.86	-33.41	6.70	-13.02
Water Island	Mean (m)	-2.75	-1.48	-8.59	-1.31	23.33	9.20
	1 St Dev	6.38	11.69	4.56	5.35	5.69	3.10
	Max Accretion	4.91	18.67	-1.42	8.23	31.24	14.24
	Max Erosion	-16.08	-16.93	-14.77	-9.89	13.89	2.69
NPS	Mean (m)	1.63	2.47	-5.59	-5.15	23.45	16.80
	1 St Dev	11.26	15.67	7.87	4.10	5.46	1.74
	Max Accretion	15.77	25.53	8.90	3.43	32.04	20.38
	Max Erosion	-17.49	-14.91	-15.44	-16.23	14.39	13.59
Blue Point Beach	Mean (m)	-0.30	-14.32	11.38	-24.60	36.69	8.85
	1 St Dev	1.45	1.73	1.64	3.57	2.80	1.98
	Max Accretion	3.26	-10.38	13.52	-15.98	41.28	13.37
	Max Erosion	-2.40	-16.54	7.60	-27.84	31.54	6.52
NPS	Mean (m)	0.17	-6.32	4.50	-32.13	34.25	0.36
	1 St Dev	4.56	4.74	5.46	6.13	4.78	5.59
	Max Accretion	8.22	4.40	16.19	-17.62	42.17	7.67
	Max Erosion	-8.35	-14.84	-5.36	-41.08	20.71	-13.14
Davis Park	Mean (m)	1.96	2.87 *	-9.86 *	4.95	15.88	25.03
	1 St Dev	10.50	6.34 *	9.86 *	8.80	15.25	11.47
	Max Accretion	26.04	15.61 *	1.33 *	18.38	42.34	37.05
	Max Erosion	-14.31	-6.30 *	-33.99 *	-15.43	-2.76	-8.26
NPS - Watch Hill	Mean (m)	-5.94	0.68	-11.14	-9.01	21.31	-4.10
	1 St Dev	9.82	11.41	13.23	13.08	10.68	10.95
	Max Accretion	48.95	33.45	17.26	27.52	43.54	13.92
	Max Erosion	-19.36	-15.20	-41.44	-25.37	4.98	-30.54
Otis Pike Wilderness Area	Mean (m)	-1.50	-4.51	-8.20	-6.94	22.73	1.58
	1 St Dev	9.92	8.73	8.57	12.46	9.77	16.14
	Max Accretion	18.90	23.41	17.99	23.90	44.03	33.02
	Max Erosion	18.90	-22.97	-42.35	-33.00	2.95	-37.67

* indicates that there is a gap in the shoreline data within the administrative unit during the specified time period

Table B-1 (continued). Statistical values of annual and 5-year shoreline changes for individual administrative units of Fire Island, 2007 – 2012.

Administrative Units		Spring 2007 to Spring 2008	Spring 2008 to Spring 2009	Spring 2009 to Spring 2010	Spring 2010 to Spring 2011	Spring 2011 to Spring 2012	Spring 2007 to Spring 2012
Smith Point Park	Mean (m)	-0.85	-2.27 *	-9.59 *	---	---	0.00
	1 St Dev	12.50	18.19 *	23.23 *	---	---	21.68
	Max Accretion	42.12	56.12 *	96.47 *	---	---	55.21
	Max Erosion	-30.06	-39.25 *	-73.67 *	---	---	-45.03

* indicates that there is a gap in the shoreline data within the administrative unit during the specified time period

Table B-2. Statistical values of annual and 5-year shoreline displacement of zones of interest.

