



Back Barrier Erosion Monitoring at Cumberland Island National Seashore

2018 Data Summary—Version 2.0

Natural Resource Data Series NPS/SECN/NRDS—2019/1201



ON THE COVER

Island margin looking south at Raccoon Key on Cumberland Island National Seashore. Photo by J.M. McDonald, SECN.

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Revision Log

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11/29/2018	J. M. McDonald	Minor text edits for accuracy of water body names, added revision log	Clarification	2.0
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Summary and Key Findings

In 1999, the National Park Service's (NPS) Inventory and Monitoring (I&M) Program (now I&M Division) substantially expanded a pilot long-term ecological monitoring program known as "Vital Signs Monitoring" to cover more than 270 parks. The program was designed to provide the minimum infrastructure required to identify and monitor the conditions of the highest priority resources within the National Park System (Fancy et al. 2009). The Southeast Coast Network (SECN) was one of thirty-two networks formed to implement the I&M Division's program and is tailored to the specific needs of the parks within the network.

The overarching purpose of SECN natural resource monitoring is to (1) collect and produce scientifically sound data that describes the current status of—and long-term trends in—the composition, structure, and function of park ecosystems, and (2) to determine how current management practices are sustaining these systems. The Southeast Coast Network achieves the above purposes by implementing long-term monitoring protocols and providing additional technical assistance when necessary. This report provides the results of a technical assistance project implemented at Cumberland Island National Seashore (CUIS) to monitor island margin retreat on the back barrier (west) side of the island.

On 19–20 June 2017, the Southeast Coast Network and the United States Geological Survey (USGS) conducted an island margin survey of five sites on the back barrier side of Cumberland Island National Seashore. These five sites, Cumberland Wharf (CW), Brickhill Bluff (BB), Plum Orchard (PO), Dungeness Wharf (DW), and Raccoon Key (RK), had previously been monitored by the USGS from December 2011 to February 2013 to determine the average rate of island margin retreat at these pre-identified erosional hotspots (Calhoun and Riley 2016). The purpose of the 2017 survey was to determine if the long-term rates of island margin retreat from 2013 to 2017 (which includes the effects of Hurricane Matthew) is consistent with the rates observed from 2011 to 2013.

On 27–28 March 2018, the five back barrier sites were again resurveyed by the Southeast Coast Network to determine the

potential influence Hurricane Irma had on the island. A brief summary of the 2017 and 2018 surveys is provided below. The main report provides some background on each of the study sites, a general overview of the methods used to collect and process the data, and a more in-depth look at the results of the surveys.

Cumberland Wharf

- The Cumberland Wharf survey was 153 meters (502 feet [ft]) in length along the top of the bluff.
- From 2013 to 2017, 84% of the surveyed area showed some change in position.
- From 2017 to 2018, 100% of the surveyed area showed some change in position.
- From 2013 to 2017, maximum retreat was 5.74 meters (18.8 ft) with an average of 1.82 meters (6.0 ft).
- From 2017 to 2018, maximum retreat was 2.37 meters (7.8 ft) with an average of 0.98 meters (3.2 ft).
- From 2013 to 2017, maximum rate was 1.32 meters per year (4.3 ft per year) with an average of 0.43 meters per year (1.4 ft per year).

Brickhill Bluff

- The Brickhill Bluff survey was 233 meters (764.4 ft) in length along the top of the island margin.
- From 2013 to 2017, 88% of the surveyed area showed some change in position.
- From 2017 to 2018, 97% of the surveyed margin showed some change in position.
- From 2013 to 2017, the maximum retreat was 3.64 meters (11.9 ft) with an average of 1.19 meters (3.9 ft).
- From 2017 to 2018, the maximum retreat was 2.53 meters (8.3 ft) with an average of 1.05 meters (3.4 ft).
- From 2013 to 2017, maximum rate was 0.83 meters per year (2.7 ft per year) with an average of 0.28 meters per year (0.9 ft per year).

Plum Orchard

- The Plum Orchard survey was 249 meters (816.9 ft) in length along the top of the island margin.
- From 2013 to 2017, 72% of the surveyed area showed some change in position.
- From 2017 to 2018, 73% of the surveyed margin showed some change in position.
- From 2013 to 2017 the maximum retreat was 3.21 meters (10.5 ft) with an average of 0.82 meters (2.7 ft).
- From 2017 to 2018 the maximum retreat was 2.67 meters (8.8 ft) with an average of 0.47 meters (1.5 ft).
- From 2013 to 2017, maximum rate was 0.74 meters per year (2.4 ft per year) with an average of 0.19 meters per year (0.6 ft per year).

Dungeness Wharf

- The Dungeness Wharf survey was 172 meters (564.3 ft) in length.
- From 2013 to 2017, 100% of the surveyed area showed some change in position.
- From 2017 to 2018, 95% of the surveyed margin showed some change in position.
- From 2013 to 2017 the maximum retreat was 5.79 meters (19.0 ft) with an average of 2.06 meters (6.8 ft).
- From 2017 to 2018, the maximum retreat was 1.89 meters (6.2 ft) with an average of 0.74 meters (2.4 ft).
- From 2013 to 2017, maximum rate was 1.33 meters per year (4.4 ft per year) with an average of 0.47 meters per year (1.5 ft per year).

Raccoon Key

- The Raccoon Key survey was 400 meters (1,312 ft) in length.
- From 2013 to 2017, 100% of the surveyed area showed some change in position.
- From 2017 to 2018, 90% of the surveyed margin showed some change in position.
- From 2013 to 2017 the maximum retreat was 7.86 meters (25.8 ft) with an average of 2.82 meters (9.3 ft).
- From 2017 to 2018 the maximum retreat was 6.72 meters (22.0 ft) with an average of 1.16 meters (3.8 ft).
- From 2013 to 2017, maximum rate was 1.81 meters per year (5.9 ft per year) with an average of 0.64 meters per year (2.1 ft per year).

Cumberland Island National Seashore - Back-Barrier Island Margin Monitoring

Southeast Coast Network
National Park Service
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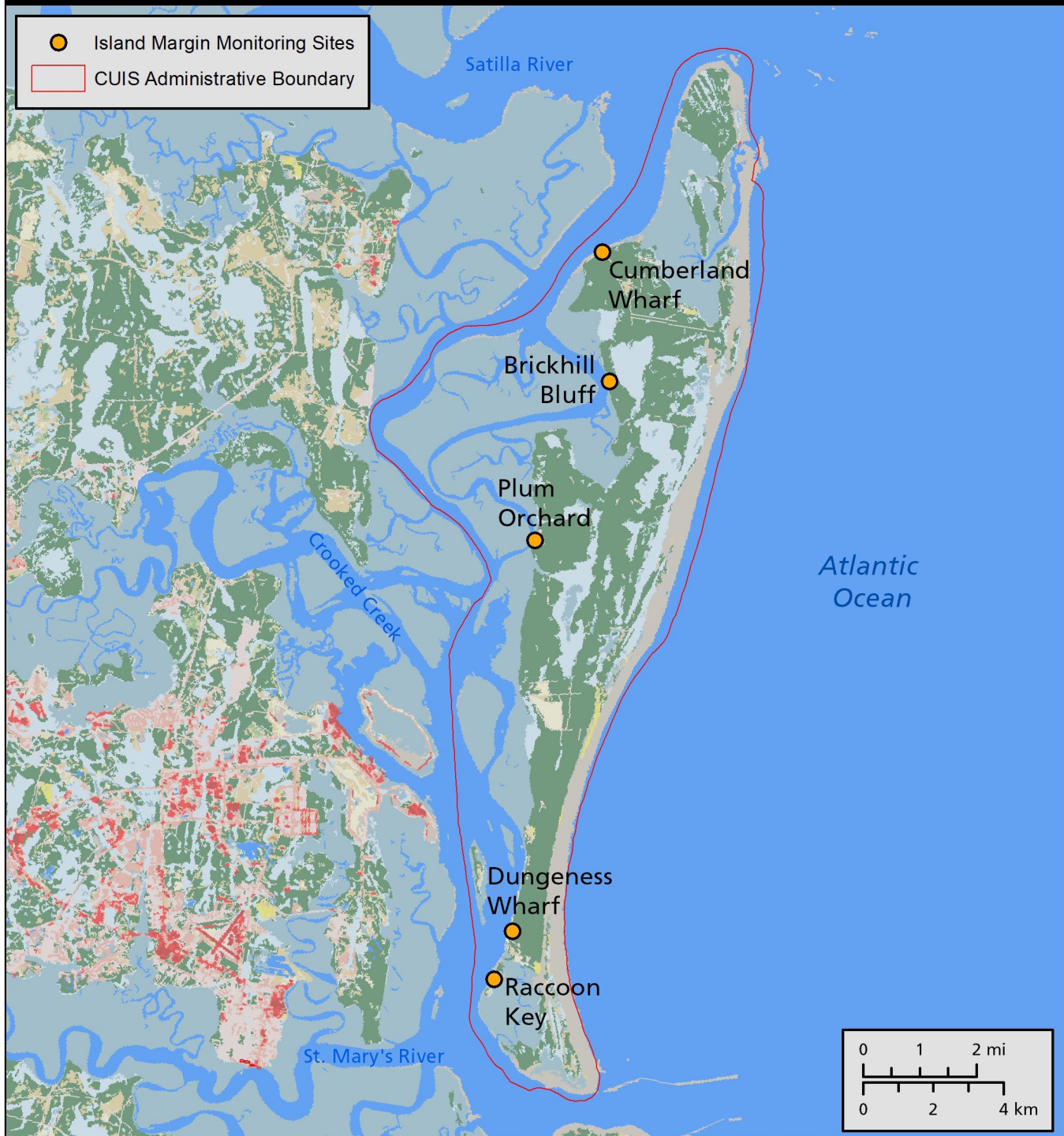


Figure 1. Overview map of Cumberland Island National Seashore (CUI) with the locations of the island margin monitoring sites.

