1990

Louisiana Barrier Island Change Analysis Derived From a Geographic Information System (GIS) Based on Sequential Aerial Photography.

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Order Number 9104181

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The Louisiana State University and Agricultural and Mechanical Col., 1990

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LOUISIANA BARRIER ISLAND CHANGE ANALYSIS DERIVED FROM A GEOGRAPHIC INFORMATION SYSTEM (GIS) BASED ON SEQUENTIAL AERIAL PHOTOGRAPHY

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Marine Sciences

by
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May, 1990

ACKNOWLEDGEMENTS

I would like to express special appreciation to Dr. Irv Mendelssohn for his guidance and example, to Dr. John Hill for providing an access to the world of environmental image analysis, to Dr. Larry Rouse, for his technical expertise and insight, and to Dr. William Patrick for his support and encouragement. I also wish to thank Dr. Donald Baltz for consenting, at the last possible moment, to fill the committee position vacated by Dr. Robert Costanza. In addition, I would like to express my gratitude to Bo Blackmon, of the Louisiana Department of Natural Resources, for assistance far above the call of duty, to Texaco Corporation for providing funds for the completion of the field investigations, and to the staff and faculty of the Remote Sensing and Imaging Processing Laboratory at LSU for their support. Finally, I dedicate this work to my wife Susan and son Gabriel, who have patiently seen me through this endeavor.

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ABSTRACT

Surface feature maps were derived from color-infrared aerial photographs for Louisiana's Timbalier Island and Eastern Isles Dernieres. These provided a basis for the implementation of a barrier island Geographic Information System (GIS), a quantitative spatial framework through which specific proximal and temporal interactions could be examined. This system was utilized to observe relationships between changes in island shorelines and surface areas relative to location and extent of island cover categories. It was further employed to test the applicability of the *rollover* and *deltaic barrier cycle* models of island dynamics within the context of the Louisiana coastal environment.

Both islands exhibited significant changes, including net losses in island width and surface area. However, results indicated that areas containing marsh or swale experienced significantly lower rates of shoreline erosion than other areas. Combining shoreline change data from this study with that from previous studies indicated a consistent long-term trend of shoreline retreat. Based on these combined observations, Timbalier Island can be expected to persist through the year 2140, and the Eastern Isles Dernieres through 2040.

The *rollover* model (Godfrey and Godfrey, 1974) describes a shoreward migration of barrier islands in response to increasing sea levels. The *deltaic barrier cycle* (Penland and Boyd, 1981) describes a sequence of stages associated with the formation, abandonment, and eventual subsidence of major river deltas. Neither Timbalier Island nor the Eastern Isles Dernieres showed significant accretion on their bay sides, precluding any net landward migration, responses fundamentally inconsistent with the *rollover* model. Timbalier Island underwent a steady westward lateral migration, consistent with the *flanking barrier* stage of the *deltaic barrier cycle*. However, the Eastern Isles Dernieres, which represents the *transgressive barrier arc* stage, exhibited a westward, rather than eastward lateral migration and no net landward migration, responses inconsistent with the *deltaic barrier cycle* model.

INTRODUCTION

The intent of this study was to examine patterns of change within Louisiana barrier islands. Methods were employed to test the validity of two widely accepted models of barrier island dynamics within the context of the Louisiana coastal environment. The data was further evaluated to provide insight into the relationship of island cover categories to shoreline and surface change rates. Study areas were selected which represented different stages of barrier island development. In addition, because the northern Gulf of Mexico is characterized by varying levels of oil and gas exploration and extraction operations, some of which may influence barrier island dynamics, study areas with differing degrees of impact from oil and gas activity were selected.

Most studies of barrier systems have focused on the geologic record (Fisk, 1944; Peyronnin, 1962; Frazier, 1967; Kwon, 1970; Otvos, 1970a; Boyd and Penland, 1984; etc.). These studies provide insight into the mechanisms of barrier island formation. The major theories of barrier development include the coalescing and emergence of offshore bars (deBeaumont, 1845), the formation and breaching of longshore prograded spits (Gilbert, 1885), and the submergence of land surrounding a coastal beach ridge (McGee, 1890).

The Louisiana barrier islands consist of a discontinuous, sandy, low relief chain. They cover a surface area of 93 km^2, extending approximately 200 km south and westward along the Gulf of Mexico from Chandeleur Sound to a point south of Morgan City, Louisiana (Mendelssohn et al., 1987; Figure 1). These islands occupy the remnant edges of former active delta lobes of the Mississippi River. They are experiencing high rates of land loss due to a number of factors, many of which may be unique to the Louisiana coastal environment

Barrier systems are subject to wind and wave activity and are continuously being reworked by these forces. Dynamic models are often

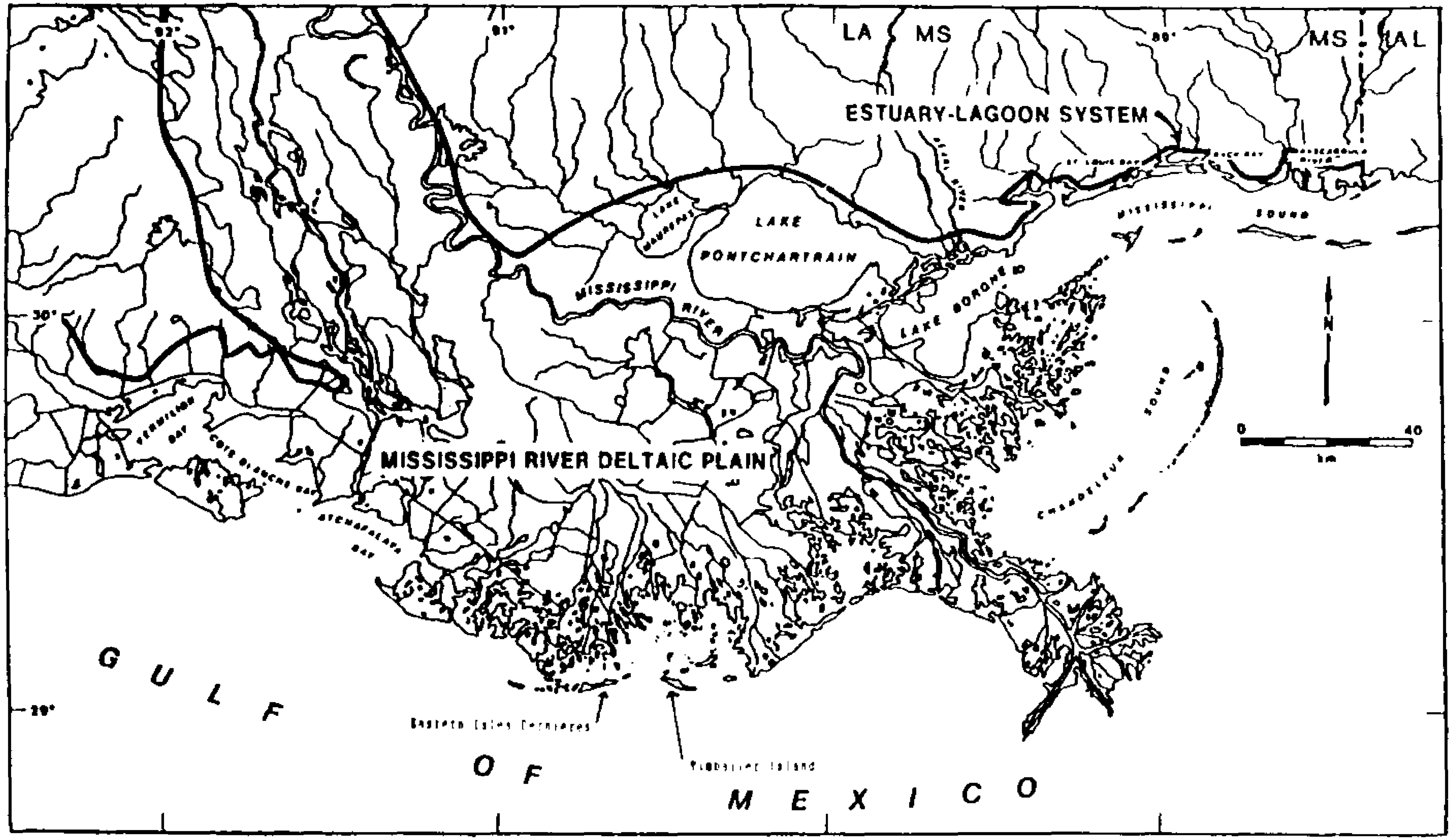


Figure 1. Southeastern Louisiana, showing the Mississippi River deltaic plain, present delta, and barrier islands along the perimeter of former deltas (after Fisk, 1944).

