**Case Study: Deer Island, Florida Time Period Shoreline Analysis Using DSAS**

**Abstract**

The perpetuation of climate change and sea level rise have led to concerns in shoreline dynamics in the Gulf of Mexico. Shoreline dynamics in areas of coastal development have been intensely studied, however many under-developed shorelines have yet to be analyzed. In this study we used seven NAIP (National Agriculture Imagery Program) aerial images, from 1994 to 2019, of our study area near Cedar Key, FL. The cloud-free images were collected during relatively similar mean river discharge levels and during (mostly) the same season. We assessed the shoreline changes using the ArcMap extension DSAS (Digital Shoreline Analysis Systems) on two different time periods in from the imagery, 1994-2007 and 2010-2019. The DSAS analysis is a transect- based approach and is used to quantify shoreline changes on a linear ocean shoreline. From this analysis we have been able to determine the greatest areas of impact and speculate on possible factors that may be contributing to an escalated shoreline change rate during these brief selected time frames.

**1. Introduction**

Shoreline changes can occur due to multiple factors including anthropogenic, hurricane intensity, and SLR (sea-level rise) (Yu et al., 2011). The combination of these processes can influence erosion and accretion. Shoreline changes may affect their resilience to storm surges including flooding and species diversity implications (Desantis et al., 2007). It was observed by USGS (US Geological Survey) that shoreline changes along the Gulf of Mexico, specifically in Florida, were relatively steady between the 1800s and 1990s (Morton et al., 2005). Since then, the Gulf of Mexico coastline, with its low relief geomorphology particularly along the west coast of Florida, has been noted to be vulnerable to coastal erosion (Geselbracht et al., 2011).

***1.1 Climate change and SLR***

More recently, SLR perpetuated by climate change and its impacts on coastal zones has come to be of growing interest. The Earth’s climate is warming due to an accumulation of greenhouse gases in the atmosphere, largely in part due to anthropogenic fossil fuel burning and deforestation. Warming climate change causes thermal expansion of sea water, and land ice to melt into the ocean, initiating SLR (Cazenave and Cozannet, 2013). Sea-level rise is considered to be a likely candidate for widespread global erosion. Erosion occurs when SLR drifts the high-water line (line on the shore where the water usually reaches at high water) landward in relation to the slope of the coastal area. Erosion on sandy beaches involves the relocating of sand from the beach to offshore, normally recognized during storm events. Storm events will temporarily increase the local sea-level of the sandy beach, where ultimately storm waves are able to reach higher elevations on the beach. After a storm event much of the sand should return back to the beach by swell waves at the time of normal sea water levels. This exchange implies that sea water levels have a relationship with sandy beach erosion (Zhang et al., 2004).

***1.2 Characteristics of sandy shorelines and sedimentation***

Sandy shorelines are characterized by active environments and unstable substrata, which consists of sand, mixed sand, quartz, and/or silica. The unstable nature of sandy shores make a harsh ecosystem for biota and may incorporate a significant range of physical environment conditions and ecosystem functioning. These shorelines accumulate sediment accretion by wave deposited particles. Particles originate from inland erosion and may be transported by rivers (Brown and McLachlan, 2001). Sediment to sandy shores may also be added by marine biogenic sources such as pieces of marine skeletons, sponge spicules, and shell fragments (Brown and McLachlan, 1990). Threats to sandy shorelines include disruption of sand transport, storms, SLR, and human activities.

***1.3 Suwannee River sedimentation and discharge***

The Suwannee River is the second largest river in Florida spanning 396 kilometers long and is considered to be a significant point source of sedimentation near our study site, approximately 11 kilometers north. The Suwannee River is a partially spring-fed system which also drains the coastal plain of Georgia and provides a restricted point source input of siliciclastic sediment, creating a small 20-kilometer delta. The surrounding coastal regions of the Suwannee River are otherwise known to be sediment starved, but a great significant sedimentology event has been shown that the Suwannee River has reworked ancestral fluvial sands and serves as a source for sandier marsh sediments (Wright et al., 2002). The Suwannee River normally has high discharge peaks between February and April and low discharge peaks between August and October (Purtlebaugh and Allen, 2010). The average annual discharge is 300 m^3/c with a minimum of 83 m^3/c and a maximum discharge of 2400 m^3/c (Wright et al., 2002).

***1.4 Human development and impacts***

Three Florida counties encompass the region of our study site, Dixie, Levy, and Taylor. These counties which are projected to increase in human population by 2045 as depicted in Figure 3. These Florida counties are recorded to have lowest population densities along the Florida coastline (Geselbracht 2007). In the future it could be likely that businesses and people will want to develop housing along this shoreline. Human development on coastlines may accelerate coastal erosion by creating a fixed position of the shoreline and stabilizing inlets (Finkl and Charlier, 2003). Increased human developments may also negatively impact coastal species diversity. Species biodiversity is threatened by the increase of urbanization and environmental coastal degradation (Finkl and Charlier, 2003). Czech’s et al. (2000) documents urbanization as the highest cause for species endangerment. For example, the shorebird piping plover (*Charadrius melodus*) is known to forage and nest in areas of low human population (Thomas, Kvitek, and Bretz, 2002), implying that shoreline areas with higher human densities would not be an ideal habitat for this species. Species biodiversity, both vegetative and animal, could be at risk due to an increase of urbanization along coastlines (McKinney, 2006) and accelerated shoreline erosion.

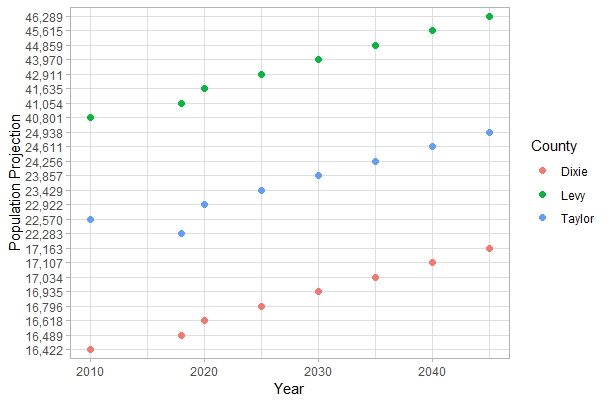


Figure 1- Generated figure based on census and projection data from Bureau of Economic and Business Research (<https://www.bebr.ufl.edu/population>).