Administrative Units		Spring 2007 to Spring 2008	Spring 2008 to Spring 2009	Spring 2009 to Spring 2010	Spring 2010 to Spring 2011	Spring 2011 to Spring 2012	Spring 2007 to Spring 2012
NPS Land	Mean (m)	0.38	-3.78	-4.49	-11.69	21.40	1.78
	1 St Dev	10.84	11.88	11.60	12.14	10.05	14.43
	Max Accretion	27.40	33.45	34.15	27.52	44.03	34.49
	Max Erosion	-27.85	-41.13	-42.35	-45.18	-8.69	-37.67
Community Land	Mean (m)	0.44	5.52 *	-5.19 *	-13.05	17.30	5.68
	1 St Dev	8.34	18.68 *	17.72 *	14.39	10.45	13.93
	Max Accretion	25.27	45.17 *	38.41 *	19.69	42.34	37.05
	Max Erosion	-20.59	-33.86 *	-38.78 *	-41.45	-2.76	-25.92
Robert Moses State Park	Mean (m)	-3.97	-14.89	-16.91 *	---	---	-4.89
	1 St Dev	14.61	21.64	18.26 *	---	---	51.74
	Max Accretion	48.95	23.72	26.39 *	---	---	359.20
	Max Erosion	-60.84	-125.67	-53.51 *	---	---	-47.30
shoreline position downdrift of jetty	Mean (m)	-14.23	-44.23	---	---	---	80.45
	1 St Dev	28.51	36.54	---	---	---	94.87
	Max Accretion	48.95	-0.95	---	---	---	359.20
	Max Erosion	-60.84	-125.67	---	---	---	-16.81
shoreline position updrift of jetty	Mean (m)	-2.25	-9.93	-16.91	---	---	-19.59
	1 St Dev	9.66	12.38	18.26	---	---	11.19
	Max Accretion	17.70	23.72	26.39	---	---	0.08
	Max Erosion	-22.71	-65.03	-53.51	---	---	-47.30
Smith Point County Park	Mean (m)	-0.85	-2.27 *	-9.59 *	---	---	0.00
	1 St Dev	12.50	18.19 *	23.23 *	---	---	21.68
	Max Accretion	42.12	56.12 *	-73.67 *	---	---	55.21
	Max Erosion	-30.06	-39.25 *	96.47 *	---	---	-45.03
shoreline position influenced by inlet and jetty	Mean (m)	1.28	1.14	-5.78	---	---	11.29
	1 St Dev	18.10	22.66	33.39	---	---	24.05
	Max Accretion	42.12	56.12	96.47	---	---	50.18
	Max Erosion	-29.20	-39.25	-73.67	---	---	-31.39

* indicates that there is a gap in shoreline data within the administrative unit during the specified time period

Table B-2 (continued). Statistical values of annual and 5-year shoreline displacement of zones of interest.

Administrative Units		Spring 2007 to Spring 2008	Spring 2008 to Spring 2009	Spring 2009 to Spring 2010	Spring 2010 to Spring 2011	Spring 2011 to Spring 2012	Spring 2007 to Spring 2012
shoreline position not influenced by jetty	Mean (m)	-1.59	-3.63 *	-11.11 *	---	---	-3.92
	1 St Dev	9.73	15.89 *	17.41 *	---	---	19.33
	Max Accretion	23.18	48.32 *	27.09 *	---	---	55.21
	Max Erosion	-30.06	-34.69 *	-46.20 *	---	---	-45.03
Total Ocean Shoreline	Mean (m)	-0.18	-3.66 *	-7.45 *	-12.62 *	20.65 *	1.55
	1 St Dev	11.65	17.54 *	17.21 *	12.92 *	10.66 *	25.88
	Max Accretion	48.95	56.12 *	96.47 *	27.52 *	54.06 *	359.20
	Max Erosion	-60.84	-125.67 *	-73.67 *	-45.18 *	-8.69 *	-47.30

* indicates that there is a gap in shoreline data within the administrative unit during the specified time period

Appendix C. Tables of Seasonal Shoreline Change at Fire Island National Seashore

Statistical tables of shoreline changes were also determined for seasonal changes between 2007 and 2012 (Table C-1 and Table C-2). These include mean, one standard deviation, and the values of vectors that experienced maximum shoreline accretion (growth) and maximum erosion (loss).

Statistical values of seasonal shoreline change were calculated for each administrative unit of Fire Island from west to east (Table C-1). Statistical values were also calculated for ‘zones of interest’ that include the combination and separation of administrative units to more closely investigate the impacts of either administrative policy on shoreline change mitigation or on the impact of hard structures on proximal shoreline change (Table C-2).

Table C-1. Statistical values of seasonal shoreline changes for individual administrative units of Fire Island, 2007 – 2012.

