LANDSAT TM-BASED ANALYSIS OF LAND AREA AND VEGETATION COVER CHANGE ON SIX SELECTED ALABAMA AND MISSISSIPPI BARRIER ISLANDS (1984-2011)

by

HUNTER CLARKE WINSTANLEY

DR. LUOHENG HAN, COMMITTEE CHAIR
DR. BEHZAD MORTAZAVI
DR. JOE WEBER

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ABSTRACT

Cat Island, West Ship Island, East Ship Island, Horn Island, Petit Bois Island, and Dauphin Island are located 10-20 kilometers south of the Mississippi and Alabama coastlines. These six barrier islands serve as an important shield to southern areas of Mississippi and Alabama from tropical cyclone (hurricane) impacts such as storm surge and destructive waves. The islands are also home to a delicate ecosystem of many different types of flora and fauna. Over the course of the past three decades, all six islands have been subjected to several hurricane events. This, coupled with the natural state of the erosion, has led to the islands losing total land area and vegetation. This thesis research focuses on quantifying the vegetation loss and total land area loss on Cat Island, West Ship Island, East Ship Island, Horn Island, Petit Bois Island, and Dauphin Island during the time period from 1984 to 2011. A special focus is given to impacts of Hurricanes Georges, Ivan, Katrina, Gustav, and Ike which affected the northern Gulf Coast in 1998, 2004, 2005, and 2008, respectively. This research utilizes Landsat 5 Thematic Mapper Imagery. Supervised classifications and Normalized Difference Vegetation Index (NDVI) analyses are performed on each scene to analyze the total land area and vegetation cover of each island. The results of this research show the total extent of land and vegetation loss on each island from 1984 to 2011, and which islands are most vulnerable to erosion and vegetation loss. The results also reveal how all five hurricanes affected each individual island.

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1. INTRODUCTION

1.1 Barrier Islands and Their Importance

Barrier Islands are defined as “an unconsolidated elongate body of sand or gravel lying above the high-tide level and separated from the mainland by a lagoon or marsh” (Komar 1976). More than 15,000 barrier islands exist throughout the world. Barrier islands comprise approximately 10% of the world’s ocean facing shorelines. Nearly half of these barrier islands are in current erosion phases (Pilkey et al. 2009). Barrier islands are far more important than bringing tourists or vacationers to their beaches. These islands are a coastal region’s main line of defense during severe storm events. Because so many people throughout the world live near the ocean, the erosional state of nearly half of the earth’s barrier islands is a significant issue.

Barrier islands in the tropical and subtropical regions of Earth protect the mainland coastal areas from hurricane impacts, such as large waves and storm surge. These islands are also very important to local ecosystems. They make homes for local flora and fauna, as well as sanctuaries for migratory bird species. These islands are subjected to the some of the harshest environmental conditions and, therefore, are always in a state of erosion and re-building.

Barrier islands are often long, narrow, and parallel to the main coastline. Most islands are separated from the main coastlines by narrow inlets, bays, or sounds. The majority of barrier islands in the United States are found in small island chains. Narrow tidal channels often separate the islands in the chain from one another.

There are four main habitat zones that comprise most barrier islands: salt marsh, barrier flat overwash, dunes, and beach. Salt marshes are typically low-lying areas on the back side of the barrier island. Various types of grasses help stabilize this area of barriers islands. The salt marshes are typically flooded by tidal movements on a daily basis. The main purpose of the salt marshes is to remove toxins in runoff from land-based rivers and streams. The barrier flat overwash zone is formed by various sediments which are pushed onto the island by storms and large waves. This area is stabilized by shrubs and grasses. This barrier flat overwash zone can be flooded at times during high tide. Dunes are areas of large piles of sand that are stabilized by vegetation. The dune zone is often characterized by steep topographic relief, and it helps protect areas of the island from hurricane induced storm surge flooding. The beach zone is located on the front, ocean-facing side of the barrier island. Wind and wave action deposit and rob sand and sediment along the beach zone of barrier islands. Most of the beach is usually covered with water, daily, at times of high tide (NOAA 2012). Each of these zones combine to create a delicate ecosystem that helps maintain the local environment and protect coastal areas.

1.2 Environmental Impacts on Barrier Islands

Wave activity is the most obvious and most common environmental condition that affects barrier islands. Wave activity affects barrier islands at nearly all times of every day. The role of wave activity is to remove and deposit sand and sediment along the ocean side of the barrier islands. Winds also play a critical role in the formation of dunes on barrier islands. Winds help transport sand from ocean-facing beaches and deposit it along the dune area.

Long shore currents also affect the movement of sediment along the ocean-facing beaches of barrier islands. Long shore currents are typically formed by waves that strike the barrier island coastline at an angle. These currents can remove sand from one end of the island, and deposit it at the other end of the island. This can result in significant erosion along one end of an island.

Tidal activity also plays a significant role in removing and depositing sand and sediment from one part of the barrier island to another part. Tides move sand and sediment from the ocean-facing beaches into the salt marshes of barrier islands. As a result, the ocean-facing beaches are often reduced in size, while the sound sides are increased in size.

Sea level changes have a dramatic impact on the structure and health of barrier islands. Throughout history, lowering sea levels result in the growth of barrier islands. Rising sea levels, however, result in land area loss of most barrier islands. Future rises in sea levels will make barrier islands more susceptible to the impacts of hurricanes and other severe storms.

Severe storms have the greatest impact on barrier islands throughout the world. Tropical cyclones are typically the most destructive of all storms to barrier islands. After extreme hurricane events, barrier islands that are directly impacted will suffer from severe overwash scars, vegetation loss, beach erosion, and breaching. The storm surge and large waves from hurricane events often produce the most damage to barrier islands (Freudenrich 2012). Barrier islands are a coastal regions first line of defense from severe storms such as hurricanes. If these islands did not exist, mainland coastal regions would be at increased risk from the extreme overwash and storm surges that barrier islands experience.

1.3 Barrier Islands in This Study

Barrier Island	Length	Width	Total Land Area	Location
Dauphin Island	24 kilometers	2.5 kilometers	1505 hectares	AL
Petit Bois Island	10 kilometers	0.85 kilometers	375 hectares	MS
Horn Island	19 kilometers	1.25 kilometers	1197 hectares	MS
East Ship Island	3.25 kilometers	0.4 kilometers	80.1 hectares	MS
West Ship Island	4.5 kilometers	0.65 kilometers	160 hectares	MS
Cat Island	7.65 kilometers	4.75 kilometers	683 hectares	MS

Table 1: Barrier islands size and location

This thesis research focuses on six barrier islands that lie south of the Alabama and Mississippi coastlines. The six islands in this study are Dauphin Island, Petit Bois Island, Horn Island, East Ship Island, West Ship Island, and Cat Island. Of all six islands, Dauphin Island is the only island located south of the Alabama coastline. The remaining five barrier islands lie south of the Mississippi coastline. Dauphin Island is also the only island in this study that is developed and populated.

1.3.1 Dauphin Island

Dauphin Island, Alabama is a 24 kilometer-long barrier island located in the Gulf of Mexico, approximately 10 kilometers south of the mainland of Mobile County. The geography of the eastern end of Dauphin Island is significantly different from the western end. The eastern portion is the thickest and healthiest area of the island. Large sand dunes, commercial and residential development, and pine forests in the bird sanctuary dominate the landscape. The eastern portion is nearly 2.5 kilometers wide from south to north (Froede 2008). This area is less vulnerable to land loss, beach erosion, and devastation from hurricane impacts when compared to other areas of the island.

Much of the eastern portion of the island is protected from large swells and surge generated from hurricanes by a small former island named Pelican-Sand Island. This island began to slowly migrate to the northwest in 1970, and connected with the southern beaches of Dauphin Island in early 2008. This land mass has remained connected to the southern beaches of Dauphin Island since that time (Gibson, Campbell 2008). Thus, Pelican-Sand Island is no longer an island (Figures 1 and 2). However, this land mass extends into the Gulf of Mexico in a northwest to southeast direction. This narrow strip of land protects the eastern end of Dauphin Island by diminishing the wave and surge energy from hurricanes.

Figure 1: Aerial photograph from 1940 showing Pelican and Sand Islands off the coast of Dauphin Island (University of Alabama Cartographic Research Laboratory 2012)

Figure 2: Aerial photograph from 2009 showing Pelican-Sand Island conncected to Dauphin Island (University of Alabama Cartographic Research Laboratory 2012)

The western segment of Dauphin Island is signigificantly different when compared to the eastern portion. There are no sand dunes that protect the beaches from erosion, and the topography is extremely flat. Much of the western portion of the island is undeveloped and considerably thin. This area of the island has been overwashed by storm surge and large waves from numerous hurricanes in the past. The western end of the island has suffered significant beach erosion over the past decades, and future hurricanes will only exacerbate this problem

One of the most dramatic changes to the western end in recent history was the formation of a two-kilometer wide breach in the undeveloped portion. This breach was caused from the severe impacts of Hurricane Katrina in 2005, and thus named the Katrina Cut.

Powerful storm surge and waves generated from the hurricane formed the breach in an area that was previously weakend by Hurricane Ivan in 2004. Hurricane Ivan formed several small channels just to the west of where the development of houses ends on Dauphin Island (Froede 2008). In 2011, the Katrina Cut was filled with 185,000 tons of rock (Raines 2011), preventing waters of the Gulf of Mexico from flowing freely through center of the island. This will help protect residents of south Mobile County by reducing wave energy in the Mississippi Sound.

The west end of Dauphin Island has been robbed of beach nourishment due to dredging of the Mobile Bay ship channel. Experts believe that over ten million cubic meters of sand has been prevented from reaching the beaches of Dauphin Island because of the dredging. This has led to significant erosion of beaches along the western end of the island, and as a result, many homes have been lost along the Gulf facing beaches. Some studies have shown that the beaches on both ends of the island have been receeding by nearly three meters per year (Douglas 2010). This a far greater concern for the western end because it is significantly thinner and more exposed than the eastern end. This rate of erosion, especially along the western end, make the island increasingly vulnerable to hurricane events.

1.3.2 Petit Bois Island

Petit Bois Island is located 13 kilometers south of the Mississippi Coastline, and it is the eastern most barrier island off the coast of Mississippi (Morton 2008). It is also the third largest of all Mississippi barrier islands. Petit Bois Island is undeveloped and protected by the United States federal government. In 1971, Gulf Islands National Seashore was created by the United States Congress. This National Park entity encompassed all of Petit Bois Island, Horn Island, East

Ship Island, and West Ship Island. All of these islands are still within the present boundaries of Gulf Islands National Seashore. In 1978, Petit Bois Island was also designated as a Wilderness Area by the federal government of the United States.

The island is home to small pine forests which were badly damaged by Hurricanes Georges, Ivan, and Katrina in 1998, 2004, and 2005, respectively. The island is only about one kilometer wide from north to south at its thickest point, which leaves it incredibly vulnerable to complete storm surge inundation from hurricanes. Sand dunes located on the Gulf of Mexico facing beaches reach as high as six meters in elevation. The beaches which face the Mississippi Sound on the north side of the island also have sand dunes. However, these dunes only reach a maximum height of approximately two meters in elevation (Marsh 2012). Petit Bois Island protects the mainland Mississippi Coastline from the Alabama/Mississippi border to Pascagoula, MS.

1.3.3 Horn Island

Horn Island is the largest barrier island off the coast of mainland Mississippi. The Island stretches in an east to west direction. It is long and slender, and it is dominated by pine forests, shrubery, sand dunes, and freshwater lakes (Lucas and Carter 2010). Horn Island is located approximately 10 kilometers south of the Mississippi Coast, and it is situated directly in between Petit Bois Island to the east and East Ship Island to the west. The island is approximately 19 kilometers in length and 1.5 kilometers wide at its thickest point. Horn Island serves as an important refuge for several species of birds including ospreys and bald eagles

(Marsh 2012). Horn Island protects the mainland Mississippi coastline fome Pascagoula, MS to Ocean Springs, MS.

1.3.4 West and East Ship Island

Ship Island (West and East Ship Island) lies aprroximately 15 kilometers south of the Mississippi Coastline. West and East Ship Island lie between Cat Island and Horn Island. Ship Island has been split into a west and east segment several times throughout recorded history (Morton 2008). Hurricanes in 1853 and 1947 were responsible for breaching the island, and the island was once again breached by Hurricane Betsy in 1965. East and West Ship Island were on their way to fully connecting again in the late 1960s. However, category five Hurricane Camille formed a large channel between the islands that has never closed. This channel was officially named the “Camille Cut.” The Camille Cut became more narrow during periods with little hurricane activity. However, Hurricane Katrina in 2005 significantly widened the Camille Cut, and left East Ship Island drastically smaller. After Hurricane Katrina made landfall on the Gulf Coast, the Camille Cut stretched over three miles from West Ship Island to East Ship Island. West Ship Island is larger than East Ship Island and has suffered less damage from hurricane events (Marsh 2012). West and East Ship Island protect the mainland Mississippi coastal areas near Biloxi, MS.

In fall 2011, the state of Mississippi and the United States federal government began work on a 300 million dollar, 30 month project to restore Ship Island. The project will have three different phases. The first phase of the project involves pumping hundreds of thousands of cubic yards of sand onto the north shore of West Ship Island. The second phase involves rejoinging West Ship Island and East Ship Island. Approximately 13 million cubic yards of sand will be used to fill in the Camille Cut. The final phase of this project involves using 5.4 million cubic yards of sand to fortify the southern beaches of East Ship Island (Kirgan 2011). This project is crucial to the future of West and East Ship Island. East Ship Island has been significantly reduced in size since the Camille Cut was formed in 1969. Sand fortification and rejoining the islands will help protect both segments from future severe storm events and natural erosion processes. Also, rejoining the two islands will help reduce wave energy in the Mississippi Sound, which impacts communities along the Mississippi coastline.

1.3.5 Cat Island

Cat Island is the western most island in this study. The shape of the island is entirely different when compared to the other five islands within this study. Cat Island is shaped in the form of a sideways “T”, unlike its linear shaped island neighbors to the east. It is the only Mississippi barrier island in this study that is not completely within the boundaries of Gulf Islands National Seashore. None of the island was owned by the National Park Service until 2002. During that year, the southern tip and western half of the island was purchased by the United States federal government and became part of Gulf Islands National Seashore. The remaining eastern half of Cat Island remains privately owned. Cat Island measures approximately six kilometers from east to west, and the eastern beaches measure aproximately four kilometers in length from north to south (Marsh 2012). Cat Island protects the mainland coastal areas of Mississippi from Gulfport, MS to Pass Christian, MS.

1.4 Hurricanes

This research included a special focus on the impacts to all six barrier islands brought by five different hurricanes. These five hurricanes include: Hurricane Georges in 1998, Hurricane Ivan in 2004, Hurricane Katrina in 2005, Hurricane Gustav in 2008, and Hurricane Ike in 2008. Each hurricane brought different impacts to each barrier island. The results of this research showed how these hurricane effected land area and vegetation cover change on each barrier island.

Hurricane Georges made landfall near Biloxi, MS on September 28, 1998, with maximum sustained winds of 90 knots. Hurricane Ivan made landfall in Gulf Shores, AL on September 16, 2004, with maximum sustained winds of 105 knots. Hurricane Katrina made landfall in Plaquimines Parish, LA on August 29, 2005, with maximum sustained winds of 110 knots (Blake, Gibney 2011). Hurricane Gustav made landfall near Cocodrie, LA on September 1, 2008, with maximum sustained winds of 95 knots (Beven, Kimberlain 2009). Hurricane Ike made landfall near Galveston, TX on September 12, 2008, with maximum sustained winds of 85 knots. Hurricane Ike struck the coastline farther away from the study area than the four other hurricanes in this study (Berg 2009). However, Ike had a large windfield and generated surge and damaging waves throughout most of the Gulf of Mexico. Because of this, as well as Ike occurring less than two weeks after Gustav, the storm is included in this study. In addition to analyzing the impacts of the five previously mentioned hurricanes, changes temperature, precipitation, and sea level throughout the study time period were examined.

1.5 Purpose of this Study

The pupose of this study is to use remote sensing techniques to quantify the change in land area and vegetation cover on each barrier island in this study, during the time period of 1984-2011. The results of this research show the change in the total area of land and vegetation cover on each barrier island. This research also analyzes how all five hurricanes contributed to land area and vegetation cover change on each individual island. The results of this research are used to show how the islands lost land area and vegetation throughout the study period, and how hurricanes exacerbated this issue. This research is also used to create a simple methodology to anaylze the land area and vegetation cover change on barrier islands throughout the world.

2. LITERATURE REVIEW

2.1 Historic Changes to the Alabama and Mississippi Barrier Islands

The Gulf-facing barrier islands off the coasts of Alabama and Mississippi have been evolving since they were originally discovered and charted. Charts and maps, dating pre-1850, show that these islands have undergone dramatic changes in less than 200 years. Cat Island, Ship Island, Horn Island, Petit Bois Island, and Dauphin Island have changed morphologically, and their total sizes have decreased significantly since 1847. Dauphin Island and Petit Bois Island were once connected. During the 18th century, Dauphin Island was conncected to Petit Bois Island, which now lies south of the mainland of Jackson County, Mississippi. The exact time in which Petit Bois Island separated from Dauphin Island and moved westward is unknown. This event significantly reduced the size of Dauphin Island.

Dauphin Island has grown westward since Petit Bois Island separated in the 1700s. The far west end of Dauphin Island now overlaps the orginal position of the east end of Petit Bois Island when it first separated. Dauphin Island has also seen significant migrations to the north. This is a result of overwash and erosion of the Gulf front beaches, and sand being deposited on the northern beaches. Between 1847 and 1940, Dauphin Island actually experienced net gains in its overall land area. The island is estimated to have grown at a rate of 0.73 hectares per year. There was an even larger growth rate between 1940 and 1958. During this time period, the island saw its total size increase by 7.17 hectares per year. Dauphin Island has experienced a net loss in total land area since 1958. From 1958 to 1996, the island lost 6.1 hectares of land per year on average. This rate slowed from 1996 to 2007, with the island only losing 2.2

hectares of land per year. Land loss rates were significantly higher in this time frame in 2004 and 2005. This is a result of the impacts of Hurricanes Ivan and Katrina.

Previous studies show that the five Mississippi barrier islands have also experienced historical land loss. Petit Bois Island is estimated to have lost nearly 52% of its overall land area from 1848 to 2007. From 1848 to 1917, Petit Bois Island experienced a land loss rate of approximately 1.5 hectares per year. That rate, however, increased to 3.9 hectares per year from 1917 to 1950, and 5.9 hectares from 1986 to 2007. Petit Bois Island's land loss rate from 1951 to 1985 was slightly lower at 2.3 hectares per year. From 2000 to 2007, the island lost nearly 6.3 hectares per year. This increased rate is associated with the impacts of Hurricanes Ivan in 2004 and Katrina in 2005.

Horn Island has undergone some significant changes throughout its history. The island's east end has significantly eroded and receded to the west over the past century and a half. However, since 1848, Horn Island has lost the least amount of land than any of its Mississippi barrier island neighbors. Though the island has lost less land than its neighboring islands, it has still seen a 19% reduction in its total land area from 1848 to 2007. From 1848 to 1917, Horn Island lost an average of 0.3 hectares of land per year. That rate increased to 3.6 hectares of land per year from 1917 to 1950. The land loss rate associated with Horn Island slowed slightly to 3.0 hectares per year from 1950 to 1986. Land loss rates were similar from 1986 to 2007 at 3.1 hectares per year. However, from 2000 to 2007, Horn Island lost an average of 8.6 hectares per year. This increase over the past decade is likely a result of the impacts brought by Hurricanes Ivan in 2004 and Katrina in 2005.

Ship Island (East and West combined) has been experiencing substantial land loss over the past two centuries. Ship Island has lost approximately 60% of its total land area from 1848 to 2007 (Morton 2008). From 1848 to 1917, the island only lost an average of 0.6 hectares of land per year. However, that rate began to increase as the twentieth century progressed. Ship Island lost an average of 2.6 hectares of land from 1917 to 1950, and 2.4 hectares per year from 1950 to 1986. Approximately 20 hecatres of sand was articially added to the north shore of the island near Fort Massachusetts during the 1950 to 1986 time frame. Thus, the reason for the land loss rate dropping from 2.6 hectares per year to 2.4 hectares per year. The land loss rate of Ship Island accelerated from 1986 to 2007 to 6.4 hectares per year. The rate was even higher from 2000 to 2007 at 12.1 hectares per year. The increase in the rate from 1986 to 2007 was due to strong hurricane impacts, such as Katrina in 2005.

Cat Island has experienced the least morphologic change when compared to East and West Ship Island, Horn Island, Petit Bois Island, and Dauphin Island. The shape, orientation, and elevation of the island has prevented interior breaching from hurricanes' storm surge and waves. The exposed southeastern beaches are the only portions of Cat Island that have suffered significant overwash and breaching from hurricanes. The core of Cat Island has remained almost entirely stable throughout recorded history.

Although the location and core of Cat Island have remained relatively unchanged throughout recorded history, the island has experienced significant land loss. From 1848 to 1917, Cat Island lost an average of 0.9 hectares of land per year. The land loss rate increased to 4.9 hectares per year from 1917 to 1950. From 1950 to 1986, the land loss rate decreased slightly to an average of 3.4 hectares per year. Land loss rates increased again from 1986 to 2007. During that time period, Cat Island lost an average of 6.1 hectares of land per year. The rate was even higher from 2000 to 2007 at 11.3 hectares per year. The increase over the past decade is probably a result of the impacts of Hurricane Katrina in 2005 (Morton 2008).

2.2 Morphologic Changes to the Mississippi Barrier Islands

Petit Bois Island is the remnant of the former western segment of Dauphin Island. It is possible that a powerful hurricane, which made landfall along the northern Gulf Coast in 1740, is responsible for creating a large breach in the center of Dauphin Island. The new island drifted westward and became Petit Bois Island. Petit Bois Island typically experiences complete salt water overwash from powerful hurricane impacts. Sand dunes, reaching as high as 4.5 meters, are located on the Gulf and Mississippi Sound facing beaches on Horn Island. These large dunes help protect the central portions of Horn Island, and limit the storm surge penetration from powerful hurricanes. Ship Island has been breached since the landfall of Hurricane Camille in 1969. However, the island experienced breaches before the Camille Cut was formed. Complete overwash and breaching have been common themes of Ship Island after hurricanes impact the northern Gulf Coast. Cat Island's sparsely vegetated northern and southern peninsulas are often overwashed and segmented during significant hurricane events (Morton 2010).

2.3 Pelican-Sand Island Historic Changes

Dauphin Island was first explored by the Spanish in the 1500s and settled by the French in 1699. Immediately, the French began mapping its physical characteristics. A map created by

French colonists in 1717 showed that Dauphin Island was connected to a small northwest to southeast oriented island along its southern beaches. The first American maps showed two small islands, Pelican and Sand, off the southern beaches of Dauphin Island. These two small islands combined to form Pelican-Sand Island in the 1970s, and the new island began slowly migrating toward to the northwest. With the aid of hurricane events, Pelican-Sand Island connected to the southern beaches of Dauphin Island in early 2008. This connection between Dauphin and Pelican-Sand Island returned Dauphin Island to a geomorphic condition similar to its state in 1717 (Froede 2009).

2.4 Protective Berms on Dauphin Island

Dauphin Island has been experiencing beach erosion due to tropical storms and hurricanes since it was originally settled in 1699. Hurricane Katrina's significant impact on the developed western end of the island demonstrated the need for beach nourishment and protection. The Town of Dauphin Island began constructing sand berms along the Gulf facing beaches in January 2007. This project aimed to protect the beach front houses from the severe beach erosion caused by Katrina's storm surge. However, elevated wave action began to erode the protective berms before the project was complete in May 2007. The erosion of the berms indicates the fragility of Dauphin Island's Gulf facing beaches and shoreline (Froede 2007).

2.5 Protective Artificial Sand Dunes on Dauphin Island

Hurricane Georges, which impacted the northern Gulf Coast in late September 1998, was responsible for eroding dunes and beaches along the exposed, developed western end of

Dauphin Island. FEMA grants were used to construct artificial sand dunes along the Gulf facing beaches to protect residential property from future flooding events. However, in September 2002, Tropical Storm Isidore, which passed to the west of Dauphin Island, produced elevated wave action that destroyed the artificial sand dune. This area, along with other areas of the exposed western segment of the island, was significantly impacted when Hurricane Ivan made landfall just to the east of Dauphin Island in 2004. The lack of protective sand dunes left the area vulnerable. Ivan's storm surge formed small channels in the central portions of the island, and flattened topographic relief. When Hurricane Katrina completely severed the island into two portions in 2005, the need for a new artificial sand dune barrier along the developed western end was reinforced. A 3.6 million dollar, 6.4 kilometer-long artificial sand dune was constructed in May 2007 to protect the vulnerable residential areas along the developed western end. The dune lasted for a total of 15 months until Hurricane Gustav made landfall along the northern Gulf Coast in late August 2008. The wave energy and storm surge generated from Gustav completely eroded the dune. FEMA, on December 4, 2008, decided that there was insufficient Gulf facing beach property to construct another protective sand dune (Froede 2010).

2.6 Hurricane Ivan's Impact on Dauphin Island

Hurricane Ivan, which made landfall near Gulf Shores, Alabama on September 16, 2004, significantly impacted portions of Dauphin Island. Pelican-Sand Island absorbed most of the wave energy and significantly reduced Ivan's impact along the east end of Dauphin Island. However, Pelican-Sand Island lost almost all of its sand dunes due to strong wave energy and storm surge flooding. The Pier and Picnic area of Dauphin Island, located just to the west of the eastern segment, also escaped Ivan's fury relatively unscathed. The developed portions of the west end of the island were not as fortunate as the Pier and Picnic area and the eastern end. Severe beach erosion left several houses standing in the surf zone. Some of these houses were left completely surrounded by Gulf water even at times of low tide. Numerous small channels were also formed in the undeveloped portion of the western end. These channel formations, along with severe beach erosion, increased the developed and undeveloped portions of Dauphin Island's susceptibility to future hurricane impacts.

2.7 Hurricane Katrina's Impact on Dauphin Island

Hurricane Katrina also brought significant impacts to Dauphin Island less than one year after Hurricane Ivan devastated the northern Gulf Coast. The damage to Dauphin Island was similar to that brought by Ivan. The eastern end of the island was damaged minimally, due in large part to its protection from Pelican-Sand Island. The Pier and Picnic region of Dauphin Island fared worse than the east end. This segment of the island was fully exposed to the large waves and damaging storm surge generated by Hurricane Katrina. Significant beach and small dune erosion resulted from Katrina's wave energy and surge. Pelican-Sand Island was also shifted a considerable distance to the northwest, connecting it to the extreme southern end of the Dauphin Island Pier. The developed and undeveloped west end of Dauphin Island received the greatest impacts from Hurricane Katrina. The developed portion of the west end suffered severe overwash scars and several homes were destroyed. The undeveloped segment suffered a two-kilometer breach due to the hurricane's powerful storm surge (Froede 2008).

2.8 Hurricane Katrina's Impact on the Mississippi Barrier Islands

Hurricane Katrina also significantly impacted Cat Island, West Ship Island, East Ship Island, Horn Island, and Petit Bois Island. Cat Island and East and West Ship Islands received the strongest and highest storm surge associated with Katrina. Small structures that survived category five Hurricane Camille (1969) on Cat Island, were completely destroyed by Hurricane Katrina's storm surge. Camille produced an approximate storm surge of five meters on Cat Island, while Hurricane Katrina inundated the island with a surge of nearly eight meters. Due to East Ship Island's low elevation, forests on the island were severely damaged and completely removed in most areas by Hurricane Katrina. Katrina's surge and powerful waves also significantly widened the Camille Cut which separates West Ship Island from East Ship Island. The storm surge from Katrina was less intense on Horn Island, Petit Bois Island, and Dauphin Island, ranging from 3.5 to 5.5 meters in height (Fritz, et. al. 2007).

2.9 Hurricane Katrina's Impact on Barrier Island Vegetation

Hurricane Katrina was responsible for vegetation destruction on the Mississippi and Alabama barrier islands. Salt water intrusion and overwash from the hurricane's storm surge significantly impacted the vegetation especially on Cat Island and East Ship Island. Pine trees suffered the worst from the salt water flooding, and from the high winds generated by Hurricane Katrina. The storm surge overwash was responsible for removing vegetation on the northern and southern exposed peninsulas of Cat Island. A precipitation drought persisted after the landfall of Hurricane Katrina, resulting in significant vegetation loss. The salt that was washed onto the vegetation from the storm surge lingered due to the lack of rainfall. Thus, plant species, that would have otherwise survived Katrina's immediate impacts, perished. Less than one year after Katrina's landfall, East Ship Island had lost nearly 100 percent of all its pine trees. Horn Island is home to extensive, dense pine forests which are elevated compared to East Ship Island. Therefore, the damage to these forests from salt water flooding and overwash from Katrina was limited (Otvos, Carter 2008).

2.10 Hyperspectral Analysis of Horn Island

The major barrier islands off the coast of Mississippi have steadily diminished in size since they were mapped in the 1850s. Horn Island is the largest of the Mississippi barriers, and it is located approximately 15 kilometers south of the mainland Mississippi coastline. A 2004 study used LiDAR and Hyperspectral imagery to map various species of flora and dunes, as well as determine the total size of Horn Island. The results of the study were compared to a similar study conducted in 1978 to determine the change in specific features on Horn Island, in addition to the island's total size. Fresh water ponds and lagoons on Horn Island increased in size by eight hectares from 1978 to 2004. The shoreline of Horn Island diminished from 157 hectares to 113 hectares. Beach dunes and stable dunes lost a total of 63 and 52 hectares, respectively. The meadow and marsh categories gained 143 and 76 hectares, respectively. Woodland areas were reduced in size from 190 hectares to 96 hectares over the course of the study period. Horn Island's total size diminished from 1339 hectares to 1313 hectares from 1978 to 2004 (Lucas, Carter 2010).

2.11 Landsat Based-Analysis of the Grand Bay National Estuarine Research Reserve

The Grand Bay National Estuarine Research Reserve (GBNERR) is located just north of Petit Bois Island. The boundaries of the GBNERR are located in extreme southeastern Mississippi. The land cover within the GBNERR is similar to the barrier islands off the coast of Mississippi. The GBNERR is dominated by pine forests, wetlands, open water, and barren land. This study utilized Landsat MSS, Landsat TM, and Landsat ETM+ imagery. Unsupervised classifications and NDVI analyses were performed to delineate boundaries of open water, pine forests, barren land, and wetlands. The results of this research showed that wetlands made up 56% of the total area of the GBNERR in 1974. However, wetlands only made up 50% of the GBNERR in 2001. The area of open water increased throughout the study period, likely due to erosion and sea-level rise. The area of forests increased slightly, and the area of barren land decreased slightly (Hulbert 2006).

2.12 Remote Sensing Based Assessment of Hurricane Katrina's Impacts in Louisiana

Various types of remotely sensed data were used to map changes brought to Louisiana by Hurricane Katrina in 2005. High resolution imagery from satellites such as QuickBird and Ikonos was used to identify changes in the urban landscape in the New Orleans area. These high resolution images clearly showed levee breaches and urban flooding within New Orleans. Thus, higher spatial resolution imagery proved to be the best type of data for monitoring urban change after hurricane events. However, moderate spatial resolution with higher spectral resolution imagery was proven to be more effective for mapping wetlands and vegetation. Landsat TM and MODIS imagery were used to map wetland losses after Hurricane Katrina and monitor its recovery post storm. Landsat and MODIS imagery determined that Hurricane Katrina destroyed 260 square kilometers of wetlands in southeastern Louisiana (Klemas 2009).