***1.5 Sandy shorelines as habitats for animal species biodiversity***

***1.6 Hurricanes, storm events, and functions of barrier islands***

***1.7 Reason for effort***

In the mid-1960s the US Army Corps of Engineers constructed spoil islands as part of the cross Florida barge canal project. These spoil islands consist of a straight line of islands perpendicular to the west Florida coast. Coastal changes have severely eroded or inundated these spoil islands, thus reducing habitat for animals (Vitale, 2019). Derrick Key is an example of a spoil island that was clearly visible in aerial photographs in 1982 and now the island is completely submerged (in 2016 photography). Major shoreline differences are noticeably observed in the 34 years, time between the imagery, for this specific spoil island. Large scale efforts to analyze shoreline changes in Florida have been studied in the past (Yu et al., 2010; Sassaman et al., 2017; Houston, 2015; Li and Gong, 2015), however it is interesting to note the effects of SLR on a smaller or regional scale, which might highlight processes which might be affecting ecosystems and habitats on a larger-scale.



Figure 2 - Island degradation of Derrick Key in the Cedar Keys, Florida from 1982 (left) to 2016 (right), (Vitale, 2019).

**2. Materials and methods**

***2.1 Study Area***

Our study area is located on the west-central Florida coastline in the Suwannee Sound region of the Big Bend. The selected shoreline is a small barrier island called Deer Island. Deer island is a privately owned uninhabited island approximately 13 kilometers north of the main villages of Cedar Key, Florida. Historically, Native Americans intermittently inhabited Deer Island for thousands of years. Early Florida settlers were reported to live and camp on the island as well. The 1800 Florida census registered only 4 people to have identified this island as their home. There is a cabin near the south of the island depicted on a 1951 USGS Cedar Key Quadrangle map (USGS, 1955). This island is specifically located in the Big Bend Aquatic Seagrass Preserve and connects with the Lower Suwannee National Wildlife Refuge (http://www.beachrealtyfla.com/DeerIsland.htm). Deer Island is approximately 364217 square meters of total area and consists of 101171 upland square meters (27.7%) and 80937 square meters (22.2%) of wetland with elevations as high as 4.3 meters. The island is densely forested with large pines, cedars, palms, oaks, palmettos and many more plant species (<https://www.privateislandsonline.com/united-states/florida/deer-island>). The shoreline attributes reported on Deer island is about 1.3 +/- kilometer of Gulf of Mexico white sand beach and approximately 1.3 +/- kilometer of waterfront facing the mainland ( <https://images1.loopnet.com/d2/Z4L1-alqEsAlhPT_YJ25N8OMkXU3L_mAPAZYXiq2OVg/document.pdf>).



Figure 3- Location of Deer Island, Florida. A) Map of the entire state of Florida; B) Zoomed into map scale of 2.3758 to location; C) Zoomed into map scale of 0.03 to Deer Island with a scale bar in kilometers. Shoreline shapefile was provided by my.fwc.com, (1 to 2,000,000 Scale), and digitized in 2017.

***2.3 Imagery selection process***

Locating relatively cloud-free imagery for a specific location can be an exhaustive effort. Since our study location is unpopulated and contains no popular historic landmarks, aerial or satellite passes of this area are not frequent. To reduce the effort on locating usable imagery, Google Earth Pro was utilized. Google Earth Pro does not capture any of its own imagery, it does however locate and use imagery, in its finder view, that is comparatively cloud-free and with the highest resolution. Google Earth Pro was able to give minimal metadata of the imagery such as which agency captured the imagery and the date of the image, when using the time slider feature. Upon inspection it was determined that NAIP (National Agriculture Imagery Program) was the agency that acquired the most frequent and most detailed aerial imagery of our study site. The specifications for NAIP aerial imagery require 1-meter ground sample distance with a horizontal accuracy that matches within six meters of photo-identifiable ground control points. These points are then used during imagery inspection. Contractually, NAIP makes attempts to comply with the specification that no more than 10% cloud cover be allowed in each aerial imagery tile. Aerial imagery are available as digital ortho quarter quad tiles (DOQQs) geotiffs, and which also correspond to the USGS topographic quadrangles (https://www.fsa.usda.gov/programs-and-services/aerial-photography/imagery-programs/naip-imagery/). It was also important to select imagery that were fairly in the same time of the year, similar river discharge and precipitation levels. All imagery chosen are between the months of October through January. Normally, during the Florida winter months, precipitation and river discharge levels are generally low (Bhardwaj and Misra, 2019).