Administrative Units		Spring 2007 to Fall 2007	Fall 2007 to Spring 2008	Spring 2008 to Fall 2008	Fall 2008 to Spring 2009	Spring 2009 to Fall 2009	Fall 2009 to Spring 2010	Spring 2010 to Fall 2010	Fall 2010 to Spring 2011	Spring 2011 to Fall 2011	Fall 2011 to Spring 2012
Robert Moses State Park	Mean (m)	-14.83	10.34	-11.59	-4.04	-8.77	-11.90 *	18.95	---	---	-12.51
	1 St Dev	30.20	34.56	25.68	32.26	23.49	21.01 *	12.59	---	---	14.56
	Max Accretion	33.28	202.10	80.00	69.49	58.08	26.27 *	42.71	---	---	116.32
	Max Erosion	-171.13	-80.52	-88.48	-130.31	-90.38	-63.08 *	-17.12	---	---	-70.49
NPS - Lighthouse	Mean (m)	-15.15	4.75	-11.43	6.45	-3.56	12.67	0.22	-17.54	11.59	-2.82
	1 St Dev	10.84	6.04	13.24	10.77	13.54	10.53	2.41	5.84	8.57	6.50
	Max Accretion	-0.43	16.58	5.32	21.55	34.64	32.71	6.50	-6.33	29.33	12.54
	Max Erosion	-41.85	-6.33	-41.19	-18.64	-20.70	-3.95	-4.59	-30.60	-7.21	-17.08
Kismet	Mean (m)	-10.30	9.21	-20.16	8.52	-1.60	16.77	-5.19	-18.83	25.10	4.29
	1 St Dev	1.30	4.83	2.20	4.08	3.58	5.82	1.29	1.49	1.69	1.52
	Max Accretion	-8.44	14.58	-14.87	14.92	8.69	23.09	-2.00	-16.09	28.53	7.12
	Max Erosion	-13.44	0.83	-22.97	1.61	-5.48	5.71	-7.03	-20.97	22.37	1.48
NPS	Mean (m)	-13.76	10.83	-19.39	4.55	14.63	0.04	-7.77	-17.23	21.16	7.10
	1 St Dev	0.68	0.44	1.40	2.46	2.72	2.56	1.33	0.87	2.01	2.31
	Max Accretion	-12.64	11.55	-17.91	8.20	17.71	3.65	-6.16	-16.12	24.64	9.97
	Max Erosion	-14.64	10.36	-21.24	1.81	10.57	-3.34	-9.66	-18.21	18.65	3.07
Seabay Beach	Mean (m)	-15.46	10.65	-23.17	14.50	18.18	-6.90	-13.01	-12.92	20.74	5.43
	1 St Dev	0.29	1.07	1.11	2.78	0.36	1.75	2.00	1.91	1.70	1.07
	Max Accretion	-14.97	12.78	-25.26	17.89	18.64	-4.42	-15.46	-10.99	23.43	6.90
	Max Erosion	-15.72	9.82	-22.12	10.51	17.62	-9.03	-10.33	-15.86	18.58	3.90
NPS	Mean (m)	-17.19	13.98	-18.29	17.78	12.85	-14.28	-14.57	-5.49	18.22	2.23
	1 St Dev	1.47	0.81	3.91	1.72	4.94	2.22	0.89	2.54	1.56	1.57
	Max Accretion	-14.56	15.00	-13.75	21.32	17.15	-9.66	-13.55	-0.88	19.85	5.03
	Max Erosion	-18.39	12.64	-25.32	15.59	2.65	-16.50	-16.14	-9.46	14.10	-0.21
Saltaire	Mean (m)	-12.12	19.47	-9.67	25.71	-13.11	-3.03	-12.42	-6.11	16.44	4.63
	1 St Dev	9.69	4.48	11.41	15.88	13.00	9.95	2.70	9.70	5.94	5.47
	Max Accretion	7.49	26.58	14.20	44.54	7.21	13.06	-7.26	12.65	23.23	17.14
	Max Erosion	-31.56	10.12	-30.81	-6.46	-32.18	-18.30	-17.45	-19.68	1.17	-4.53

* indicates that there is a gap in the shoreline data within the administrative unit during the specified time period

Table C-1 (continued). Statistical values of seasonal shoreline changes for individual administrative units of Fire Island, 2007 – 2012.

