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The Problem of Critically Eroded Areas (CEA): An Evaluation of Florida Beaches

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ABSTRACT

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Beach erosion is a worldwide problem that has increasingly impacted Florida shorelines. Government studies classified 225 km of Florida beaches as critically eroded in 1985, while critical erosion was observed along 370 km in 1993. Critically eroded areas (CEA) increased 145 km (64%) in eight years despite coastal protection works implemented in Florida. Three hypotheses that may be related to the increase of CEA are analyzed: (1) protective efforts have been insufficient to reduce erosion in Florida, (2) methods of erosion mitigation have not been effective, and (3) identification of CEA depends on the definition of critical erosion used. Evaluation of these three hypotheses is based on the identification of CEA, distribution of coastal protection works, and the official definition of critical erosion as applied by government agencies in Florida. This study estimated that about 124 km of Florida beaches are CEA and approximately 280 km of beaches are protected although reduction has been implemented along eroded and non-eroded beaches. Significant differences observed between official data and this study reflect the importance of the definition of erosion used to classify CEA. This study is based on long-term shoreline changes while government documents consider anthropogenic factors in the definition of the CEA.

INTRODUCTION

Coastal erosion is a complex physical process involving many natural and human-induced factors (COE, 1984; NRC, 1990; BINDERUP, 1997). Beaches are dynamic environments that can erode or accrete to reach equilibrium with short-term natural forces (*i.e.* waves, tides, and wind) and long-term processes such as relative sea-level fluctuations. Natural coastal processes have shaped Florida shores for a long time. However, during the last 100 years, human activities have significantly contributed to shoreline changes (COE, 1984; FDNR, 1986). When urban development began, human activities were concentrated mainly on harbor areas, while coastal development progressed slowly as small fishing villages. Following the economic growth, extensive residential, commercial, industrial, recreational, and resort developments gradually replaced the fishing villages. In Florida, the state's beautiful sandy beaches associated with a pleasant tropical climate stimulated man's desire to be as close to the ocean as possible. As a result, coastal counties that have its shorelines dominated by sandy beaches account for 66% of Florida's population and comprise only 37% of the state's total area. The average population density of these coastal counties is about 78% greater than the average population density for the state. Man's encroachment to the sea has caused significant interference with natural coastal processes. Beach erosion is one of the coastal problems that has been greatly discussed by coastal scientists, government agencies, local authorities, and beachfront owners. However, controversies arise regarding the perception and exact definition of beach erosion, mainly due to the diverse interest of the different parts in the subject.

Beach erosion is a worldwide problem (BIRD, 1985) that has become increasingly critical along Florida shorelines. Florida has about 1,300 km of beaches that represent about 25% of the total U.S. sandy shores (FINKL, 1996). As Florida beaches are important recreational assets that maintain local and regional economies, government agencies and private beachfront owners (including vacation-resort areas) are particularly interested in the understanding of beach erosion and its related processes. About 225 km of Florida beaches were classified as critical erosion areas in 1985 (FDNR, 1985), while 370 km were critically eroding in 1993 (CLARK, 1993). According to these governmental studies, critical erosion areas increased 145 km (64%) in eight years despite the coastal protection works implemented along Florida shorelines. Such an increase suggests that protective measures have been insufficient to reduce beach erosion in Florida, or that the methods applied have not been effective. Either case requires an evaluation of the coastal protection strategies applied to Florida's beaches to identify problem areas, possible causes, and potential solutions to enhance erosion mitigation. Previous studies (*e.g.* ESTEVES, 1997; FINKL and ESTEVES, 1998) indicate that perception of beach erosion tends to be associ-

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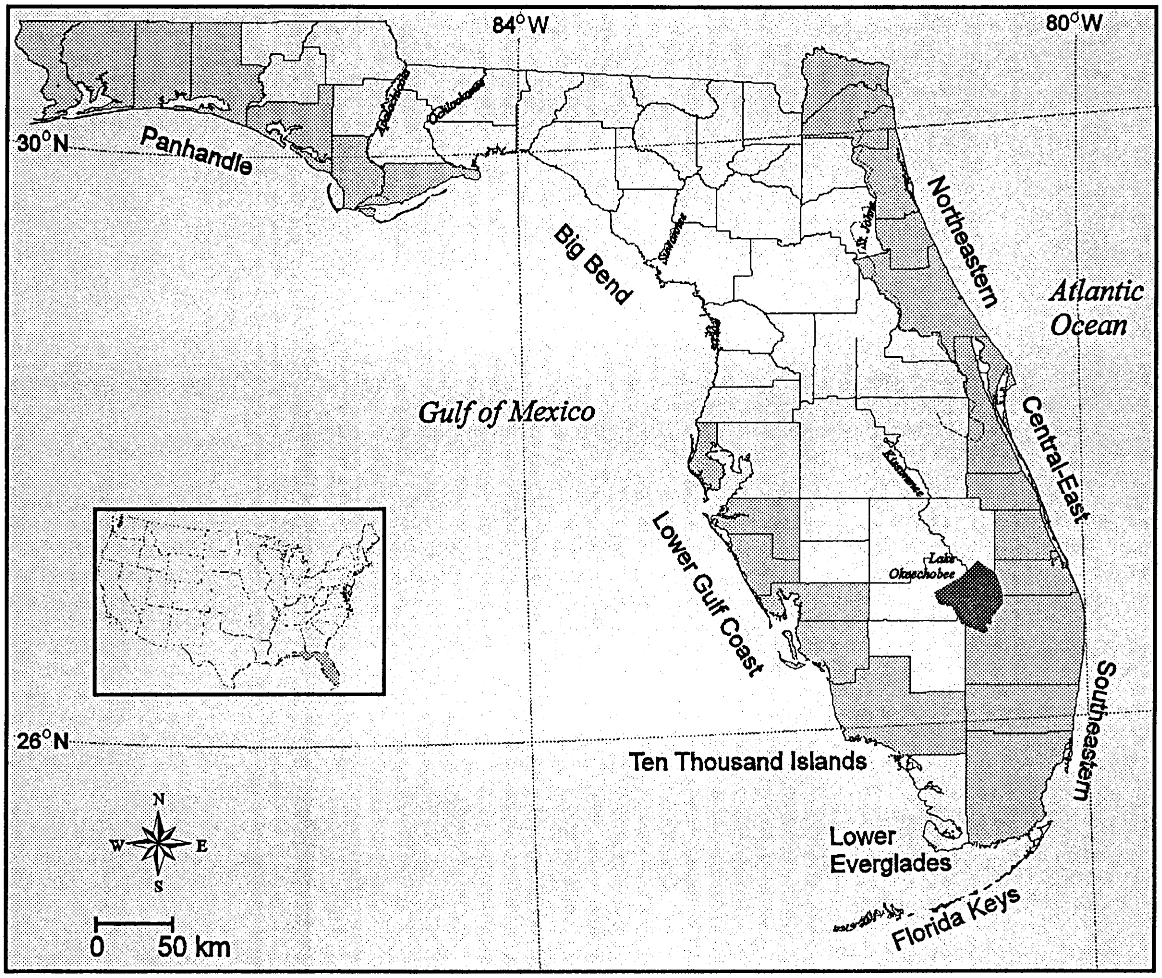

Figure 1. The study area (shaded) takes in about 1,240 km along 25 coastal counties where sandy beaches are the dominant environment. Sandy beaches predominate along five coastal segments: the Panhandle and the Lower Gulf Coast fronting the Gulf of Mexico, and the Northeastern, Central-East, and the Southeastern segments along the central-western margins of the north Atlantic Ocean.

ated with developed shores, mainly where sandy beaches are important to the economy. This paper evaluates the present distribution, extension, and characterization of beach erosion and protection in Florida and attempts to correlate trends in beach stability with the presence of coastal protection works and their relation with levels of urban development.

Study Area

This study focuses on Florida coastal segments where sandy beaches make up the dominant environment. Thus, the study area includes the Panhandle and Lower Gulf shores on the Gulf of Mexico and most of the Atlantic coast (Figure 1). Not included in this study are: the salt marshes along the Big Bend shores, the mangrove forests along the Ten Thousand Island area, the general area of Florida Bay, as well as the rocky shores of the Florida Keys. This study is unique in the sense that beach erosion and protection were for the first time comprehensively evaluated on a statewide basis covering the great majority (about 1,240 km or 95%) of Florida's sandy beaches (ESTEVES, 1997).

Methods of Analysis

Coastal segments on the Atlantic and Gulf coasts of Florida were mapped on a county-by-county basis in terms of five primary conditions: (1) dominant natural shoreline environments (sandy beaches, rocky shores, marshes, mangroves), (2) levels of urban development (*e.g.* high, moderate, and low density of infrastructure), (3) direction of shoreline changes (accretion, stable, eroded, and critically eroded), (4) the presence and distribution of coastal protections works (*e.g.* seawalls, groin fields, and beach nourishment projects), and (5) presence of sensitive ecological communities (*e.g.* sea turtle nesting sites, coral reefs, Sabellariid worm reefs, and seagrass beds). These parameters are graphically represented in 22 maps prepared at a nominal scale of about 1:250,000 from where data analyzed in this report were extracted. Combi-

Table 1. *Definition of the parameters used to categorize Florida shore segments.*

Parameter	Classes	Definition
Degree of urban development	High	More than 60% of the coastal area (within 500 m from the shoreline represented in the USGS topographic maps) covered by buildings, roads, infrastructure or facilities
	Intermediate	30% to 60% of the coastal area is built up
	Low/None	Less than 30% of the coastal area (within 500 m from the shoreline) built up
Shoreline change*	Accreted	>0.5 m a^{-1}
	Stable	-0.5 to 0.5 m a^{-1}
	Eroded	-0.5 to -1.0 m a^{-1}
	Intensely eroded	>-1.0 m a^{-1}
Shore protection measures	No	Absence of shore protection works
	Yes	Presence of shore protection measures (*i.e.*, seawalls, groins, beach nourishment)

*Shoreline change classes are based on long-term trends of the MHW mark moving shoreward (negative rates), seaward (positive rates), or oscillating about a mean value bounded by a value of ± 0.5 m a^{-1} (*i.e.*, remaining in about the same relative position).

nations of the five parameters used to classify coastal segments permitted potential classification of Florida shores into 72 different classes when considering three classes of urban development, four classes of shoreline change, three classes of coastal protection works, and presence or absence of environmental concerns. This report presents a simplified classification (comprising 24 classes of shore segments) that is sufficient to relate trends of shoreline change with presence of coastal urban development and coastal protection works. The classes of the parameters used in the simplified classification of coastal segments presented in this report are defined according to Table 1.