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| --- | --- | --- | --- |
| Date | Median River Discharge (cfs)  Station ID= 02323500 | Observed weather | Metadata (USGS Earth Explorer) |
| January 20, 1994 | Value= 9710 | Avg Temp (C)- 3.41 Precipitation (cm)- 0.00  Max Wind Speed (KPH)- 19.31 | Entity ID DI00000000018672 (found in DOQ)  Map Projection UTM  Projection Zone 17N  Datum NAD83  Resolution 1.0  Units METER  Number of Bands 3  Sensor Type RGB |
| December 30, 1998 | Value= 6370 | Avg Temp (C)- 9.30 Precipitation (cm)- 0.00  Max Wind Speed (KPH)- 25.75 | Entity ID DI00000001164809 (found in DOQ)  Map Projection UTM  Projection Zone 17N  Datum NAD83  Resolution 1.0  Units METER  Number of Bands 3  Sensor Type RGB |
| November 02, 2007 | Value= 2350 | Avg Temp (C)- 19.31  Precipitation (cm)- 0.00  Max Wind Speed (KPH)- 22.53 | Entity ID N\_2908356\_NW\_17\_1\_20071102 (found in NAIP)  Map Projection UTM  Projection Zone 17N  Datum NAD83  Resolution 1.0  Units METER  Number of Bands 3  Sensor Type CLR |
| September 19, 2010 | Value= 4240 | Avg Temp (C)- 25.32 Precipitation (cm)- 0.00  Max Wind Speed (KPH)-24.14 | Entity ID M\_2908356\_NW\_17\_1\_20100919 (found in NAIP)  Map Projection UTM  Projection Zone 17N  Datum NAD83  Resolution 1.0  Units METER  Number of Bands 4  Sensor Type CNIR |
| October 13, 2013 | Value= 8200 | Avg Temp (C)- 22.13 Precipitation (cm)- 0.00  Max Wind Speed (MPH)- 10 | Entity ID M\_2908356\_NW\_17\_1\_20131013 (found in NAIP)  Map Projection UTM  Projection Zone 17N  Datum NAD83  Resolution 1.0  Units METER  Number of Bands 4  Sensor Type CNIR |
| November 12, 2015 | Value= 6070 | Avg Temp (C)- 19.27 Precipitation (cm)- 0.00  Max Wind Speed (KPH)- 16.09 | Entity ID M\_2908356\_NW\_17\_1\_20151112 (found in NAIP)  Map Projection UTM  Projection Zone 17N  Datum NAD83  Resolution 1.0  Units METER  Number of Bands 4  Sensor Type CNIR |
| October 26, 2017 | Value= 7990 | Avg Temp (C)- 12.60 Precipitation (cm)- 0.00  Max Wind Speed (KPH)- 14.48 | Entity ID M\_2908356\_NW\_17\_1\_20171026 (found in NAIP)  Map Projection UTM  Projection Zone 17N  Datum NAD83  Resolution 1.0  Units METER  Number of Bands 4  Sensor Type CNIR |
| November 10, 2019 | Value = 5190 | Avg Temp (C)- 14.12 Precipitation (cm)- 0.00  Max Wind Speed (KPH)- 11.27 | Entity ID M\_2908356\_NW\_17\_060\_20191110 (found in NAIP)  Map Projection UTM  Projection Zone 17N  Datum NAD83  Resolution 0.60  Units METER  Number of Bands 4  Sensor Type CNIR |

Table 1- Table of information for each aerial image used in this analysis including date, median river discharge, observed weather, and additional imagery metadata. River discharge information is calculated by data from idesandcurrents.noaa.gov at Cedar Key, Florida Station 8727520, and observed weather provided by [www.wunderground.com](http://www.wunderground.com). Imagery metadata is provided by USGS Earth Explorer, <https://earthexplorer.usgs.gov/> .

|  |  |
| --- | --- |
| Sensor Type | Bands and wavelength (µm) |
| CLR/ RGB | Blue 400–500  Green 500–600  Red 600–700 |
| CNIR | Blue 400–500  Green 500–600  Red 600–700  Near Infrared 800–900 |

Table 2 - National Agriculture Imagery Program (NAIP) aerial imagery band wavelength ranges in units (µm) (<https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/APFO/support-documents/pdfs/fourband_infosheet_2017.pdf>)

***2.3. Digital Shoreline Analysis System (DSAS)***

The DSAS is a GIS-based system created and maintained by USGS (United States Geological Survey). For this analysis the DSAS ArcGIS extension was used. The DSAS extension casts transects along the baselines (starting point for transects) and measures the gaps between the shoreline positions during defined years. These shoreline positions provide the basic data needed to calculate their shifts. The calculations are based on shoreline geometry indicators. In this study both LRR (Linear Regression Rate) and NSM (Net Shoreline Movement) were selected. A linear regression rate-of-change can be ascertained by fitting a least-squares regression line to every shoreline point in a transect. The regression line is positioned so that the sum of the squared residuals is at its most minimal (<https://pubs.usgs.gov/of/2018/1179/ofr20181179.pdf>). The linear regression rate is the slope of the regression line. The NSM is the distance between the oldest shoreline portion to the youngest shoreline position for each transect, calculated in meters.

Figure 4 - DSAS generates transects that are cast perpendicular to the reference baseline at a user-specified spacing alongshore.  DSAS measures the distance between the baseline and each shoreline intersection along a transect, and combines date information, and positional uncertainty for each shoreline, to  generate the change metrics (<https://www.usgs.gov/centers/whcmsc/science/digital-shoreline-analysis-system-dsas?qt-science_center_objects=0#qt-science_center_objects>)

The DSAS calculations require an operational workflow to gather and create the necessary components. The components needed are shoreline baselines, additional shorelines of interest (varying in different time periods), DSAS transects (which are cast some the baseline and intersect the additional shorelines positions), measurement distances, measurement points, and shoreline uncertainty. All objects used in the DSAS are stored in an ArcGIS Personal Geodatabase, as per USGS requirements for this analysis. The DSAS operational workflow includes the following steps: (1) Set default parameters and fields to created shoreline and baseline layers, transects, shoreline calculations, metadata and file output locations; (2) Cast transects and select their maximum search distance, transect spacing, and smoothing distance; (3) Calculate change statistics such as confidence intervals, shoreline intersection threshold, rate of output display, and summary report; (4) Create data visualization for LRR and NSM; and (5) Shoreline forecasting for a 10 and/or 20 year forecast.

***2.4 DSAS parameters and selections***

Geotiff imagery selected from NAIP are in UTM (Universal Transverse Mercator) 17N and in the datum NAD83 (Table 1). Each aerial imagery shoreline was traced and digitized via ArcGIS editing features. Shorelines were then merged into a single shapefile using the ArcGIS tool Merge. A 100-meter buffer was then calculated around the merged shorelines shapefile using the ArcGIS tool Buffer. A section of the buffer was selected to act as the baseline for transect casting for the DSAS calculations. The baseline selected can be found on the east side of Deer Island and is entirely inland. Both a baseline shapefile and merged shoreline shapefile are required for DSAS calculations (Figure 5, Inputs).

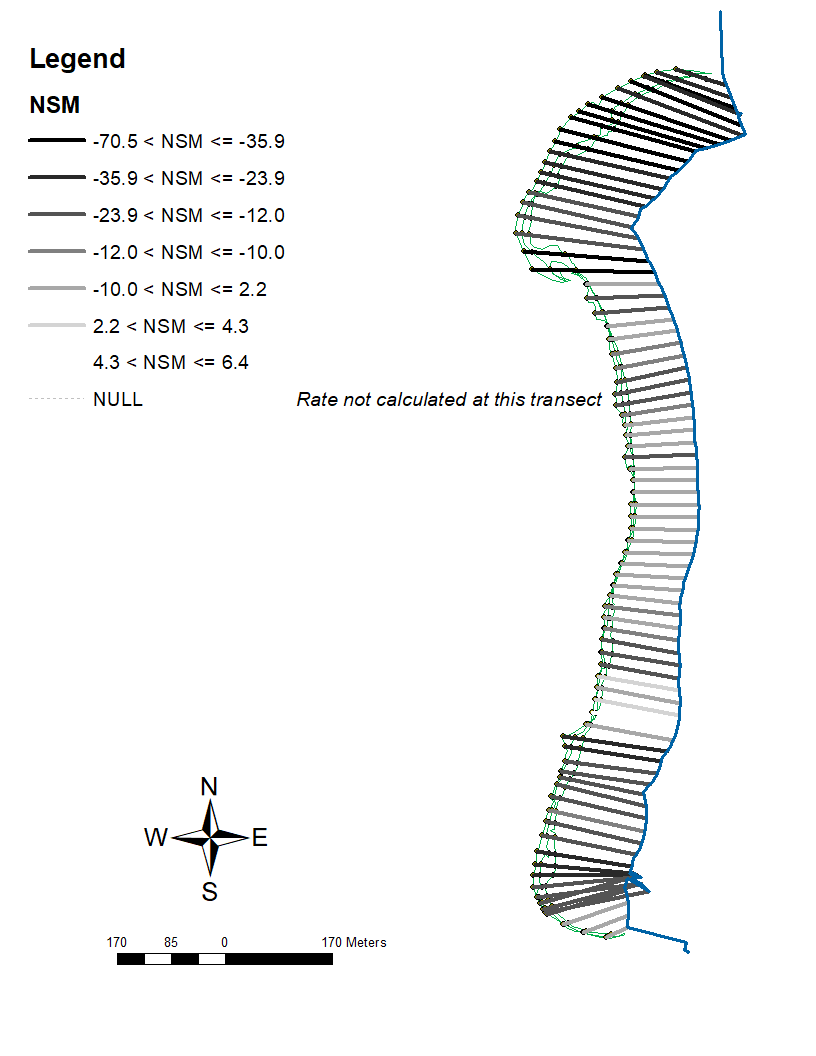
The parameters set for this analysis were a 20-meter transect spacing, a 2000-meter search distance for shorelines, and a smoothing distance of 500 meters. A 20-meter transect spacing was the minimum transect spacing allowed for the size of the study site. A 2000-meter search distance looks for shorelines 2000 meters way from the baseline. A smoothing distance is a user- specified smoothing value which can facilitate and orthogonal transect intersect by creating a baseline (which is not displayed in the final product). The intention of the smoothing distance is to prevent transects from intersecting with one another when there is a curve in the baseline. The larger the smoothing distance results in a longer reference line and produce more uniform transect orientations, which is recommended for smaller shorelines. The default setting for 90% confidence interval too calculate LRR and NSM rates remain unchanged.



Figure 5 - DSAS components and operational workflow.

**3. Results**

The calculations for the shoreline analysis are displayed in a black and white colorramp. The LRR coloramp displays rates of change of meters per year. The NSM coloramp displays the distance of measurements in meters. The DSAS calculations follows the standard that a negative rate implies erosion and a positivie rate implies accretion. The interpretation of the results go as follows.

***3.1 Shoreline analysis from 1994-2007***

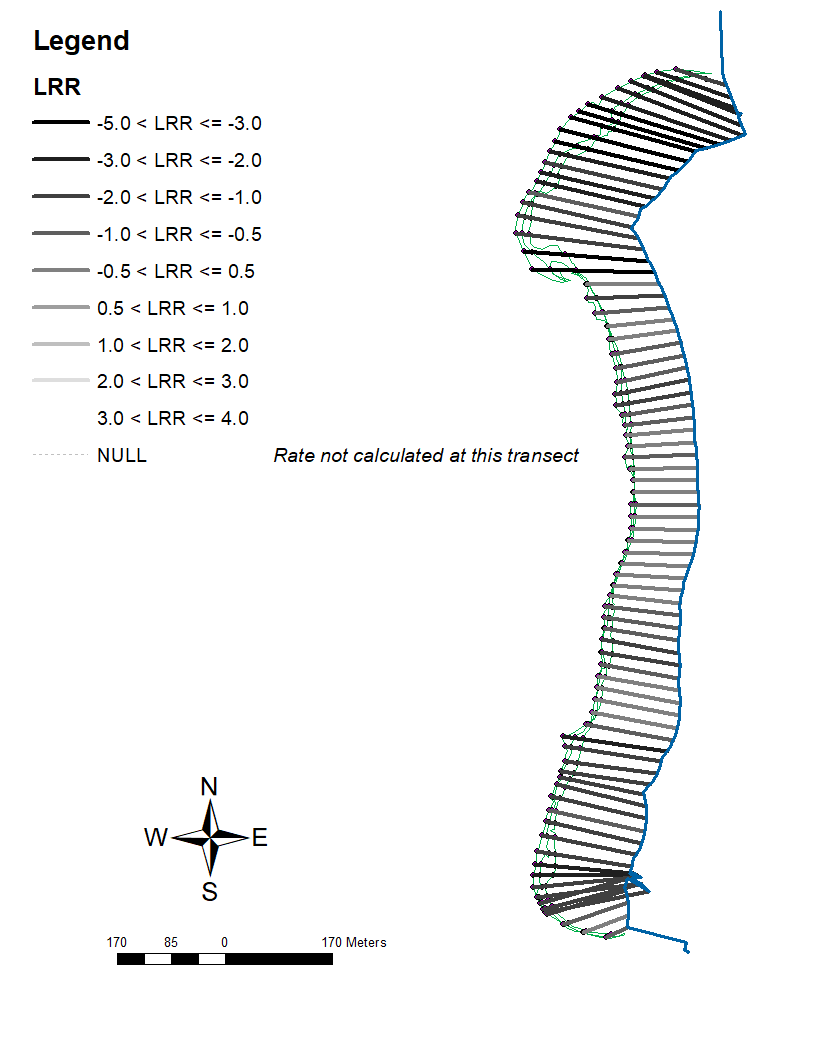


Figure 6- Results of Linear Regression Rates model (left) and Net Shoreline Movement model (right). Shorelines are located on the west side of each panel. Baselines are located on the east side of each panel. The imagery used in this analysis is from 1994-2007.

The DSAS results, Figure 6 (left) display that there were relatively high LRR rates between the years of 1994- 2007. The high LRR erosion rates range from -3.0 to -5.0 (m/yr) and the highest LRR accretion rates range from 3.0 to 4.0 (m/yr). The majority of the transects fall between -0.5 and -5.0 (m/yr) LRR erosion rates. For the NSM calculations (Figure 6, right), the most net shoreline erosion occurred on the north end of Deer Island. The highest erosion distance measurement of the NSM analysis range from -35.9 to -70.5 meters and the highest accretion distance measurements range from 4.3 to 6.4 meters. In the NSM analysis, there is only one transect line that falls in the maximum range of accretion, all other transects are displaying moderate to high erosion meter measurements.

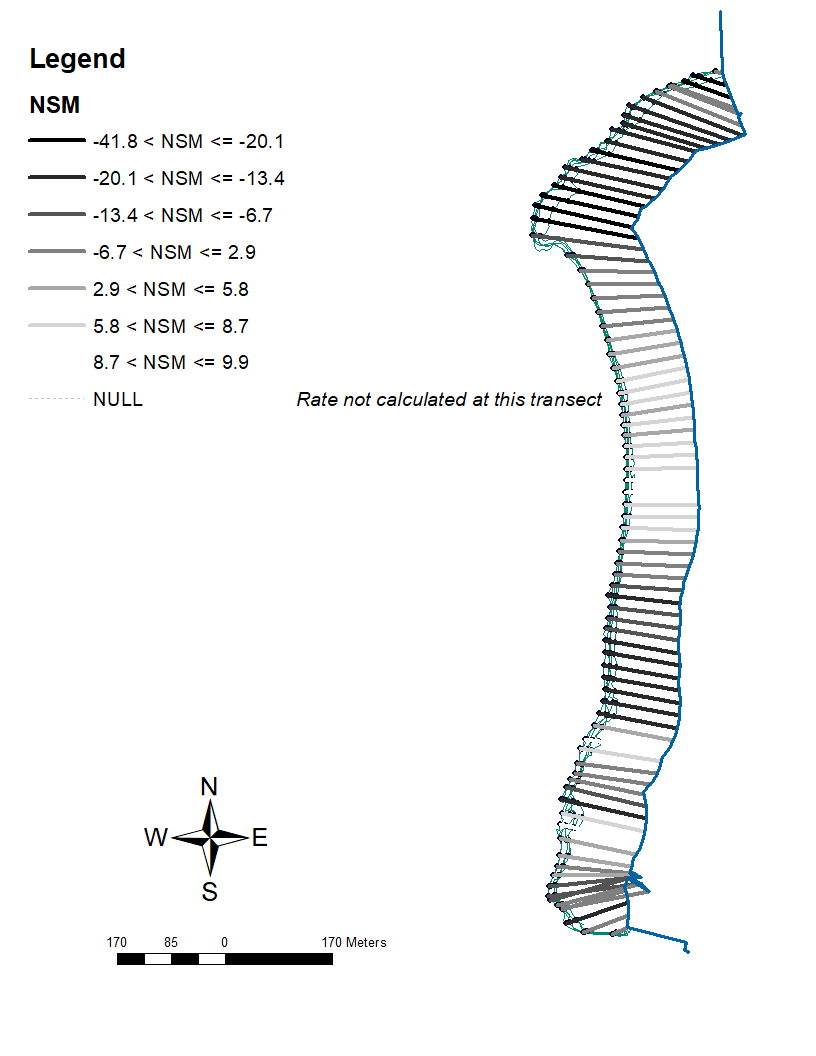
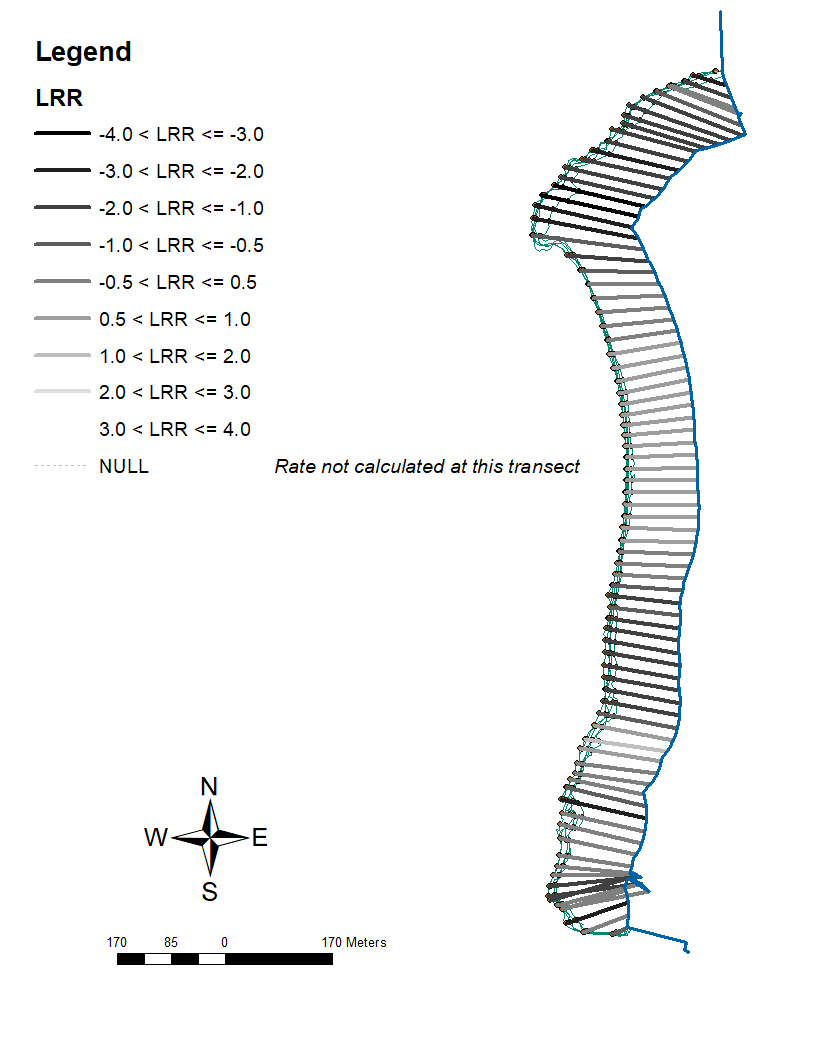
***3.2 Shoreline analysis from*** ***2010-2019***

Figure 7- Results of Linear Regression Rates model (left) and Net Shoreline Movement model (right). Shorelines are located on the west side of each panel. Baselines are located on the east side of each panel. The imagery used in this analysis is from 2010-2019.

The results displayed in Figure 7 demonstrate a different outcome compared to Figure 6. The high erosion LRR rates (left) in this analysis range from -3.0 to -4.0 (m/yr) and the highest LRR accretion rates range from 3.0 to 4.0 (m/yr). The LRR erosion rates during 2010-2019 do not go as high as in 1994-2007. For the NSM (right), the highest erosion distance measurements range from -20.41 to -41.8 meters and the maximum accretion distance measurements range from 8.7 to 9.9 meters. The figure above depicts Deer Island as having moderate to high LRR erosion rates, while the NSM shows accretion in the center of the island with some acute high erosion locations in the north and south end of the island.

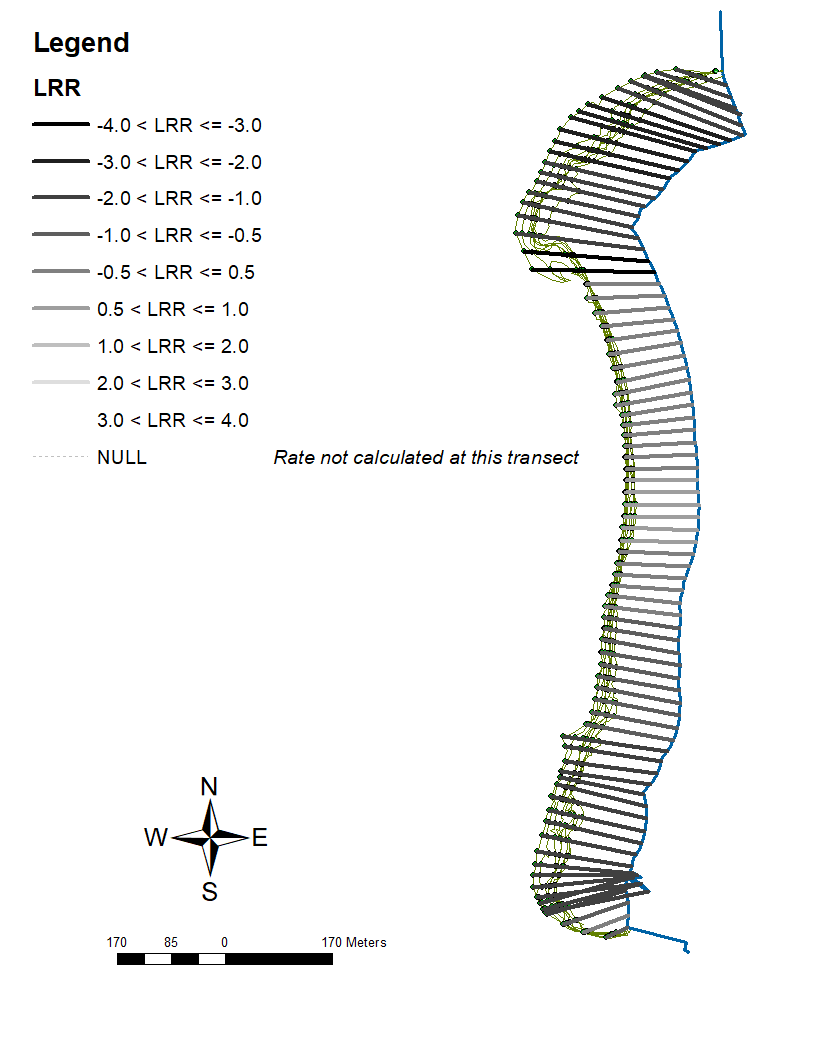
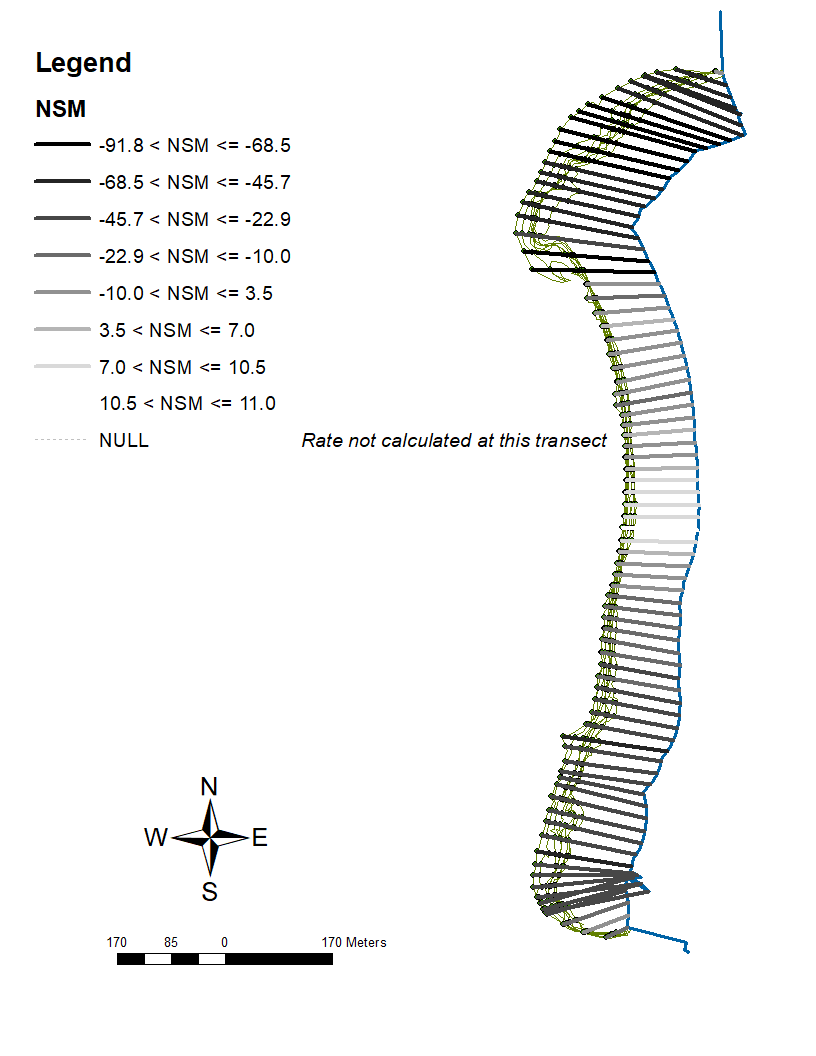
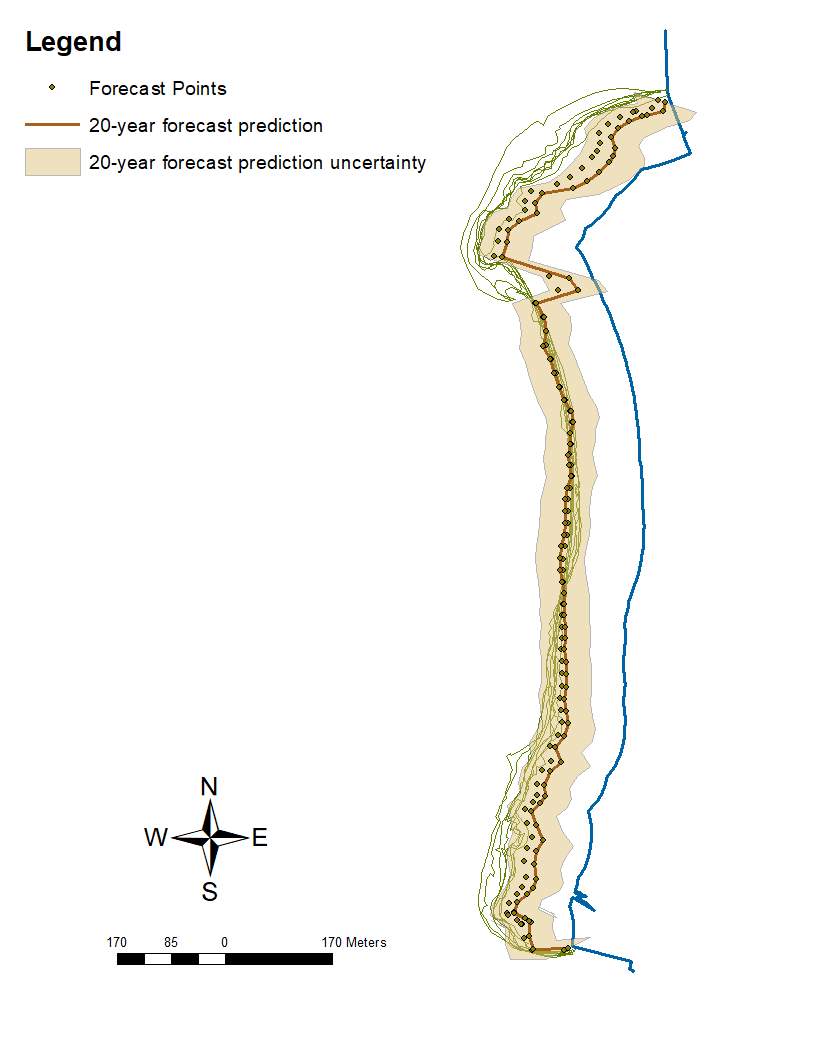
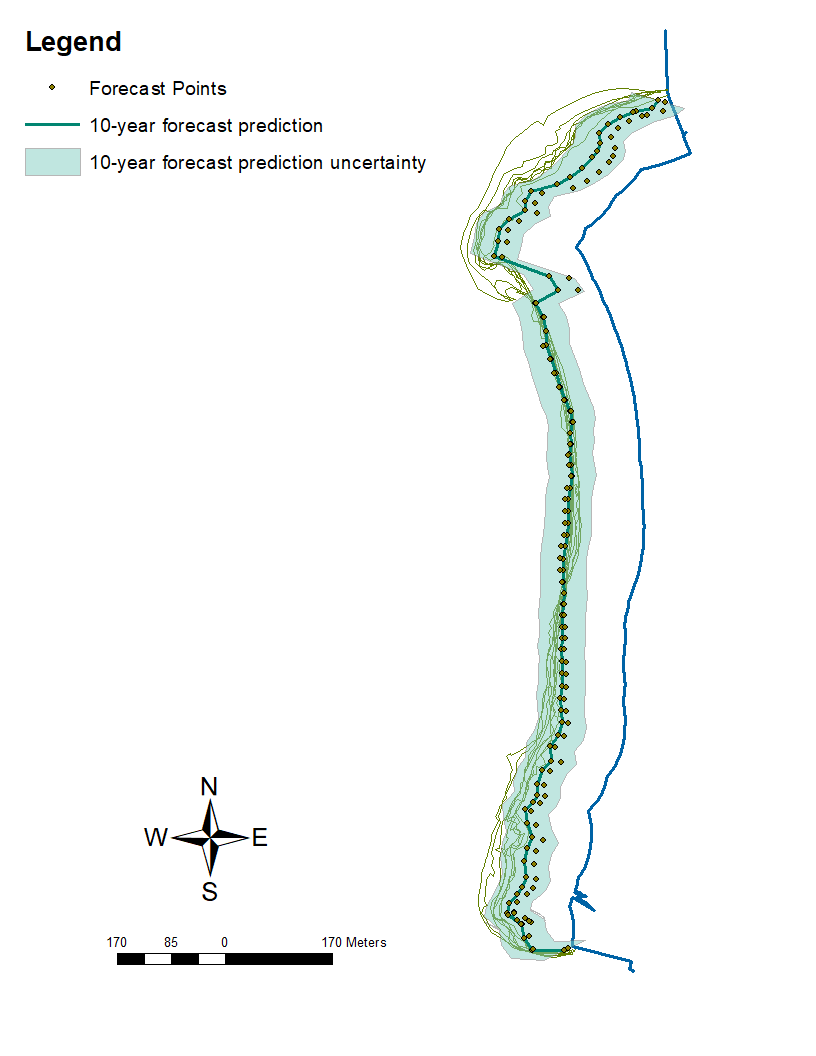
***3.3 Shoreline analysis from 1994-2019***