Administrative Units		Spring 2007 to Fall 2007	Fall 2007 to Spring 2008	Spring 2008 to Fall 2008	Fall 2008 to Spring 2009	Spring 2009 to Fall 2009	Fall 2009 to Spring 2010	Spring 2010 to Fall 2010	Fall 2010 to Spring 2011	Spring 2011 to Fall 2011	Fall 2011 to Spring 2012
Fair Harbor	Mean (m)	-20.37	17.88	13.19	20.57	-16.11	-4.95	-13.07	-14.58	19.18	6.29
	1 St Dev	5.43	9.06	12.39	19.85	7.08	9.27	1.40	5.43	5.05	5.27
	Max Accretion	-10.85	31.36	29.90	52.07	-2.48	10.11	-10.02	-2.69	27.20	17.58
	Max Erosion	-28.28	3.97	-11.59	-8.50	-28.18	-16.54	-16.12	-22.19	8.82	-0.85
Dunewood	Mean (m)	-10.49	14.85	-21.92	55.62	-21.83	0.17	-9.30	-14.82	27.48	-0.41
	1 St Dev	4.32	1.24	5.51	2.40	3.47	2.91	2.32	1.44	3.10	2.82
	Max Accretion	-4.76	16.27	-12.77	59.27	-14.22	2.97	-5.41	-12.41	32.03	4.03
	Max Erosion	-16.17	11.87	-28.97	52.13	-25.61	-6.01	-13.37	-17.22	21.16	-4.76
Lonleyville	Mean (m)	-4.77	13.32	-23.06	37.66	0.36	-15.80	-4.03	-12.69	21.21	6.51
	1 St Dev	1.23	0.65	9.33	17.23	7.72	4.80	1.05	1.73	2.03	2.53
	Max Accretion	-2.52	15.16	-1.15	57.84	14.51	-7.12	-2.06	-9.58	25.37	10.95
	Max Erosion	-6.93	12.57	-29.74	2.42	-12.94	-24.83	-5.74	-16.11	16.86	0.46
Town of Islip	Mean (m)	-3.45	9.83	8.23	-6.41	16.21	-26.63	-1.38	-12.32	26.54	4.22
	1 St Dev	0.81	4.27	3.57	3.62	3.86	0.91	1.31	1.38	2.45	3.11
	Max Accretion	-1.59	15.31	14.10	1.57	23.08	-24.95	0.58	-9.27	29.74	9.83
	Max Erosion	-4.93	2.15	0.04	-12.77	11.50	-27.81	-3.77	-14.65	18.63	-0.85
Atlantique	Mean (m)	-4.14	2.14	11.90	-17.56	27.17	-20.20	-2.19	-11.66	30.96	-0.65
	1 St Dev	2.98	1.28	2.18	3.40	2.53	5.91	3.57	3.18	3.74	2.21
	Max Accretion	-0.94	4.43	14.46	-12.49	30.43	-11.23	3.55	-5.25	40.74	2.85
	Max Erosion	-8.72	0.62	8.48	-21.78	22.64	-29.28	-6.04	-19.04	24.14	-6.30
NPS	Mean (m)	-2.96	5.16	2.67	-12.74	28.67	-8.42	-6.95	-16.03	32.56	1.01
	1 St Dev	3.58	0.82	9.32	6.45	1.10	1.63	0.72	2.05	4.80	2.08
	Max Accretion	2.99	6.38	13.43	-3.93	30.51	-5.27	-6.10	-13.01	41.07	4.16
	Max Erosion	-7.99	3.45	-12.09	-20.28	26.87	-10.72	-8.49	-19.24	25.34	-3.23
Robins Rest	Mean (m)	5.63	10.75	-25.49	-0.04	29.78	-1.75	-8.38	-17.84	29.64	-4.48
	1 St Dev	2.03	3.02	6.07	1.21	0.41	1.33	0.44	3.85	4.01	2.14
	Max Accretion	7.98	14.29	-14.36	1.35	30.40	-0.49	-7.58	-13.96	36.08	-0.20
	Max Erosion	2.63	5.35	-32.39	-2.79	28.99	-4.49	-9.03	-23.58	24.29	-7.23

* indicates that there is a gap in the shoreline data within the administrative unit during the specified time period

Table C-1 (continued). Statistical values of seasonal shoreline changes for individual administrative units of Fire Island, 2007 – 2012.