Estimates of shoreline change rates along Florida shores were based on historical shoreline position data obtained from the "Historical Shoreline Position Database" maintained by the Florida Department of Environmental Protection (FDEP), Bureau of Beaches and Coastal Processes (Tallahassee, Florida). Three different time intervals were used to calculate average rates to represent long-, intermediate, and short-term shoreline changes. The average rates were calculated by subtracting shoreline positions measured for two different years and dividing the result by the time interval between those two years (LEATHERMAN, 1983; GALGANO and LEATHERMAN, 1991). Relative rates of shoreline change based on the entire monitoring period summarize the overall direction of shoreline movement and are useful to characterize long-term trends (MORTON, 1991). Long-term shoreline change rates were calculated using the longest record available for each county that varied from 89 to 137 years. Short-term shoreline change rates were estimated using the most recent time interval of ten years or less. Intermediate shoreline change rates were calculated using a time interval spanning the last 40 to 60 years. Shoreline change rates calculated for each FDEP monument were graphically displayed on a county-by-county basis. However, only long-term rates were used to represent the status of shoreline changes in Florida to reduce the high variability associated with short-term processes (MCBRIDE and BYRNES, 1997).

THE STATUS OF BEACH EROSION IN FLORIDA

Florida's beaches are important environmental resources that: (1) provide storm surge protection and flood control to coastal communities, (2) support recreational activities, (3) provide habitat for numerous species, and (4) are a major source of revenue for local and state economies. Therefore, excessive erosion may endanger the structural integrity of beaches and upland coastal structures, generally leading to great monetary losses due to storm damage or even larger expenditures to protect the shore and prevent such losses. To avoid property damage and a degraded local and state economy due to beach erosion, much interest has been shown in the identification of erosion problem areas (EPA) and in the definition for the best management practice (BMP) that could be implemented along specific coastal segments. However, as recreational beaches are usually geographically associated with developed shorelines, perceptions of beach erosion may be prejudiced or overstated according to local interests (FINKL and ESTEVES, 1998).

Table 2 shows the results of three different studies that evaluate the extension of critically eroded areas (CEA) in Florida on a county basis. The two first studies (1985 and 1993) were conducted by the Florida Department of Natural Resources (FDNR), now called Florida Department of Environmental Protection (FDEP). A comparison between these two studies show alarming trends: (1) in eight years, the extension of CEA increased about 50% (from 108 km in 1985 to 162.3 km in 1993) along the Gulf Coast and about 73% (from 116.8 km in 1985 to 202.1 km in 1993) along the Atlantic Coast; (2) 13 of the 25 coastal counties analyzed had an increase of the CEA extension, including 8 counties with an increase greater than 100% (*e.g.* Manatee, Sarasota, Lee, Collier, Volusia, Martin, Broward, and Dade); (3) Pinellas County had 0% of its shoreline classified as CEA in 1985 and 56% in 1993, meaning that in eight years more than half of its entire shoreline became critically eroded, and (4) coastal counties along the Florida Panhandle (the most undeveloped shores in the state) showed a decrease in the extension of CEA in the order of 140%. The results of our assessment are displayed in the last two columns in Table 2 and show very distinct numbers of the CEA extension in Florida. About 123.7 km (10%) of the 1,242.3 km of Florida beaches in the study area were classified as CEA that is much lower than the 224.8 km (18.1%) and the 364.4 km (29.3%) obtained in the 1985 and 1993 studies, respectively. Attention should be paid to the great differences between the results of the official studies and our assessment, mainly along the most urbanized counties such as Dade, Broward, and Palm Beach that showed a significant decrease in the extension of CEA.

Intriguing questions arise from the results presented in Table 2: (1) How is it possible that the extension of CEA had greatly increased from 1985 to 1993 and decreased since

Table 2. *Length of critically eroded areas (CEA) along Florida beaches by coastal county.*