Introduction

On 19–20 June 2017, the Southeast Coast Network (SECN) and the United States Geological Survey (USGS) conducted a survey of five sites on the back barrier side of Cumberland Island National Seashore (Figure 1). These five sites, Cumberland Wharf (CW), Brickhill Bluff (BB), Plum Orchard (PO), Dungeness Wharf (DW), and Raccoon Key (RK), had been previously surveyed by the USGS from December 2011 to February 2013 to determine the average rate of island margin retreat at these pre-identified erosional hotspots (Calhoun and Riley 2016). The purpose of the 2017 survey was to redo the USGS surveys and determine if the rates of island margin retreat from 2013 to 2017 (which includes the effects of Hurricane Matthew) are consistent with the rates observed from 2011 to 2013. On 27–28 March 2018, the five back barrier sites were again resurveyed by the network to determine the influence Hurricane Irma had on the back barrier island margin.

This report provides the results of a technical assistance project implemented at Cumberland Island National Seashore (CUIS) to monitor island margin retreat on the back barrier (west) side of the island. The following sections provide an introduction to the island and the sites that were surveyed, provides a description of the methods that were used to conduct the survey and process the collected data, and presents the results of the 2017 and 2018 surveys. The results of the SECN surveys are compared to the 2011–2013 USGS surveys and an aerial photograph analysis conducted by Jackson (2006) for 1983–2002 to provide context for the island margin retreat captured by the most recent surveys.

The USGS survey of the five sites consisted of an initial survey in 2011 or 2012 and a resurvey in 2013 (Calhoun and Riley 2016). The USGS survey monitored island margin position using the methods described in this document as well as with traditional bank pins and photo-electronic erosion pins. Calhoun and Riley (2016) also monitored hydrodynamics and hydroacoustics to help determine the cause of observed island margin retreat. The study by Jackson (2006) utilized aerial photographs to determine rates of island margin retreat along the entirety of Cumberland Island National Seashore. While the resolution of the study by Jackson (2006) is not as fine as the current survey or the surveys conducted by Calhoun and Riley (2016), they provide a broad look at long-term rates of erosion on the

back barrier-side of the island. At the end of the report, an appendix is provided to describe the sites surveyed and provide assistance to those that wish to conduct their own resurveys.

Study Area

Cumberland Island is Georgia's southernmost barrier island and is located near the Georgia/Florida border in Camden County, Georgia. The island is influenced by the Satilla River to the north, the St Marys River to the south, and the Crooked River/Cumberland River in between (Figure 1). Cumberland Island is composed of a central 'core' of Pleistocene barrier island sediments with a narrow, seaward veneer of Holocene sands (Griffin 1982). The ocean-to-estuary profile of Cumberland Island is typical of large barrier islands. The ocean (east) side of the island is characterized by wide sandy beaches beyond which (to the west) are primary and secondary dunes with lower interdunal areas (Alber et al. 2005). The back-barrier (west) side of the island is characterized by salt marsh and tidal creeks. In some areas the island margin is being actively eroded by wave action coupled with fluvial processes from the tidal creeks and rivers that flow through and past the island (Calhoun and Riley 2016). The five sites that were surveyed for this project are influenced by St. Andrew's Sound (Cumberland Wharf), Brickhill River (Brickhill Bluff and Plum Orchard), and Crooked River, St. Marys River, and Cumberland Sound (Dungeness Wharf and Raccoon Key). The following sections describe the five survey locations in more detail.

Cumberland Wharf

The island margin at Cumberland Wharf is a bluff located on the north end of the park (Figure 1). The bluff is high (greater than 5 meters [16.4 ft]), sandy, and in many spots very undercut (approximately 1 meter [3.3 ft]). Large rotational slumps and undercut failures were observed by Calhoun and Riley (2016) as well as during the resurveys of 2017 and 2018. The bluff face is exposed fine to medium sands with little organic material while the top of the bluff is heavily vegetated with shrubs and intermittent large trees (Calhoun and Riley 2016). The base of the bluff is protected from erosion by an apron of eroded bluff sediments and slump blocks that have not yet been eroded away.

Brickhill Bluff

Brickhill Bluff is located near the north end of the park on the cutbank side of a meander bend of Brickhill River (Figure 1). The island margin is an approximately 1.5 meters (4.9 ft) tall near-vertical bank composed of very fine sand with a thin layer of shells near the surface (Calhoun and Riley 2016). A designated back country campsite occupies this portion of the island and visitor use is contributing to island margin erosion and bank instability. Canopy cover is thick along the island margin but the understory is relatively open. In a number of places, large trees have toppled and are now providing some bank protection (Calhoun and Riley 2016).

Plum Orchard

Plum Orchard is located near the center of the island on the cutbank side of a meander bend of Brickhill River (Figure 1). The island margin is only 1.1 meters (3.6 ft) tall and composed of consolidated sands with high clay and organic content that is topped with a layer of shells (Calhoun and Riley 2016). A dock and boat launch are located near the middle of this site. There are also several historical structures near the island margin, one of which is protected by a wooden seawall. Canopy cover is high at the northern and southern ends of the site, while the understory is a well-manicured lawn. Significant undercutting of the banks just north of the boat launch were observed in 2017 and 2018. Additionally, erosion rates at this portion of Plum Orchard may be influenced by surface runoff (Pers. comm., John Fry, Chief of Resource Management at Cumberland Island NS, November 2018).

Dungeness Wharf

Dungeness Wharf is located near the south end of the island on Cumberland Sound and is one of the primary drop off points for visitors (Figure 1). The island margin is an approximately 2.8 meters (9.2 ft) tall near-vertical bank composed of fine to medium sand overlain by shell material at the surface (Calhoun and Riley 2016). This site is located just north of an historic rock masonry seawall. Jackson (2006) identified a significant amount of island margin retreat to the north and south of the Dungeness Wharf seawall. The island margin is heavily vegetated in some areas and, similar to Brickhill Bluff, has large toppled trees from past erosion events that may be providing protection to the island margin (Calhoun and Riley 2016).

Raccoon Key

Raccoon Key is located on the south end of the island and is bordered by Cumberland Sound to the west (Figure 1). The island margin is a near-vertical bank and is only 0.6 meters (2 ft) tall. The bank is composed of highly bioturbated marsh-like sediment with high clay and organic content (Calhoun and Riley 2016). The upper portion of the bank has high root density and the bank tends to break off into clumps when the lower unrooted portion is eroded away (see cover photo). One large dredge spoil mound occupies the northern portion of this site. A small tidal channel bisects the island margin where the surveys were conducted.

Methods

The methods used to survey the island margin monitoring sites were the same as those used by Calhoun and Riley (2016). A combination of real-time kinematic (RTK) GPS (global positioning system) and total station surveys were used to delineate the island margin at each site. The island margin was defined as the westernmost extent of the island upland (CW, BB, PO, and DW) or marsh-beach interface (RK) and the near-vertical soil profile at the land-water interface that is susceptible to erosive forces (Calhoun and Riley 2016). At each site, a Trimble R10 GPS receiver was set up on the permanent benchmark used for the Calhoun and Riley (2016) surveys. The RTK signal from the base station was boosted using a Trimble TDL 450H UHF (ultra high frequency) data radio to extend the RTK signal up to 5 kilometers (3.1 miles) from the base station. A second R10 GPS receiver was mounted on a survey pole in 'rover' mode and RTK points were taken where satellite coverage was sufficient. RTK surveys work well in open areas and under light canopy and was used where position solutions with horizontal error ranges less than 0.02 meters (0.07 ft) could be obtained. For the purposes of this survey, there was no vertical error cutoff because the purpose of the survey was to monitor horizontal island margin retreat. Survey point spacing was dependent on the complexity of the island

margin and spaced no greater than 0.5 meters (1.64 ft) apart in straight sections.