Administrative Units		Spring 2007 to Fall 2007	Fall 2007 to Spring 2008	Spring 2008 to Fall 2008	Fall 2008 to Spring 2009	Spring 2009 to Fall 2009	Fall 2009 to Spring 2010	Spring 2010 to Fall 2010	Fall 2010 to Spring 2011	Spring 2011 to Fall 2011	Fall 2011 to Spring 2012
NPS	Mean (m)	4.75	19.15	-39.64	1.53	31.40	0.84	-10.50	-23.12	26.96	-2.36
	1 St Dev	2.79	2.84	3.08	2.10	1.42	1.76	1.49	4.04	9.12	4.21
	Max Accretion	9.83	23.26	-34.63	6.14	32.98	4.00	-8.23	-16.45	35.89	4.31
	Max Erosion	0.40	14.32	-45.74	-0.93	29.05	-1.81	-13.43	-28.01	12.09	-6.84
Summer Club	Mean (m)	-10.07	27.44	-48.38	10.29	28.41	6.62	-16.85	-20.61	16.74	0.74
	1 St Dev	7.51	2.33	1.07	4.10	2.73	2.79	2.72	0.91	2.31	1.99
	Max Accretion	0.41	30.13	-46.59	16.89	31.41	11.35	-13.14	-18.79	20.55	3.99
	Max Erosion	-21.36	23.61	-50.14	6.18	23.97	3.59	-20.26	-22.02	12.81	-2.75
Corneille Estates	Mean (m)	-26.95	27.52	-38.63	10.41	25.86	9.25	-19.59	-19.13	8.88	8.41
	1 St Dev	2.25	1.50	6.44	1.97	1.39	1.38	0.67	1.81	2.81	2.06
	Max Accretion	-22.68	29.04	-29.54	14.06	27.38	11.29	-18.75	-15.78	12.58	11.01
	Max Erosion	-29.54	24.77	-47.93	8.12	23.29	7.02	-20.66	-21.05	4.28	6.02
Ocean Beach	Mean (m)	-2.97	9.30	-17.94	18.15	14.62	0.43	-20.04	-13.02	19.25	-4.32
	1 St Dev	6.85	7.48	11.29	7.53	5.61	6.36	2.41	4.59	6.73	7.06
	Max Accretion	6.29	23.70	5.82	28.71	27.11	12.65	-14.66	-4.85	38.05	12.63
	Max Erosion	-25.29	-1.52	-31.06	1.33	7.09	-13.71	-24.84	-21.55	3.39	-16.11
Seaview	Mean (m)	-10.52	0.57	-5.79	-3.77	31.64	-12.17	-8.07	-4.19	9.69	1.42
	1 St Dev	4.63	4.05	14.62	10.97	7.61	9.08	3.23	13.10	7.83	5.63
	Max Accretion	-0.29	6.70	14.29	12.98	48.67	-0.35	-1.61	14.65	25.00	10.95
	Max Erosion	-15.57	-5.36	-26.77	-20.88	23.15	-35.84	-16.54	-24.04	-3.19	-12.79
Ocean Bay Park	Mean (m)	-10.49	11.40	-10.08	8.93	18.98	-32.21	6.89	0.76	10.47	-0.63
	1 St Dev	4.08	6.12	3.42	11.87	12.37	6.13	3.32	5.75	7.70	2.58
	Max Accretion	-1.87	21.05	-1.05	23.30	47.83	-21.22	12.22	10.48	25.66	6.49
	Max Erosion	-17.02	-3.74	-17.33	-14.44	-0.48	-44.61	-0.73	-7.01	-2.27	-5.65
Point O'Woods	Mean (m)	-4.72	13.24	-10.47	4.18	-5.23	1.39	-0.21	-18.10	29.56	5.46
	1 St Dev	3.33	3.55	15.32	13.44	15.04	28.61	6.71	11.02	4.59	4.08
	Max Accretion	1.70	22.46	22.94	31.54	21.09	36.47	11.39	3.79	44.55	13.61
	Max Erosion	-9.78	7.92	-34.28	-24.54	-26.27	-44.32	-9.90	-30.91	22.30	-2.58

* indicates that there is a gap in the shoreline data within the administrative unit during the specified time period

Table C-1 (continued). Statistical values of seasonal shoreline changes for individual administrative units of Fire Island, 2007 – 2012.