Figure 8- Results of Linear Regression Rates model (left) and Net Shoreline Movement model (right). Shorelines are located on the west side of each panel. Baselines are located on the east side of each panel. The imagery used in this analysis is from 1994-2019.

The results in Figure 8 includes all the shorelines from Figures 6 and 7 for its LRR and NSM calculations. The high erosion LRR rates (left) in this analysis range from -3.0 to -4.0 (m/yr) and the highest LRR accretion rates range from 3.0 to 4.0 (m/yr), which are the same rates as the as the calculations in Figure 7. The north and south ends of Deer Island show high LRR erosion rates, while the center of the island has seen some rates of accretion. For the NSM (right), the highest erosion distance measurements are from -68.5 to -91.8 meters and the maximum accretion distance measurements are from 10.5 to 11.0 meters. The largest erosion measurement distance is seen at the north end of Deer Island, while the middle has some areas of accretion and light erosion. The south side of Deer Island has some acute peaks of erosion, however not as high as the north end.

***3.4 Shoreline analysis for 10 and 20-year prediction***

Figure 9- Shoreline prediction for 10-year (left) and 20-year (right), including uncertainty. Shorelines are located on the west side of each panel. Baselines are located on the east side of each panel. Forecast points were created by DSAS to assist in the prediction model. The thicker black (left) and brown (right) lines depict the DSAS shoreline prediction. The lighter shaded region indicates the uncertainty of the predicted shoreline.

The DSAS calculations for future shoreline predictions are depicted in Figure 9. The 10-year prediction (left) demonstrates a uniformity of erosion particularity in the south and center of Deer Island. The north end of Deer Island has an acute area right before the shoreline bulge that is projected to be completely eroded by the 10-year prediction. The center of Deer Islands has a slight accretion area, but the majority of the 10-year projection is predicting that the west shoreline of Deer Island will erode. The 20-year prediction is very similar to the 10-year prediction model, but with more drastic erosion in the north end. The most eroded section of Deer Island (toward the north end) is getting close to the baseline.

**4. Discussion and conclusion**

Despite analyzing such brief time periods on a small shoreline, many changes have occurred. Note that in Figure 6, a small hook shoreline feature (on the north end) can be observed and is completely gone by the time period of Figure 7. Even erosion of small features such as that hook like shoreline can make an impact on the available habitats for animals.

Many species depend on shorelines for food, nesting, and shelter (O'Connell et al., 2005). Shorebirds rely on shorelines for feeding habitats during migration in the winter months. Habitat loss, due to erosion, limits the availability of food and resources for these shorebirds, possibly resulting in increased competition. This increased competition may exclude individuals from a foraging site, increase mortality rates for these excluded shorebirds, and ultimately lead to limitations in numbers (Galbraith et al., 2002). During a high erosion storm event, many sandy-shore animals may also be washed up to shore, stranded upshore, or left to die to exposure. Sandy- shore creatures naturally are able to survive storm events due to their defense mechanisms but are not always able to survive in the event of significant shoreline erosion (BROWN and McLachlan, 2002). Whether shorelines erode slowly, but constantly, or in a storm event, extreme shoreline erosion negatively impacts animal species.

Results in this analysis suggest that more shoreline erosion occurred during the 1994- 2007 time frame. The transects results depict more erosion in the NSM analysis (Figure 6, right) than compared to the time frame of 2010- 2019 analysis (Figure 7, right). It is curious for us to think about how and why this seemingly obvious drastic NSM erosion has occurred in the earlier time frame analysis. A year prior to the first imagery in the time series the Storm of the Century, March 1993, caused devasting damage to the surrounding areas such as 3-meter surge waters in Waccasassa Bay (approximately 30 kilometers south of our study site), a storm deposit which reached 12 cm on the levees and up to 2 cm on the marsh surface. There is evidence during the storm event that sandy coasts were susceptible to shoreline erosion (Goobred and Hine, 1995). Despite the Storm of the Century happening prior to our shoreline analysis, an abrupt shoreline erosion due to an intense weather event coupled with SLR might have triggered an unbalance of natural erosion and accretion rates on Deer Island during the 1994- 2007 time frame.

It is interesting to note, that although the overall shoreline experienced erosion, possible accretion might have occurred in the middle of the shoreline during 2010-2019 (Figure 7). Accretion for our study site can only come from intense meteorological events since there is a scant supply of sand being dispersed (Goodbred et al., 1998).

Suwannee river

SLR

**References**

U.S. Geological Survey, 1955, USGS 1:24000-scale Quadrangle for Cedar Key, FL 1955: U.S. Geological Survey. (<https://www.sciencebase.gov/catalog/item/5a8a3ffbe4b00f54eb3ec75e>)

McLachlan, A. "Sandy beach ecosystems,[in:] Ecology of sandy shores." (1990): 197-226.