2.13 Landsat TM Analysis of Hog Island, Virginia

Landsat TM data was utilized to monitor changes in landform features on Hog Island, which is located off the coast of Virginia. The methodology began by collecting Landsat TM imagery during the late summer months of the following years: 1984, 1988, 1993, 1998, 2004, and 2010. The Landsat TM scenes were subset to only include Hog Island. Supervised classifications, using the maximum likelihood classifier method, were performed using the ENVI 4.7 software package. All pixels within the subset image were categorized into the following five classes: woody, bare sand, grassland, water, and marsh. Results showed a 37% net loss in bare sand and a 14% net loss in grassland areas throughout the study time period. Woody vegetation increased 285% from 1984 to 2010. Throughout the study time frame, there was very little change in the total area of Hog Island (Zinnert et al. 2011).

2.14 Remote Sensing and GIS-Based Analysis of Cedar Island, Virginia

Aerial photography, high resolution satellite imagery, and topographic maps were utilized to analyze shoreline erosion on Cedar Island, Virginia. Cedar Island is an undeveloped, unpopulated barrier island off the southeastern coast of Virginia near the Delmarva Peninsula. The authors' methodology began by collecting archived Naval Oceanographic Service topographic maps for the following years: 1852, 1910, 1959, 1960, 1961, 1962, and 1980. These were used to digitize the shoreline of Cedar Island for the previously mentioned years. An archived USGS digital orthophoto quadrangle was used to delineate the 1994 shoreline. Data from the Virginia Geographic Information Network was used to digitize the shoreline boundary for 2002. Ikonos imagery was collected to digitize the 2006 shoreline of Cedar Island, and an aerial photograph was used to delineate the 2007 shoreline. GPS coordinates were used to georeference the 2007 aerial photograph. These digitized shorelines were analyzed using ArcMap. The results show that the island's endpoints regressed at a rate of 4.6 meters per year from 1852 to 2007. However, from 1994 to 2007, the island's endpoints regressed at a rate of 12.6 meters per year (Nebel et al. 2012).

3. METHODOLOGY

3.1 Landsat 5 TM Overview

Landsat 5 Thematic Mapper (TM)		
Band	Spectral Resolution (micrometers)	Spatial Resolution (meters)
Band 1: Blue	0.45-0.52	30X30
Band 2: Green	0.52-0.60	30X30
Band 3: Red	0.63-0.69	30X30
Band 4: Near Infrared	0.76-0.90	30X30
Band 5: Mid Infrared	1.55-1.75	30X30
Band 6: Thermal	10.40-12.50	120X120
Band 7: Mid Infrared	2.08-2.35	30X30

Table 2: Landsat 5 TM characteristics

The methodology of this study began by collecting archived satellite imagery from Landsat 5 Thematic Mapper(TM), beginning in 1984. Landsat 5 was lauched on March 1, 1984, thus the reason for the study time period beginning in 1984. Landsat 5 TM has a total of seven different bands with a spectral range of 0.45-12.5 micrometers (Table 2). The swath width of Landsat 5 TM is 185 kilometers, and the image size produced from the sensor 185x172 kilometers. Orginally, Landsat 5 had another sensor onboard, the Multispectral Scanning System(MSS). However, the MSS sensor was discontinued in August 1995 (NASA 2012). Therefore, this study will only utilize imagery acquired by the Thematic Mapper sensor.

3.2 Landsat 5 TM Image Acquisition

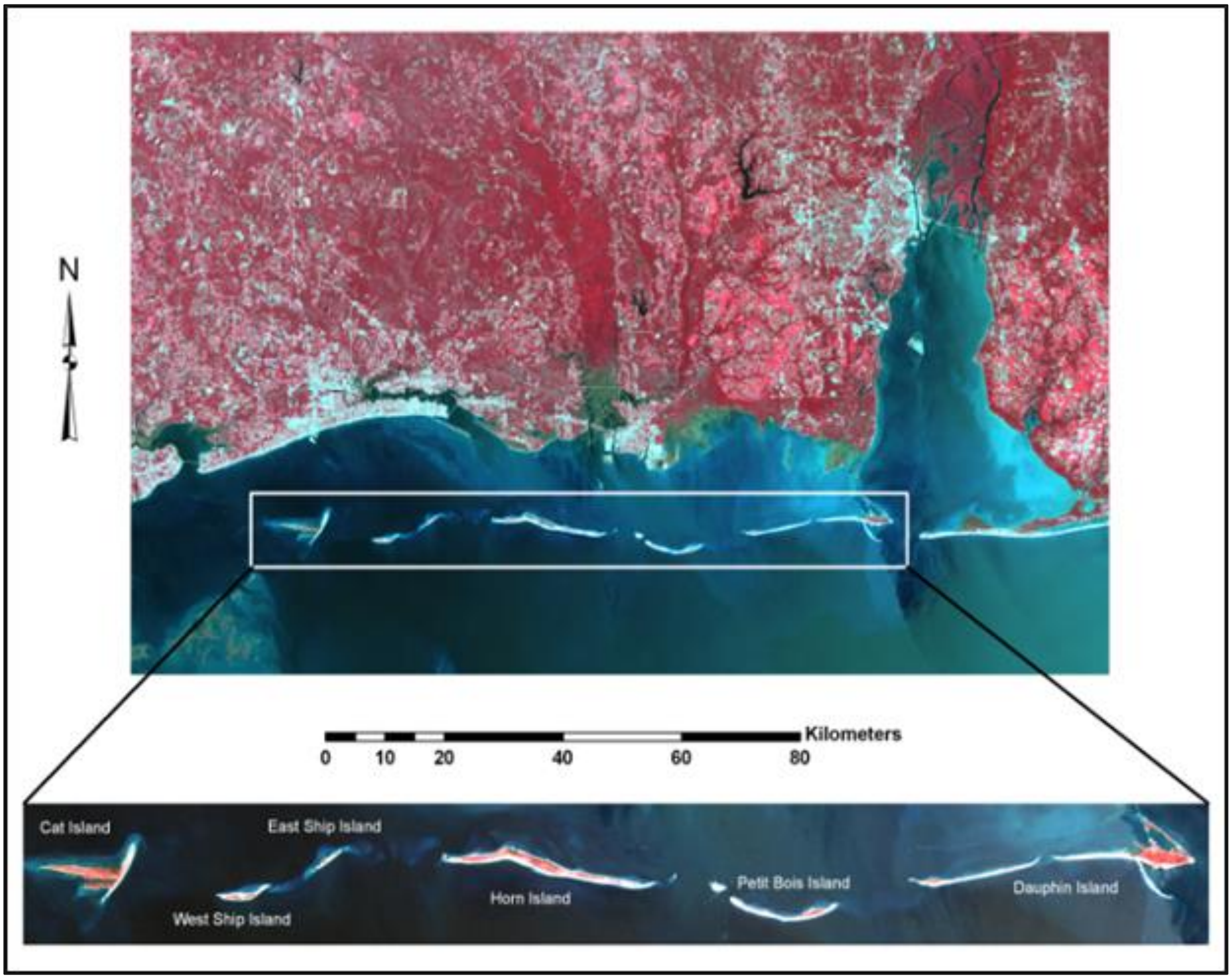

Figure 3: Study area map showing all six barrier islands

Landsat 5 TM imagery was acquired using the United States Geological Survey's Global Visualization Viewer (GLOVIS). One Landsat 5 TM image covers the entire study area (Figure 3). Therefore, only one image was needed per date. Images for this study were only collected for summer months in order to ensure maximum vegetation growth on each island. Also, only cloud free images were acquired for this analysis.

The study began by collecting images in an eight year interval starting from 1984 and ending in 2008. The first four images that were acquired from GLOVIS were orginally captured by Landsat 5 on the following dates: September 6, 1984, September 12, 1992, August 17, 2000, and August 7, 2008. The acquisition of this data allowed for an analysis to show the change in the land and vegetation area associated with all six islands in eight year intervals.

Next, Landsat 5 TM imagery was aquired from GLOVIS to show the impacts that Hurricanes Georges, Ivan, Katrina, Gustav, and Ike brought to each island, individually. One Landsat 5 TM image was acquired for August 28, 1998, and one was also retrieved for September 16, 1999. This allowed for an analysis that would show the impacts brought by Hurricane Georges on September 28, 1998. The image from August 28, 1998, showed the state of the islands before Georges made landfall on the northern Gulf Coast. The image from September 16, 1999, was used to show the state of the vegetation and land area of each island nearly one year after Georges impacted the northern Gulf Coast.

Images were also aquired for the dates of June 9, 2004, and June 12, 2005. This allowed for an analysis which showed the impacts brought to each island by Hurricane Ivan on September 16, 2004. The June 9, 2004 image was used show the total land and vegetation area of each island before Hurricane Ivan made landfall in Gulf Shores, Alabama. The image from June 12, 2005, was utilized to show how Ivan effected each island’s land and vegetation area.

The image from June 12, 2005, was also utilized to show the land and vegetation area of each island before Hurricane Katrina devestated the northern Gulf Coast on August 29, 2005. One image was also aquired for the date of September 3, 2006. This image was used to show

how the land and vegetation area of each island changed after Katrina made landfall in Louisiana and Mississippi.

The August 7, 2008 image was also utitlized to show the total area of land and vegetaiton of all six islands before Hurricanes Gustav and Ike effected the region on September 1, 2008 and September 12, 2008, respectively. An image from the date of July 9, 2009, was also aquired from GLOVIS. This image was utilized to show the impacts that Hurricanes Gustav and Ike brought to all six islands in the study area.

Two images, from September 14, 2010 and August 16, 2011, were also aquired from GLOVIS. These images were utilized to show the state of the islands' vegetation and land area during the most recent two years of the study time frame.

3.3 Image Pre-Processing

Each Landsat 5 TM scene was analyzed using the ERDAS IMAGINE software package. The Landsat 5 TM images were geometrically corrected using latitude and longitude coordinates from Google Earth scenes. The neareast neighbor resampling method was used to geometrically rectify each Landsat 5 TM scene in this study image (Lillesand et al. 2008). Geometric corrections were performed in order to elminate any geometric distortions from the raw digital image.

3.4 Image Analyses

Each island was subset from each Landsat 5 TM scene using the ERDAS IMAGINE software package. Next, supervised classifications were performed on each island in each subset image. The supervised classifications were performed using the maximum likelihood classifier. All six islands are primarily dominated by sand, fresh water lakes, pines, shrubs, and marsh. Thus, supervised classifications were used to seperate areas of water, sand, pines/shrubs, and marsh into individual classes on each island. The pines and shrubs grow together in most areas on all six islands. Therefore, pines and shrubs were grouped into one class. After the supervised classifications were completed, the total area of sand, pines/shrubs, and marsh on each island was calculated. The areas of sand, pines/shrubs, and marsh were summed in order to quantify the total land area of each island. The mean area of total land and vegetation cover throughout the entire study time frame was also determined for each island. Color coded images were created to show areas of water, sand, pines/shrubs, and marsh on each subset image for each year during the study time period. These color coded images were also created to effectively illustrate how the size and land cover of each island has changed from 1984 to 2011.

In addition to supervised classifications, NDVI analyses were performed on each subset image using the ERDAS IMAGINE and ArcGIS software packages. NDVI analyses were used to identify the total area of healthy vegetation on each island. The NDVI analyses were created using the following algorithm: (Near Infrared Band – Red Band / Near Infrared Band + Red Band) (Lillesand et al. 2008). Therefore, the NDVI algorithm used for Landsat 5 TM images was: (Band 4 – Band 3 / Band 4 + Band 3). The NDVI analyses produced new images with new cell values. The new NDVI images had cell values ranging from -1 to 1. Values ranging from -1 to 0 were considered to be water. For this study, values ranging from 0 to 0.1 were considered to be sand or unhealthy vegetation, and values ranging from 0.1 to 1 were considered healthy vegetation (Hulbert 2006). The NDVI analyses were performed to quantify the total area of healthy vegetation on each island for each year in the study time period.

Accuracy assessments were performed using the Equalized Random method in ERDAS IMAGINE. The accuracy of the September 14, 2010 supervised classification images for Cat Island, West Ship Island, East Ship Island, Horn Island, and Petit Bois Island was assessed using a Google Earth image from September 2, 2010. The accuracy of the August 16, 2011 Dauphin Island supervised classification image was assessed using a Google Earth image from July 31, 2011. No Google Earth scenes were available to assess the accuracy of the other classified subset images.

A total of 48 sample points were placed on Cat Island, Horn Island, Petit Bois Island, and Dauphin Island supervised images. An equal number of sample points were given to each class. Therefore, 12 sample points were given to the water class, sand class, pine/shrub class, and the marsh class.

Due to the small size of West and East Ship Island, a fewer number of sample points were used. West Ship Island was given a total of 21 sample points. Because there is very little marsh on West Ship Island, the marsh category was omitted from the accuracy assessment. Seven sample points were given to the water class, the sand class, and the pine/shrub class. East Ship Island was given a total of 15 sample points. Because East Ship Island had very little marsh in 2010, the marsh category was also omitted from the Island's accuracy assessment.

Therefore, five sample points were given to each the water class, sand class, and pine/shrub class.

The coordinates of these points were matched with the Google Earth imagery to determine the accuracy of the supervised classifications. First, the accuracy of the supervised classifications was determined for each island. Afterwards, the total number of sample points, and the total number of accurately classified sample points on all six islands were used to determine the accuracy of all six supervised classifications, combined.

Shapefiles for each island were also created using the September 6, 1984 and August 16, 2011 images. The shapefiles were created using ArcMap (Nebel et al. 2012). Using ArcMap, polylines were traced along the shorelines of each island, in an effort to show how the shape of each island has changed throughout the entire study time period. These shapefiles were also created to show how the shorelines of each island have eroded and receded.

3.5 Field Photographs

Photographs were taken in the field in select locations on Dauphin Island (Figures 75-86). Photographs were taken in order to show true ground conditions in select locations on Dauphin Island. Because most of the island is private property, the photograph locations were limited. However, a number of photographs were takin in the National Audubon Bird Sanctuary near the eastern end of Dauphin Island. The bird sanctuary is a protected area, and it allows individuals to view this portion of the island in pristine condition before human settlement and development. Photographs were taken along the eastern most point of Dauphin Island showing

Pelican Bay. Marsh along the northern shore of Dauphin Island was also photographed. Photographs, showing the connecting point of Dauphin Island and Pelican-Sand Island and the western most point of human development, were also taken. Access to the undeveloped portion of Dauphin Island is not allowed. Therefore no photographs were taken along undeveloped western segment. Over 100 photographs were taken on Dauphin Island. Some of the photographs were redundant, and some were of low quality. Therefore, only a select few were added to this research. Due to no available boat access, zero photos of locations on the Mississippi barrier islands were taken.

3.6 Acquisition of Other Variables

In addition to analyzing the impacts of the five hurricane events in this study, the trends of temperature, precipitation, and sea levels were also examined. The temperature, precipition, and sea level data were aquired from the National Atmospheric and Oceanic Administration (NOAA) observation station located on the eastern end of Dauphin Island. Because Dauphin Island is the only island in this study with a weather station dating before 1984, the data from this station were used for the entire study area. The data were used to indicate other factors that may contribute to land area and vegetation decline on each island throughout the study time period.

4. RESULTS

4.1 Cat Island

Cat Island				
Date	Total Land Area (hectares)	Healthy Vegetation (hectares)	Pines and Shrubs (hectares)	Marsh (hectares)
9-06-84	898	627	456	282
9-12-92	851	506	448	254
8-28-98	894	490	443	264
9-16-99	701	443	394	119
8-17-00	823	487	374	321
6-09-04	829	584	363	285
6-12-05	817	506	251	371
9-03-06	565	277	212	104
8-07-08	715	531	391	223
7-09-09	686	415	230	306
9-14-10	684	488	347	234
8-16-11	683	433	259	263

Table 3: Cat Island land area and vegetation cover change

Cat Island Mean Deviation				
Date	Total Land Area (mean = 762)	Healthy Vegetation Area (mean = 482)	Pines and Shrubs Area (mean = 347)	Marsh Area (mean = 252)
9-06-84	+136	+145	+109	+30
9-12-92	+89	+24	+101	+2
8-28-98	+132	+8	+96	+12
9-16-99	-61	-39	+47	-133
8-17-00	+61	+5	+27	+69
6-09-04	+67	+102	+16	+33
6-12-05	+55	+24	-96	+119
9-03-06	-197	-205	-135	-148
8-07-08	-47	+49	+44	-29
7-09-09	-76	-67	-117	+54
9-14-10	-78	+6	0	-18
8-16-11	-79	-49	-88	+11

Table 4: Deviation from the mean area of each category on Cat Island

Cat Island Total Land Area		
Storm	Percentage Change	Area Change (Hectares)
1. Katrina (2005)	-30.84%	817-565
2. Georges (1998)	-21.59%	894-701
3. Gustav/Ike (2008)	-4.06%	715-686
4. Ivan (2004)	-1.45%	829-817
Total (1984-2011)	-23.94%	898-683

Table 5: Ranking each hurricane in terms of percentage change

Cat Island steadily lost land area throughout the study time period (Table 3). The total land area of Cat Island permenantly stays below the mean for all years in this study after Hurricane Katrina's impact (Table 4). Hurricane Katrina proved to be the most devestating in terms of land area loss on Cat Island (Table 5). After Hurricane Katrina devestated the northern Gulf Coast, Cat Island only owned 565 hectares of land. This was not only down 30.86% from the previous year, but it was down 333 hectares (-37.08%) from its total land area in 1984. The island was quickly able to recover a significant portion of its lost land after Hurricane Katrina. From 2006 to 2008, the island gained 150 hectares of land. Cat Island was not able to recover any of the land area it lost after Hurricanes Gustav and Ike impacted the Gulf Coast. (Figures 4-15).

Cat Island Total Healthy Vegetation		
Storm	Percentage Change	Area Change (Hectares)
1. Katrina (2005)	-45.26%	505-277
2. Gustav/Ike (2008)	-21.85%	531-415
3. Ivan (2004)	-13.36%	584-506
4. Georges (1998)	-9.59%	490-443
Total (1984-2011)	-30.94%	627-433

Table 6: Ranking each hurricane in terms of percentage change

Similar to total land area, the total healthy vegetation on Cat Island has experienced a steady decline from 1984 to 2011 (Table 3). Cat Island's area of healthy vegetation fluctuates below and above the mean throughout the entire study period (Table 4). Hurricane Katrina proved to be the most devastating storm in terms of total healthy vegetation destruction on Cat Island (Table 6). After Hurricane Katrina devastated the Gulf Coast, Cat Island's total area of healthy vegetation was down 55.82% from its total in 1984. The island was able to gain 254 hectares of total healthy vegetation from 2006 to 2008. Cat Island has lost 30.94% of its total healthy vegetation from 1984 to 2011.

Cat Island Pines and Shrubs		
Storm	Percentage Change	Area Change (Hectares)
1. Gustav/Ike (2008)	-41.17%	391-230
2. Ivan (2004)	-30.85%	363-251
3. Katrina (2005)	-15.54%	251-212
4. Georges (1998)	-11.06%	443-394
Total (1984-2011)	-43.2%	456-259

Table 7: Ranking each hurricane in terms of percentage change

The pines and shrubs on Cat Island have decline steadily throughout the study time period (Table 3). The area of pines and shrubs on Cat Island stays above the mean until Hurricane Ivan's impact. After Hurricane Ivan, the year 2008 is the only year in which the area of pines and shrubs is above the mean (Table 4). Hurricanes Gustav and Ike were the most devastating in terms of pine and shrub loss on Cat Island (Table7). After the two hurricanes made landfall along the Gulf Coast, the total area of pines and shrubs on Cat Island was down 49.56% from its total in 1984. The island's pines and shrubs rebounded significantly after Hurricanes Gustav and Ike's impacts. From 2009 to 2010, Cat Island gained 117 hectares of pines and shrubs. The island then lost 88 hectares from 2010 to 2011. From 1984 to 2011, Cat Island lost 197 hectares (-43.2%) of its total area of pines and shrubs (Figures 4-15).

Cat Island Marsh		
Storm	Percentage Change	Area Change (Hectares)
1. Katrina (2005)	-71.97%	371-104
2. Georges (1998)	-54.92%	264-119
3. Ivan (2004)	+30.85%	285-371
4. Gustav/Ike (2008)	+37.22%	223-306
Total (1984-2011)	-6.74%	898-683

Table 8: Ranking each hurricane in terms of percentage change

The area of mash on Cat Island has fluctuated significantly throughout the entire study period (Table 3). The area of marsh on Cat Island also fluctuates below and above the mean throughout the study time period. The area of marsh was significantly below the mean after Hurricanes Georges and Katrina (Table 4). Cat Island has seen significantly higher fluctuations in its area of marsh when compared to its neighboring islands (Figure 140). Hurricanes Georges and Katrina significantly reduced the area of marsh on the island. Hurricanes Gustav/Ike and Ivan had no negative impact on the area of marsh on Cat Island. Hurricane Katrina was by far the most destructive in terms of marsh loss on Cat Island (Table 8). After Hurricane Katrina devastated the northern Gulf Coast, the total area of marsh located on Cat Island was down 63.12% from its total in 1984. From 1984 to 2011, Cat Island's marsh only experienced a net loss of 19 hectares (-6.74%) (Figures 4-15).