Administrative Units		Spring 2007 to Fall 2007	Fall 2007 to Spring 2008	Spring 2008 to Fall 2008	Fall 2008 to Spring 2009	Spring 2009 to Fall 2009	Fall 2009 to Spring 2010	Spring 2010 to Fall 2010	Fall 2010 to Spring 2011	Spring 2011 to Fall 2011	Fall 2011 to Spring 2012
NPS - Sailors Haven	Mean (m)	-8.96	13.20	-3.74	2.31	1.95	-2.27	-4.14	-12.36	16.24	-1.25
	1 St Dev	9.98	5.59	17.05	12.45	7.01	10.92	2.83	5.27	5.47	4.79
	Max Accretion	8.29	26.71	30.19	24.93	13.45	17.30	2.43	3.34	27.02	9.44
	Max Erosion	-31.58	3.87	-36.51	-24.79	-14.65	-25.28	-12.08	-20.68	4.58	-13.71
Cherry Grove	Mean (m)	-6.75	9.67	-13.18	7.54	0.16	-0.89	-1.78	-11.78	13.88	6.36
	1 St Dev	6.53	3.96	8.57	5.90	4.36	6.73	3.01	2.81	3.32	2.49
	Max Accretion	2.40	15.64	0.18	17.84	6.98	7.65	4.68	-6.64	19.50	10.68
	Max Erosion	-18.96	0.64	-26.28	-2.44	-10.85	-21.17	-7.31	-17.19	6.80	0.72
NPS	Mean (m)	-7.48	15.48	-5.07	5.46	9.67	-35.53	3.05	-8.24	3.89	7.87
	1 St Dev	5.28	4.40	3.27	4.79	1.41	5.62	2.46	2.37	3.50	4.67
	Max Accretion	0.91	21.25	4.80	12.27	13.54	-21.84	7.48	-2.62	11.72	18.55
	Max Erosion	-14.29	7.97	-14.84	-3.50	7.39	-42.33	-2.28	-11.81	-2.49	-0.90
Fire Island Pines	Mean (m)	-10.88	10.26	-7.90	25.66	-0.14	-18.92	-4.65	-11.94	13.43	-3.58
	1 St Dev	5.70	6.51	16.55	20.27	8.66	13.50	4.33	6.09	4.50	5.86
	Max Accretion	4.41	19.23	22.63	58.10	17.35	17.12	5.98	-1.02	23.74	10.25
	Max Erosion	-22.44	-9.22	-35.51	-6.43	-17.13	-36.40	-14.10	-26.05	2.90	-14.37
NPS - Talisman/ Barrett Beach	Mean (m)	-8.59	17.17	-16.42	1.94	4.33	-8.69	-2.68	-10.19	17.61	6.02
	1 St Dev	5.68	4.39	17.84	20.28	16.83	19.96	5.19	11.64	12.47	6.44
	Max Accretion	6.10	25.62	24.93	31.58	36.63	21.04	8.46	18.36	40.64	18.83
	Max Erosion	-18.81	6.92	-42.79	-51.90	-20.61	-49.19	-13.22	-28.72	-2.78	-10.78
Water Island	Mean (m)	-19.48	16.72	-2.24	0.75	-1.27	-7.31	-11.11	9.79	4.69	18.65
	1 St Dev	3.80	3.35	18.84	7.94	9.25	5.42	2.59	5.84	2.85	6.90
	Max Accretion	-14.59	19.93	26.33	14.30	13.65	0.47	-5.22	16.32	11.22	27.22
	Max Erosion	-24.82	7.77	-25.22	-9.26	-12.56	-17.67	-14.83	-0.25	-1.14	4.50
NPS	Mean (m)	-9.62	11.25	-18.86	21.33	-11.07	5.47	-4.16	-0.99	11.05	12.40
	1 St Dev	5.68	7.43	23.76	9.47	9.71	6.24	3.26	4.88	7.45	9.22
	Max Accretion	-2.87	23.44	24.26	31.87	12.64	14.67	0.80	8.31	29.40	27.10
	Max Erosion	-23.94	-2.05	-45.24	-4.66	-23.75	-6.72	-10.67	-8.11	3.38	-4.88

* indicates that there is a gap in the shoreline data within the administrative unit during the specified time period

Table C-1 (continued). Statistical values of seasonal shoreline changes for individual administrative units of Fire Island, 2007 – 2012.