used to describe changes in island shorelines and surface area. The Godfrey and Godfrey (1974) *rollover* model describes island responses to rising sea levels. Through a cycle of breaching, overwash, and restabilization of dunes and marshes, island sediments are gradually *rolled* up the inshore slope while maintaining a consistent surface expression. However, there are fundamental differences between the United States Atlantic coast, where the *rollover* model was formulated, and the Mississippi River deltaic plain. The Penland and Boyd (1981) *deltaic barrier cycle* model describes a sequence of barrier island stages associated with the formation, abandonment, disintegration, and eventual reoccupation of major river deltas. This study examines the validity of these two models within the context of the Louisiana coastal environment.

Digitized surface feature maps, derived from aerial photographs of the islands from fall 1978 through winter 1985, comprise the basic information sources for this study. Computer image processing techniques were used to extract spatial change data and to determine statistical relationships. The validity of the *Rollover* model was tested by determining:

1. Direction and extent of changes in island shorelines,
2. Changes in island surface area, and
3. Changes in location of marsh and dunes.

Validity of the *Deltaic Cycle* model was tested by additionally determining:

4. Degree and direction of lateral migration.

In addition to an understanding of the dynamics of barrier island change, it is important to know which factors contribute to these changes. For instance, the presence or absence of certain surface features may have a significant impact on the stability of island sediments. Therefore, an examination of the type, location, and extent of cover categories relative to areas of change was undertaken in order

to provide some insight into these relationships.

Therefore, this study examines changes in shorelines and surface features of two Louisiana barrier islands. Data was collected and analyzed to test the validity of two widely accepted models of barrier island dynamics, as well as to determine the impact of island cover categories on change rates.

BACKGROUND AND LITERATURE REVIEW

The coastal wetlands of Louisiana represent nearly 40 percent of the total wetlands of the continental United States (Gagliano et al., 1981). The aerial extent of intertidal marsh areas have been shown to be strongly correlated with commercial fisheries harvests (Turner, 1977), providing Louisiana with the nations largest commercial fishery in terms of tons landed (Deegan et al., 1984). The estimated economic value of Louisiana's coastal zone (including oil and gas revenues) is over one billion dollars per year (Mendelssohn et al., 1983). However, these areas have been experiencing some of the highest rates of land loss of any coastal system in the United States, with annual losses estimated to be as high as 102 km/yr (Gagliano et al., 1981).

Coastal barriers are thought to provide shelter for mainland shores and bays, lessening the impact of storm tides and waves (Dolan, 1973, 1976; Godfrey 1976; Leatherman, 1979a). In order to maintain this degree of protection their management and preservation is essential. However, proper management requires an understanding of the processes involved in the formation and dynamics of barrier island systems. Therefore, a review of the literature was undertaken to provide a theoretical framework for interpreting the changes and interactions observed within the Louisiana barrier island environment.

I. Louisiana Deltaic Processes

Coastal Louisiana is dominated by the sedimentation processes of the Mississippi River. The Mississippi deltaic plain consists of an extensive network of interconnected distributary channels (Figure 1) which radiate southward through the Mississippi alluvial valley to the Gulf of Mexico (Fisk, 1944; Kolb and Van Lopik, 1958; Frazier, 1967; Coleman, 1981; Penland et al., 1985). These channels enlarge and

coalesce to form ponds, open lakes, and eventually bays open to the Gulf (Morgan, 1967).

Throughout the Quaternary, southern Louisiana has been the recipient of tremendous quantities of sediments through the periodic advance and retreat of continental ice sheets (Frazier, 1967). The weight of these sediments has caused isostatic downwarping of the earth's crust south of an east-west line running through Baton Rouge, Louisiana, and uplifting north of this line (Adams et al., 1978). According to Frazier (1967), the Mississippi River has built six major delta complexes (Figure 2) consisting of at least 16 minor lobes (Figure 3) during the last 7,000 years of the Holocene Epoch (the most recent period of glacial retreat).

The location and timing of each deltaic lobe is a function of sediment input, subsidence, and sea level rise. As the sediments build up over older surfaces the slope is reduced, eventually resulting in a shift of the main channel (Figure 4) to a steeper and, therefore, more efficient hydrologic gradient (Fisk, 1944; Frazier, 1967). Once a distributary lobe has been abandoned, the process of subsidence, erosion, and reworking of the deltaic sediments continues, resulting eventually in complete submergence (Fisk, 1944; Kolb and Van Lopik, 1958; and Frazier, 1967). With continued subsidence the area may once again capture the river and become active for another cycle. Large river systems such as the Mississippi deposit new deltas in the order of one every 1000 years (Frazier, 1967). Typical timing of Mississippi deltaic cycles is 600-1600 years (Boyd and Penland, 1984).

Within the last 100 years the process of delta cycling has been at least temporarily preempted by man through the construction of continuous flood containment levees along the southern extent of the Mississippi River (Fisk, 1944). These levees, while reducing the risk of property damage due to overbank flooding, have precluded the periodic distribution of river-borne sediments to the surrounding delta marshes. The result has been a net rate of coastal erosion in Louisiana currently estimated as high as 100 km^2 per year (Gagliano et al., 1981) as the

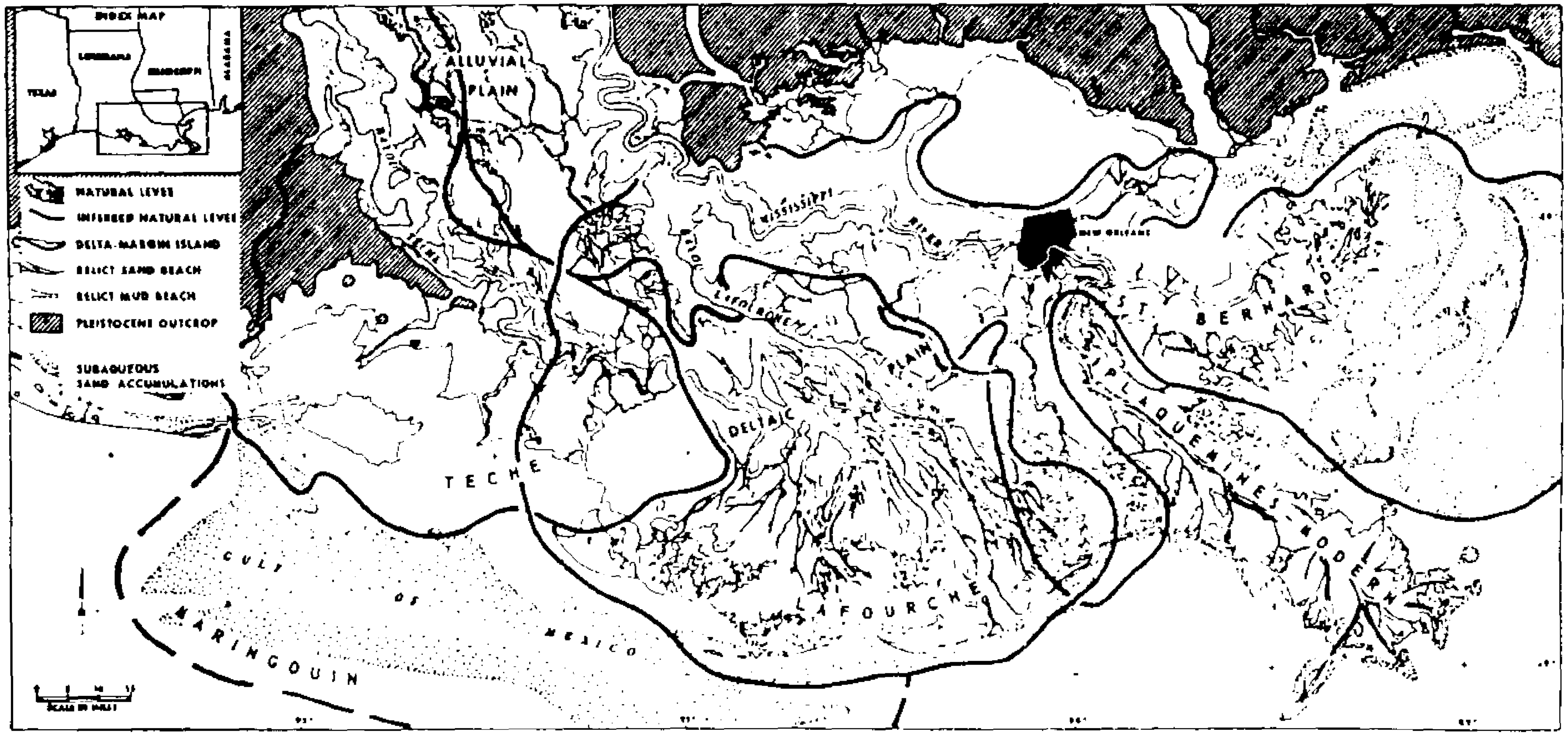


Figure 2. Major deltaic lobes of the Mississippi River (Frazier, 1967).

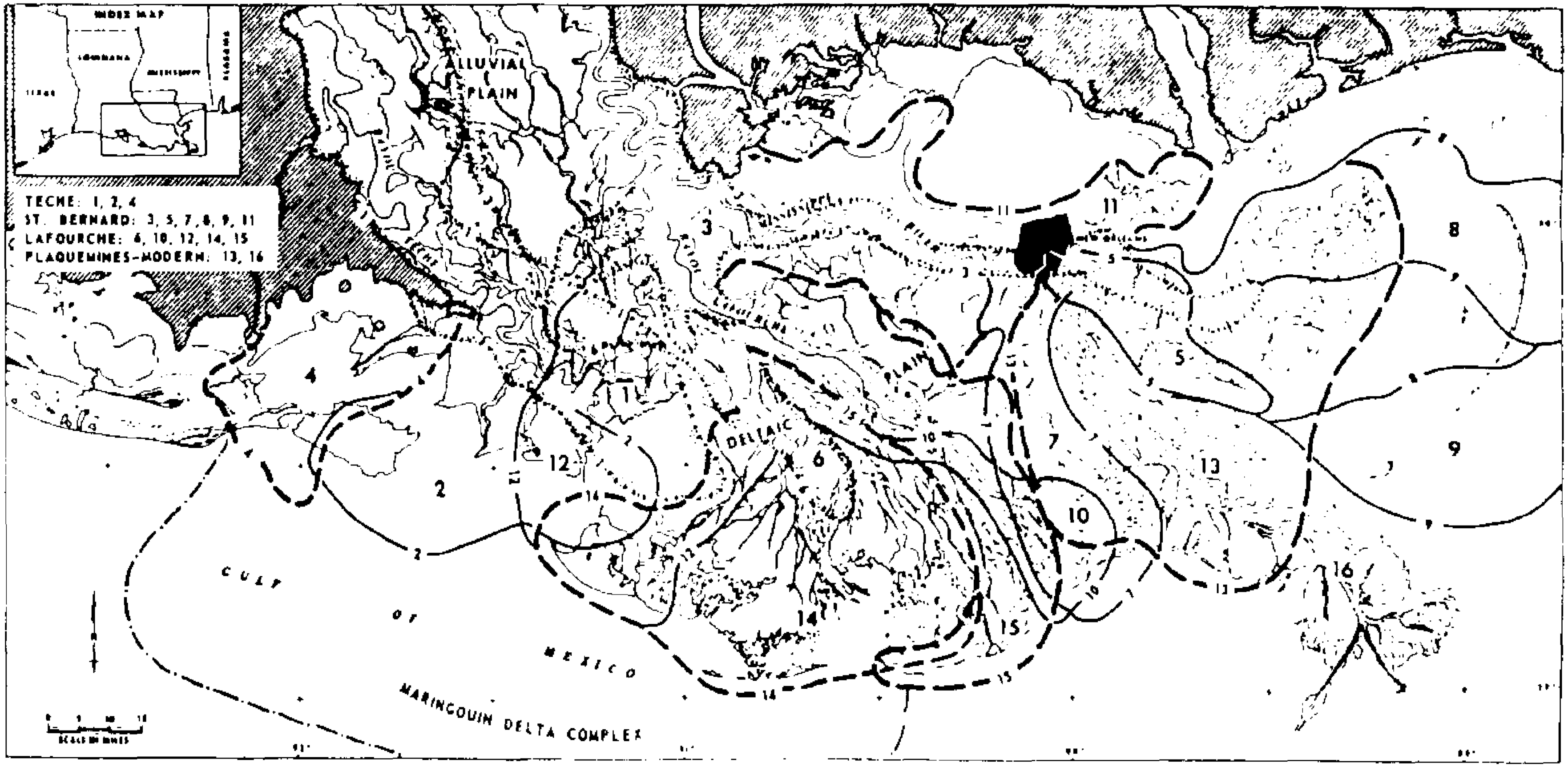


Figure 3. Sequence of formation of Mississippi River sub-delta lobes (Frazier, 1967).

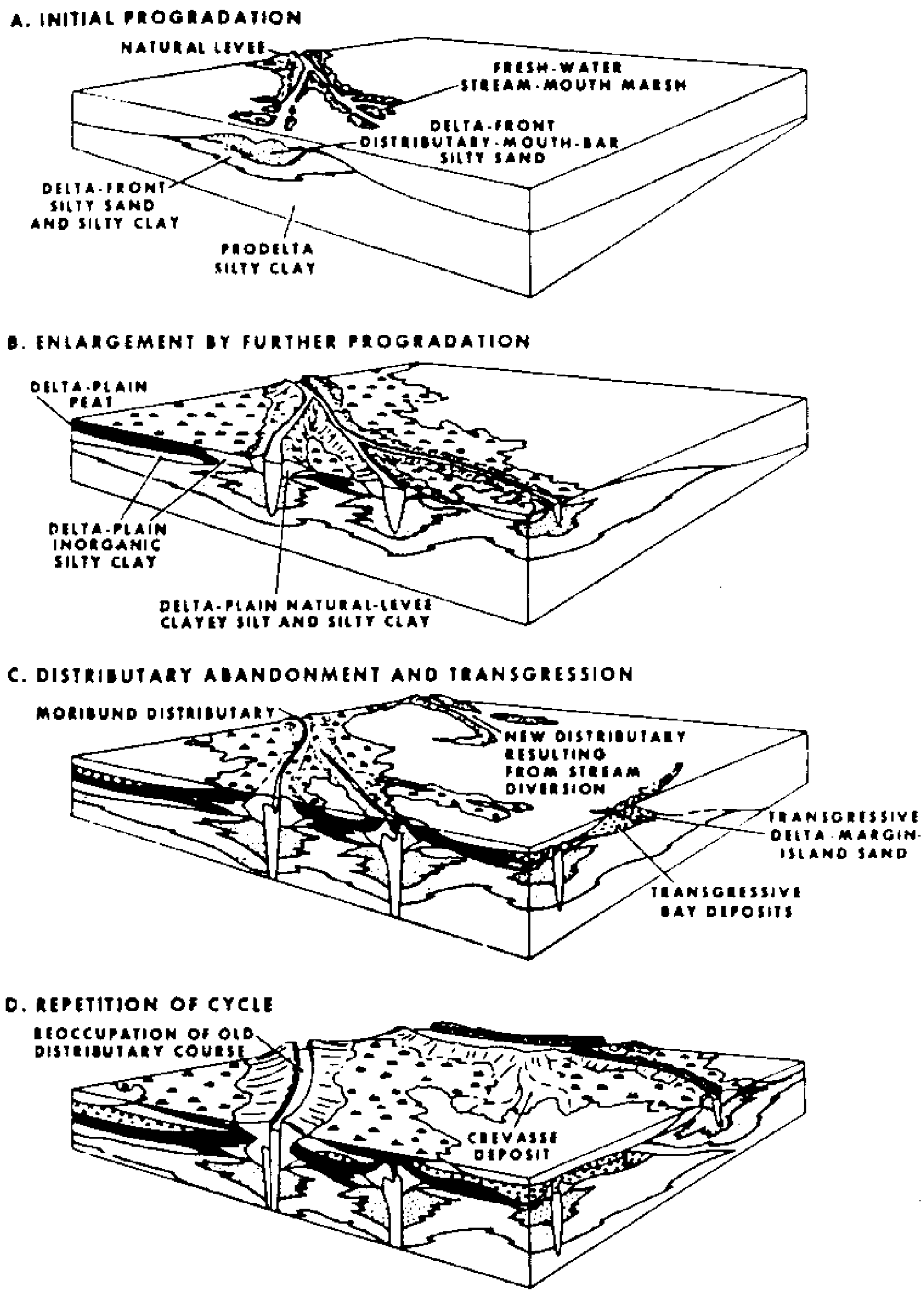


Figure 4. Sequence of river delta initiation, growth, and abandonment (Frazier, 1967).

active mouth of the Mississippi builds farther out into the Gulf and its sediment load is deposited into increasingly deeper water.

II. Theories of Barrier Island Origin

The means of formation of barrier islands has been a highly debated and discussed subject since the publication of deBeaumont's original work in 1845 (Schwartz, 1973; Leatherman, 1985). Most current thoughts concerning barrier island genesis are founded on theories established prior to the turn of the last century. These include deBeaumont's (1845) emergent bar theory, Gilbert's (1885) theory of shoreline drift and prograding spit formation, and McGee's (1890) theory of submergence of coastal lowlands behind a beach ridge.

A. Emergent Bar Theory

According to deBeaumont's *Lecons de Geologie Pratique* (1845), barrier islands form due to shallow water wave action scouring and redepositing bottom sediments. In this way a parallel offshore bar is built up which eventually becomes subaerial (Figure 5). This "emergent bar" theory, has had the least common acceptance with recent workers (Hoyt, 1970). However, this theory has enjoyed a history of acceptance (Johnson, 1919) and is supported in certain situations by recent evidence (Otvos, 1970a; 1970b; 1979).

Johnson (1919) favored deBeaumont's emergent bar theory over Gilbert's (1885) prograding spit hypothesis based on topographic sections across several mid-Atlantic barriers. He constructed theoretical profiles based on an emergent bar versus a prograded spit and compared these to the profiles which he had observed. His conclusions were that the profiles best fit a model of wave approach and sediment distribution normal to the shore, not along shore. He also

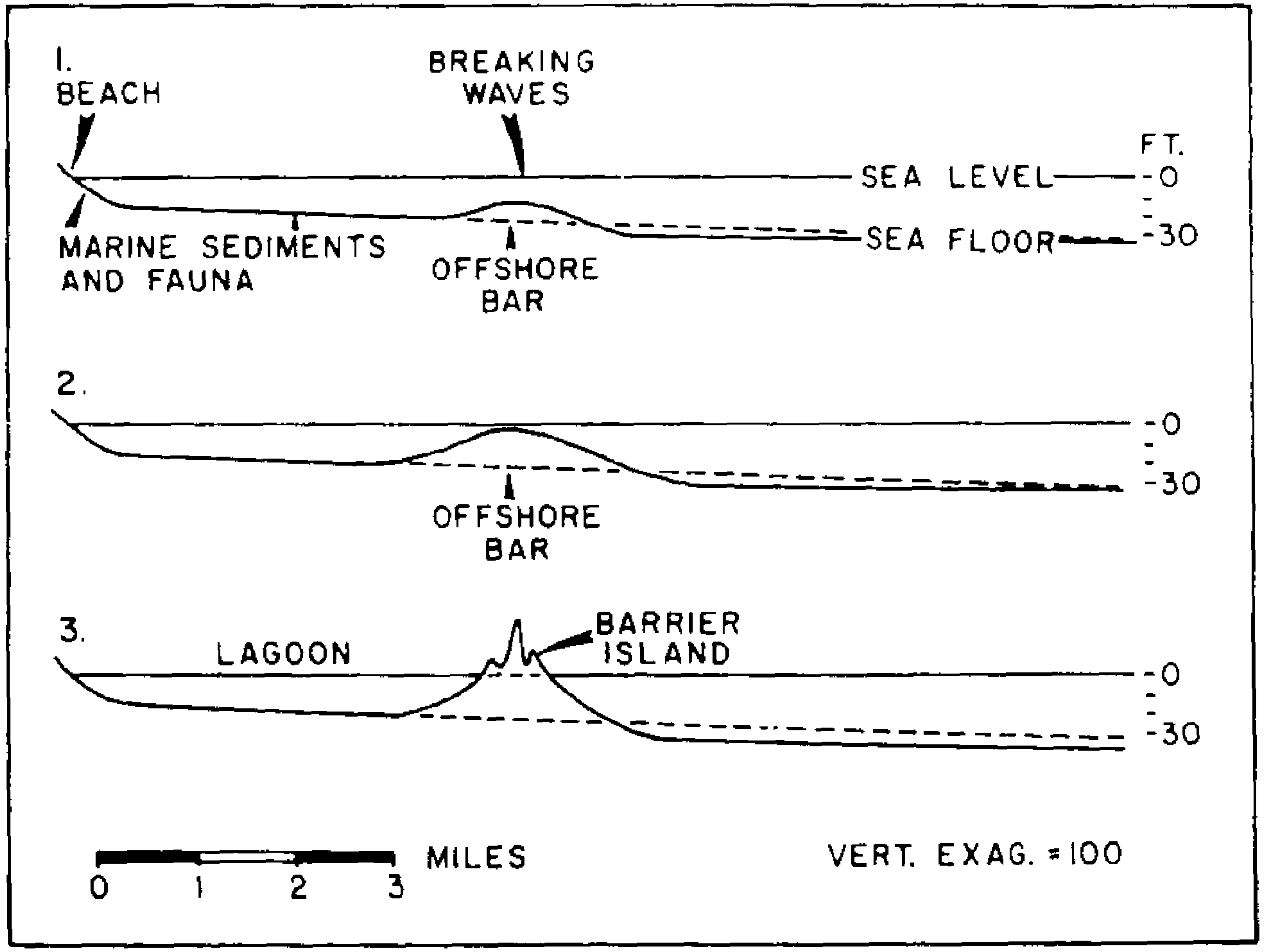


Figure 5. deBeaumont's (1845) emergent bar theory of barrier island formation (from Hoyt, 1967).

concluded that barriers could not form under conditions of submergence, and, therefore, must have formed during a period of falling seas.

Fisher (1973) repeated Johnson's profiles along the Virginia-North Carolina coast and adding an additional 13 profiles, as well as profiles along non-barrier coasts including spits and headland shorelines. In general, all shorelines along a particular segment of coast exhibit the same offshore characteristics. Applying quantitative values to Johnson's profiles and comparing them to Fisher's results showed Johnson's to be both ambiguous and incorrect.

Otvos (1970a), using sediment core data from the Mississippi Sound barriers and lagoon, suggested that certain barrier islands in the northern Gulf of Mexico may, in fact, have developed through the emergence of submarine shoals. Citing as support for this theory the reemergence of Grand Gosier island in the southern Chandeleur Islands after being reduced to submarine shoals during passage of hurricane Camile in 1969. However, Hoyt (1970) contested Otvos's assertions, claiming instead that the Chandeleurs were, in fact, examples of beach ridges abandoned through submergence of the inshore marsh. Hoyt also pointed to the lack of open marine sediments in Otvos' core samples as proof that the islands did not form from offshore bars. He asserts that an offshore bar must, by definition, inclose open marine sediments.

In defense of his earlier work, Otvos (1970b) cited examples of many open coasts, including Barataria Bay, which are essentially estuarine or lagoon and, therefore, would not contain open marine fauna. He also points out that open marine sedimentation rates are relatively slow, while barrier island formation can occur quite rapidly. As examples he cites the growth of the Nauset Beach Spit at Cape Cod, Mass. (9 km in 120 yrs) and Horn and Petit Bois islands in the Mississippi Sound (5 km lateral drift in 100 yrs). He reemphasized the observed and recorded reemergence of Grand Gosier Island as proof that barrier islands can form from submarine shoals. Otvos later (1979) cited historical charts since the 18th century which record the reemergence of numerous small and some large islands from shoals, especially in the

southern Chandeleurs after storm destruction of preexisting islands.

B. Prograding Spit Theory

Gilbert (1885) suggested a mode of barrier island formation from sediments transported along the shoreline through littoral and longshore drift. With a gentle offshore slope and shallow water depths, waves should break some distance from the shore. Currents occurring in this line of agitation should move the suspended sediments parallel to the shore, building into a continuous outlying ridge. In this manner a spit would form as an extension from the headland, lengthen, and eventually breach, forming an island (Figure 6).

Although Johnson's (1919) work strongly influenced later authors, by the second half of the 20th century investigators were again considering alternatives to deBeaumont's theory of barrier origin (Schwartz, 1973). Van Straaten (1965) used extensive core samples, grain size analysis, and carbon dating to theorize that the Dutch barrier ridges formed after the Holocene high sea (6000 BP) during a period of not more than 2000 years. He postulated that formation was primarily by longshore drift at an estimated rate of three million cubic meters per year or three times the current rate.

LeBlanc and Hodgson (1959), working in the northwest Gulf of Mexico, described the Texas barrier islands as characterized by a series of alternating beach ridge and swale formations parallel to the mainland coast. They postulate the formation of the islands as the accumulation of riverine sediments through longshore currents. They envisioned this as occurring approximately 5000 BP, at the beginning of the present Holocene standstill, after the river valleys filled with sediment. They considered the ridge and swale formations as evidence of shoreline regression and note only a few examples of transgression on the Texas coast (Figure 7).

Otvos (1979) offered further support to the spit progradation

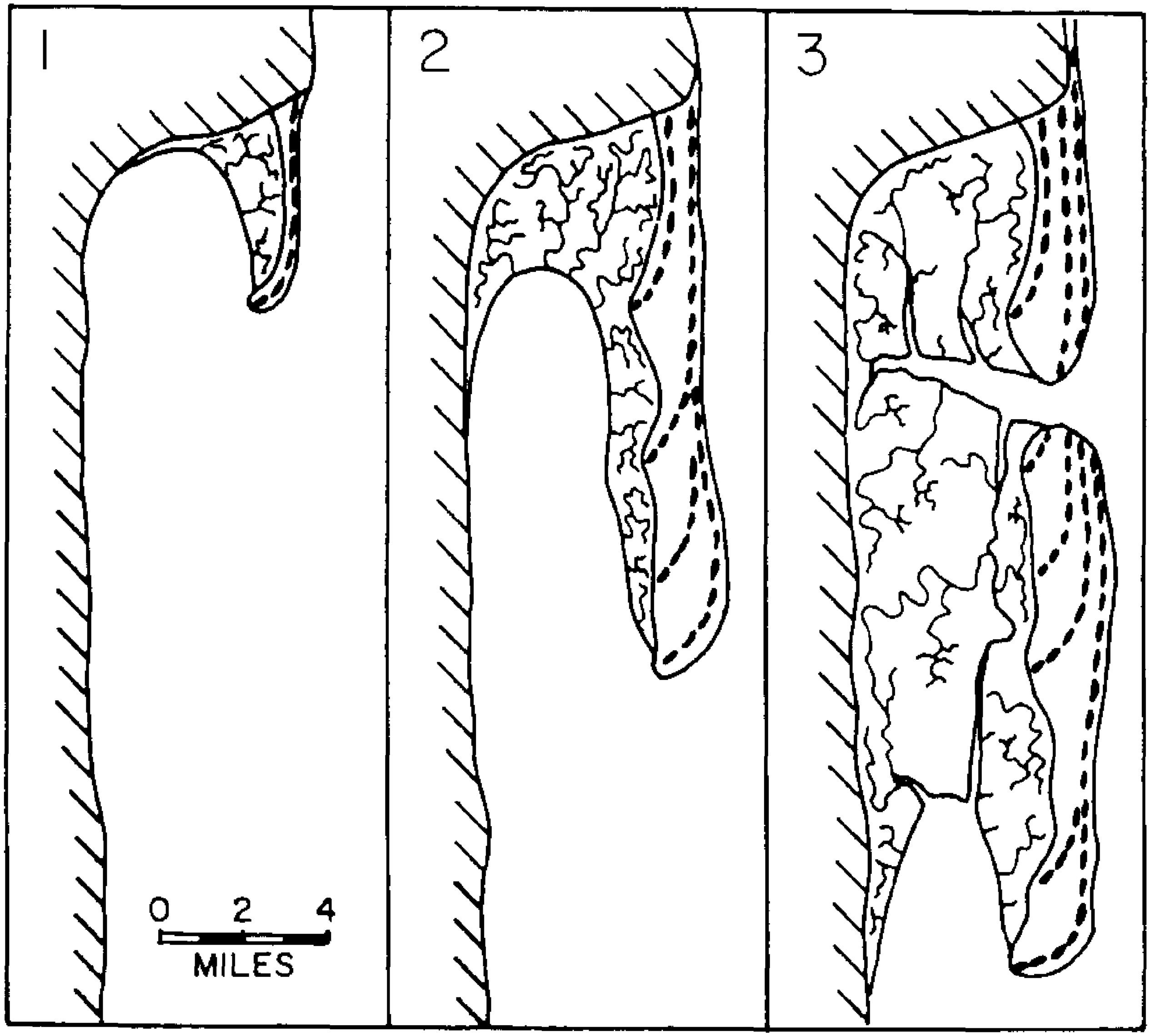


Figure 6. Gilbert's (1885) prograded spit theory of barrier island formation (from Hoyt, 1967).

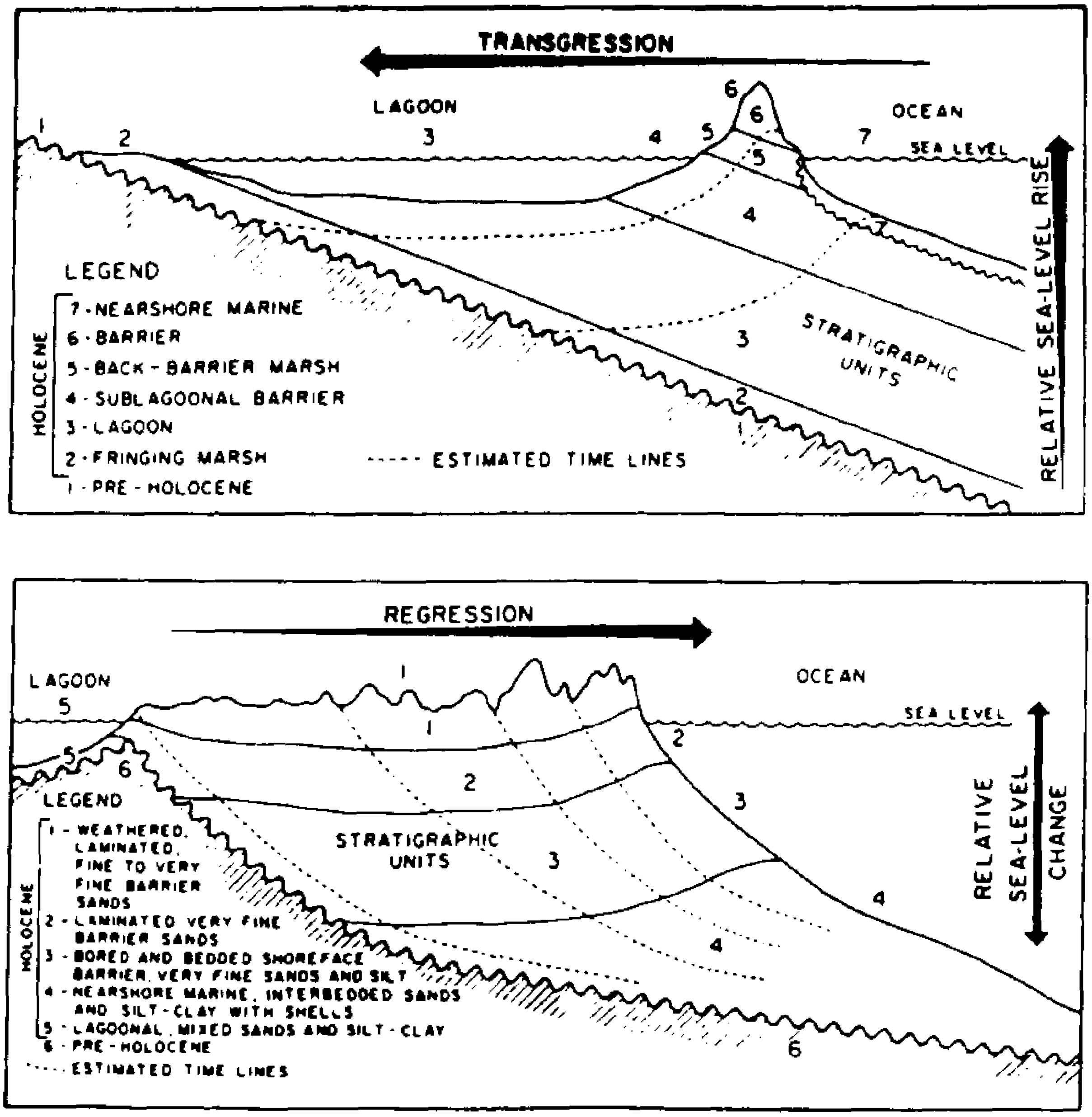


Figure 7. Transgressive and regressive barrier island migration strategies (Nummedal, 1983).

hypothesis. He suggested that alternating spit growth and reattachment on the island downdrift end is a major mechanism for island migration in the Mississippi Sound, resulting in a characteristic ridge and swale pattern. He notes this same trend on Timbalier Island, on the central Louisiana coast.

Hoyt (1967) argued against the prograding spit theory on the same grounds as for the emergent bar. That is, that if barrier formation was through the enclosure of a formerly open marine area, then Van Straaten and other workers sample cores should contain evidence of marine fauna. This was not the case for any of the lagoon core samples reported. Fisher (1968), while agreeing with Hoyt concerning deBeaumont's and Johnson's emergent bar, suggested that the formation of complex spits during submergence and reworking of headlands could proceed at a sufficiently rapid pace to preclude formation of marine sediments shoreward of the newly formed island or promontory. He also suggests that there is no one single explanation for all barrier islands.

C. Submerged Beach Ridge

McGee (1890), noted the evidence of a continuous rise in sea level through observation of damage to coastal structures. He postulated that coastal barriers formed through the submergence of lower lying coastal lands during rising sea levels, eventually isolating coastal ridges and dunes from the mainland (Figure 8). This theory seems to have been essentially overlooked until the later half of the 20th century (Schwartz, 1973; Leatherman, 1985).

Zenkovitch (1962), studying barrier island and lagoon sediment cores along the Black Sea and Kamchatka Peninsula, determined that lagoon muds tended to overlay terrestrial surfaces. He interpreted this as an indication that these barriers existed prior to the creation of the lagoons. He proposed that barrier islands originated as wave built terraces or as shallow water shoreline ridges created by the migration

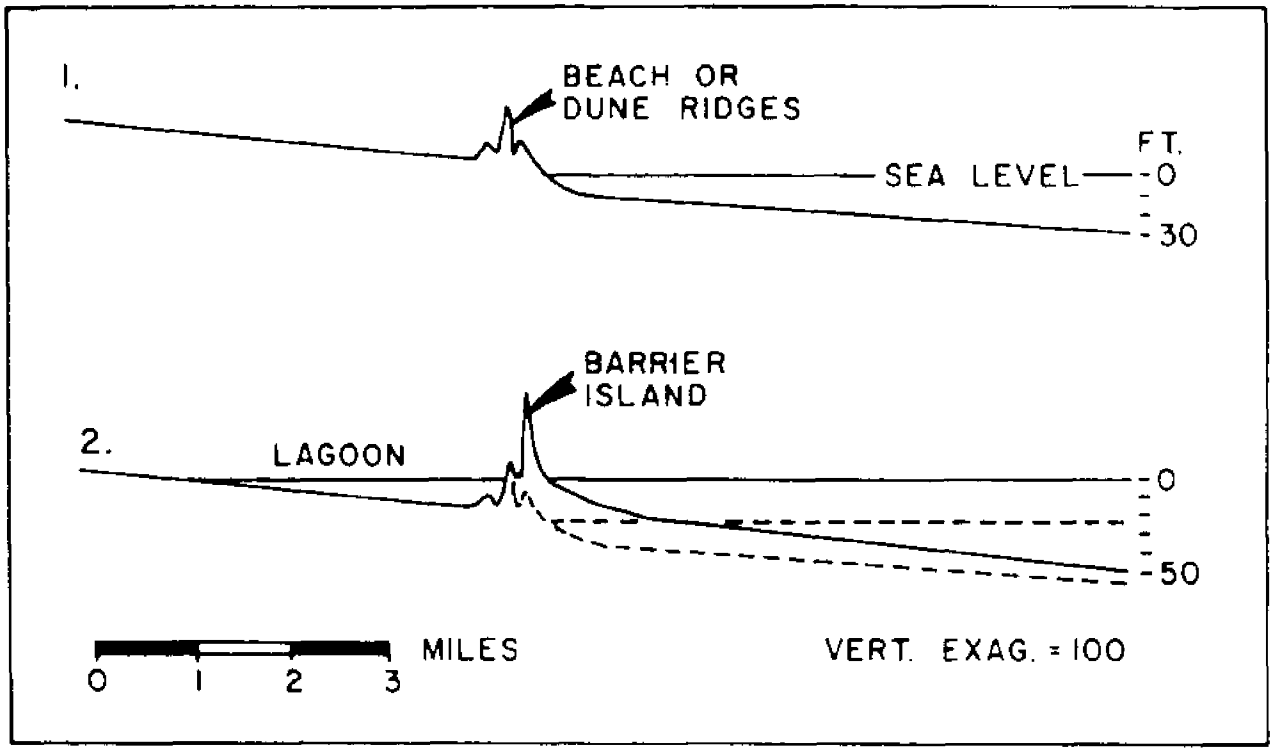


Figure 8. McGee's (1890) submerged beach ridge theory of barrier island formation (from Hoyt, 1967).

of offshore bars through transversal drifting of sediments normal to the shoreline. He considered an abundant sediment supply and a bottom slope of 0.005-0.01 necessary for formation of wave built terraces and slopes of 0.001-0.005 for construction of beach ridges. This process would have occurred during a period of steady or falling seas. With the resumption of sea transgression, the lower elevation inshore surfaces would become flooded, forming lagoons, and transforming the ridges and terraces into islands. He further theorized that with continued submergence and an adequate sediment supply the islands should retreat shoreward.

Sediment cores from the Massachusetts coast led McIntire and Morgan (1963) to the conclusion that Plum Island had originated as a Pleistocene coastal ridge which had become detached from the mainland through submergence of surrounding areas. They placed the original location of the island offshore from its present position, indicating a shoreward migration with continued rise of sea level.

Hoyt (1967), viewed this sequence of partial submergence of a preexisting coastal ridge or dune as the only acceptable mechanism for barrier island formation. As evidence against the emergent offshore bar and progradational spit theories, he points to the absence of neritic (above the continental shelf) or open marine sediments in core samples from Atlantic and Gulf barrier lagoons. Hoyt did think that barriers could form from prograding spits under certain circumstances, though marine sediments should be evident behind these barriers.

Fisher (1968), in response to Hoyt's (1967) arguments, suggested that terrestrial sediments, specifically coastal woodland debris, should be evident behind former coastal ridges. Since this has not been found in most barrier lagoon cores there is no conclusive evidence of a terrestrial existence prior to the formation of the barrier. Fisher also suggests that barrier chains originating as preexisting ridges should have an irregular shape matching that of the coast, rather than the smooth arcuate or lobate forms normally observed. Otvos (1970a), also took exception to Hoyt's suggestion that marine sediments must be

present landward of barrier islands formed other than by the drowning of coastal ridges. He insisted that many open marine facing shores have marsh or lagoon-like conditions and that bay spits can form rapidly enough to preclude the accumulation of marine sediments.

As a variation on the submerged beach ridge hypothesis, Leontiev (1965) proposed that barriers represent relict Holocene submarine bars which formed during an early post-glacial transgression. Laboratory wave tank experiments which he conducted at Moscow University indicated that offshore bars could not exceed sea level during stand still or submergence. Therefore, present day barrier islands must have formed through exposure of these preexisting submarine bars during a receding sea. He cites evidence that seas were 3-5 m above present levels 6000 years BP, that they receded to a level 3-5 m below present, and then began to rise again 4000-4500 years BP. Leontiev and Nikiforov (1965) elaborate on the theory of barrier formation through the exposure of formerly submarine bars during receding sea levels. They suggest that submarine bars can form when there is a gentle nearshore slope, an abundant sediment supply, an active transversal debris drift, and rising sea level. They claim that coastal erosion and barrier island formation are both due to recent fluctuations in sea level.

D. Multiple Causes

Most researchers today recognize evidence of a variety of origins for barrier islands, determined by the prevailing environmental conditions (Schwartz, 1973). Zeigler (1959) was one of the first to suggest the possibility of multiple causality in barrier genesis. In one of the first studies to utilize time sequence aerial photography, he described three types of barrier island, each derived through different means of formation. The first, erosion remnant islands, develop through the drowning of cuestas (ridges dividing coastal Pleistocene watersheds). The second type, marsh islands, begin as mud flats, become

vegetated, and begin to accumulate sediments and peat. The last type, beach ridge islands, develop by littoral drift accompanying headland erosion during both rising and falling seas, thereby forming a ridge and swale shoreline.

Colquhoun et al. (1968), using field observations and laboratory wave tank experiments, and Pierce and Colquhoun (1970), using sediment cores and aerial photography, suggested two types of barrier island formation. They described the primary means of formation as the submergence of a preexisting beach ridge during a period of sea transgression. Islands formed in this manner would overlie terrestrially derived substrates. They described secondary barrier formation as occurring over marine sediments during periods of standstill or regression. Pierce and Colquhoun (1970) pointed to the extreme irregularity of North Carolina's Pamlico Sound shoreline as an indication that the barriers did not form from prograded spits. If this had been the case, the Sound shoreline would have been exposed to storm and wave energy during barrier formation, resulting in a reworking of shore sediments and a smoothing of its shape. They felt that barriers were formed, not by mutually exclusive methods, but could result from submergence of a beach ridge or from spit extension, during rising or falling seas.

Schwartz (1971), in an attempt to extend Pierce and Colquhoun's (1970) primary and secondary barriers to incorporate the theories of Hoyt (1967), Fisher (1968), and Otvos (1970a), formalized a schematic of barrier origin:

I. Primary (Engulfed Beach Ridge),

II. Secondary,

1. Breached Prograded Spit,
2. Emergent Bar,
    A. During Sea Transgression,
    B. During Sea Regression,

III. Composite (Combination of the Above).

Otvos (1985), using northern Gulf of Mexico barrier island core samples, suggested the use of foraminiferal biotopes and sediment parameters from barrier platforms (Oertel, 1985) to provide essential information for determining island origin and developmental stage. He proposed three basic platform types (Figure 9):

1. Aggradational/Progradational - overlies marine sediments on gently sloping nearshore bottoms with adequate sand supplies - formed through the construction of platforms by shoaling waves over which the island aggrades,
2. Composite - accreted around Pleistocene high ground as an intertidal/supratidal veneer along the flanks - formed during rising sea level as engulfed pre-Holocene littoral ridges and other high ground,
3. Transgressive - covers lagoon bay or deltaic sediments - formed through erosional detachment of mainland beaches and/or through aggradation from subaqueous shoals seaward of receding subaerial delta remnants.

As examples of transgressive platforms he lists the Chandeleur Islands and the Isles Dernieres along the Louisiana deltaic coast; for composite platforms, Dauphine Island and Santa Rosa Island in the Mississippi Sound; and for aggradational/progradational platforms, Timbalier Island and the western Isles Dernieres.

E. Louisiana Deltaic Barriers

Barrier islands appear to be particularly common along the flanks of large river deltas around the world, especially in areas where deposition has ceased and sediments are being reworked (Shepard, 1960; Kwon, 1970; Penland and Boyd, 1981). Penland et al. (1981) and Boyd and Penland (1984) described deltaic barrier development as a repetitive sequence of events consisting of delta formation, abandonment,