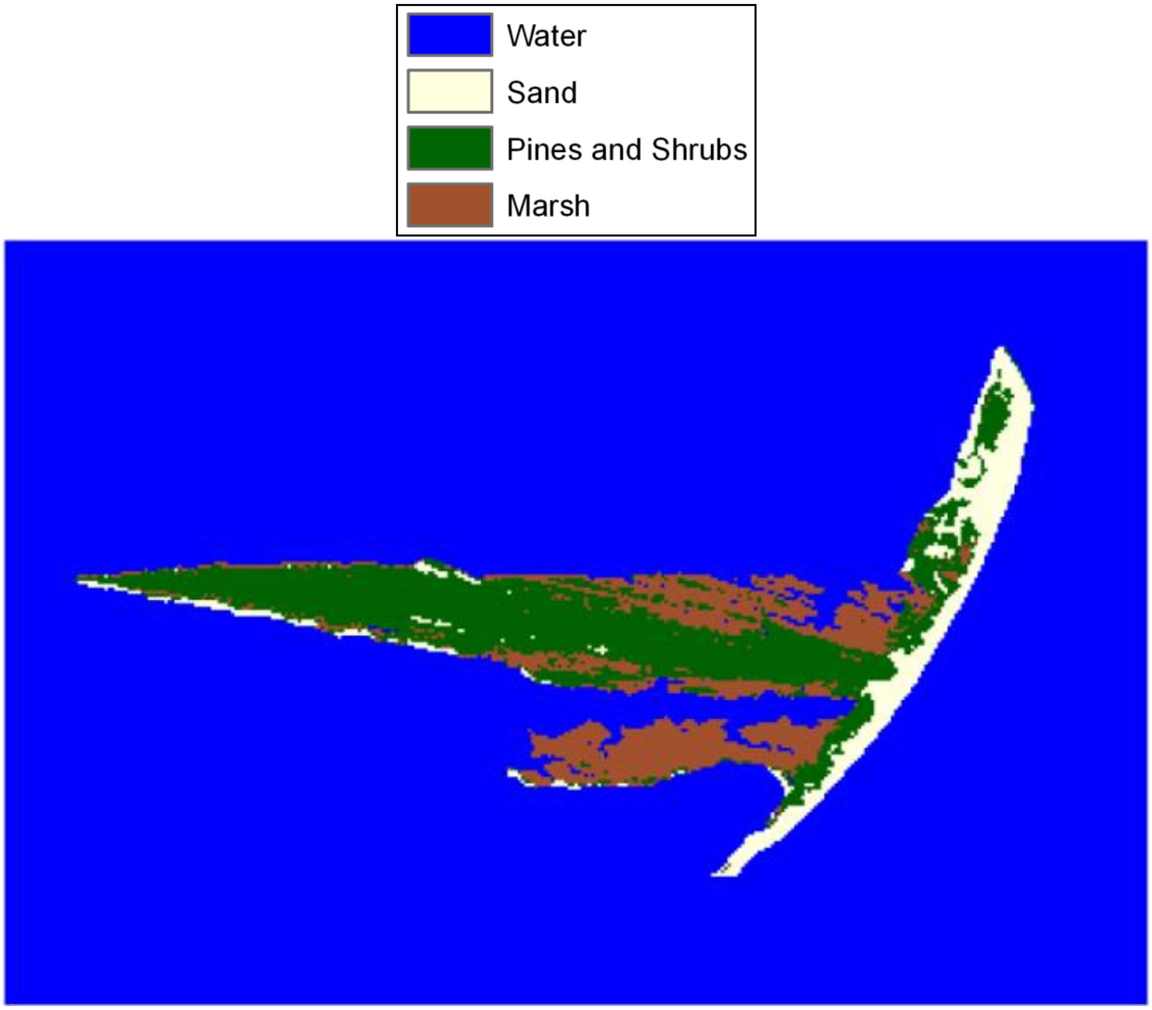

Figure 4: 1984 supervised classification of Cat Island

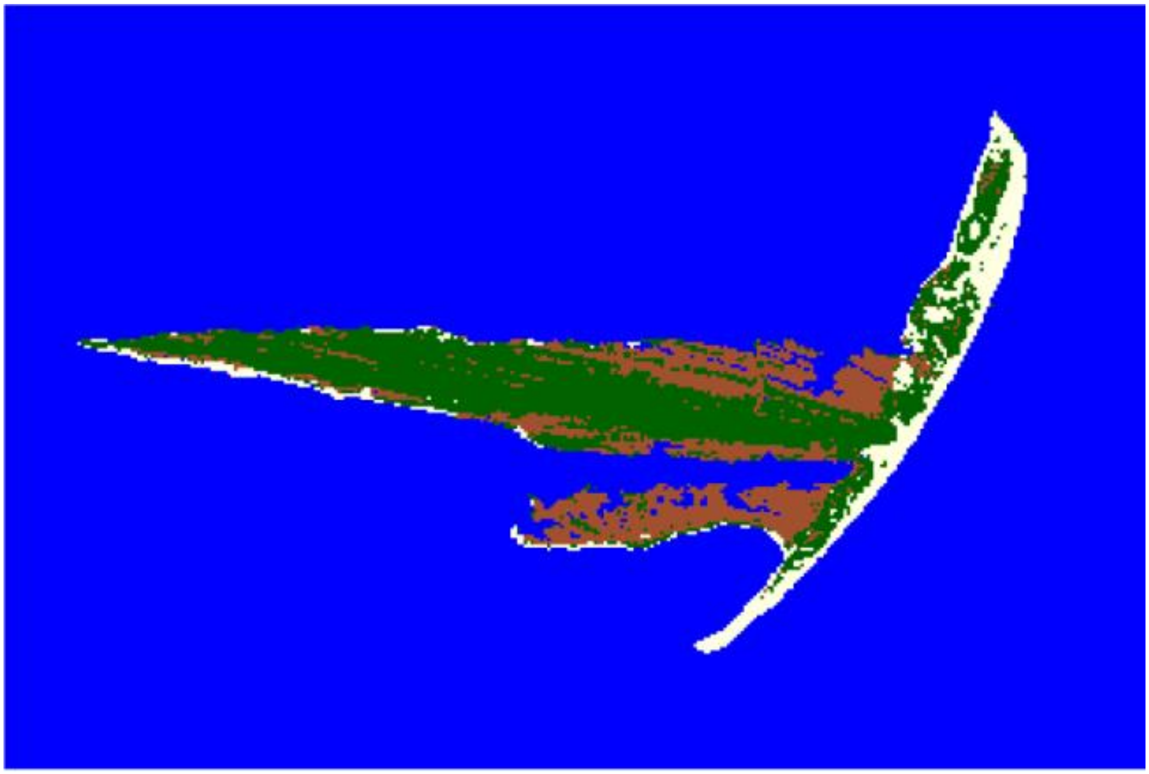

Figure 5: 1992 supervised classification of Cat Island

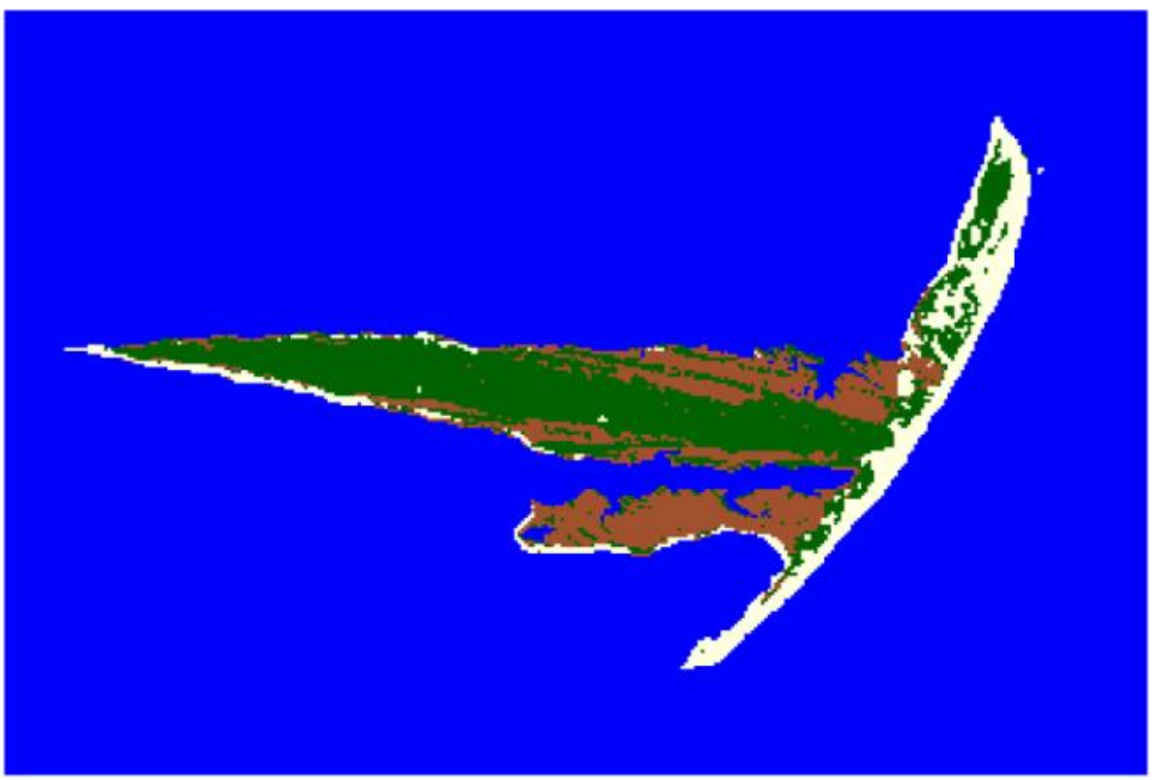

Figure 6: 1998 (prior to Georges) supervised classification of Cat Island

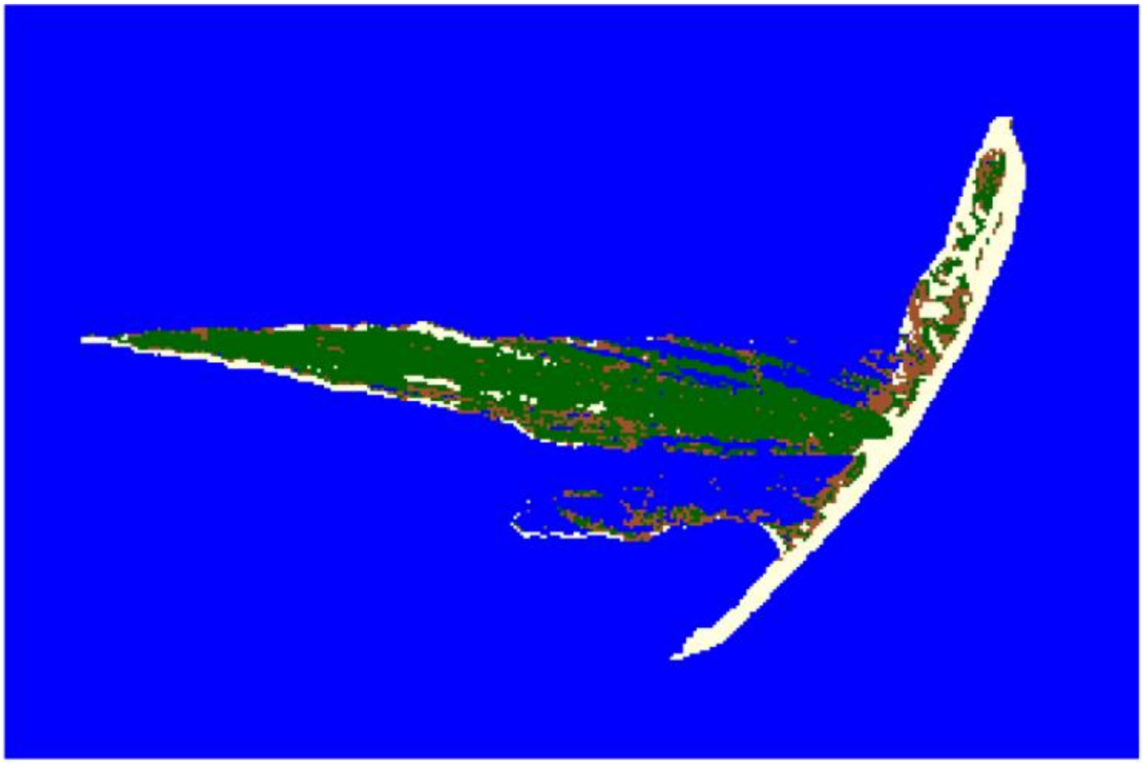

Figure 7: 1999 (after Georges) supervised classification of Cat Island

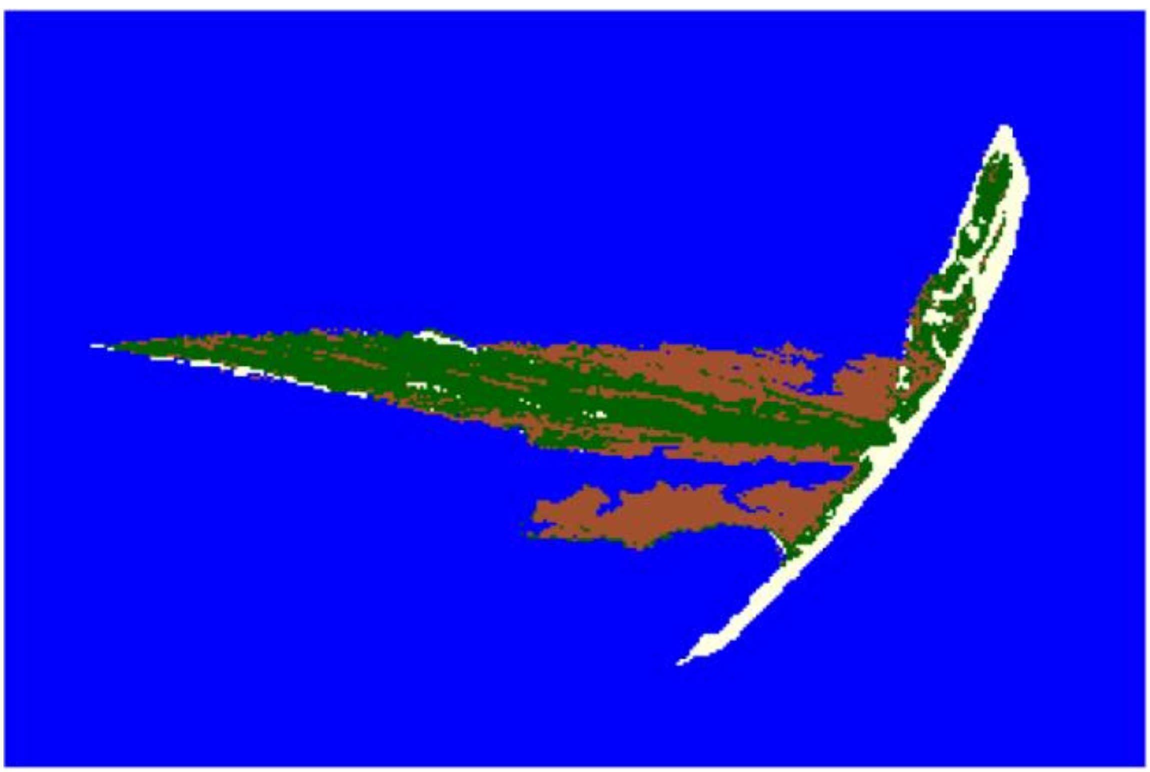

Figure 8: 2000 supervised classification of Cat Island

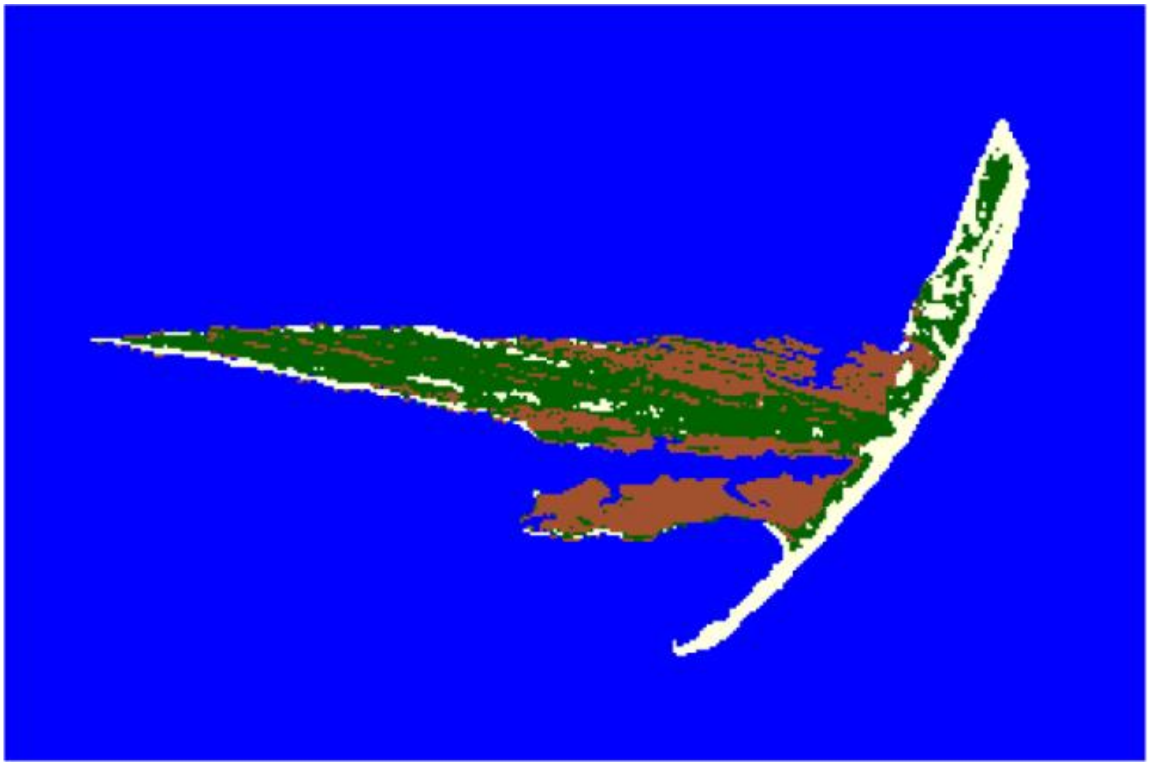

Figure 9: 2004 (prior to Ivan) supervised classification of Cat Island

Figure 10: 2005 (after Ivan, before Katrina) supervised classification of Cat Island

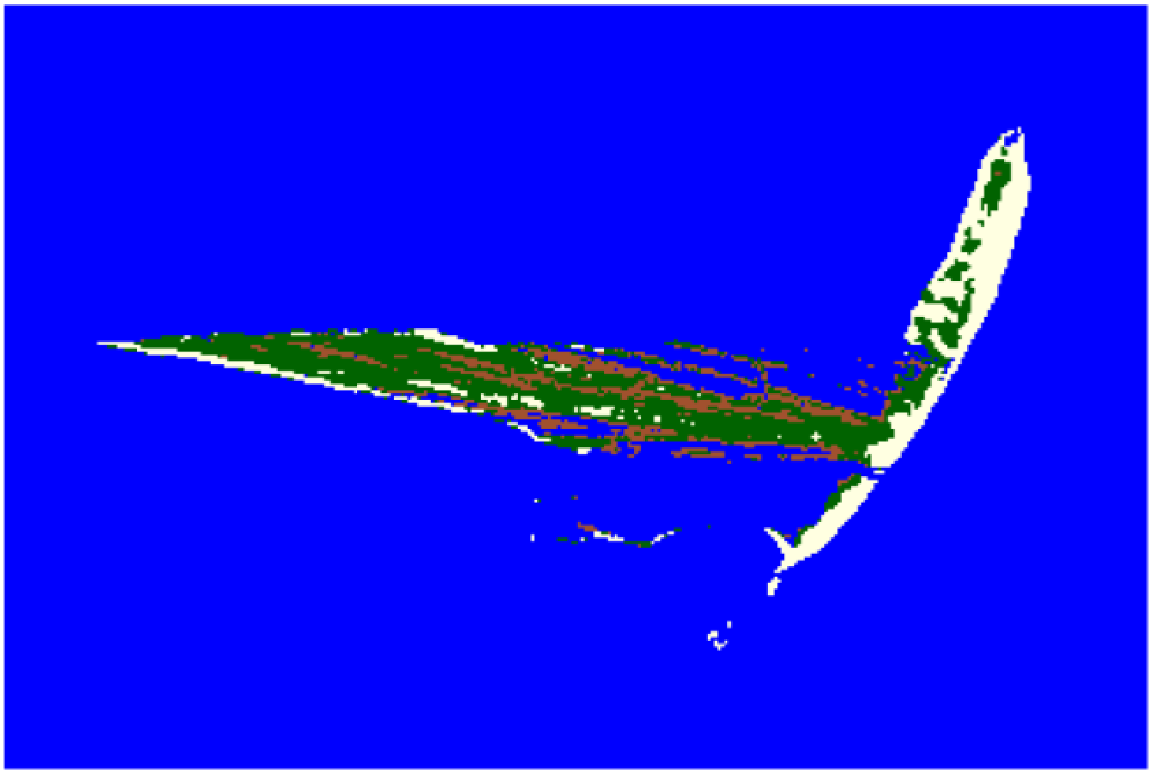

Figure 11: 2006 (after Katrina) supervised classification of Cat Island

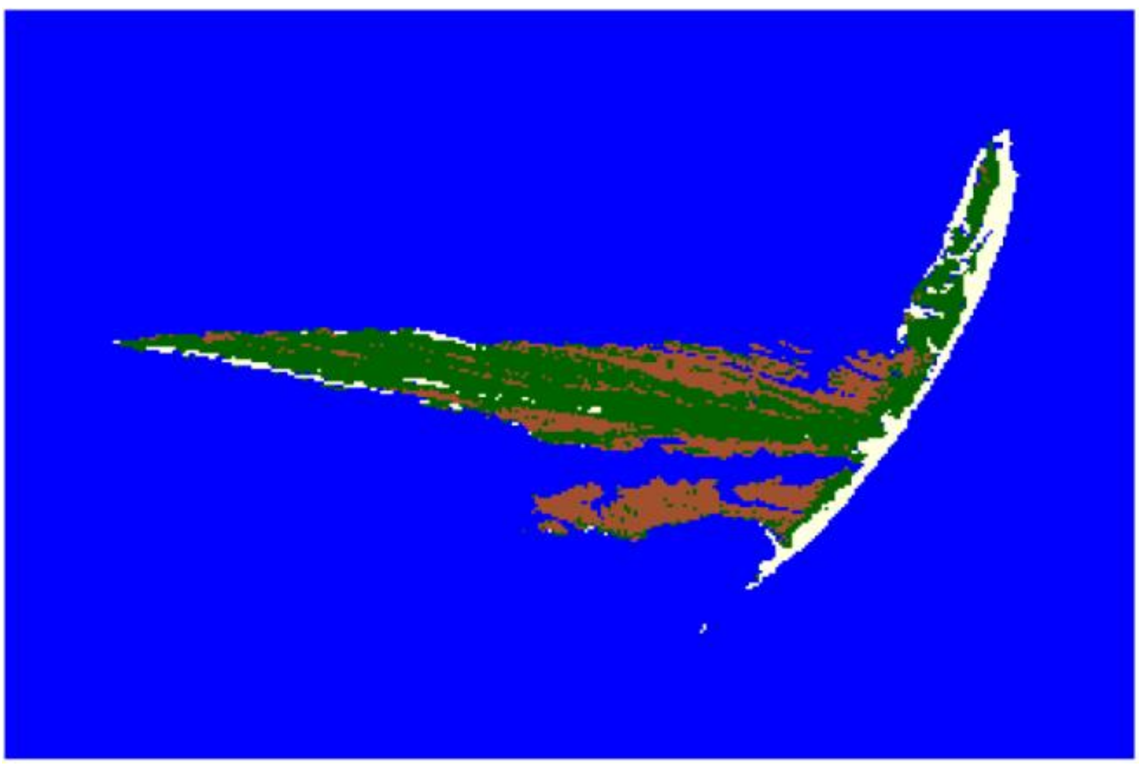

Figure 12: 2008 (before Gustav and Ike) supervised classification of Cat Island

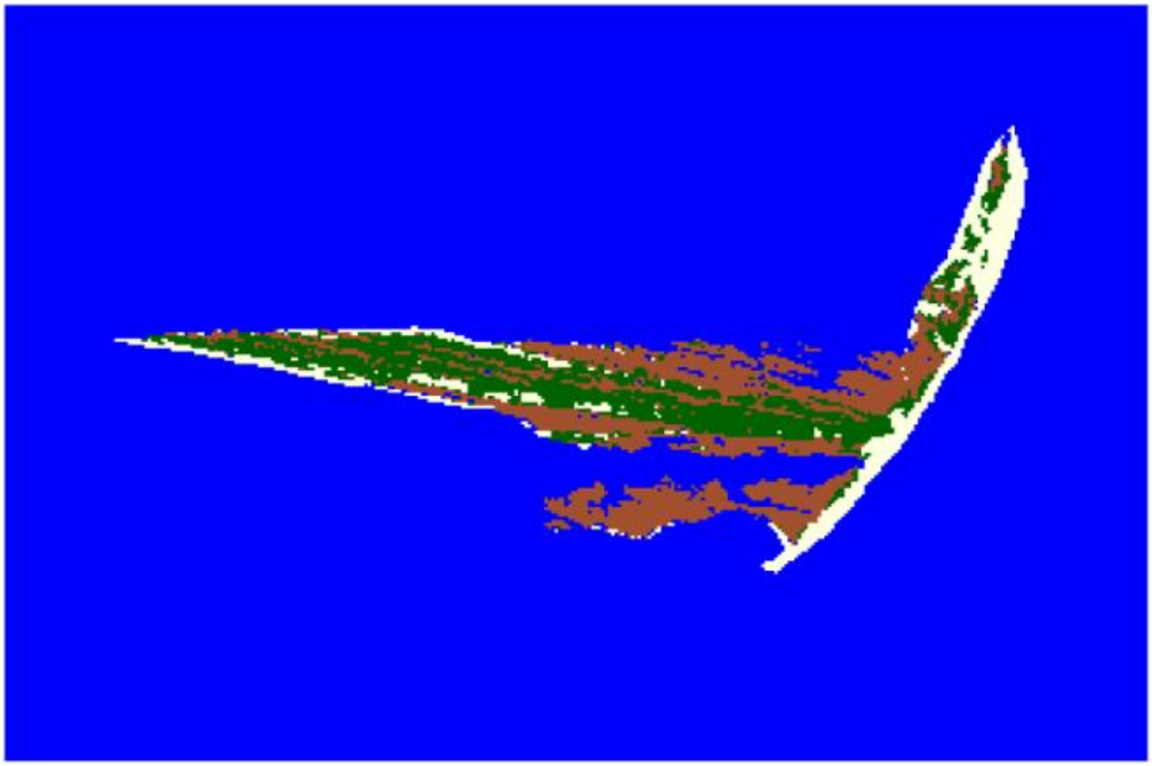

Figure 13: 2009 (after Gustav and Ike) supervised classification of Cat Island

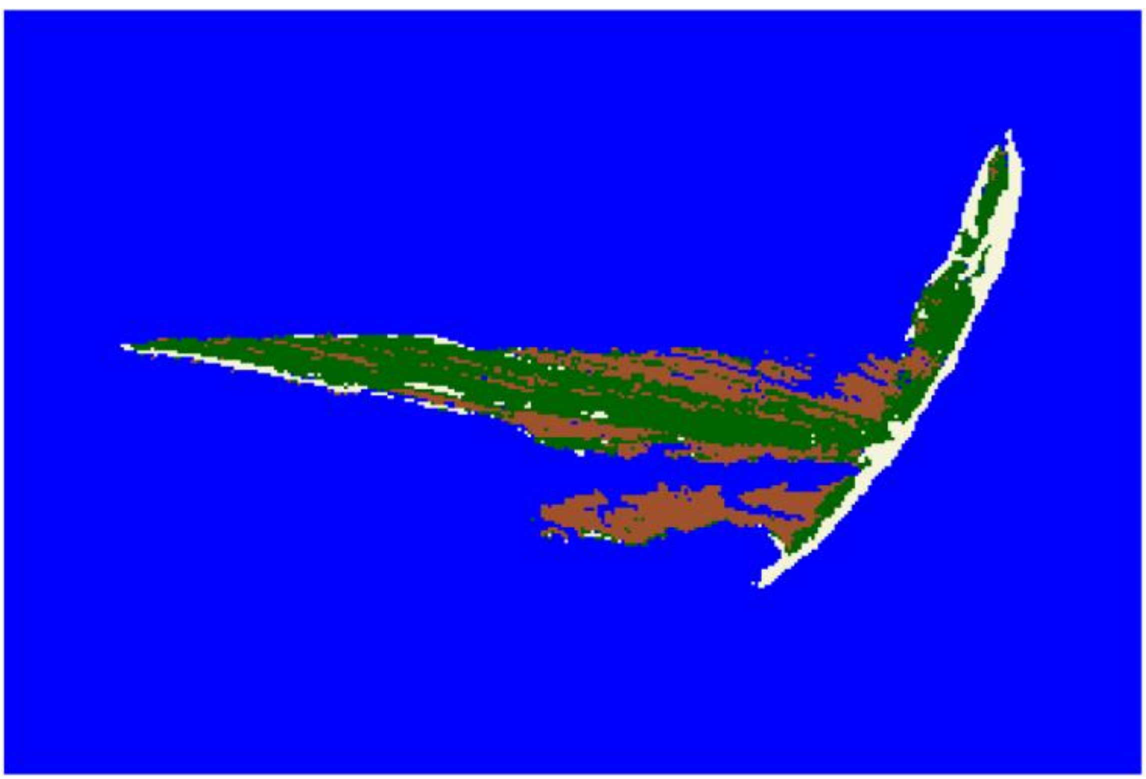

Figure 14: 2010 supervised classification of Cat Island

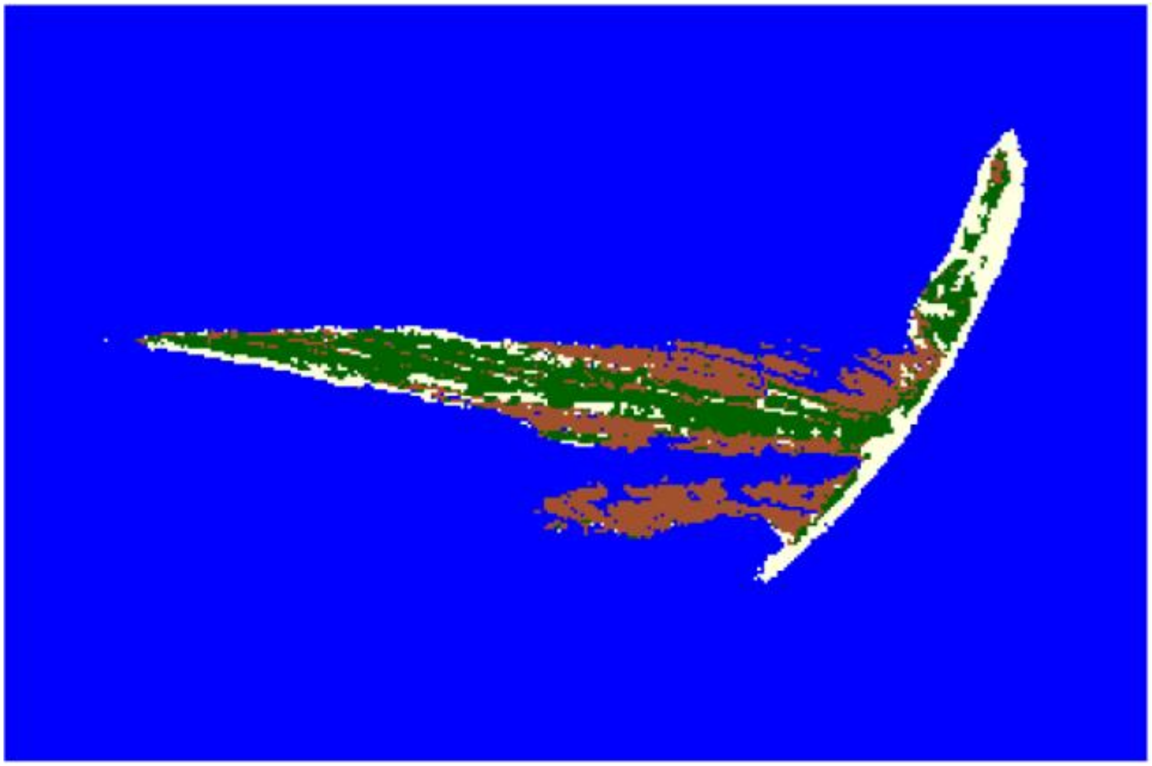

Figure 15: 2011 supervised classification of Cat Island

4.2 West Ship Island

West Ship Island			
Date	Total Land Area (hectares)	Healthy Vegetation (hectares)	Pines and Shrubs (hectares)
9-06-84	238	144	92
9-12-92	212	109	94
8-28-98	224	90	72
9-16-99	206	93	54
8-17-00	187	90	75
6-09-04	194	102	65
6-12-05	168	85	59
9-03-06	168	74	52
8-07-08	143	86	71
7-09-09	158	78	55
9-14-10	159	95	71
8-16-11	160	72	62

Table 9: West Ship Island land area and vegetation cover change

West Ship Island Mean Deviation			
Date	Total Land Area (mean = 185)	Healthy Vegetation (mean = 93)	Pines and Shrubs (mean = 69)
9-06-84	+53	+51	+23
9-12-92	+27	+16	+25
8-28-98	+39	-3	+3
9-16-99	+21	0	-15
8-17-00	+2	-3	+6
6-09-04	+9	+9	-4
6-12-05	-17	-8	-10
9-03-06	-17	-19	-17
8-07-08	-42	-7	+2
7-09-09	-27	-15	-14
9-14-10	-26	+2	+2
8-16-11	-25	-21	-7

Table 10: Deviation from the mean of each category on West Ship Island

West Ship Island Land Area		
Storm	Percentage Change	Area Change (Hectares)
1. Ivan (2004)	-13.4%	194-168
2. Georges (1998)	-8.04%	224-206
3. Katrina (2005)	0%	168-168
4. Gustav/Ike (2008)	+10.49%	143-158
Total (1984-2011)	-32.77%	238-160

Table 11: Ranking each hurricane in terms of percentage change

West Ship Island has experienced a steady decline in its land area from 1984 to 2011 (Table 9). The total area of land stayed permanently below the mean of all years in the study period after Hurricane Ivan (Table 10). Hurricane Ivan proved to be the most devastating storm in terms of land area loss on West Ship Island (Table 11). After Hurricane Ivan struck the northern Gulf Coast, West Ship Island's total land area was down 29.41% from its original total in 1984. The island has lost a total of 78 hectares (-32.77%) of its total land area from 1984 to 2011 (Figures 16-27).

West Ship Island Healthy Vegetation		
Storm	Percentage Change	Area Change (Hectares)
1. Ivan (2004)	-16.67%	102-85
2. Katrina (2005)	-12.94%	85-74
3. Gustav/Ike (2008)	-9.3%	86-78
4. Georges (1998)	+3.33%	90-93
Total (1984-2011)	-50%	144-72

Table 12: Ranking each hurricane in terms of percentage change

The healthy vegetation on West Ship Island also experienced a steady decline throughout the study time period (Table 9). The area of total healthy vegetation fluctuated below and above the mean throughout the entire study period (Table 10). Hurricane Ivan proved to be the most destructive storm in terms of healthy vegetation loss on West Ship Island

(Table 12). After Ivan made landfall along the northern Gulf Coast, West Ship Island's healthy vegetation area was down 59 hectares (-40.97%) from its total of 144 hectares in 1984. The island has lost 72 hectares (-50%) of its total healthy vegetation from 1984 to 2011.

West Ship Island Pines and Shrubs		
Storm	Percentage Change	Area Change (Hectares)
1. Georges (1998)	-25%	72-54
2. Gustav/Ike (2008)	-22.54%	71-55
3. Katrina (2005)	-11.86%	59-52
4. Ivan (2004)	-9.23%	65-59
Total (1984-2011)	-32.61%	92-62

Table 13: Ranking each hurricane in terms of percentage change

The area of pines and shrubs on West Ship Island declined steadily from 1984 to 2011 (Table 9). The area of pines and shrubs fluctuated below and above the mean throughout the study time period (Table 10). Hurricane Georges was the most destructive storm in terms of pines and shrub loss on West Ship Island (Table 13). After Hurricane Georges made landfall on the northern Gulf Coast, West Ship Island's area of pines and shrubs was down 38 hectares (-41.30%) from its total in 1984. However, the area of pines and shrubs increased by 38.89% in the two years after Georges impacted the Gulf Coast. From 1984 to 2011, the island lost 30 hectares (-32.61%) of its total area of pines and shrubs (Figures 16-27).

There was very little marsh area located on West Ship Island from 1984 to 2011. During most years, West Ship Island had less than one hectare of marsh. Therefore, no detailed analysis of marsh area change on the island was performed in this study.

4.3 East Ship Island

East Ship Island				
Date	Total Land Area (hectares)	Healthy Vegetation (hectares)	Pines and Shrubs (hectares)	Marsh (hectares)
9-06-84	159	65	46	8
9-12-92	132	48	47	7
8-28-98	149	48	37	13
9-16-99	119	28	21	5
8-17-00	112	33	25	8
6-09-04	149	35	19	5
6-12-05	89.4	17	14	2.4
9-03-06	45.7	7	6	0.8
8-07-08	50.6	16	10	0.8
7-09-09	50.6	6	3	0.8
9-14-10	60.3	20	7	0.4
8-16-11	80.1	7	4	0.8

Table 14: East Ship Island land area and vegetation cover change

East Ship Island Mean Deviation				
Date	Total Land Area (mean = 100)	Healthy Vegetation (mean = 28)	Pines and Shrubs (mean = 20)	Marsh (mean = 4)
9-06-84	+59	+37	+26	+4
9-12-92	+32	+20	+27	+3
8-28-98	+49	+20	+17	+9
9-16-99	+19	0	+1	+1
8-17-00	+12	+5	+5	+4
6-09-04	+49	+7	-1	+1
6-12-05	-10.6	-11	-6	-1.6
9-03-06	-54.3	-21	-14	-3.2
8-07-08	-49.4	-12	-10	-3.2
7-09-09	-49.4	-22	-17	-3.2
9-14-10	-39.7	-8	-13	-3.6
8-16-11	-19.9	-21	-16	-3.2

Table 15: Deviation from the mean of all categories on East Ship Island

East Ship Island Total Land Area		
Storm	Percentage Change	Area Change (Hectares)
1. Katrina (2005)	-48.89%	89.4-45.7
2. Ivan (2004)	-40%	149-89.4
3. Georges (1998)	-20.13%	149-119
4. Gustav/Ike (2008)	0%	50.6-50.6
Total (1984-2011)	-49.62%	159-80.1

Table 16: Ranking each hurricane in terms of percentage change

East Ship Island has lost a greater percentage of land area than any island in this study (Table 14). The total area of land remained permanently below the mean after Hurricane Ivan made landfall along the northern Gulf Coast (Table 15). The Camille Cut was significantly widened after the impacts of Hurricane Katrina. Significant erosion of East Ship Island led to the widening of the Camille Cut. Hurricane Katrina was the most destructive storm in terms of land area loss on East Ship Island (Table 16). After Hurricane Katrina devastated the Gulf Coast, East Ship Island had lost 113.3 hectares (-71.26%) from its land area total in 1984. However, East Ship Island's land area increased 75.27% from 2006 to 2011. From 1984 to 2011, East Ship Island lost 78.9 hectares (-49.62%) of its total land area (Figures 16-27).

East Ship Island Total Healthy Vegetation		
Storm	Percentage Change	Area Change (Hectares)
1. Gustav/Ike (2008)	-62.5%	16-6
2. Katrina (2005)	-58.82%	17-7
3. Ivan (2004)	-51.43%	35-17
4. Georges (1998)	-41.67%	48-28
Total (1984-2011)	-89.23%	65-7

Table 17: Ranking each hurricane in terms of percentage change

East Ship Island lost a greater percentage of healthy vegetation than any other island in this study. The island experienced a steady decline of healthy vegetation until Hurricane Katrina. After Hurricane Katrina impacted the Gulf Coast, the area of healthy vegetation on East Ship Island began to fluctuate (Table 14). The area of healthy vegetation on East Ship Island remained below the mean after Hurricane Ivan's impact (Table 15). Hurricanes Gustav and Ike were the most destructive storms in terms of percentage of healthy vegetation loss on East Ship Island (Table 17). After the two storms affected the Gulf Coast in 2008, East Ship Island's total area of healthy vegetation had decreased by 59 hectares (-90.77%) from its total in 1984. From 1984 to 2011, East Ship Island lost a total of 58 hectares (-88.89%) of its healthy vegetation.

East Ship Island Pines and Shrubs		
Storm	Percentage Change	Area Change (Hectares)
1. Gustav/Ike (2008)	-70%	10-3
2. Katrina (2005)	-57.14%	14-6
3. Georges (1998)	-43.24%	37-21
4. Ivan (2004)	-26.32%	19-14
Total (1984-2011)	-91.3%	46-4

Table 18: Ranking each hurricane in terms of percentage change

The decline of the area of pines and shrubs on East Ship Island was similar to the area of all healthy vegetation (Table 14). The area of pines and shrubs on the island remained below the mean after June 2004 (Figure 15). Hurricanes Gustav and Ike combined to be the most destructive storms in terms of pine and shrub loss on East Ship Island (Table 18). After the two hurricanes made landfall, East Ship Island's area of pines and shrubs was down 43 hectares (-93.48%) from its total in 1984. From 1984 to 2011, the island lost 42 hectares (-92.04%) of its pines and shrubs. East Ship Island has experienced the greatest percentage decline of its pines and shrubs when compared to its five neighboring islands (Figures 16-27).

East Ship Island Marsh		
Storm	Percentage Change	Area Change (Hectares)
1. Katrina (2005)	-66.67%	2.4-0.8
2. Georges (1998)	-61.54%	13-5
3.Ivan (2004)	-52%	5-2.4
4. Gustav/Ike (2008)	0%	0.8-0.8
Total (1984-2011)	-90%	8-0.8

Table 19: Ranking each hurricane in terms of percentage change

Similar to the area of pines and shrubs and all healthy vegetation, the marsh on East Ship Island has experienced a significant decline (Table 14). The area of marsh on the island remained below the mean after Hurricane Ivan made landfall along the northern Gulf Coast (Table 15). Hurricane Katrina was the most devastating storm in terms of percentage of marsh loss on East Ship Island (Table 19). After the storm made landfall on the northern Gulf Coast, the area of marsh on East Ship Island was down 7.2 hectares(-90%) from its total in 1984. The island's peak in marsh area was in 1998. After Hurricane Katrina, the island had lost 12.2 hectares (-93.85%) of marsh from its total in 1998. From 1984 to 2011, East Ship Island lost 7.2 hectares (-90%) of its total marsh (Figures 16-27).

Figure 16: 1984 supervised classification of West and East Ship Island

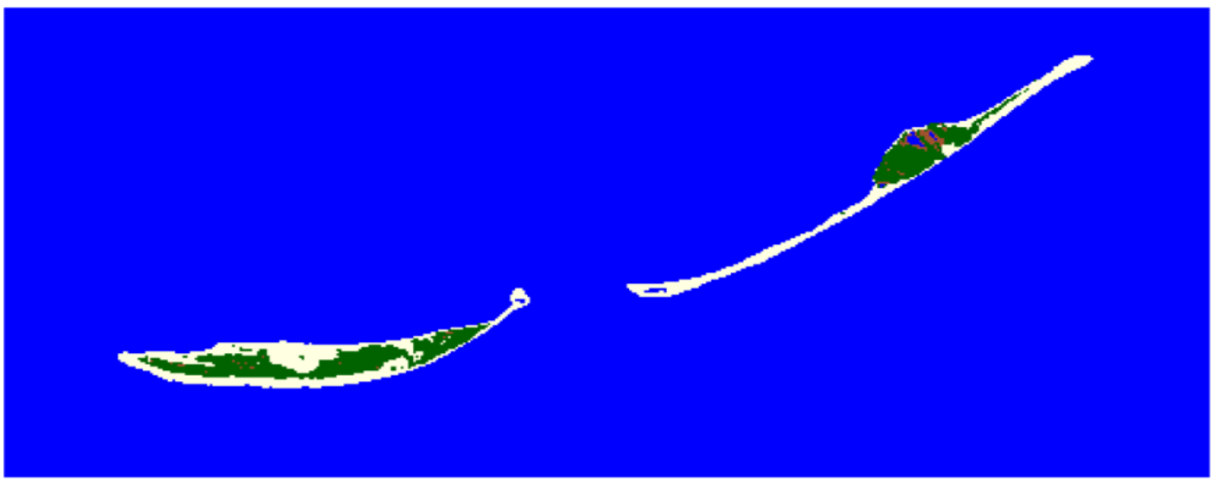

Figure 17: 1992 supervised classification of West and East Ship Island

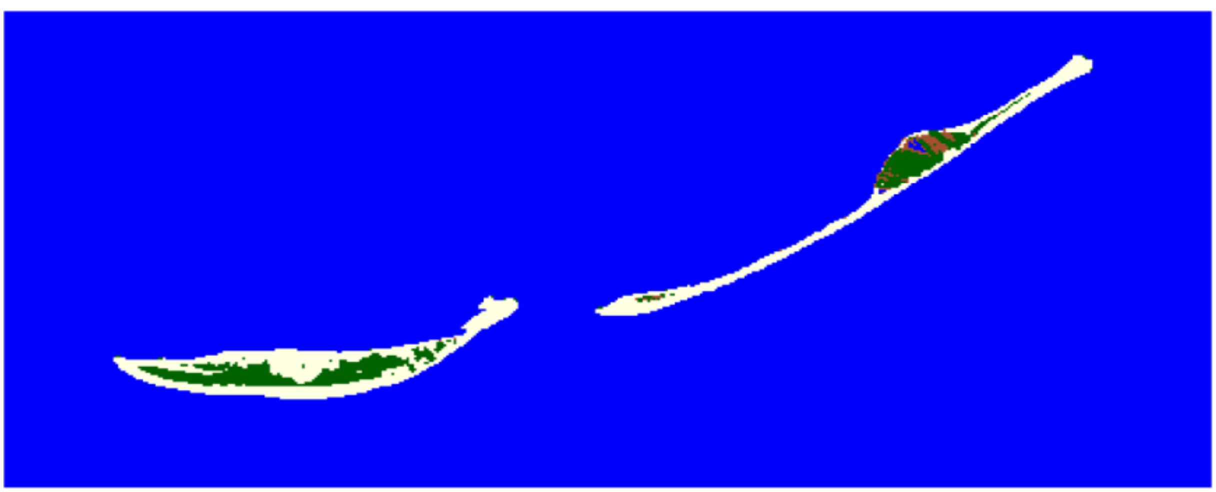

Figure 18: 1998 (before Georges) supervised classification of West and East Ship Island

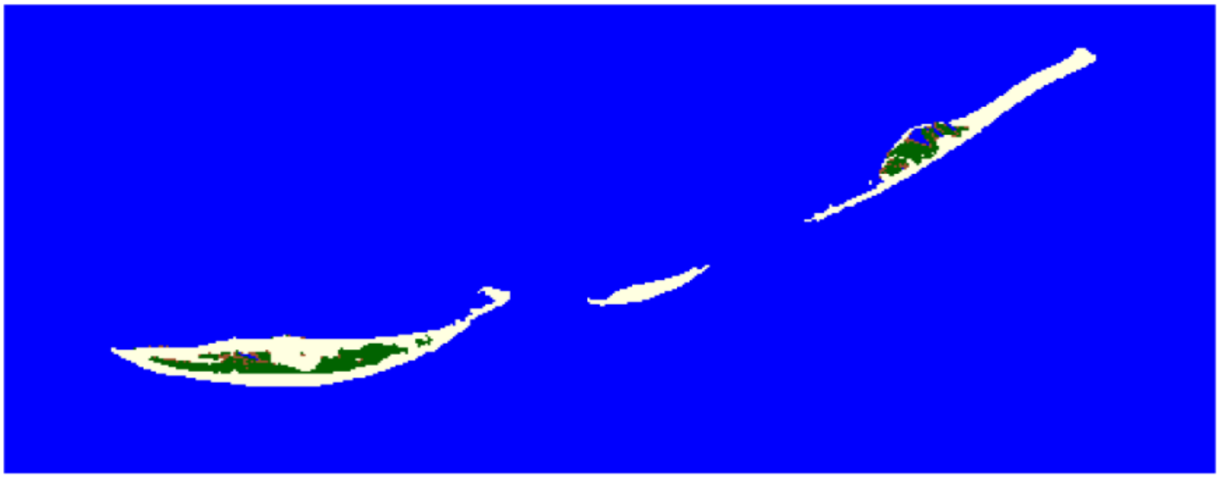

Figure 19: 1999 (after Georges) supervised classification of West and East Ship Island

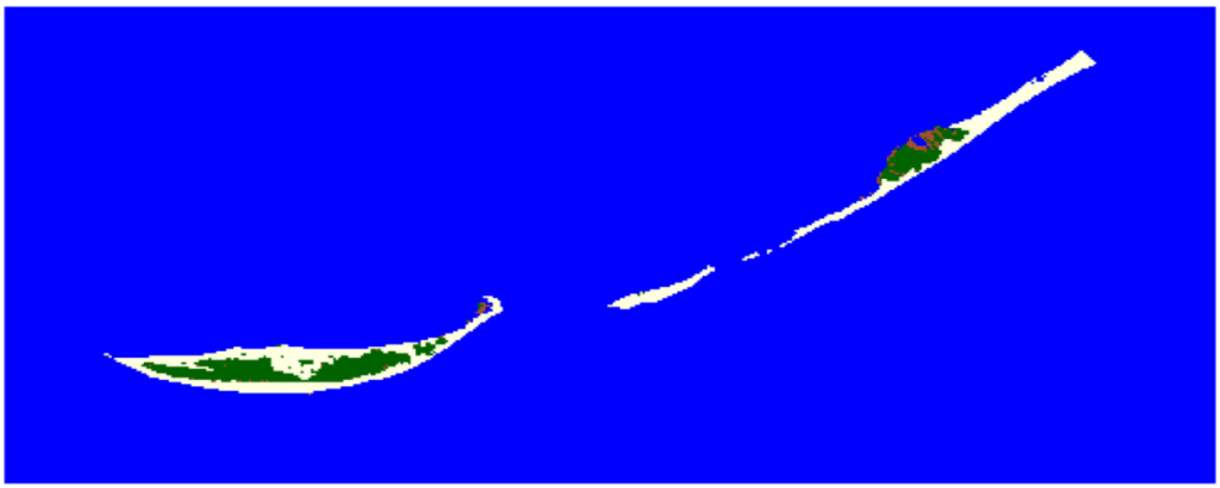

Figure 20: 2000 supervised classification of West and East Ship Island

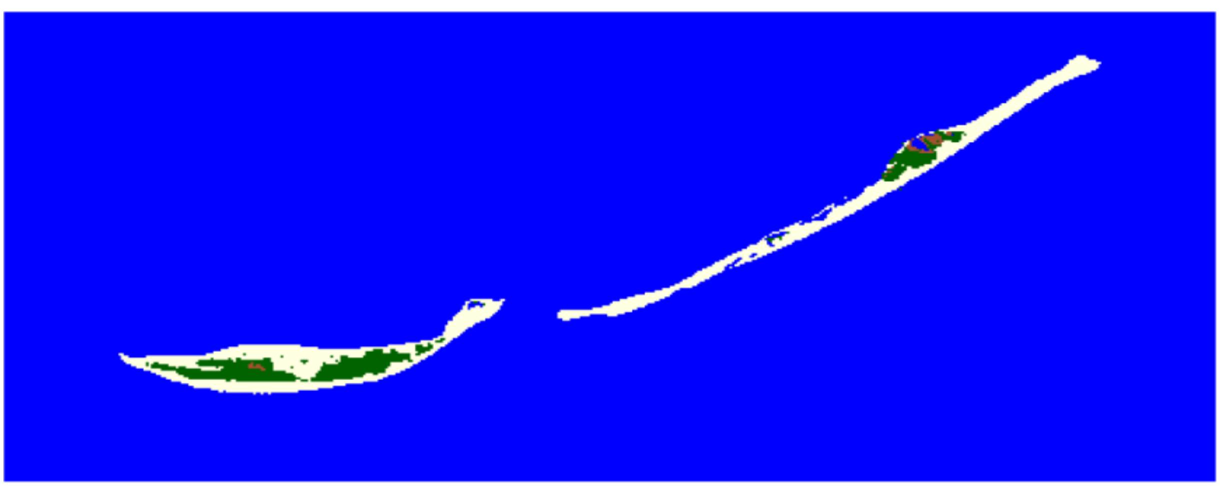

Figure 21: 2004 (before Ivan) classification of West and East Ship Island

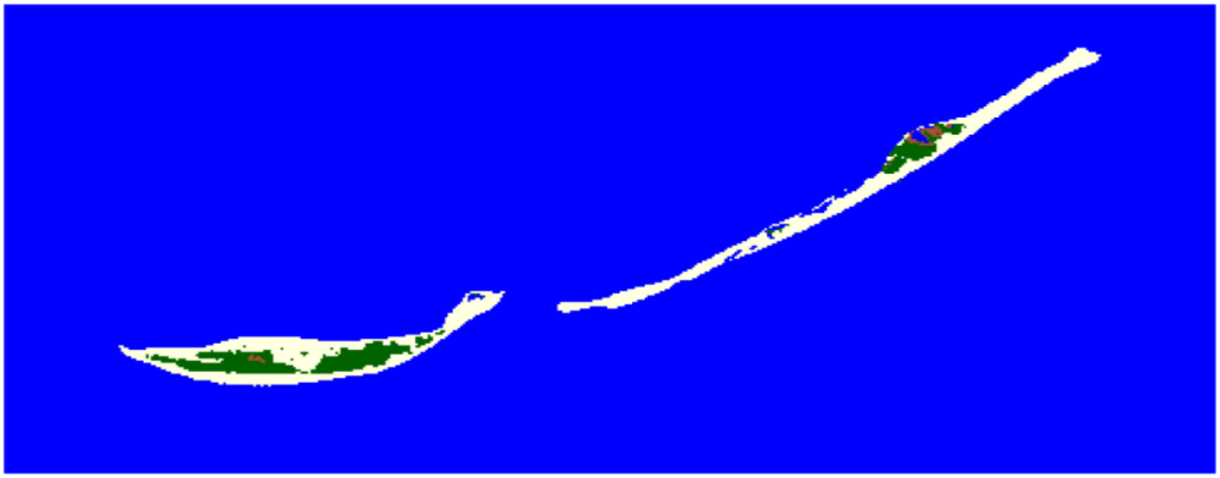

Figure 22: 2005 (after Ivan, before Katrina) supervised classification of West and East Ship Island

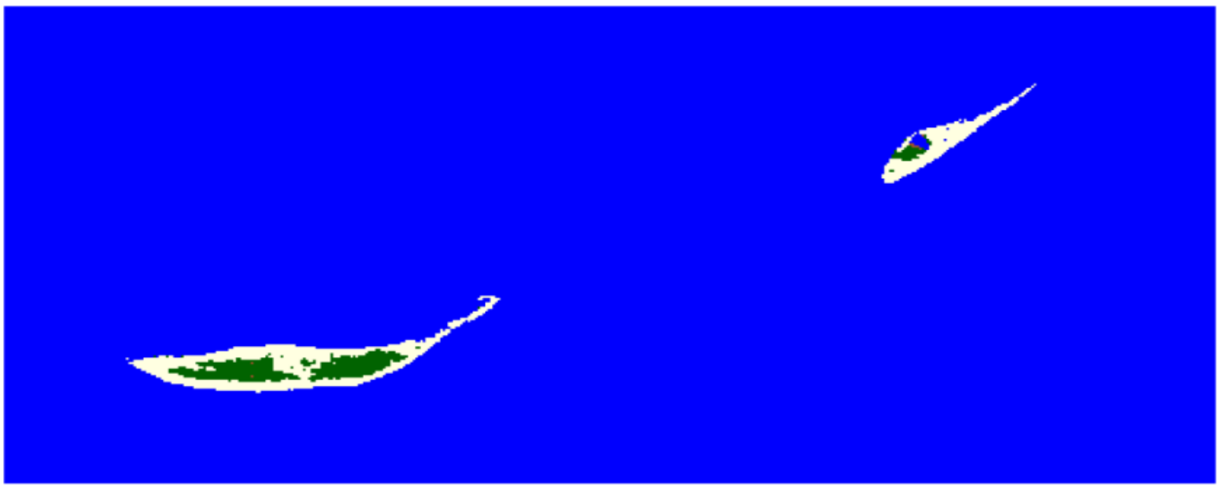

Figure 23: 2006 (after Katrina) supervised classification of West and East Ship Island

Figure 24: 2008 (before Gustav and Ike) supervised classification of West and East Ship Island

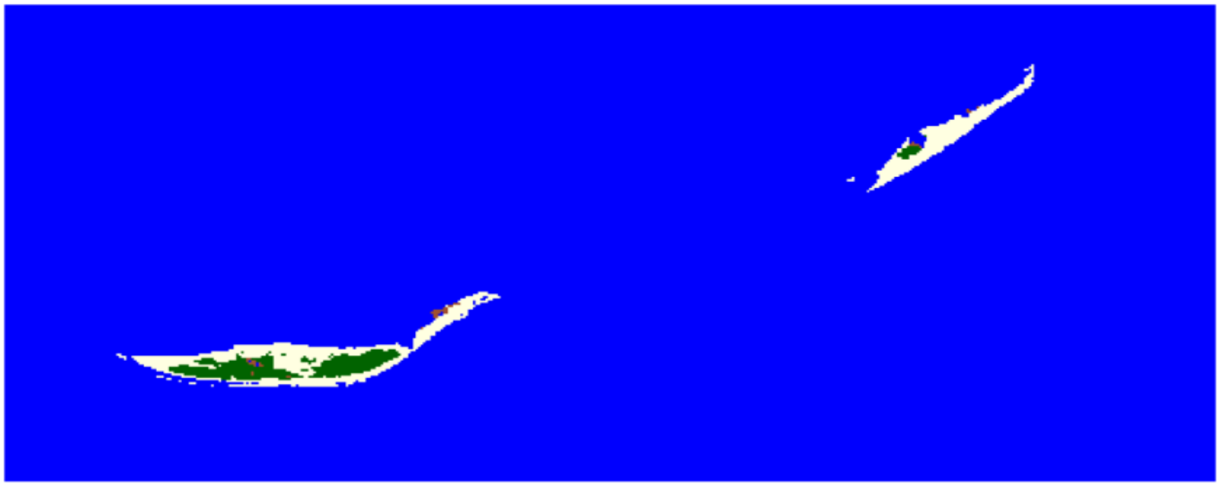

Figure 25: 2009 (after Gustav and Ike) supervised classification of West and East Ship Island

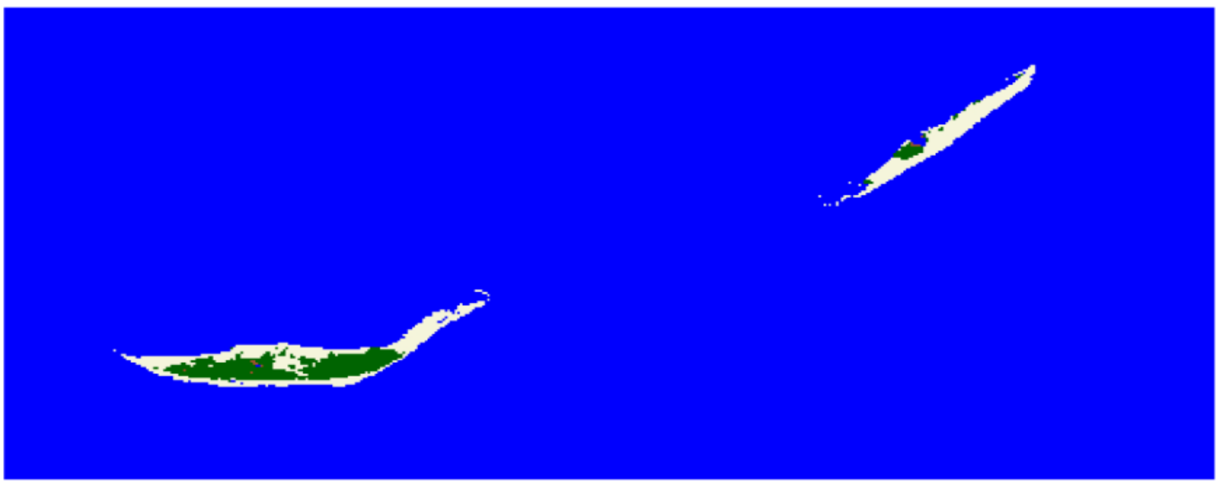

Figure 26: 2010 supervised classification of West and East Ship Island

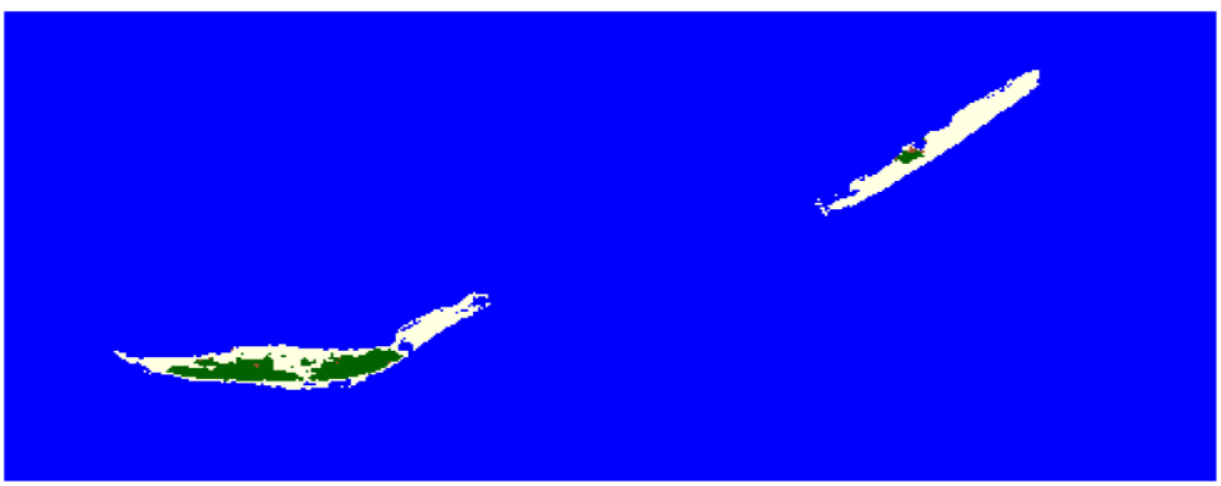

Figure 27: 2011 supervised classification of West and East Ship Island

4.4 Horn Island

Horn Island				
Date	Total Land Area (hectares)	Healthy Vegetation (hectares)	Pines and Shrubs (hectares)	Marsh (hectares)
9-06-84	1418	800	597	46
9-12-92	1314	668	595	77
8-28-98	1410	709	580	83
9-16-99	1361	649	499	68
8-17-00	1304	675	617	75
6-09-04	1312	700	520	42
6-12-05	1212	662	514	76
9-03-06	1225	539	466	57
8-07-08	1157	622	555	62
7-09-09	1204	568	459	83
9-14-10	1165	669	493	86
8-16-11	1197	532	428	74

Table 20: Horn Island land area and vegetation cover change

Horn Island Mean Deviation				
Date	Total Land Area (mean = 1273)	Healthy Vegetation (mean = 649)	Pines and Shrubs (mean = 527)	Marsh (mean = 69)
9-06-84	+145	+151	+70	-23
9-12-92	+41	+19	+68	+8
8-28-98	+137	+60	+53	+14
9-16-99	+88	0	-28	-1
8-17-00	+31	+26	+90	+6
6-09-04	+39	+51	-7	-27
6-12-05	-61	+13	-13	+7
9-03-06	-48	-110	-61	-12
8-07-08	-116	-27	+28	-7
7-09-09	-69	-81	-68	+14
9-14-10	-108	+20	-34	+17
8-16-11	-76	-117	-99	+5

Table 21: Deviation from the mean of all categories on Horn Island

Horn Island Land Area		
Storm	Percentage Change	Area Change (Hectares)
1. Ivan (2004)	-7.62%	1312-1212
2. Georges (1998)	-3.48%	580-499
3. Katrina (2005)	+1.07%	1212-1225
4. Gustav/Ike (2008)	+4.06%	1157-1204
Total (1984-2011)	-15.59%	1418-1197

Table 22: Ranking each hurricane in terms of percentage change

Horn Island's land area loss was significantly less than its neighboring Mississippi Islands. Horn Island's land area fared much better throughout the study time period when compared to Petit Bois Island and East Ship Island (Table 20). However, the total land area remained below the mean after Hurricane Ivan made landfall (Table 21). Hurricane Ivan proved to be the most devastating in terms of land area loss on Horn Island (Table 22). After Hurricane Ivan impacted the northern Gulf Coast, Horn Island's land area was down 206 hectares (-14.53%) from its total in 1984. From 1984 to 2011, Horn Island lost 221 hectares (-15.59%) of its total land area (Figures 28-39).

Horn Island Total Healthy Vegetation		
Storm	Percentage Change	Area Change (Hectares)
1. Katrina (2005)	-18.58%	662-539
2. Gustav/Ike (2008)	-8.68%	622-568
3. Georges (1998)	-8.46%	709-649
4. Ivan (2004)	-5.43%	700-662
Total (1984-2011)	-33.5%	800-532

Table 23: Ranking each hurricane in terms of percentage change

Horn Island experienced a steady decline in healthy vegetation throughout the study time period (Table 20). The area of healthy vegetation was below the mean in most years after Hurricane Katrina's impacts (Table 21). Hurricane Katrina was the most damaging storm to affect Horn Island in terms of total healthy vegetation loss (Table 23). After Hurricane Katrina made landfall along the northern Gulf Coast, Horn Island's area of healthy vegetation was down 261 hectares (-32.63%) from its total in 1984. From 1984 to 2011, Horn Island lost 268 hectares (-33.5%) of its total area of healthy vegetation.

Horn Island Pines and Shrubs		
Storm	Percentage Change	Area Change (Hectares)
1. Gustav/Ike (2008)	-17.3%	555-459
2. Georges (1998)	-13.97%	580-499
3. Katrina (2005)	-9.34%	514-466
4. Ivan (2004)	-1.15%	520-514
Total (1984-2011)	-28.31%	597-428

Table 24: Ranking each hurricane in terms of percentage change

Similar to the area of total healthy vegetation, the area of pines and shrubs on Horn Island experienced a steady decline from 1984 to 2011 (Table 20). The area of pines and shrubs stayed below the mean in most years after Hurricane Georges' impacts (Table 21). Hurricanes Gustav and Ike combined to be the most destructive in terms of pine and shrub loss on Horn Island (Table 24). After both hurricanes made landfall along the Gulf Coast, Horn Island's area of pines and shrubs was down 138 hectares (-23.12%) from its total in 1984. From 1984 to 2011, Horn Island lost 169 hectares (-28.34%) of its pines and shrubs (Figures 28-39).

Horn Island Marsh		
Storm	Percentage Change	Area Change (Hectares)
1. Katrina (2005)	-25%	76-57
2. Georges (1998)	-18.07%	83-68
3. Gustav/Ike (2008)	+33.87%	62-83
4. Ivan (2004)	+80.95%	42-76
Total (1984-2011)	+60.87%	46-74

Table 25: Ranking each hurricane in terms of percentage change

Horn Island has experienced a significant increase in its area of marsh from 1984 to 2011. From 1984 to 2011, Horn Island's area of marsh increased by 28 hectares (+60.87%) (Table 20). The area of marsh on Horn Island fluctuated below and above the mean throughout the study time period (Table 21). Hurricane Katrina was the most devastating storm in terms of marsh area loss on Horn Island (Table 25). After Hurricane Katrina devastated the northern Gulf Coast, Horn Island's area of marsh was actually up 11 hectares from its total in 1984. However, after Katrina, the island's total area of marsh was down 26 hectares (-31.33%) from its pre-Katrina peak in 1998 (Figures 28-39).

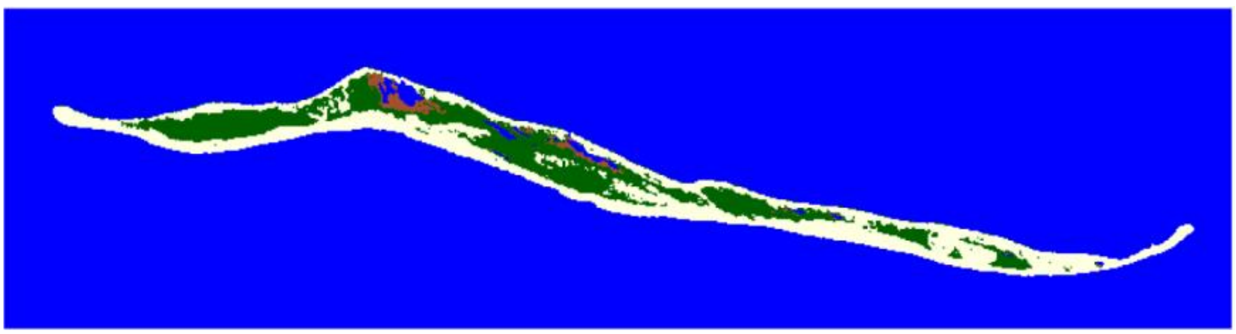

Figure 28: 1984 supervised classification of Horn Island

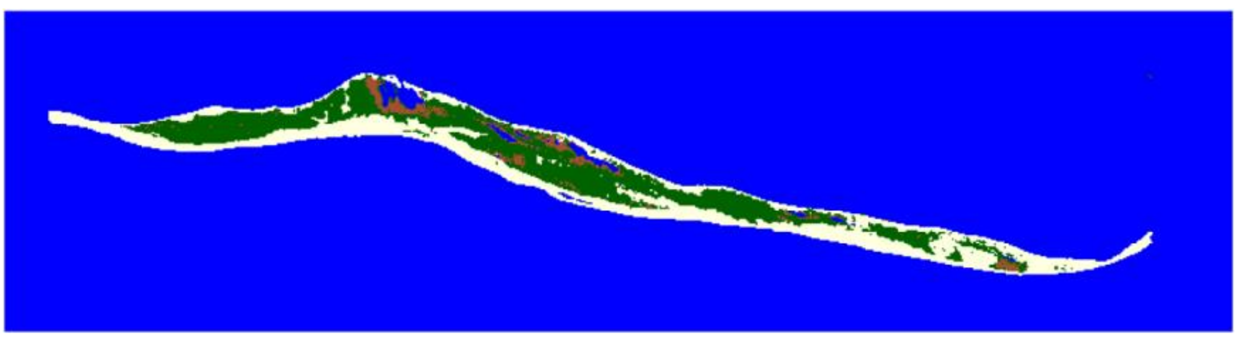

Figure 29: 1992 supervised classification of Horn Island

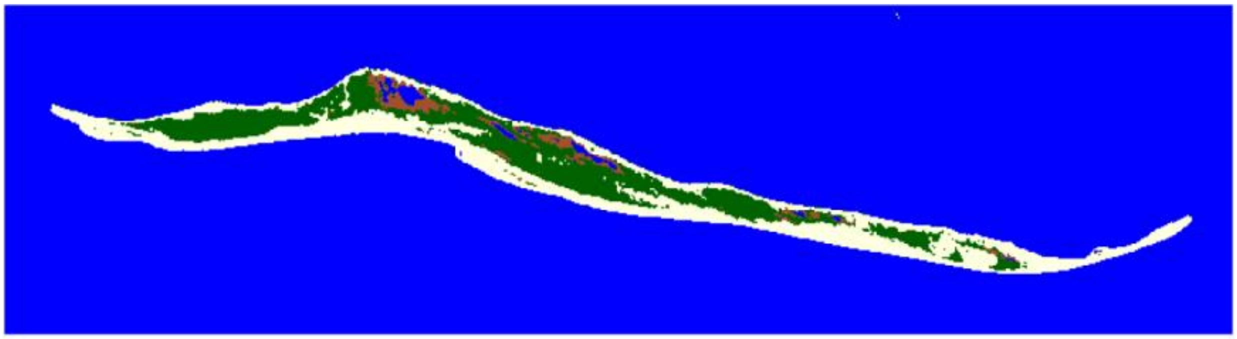

Figure 30: 1998 (before Georges) supervised classification of Horn Island

Figure 31: 1999 (after Georges) supervised classification of Horn Island

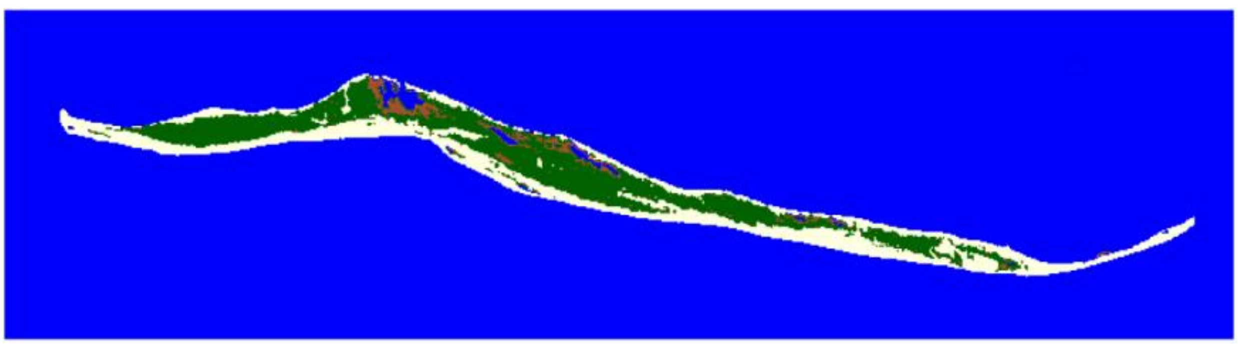

Figure 32: 2000 supervised classification of Horn Island

Figure 33: 2004 (before Ivan) supervised classification of Horn Island

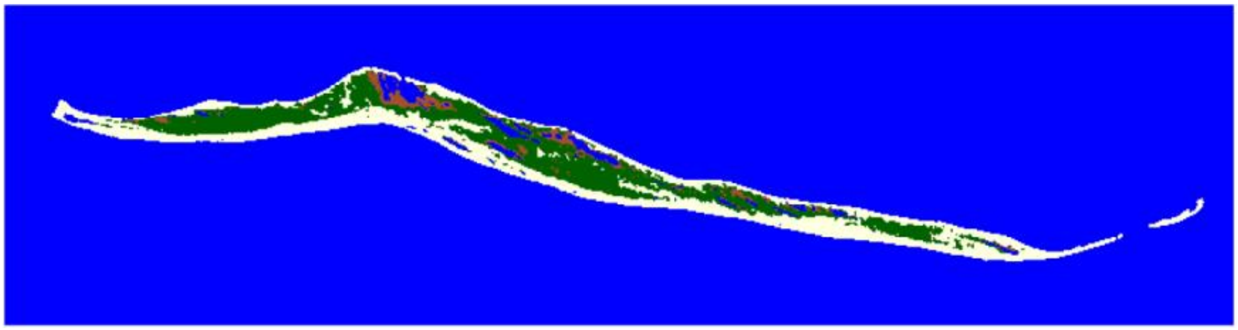

Figure 34: 2005 (after Ivan, before Katrina) supervised classification of Horn Island

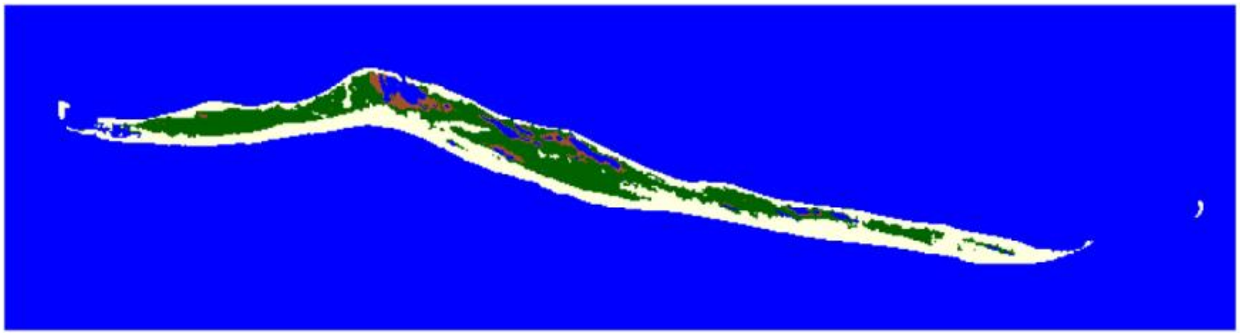

Figure 35: 2006 (after Katrina) supervised classification of Horn Island

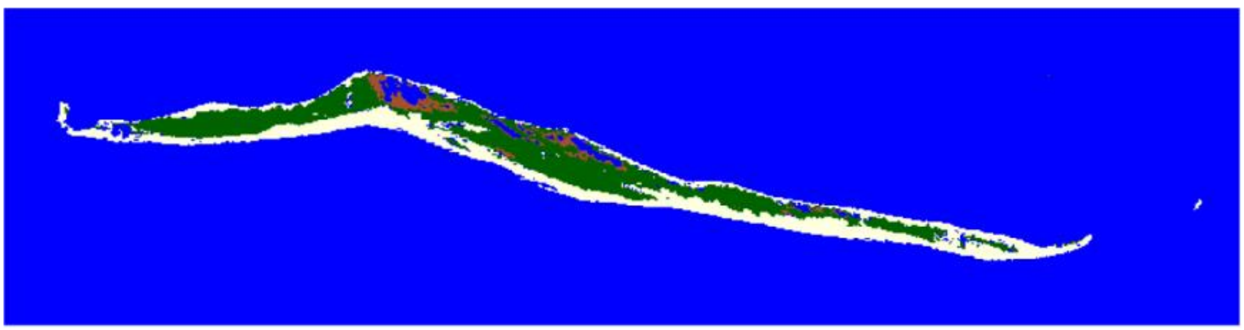

Figure 36: 2008 (before Gustav and Ike) supervised classification of Horn Island

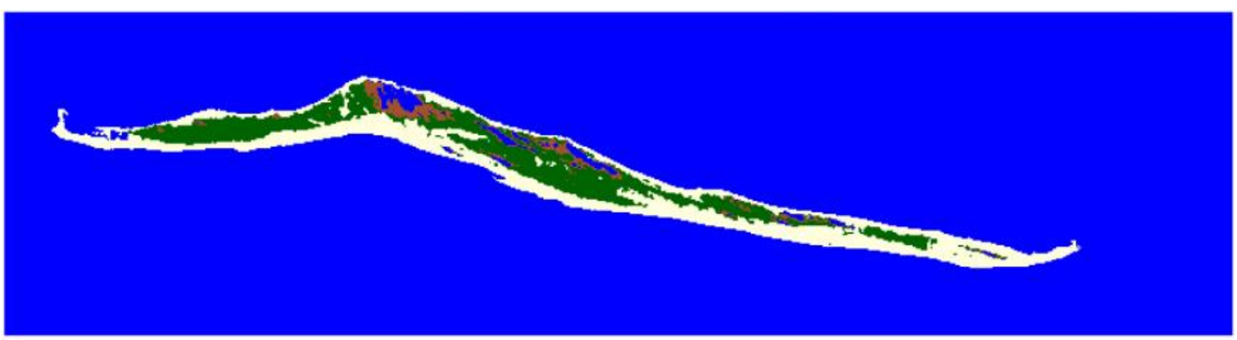

Figure 37: 2009 (after Gustav and Ike) supervised classification of Horn Island

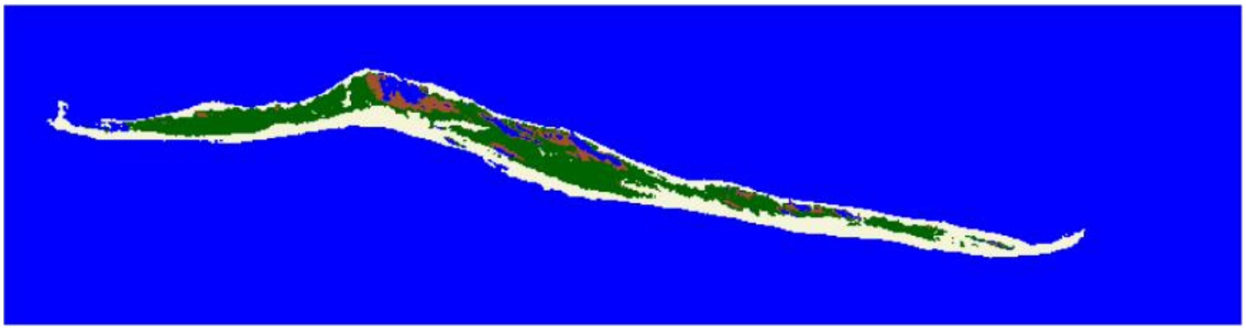

Figure 38: 2010 supervised classification of Horn Island

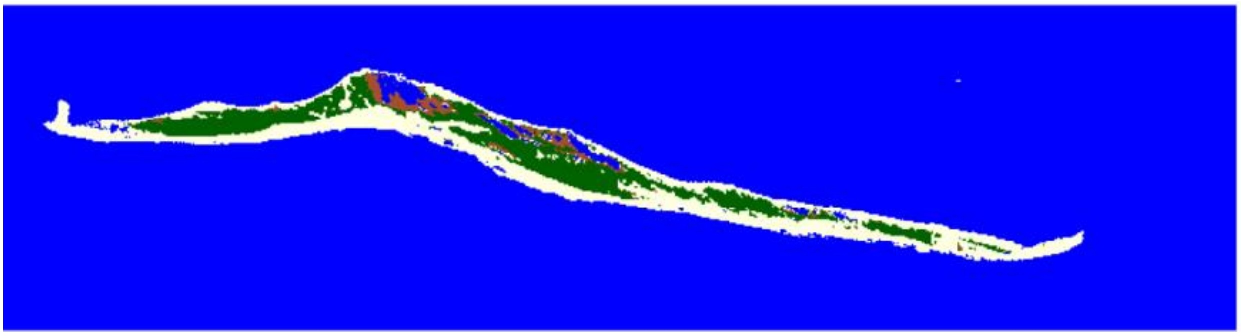

Figure 39: 2011 supervised classification of Horn Island

4.5 Petit Bois Island

Petit Bois Island				
Date	Total Land Area (hectares)	Healthy Vegetation (hectares)	Pines and Shrubs (hectares)	Marsh (hectares)
9-06-84	551	350	224	7
9-12-92	488	263	232	15
8-28-98	503	266	205	16
9-16-99	456	213	129	10
8-17-00	422	257	190	18
6-09-04	420	219	150	4
6-12-05	379	169	121	18
9-03-06	396	119	86	8
8-07-08	366	181	118	8
7-09-09	372	141	81	9
9-14-10	350	178	100	8
8-16-11	375	145	87	3

Table 26: Petit Bois Island land area and vegetation cover change

Petit Bois Island Mean Deviation				
Date	Total Land Area (mean = 423)	Healthy Vegetation (mean = 208)	Pines and Shrubs (mean = 143)	Marsh (mean = 10)
9-06-84	+128	+142	+81	-3
9-12-92	+65	+55	+89	+5
8-28-98	+80	+58	+62	+6
9-16-99	+33	+5	-14	0
8-17-00	-1	+49	+47	+8
6-09-04	-3	+11	+7	-6
6-12-05	-44	-39	-22	+8
9-03-06	-27	-89	-57	-2
8-07-08	-57	-27	-25	-2
7-09-09	-51	-67	-62	-1
9-14-10	-73	-30	-43	-2
8-16-11	-48	-63	-56	-7

Table 27: Deviation from the mean of all categories on Petit Bois Island

Petit Bois Island Land Area		
Storm	Percentage Change	Area Change (Hectares)
1. Ivan (2004)	-9.76%	420-379
2. Georges (1998)	-9.34%	503-456
3. Gustav/Ike (2008)	+1.64%	366-372
4. Katrina (2005)	+4.48%	379-396
Total (1984-2011)	-31.94%	551-375

Table 28: Ranking each hurricane in terms of percentage change

Petit Bois Island has experienced a steady decline in land area from 1984 to 2011 (Table 26). The total land area remained below the mean after August 2000 (Table 27). Hurricane Ivan was the most devastating storm in terms of land area loss on Petit Bois Island (Table 28). After Hurricane Ivan affected the northern Gulf Coast, Petit Bois Island's total land area was down 172 hectares (-31.22%) from its total in 1984. From 1984 to 2011, Petit Bois Island lost 176 hectares (-31.94%) of its total land area (Figures 40-51).

Petit Bois Island Total Healthy Vegetation		
Storm	Percentage Change	Area Change (Hectares)
1. Katrina (2005)	-29.59%	169-119
2. Ivan (2004)	-22.83%	219-169
3. Gustav/Ike (2008)	-22.1%	181-141
4. Georges (1998)	-19.92%	266-213
Total (1984-2011)	-58.57%	350-145

Table 29: Ranking each hurricane in terms of percentage change

Petit Bois Island has experienced a significant decline in its total area of healthy vegetation throughout the study time period (Table 26). The area of healthy vegetation remained below the mean after Hurricane Ivan made landfall along the northern Gulf Coast (Table 27). Each hurricane produced significant damage to the healthy vegetation located on Petit Bois Island. Hurricane Katrina was the most devastating storm in terms of total healthy vegetation loss on Petit Bois Island (Table 29). After Hurricane Katrina made landfall on the northern Gulf Coast, Petit Bois Island's area of healthy vegetation was down 231 hectares (-66%) from its total in 1984. From 1984 to 2011, Petit Bois Island lost a total of 205 hectares (-58.57%) of its healthy vegetation.

Petit Bois Island Pines and Shrubs		
Storm	Percentage Change	Area Change (Hectares)
1. Georges (1998)	-37.07%	205-129
2. Gustav/Ike (2008)	-31.36%	118-81
3. Katrina (2005)	-28.93%	121-86
4. Ivan (2004)	-19.3%	150-121
Total (1984-2011)	-61.16%	224-87

Table 30: Ranking each hurricane in terms of percentage change

Petit Bois Island has also experienced a steady, significant decline of its area of pines and shrubs (Table 26). The area of pines and shrubs on Petit Bois Island remained completely below the mean after Hurricane Ivan's impacts (Table 27). Each hurricane was responsible for severe losses in the area of pines and shrubs on Petit Bois Island. Hurricane Georges was the most destructive storm in terms of pine and shrub loss on Petit Bois Island (Table 30). After Hurricane Georges made landfall along the northern Gulf Coast, Petit Bois Island's area of pines and shrubs was down 95 hectares (-42.41%) from its total in 1984. From 1984 to 2011, Petit Bois Island lost 137 hectares (-61.16%) of its pines and shrubs (Figures 40-51).

Petit Bois Island Marsh		
Storm	Percentage Change	Area Change (Hectares)
1. Katrina (2005)	-55.56%	18-8
2. Georges (1998)	-37.5%	16-10
3. Gustav/Ike (2008)	+12.5%	8-9
4. Ivan (2004)	+350%	4-18
Total (1984-2011)	-57.14%	7-3

Table 31: Ranking each hurricane in terms of percentage change

Petit Bois Island has experienced fluctuations in its area of marsh throughout the study time period (Table 26). The area of marsh on the island remained completely below the mean after Hurricane Katrina made landfall along the northern Gulf Coast (Table 27). Hurricane Katrina was the most destructive storm in terms marsh area loss on Petit Bois Island (Table 31). After Hurricane Katrina devastated the northern Gulf Coast, Petit Bois Island's area of marsh was actually up one hectare from its total in 1984. However, after Katrina, the area of marsh on Petit Bois Island was down 10 hectares (-55.56%) from its pre-Katrina peak in 2005. From 1984 to 2011, Petit Bois Island lost four hectares (-57.14%) of marsh (Figures 40-51).

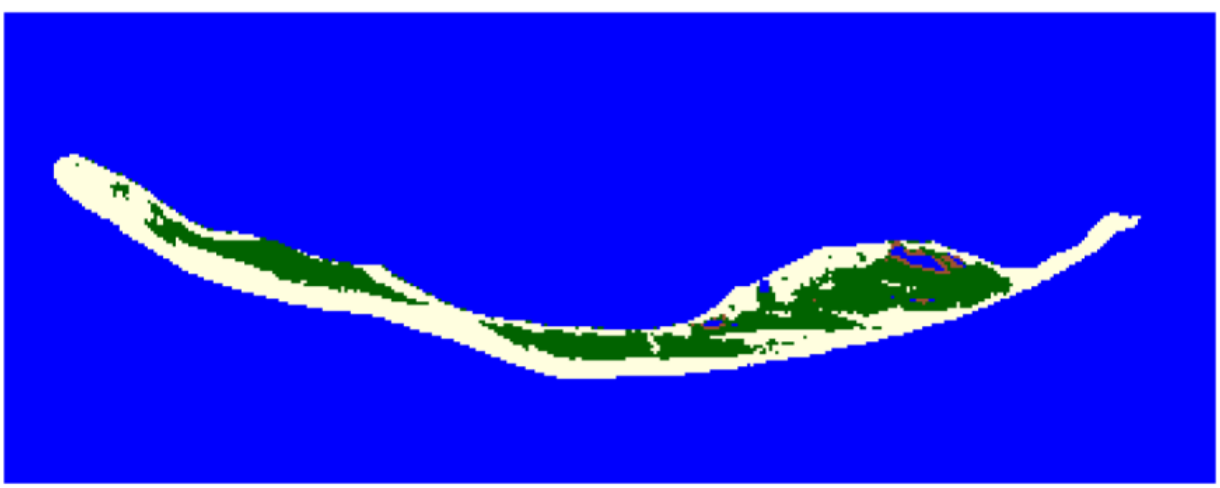

Figure 40: 1984 supervised classification of Petit Bois Island

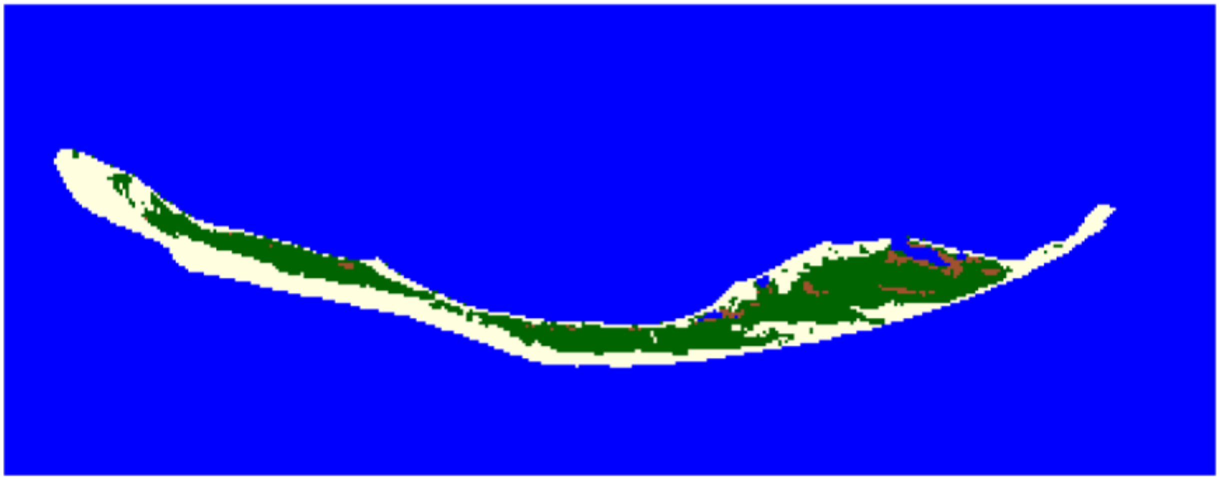

Figure 41: 1992 supervised classification of Petit Bois Island

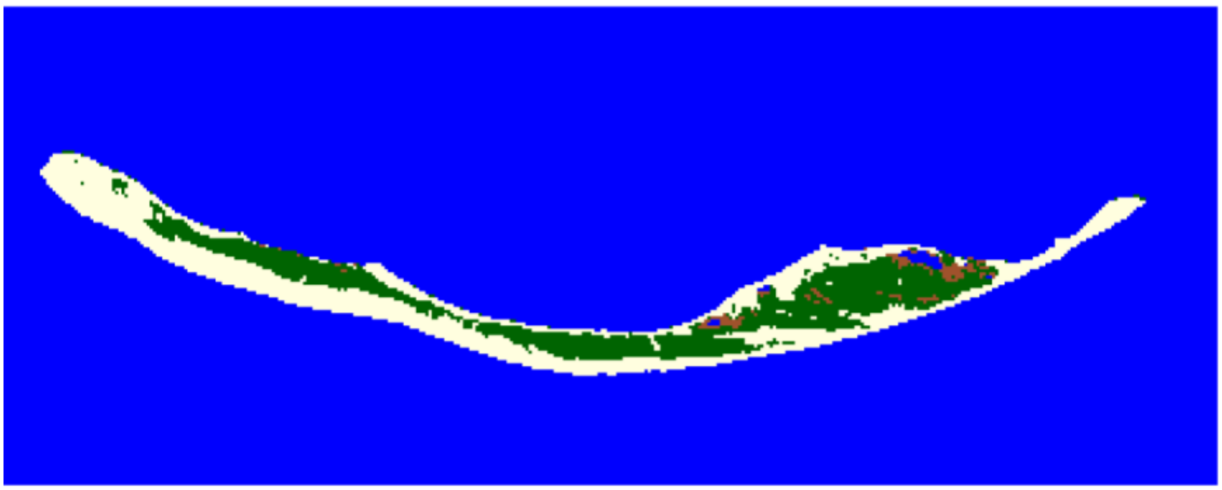

Figure 42: 1998 (before Georges) supervised classification of Petit Bois Island

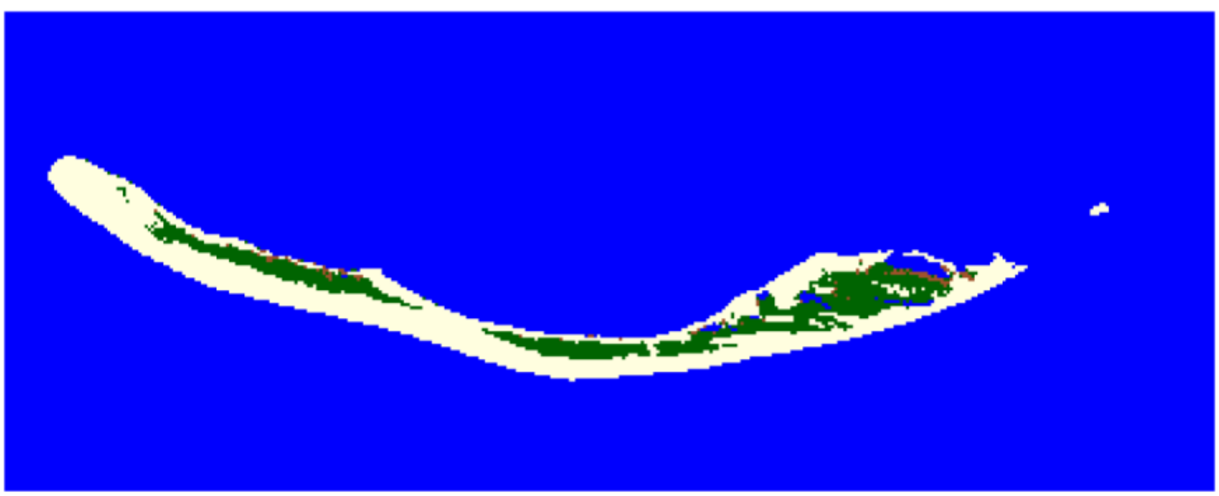

Figure 43: 1999 (after Georges) supervised classification of Petit Bois Island

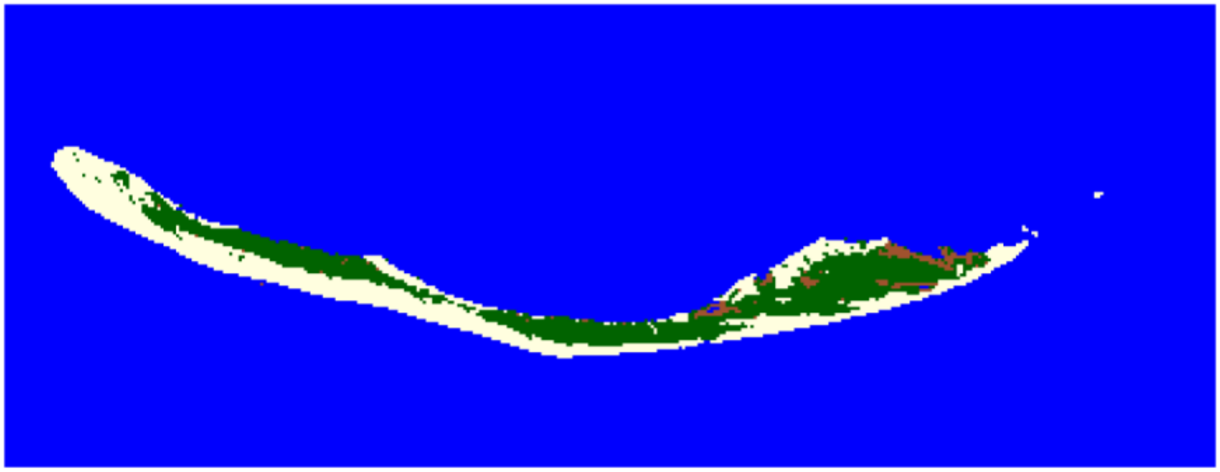

Figure 44: 2000 supervised classification of Petit Bois Island

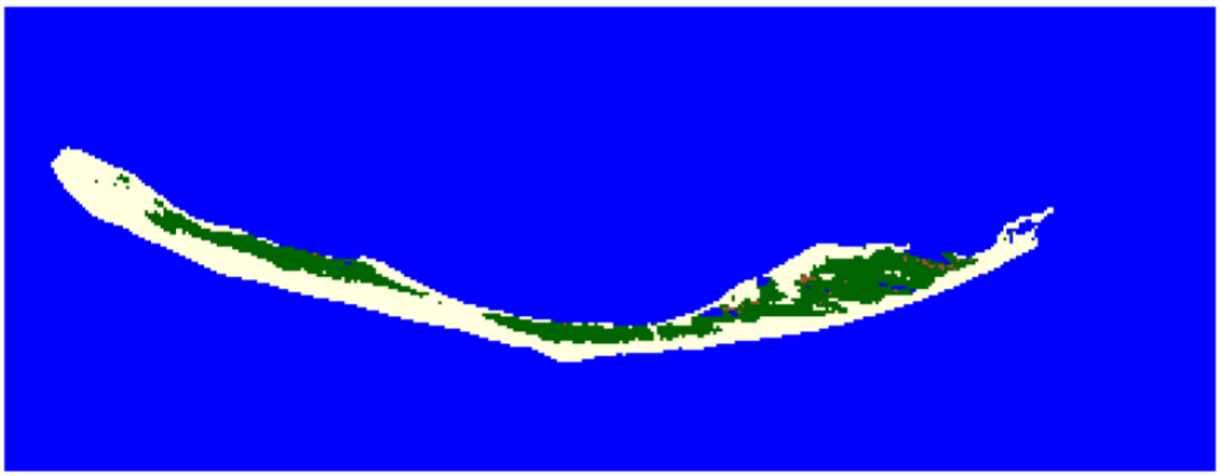

Figure 45: 2004 (before Ivan) supervised classification of Petit Bois Island

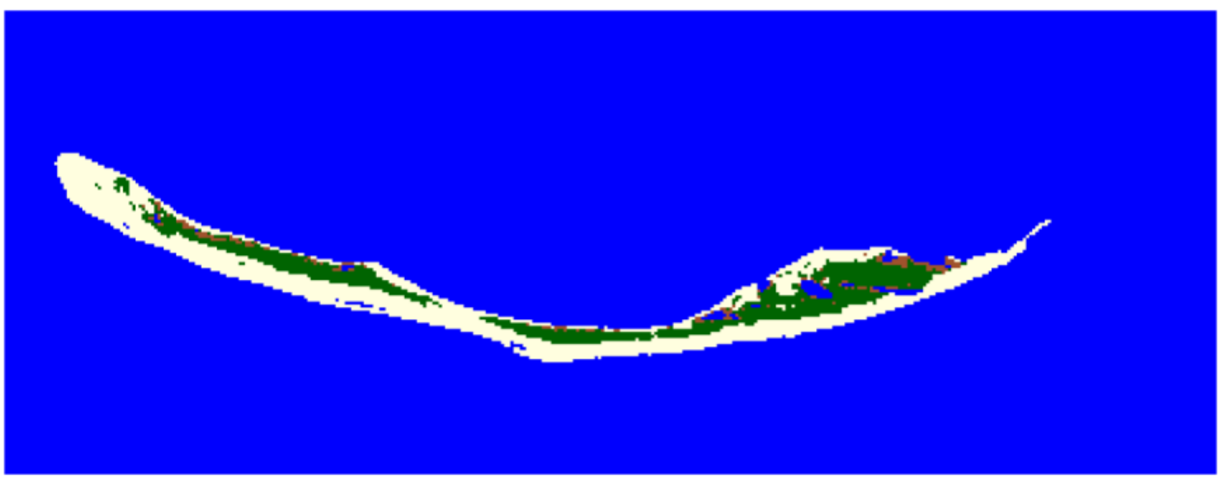

Figure 46: 2005 (after Ivan, before Katrina) supervised classification of Petit Bois Island

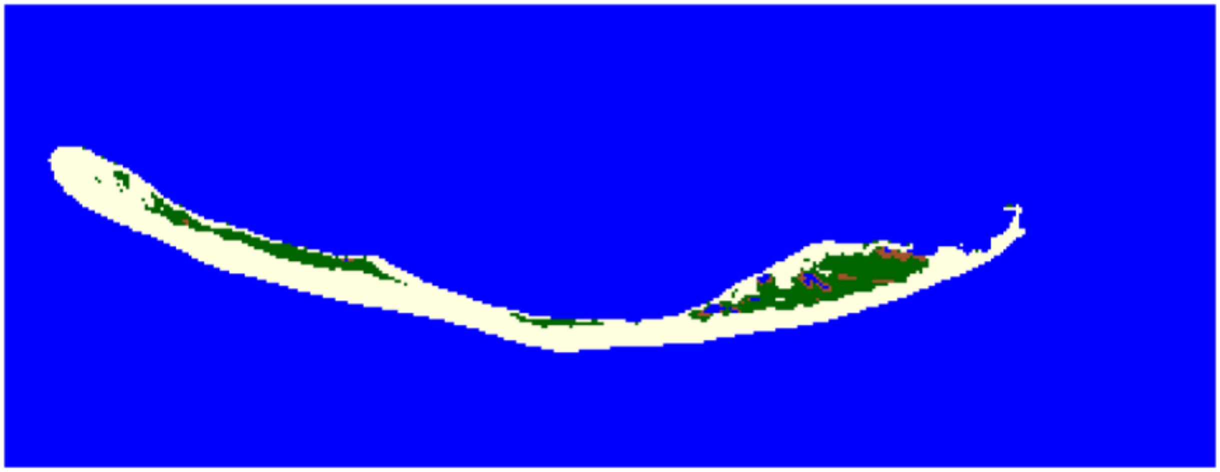

Figure 47: 2006 (after Katrina) supervised classification of Petit Bois Island

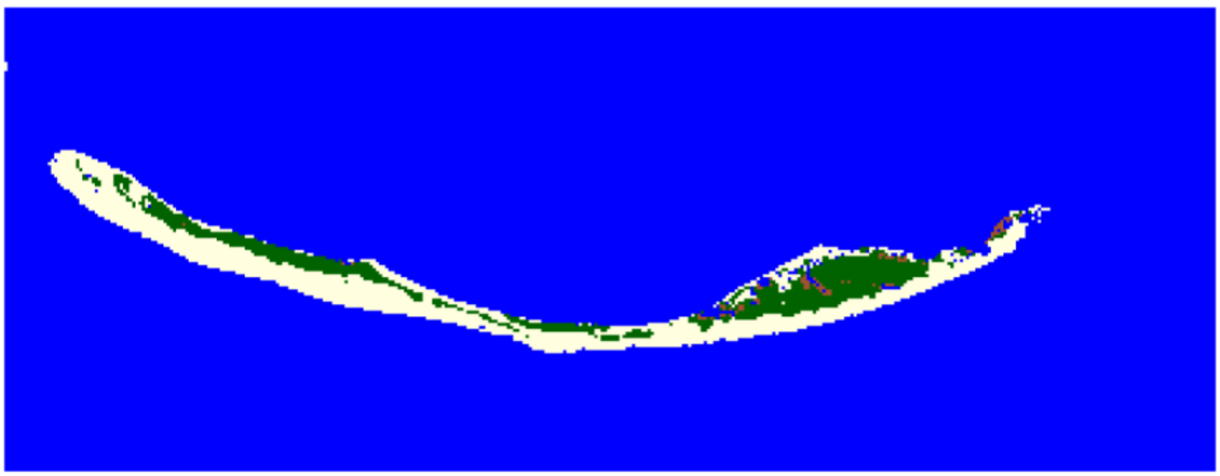

Figure 48: 2008 (before Gustav and Ike) supervised classification of Petit Bois Island

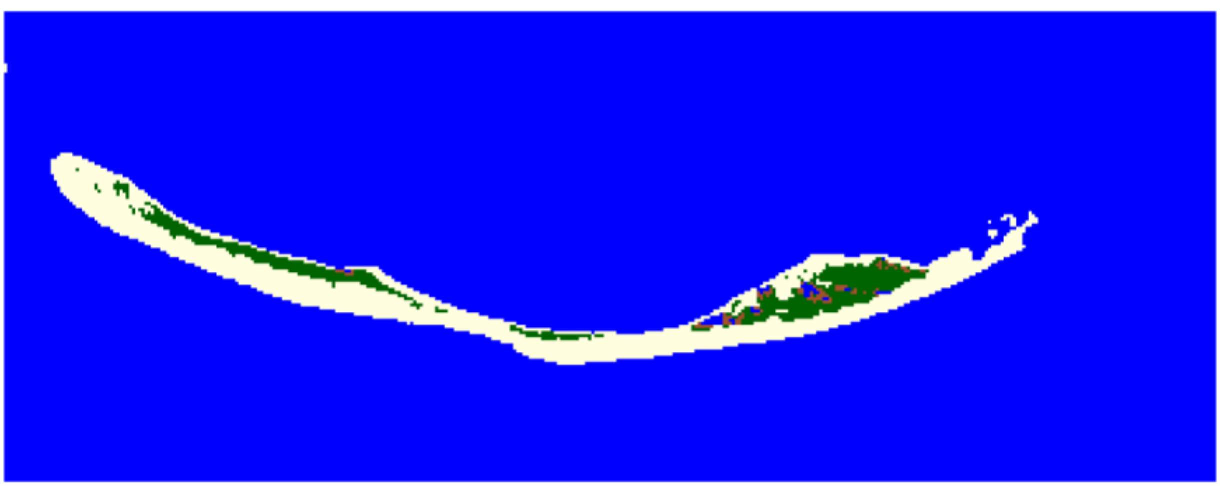

Figure 49: 2009 (after Gustav and Ike) supervised classification of Petit Bois Island

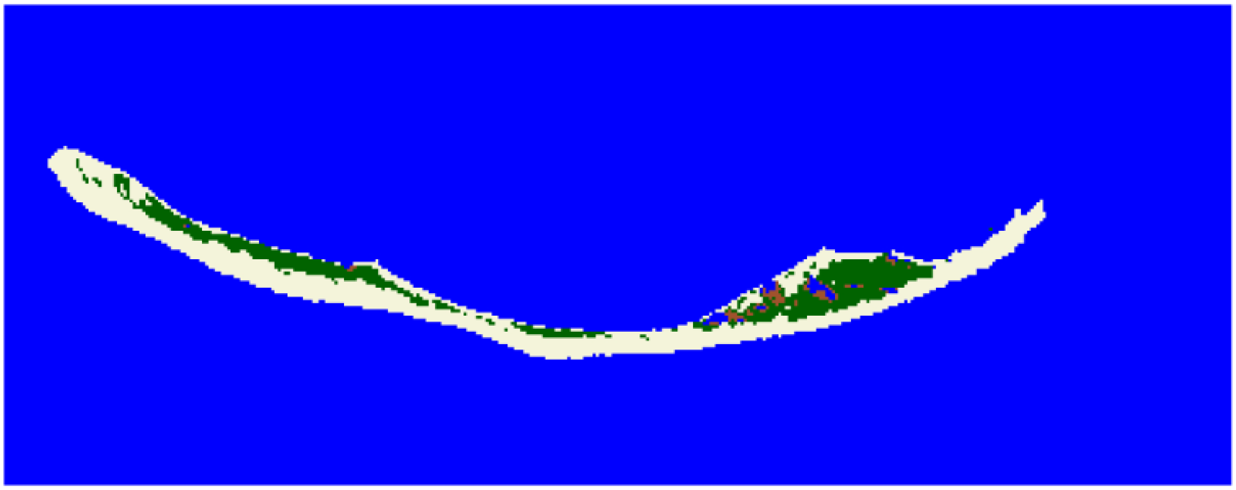

Figure 50: 2010 supervised classification of Petit Bois Island

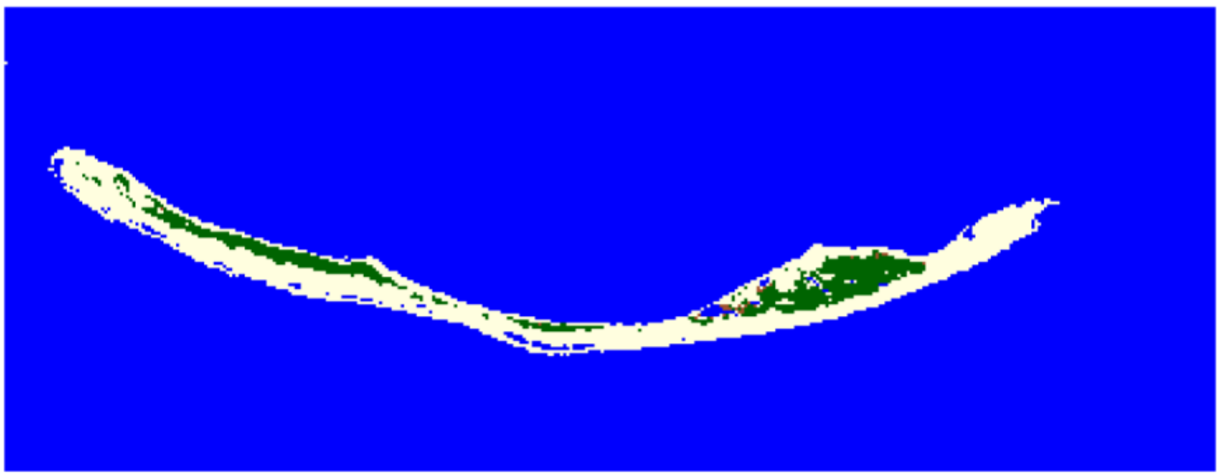

Figure 51: 2011 supervised classification of Petit Bois Island

4.6 Dauphin Island

Dauphin Island				
Date	Total Land Area (hectares)	Healthy Vegetation (hectares)	Pines and Shrubs (hectares)	Marsh (hectares)
9-06-84	1665	941	723	64
9-12-92	1579	606	568	76
8-28-98	1647	861	647	74
9-16-99	1602	921	744	84
8-17-00	1635	689	629	71
6-09-04	1600	835	760	113
6-12-05	1389	714	489	68
9-03-06	1558	579	403	89
8-07-08	1618	755	542	85
7-09-09	1432	613	527	73
9-14-10	1514	719	629	119
8-16-11	1505	493	494	72

Table 32: Dauphin Island land area and vegetation cover change

Dauphin Island Mean Deviation				
Date	Total Land Area (mean = 1562)	Healthy Vegetation (mean = 727)	Pines and Shrubs (mean = 596)	Marsh (mean = 83)
9-06-84	+103	+214	+127	-19
9-12-92	+17	-121	-28	-7
8-28-98	+85	+134	+51	-9
9-16-99	+40	+194	+148	+1
8-17-00	+73	-38	+33	-12
6-09-04	+38	+108	+164	+30
6-12-05	-173	-13	-107	-15
9-03-06	-4	-148	-188	+6
8-07-08	+56	+28	-54	+2
7-09-09	-130	-114	-69	-10
9-14-10	-48	-8	+33	+36
8-16-11	-57	-234	-102	-11

Table 33: Deviation from the mean of all categories on Dauphin Island

Dauphin Island Land Area		
Storm	Percentage Change	Area Change (Hectares)
1. Ivan (2004)	-13.19%	1600-1389
2. Gustav/Ike (2008)	-11.5%	1618-1432
3. Georges (1998)	-2.73%	1647-1602
4. Katrina (2005)	+12.17%	1389-1558
Total (1984-2011)	-9.61%	1665-1505

Table 34: Ranking each hurricane in terms of percentage change

Dauphin Island has lost the least amount of land area compared to the other five islands in this study (Table 32). The total area of land remained mostly below the mean after Hurricane Ivan's impacts (Table 33). Hurricane Ivan was the most devastating storm in terms of land area loss on Dauphin Island (Table 34). After Hurricane Ivan devastated the northern Gulf Coast, Dauphin Island's total land area was down 276 hectares (-16.58%) from its total in 1984. Dauphin Island's land area has rebounded since the impacts of Hurricane Ivan. From 1984 to 2011, Dauphin Island lost a total of 160 hectares (-9.6%) of its land area (Figures 52-63).

Dauphin Island Total Healthy Vegetation		
Storm	Percentage Change	Area Change (Hectares)
1. Katrina (2005)	-18.91%	714-579
2. Gustav/Ike (2008)	-18.81%	755-613
3. Ivan (2004)	-14.49%	835-714
4. Georges (1998)	+6.97%	861-921
Total (1984-2011)	-47.61%	941-493

Table 35: Ranking each hurricane in terms of percentage change

Unlike the land area, the total area of healthy vegetation on Dauphin Island has experienced a significant decline from 1984 to 2011 (Table 32). The area of healthy vegetation remained mostly below the mean after Hurricane Ivan's impacts (Table 33). Hurricane Katrina proved to be the most devastating in terms of percentage of total healthy vegetation loss on

Dauphin Island (Table 35). After Hurricane Katrina devastated the northern Gulf Coast, Dauphin Island's area of healthy vegetation was down 362 hectares (-38.47%) from its total in 1984. From 1984 to 2011, Dauphin Island lost 448 hectares (-47.61%) of its total area of healthy vegetation.

Dauphin Island Pines and Shrubs		
Storm	Percentage Change	Area Change (Hectares)
1. Ivan (2004)	-35.66%	760-489
2. Katrina (2005)	-17.59%	489-403
3. Gustav/Ike (2008)	-2.77%	542-427
4. Georges (1998)	+14.99%	647-744
Total (1984-2011)	-31.67%	723-494

Table 36: Ranking each hurricane in terms of percentage change

The area of pines and shrubs located on Dauphin Island has experienced some fluctuations throughout the study time period. However, the island has experienced a significant decline in its area of pines and shrubs from 1984 to 2011 (Table 32). The area of pines and shrubs on the island remained mostly below the mean after Hurricane Ivan's impacts (Table 33). Hurricane Ivan was the most destructive storm in terms of pine and shrub loss on Dauphin Island (Table 36). After Hurricane Ivan struck the northern Gulf Coast, Dauphin Island's area of pines and shrubs was down 234 hectares (-32.37%) from its total in 1984. From 1984 to 2011, Dauphin Island lost 229 hectares (-31.67%) of its pines and shrubs (Figures 52-63).

Dauphin Island Marsh		
Storm	Percentage Change	Area Change (Hectares)
1. Ivan (2004)	-39.82%	113-68
2. Gustav/Ike (2008)	-14.12%	85-73
3. Georges (1998)	+13.51%	74-84
4. Katrina (2005)	+30.88%	68-89
Total (1984-2011)	+12.5%	64-72

Table 37: Ranking each hurricane in terms of percentage change

Dauphin Island has experienced fluctuations in its area of marsh from 1984 to 2011 (Table 32). The area of marsh on Dauphin Island fluctuated below and above the mean throughout the entire study time period (Table 33). Hurricane Ivan was the most destructive storm in terms of marsh loss on Dauphin Island (Table 37). However, after Hurricane Ivan devastated the northern Gulf Coast, the area of marsh was actually up four hectares from its total in 1984. From 1984 to 2011, the area of marsh increased by 8 hectares (+12.5%) (Figures 52-63).

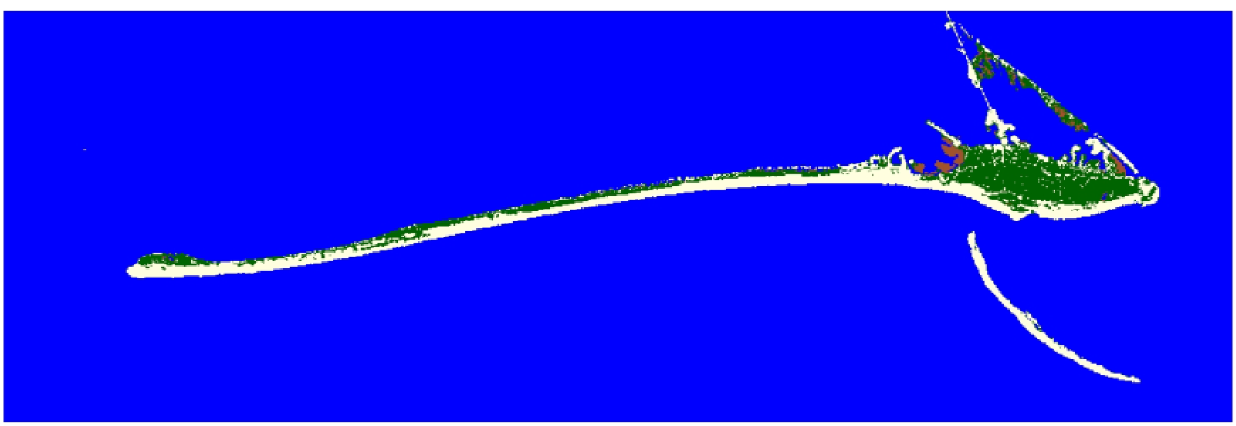

Figure 52: 1984 supervised classification of Dauphin Island

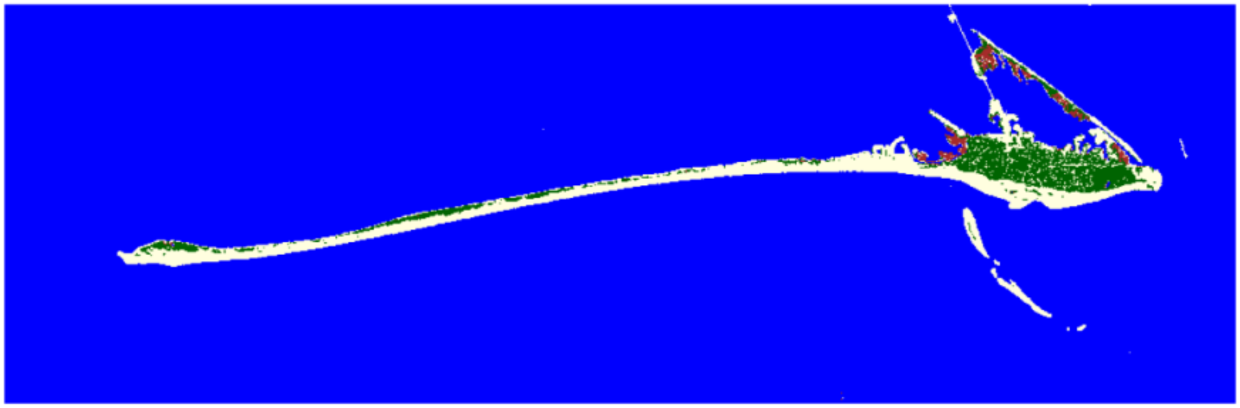

Figure 53: 1992 supervised classification of Dauphin Island

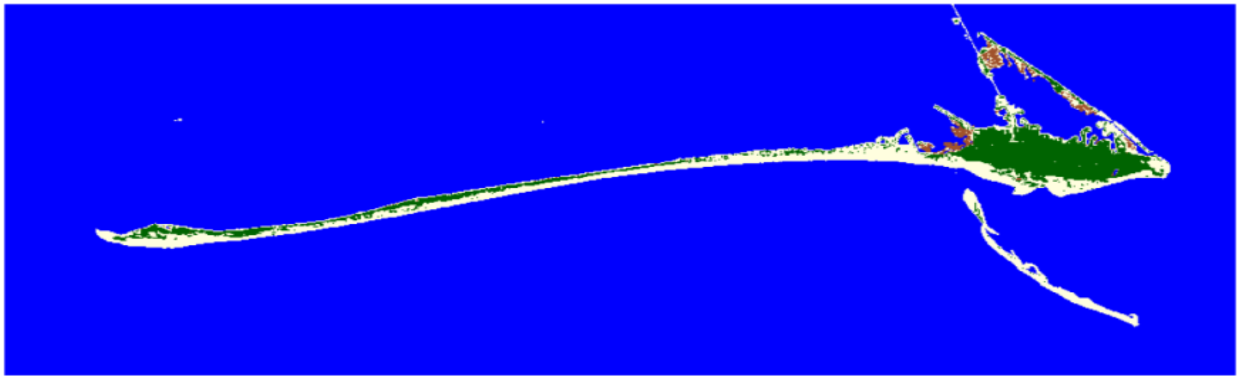

Figure 54: 1998 (before Georges) supervised classification of Dauphin Island

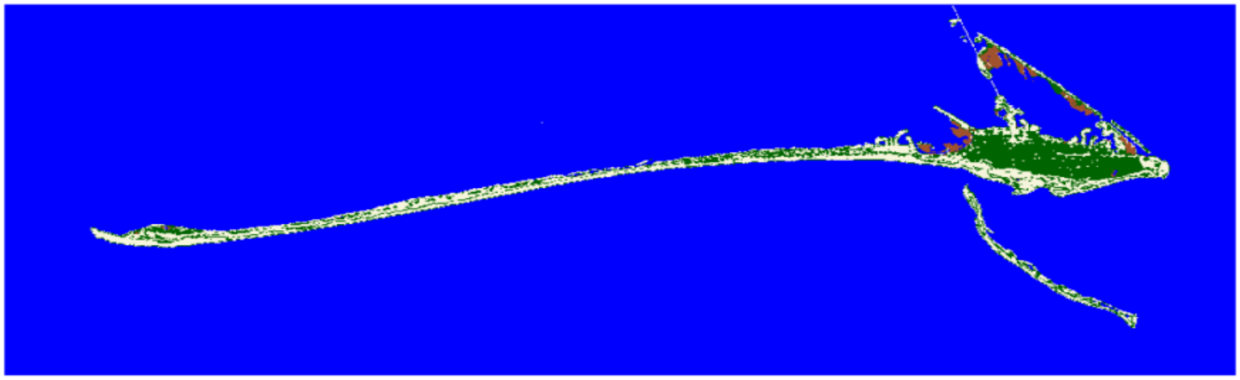

Figure 55: 1999 (after Georges) supervised classification of Dauphin Island

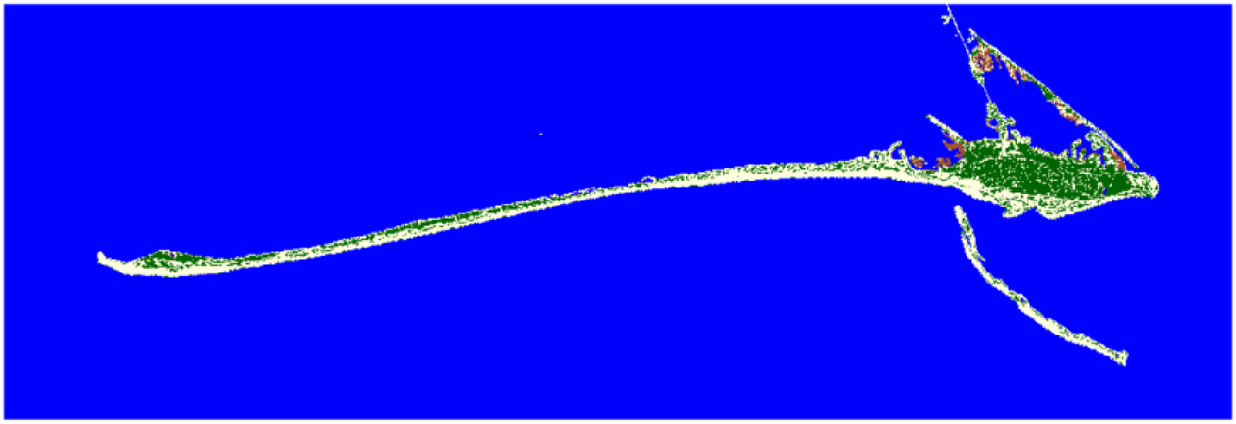

Figure 56: 2000 supervised classification of Dauphin Island

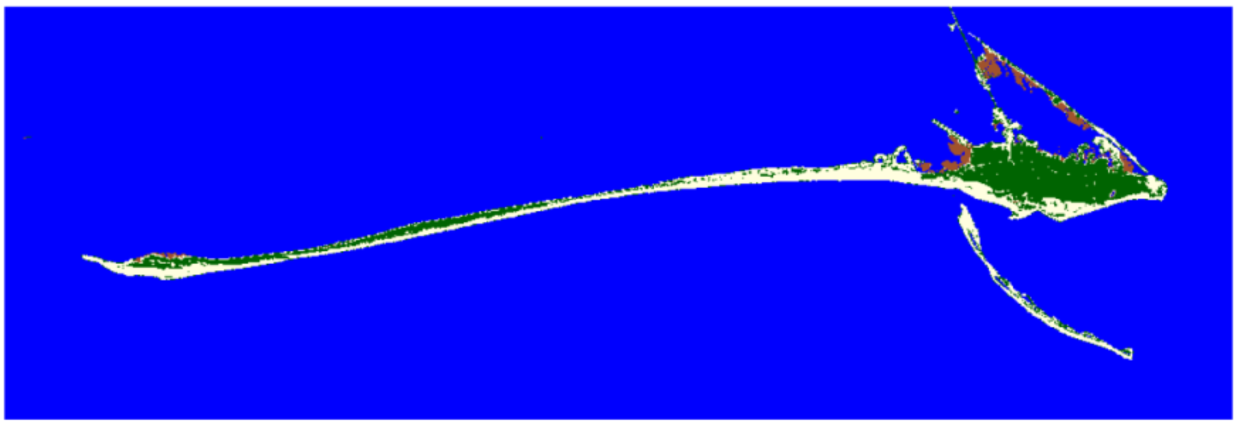

Figure 57: 2002 (before Ivan) supervised classification of Dauphin Island

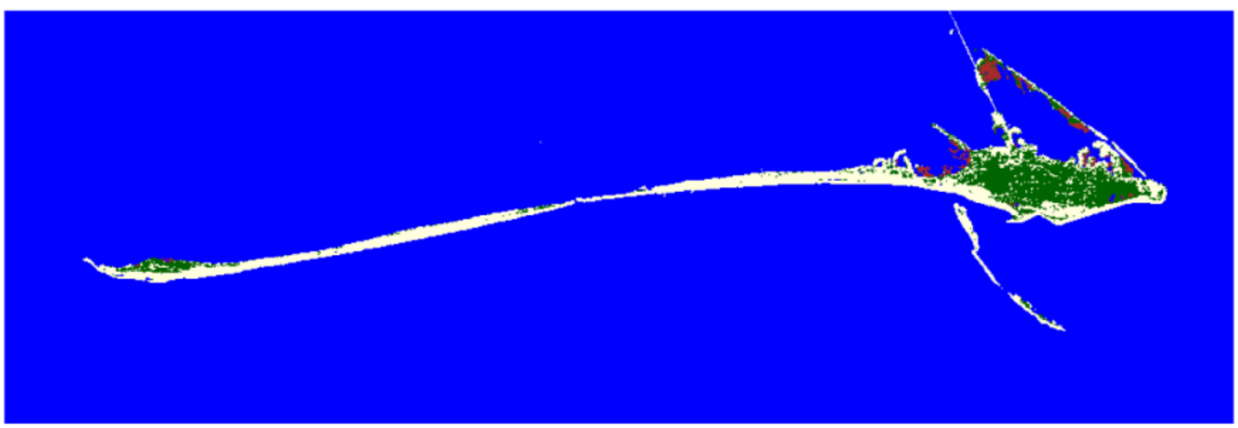

Figure 58: 2005 (after Ivan, before Katrina) supervised classification of Dauphin Island

Figure 59: 2006 (after Katrina) supervised classification of Dauphin Island

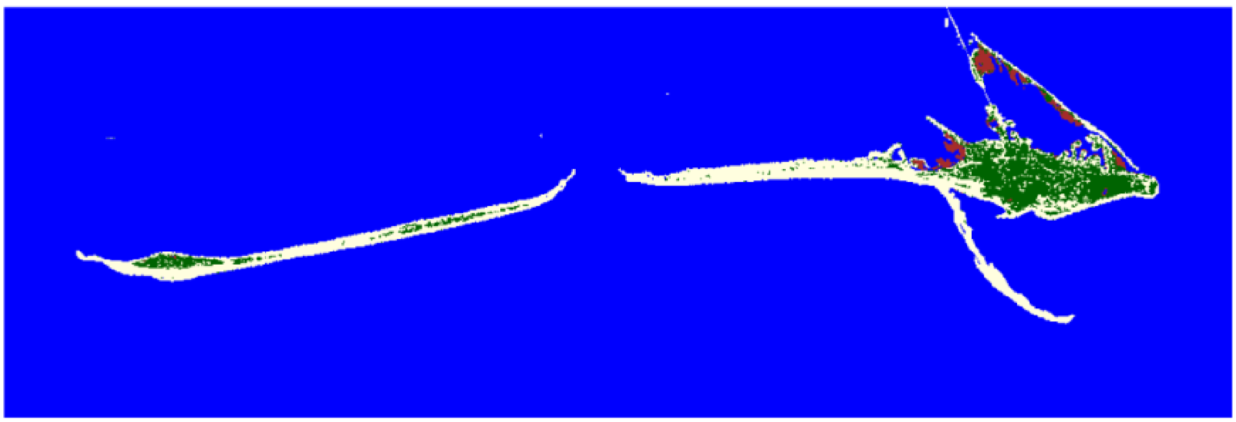

Figure 60: 2008 (before Gustav and Katrina) supervised classification of Dauphin Island

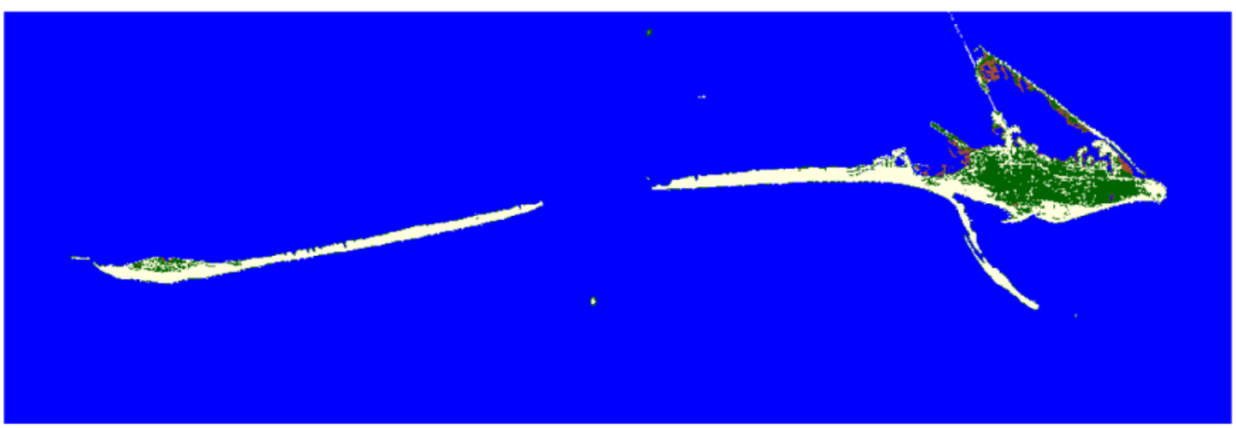

Figure 61: 2009 (after Gustav and Ike) supervised classification of Dauphin Island

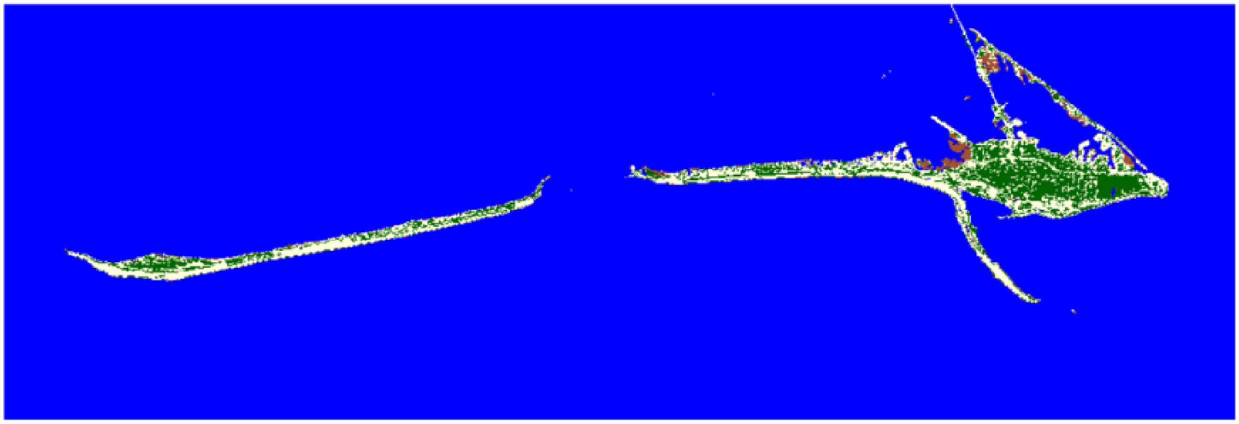

Figure 62: 2010 supervised classification of Dauphin Island

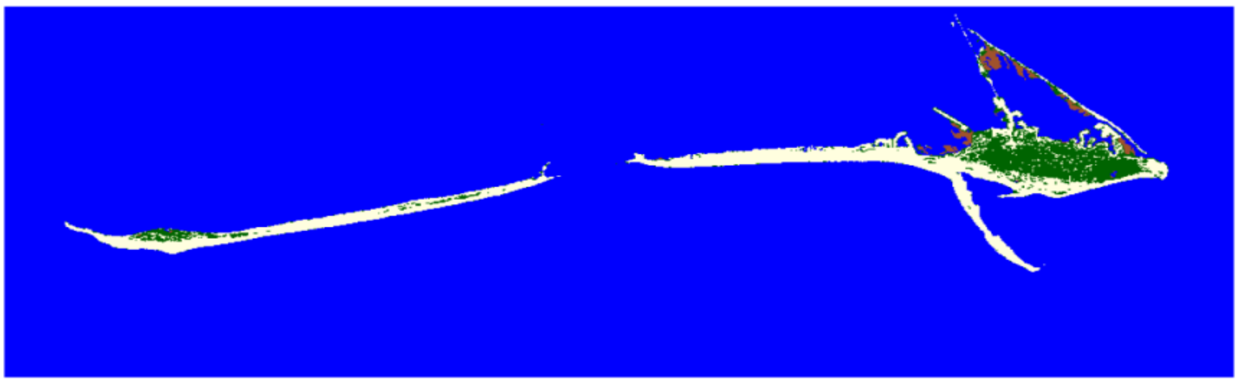

Figure 63: 2011 supervised classification of Dauphin Island

4.7 All Barrier Islands

All Barrier Islands Combined				
Date	Total Land Area (hectares)	Healthy Vegetation (hectares)	Pines and Shrubs (hectares)	Marsh (hectares)
9-06-84	4929	2927	2097	408
9-12-92	4576	2200	1983	431
8-28-98	4826	2463	1984	450
9-16-99	4444	2346	1841	293
8-17-00	4484	2231	1910	496
6-09-04	4504	2476	1878	451
6-12-05	4055	2153	1448	537
9-03-06	3959	1595	1228	260
8-07-08	4051	2191	1688	380
7-09-09	3902	1820	1357	476
9-14-10	3932	2169	1648	449
8-16-11	4001	1681	1332	413

Table 38: All barrier islands land area and vegetation cover change

All Barrier Islands Combined Mean Deviation				
Date	Total Land Area (mean = 4305)	Healthy Vegetation (mean = 2188)	Pines and Shrubs (mean = 1700)	Marsh (mean = 420)
9-06-84	+624	+739	+397	-12
9-12-92	+271	+12	+283	+11
8-28-98	+521	+275	+284	+30
9-16-99	+139	+158	+141	-127
8-17-00	+179	+43	+210	+76
6-09-04	+199	+288	+178	+31
6-12-05	-250	-35	-252	+117
9-03-06	-346	-593	-472	-160
8-07-08	-254	+3	-12	-40
7-09-09	-403	-368	-343	+56
9-14-10	-373	-19	-52	+29
8-16-11	-304	-507	-368	-7

Table 39: Deviation from the mean of all classes on all barrier islands

All Islands Total Land Area		
Storm	Percentage Change	Area Change (Hectares)
1. Ivan (2004)	-9.97%	4504-4055
2. Georges (1998)	-7.92%	4826-4444
3. Gustav/Ike (2008)	-3.68%	4051-3902
4. Katrina (2005)	-2.37%	4055-3959
Total (1984-2011)	-18.83%	4929-4001

Table 40: Ranking each hurricane in terms of percentage change

The entire barrier island chain experienced a steady decline of its total area of land (Table 38). The total land area of all barrier islands remained completely below the mean after Hurricane Ivan's impacts (Table 39). Hurricane Ivan proved to be the most devastating in terms of land area loss for all six barrier islands combined (Table 40). After Hurricane Ivan devastated the northern Gulf Coast, the combined total land area of all six islands was down 874 hectares (-17.73%) from 1984. From 1984 to 2011, all six barrier islands combined to lose 928 hectares (-18.83%) of their total land area.

All Islands Total Healthy Vegetation		
Storm	Percentage Change	Area Change (Hectares)
1. Katrina (2005)	-25.95%	2153-1595
2. Gustav/Ike (2008)	-16.93%	2191-1820
3. Ivan (2004)	-13.05%	2476-2153
4. Georges (1998)	-4.75%	2463-2346
Total (1984-2011)	-42.57%	2927-1681

Table 41: Ranking each hurricane in terms of percentage change

The entire barrier island chain experienced significant healthy vegetation losses throughout the study time period (Table 38). The area of healthy vegetation on all barrier islands remained mostly below the mean after Hurricane Ivan's impacts (Table 39). Hurricane

Katrina was the most destructive in terms of total healthy vegetation loss on all six islands (Table 41). After Hurricane Katrina devastated the northern Gulf Coast, the total healthy vegetation on all six islands was down 1332 hectares (-45.51%) from 1984. From 1984 to 2011, the combined total area of healthy vegetation on all six islands decreased by 1246 hectares (-42.57%).

All Islands Pines and Shrubs		
Storm	Percentage Change	Area Change (Hectares)
1. Ivan (2004)	-22.9%	1878-1448
2. Gustav/Ike (2008)	-19.61%	1688-1357
3. Katrina (2005)	-15.19%	1448-1228
4. Georges (1998)	-7.21%	1984-1841
Total (1984-2011)	-36.48%	2097-1332

Table 42: Ranking each hurricane in terms of percentage change

The entire barrier island chain experienced a significant loss of pines and shrubs from 1984 to 2011 (Table 38). The area of pines and shrubs on all barrier islands remained completely below the mean after Hurricane Ivan made landfall along the northern Gulf Coast (Table 39). Hurricane Ivan was the most destructive storm in terms of pine and shrub loss on all six barrier islands combined (Table 42). After Hurricane Ivan devastated the northern Gulf Coast, the combined area of pines and shrubs on all six barrier islands was down 649 hectares (-30.95%) from its total in 1984. From 1984 to 2011, all six barrier islands combined to lose 765 hectares (-36.48%) of their pines and shrubs.

All Islands Marsh		
Storm	Percentage Change	Area Change (Hectares)
1. Katrina (2005)	-51.58%	537-260
2. Georges (1998)	-34.89%	450-293
3. Ivan (2004)	+19.07%	451-537
4. Gustav/Ike (2008)	+25.26%	380-476
Total (1984-2011)	+1.23%	408-413

Table 43: Ranking each hurricane in terms of percentage change

The barrier island chain has experienced fluctuations and a slight increase in its marsh area throughout the study period (Table 38). The area of marsh on all barrier islands fluctuated below and above the mean throughout the entire study time period (Table 39). Hurricane Katrina was the most destructive storm in terms of marsh loss throughout the entire barrier island chain (Table 43). After Hurricane Katrina devastated the northern Gulf Coast, the combined area of marsh on all six barrier islands was down 148 hectares (-36.27%) from its total in 1984. From 1984 to 2011, the combined area of marsh on all six barrier islands increased by five hectares (+1.23%).

4.8 Shapefiles

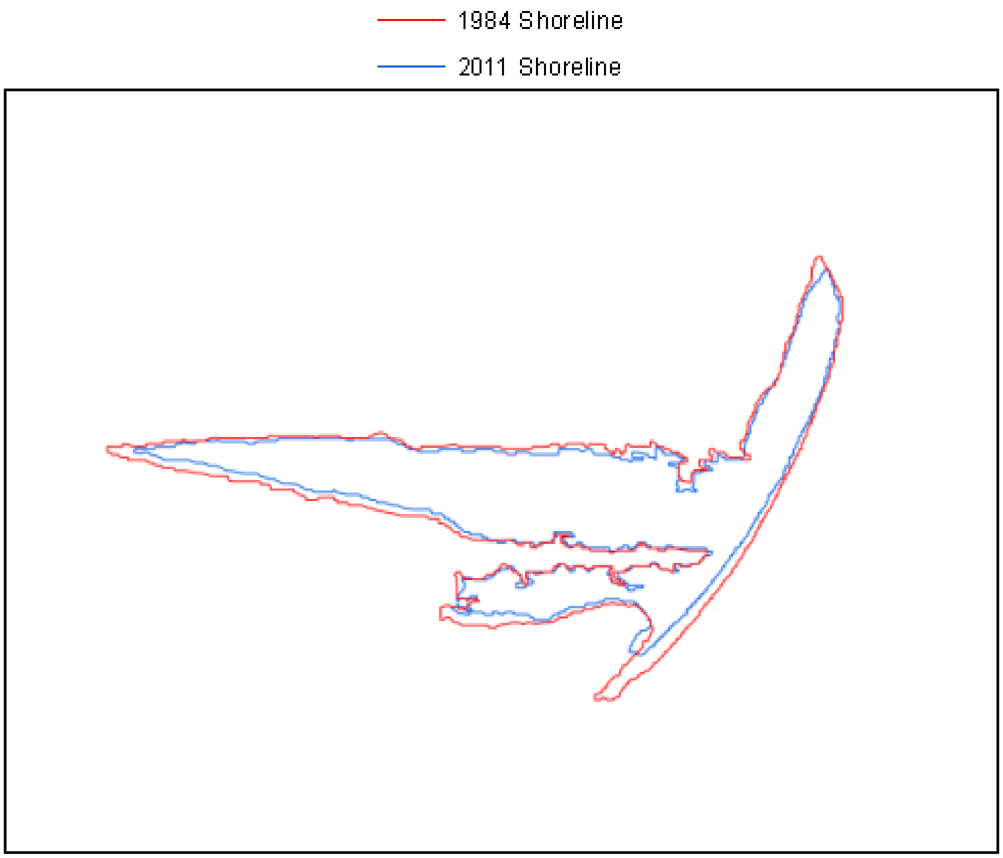

Figure 64: Shapefiles showing the 1984 and 2011 shorelines of Cat Island

The shapefiles created for Cat Island (Figure 64) show the island's shorelines as they existed in 1984 and 2011. The two shapefiles show that the setting and structure of Cat Island have changed minimally from 1984 to 2011. The southeastern tip of the island appears to have changed the most. The two shapefiles show that the southeastern tip of the island has receded considerably to the north. The island's western point has receded slightly to the east as well. The entire island is slightly less thick in 2011 when compared to 1984.

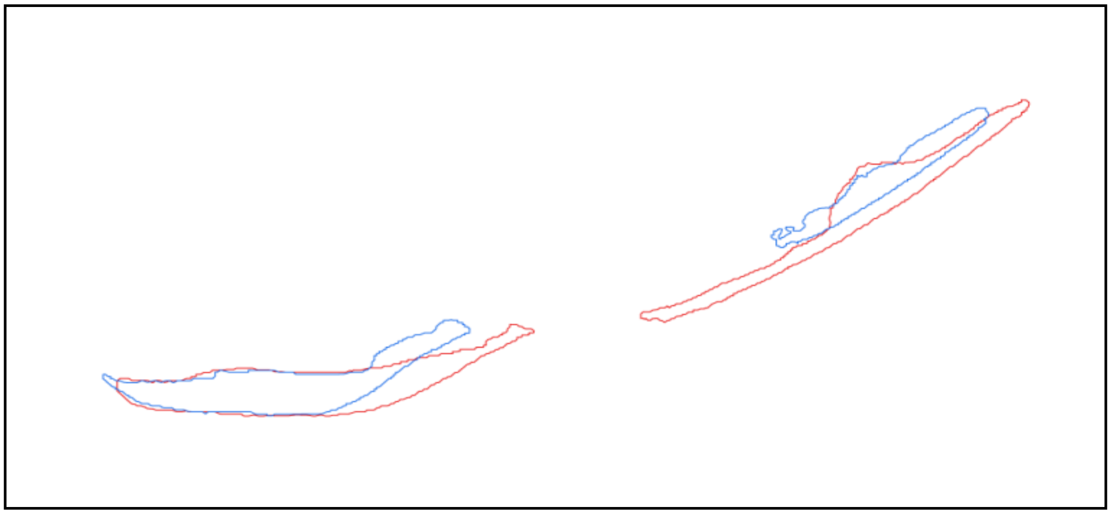

Figure 65: Shapefiles showing the 1984 and 2011 shorelines of West and East Ship Island

The shapefiles created for West and East Ship Island (Figure 65) show how greatly these islands have changed. The interior setting of West Ship Island has changed little. However, the eastern end of the island has receded significantly to the west. The eastern end of the island has also shifted slightly to the north. East Ship Island has changed dramatically from 1984 to 2011. The western half the island has completely disappeared throughout the study period. The interior of the island has become slightly less thick. The physical setting of the island has shifted slightly to the north as well. Because West Ship Island has receded to the west, and East Ship Island has receded to the east, the Camille Cut was significantly wider in 2011 when compared to 1984.

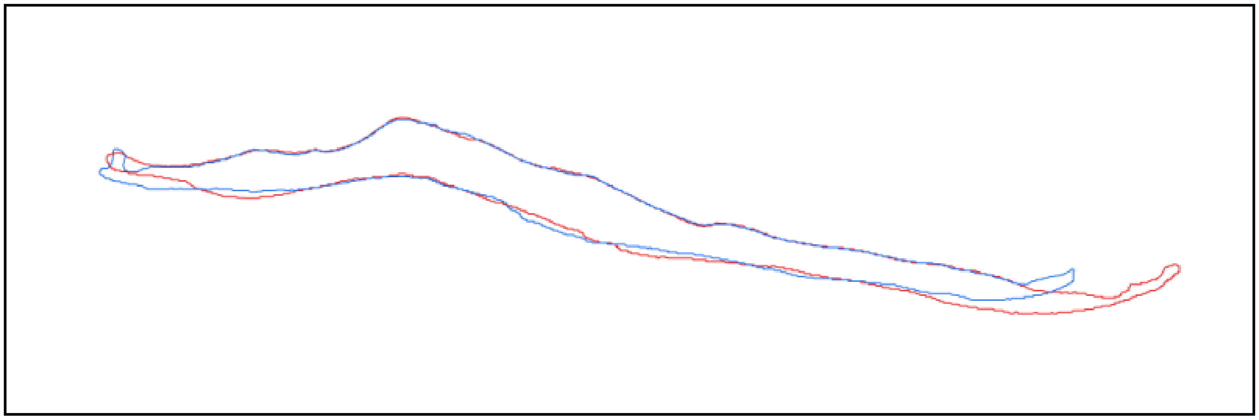

Figure 66: Shapefiles showing the 1984 and 2011 shorelines of Horn Island

The 1984 and 2011 shapefiles show that the setting of Horn Island (Figure 66) has changed little throughout the study time period. The biggest change is associated with the eastern end of the island. The eastern end of the island receded considerably to the west from 1984 to 2011. The island appears to be slightly thicker in 1984 when compared to 2011. The western end of the island has undergone some slight changes as well. The western tip of the island pointed toward the west in 1984. However, the western tip of the island pointed to the north in 2011.

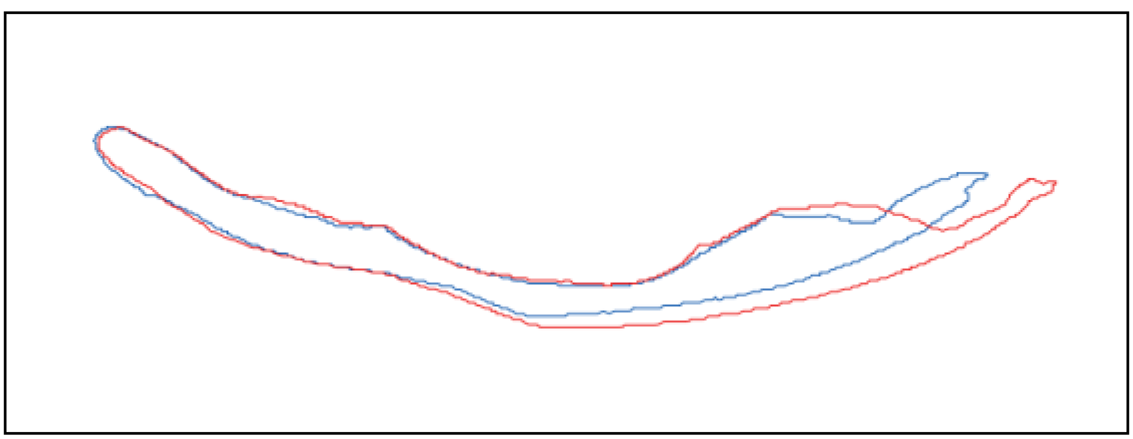

Figure 67: Shapefiles showing the 1984 and 2011 shorelines of Petit Bois Island

The 1984 and 2011 shapefiles created for Petit Bois Island (Figure 67) show that the island has undergone some significant changes. The island has become considerably thinner in its eastern portion. The eastern end has receded to the west and also shifted to the north. The southern beaches have shifted to the north over the course of the study time period as well. These shapefiles clearly show how the island lost considerable land area from 1984 to 2011.

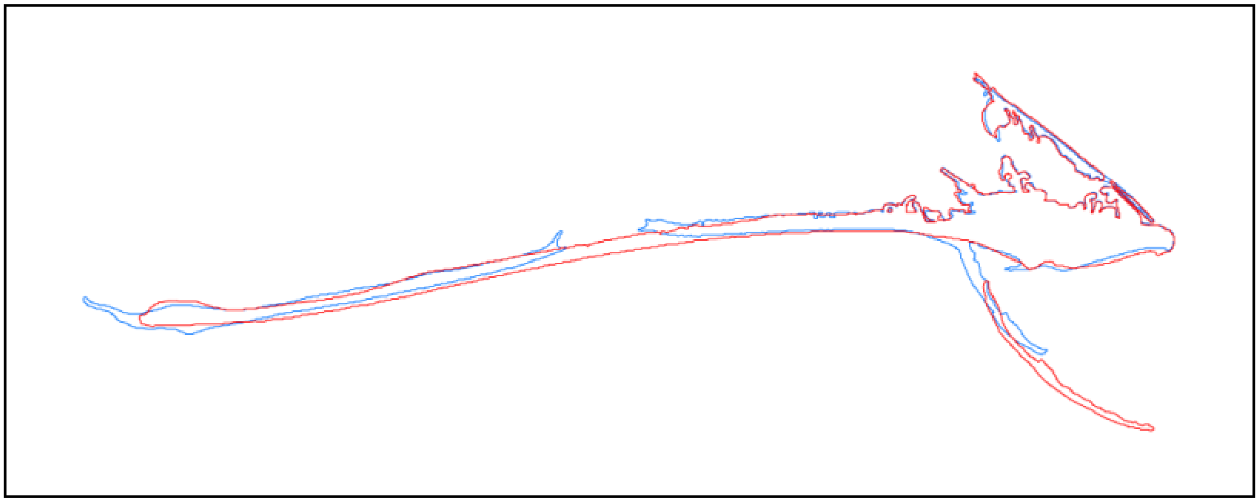

Figure 68: Shapefiles showing the 1984 and 2011 shorelines of Dauphin Island

The 1984 and 2011 shapefiles created for Dauphin Island (Figure 68) clearly show the major changes the island has undergone. The most obvious change is the Katrina Cut in the center of the island. The western tip of the island actually extended farther to the west in 2011 when compared to 1984. The eastern segment has undergone slight changes. The southeastern beaches receded slightly to the north from 1984 to 2011. The shapefiles clearly show how Pelican-Sand Island migrated to the northwest and became attached to Dauphin Island.

4.9 Accuracy Assessments

Cat Island Accuracy Assessment			
Category	Number of Points Sampled	Correctly Classified Points	Percent Correct
Water	12	12	100
Sand	12	11	92%
Pines/Shrubs	12	10	83%
Marsh	12	11	92%
Total	48	44	92%

Table 44: Accuracy assessment of the 9/14/2010 Cat Island supervised classification

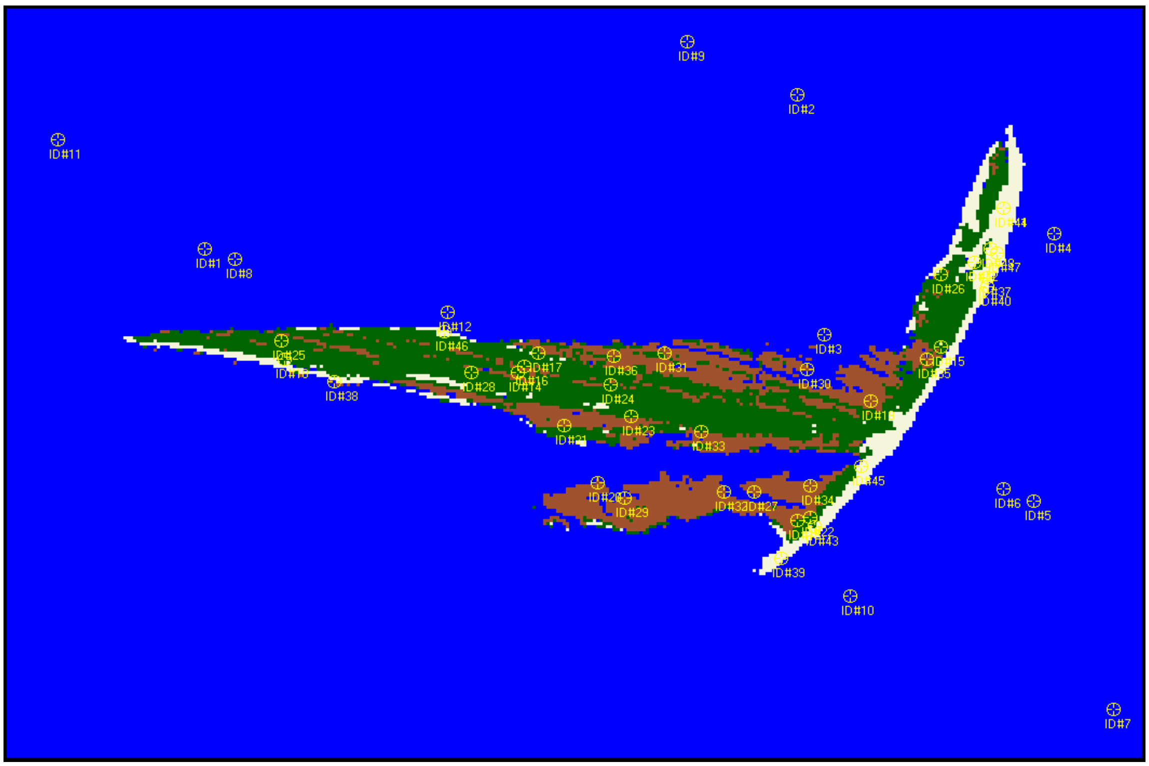

Figure 69: Accuracy assessment of the Cat Island supervised classification image

The accuracy assessments reveal 92% of the pixels in the subset September 14, 2010 Landsat 5 TM scene of Cat Island were correctly classified (Table 44). The pine and shrub class was the only class not to have 90% or greater accuracy. The two incorrectly classified sample points of the pine/shrubs class should have been classified as marsh. The one incorrectly classified sample point in the marsh class should be classified as pine/shrub. The one incorrectly classified sample point of the sand class should have been classified as marsh (Figure 69).

West Ship Island Accuracy Assessment			
Category	Number of Points Sampled	Correctly Classified Points	Percent Correct
Water	7	7	100
Sand	7	7	100
Pines/Shrubs	7	6	86%
Total	21	20	95%

Table 45: Accuracy assessment of the 9/14/2010 West Ship Island supervised classification

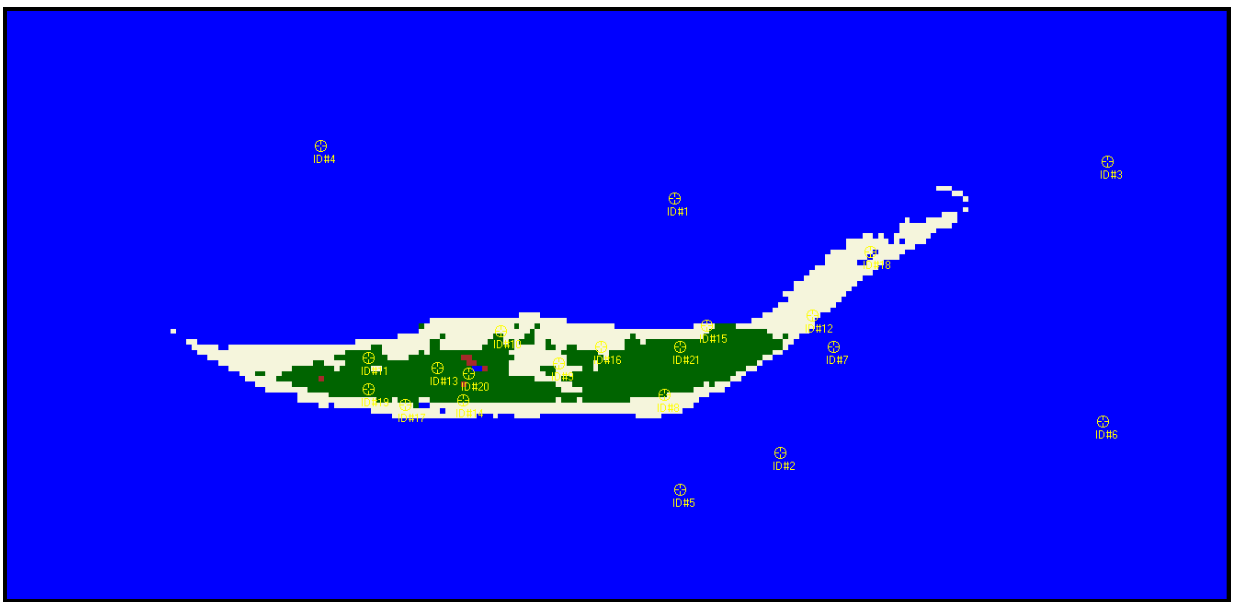

Figure 70: Accuracy assessment of the West Ship Island supervised classification image

Accuracy assessments reveal that 95% of the pixels in the subset September 14, 2010 Landsat 5 TM scene of West Ship Island were correctly classified (Table 45). The only sample point that was not classified correctly was in the pine/shrub class. The incorrectly classified pixel should have been in the sand class (Figure 70).

East Ship Island Accuracy Assessment			
Category	Number of Points Sampled	Correctly Classified Points	Percent Correct
Water	5	5	100%
Sand	5	5	100%
Pines/Shrubs	5	4	80%
Total	15	14	93%

Table 46: Accuracy assessment of the 9/14/2010 East Ship Island supervised classification

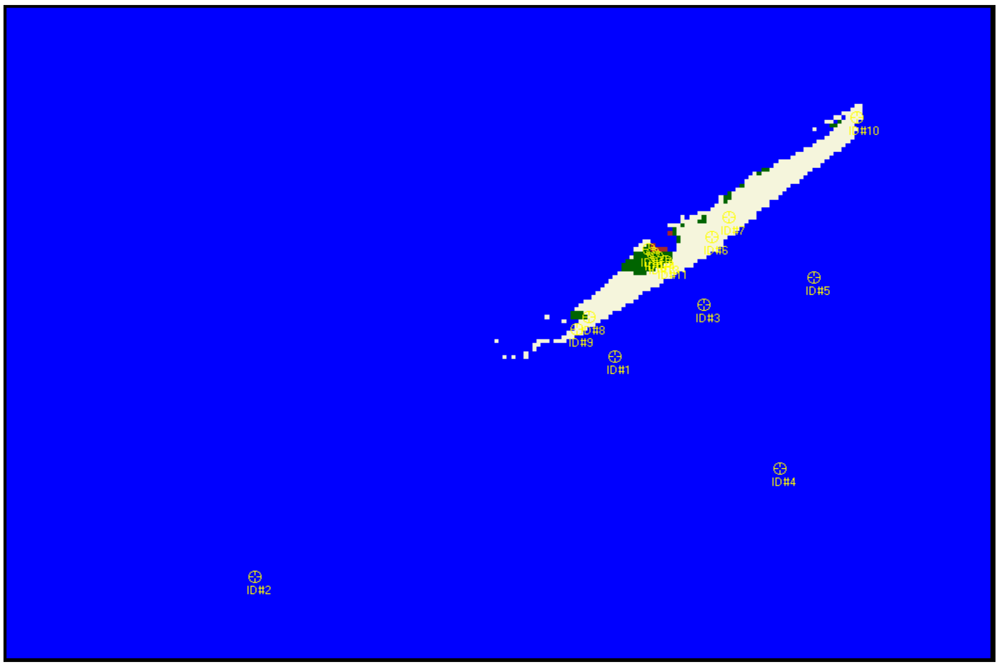

Figure 71: Accuracy assessment of the West Ship Island supervised classification image

Accuracy assessments reveal that 93% of the pixels in the subset September 14, 2010 Landsat 5 TM scene of East Ship Island were correctly classified (Table 46). Only one sample point in the pine/shrub class was incorrectly classified. The incorrectly classified pixel should have been placed in the sand class (Figure 71).

Horn Island Accuracy Assessment			
Category	Number of Points Sampled	Correctly Classified Points	Percent Correct
Water	12	12	100%
Sand	12	10	83%
Pines/Shrubs	12	11	92%
Marsh	12	10	83%
Total	48	48	90%

Table 47: Accuracy assessment of the 9/14/2010 Horn Island supervised classification

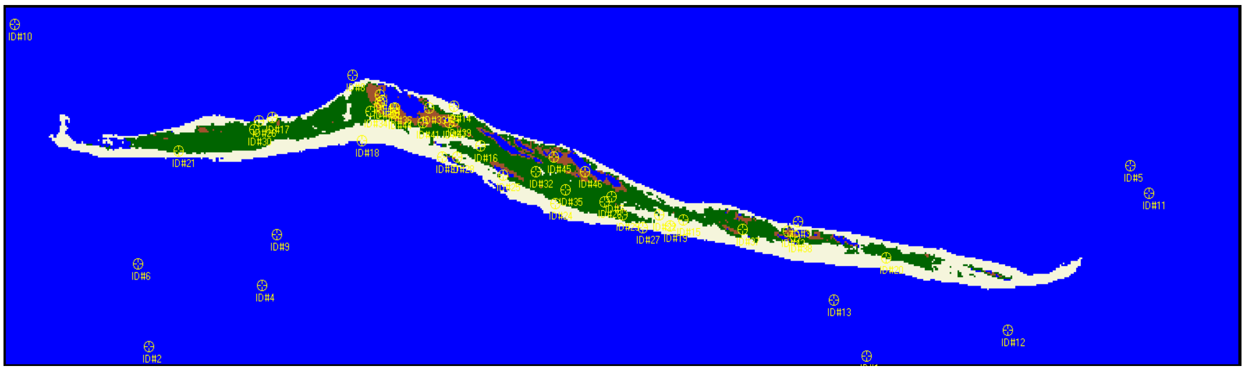

Figure 72: Accuracy assessment of the Horn Island supervised classification image

Accuracy assessments reveal that 90% of the pixels in the subset September 14, 2010 Landsat 5 TM scene of Horn Island were correctly classified (Table 47). Two of the sample points in the sand class were incorrectly classified. One should have been in the pine/shrub class, and the other should have been placed in the marsh class. One of the sample points in the pine/shrub class was incorrectly classified. The pixel should have been placed in the marsh class. Two sample points in the marsh class were incorrectly classified. One should have been placed in the sand class, and one should have been placed in the pine/shrub class (Figure 72).