Administrative Units		Spring 2007 to Fall 2007	Fall 2007 to Spring 2008	Spring 2008 to Fall 2008	Fall 2008 to Spring 2009	Spring 2009 to Fall 2009	Fall 2009 to Spring 2010	Spring 2010 to Fall 2010	Fall 2010 to Spring 2011	Spring 2011 to Fall 2011	Fall 2011 to Spring 2012
Blue Point Beach	Mean (m)	-9.36	9.06	-24.50	10.18	16.48	-5.10	-8.48	16.48	-5.10	-8.48
	1 St Dev	1.68	0.69	16.16	15.40	3.12	1.70	0.77	3.12	1.70	0.77
	Max Accretion	-5.90	10.02	0.13	31.12	20.50	-1.37	-6.62	20.50	-1.37	-6.62
	Max Erosion	-11.66	7.61	-44.83	-10.51	8.98	-7.77	-9.51	8.98	-7.77	-9.51
NPS	Mean (m)	-9.53	9.70	-10.62	4.68	24.92	-20.59	-7.33	-24.80	28.57	-7.33
	1 St Dev	4.85	2.39	18.31	19.39	16.34	17.97	3.77	5.77	4.64	3.77
	Max Accretion	-1.28	14.28	20.12	38.73	45.03	6.46	0.46	-13.35	36.48	0.46
	Max Erosion	-16.43	4.27	-43.33	-25.49	1.89	-43.24	-13.82	-33.35	18.80	-13.82
Davis Park	Mean (m)	-10.57	12.53	-8.13	26.47 *	2.28 *	-11.92	1.90	3.05	7.92	7.96
	1 St Dev	5.98	6.47	20.06	4.84 *	14.84 *	7.36	3.79	9.43	12.35	5.49
	Max Accretion	2.93	23.99	32.62	36.39 *	15.49 *	4.03	9.59	15.85	32.01	22.19
	Max Erosion	-21.08	2.26	-32.11	20.33 *	-37.10 *	-31.53	-5.65	-14.15	-9.06	0.38
NPS - Watch Hill	Mean (m)	-11.86	5.91	1.01	-0.33	10.46	-21.60	-3.93	-5.07	9.92	11.39
	1 St Dev	5.09	6.32	20.12	24.60	18.58	12.03	4.19	11.20	5.33	11.97
	Max Accretion	4.28	24.38	41.14	35.64	44.30	10.95	5.12	26.22	27.72	34.58
	Max Erosion	-18.71	-4.39	-26.75	-54.01	-37.06	-39.52	-12.38	-17.92	0.16	-7.96
Otis Pike Wilderness Area	Mean (m)	-6.98	6.92	-3.50	-3.50	1.14	8.58	-16.12	-5.20	15.93	7.76
	1 St Dev	5.76	7.14	18.59	18.59	19.60	15.82	17.43	8.91	6.85	7.56
	Max Accretion	10.63	30.54	43.42	43.42	38.67	40.55	23.83	20.68	36.82	29.06
	Max Erosion	10.63	-7.14	-44.33	-44.33	-50.31	-24.09	-55.98	-29.76	-2.03	-11.36
Smith Point County Park	Mean (m)	-7.81	7.11	-4.92	3.02	7.98	-18.57	-4.40	---	---	0.23
	1 St Dev	10.72	10.51	17.34	16.39	13.42	21.62	10.53	---	---	15.74
	Max Accretion	64.63	35.49	43.19	42.20	39.61	67.55	24.60	---	---	59.63
	Max Erosion	-39.56	-36.90	-38.81	-36.04	-90.38	-60.47	-38.65	---	---	-28.69

* indicates that there is a gap in the shoreline data within the administrative unit during the specified time period

Table C-2. Statistical values of annual and 5-year shoreline displacement of zones of interest.