To monitor the areas that did not have sufficient satellite coverage to obtain a RTK solution, a total station was integrated into the RTK survey through re-sectioning (Figure 2). Re-sectioning is done by obtaining a position solution on two points (using either RTK or total station) and then surveying those same points with a total station (total station is set up to make a triangle with the previously surveyed points) to back calculate the total station location. Some of the sites required multiple total station setups due to tidal incursion of the beach front during the survey and the presence of large tree falls and/or thick understory.

Once the surveys were complete, the data were downloaded and the R package *Analyzing Moving Boundaries in R* (AMBUR; Jackson 2010) was used to determine the amount of retreat that occurred at each monitoring site. The island margin position points were connected to create a line representing the island margin position during the survey. From these island margin lines, transects were cast (1 meter apart) perpendicular to the island margins and change between subsequent years was calculated by determining the length of the transects between the island margin lines.

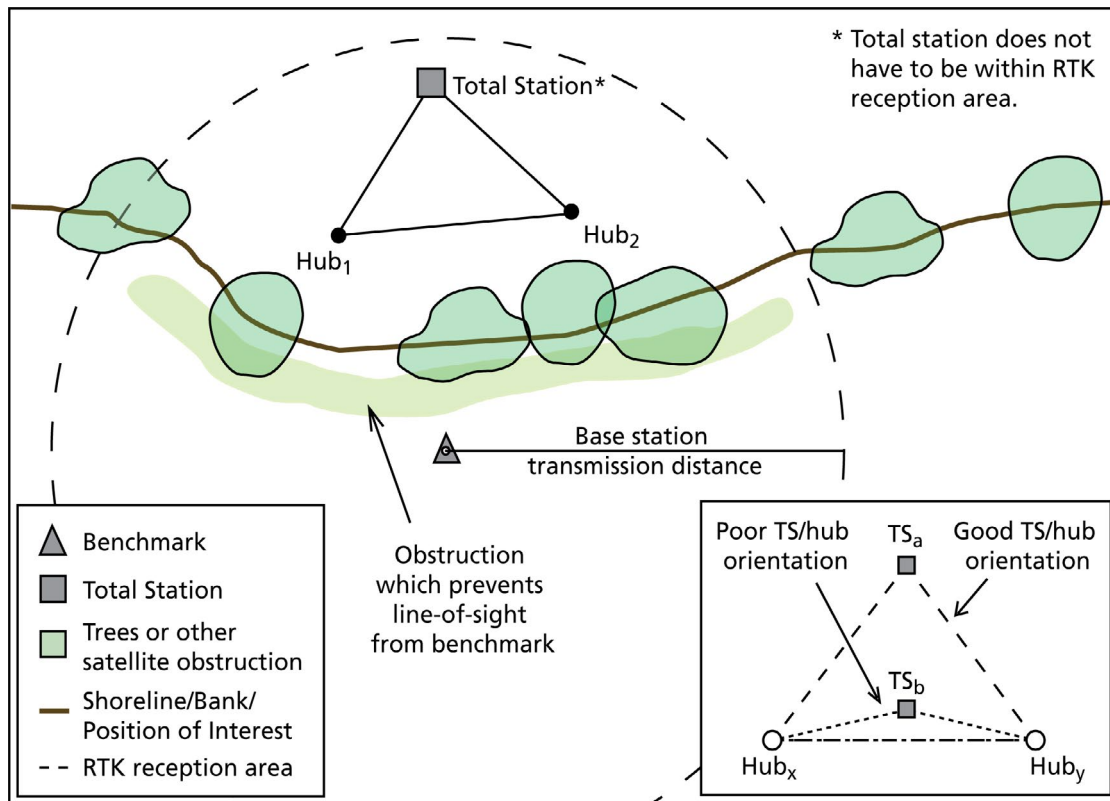


Figure 2. Example setup for an integrated survey using the re-section method to setup the total station. Inset shows the difference between poor and good total station/hub orientations.

Results

The following section describes the results of the surveys that were conducted by Southeast Coast Network during 2017 and 2018 at each of the five island margin monitoring sites. The results (rates of change) of the 2017 and 2018 surveys are compared to the rates of change of the USGS 2011–2013

survey and the aerial photograph analysis conducted by Jackson (2006) for 1983–2002 (Table 1). A detailed description of how to get to each site, whether tides need to be taken into account when surveying the site, and other general information for each site can be found in Appendix A.

Table 1. Summary of the change in shoreline position (horizontal) at Cumberland Island National Seashore.

Parameter	Cumberland Wharf (CW)	Brickhill Bluff (BB)	Plum Orchard (PO)	Dungeness Wharf (DW)	Raccoon Key (RK)
Survey Length (meters)	153	233	249	172	400
2017 %Change in Position (Retreat)	84%	88%	72%	100%	100%
2018 %Change in Position (Retreat)	100%	97%	73%	95%	90%
2011–2013 Maximum (meters)	1.41	1.99	1.94	2.40	2.34
2013–2017 Maximum (meters)	5.74	3.64	3.21	5.79	7.86
2017 Maximum rate (meters per year)	1.32	0.83	0.74	1.33	1.81
2018 Maximum (meters)	2.37	2.53	2.67	1.89	6.72
2017 Average (meters)	1.82	1.19	0.82	2.06	2.82
2018 Average (meters)	0.98	1.05	0.47	0.74	1.16
1983–2002 Annual Rate (meters per year)	1.87	0.50	0.65	1.90	1.90
2012–2013 Annual Rate (meters per year)	0.25	0.47	0.26	0.37	0.77
2013–2017 Annual Rate (meters per year)	0.43	0.28	0.19	0.47	0.64
2017 Standard Deviation (meters)	1.10	0.82	0.73	1.02	1.15
2018 Standard Deviation (meters)	0.57	0.54	0.47	0.36	1.26

Cumberland Wharf

The resurveys of Cumberland Wharf took place on 19 June 2017 and 27 March 2018. Though the bluff top is within range of the base station, canopy cover prevented RTK GPS from being reliable (Figure 3). During the resurveys of 2017 and 2018, one total station setup was sufficient to survey the island margin. Tides need to be taken into account when surveying this site. At high tide the beach is too small to survey large portions of the bluff.

The 2017 survey was approximately 153 meters (502 ft) in length of which 84% showed some signs of retreat (Table 1). The maximum amount of change was detected on the far eastern portion of the surveyed area where a rotational slump caused approximately 5.74 meters (18.8 ft) of retreat (Figure 3). The surveyed margin had an average of 1.82 meters (6 ft) of retreat and a mean annual rate of retreat of 0.43 meters per year (1.4 ft per year). This mean annual rate of retreat is greater than the USGS surveyed rate (2011–

2013) but less than the rate estimated by Jackson (2006) for 1983–2002.

The 2018 survey was approximately 150 meters (492 ft) in length of which 100% showed some signs of retreat (Table 1). Similar to the 2017 survey, the maximum amount of change was detected on the far eastern portion of the bluff margin where 2.37 meters (7.8 ft) of retreat was recorded (Figure 3). The average amount of retreat for this portion of Cumberland Wharf was 0.98 meters (3.2 ft) which is less than the average amount of retreated observed by the 2017 survey. The average amount of retreat is much greater than the mean annual rate from the 2011–2013 and 2017 surveys but less than the mean annual rate from Jackson (2006) for 1983–2002. The significant amount of island margin retreat that was observed at CW between the 2017 and 2018 surveys includes the effects of Hurricane Irma.



Figure 3. Island margin retreat at Cumberland Wharf.

Brickhill Bluff

Brickhill Bluff is located near the north end of the park on the cutbank side of a meander bend of Brickhill River (Figure 1). The survey required an integrated survey (both RTK and total station were used). Though the cutbank is within range of the base station, canopy cover prevented RTK GPS from being reliable. During the resurvey of 2017 (June 20) three total station setups were needed because there were a lot of downed trees on the beach preventing line-of-sight. Four total station setups were needed during the 2018 survey because the tide came in during the survey and greatly reduced the area on the beach that could be used to setup the total station. Tides need to be taken into account when surveying this site. At high tide the beach is too small and the large woody debris on the beach is too dense to survey large portions of the shoreline.

The 2017 survey was approximately 233 meters (764 ft) in length of which 88% showed some signs of retreat (Table 1). The maximum amount of change was detected on the southern portion of the surveyed area where the

margin retreated 3.64 meters (11.9 ft; Figure 4). The mean annual rate of retreat for this portion of Brickhill Bluff was estimated to be 0.28 meters per year (0.9 ft per year). The mean annual rate of retreat was lower than the 2011–2013 USGS survey and the rate of retreat estimated by Jackson (2006) for 1983–2002.

The 2018 survey was approximately 233 meters (764 ft) in length of which 100% showed some signs of retreat (Table 1). The maximum amount of change was detected near the middle of the surveyed area where the margin retreated 2.53 meters (8.3 ft; Figure 4). The average amount of retreat per transect for this portion of Brickhill Bluff was 1.05 meters (3.44 ft) which is less than the average amount of retreat observed by the 2017 survey. When corrected for the amount of time between surveys, the average amount of retreat was significantly higher than the annual rate of retreat observed by all previous studies. The significant amount of island margin retreat that was observed at BB between the 2017 and 2018 surveys includes the effects of Hurricane Irma.