County	Total Length[a,b] (km)	CEA (1985) Length[c] (km)	CEA (1985) % (of total)	CEA (1993) Length[b] (km)	CEA (1993) % (of total)	CEA (this study) Length (km)	CEA (this study) % (of total)
Escambia	62.4	4.8	7.7	7.9	12.7	4.9	7.9
Santa Rosa	8.0	0.0	0.0	0.0	0.0	0.0	0.0
Okaloosa	38.3	0.0	0.0	0.0	0.0	1.5	3.9
Walton	41.1	0.0	0.0	0.0	0.0	0.0	0.0
Bay	66.1	29.7	44.9	18.7	28.3	19.0	28.7
Gulf	46.2	19.2	41.6	0.2	0.4	21.0	45.5
Franklin	87.6	19.2	21.9	3.7	4.2	2.2	2.5
Pinellas	64.5	0.0	0.0	33.6	52.9	8.0	12.4
Manatee	19.7	5.6	28.4	14.3	72.6	7.3	37.0
Sarasota	55.7	7.1	12.7	32.2	57.8	4.6	8.3
Charlotte	19.6	8.0	40.8	7.1	36.2	2.2	11.2
Lee	75.9	7.2	9.5	27.2	35.8	18.0	23.7
Collier	73.9	7.2	9.7	17.4	23.5	3.1	4.2
Total Gulf Coast	658.9	108.0	16.4	162.3	24.6	91.8	13.9
Nassau	20.4	11.7	57.4	10.0	49.0	2.9	14.2
Duval	24.1	0.0	0.0	16.1	66.8	1.3	5.4
St. Johns	66.1	12.0	18.2	7.4	11.2	3.4	5.1
Flagler	29.1	9.6	33.0	4.7	16.2	0.0	0.0
Volusia	78.5	1.6	2.0	13.2	16.8	1.8	2.3
Brevard	115.2	32.9	28.6	24.5	21.3	3.0	2.6
Indian River	36.0	9.6	26.7	10.6	29.4	0.0	0.0
St. Lucie	34.6	0.0	0.0	3.7	10.7	0.0	0.0
Martin	34.4	9.6	27.9	19.5	56.7	10.0	29.1
Palm Beach	72.9	24.2	33.2	35.1	48.1	0.0	0.0
Broward	38.6	1.6	4.1	29.3	75.9	4.5	11.7
Dade	33.5	4.0	11.9	28.0	83.6	5.0	14.9
Total Atlantic	583.4	116.8	20.0	202.1	34.6	31.9	5.5
Total	1,242.3	224.8	18.1	364.4	29.3	123.7	10.0

[a]Gulf Coast data from Balsillie and Clark (1992)
[b]Atlantic Coast from Clark (1993); [c]from FDNR (1985)

then; (2) Why are developed counties more susceptible to beach erosion than undeveloped counties; (3) What is the main cause of CEA in Florida; and (4) Where and how has coastal protection been implemented to mitigate beach erosion in the state?

Definitions of Beach Erosion

Beach erosion has been discussed by a variety of public agencies, proprietary organizations, and coastal researchers, groups that have different intents and defend diverse interests. Definitions of beach erosion are usually vague, consequently has often changed to more adequately fit the necessity of specific discussion groups (FINKL and ESTEVES, 1998). This might be the answer for the first two questions posed above. The differences observed between the numbers presented in Table 2 probably result from the methods of evaluation used in previous studies, mainly regarding the definition of eroded areas. The FDEP defines EPA as beaches that fit one of the following three categories (CLARK, 1993): (1) high erosion rates or recent significant erosion conditions, (2) moderate or low erosion rates, but with a narrow beach fronting a highly developed area, or (3) restored beaches with active maintenance nourishment programs. As defined, the EPA reported in government documents are strongly dependent on the threat to human presence or upland development (*e.g.* COE, 1971; FDNR, 1985, 1986; CLARK, 1993). This close relationship is emphasized by the U.S. Army Corps of Engineers (1971) which defines CEA as "...[locations] *where the rate of erosion indicates that action to halt the erosion may be justified, when considered in conjunction with economic, industrial, recreational, agricultural, navigational, demographic, ecological and other relevant factors*". The study conducted by the FDEP in 1985 does not provide the definitions used to classify beaches as CEA, but probably are similar to the definitions used by CLARK (1993). Consequently, the differences in the extension of CEA presented in 1985 and 1993 depend mainly on the growth of urban development along the shorelines.

This study perceives erosion based on the long-term shoreline change rates independently of present characteristics of the coast as described in Table 1. The characteristics of the coast potentially threatened by shoreline retreat are essential to establish the BMP to deal with erosion but should not be considered *inter alia* in the definition of eroded areas. Beach erosion in Florida is already a serious problem without considering its threat to upland development. Ten out of the 25 counties evaluated in this study have more than 20% of their shorelines classified as eroded or critically eroded (*viz.* Dade, Broward, Martin, St. Lucie, Nassau, Lee, Manatee, Gulf, Bay, and Escambia counties). Manatee and Gulf counties lead the EPA with more than 50% their shoreline classified as eroded or critically eroded (58.5% and 56.3%, respectively). Using

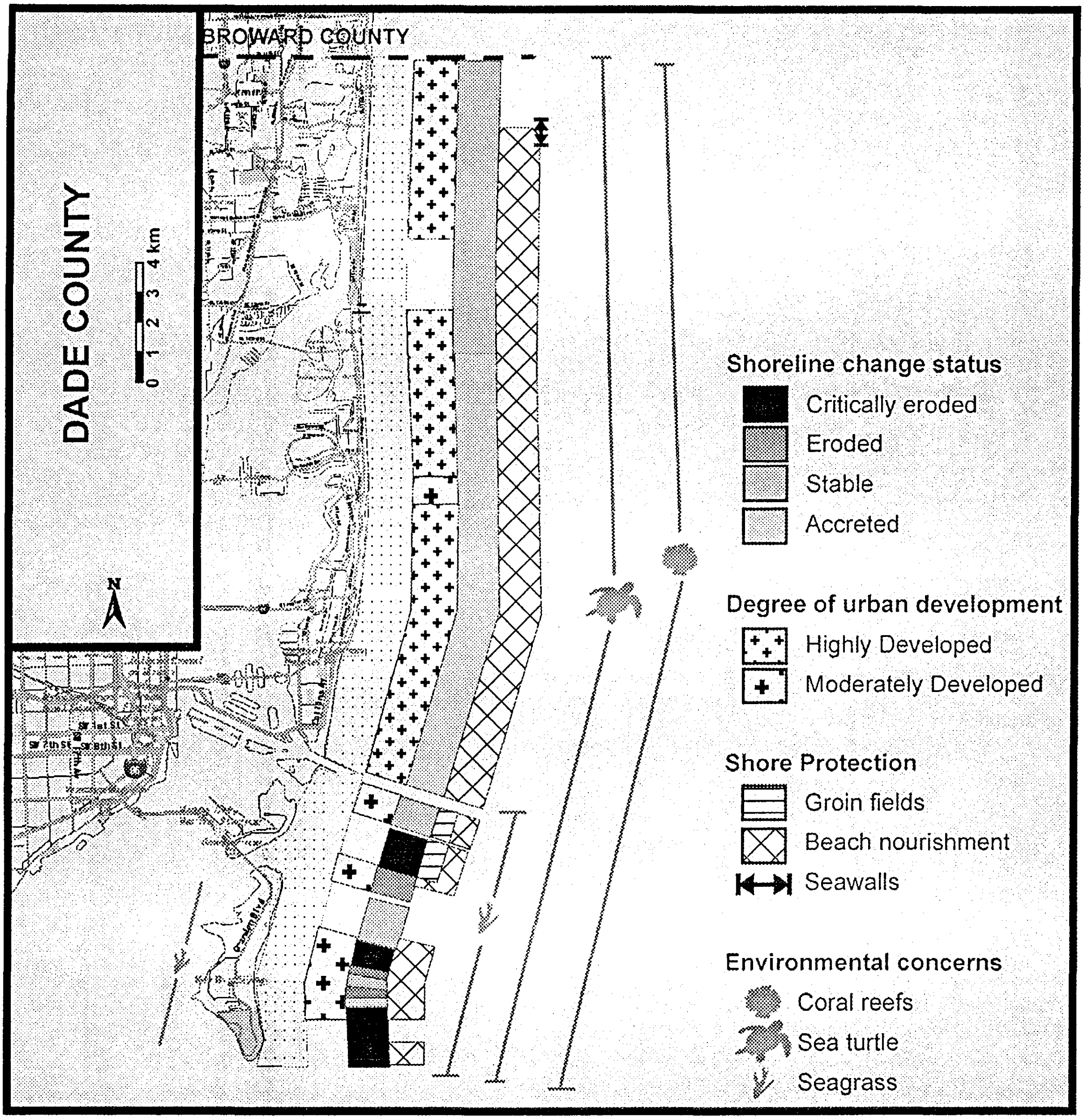

Figure 2. Dade County has highly developed, non-eroded shorelines with extensive beach nourishment projects. Areas formerly regarded as eroded (*e.g.* Miami Beach *per se*) are classified in this study as stable or accreted due to coastal protection. Note the association of EPA and CEA with tidal inlets and the presence of coastal protection along eroded and non-eroded beaches.

anthropogenic activities as to define CEA appears to contribute to potential misunderstanding of the processes involved in shoreline change. For example, consideration of restored beaches with regular maintenance programs as CEAs must *per force* include several coastal segments that are no longer under threat of severe erosion due to mitigation efforts. Various restored beaches are stable or even accreted and should not be included as EPA (*i.e.* Miami Beach, Figure 2). The effects of beach restoration on the estimates of shoreline changes is clearly shown in Figure 3, where a possibly long-term eroding shore (between R-33 and R-75) was masked by beach replenishment. Additionally, defining areas where narrow beaches front urban shores as CEA could be considered an unrealistic over-simplification of the consequences of inappropriate human encroachment on the shore. In many cases, the beach narrowed because the backshore was stabilized by the presence of buildings, which rendered the shoreline vulnerable in dynamic coastal environment.

Beach Erosion and Tidal Inlets

About 72% of the total length of eroded or critically eroded beaches in Florida are geographically associated to tidal inlets (Table 3); consequently the proximity with such entranc-

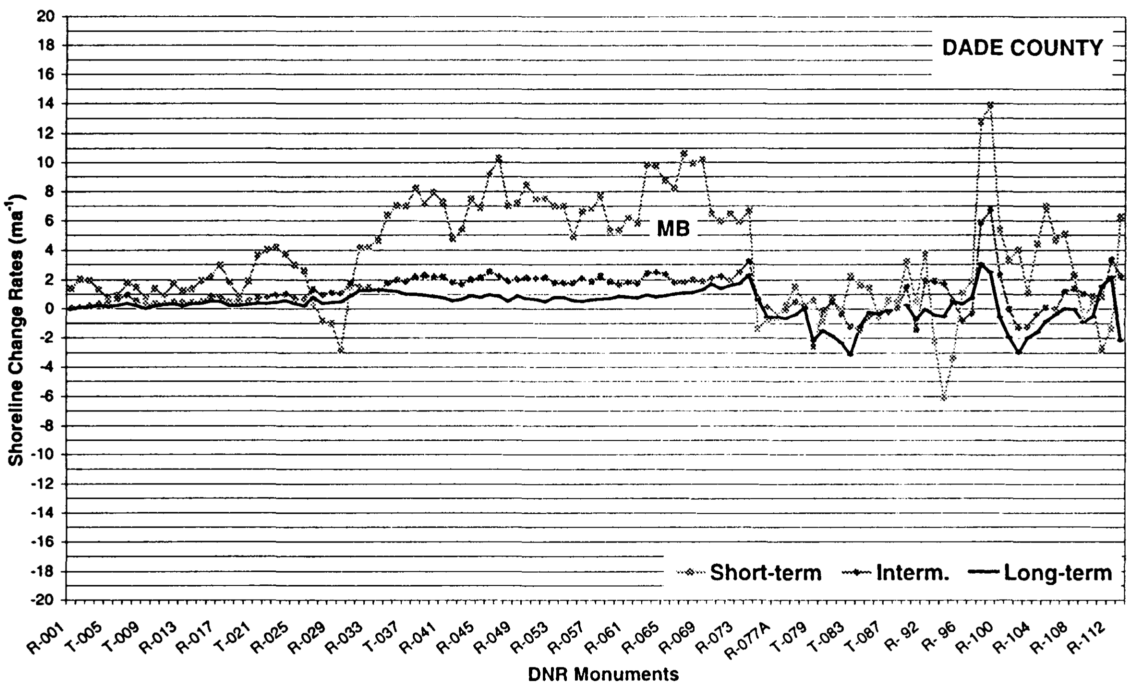

Figure 3. Shoreline change rates (m a⁻¹) based on historical shoreline data for Dade County. The highly variable short-term rates contrast with a smoother curve for long-term rates of change, except in the vicinity of inlets in the southern section (to the right of monument R-073), where even long-term rates are variable. The influence of the Miami Beach restoration project (MB), *i.e.* affect on the estimation of short-term change rates for shoreline position, is clearly positive.

es is the main cause of beach erosion in the state. The association of beach erosion and tidal inlets can be observed in the southern part of Figure 2. The Central-East coastal segment has the least number of eroded beaches in Florida but the Southeastern segment is the least eroded according to the total length of eroding shorelines (Table 3). Although the Southeastern is the least eroded coastal segment in Florida, 91% of its eroded beaches are associated with inlets. Our estimates are not far from the assessment conducted by DEAN (1990) that concluded about 85% of the beach erosion is associated with tidal inlets. Sixty-nine eroded shoreline segments are identified in Florida, 49 (71%) of which occur along the Gulf Coast and 20 (29%) along the Atlantic Coast (Table 3). Most of the erosional shoreline segments (53.6%) occur along the Lower Gulf Coast although the Panhandle and the Lower Gulf have the same length of eroding shorelines (Table 3). The average length of erosional areas along the Panhandle and the Lower Gulf Coast is 5.9 km and 1.9 km respectively, mainly due to the presence of tidal inlets and short barrier islands in the Lower Gulf. The influence of tidal inlets on adjacent shorelines is a function of the size and number of inlets and sediment budget changes (FITZGERALD, 1988, cited *in* FENSTER and DOLAN, 1996) resulting in the greater percentages of eroded beaches along the Gulf Coast. Washover events during storms, inlet migration, and net reduction in the longshore sediment flux due to deposition in sinks such

Table 3. *Eroded beaches in Florida and their relation to tidal inlets.*

	Eroded Beaches				Eroded Beaches Associated with Inlets*	
Coastal Segments	Length (km)	% of the Total	No. of Eroded Areas	% of the Total	Length (km)	% of the Total
Panhandle	70.7	36.3	12	17.4	44.7	63.0
Lower Gulf	70.9	36.4	37	53.6	54.1	76.3
Gulf	141.6	72.7	49	71.0	98.8	69.8
Southeastern	13.5	6.9	7	10.2	12.3	91.0
Central-East	19.5	10.0	4	5.8	13.5	57.9
Northeastern	20.2	10.4	9	13.0	11.7	57.9
Atlantic	53.2	27.3	20	29.0	37.5	70.5
Total	194.8	100.0	69	100.0	140.4	72.0

*Eroded beaches immediately adjacent to inlets

Table 4. *Simplified classification of Florida coastal segments based on levels of urban development, shoreline change status, and presence of coastal protection.*

Level of Urban Development	Shoreline Change Status	Shore Protection Measures	Coastal Segments (% of total length) Pan-handle	Lower Gulf	North-eastern	Central-East	South-eastern	Florida (% of total length)
High	Critically eroded	No	—	2.0	—	—	0.5	0.5
		Yes	—	6.5	0.5	—	0.0	2.0
	Eroded	No	1.0	2.0	—	—	—	0.5
		Yes	—	3.5	0.0	0.0	1.0	1.0
	Stable	No	16.5	13.5	—	3.5	19.0	11.0
		Yes	7.5	20.5	23.5	13.5	40.0	18.5
	Accreted	No	3.5	9.0	4.5	8.0	1.0	6.0
		Yes	1.5	9.0	0.5	3.0	14.5	4.0
Intermediate	Critically eroded	No	—	1.5	2.5	1.5	—	1.0
		Yes	—	0.5	1.5	—	0.5	0.5
	Eroded	No	1.0	0.0	1.0	—	0.0	0.5
		Yes	—	0.5	1.0	—	1.5	0.5
	Stable	No	7.0	0.5	17.5	17.5	2.5	8.5
		Yes	1.5	1.5	—	6.0	2.0	2.0
	Accreted	No	—	2.0	4.5	2.0	—	2.0
		Yes	0.5	0.5	0.5	2.0	1.0	0.5
Low/None	Critically eroded	No	12.0	2.5	1.0	5.0	0.5	5.0
		Yes	2.0	1.0	0.5	—	4.5	1.5
	Eroded	No	3.5	3.5	0.5	5.5	—	3.0
		Yes	1.0	0.5	—	—	—	0.5
	Stable	No	21.0	5.5	31.5	24.0	5.0	18.0
		Yes	0.5	3.5	1.0	6.0	5.0	3.0
	Accreted	No	19.0	4.0	5.0	1.5	—	7.5
		Yes	0.5	1.0	1.0	0.0	—	0.5

as tidal channels, tidal deltas, or marsh surfaces are processes that contribute to shoreline erosion in the vicinity of inlets. These processes are dominant along undeveloped barrier islands such as the Panhandle and have contributed to the longest stretches of eroded shores in Florida (*e.g.* Bay and Gulf counties). The results displayed in Table 3 indicate that the presence of tidal inlets is the strongest factor affecting the occurrence, distribution, and extension of eroded beaches in Florida.

THE RELATION BETWEEN BEACH EROSION, COASTAL PROTECTION, AND DEGREE OF URBAN DEVELOPMENT

The 22 maps designed to display the characterization of Florida coastal segments were analyzed to establish the relation between levels of urban development, shoreline change status, and coastal protection. The results (percentage of total shoreline length) are presented in Table 4. This analysis showed that coastal protection (*e.g.* seawalls, groins, or beach nourishment) occurs along 34.5% of Florida shorelines; however, 28.5% occur along stable or accreted shores(22.5% along highly developed shores) and only 6% occur along eroded or critically eroded beaches (although about 16% of Florida shorelines are EPA or CEA). Thus, it clearly shows that coastal protection measures have been mainly implemented along highly developed shores, independently of eroded conditions. This relationship is exemplified by the fact that about 75% of all EPA and CEA and 57% of the non-eroded shores (stable and accreted) are protected when they front highly developed shores, while only 20% of the EPA and CEA and 12% of the non-eroded shores are protected when fronting undeveloped shores. Other interesting data can be extracted from Table 4: (1) Florida shores are mainly stable, totaling about 61% from which 37.5% are unprotected (11% along highly developed, 8.5% along intermediate, and 18% along undeveloped shores) and 23.5% protected (18.5% along highly developed, 2% along intermediate, and 3% along undeveloped shores) by seawalls, groins, or beach replenishment; (2) about 20% of Florida shorelines are classified as accreted from which 5% are protected (4% fronting highly developed shores and the remaining 1% divided along intermediate and undeveloped shores); (3) some classes are not widely represented, such as: protected EPA along undeveloped shores, unprotected CEA and EPA fronting highly developed shores, and unprotected EPA along moderately developed shores.

The presence of coastal protection along non-eroded shores suggests that (1) protection measures have been implemented to protect buildings or infrastructure built too close to the shore or (2) protection works may have interfered in the shoreline change rates and direction. Actually, both cases may occur because beaches recognized as eroded in the past are now classified as stable or accreted (*e.g.* Fisher Island and Miami Beach, Figures 2 and 3), indicating that erosion mitigation has been successful. Considering that about 16% of the Florida shoreline is eroding and about 34% has been protected, the question should not focus on whether protection has been insufficient but where and how it has been implemented. Additionally, about 6% of the Florida shoreline is classified as **protected** EPA and CEA indicating that protection has not stabilized these beaches. Because beach erosion is mainly associated with the presence of tidal inlets, beach nourishment and hard stabilization alone are probably not the BMP and mitigation of beach erosion should focus on improvement of sand bypassing around inlets.

CONCLUSIONS

Florida's sandy beaches may be characterized mainly by stable shorelines when rates and direction of long-term shoreline changes are examined. About 194.8 km (15.7%) of the 1,242 km of Florida beaches in the study area are eroding, of which 123.7 km (10%) are critically eroded shorelines (CEA). Gulf Coast beaches account for 73% and the Atlantic Coast for 27% of the total length of erosional beaches in the state. About 72% of erosion problem areas (EPA) in Florida are geographically associated with inlets, *i.e.* beaches immediately adjacent to inlets. Coastal protection works (sea defense) have been implemented along both eroded and non-eroded beaches but usually front urbanized areas. Coastal protection has not been attempted along some undeveloped or partially developed EPAs. Perhaps surprisingly, protection is observed along stable beaches where they front developed shores.

Results from this study differ from previous investigations with regard to the definition of CEA; consequently, officially estimated percentages of eroded beaches identified in Florida differs significantly from results obtained in this research. Government documents include anthropogenic factors such as the presence of narrow beaches fronting urbanized shores and the implementation of periodic beach maintenance in the definition of CEA. This study shows that some restored beaches are stable or accreted and should not be included as CEA. Thus, narrow beaches fronting developed shores might not be a result from long-term erosion but only from natural short-term fluctuations of the beach system that have threatened structures built too close to the beach. Ideally, CEA should be based on scientific observations of long-term shoreline change rates, while the presence of threatened coastal development should be considered in the establishment of the best management practice (BMP) to deal with erosion.

LITERATURE CITED

BALSILLIE, J.H. and CLARK, R.R., 1992. *The Gulf Coast of Florida: Overview of Physiography, Geology, and Historical Shoreline Change.* Tallahassee, Florida: Florida Department of Natural Resources, Division of Beaches and Shores, 19p.

BINDERUP, M., 1997. Recent changes of the coastline and nearshore zone, VejrpIsland, Denmark: Possible consequences for future. *Journal of Coastal Research,* 13(2), 417–428.

BIRD, E.C.F., 1985. *Coastline Changes: A Global Review.* Chichester: Wiley, 218p.

CLARK, R.R., 1993. Beach conditions in Florida: A statewide inventory and identification of the beach erosion problem areas in Florida. Florida Department of Environmental Protection, *Beaches and Shores Technical and Design Memorandum 89-1* (5th ed.), 202p.

COE (US ARMY CORPS OF ENGINEERS), 1984. *Shore Protection Manual* (2nd edition). Washington, DC: U.S. Government Printing Office, variously paginated.

COE (US ARMY CORPS OF ENGINEERS), 1971. *National Shoreline Protection Study.* Washington, DC: U.S. Government Printing Office, variously paginated.

DEAN, R.G., 1990. Channel entrances: Impacts on coastal erosion. *Proceedings of the 53rd Meeting of the Coastal Engineering Research Board (5–7 June 1990, Fort Lauderdale/Dania, Florida).* Vicksburg, Mississippi: CERC Final Report, pp. 51–53.

ESTEVES, L.S., 1997. Evaluation of Shore Protection Measures Applied to Eroding Beaches in Florida. Master of Science thesis, Florida Atlantic University, Boca Raton, Florida, 181p.

FDNR (FLORIDA DEPARTMENT OF NATURAL RESOURCES), 1986. *A Proposed Comprehensive Beach Management Program for the State of Florida.* Division of Shores and Beaches, Tallahassee, Florida, 80p.

FDNR (FLORIDA DEPARTMENT OF NATURAL RESOURCES), 1985. *Beach Restoration: A State Initiative.* Division of Beaches and Shores, Tallahassee, Florida, variously paginated.

FENSTER, M. and DOLAN, R., 1996. Assessing the impact of tidal inlets on adjacent barrier island shorelines. *Journal of Coastal Research,* 12(1), 294–310.

FINKL, C.W., 1996. What might happen to America's shoreline if artificial beach replenishment is curtailed: A prognosis for southeastern Florida and other sandy regions along regressive coasts. *Journal of Coastal Research,* 12(1), iii–ix.

FINKL, C.W. and ESTEVES, L.S., 1998. The state of our shores: A critical evaluation of the distribution, extension, and characterization of beach erosion and protection in Florida. *11th National Conference on Beach Preservation Technology.* Tallahassee, Florida, (in press).

GALGANO, F.A. and LEATHERMAN, S.P., 1991. Shoreline change analysis: a case study. *Coastal Sediments '91* (ASCE) pp. 1043–1053.

LEATHERMAN, S.P., 1983. Shoreline mapping: a comparison of techniques. *Shore and Beach,* 51, 28–33.

McBRIDE, R.A. and BYRNES, M.R., 1997. Regional variations in shore response along barrier island systems of the Mississippi River Delta Plain: historical change and future prediction. *Journal of Coastal Research,* 13(3), 628–654.

MORTON, R.A., 1991. Accurate shoreline mapping: past, present, and future. *Coastal Sediments '91,* 997–1010.

NRC (NATIONAL RESEARCH COUNCIL), 1990. *Managing Coastal Erosion.* Washington, D.C.: National Academy Press, 334p.