Administrative Units		Spring 2007 to Fall 2007	Fall 2007 to Spring 2008	Spring 2008 to Fall 2008	Fall 2008 to Spring 2009	Spring 2009 to Fall 2009	Fall 2009 to Spring 2010	Spring 2010 to Fall 2010	Fall 2010 to Spring 2011	Spring 2011 to Fall 2011	Fall 2011 to Spring 2012
NPS Land	Mean (m)	-8.66	9.04	-6.29	2.52	6.93	-11.46	-3.20	-8.49	15.50	5.90
	1 St Dev	7.34	7.44	18.89	18.68	16.26	18.57	5.58	10.07	8.64	8.65
	Max Accretion	10.63	30.54	43.42	38.73	45.03	32.71	18.45	26.22	41.07	34.58
	Max Erosion	-41.85	-7.14	-45.74	-54.01	-37.06	-55.98	-19.10	-33.35	-7.21	-17.08
Community Land	Mean (m)	-10.35	10.80	-9.33	15.75 *	6.02 *	-11.34	-4.97	-8.10	14.49	2.83
	1 St Dev	7.16	7.33	16.76	19.16 *	16.14 *	13.74	7.47	10.14	9.00	7.50
	Max Accretion	7.98	31.36	32.62	59.27 *	48.67 *	23.09	12.22	16.32	38.05	27.22
	Max Erosion	-29.54	-9.22	-48.92	-20.88 *	-37.10 *	-44.61	-24.84	-26.05	-9.06	-16.11
Robert Moses State Park	Mean (m)	-14.83	10.34	-11.59	-4.04	-8.77	-11.90 *	18.95 *	--	--	-12.51
	1 St Dev	30.20	34.56	25.68	32.26	23.49	21.01 *	12.59 *	--	--	14.56
	Max Accretion	33.28	202.10	80.00	69.49	58.08	26.27 *	42.71 *	--	--	116.32
	Max Erosion	-171.13	-80.52	-88.48	-130.31	-90.38	-63.08 *	-17.12 *	--	--	-70.49
<i>shoreline position downdrift of jetty</i>	Mean (m)	-48.44	32.82	-24.18	-24.21	-31.28	--	--	--	--	-10.90
	1 St Dev	65.17	87.54	47.63	63.07	44.14	--	--	--	--	34.16
	Max Accretion	33.28	202.10	80.00	69.49	58.08	--	--	--	--	116.32
	Max Erosion	-171.13	-80.52	-88.48	-130.31	-90.38	--	--	--	--	-70.49
shoreline position updrift of jetty	Mean (m)	-8.91	6.61	-9.47	-0.47	-4.77	-11.90	18.95	--	--	-12.80
	1 St Dev	9.73	5.51	18.95	20.97	14.12	21.01	12.59	--	--	6.67
	Max Accretion	18.24	25.20	32.88	44.07	48.88	26.27	42.71	--	--	3.43
	Max Erosion	-24.37	-24.59	-51.32	-64.76	-32.16	-63.08	-17.12	--	--	-33.06
Smith Point County Park	Mean (m)	-7.89	7.11	-4.92	3.02	7.98	-18.57	-4.40	--	--	0.23
	1 St Dev	10.48	10.51	17.34	16.39	13.42	21.62	10.53	--	--	15.74
	Max Accretion	61.91	35.49	43.19	42.20	39.61	67.55	24.60	--	--	59.63
	Max Erosion	-39.56	-36.90	-38.81	-36.04	-33.23	-60.47	-38.65	--	--	-28.69

* indicates that there is a gap in shoreline data within the administrative unit during the specified time period

Table C-2 (continued). Statistical values of annual and 5-year shoreline displacement of zones of interest.

Administrative Units		Spring 2007 to Fall 2007	Fall 2007 to Spring 2008	Spring 2008 to Fall 2008	Fall 2008 to Spring 2009	Spring 2009 to Fall 2009	Fall 2009 to Spring 2010	Spring 2010 to Fall 2010	Fall 2010 to Spring 2011	Spring 2011 to Fall 2011	Fall 2011 to Spring 2012
shoreline position influenced by inlet and jetty	Mean (m)	-8.69	10.24	4.08	-2.94	9.43	-14.94	-1.67	--	--	6.00
	1 St Dev	16.50	15.60	20.75	12.22	16.35	25.07	13.88	--	--	23.44
	Max Accretion	61.91	35.49	43.19	16.90	35.19	67.55	24.60	--	--	59.63
	Max Erosion	-39.56	-36.90	-31.50	-23.54	-33.23	-45.77	-38.65	--	--	-26.99
<i>shoreline position not influenced by jetty</i>	Mean (m)	-7.60	6.02	-8.06	5.39	7.43	-19.79	-5.35	--	--	-1.77
	1 St Dev	7.27	7.73	14.76	17.23	12.08	20.21	8.89	--	--	11.33
	Max Accretion	10.39	21.17	24.29	42.20	39.61	29.11	14.92	--	--	28.15
	Max Erosion	-30.93	-14.28	-38.81	-36.04	-25.59	-60.47	-26.67	--	--	-28.69
Total Ocean Shoreline	Mean (m)	-9.75	9.51	-7.59	4.07 *	3.76 *	-12.42 *	-0.73	-8.82 *	15.85 *	1.16
	1 St De	14.56	15.95	19.61	22.18 *	18.43 *	19.39 *	11.70	10.21 *	9.08	12.90
	Max Accretion	64.63	202.10	80.00	69.49 *	58.08 *	67.55 *	42.71	26.22 *	44.55	116.32
	Max Erosion	-171.13	-80.52	-88.48	-130.31 *	-90.38 *	-63.08 *	-38.65	-33.35 *	-9.06	-70.49

* indicates that there is a gap in shoreline data within the administrative unit during the specified time period

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Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov