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Monitoring Tidal Marshes of Florida's Big Bend: regional variations and geologic influences

by

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TABLE OF CONTENTS

ILLUSTRATIONS

TABLES

Monitoring Tidal Marshes of Florida's Big Bend:

regional variations and geologic influences

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ABSTRACT

The marsh morphology of Florida's Big Bend coast, as observed from Landsat TM satellite imagery, corresponds to the underlying geology. The major rock units have a direct bearing on the width of the marsh, shoreline configuration, and the presence of salt barrens, sawgrass and coastal hammocks. Climate zones influence the presence of plant species, while sea level change impacts vegetation succession differentially along the coast. Tidal creeks and freshwater from the Floridan aquifer system provide an additional control on marsh variation. A comparison of vegetation indices from 1986-1991 imagery suggests a decline in vegetative health at the gulf edge and at the upland boundary. Further comparisons with 1995 imagery will elucidate the relationships observed in this analysis.

INTRODUCTION

The tidal marshes of Florida's Big Bend coast extend along a 250 km stretch of coast from Wakulla County to Pasco County (Plate 1). This area is relatively pristine, however rapid growth is occurring from both the north and the south. Changes in climate, sea level and land use may lead to potential long-term changes along this coastline. While the shoreline itself appears unchanged in over 100 years, vegetation change provides a key to detecting important alterations in the conditions of this coastline. Remotely sensed imagery is used to characterize this coast and document the changes. This report describes factors shaping the characteristics of the marshes and observations that may be used to identify change due to natural climatic and human factors.

IMAGE ANALYSIS

Landsat Thematic Mapper (TM) imagery is the primary data source in this investigation. Aerial photography, SPOT imagery, National Wetlands Inventory (NWI) maps and other sources are also investigated. The imagery is co-registered, rectified to UTM (Universal Transverse Mercator), radiometrically corrected, and corrected for atmosphere using dark object subtraction. Analyses include classifications and vegetation indices (NDVI) of April 1986 and February 1991 imagery. Seasonality is not significant in Florida tidal marshes, although some non-marsh areas show lower NDVI (Normalized Differenced Vegetation Index) in the 1991 scene. This paper employs a simplified classification with only four categories: water, tidal marsh, upland, and barren/developed. Upland includes all nontidal vegetation. A map accuracy check is conducted using 120 stratified random samples of the four categories and referring to CIR (Color Infrared) aerial photography from 1984 and 1988 (table 1). Some changes had occurred between the dates of the imagery and the aerial photography.

Table 1. Map accuracy for imagery classification depicted in this report

Land Cover	*Map Accuracy %*
Water	100
Tidal Marsh	85
Upland	85
Barren/Developed	96
Overall Map Accuracy	91

WETLANDS DESCRIPTION

The Big Bend tidal marshes occur on a low and flat limestone surface, which is physiographically referred to as the "Coastal Swamp" zone (White, 1970). The marsh is bounded on the interior by the Gulf Coastal Lowlands, extending from Wakulla to Pasco County. The low elevation gradients make this area particularly susceptible to alterations from sea level rise (Henry et al., 1994; White, 1970). The semidiurnal tide range is less than one meter. The presence of marshes along an open coast without barrier beaches is unusual for the U.S. east coast. This is due to the lack of sand-sized material (White, 1970), and this area should be considered a rocky coast. The shoreline has been altered minimally and estimates of marsh area in recent years are remarkably similar (table2).

Table 2. Tidal marsh acreage estimated for Wakulla to Hernando County

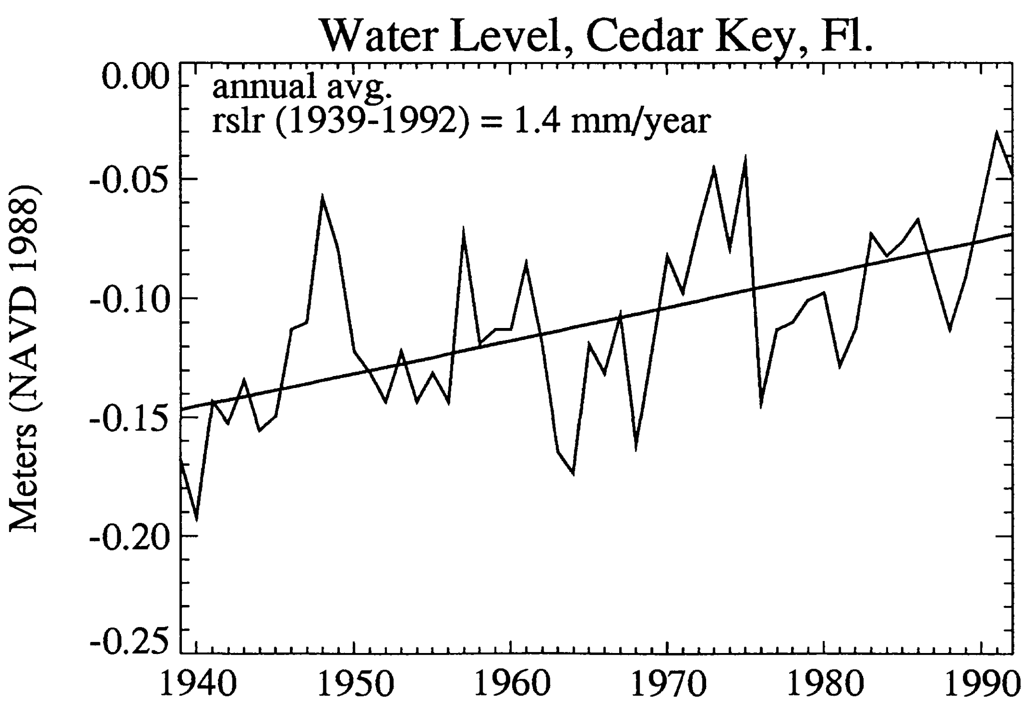
Source	*Marsh in acres*
1982 NWI*	151,290
1986 Landsat TM	160,571
1991 Landsat TM	159,736

*Lewis et al 1988

Annual precipitation for the region averages 56-62 inches (142-157 cm) from Henry et al. (1994). The northern counties experience a wet summer with moderate winter precipitation, while to the south heavy summer rainfall is followed by a drier winter. A climate zone boundary shown in Plate 1 (Henry et al., 1994) passes through the region. The frequency and severity of freezes increase north of the boundary at Cedar Key. Although this region is marginal for mangrove establishment, it may be hospitable for considerable lengths of time as documented by the distribution of mangroves in the mid-fifties (Plate 1). A series of hard freezes in the 1980's eliminated all mangroves from the entire Big Bend marsh zone. Mangroves along the coast are reestablishing, with estimated heights of one meter observed in 1993-94 field reconnaissance and detectable on 1993 satellite imagery.

Sea level along this coast has shown a trend upward over the last 50 years with fluctuations of up to 10 cm over 10 year periods (Figure 1). Data displayed is provided by NOAA NOS and referenced to the North American Vertical Datum of 1988. The gradual increase in sea level, if accompanied by marsh accretion, may have little negative impact on the marshes. However, shorelines may change where sediment is unavailable. The landward migration of the tidally influenced zone will be limited by elevation gradient and land use, and may impact upland vegetation where the gradient is low.

Figure 1. Sea level at Cedar Key, Florida 1939-1992.



VEGETATION

Big Bend tidal marshes have a thin veneer of sediment, 0-3 m deep, over the limestone. Slightly elevated limestone outcrops support sabal palm hammocks within the marsh, and to a large extent the marsh is buffered on the interior edge by the hydric hammock, a hardwood and sabal palm forest, limited primarily to the Coastal Lowlands and other wet, flat sites (Vince et al, 1989; FNAI/FDNR, 1990). The marshes are dominated by *Juncus romerianus* (black needlerush), which are flooded primarily by high tides. *Spartina alterniflora* (cordgrass) thrives on the regularly flooded banks facing the gulf and *Cladium jamaicense* (sawgrass) thrives at the marsh interior where fresh water flows, replacing *S. alterniflora* in low elevation, low salinity areas. The large expanses of tidal marsh plants effectively trap sediment and buffer storm surge (FNAI/FDNR, 1990). Salt barrens occur in some regions at the border between marsh and upland. The barrens are hypersaline environments that have sparse vegetation of *Batis, Salicornia* species, and other salt-tolerant vegetation. Patches of bare rock develop on the edges of hammocks, particularly where the hammocks have formed on rock crests having gentle relief.

GEOLOGIC CHARACTERISTICS

The bedrock along the Big Bend coast lies at or near the surface. The Tertiary limestone units in this area are an important part of the Floridan aquifer system. The shallowness of the rocks results in significant control on features in the marsh. The limestone has a karst topography generating sinkholes, solution depressions, pinnacles, and islands along the coast (Rupert and Arthur, 1990). In addition to these obvious local effects, regional variations in the morphology of the marsh coincide with the different units that have been described in the area (Plate 1). In particular, the occurrence of barrens, the smoothness of the coast, and the presence of hammocks, islands and sawgrass appear to vary with the underlying geologic formations.

The major rock units are the Ocala Limestone (sometimes called the Ocala Group) of late Eocene age (38 - 41 million years), the Suwannee Limestone of Oligocene age (25 - 33 million years old), and the St. Marks Formation of the early Miocene age (16 - 25 million years). More details and references on the geology of this coast are found in Rupert and Arthur (1990).

The St. Marks Formation

The marsh over the St. Marks Formation in Wakulla County (Plate 1) contains several spring-fed rivers, and displays a markedly irregular shoreline. Springs and sinks are commonly associated with this water-bearing limestone (Rupert and Arthur, 1990). Salt barrens are present in this area, possibly because of a quartz sandy component in this formation (Rupert and Arthur, 1990). Plate 2 illustrates the St. Marks River and adjoining marshes. This area is forested as well and is subject to prescribed burning as part of a management program. Note the salt barrens to the northwest of the marshes. This feature, unique to limited areas of the coast, helps to identify regional characteristics related to underlying geology.

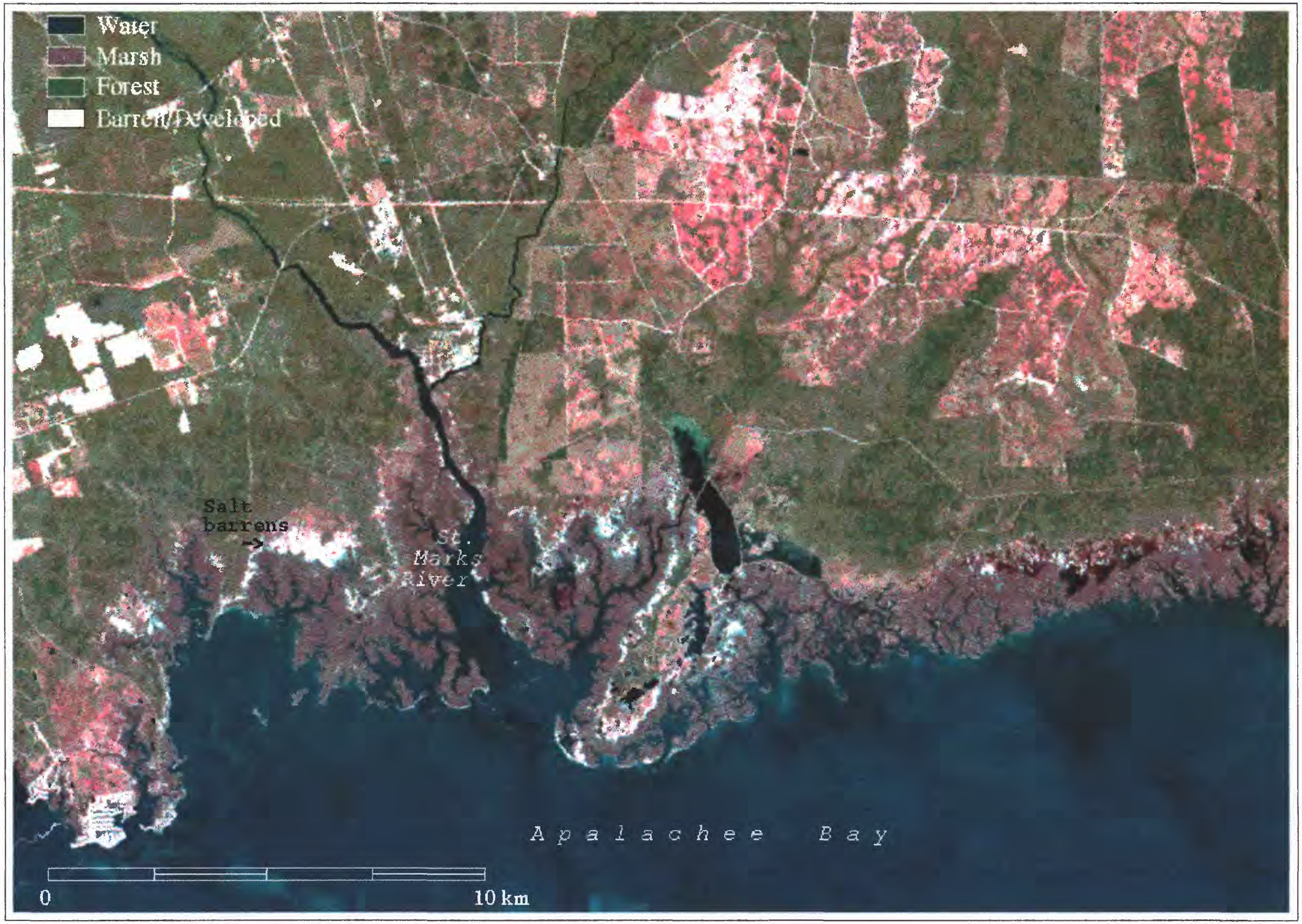


Plate 2. St. Marks, Wakulla County (Landsat TM April 1986)

The Suwannee Limestone

The region of the Suwannee Limestone (Plate 1) in Taylor County to the north, and Pasco and Hernando Counties to the south (Yon and Hendry, 1972) has a moderately wide marsh with a relatively linear coastline. The Suwannee is a hard limestone with a minor sand component and may be dolomitized in Taylor County in the Keaton Beach area (Cooke, 1945). The surface of the Suwannee is karstified with associated solution pipes and sinkholes (Yon and Hendry, 1972). Some hammocks are present and sawgrass may occur mixed with *Juncus*. Barrens occur in southern Taylor County which appears to have a discontinuous zone between the Suwannee Limestone and the 'Steinhatchee dolomite' (abandoned; Puri, 1957) of the Ocala Limestone to the south.

The Ocala Limestone

The Ocala Limestone is a more complex unit and is highly karstified (Vernon, 1951). It had originally been considered a Group with several formation members (Puri, 1957), although these members had traditionally been differentiated on fossil type rather than lithology and have not been maintained as preferred usages (Rupert and Arthur, 1990). However, the 'abandoned' members, the Steinhatchee dolomite, the Inglis/Williston, and the Crystal River formations, appear to affect coastal morphology. The Ocala Formation underlying the marsh in Hernando and Citrus Counties shows a strong karst topography (Plate 3), unlike the Suwannee Limestone region to the south. Springs are abundant in this area, and the marsh has the "archipelago" feature described by Davis et al. (1985). This area of extensive hammocks, islands, and springs corresponds to the region described as the 'Crystal River formation' (Vernon, 1951; Puri, 1957). The salt barren feature is uncommon here, pure stands of sawgrass occur, and exposed areas are usually rock outcrops, not yet colonized by marsh vegetation. Mangroves not present in the 1986 and 1991 imagery are currently recovering along the gulf edge.

The central region of the Ocala, in Levy and Dixie Counties from the Withlacoochee River to north of the Suwannee, includes the lower member of the Ocala Formation and has been referred to as the 'Inglis and Williston formations' (Vernon, 1951). The limestone north of the Withlacoochee River is highly soluble (White, 1970). Small springs and hammocks are common, the marsh is broad and is dissected by numerous tidal creeks reaching 1-3 km into the interior. The tidal creeks drain surface flow from the coastal hammocks and seepage from the Floridan aquifer system (Rupert, 1991). The Cedar Keys area is an anomaly, being composed of large sand bodies (White, 1970) and limestone islands (Vernon, 1951). The adjacent marsh has developed on an extensive complex of oyster reefs supported by freshwater from the Suwannee River, the largest river in the region.

The marsh changes appearance in northern Dixie and southern Taylor Counties. This region of narrow marsh with extensive salt barrens and a linear shoreline corresponds to what Puri et al. (1967) described as the 'Steinhatchee dolomite' member of the Ocala Formation (Plate 4). The dolomitization of limestone decreases its primary porosity (Rosenau et al, 1977) which may decrease the flow through of aquifer waters and contribute to the development of barren areas at the high water line where salts accumulate. This marsh/barren complex continues north and extends into an area tentatively identified as Suwannee Limestone. This area in southwestern Taylor County is the only area where the marsh morphology and the rock formations do not match well (see Plate 1). However, the break between the Ocala Group and the Suwannee Limestone in Taylor County is uncertain and may be discontinous (Frank Rupert, oral commun.1995; Campbell, 1993).

The association of the underlying rocks with characteristics such as extensive barrens suggest that these features will tend to remain associated with the rock types. The St. Marks region with a broad marsh and convoluted shoreline exhibits characteristic salt barrens and numerous springs. The harder Suwannee Limestone is characterized by a linear shoreline, a moderately wide marsh, tidal creeks of limited size and seepage from the Floridan aquifer system. The third region, the Ocala Limestone, has three geomorphic subregions, the 'Steinhatchee dolomite', the 'Inglis/Williston', and the 'Crystal River formations'. The Steinhatchee is identifiable by a narrow band of marsh, a linear form and numerous barren areas. The Inglis/Williston subregion has a characteristically broad marsh with numerous and long meandering tidal creeks, and extensive discharge from the aquifer through seeps, springs and solution channels. The Crystal River member exhibits a highly complex shoreline with many springs, tidal creeks, scattered limestone outcrops supporting coastal hammock vegetation, and virtually no salt barrens.

HYDROLOGIC CHARACTERISTICS

The tidal marshes occupy a low gradient limestone shelf flooded by a one meter tidal range. Meandering tidal creeks carry gulf waters up to 3 km inland. Marsh elevations and the low tidal range prevent tidal flooding of the marsh interior except at high tide and during storm surge. Aside from the tidal influence, the hydrology of the marsh is tied directly to the underlying geology, the thinly covered carbonates exposed to the process of dissolution, and the coincidence of the coast with the surface of the Floridan aquifer system (Scott, 1992). It is noteworthy the tidal marshes are absent to the south and west of the Big Bend where the top of the Floridan aquifer drops 50 feet below the land surface (Vernon, 1973).

Rivers along the coast are small and spring-fed with the exception of the Suwannee River with an average annual discharge of 298 m^3/s (1941-1994, USGS Water Resource Division records). All other rivers have an average annual discharge of 30 m^3/s and less. The Floridan aquifer system discharges significant freshwater along the marsh coast through seeps and springs, some springs producing tidal streams (Rupert and Arthur, 1990). First order coastal springs, > 3 m^3/s, are concentrated between Citrus and Hernando County with one exception in Wakulla County (Plate 1). Lower order coastal springs are scattered across the counties of the Big Bend coast. Reports indicate artesian flow from the aquifer occurs intermittently along the coast (Rupert and Arthur, 1990; Vernon, 1951).

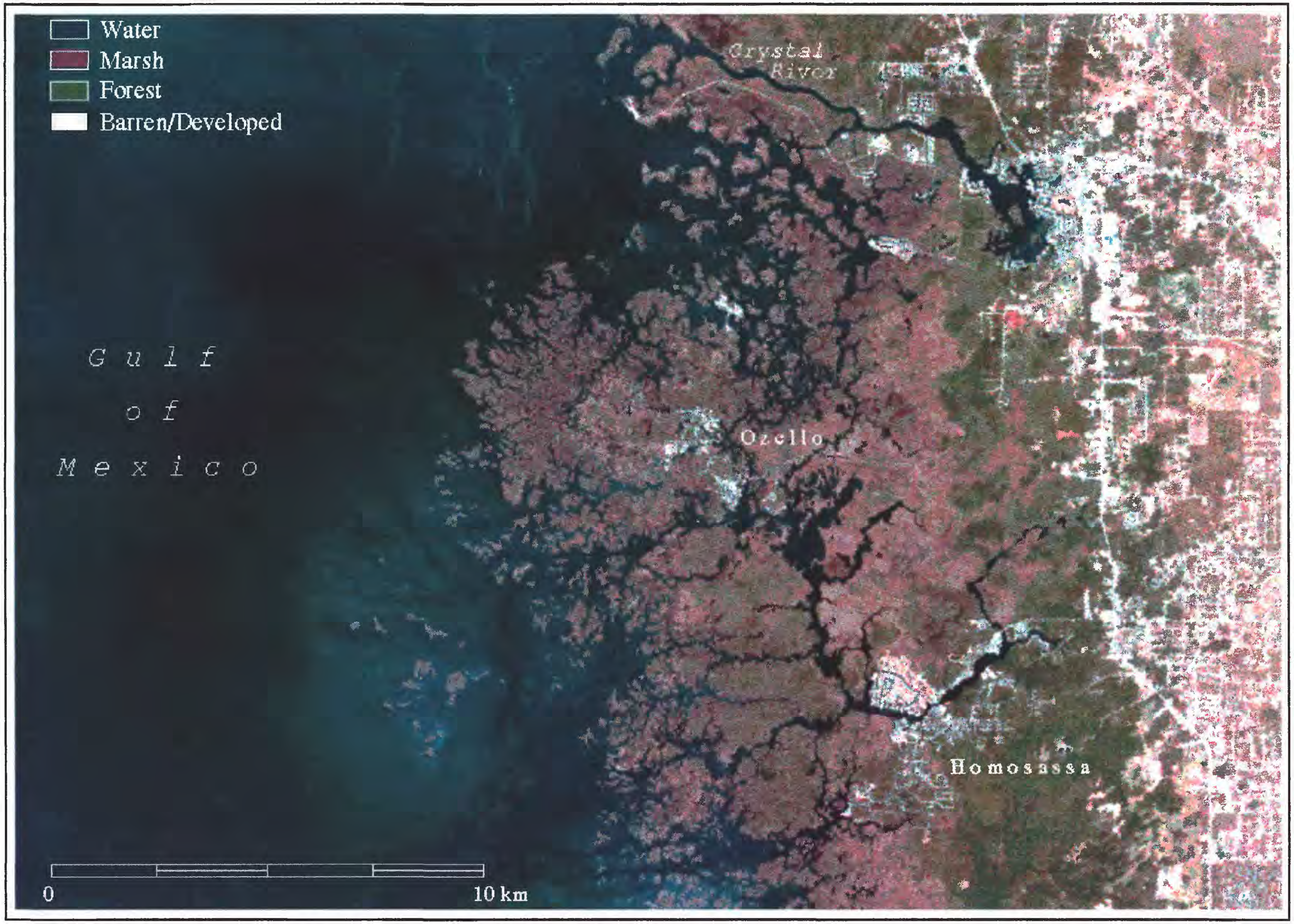


Plate 3. Ozello archipelago, Citrus County (Landsat TM April 1986)

Plate 4. Steinhatchee dolomite, Dixie County (Landsat TM April 1986)

CHANGE ANALYSIS

Change analysis based on a simple classification shows no net loss of marsh between 1986 imagery, 1991 imagery and earlier estimates of marsh acreage (table 1). Although there is no net loss, initial analysis of vegetation change based on vegetation indices shows a loss of greenness at the marsh transition zone and the gulf edge, and increases in greenness primarily as a recovery response to short-term disturbance. Seasonal and short term disturbance from which vegetation may recover include fire, storm wrack deposits, and low temperatures, as discussed earlier with respect to mangroves. Fire is a common disturbance in the vast *Juncus* marsh, both naturally occurring and as part of management programs. Recovery may occur in a few years and has been documented with satellite imagery.

It appears that vegetation succession may be occurring along the coast, not at the expense of marsh, but of upland and transitional species. The decline of greenness at the marsh interior suggests the hydrology of the area has changed, either by the increase in sea level and/or fluctuations in precipitation and fresh water flow. It is likely that species not adapted to tidal flushing are in distress, including fresh/brackish marsh species, transitional species (*Iva*) and the evergreen coastal hammock species, sabal and cedar. Examples of this may be seen at Waccasassa Bay where the coastal hammock is in severe decline (Plate 5). The marsh interior, dotted with coastal hammocks, shows a consistent NDVI decline. Aerial survey and field reconnaissance document high morbidity of these forest islands. What remains in their place are not the salt barrens of the St. Marks and the Steinhatchee areas, but exposed surfaces of karstified limestone. Field reconnaissance suggests the pocked surface gradually fills with fine sediment and is colonized by *Juncus, Distichlis* or *Salicornia* spp.

An increase of greenness (NDVI increase) in 1991 along the marsh edge at Waccasassa Bay may be an indication of recovery from wrack deposited during Hurricane Elena in 1985. The surge of high water during storms carries an accumulation of plant material that is deposited in the marsh as the flood waters subside. The gulf edge of the Fenholloway area in contrast shows a distinct loss of greenness, an indication of decreased vegetation health and vigor. It is possible this area had not yet recovered in 1991 from previous storm wrack deposits. Field reconnaissance indicates such recovery can take from 2-5+ years and may include colonization by alternative species, depending on local conditions. The coincident decrease and increase of NDVI values at the Fenholloway marsh interior indicate that in key locations marsh and transitional species may be successionally following the decline of upland species (Plate 5). This location near the Fenholloway may be at the most advanced position in a landward trend of marsh migration.

CONCLUSION

The common traits that link the Big Bend marshes in a cohesive unit include a rocky limestone shore covered with a thin veneer of sediment and colonized by *Juncus romerianus*. However, the rocky shelf itself is variable enough to create regional patterns distinguishable in satellite imagery and distinctive enough in character to cause variations in marsh morphology. The variations in the bedrock appear to control marsh width, the presence of barrens, islands and hammocks, and combined with the Floridan aquifer system, the character of the tidal creeks. For instance, areas of porous, karstified limestone with dissolution channels more readily transfer alterations in hydrologic conditions to the marsh, including changes in aquifer discharge and tidal flushing.

The initial data sets indicate that the effects of long-term sea level rise and alterations in hydrology may first appear as a decline of marginal upland plant communities and successional changes at the marsh interior. Preliminary analysis of satellite imagery shows regional variations in the response and recovery of vegetation following disturbance. Further field work and examination of April 1995 imagery, which we are performing, will clarify these trends. Knowledge of underlying characteristics such as the geology and hydrology will assist in anticipating and understanding the patterns of change observed along the coast.

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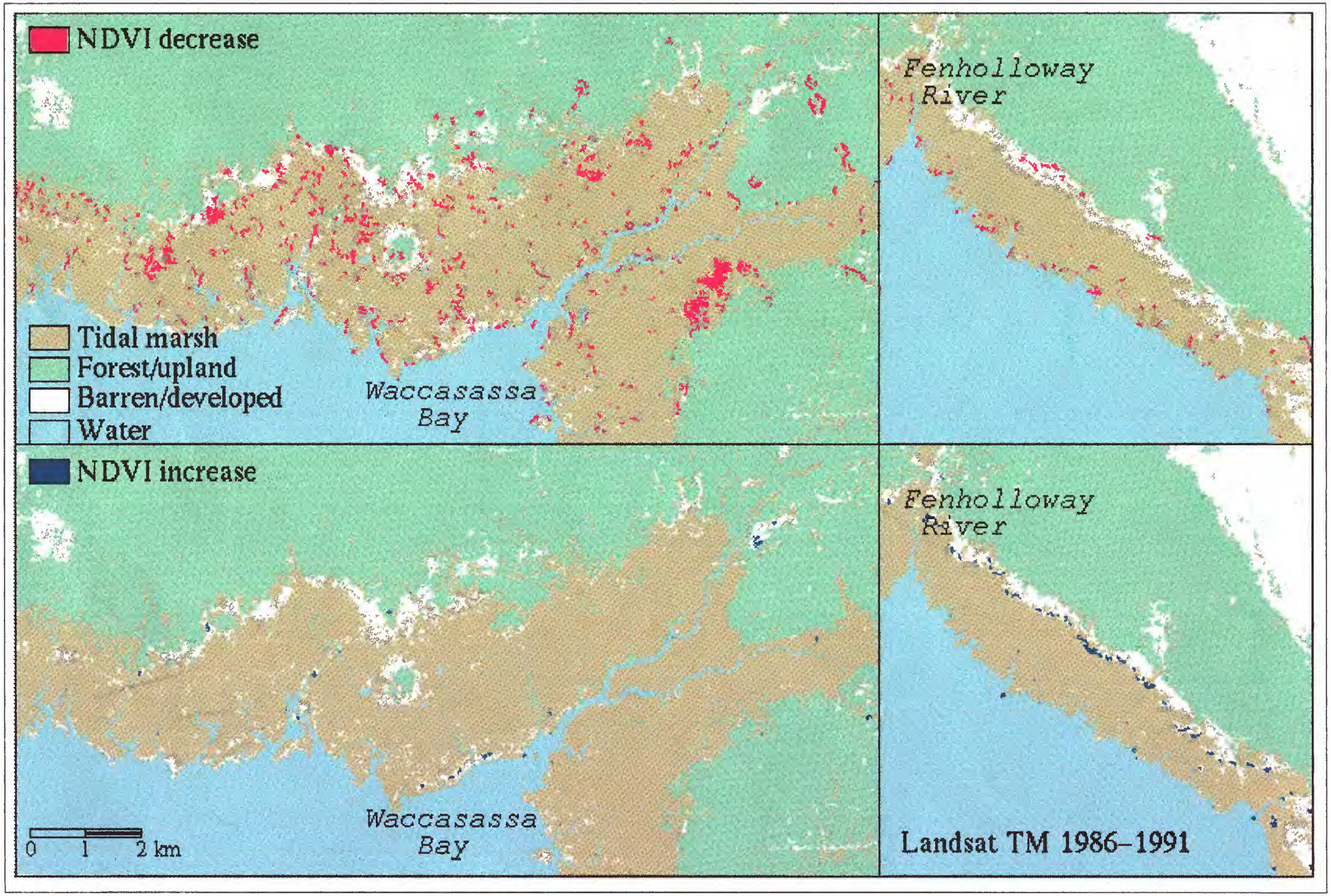

Plate 5. Changes in vegetation index (NDVI) at Waccasassa Bay and the Fenholloway River

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