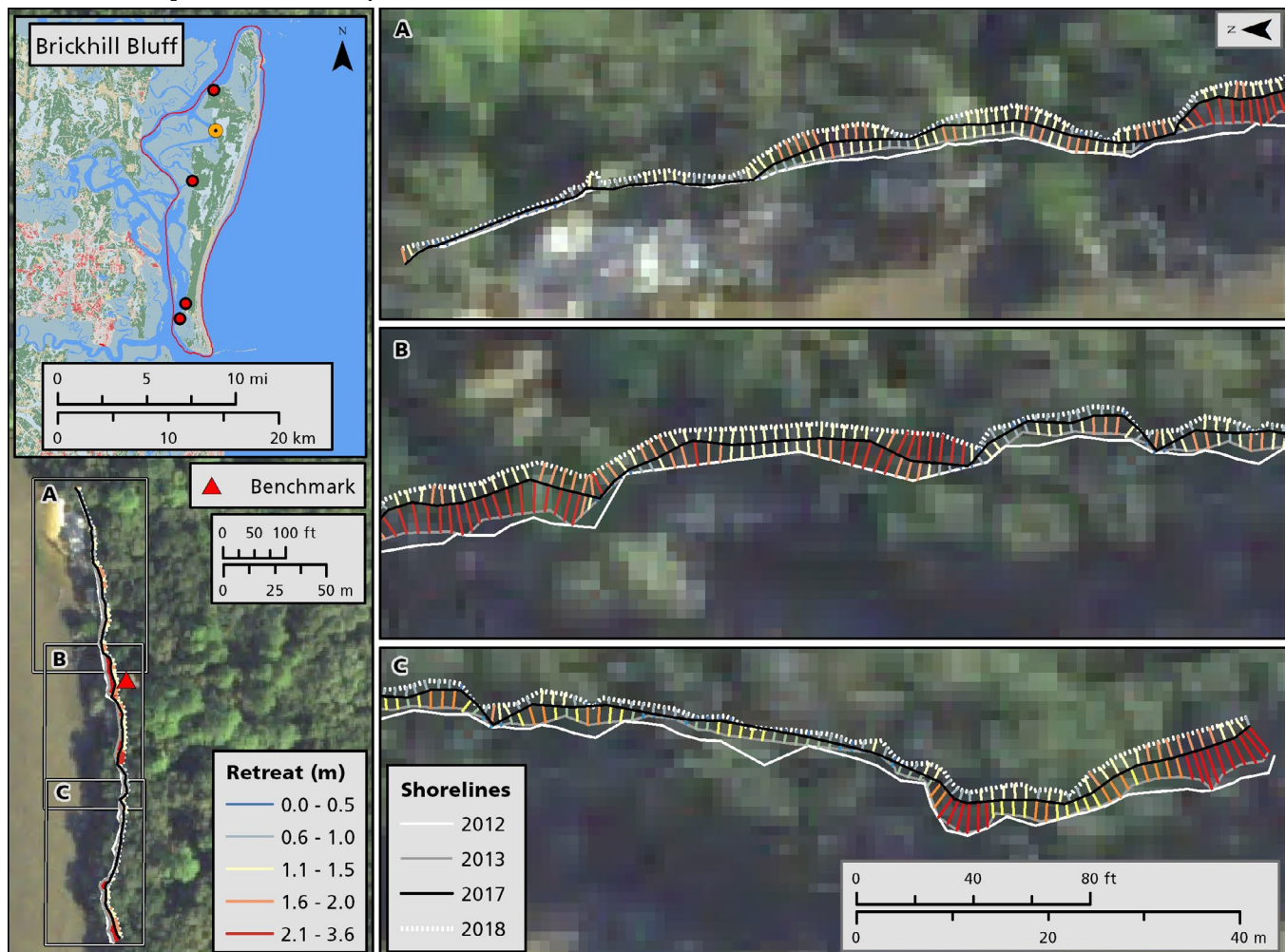


Figure 4. Island margin retreat at Brickhill Bluff.

Plum Orchard

Plum Orchard is located near the center of the island on the cutbank side of a meander bend of Brickhill River (Figure 1). The majority of the survey was done with RTK GPS. During the resurveys of 2017 (June 20) and 2018 (March 28) one total station setup was sufficient to get the points that RTK GPS could not capture due to poor satellite coverage. Tides do not need to be taken into account when surveying this site because the understory is managed (by mowing) and the total station can be setup on the inland side of the margin (where needed).

The 2017 survey was approximately 249 meters (817 ft) in length of which 72% showed some signs of retreat (Table 1). The maximum amount of change was detected in the area just north of the boat dock where the margin has retreated 3.21 meters (10.5 ft; Figure 5). The mean annual rate of

retreat for this portion of Plum Orchard was estimated to be 0.18 meters per year (0.6 ft per year) which is less than the 2011–2013 survey and the amount of retreat estimated by Jackson (2006) for 1983–2002.

The 2018 survey was approximately 251 meters (823 ft) in length of which 73% showed some signs of retreat (Table 1). The maximum amount of change was detected in the area just to the north of the boat dock where the bank retreated 2.67 meters (8.8 ft; Figure 5). The average amount of retreat for this portion of Plum Orchard was 0.47 meters which is greater than the annual rates estimated by the 2011–2013 and 2017 surveys but less than the rate estimated by Jackson (2006) for 1983–2002. The island margin retreat that was observed at PO between the 2017 and 2018 surveys includes the effects of Hurricane Irma.

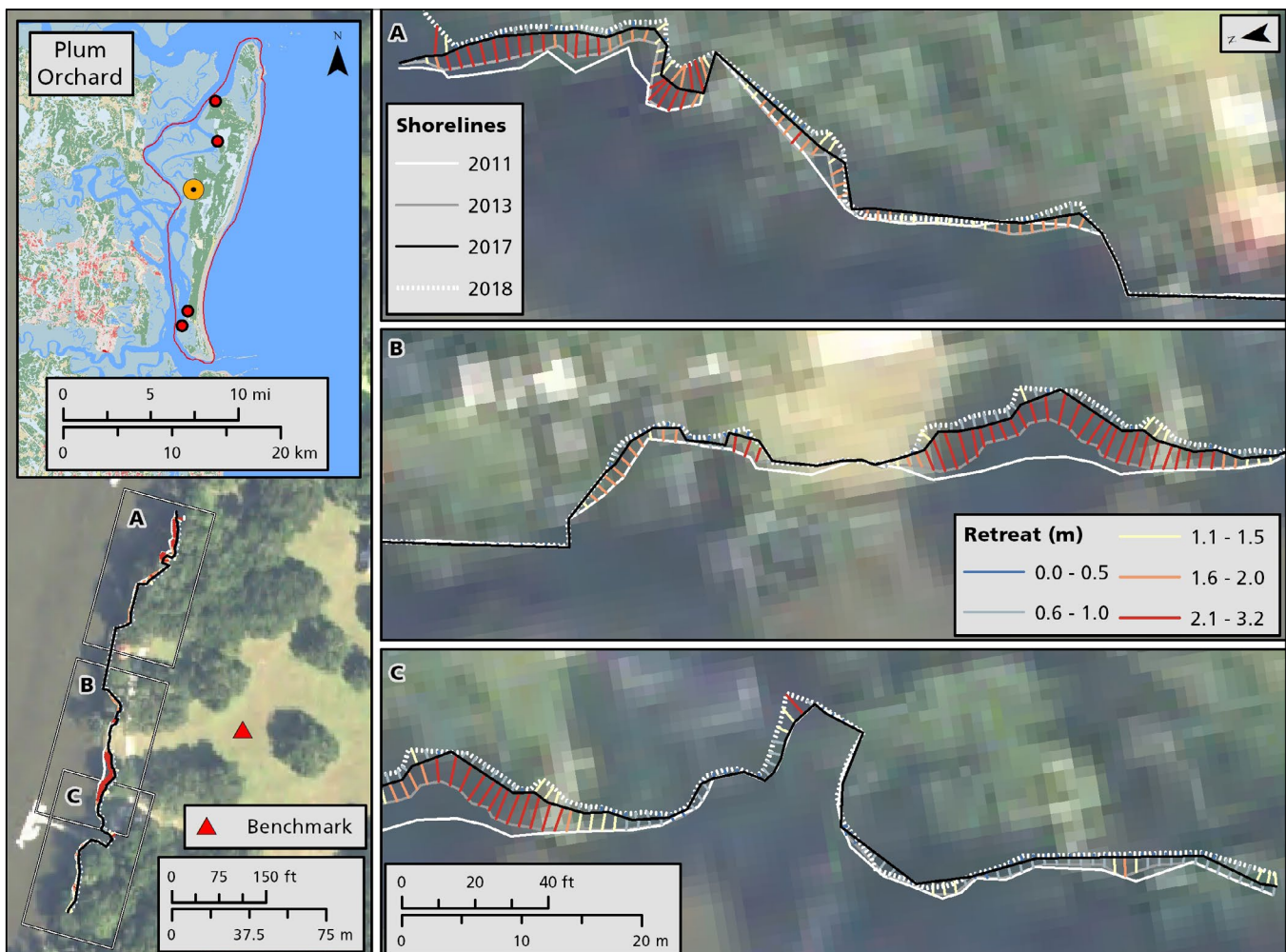


Figure 5. Island margin retreat at Plum Orchard.

Dungeness Wharf

Dungeness Wharf is located near the south end of the island on Cumberland Sound (Figure 1). While some of the island margin can be measured with RTK GPS, an integrated survey is required to survey the entire margin. During the resurveys of 2017 (June 19) and 2018 (March 28) one total station setup was sufficient to survey the areas that RTK GPS could not capture. Tides need to be taken into account when surveying this site. At high tide the beach is too small and the large woody debris on the beach is too dense to complete the survey with a total station.

The 2017 survey was approximately 172 meters (564 ft) in length of which 100% showed some signs of retreat (Table 1). The maximum amount of retreat was detected in the northern portion of the surveyed area where the island margin retreated up to 5.71 meters (18.7 ft; Figure 6). The mean annual rate of retreat for this portion of Dungeness Wharf was estimated to be 0.47 meters per year (1.5 ft per

year) which is greater than the 2011–2013 survey but much less than the rate of retreat estimated by Jackson (2006) for 1983–2002.

The 2018 survey was approximately 177 meters (581 ft) in length of which 95% showed some signs of retreat (Table 1). The maximum amount of change was detected in the northern portion of the surveyed area where the bank retreated up to 1.89 meters (6.2 ft; Figure 6). The average amount of retreat for this portion of Dungeness Wharf was 0.74 meters (2.4 ft) which is greater than the annual rate observed by the 2011–2013 and 2017 surveys but less than the rate estimated by Jackson (2006) for 1983–2002. Overall, Dungeness Wharf had much less retreat than expected based on the results from the other sites. Additionally, the maximum amount of retreat observed was slightly less than the average rate of retreat estimated by Jackson (2006) for 1983–2002.

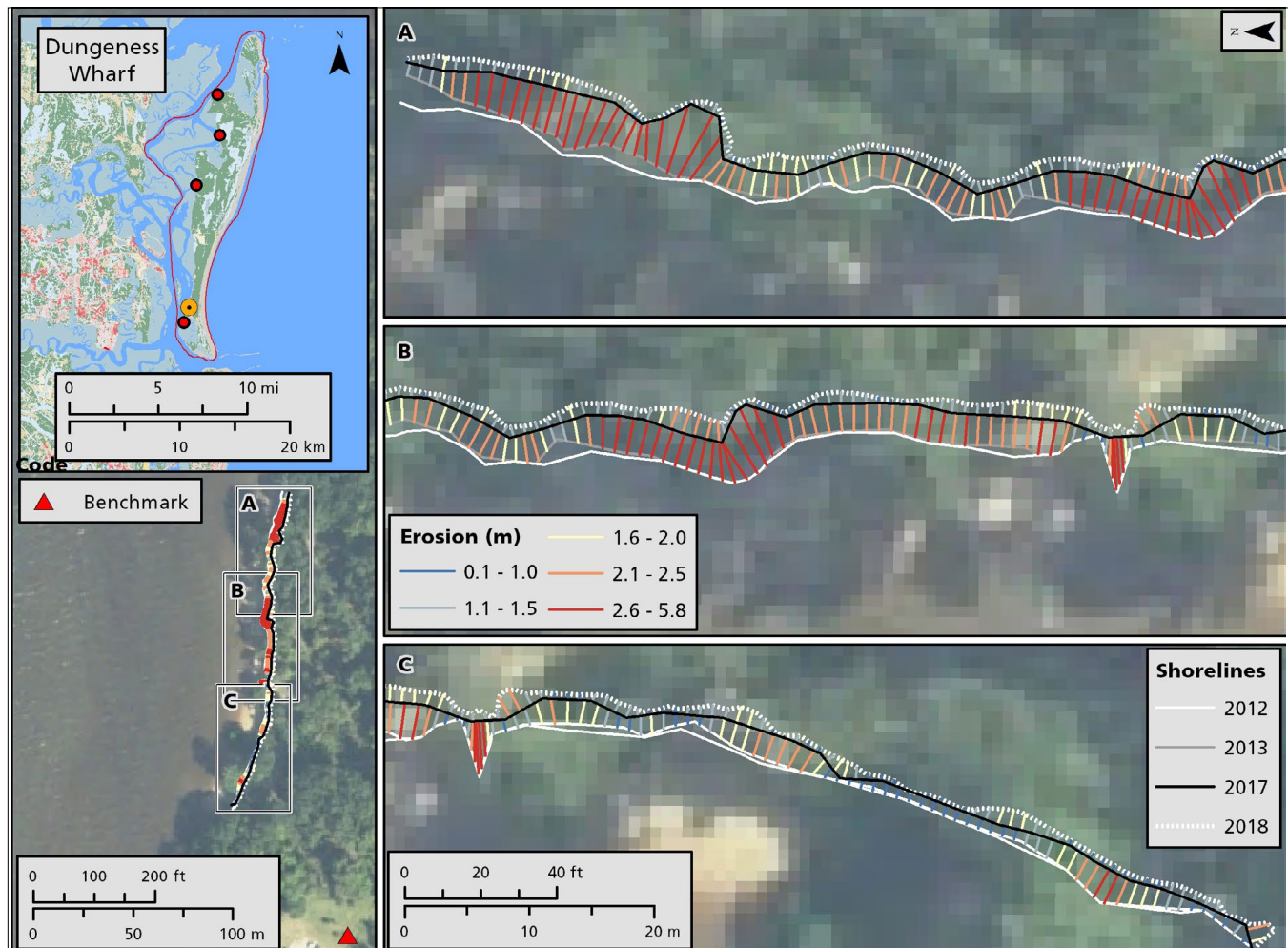


Figure 6. Island margin retreat at Dungeness Wharf.

Raccoon Key

Raccoon Key is located on the south end of the island near the confluence of Beach Creek and the St. Marys River (Figure 1). Real-time kinematic (RTK) GPS can be used to survey the entire site due to the open canopy of low marsh grasses. Tides need to be taken into account when surveying this site. At high tide, the portion of the marsh that needs to be surveyed cannot be accessed because of the tidal creek that lies between the site and the benchmark.

The 2017 survey was approximately 400 meters (1,312 ft) in length of which 100% showed some signs of retreat (Table 1). The maximum amount of change was detected in the southern portion of the surveyed area where the island margin retreated up to 7.86 meters (25.8 ft) (Figure 7). The mean annual rate of retreat for this portion of Raccoon Key was estimated to be 0.64 meters per year (2.1 ft per year) which is less than the 2011–2013 survey and the rate estimated by Jackson (2002) for 1983–2002.

The 2018 survey was approximately 424 meters (1,391 ft) in length of which 90% showed some signs of retreat (Table 1). The maximum amount of change was detected in the southern and northern portions of the surveyed area where the island margin retreated up to 6.7 meters (22 ft) in the south and 6.6 meters (21.7 ft) in the north (Figure 7). The average amount of retreat for this portion of Raccoon Key was 1.16 meters (3.8 ft) which is greater than the annual rate estimated by the 2011–2013 and 2017 surveys but less than the rate estimated by Jackson (2006) for 1983–2002. The significant amount of island margin retreat that was observed at Raccoon Key between the 2017 and 2018 surveys includes the effects of Hurricane Irma.