Petit Bois Island Accuracy Assessment			
Category	Number of Points Sampled	Correctly Classified Points	Percent Correct
Water	12	12	100%
Sand	12	10	83%
Pines/Shrubs	12	11	92%
Marsh	12	11	92%
Total	48	48	92%

Table 48: Accuracy assessment of the 9/14/2010 Petit Bois Island supervised classification

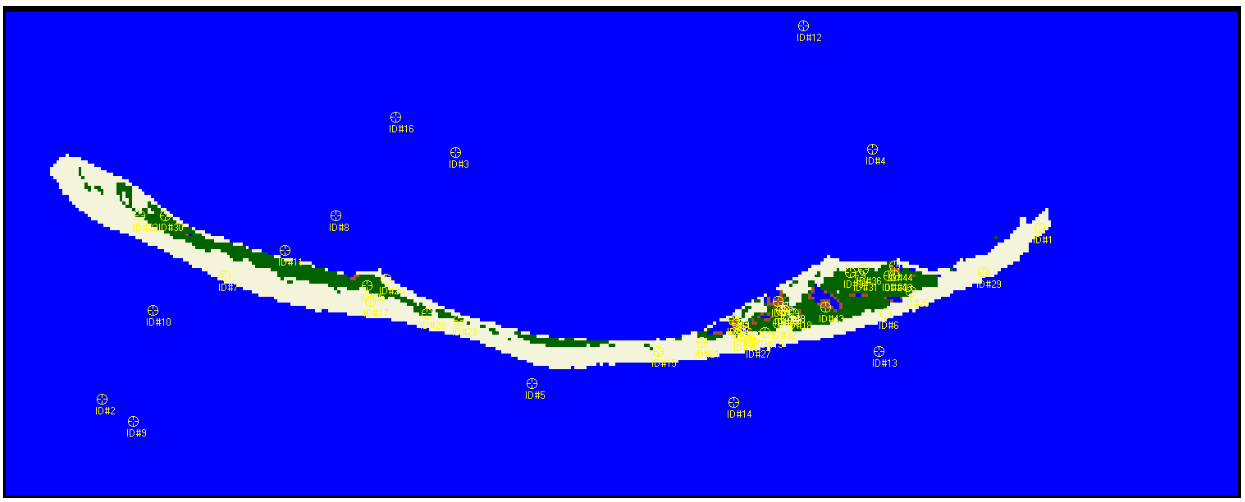

Figure 73: Accuracy assessment of the Petit Bois Island supervised classification image

Accuracy assessments reveal that 92% of the pixels in the subset September 14, 2010 Landsat 5 TM scene of Petit Bois Island were correctly classified (Table 48). Two of the sample points in the sand class were incorrectly classified. One should have been placed in the marsh class, and the other should have been placed in the pine/shrub class. One of the sample points in the pine/shrub class was incorrectly classified. It should have been placed in the marsh class. One of the marsh sample points was incorrectly classified. It should have been placed in the pine/shrub class (Figure 73).

Dauphin Island Accuracy Assessment			
Category	Number of Points Sampled	Correctly Classified Points	Percent Correct
Water	12	12	100%
Sand	12	10	83%
Pines/Shrubs	12	10	83%
Marsh	12	10	83%
Total	48	42	88%

Table 49: Accuracy assessment of the 8/16/2011 Dauphin Island supervised classification

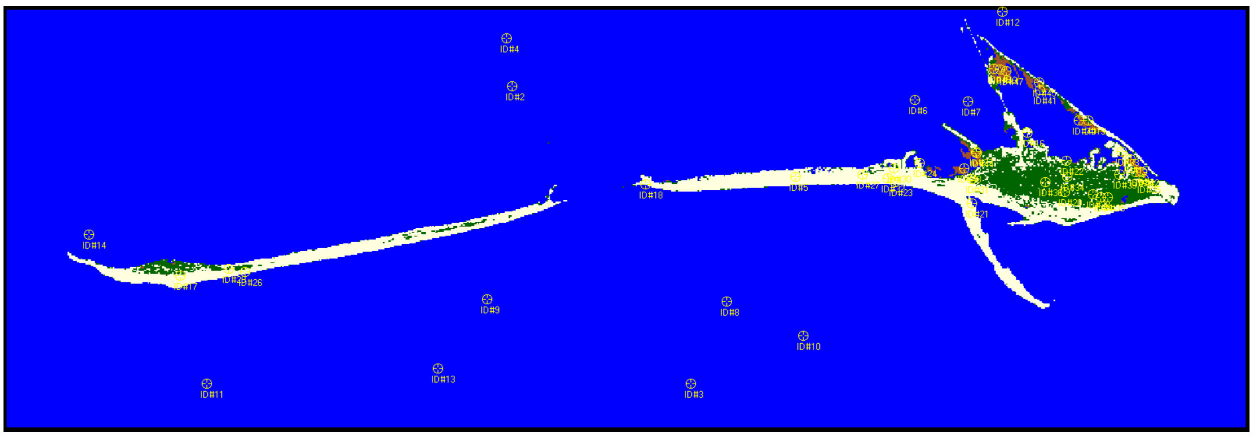

Figure 74: Accuracy assessment of the Dauphin Island supervised classification image

Accuracy assessments reveal that 88% of the pixels in the subset August 16, 2011 Landsat 5 TM scene of Dauphin Island were correctly classified (Table 49). Two sample points in the sand class were incorrectly classified. Both of these pixels should have been placed in the pine/shrub class. Two sample points in the pine/shrub class were incorrectly classified. One of these pixels should have been placed in the sand class, and one should have been placed in the marsh class. Two of the sample points in the marsh class were incorrectly classified. One should have been placed in the sand class, and one should have been placed in the pine/shrub class (Figure 74).

All Six Islands Accuracy Assessment			
Category	Number of Points Sampled	Correctly Classified Points	Percent Correct
Water	60	60	100%
Sand	60	53	88%
Pines/Shrubs	60	52	87%
Marsh	48	42	88%
Total	228	207	91%

Table 50: Combined accuracy assessment of all six barrier islands

All sample points in the water class for the entire island chain were correctly classified. Seven sample points in the sand class for the entire island chain were incorrectly classified, leading to 88% of the pixels correctly classified. Eight sample points in the pine/shrub class for the entire island chain were incorrectly classified, leading to 87% of the pixels correctly classified. Six of the sample points in the marsh class for the entire island chain were incorrectly classified, leading to 88% of the pixels correctly classified. 207 of the 228 sample points for the entire island chain were correctly classified. The accuracy assessment for the entire island chain was 91% (Table 50).

4.10 Field Photographs

Figure 75: Lake Galliard in the bird sanctuary on Dauphin Island

Figure 76: Dead pine trees in the bird sanctuary on Dauphin Island

Figure 77: Dead pine trees on the eastern end of Dauphin Island

Figure 78: Dead and snapped pine trees in the southeastern portion of the bird sanctuary

Figure 79: Remnants of a swamp in the bird sanctuary on Dauphin Island

Figure 80: Healthy pine and shrub growth in the bird sanctuary on Dauphin Island

Figure 81: Looking west from the eastern tip of Dauphin Island

Figure 82: Southeastern beaches of Dauphin Island overlooking Pelican Bay

Figure 83: Marsh growth on the northern shore of Dauphin Island

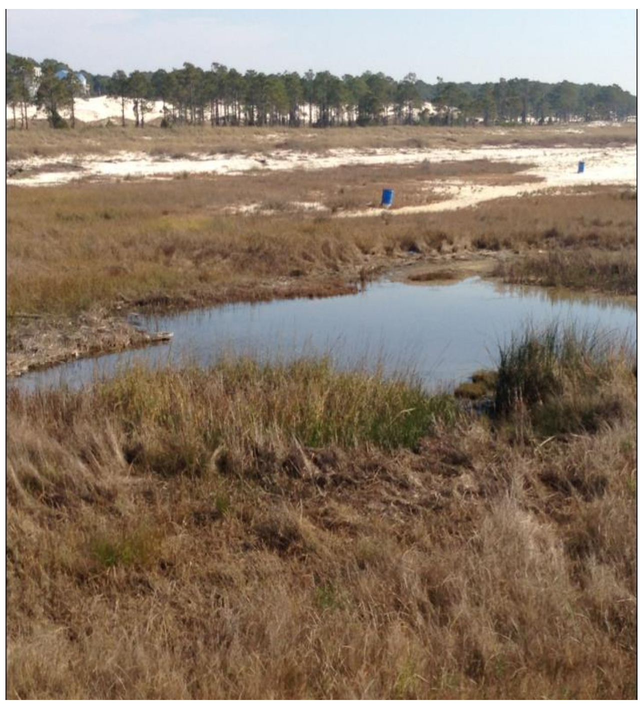

Figure 84: Small tidal pool located on the southern beaches of Dauphin Island

Figure 85: Connection point of Dauphin Island and Pelican-Sand Island

Figure 86: The western most point of development of Dauphin Island overlooking the open Gulf of Mexico

5. DISCUSSIONS

5.1 Cat Island

The shape and geomorphic structure of Cat Island changed very little from 1984 to 2011. The island suffered losses of land area, pines and shrubs, and total healthy vegetation after each hurricane made landfall on the Gulf Coast. However, only Hurricanes Georges and Katrina destroyed a significant portion of Cat Island's marsh. The island gained marsh area after Hurricanes Ivan, Gustav, and Ike. This could be due to inaccuracies in the supervised classification. However, it could also be attributed to the conversion of some land cover from pines and shrubs to marsh. The large southern marsh peninsula of Cat Island was damaged badly by Hurricane Georges, and it was almost completely destroyed by Hurricane Katrina. This area of marsh rebounded dramatically after each storm. The total land area of Cat Island has been relatively stable since Hurricane Katrina made landfall on the northern Gulf Coast in 2005. Cat Island's pines and shrubs, total healthy vegetation, and marsh have all rebounded significantly since Hurricane Katrina's devastating impacts.

5.2 West Ship Island

Similar to Cat Island, the shape and structure of West Ship Island has changed little from 1984 to 2011. However, the island did steadily lose land, total healthy vegetation, and pines and shrubs throughout the entire study period. The island actually gained land area after Hurricane Katrina made landfall in 2005. The island was home to less than one hectare of marsh during most years throughout the study period. Therefore, the area of marsh on West Ship Island experienced little to no change. The Camille Cut was close to sealing itself before

Hurricane Katrina significantly widened the channel. The Camille Cut has slowly gotten smaller over the last five years of this study, but the distance between West Ship Island and East Ship Island is still dramatically longer than before Hurricane Katrina.

5.3 East Ship Island

East Ship Island has suffered a greater percentage decline of land area and vegetation cover than any island in this study. The island stayed elongated with a thick center and freshwater lake from 1984 to 1998. After Hurricane Georges made landfall in Mississippi, part of the thin western segment of the island spilt. The split in the western part of the island sealed itself before Hurricane Ivan made landfall in Alabama in 2004. After Hurricane Ivan, East Ship Island split in almost the exact same area as it did in 1998. Hurricane Katrina left only the thick central portion of the island above water. Since Hurricane Katrina made landfall in 2005, the island has been slowly growing in length, but its thick central portion and freshwater lake are gone. Pines, shrubs, and marsh were concentrated in the central portion of the island in 1984. However, nearly all the vegetation is gone from East Ship Island in 2011.

5.4 Horn Island

Horn Island has maintained its geomorphic structure very well since 1984. The island has steadily lost healthy vegetation due to the impacts of the hurricanes. Both the eastern and western ends of the island have undergone some structural changes. The eastern end of Horn Island was split into two pieces after Hurricane Ivan made landfall in 2004. Hurricane Katrina completely eroded the original east end of the island. Therefore, the island is shorter in length than it was in 1984. The western end was twisted by erosion and sand deposition due to Hurricane Katrina. The western end now points northward instead of westward. Horn Island is home to many freshwater lakes. The largest lake is located in the central portion of the island on the northern shore. This lake has been periodically open to the salt waters of the Mississippi Sound due to beach erosion.

5.5 Petit Bois Island

Petit Bois Island has suffered from steady land area and vegetation cover loss from 1984 to 2011. The island was home to a large lagoon on the northeastern shore until Hurricane Georges made landfall in Mississippi in 1998. The lagoon was completely opened to the Mississippi Sound after Georges eroded the northeastern shoreline. Hurricane Georges also eroded some the eastern end of the island. Hurricanes Ivan and Katrina completely eroded the original eastern end of the island. One of the most dramatic changes in the island from 1984 to 2011 is how thin the island has become. Petit Bois Island has steadily thinned in area from south to north since the beginning of this study. Hurricanes Ivan and Katrina both helped shrink the island's width from south to north, considerably.

5.6 Dauphin Island

Dauphin Island has undergone some significant changes from 1984 to 2011. In 1984, Pelican-Sand Island was located at a considerable distance offshore of the southern beaches of Dauphin Island. Overtime, the island migrated closer to the southern beaches of Dauphin Island. Hurricanes Ivan and Katrina helped shift Pelican-Sand Island significantly closer to

Dauphin Island, and the two islands connected in 2008. The supervised classifications show the northwestward migration of Pelican-Sand Island from 1984 to 2008. Hurricane Ivan was responsible for creating a small split in the center of Dauphin Island. This small channel can be seen in the 2005 supervised classification. Hurricane Katrina significantly damaged this weak portion of Dauphin Island. The 2006 supervised classification shows a large breach in the central portion of Dauphin Island. Hurricane Katrina's surge dramatically widened the small channel created by Hurricane Ivan. Despite the extreme impacts of Hurricane Katrina, Dauphin Island gained significant land area after the storm made landfall. The 2006 supervised classification shows that the western segment (east and west of the Katrina Cut) is significantly thicker when compared to the 2005 classified image. This could possibly result from extensive sand deposition on the northern beaches of the island from the Hurricane Katrina's storm surge. The Katrina Cut was sealed with 185,000 tons of rocks in early 2011. However, the 2011 supervised classification does not show these rocks due to the 30-meter spatial resolution of Landsat 5 TM.

5.7 Average Rank of Each Hurricane

The average rank for each hurricane was determined by summing the ranks for land area destruction, total healthy vegetation loss, pine and shrub loss, and marsh loss on each island. The sum of these ranks was divided by the total number of land features analyzed on each island, which is 23. Each island had four land features that were analyzed (total land area, total healthy vegetation, pines and shrubs, and marsh), except for West Ship Island. The marsh category was omitted from West Ship Island. Hurricane Katrina had the highest average rank.

Katrina's average rank was 2.09. Therefore, in this study, Hurricane Katrina was the most destructive storm in terms of total land area, total healthy vegetation, pines and shrubs, and marsh loss on all six islands. Hurricanes Gustav and Ike combined to be the second most destructive. Their average rank was 2.57. Hurricane Ivan was the third most destructive to all six barrier islands. Ivan's average rank was 2.61. Hurricane Georges was the least destructive of all storms analyzed in this study. Georges had an average rank of 2.74.

5.8 Other Variables

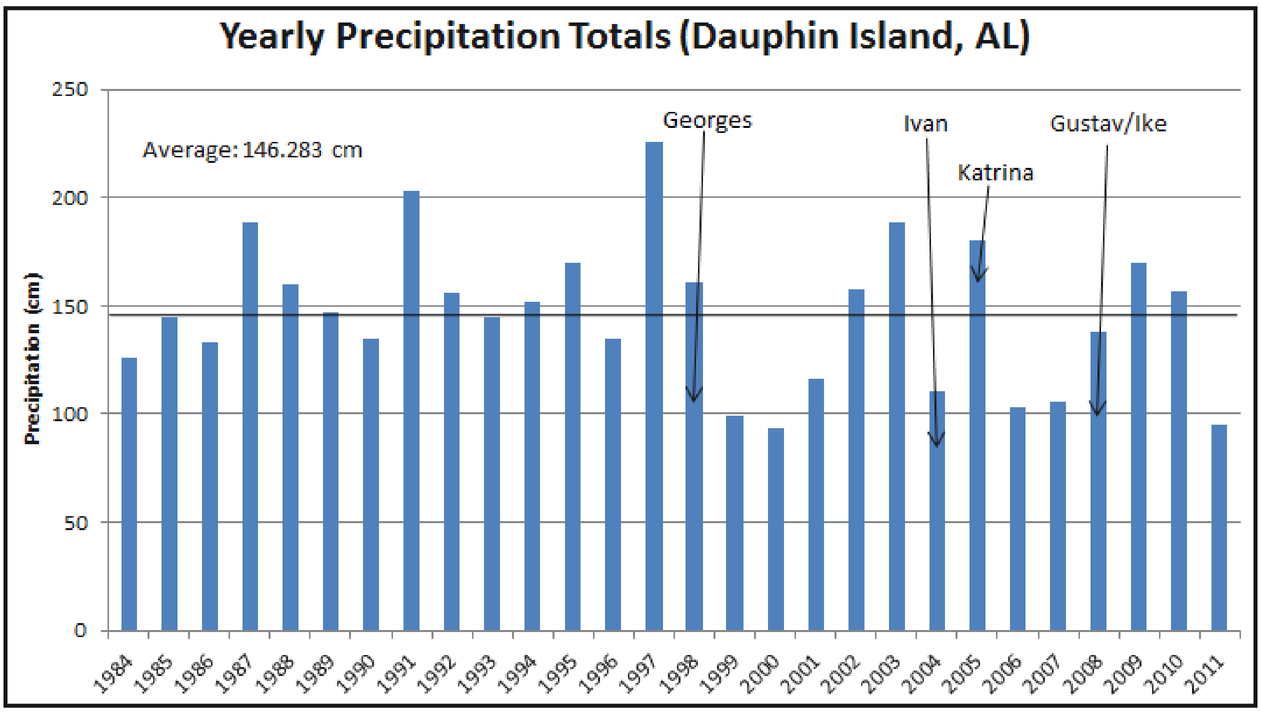

Figure 87: Yearly precipitation changes from 1984 to 2011 on Dauphin Island

The average temperature recorded at the NOAA observation station from 1984 to 2011 was 20.79 degrees Celsius. Every year during the time period of 2003-2011, with the exception of 2010, experienced above average temperatures (Figure 87). This could be a contributing factor of why, on each island, the area of total healthy vegetation remains mostly below the mean after Hurricane Ivan's impacts.

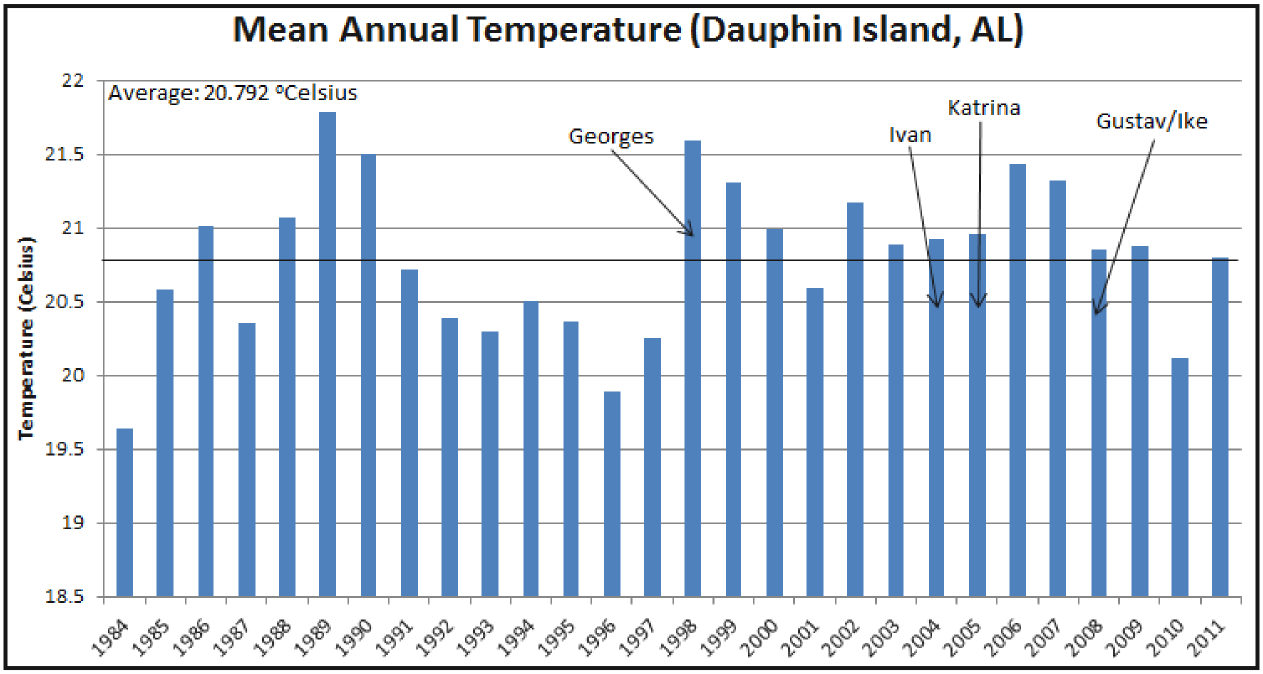

Figure 88: Mean annual temperature from 1984 to 2011 on Dauphin Island

The average yearly precipitation total recorded at the NOAA observation station from 1984 to 2011 was 146.28 centimeters. The years 2004, 2006, 2007, 2008, and 2011 were significantly below the average (Figure 88). This could also be a contributing factor of why, on each island, the area of healthy vegetation remains mostly below the mean after Hurricane Ivan made landfall.

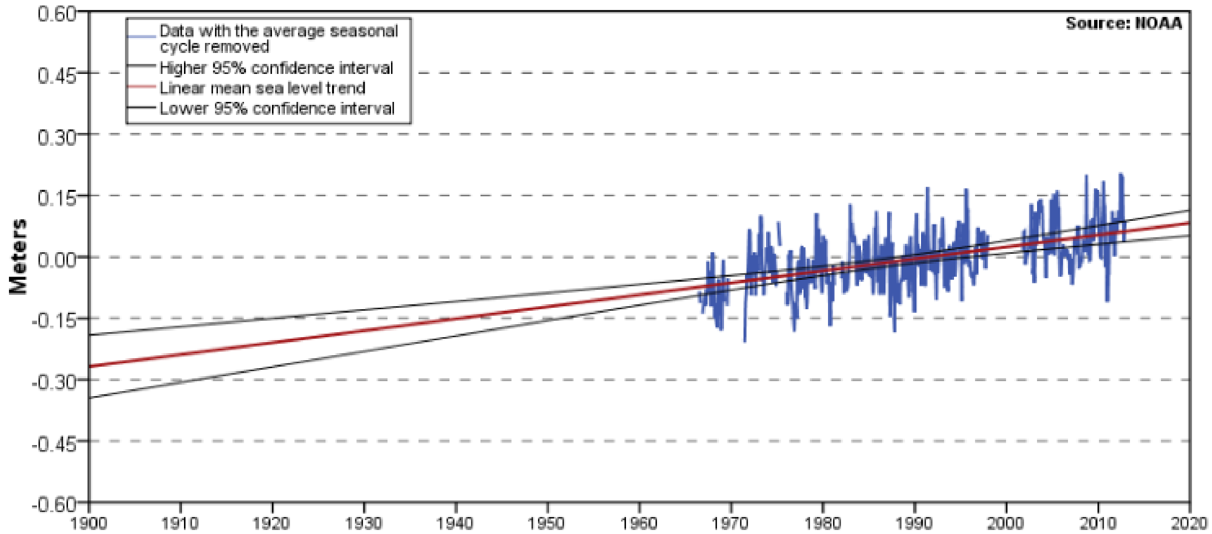

Figure 89: Mean sea level changes near Dauphin Island

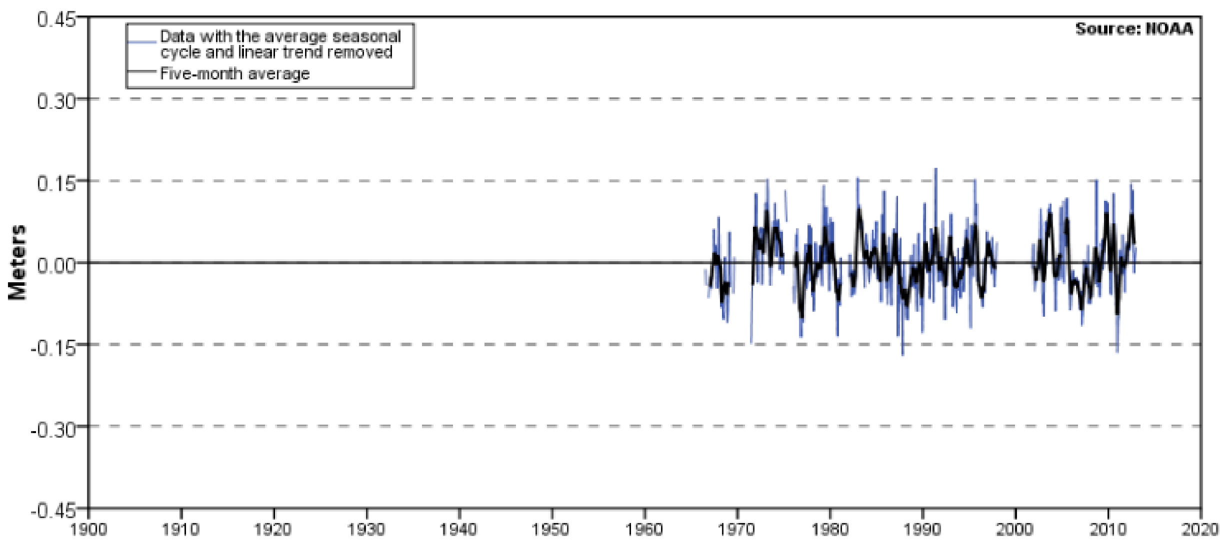

Figure 90: Mean sea level changes near Dauphin Island post 1965

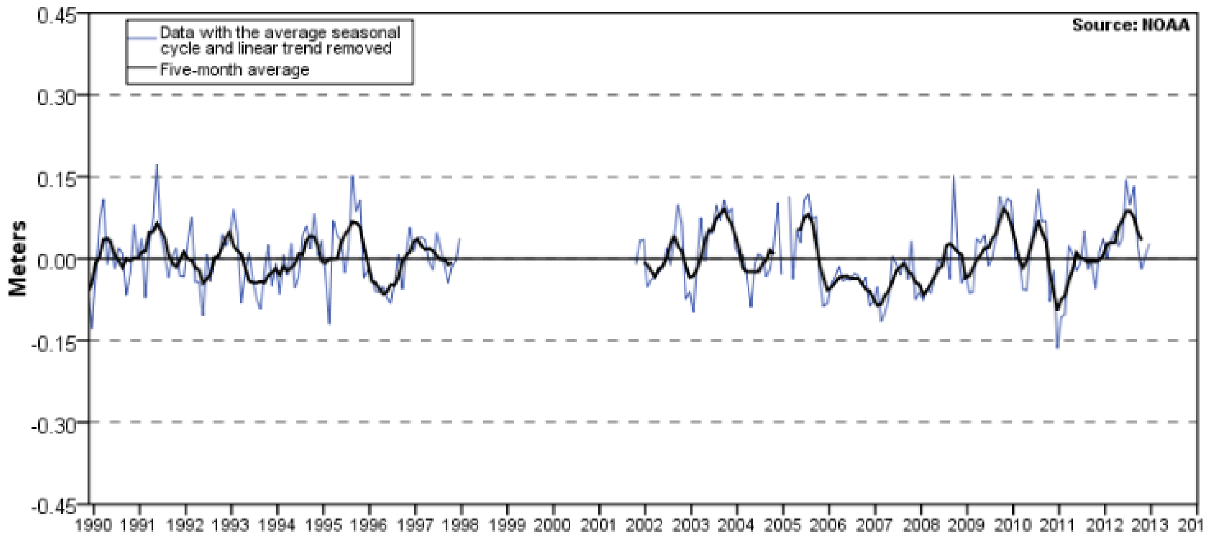

Figure 91: Fluctuations in mean sea level near Dauphin Island post 1989

Sea level changes have been recorded near Dauphin Island, post-1965. However, sea level information was unavailable from 1998 to 2001. The mean sea level rise near Dauphin Island is 2.98 +/- 0.87 millimeters per year from 1966 to 2012. The overall trend has fluctuated throughout the entire study period, but it has increased from 1984 to 2011 (Figures 89-91). Therefore, this would help explain some of the total land area loss on each island in this study.

6. CONCLUSION

The remote sensing techniques applied in this study show that all six barrier islands have seen significant changes since 1984. Supervised classifications and NDVI analyses show that the healthy vegetation cover on each island has suffered a greater decline versus the total land area. However, some barrier islands have seen significant land area loss, the worst being East Ship Island. Hurricanes have proved to produce drastic losses in vegetation cover on all six of these islands. Significant land area losses have also resulted from some of these hurricane impacts. Hurricane Katrina was responsible for significantly shortening the length of East Ship Island, resulting in a substantial widening of the Camille Cut. Remote sensing techniques also proved effective at showing the islands' total land area and vegetation rebounded after hurricane events in some cases. Although hurricanes appeared to be the main culprit for the significant changes in land area and vegetation cover of each island, changes in precipitation, temperature, and sea levels may have also played a role. GIS techniques also proved effective at showing how the shape of each island has changed throughout the entire study time frame. The created shapefiles show that each island has been reduced in size. When analyzing the created shapefiles, only Dauphin Island has increased in length from 1984 to 2011.

These six barrier islands serve as an important shield to the populated areas of southern Alabama and Mississippi. Without these islands, coastal areas of Alabama and Mississippi would be exposed to the full fury of hurricane impacts such as storm surge and large, destructive waves. These islands have proved to rebound in size after hurricane events along the Gulf Coast. However, a significant break in hurricane activity is needed to give the islands enough time to rebound to their size and status in 1984. Also, more local and federal projects need to be conducted in order to restore the islands to their previous conditions. The restoration project of West and East Ship Island is much needed and will help stabilize the most devastated island in this study, East Ship Island. The sealing of the Katrina Cut on Dauphin Island has the ability to help prevent further erosion along the breached area. However, anthropogenic restoration projects may not be enough to prevent the natural state of erosion, future impacts from hurricanes, and sea level rises.

Cat Island, West and East Ship Island, Horn Island, Petit Bois Island, and Dauphin Island have existed since the first Europeans arrived in the New World. Their future existence is crucial to the well-being of the coastal regions of Alabama and Mississippi. They are not only source of protection, but a sanctuary to a variety of wild life species. If these islands cease to exist, the populated regions of the Mississippi and Alabama coastlines will be at an increased risk of coastal flooding, destructive waves, and storm surge. Property owners near the shorelines will face the real possibility of losing their homes to the Gulf of Mexico.

These islands must be preserved, and the methods utilized in this research are valuable for analyzing their conditions in the future. The conditions of these barrier islands and barrier islands throughout the world can be analyzed using the same techniques discussed in this thesis research. Remotely sensed data and remote sensing techniques are crucial for future change detections in total size of barrier islands and land use/land cover on barrier islands throughout the world. GIS techniques are also important for mapping past, present, and future shorelines of barrier islands. The GIS techniques used in this study can be used to monitor shoreline erosion over a period of time and after hurricane events. The methodology used in this research is important for monitoring how future hurricane events and other severe storms will impact barrier islands throughout the world. These techniques are also critical for analyzing sea level changes along coastal regions. This research provides an effective methodology for monitoring the past, present, and future conditions of barrier islands located in the Gulf of Mexico and throughout the entire world.

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