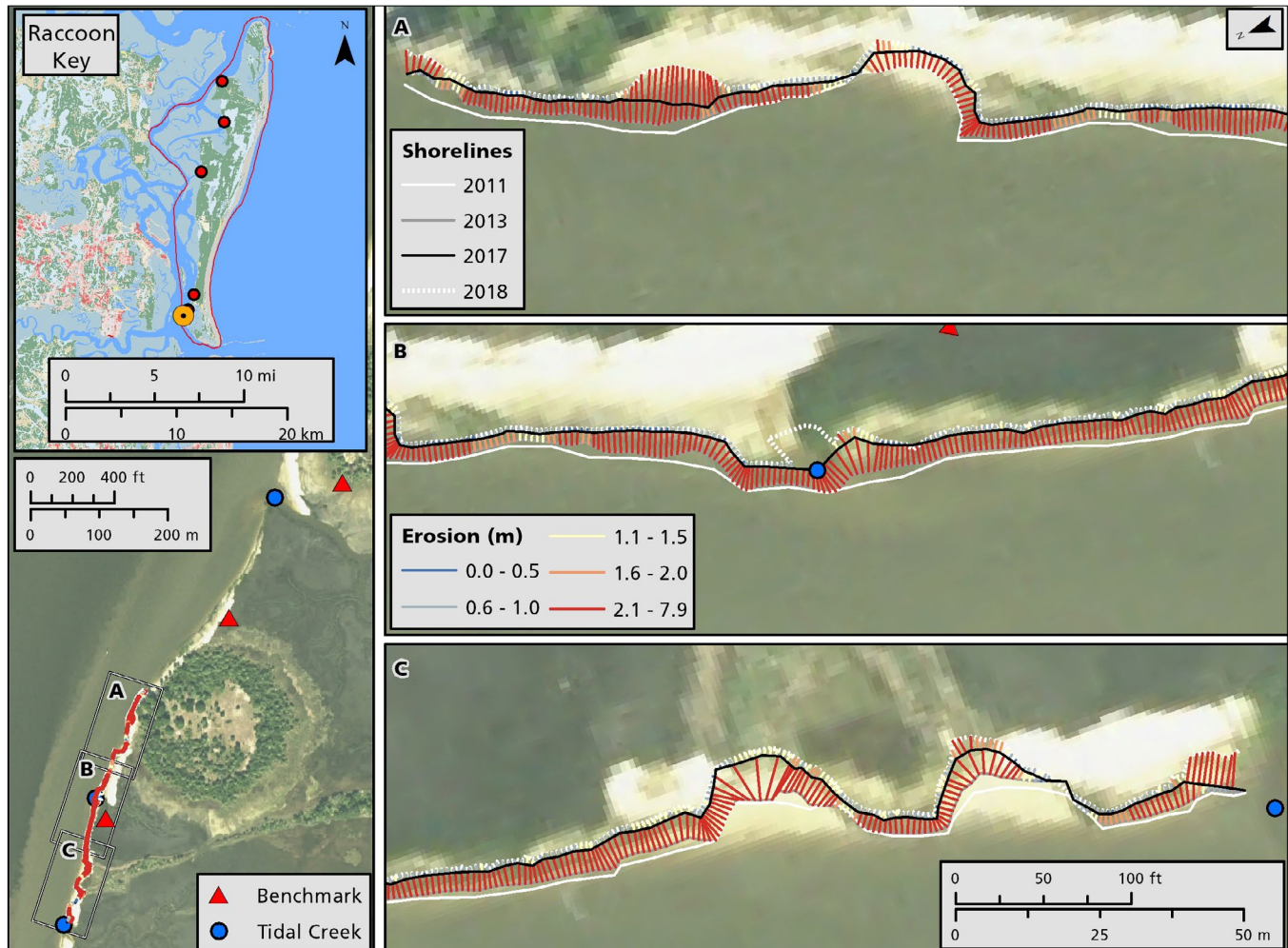


Figure 7. Island margin retreat at Raccoon Key.

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Appendix A. Cumberland Island Erosion Monitoring Site Metadata

This appendix contains information regarding the location of the survey benchmarks (Table A1), the beginning and ending points of the surveys (Table A2), and maps of each site with benchmark location, example total station locations (if needed), and survey extent (Figures A1–A5). A brief description of each site is also included to provide future researchers with the information that is needed to plan a successful resurvey.

Table A1. Benchmark coordinates. All coordinates are in UTM 17N (horizontal datum—NAD83 and vertical datum—NAVD88).

Site	Northing	Easting	Elevation (m)
Cumberland Wharf	3421835.77	457343.23	9.231
Brickhouse Bluff	3418166.10	457535.10	2.657
Plum Orchard	3413647.50	455428.50	4.077
Dungeness Wharf	3402554.10	454788.70	4.604
Raccoon Key	3401184.30	454264.90	1.469

Table A2. Coordinates for the beginning and ending points at each survey site. All coordinates are in UTM 17N (horizontal datum—NAD83).

Site	Southern Northing	Southern Easting	Northern Northing	Northern Easting
Cumberland Wharf	3421879.00	457405.00	3421950.00	457549.00
Brickhouse Bluff	3418039.00	457528.00	3418259.00	457509.00
Plum Orchard	3413561.00	455342.00	3413753.00	455395.00
Dungeness Wharf	3402619.00	454730.00	3402778.90	454755.10
Raccoon Key	3400544.00	453862.00	3400898.00	453984.00

Cumberland Wharf

Cumberland Wharf is located on the north side of the island near Terrapin Point. The benchmark is located just off the Terrapin Point trail. At the first bend near the bluff, cut north into the woods. A north-facing witness post is near the benchmark. Canopy cover is moderate near the benchmark. The survey requires an integrated survey. During the resurvey of 2017 (June 19) one total station setup was sufficient. Though the bluff top is within range of the base station, canopy cover prevented RTK GPS from being reliable (Figure 1). Tides need to be taken into account when surveying this site. At high tide the beach is too small to survey large portions of the bluff. The beach sediment is mostly sand. The bluff is high (greater than 5 meters [16.4 ft]), sandy, and in many spots, very undercut. Be careful conducting this survey near these sandy undercuts. An additional surveyor may be needed to help hold back vegetation when conducting this survey.

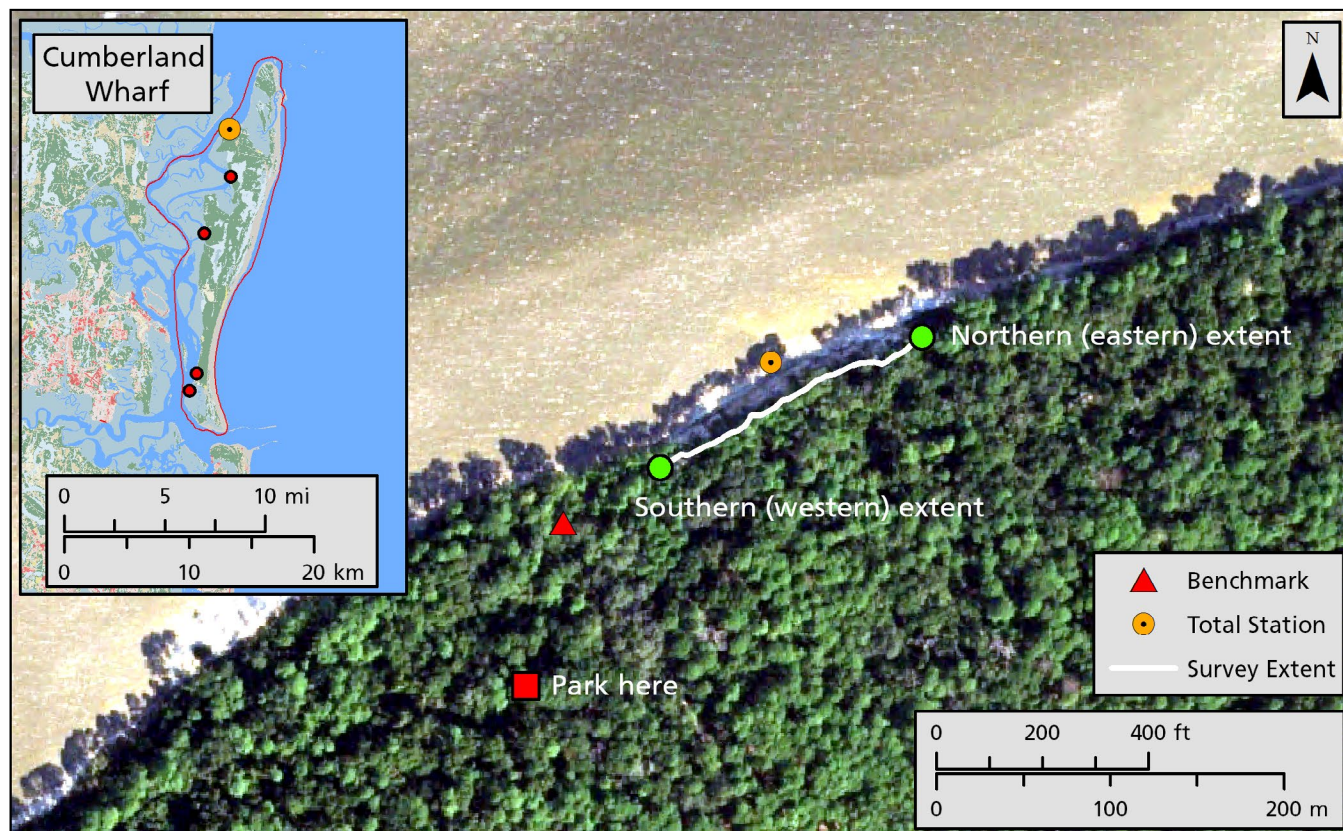


Figure A1. Map of the area near Cumberland Wharf.

Brickhill Bluff

Brickhill bluff is located on the cutbank side of a large meander on Brickhill River (Figure A2). The benchmark is located near the northern border of a small camp (Figure 1). A south-facing witness post is approximately 1 meter (3.3 ft) north of the benchmark. Canopy cover is moderate and the sky directly to the north of the benchmark is obscured by a small grove of trees. The survey requires an integrated survey. During the resurvey of 2017 (June 20) three total station setups were needed because there are a lot of failed or downed trees on the beach preventing line-of-sight (Figure A2). Though the cutbank is within range of the base station, canopy cover prevented RTK GPS from being reliable. Tides need to be taken into account when surveying this site. At high tide the beach is too small and the large woody debris on the beach is too dense to survey large portions of the cutbank. The beach sediment also needed to be taken into account when doing the survey as mud flats and oyster beds make total station stability questionable. The oyster beds also pose a safety hazard and care needs to be taken when traversing these sharp and potentially unstable platforms.

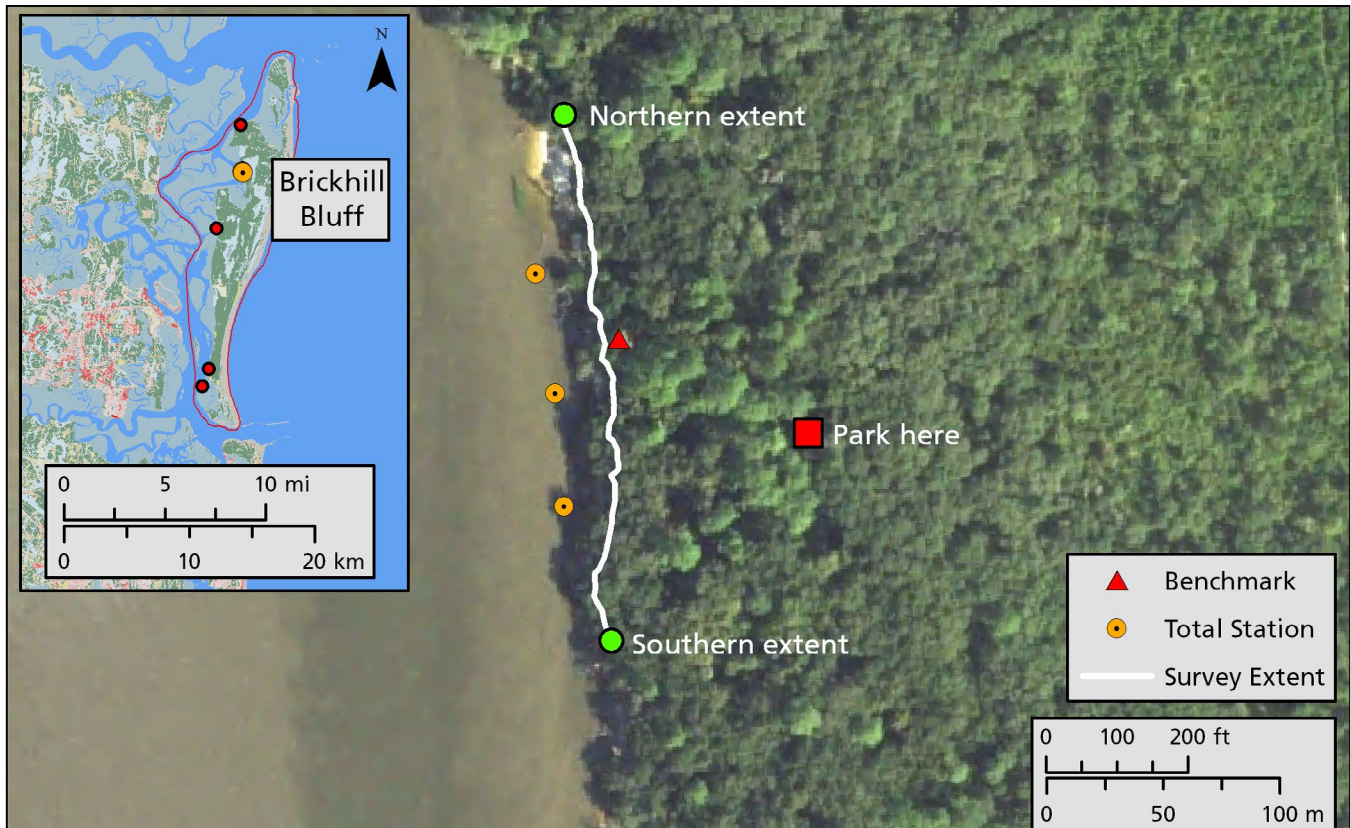


Figure A2. Map of the area near Brickhill Bluff.

Plum Orchard

Plum Orchard is located on the cutbank side of a meander of Brickhill River (Figure A3). The benchmark is located in the middle of the field. The benchmark is approximately 45 meters (147.6 ft) away from the three-sided park information sign at a heading of 67.5° (uncorrected heading). A metal detector should be brought along to help relocate the benchmark. The majority of the survey can be done with RTK GPS though a total station setup will likely be needed to fill in the gaps (integrated survey). During the resurvey of 2017 (June 20) one total station setup was sufficient to get the points that RTK GPS could not survey (Figure A3). Tides do not need to be taken into account when surveying this site. The survey begins in the south just north of where the salt marsh begins (near some fallen trees). The survey should continue north along the shore, past the pier, and to the historical structure that is about to collapse. The survey should pick up again on the north side of the historical structure and continue to the north edge of the mowed portion of the shore.

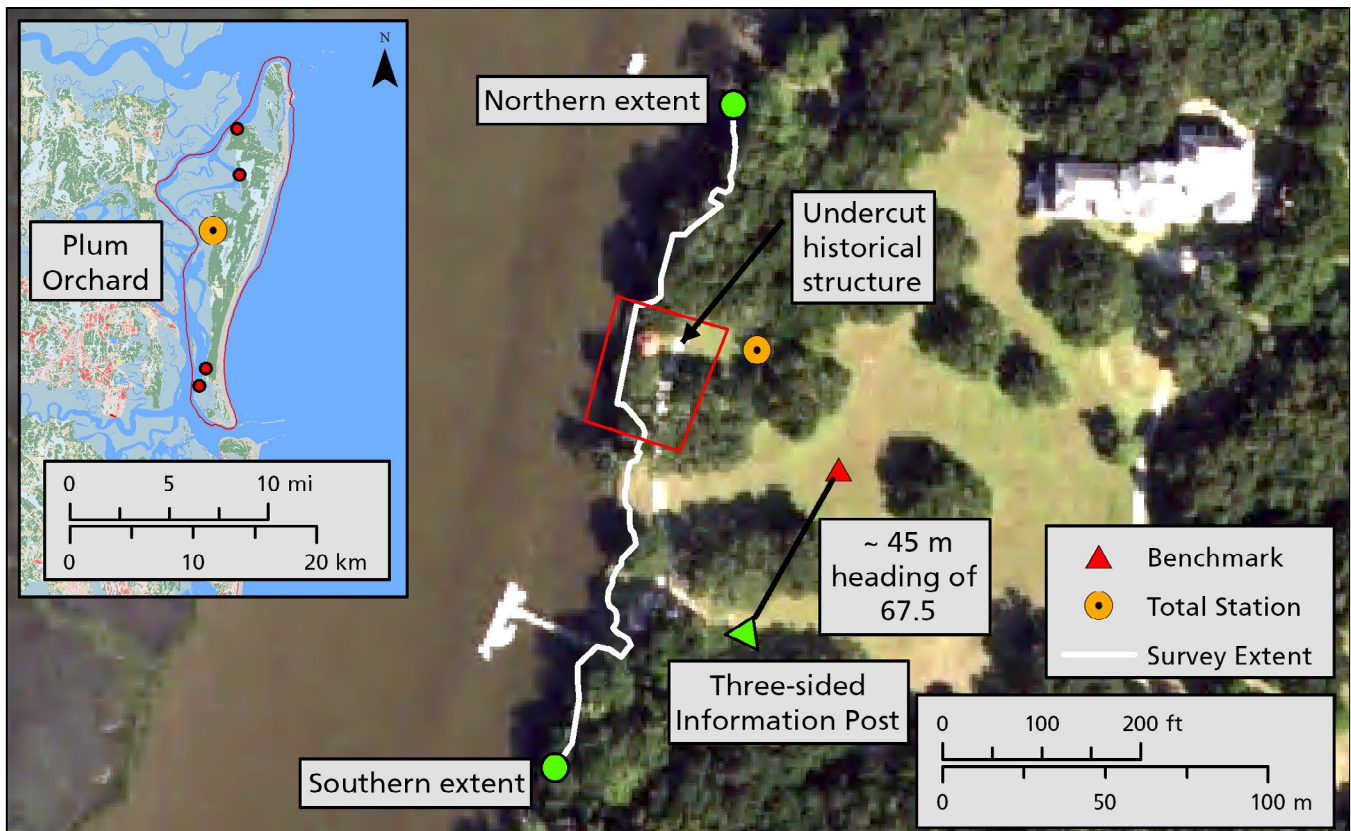


Figure A3. Map of the area near Plum Orchard.

Dungeness Wharf

Dungeness Wharf is located on the cutbank side of a large meander on Crooked River near Cumberland Sound (Figure A4). The benchmark is located just north of the parking area. A west-facing witness post is approximately 7 meters (23.0 ft) east of the benchmark. While some of the bank can be measured with RTK GPS, the survey requires an integrated survey to survey the entire bank. During the resurvey of 2017 (June 19) one total station setup was sufficient to survey the areas that RTK GPS could not capture (Figure A4). Tides need to be taken into account when surveying this site. At high tide the beach is too small and the large woody debris on the beach is too dense to survey all of the areas that RTK GPS cannot survey. In some areas, the beach sediment is too unconsolidated and mucky to set up the total station. The survey begins in the south at the northern-most portion of the seawall and continues north approximately 170 meters (558 ft).

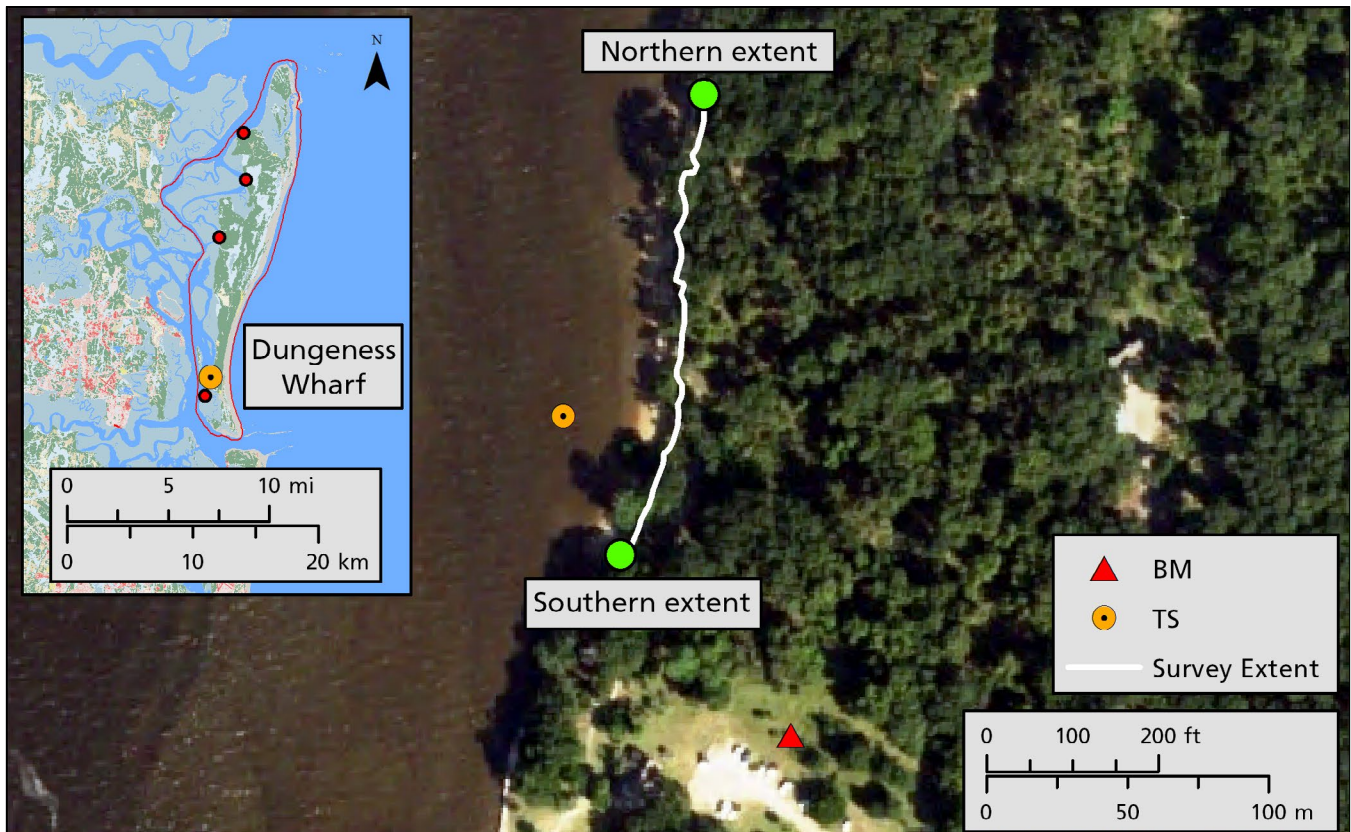


Figure A4. Map of the area near Dungeness Wharf.

Raccoon Key

Raccoon Key is located on the southern portion of the island along the St. Marys River (Figure A5). The benchmark is located just south of the vegetation separating the parking area from the salt marsh. A south-facing witness post is approximately 1 meter north of the benchmark. Real-time kinematic GPS can be used to survey the entire site due to the open canopy of low marsh grasses. Tides need to be taken into account when surveying this site. At high tide, the portion of the marsh that needs to be surveyed cannot be accessed because of the tidal creek that lies between the site and the benchmark (Figure A5). The survey should begin just north of the second large tidal creek. The survey should continue north approximately 400 meters (1,312 ft) to where the large circular dredge pile is being eroded.

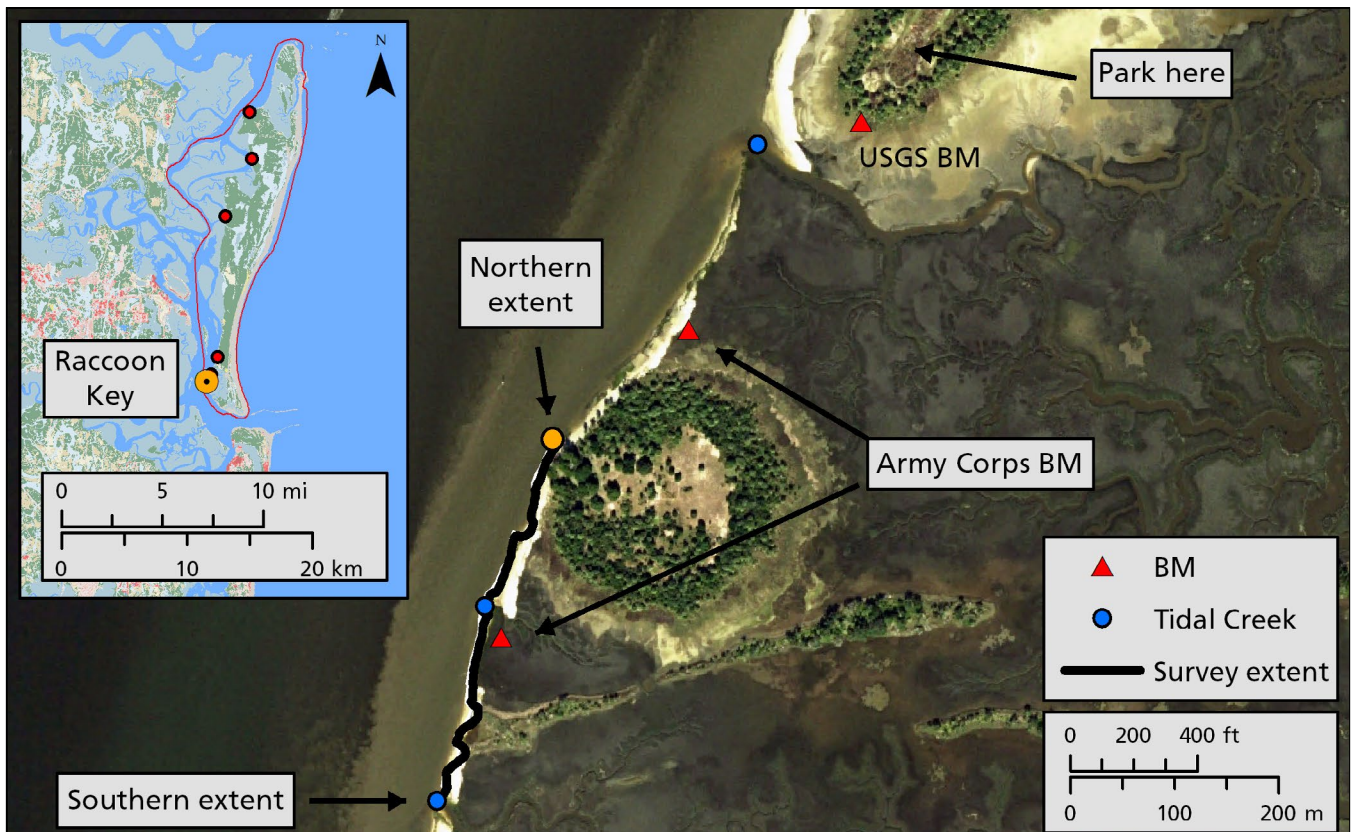


Figure A5. Map of the area near Raccoon Key.

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