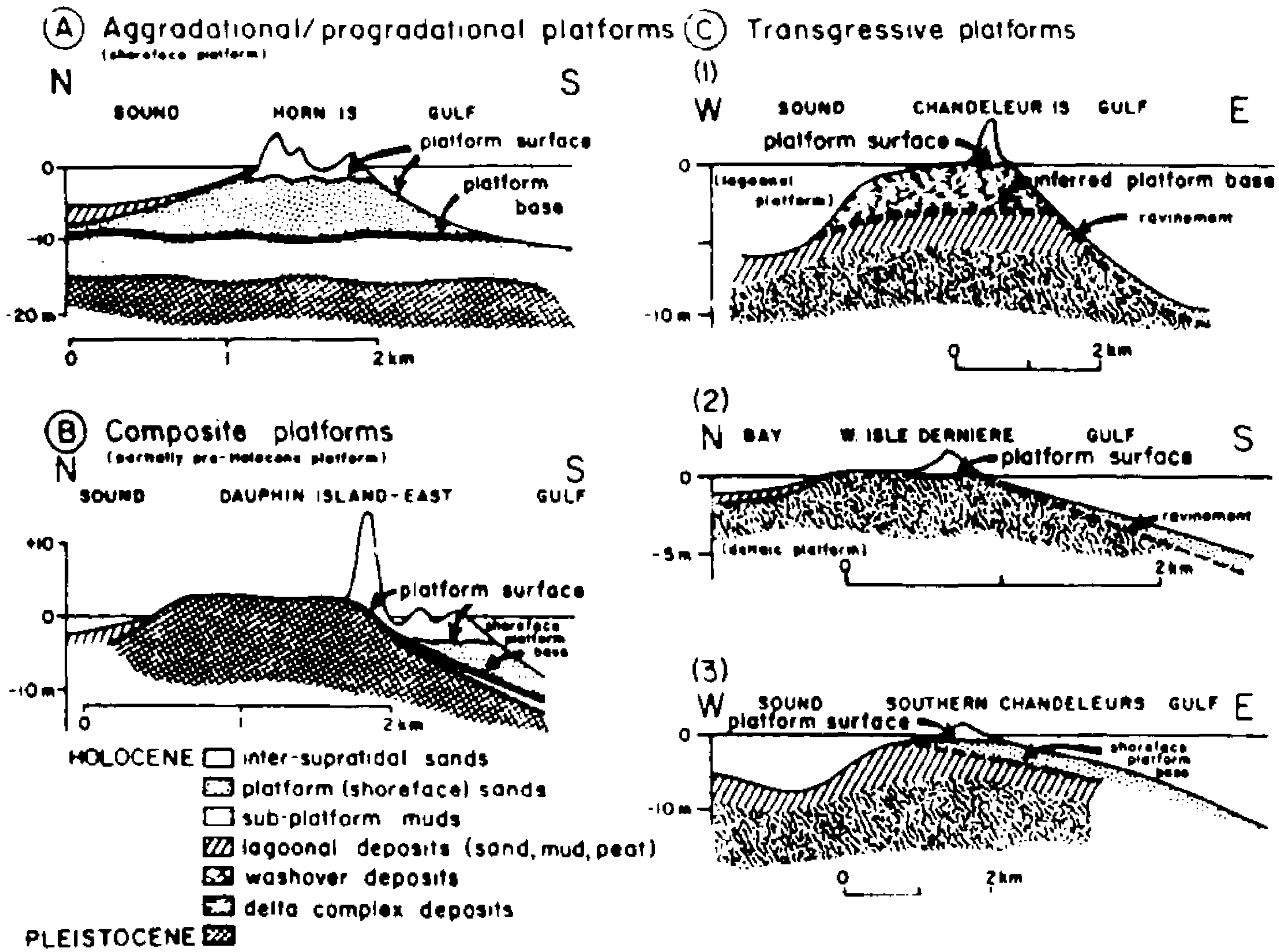


Figure 9. Barrier island platforms in the northern Gulf of Mexico (Otvos, 1985).

reworking, and subsidence, followed by eventual reoccupation and formation of a subsequent delta (Figure 10). As subsidence and erosion become dominant, the sediments of the abandoned deltaic headlands are reworked by littoral currents. The coarser sediments concentrate along the beachfront and form flanking sandy spits (Figure 11). These separate from the headland as it continues to subside, eventually forming a shoreward transgressing arc of islands (Figure 12). With continued subsidence and transgression, shoreface retreat becomes less effective as sand is continuously lost to sediment sinks, resulting in the submergence of the island as an inner shelf shoal. The *deltaic barrier cycle* encompasses the three major theories of barrier island origin as exemplified within the Louisiana coastal system (Penland et al., 1981). These include:

1. deBeaumont's (1887) *emergent bar*, represented by the Chandeleurs, and Tiger, Trinity, and Ship shoals,
2. Gilbert's *prograding spit*, represented by Timbalier Island, the Caminada spit, and Grande Isle, and
3. McGee's *sumberged beach ridge*, represented by the Isles Dernieres and the Breton-Chandeleur Islands.

III. Theories of Barrier Island Dynamics

A. Barrier Island Characteristics

Barrier islands and beaches comprise 10-13% of the worlds coasts (32,000 km), accounting for 33.6% of the coasts of North America (Cromwell, 1971). Shepard (1960) described Gulf coast barrier islands as:

1. An outlying belt of sand,
2. Separated from the mainland by a shallow body of water,
3. Having a straight seaward margin, and

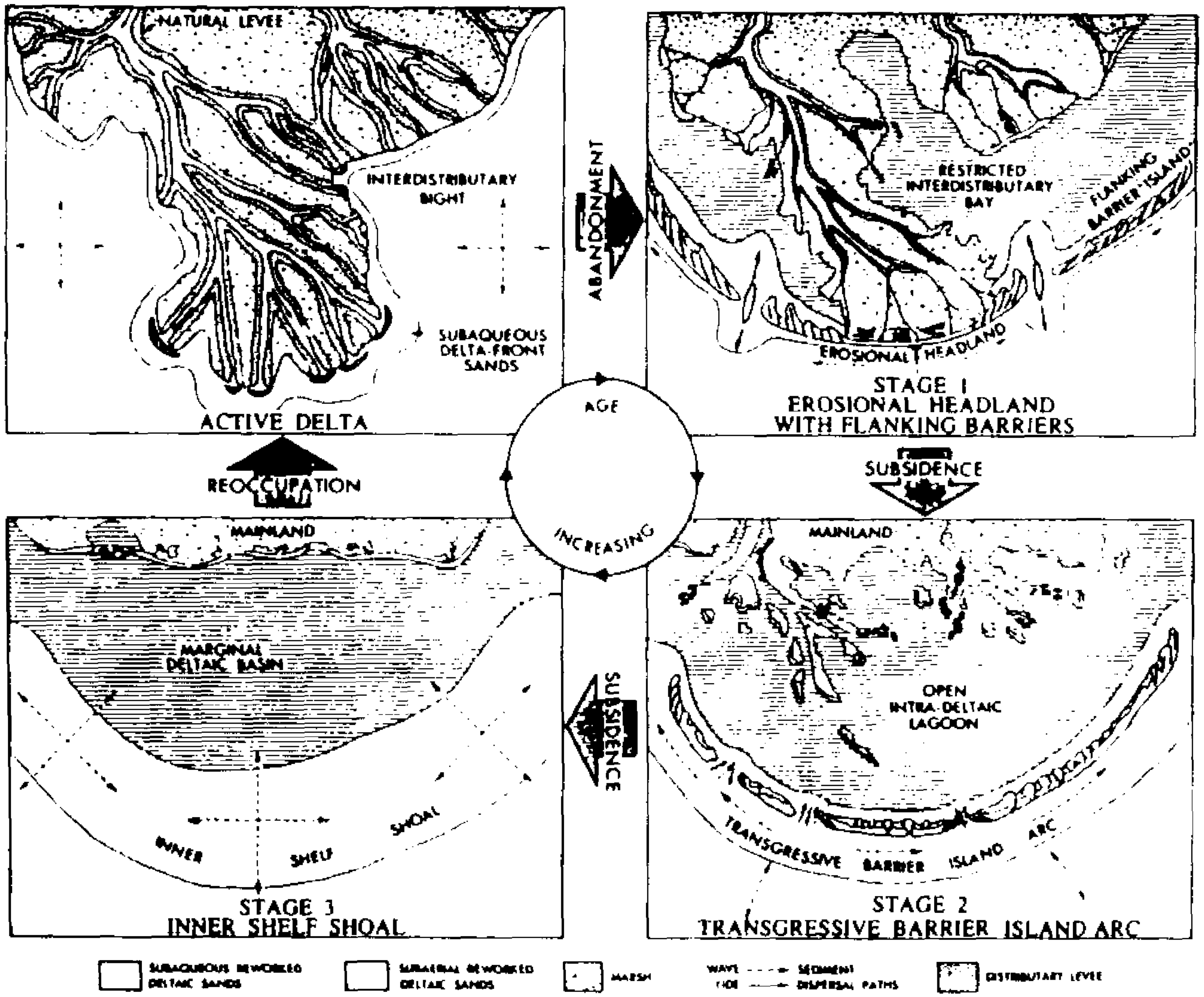


Figure 10. The deltaic barrier cycle (Penland and Boyd, 1981).

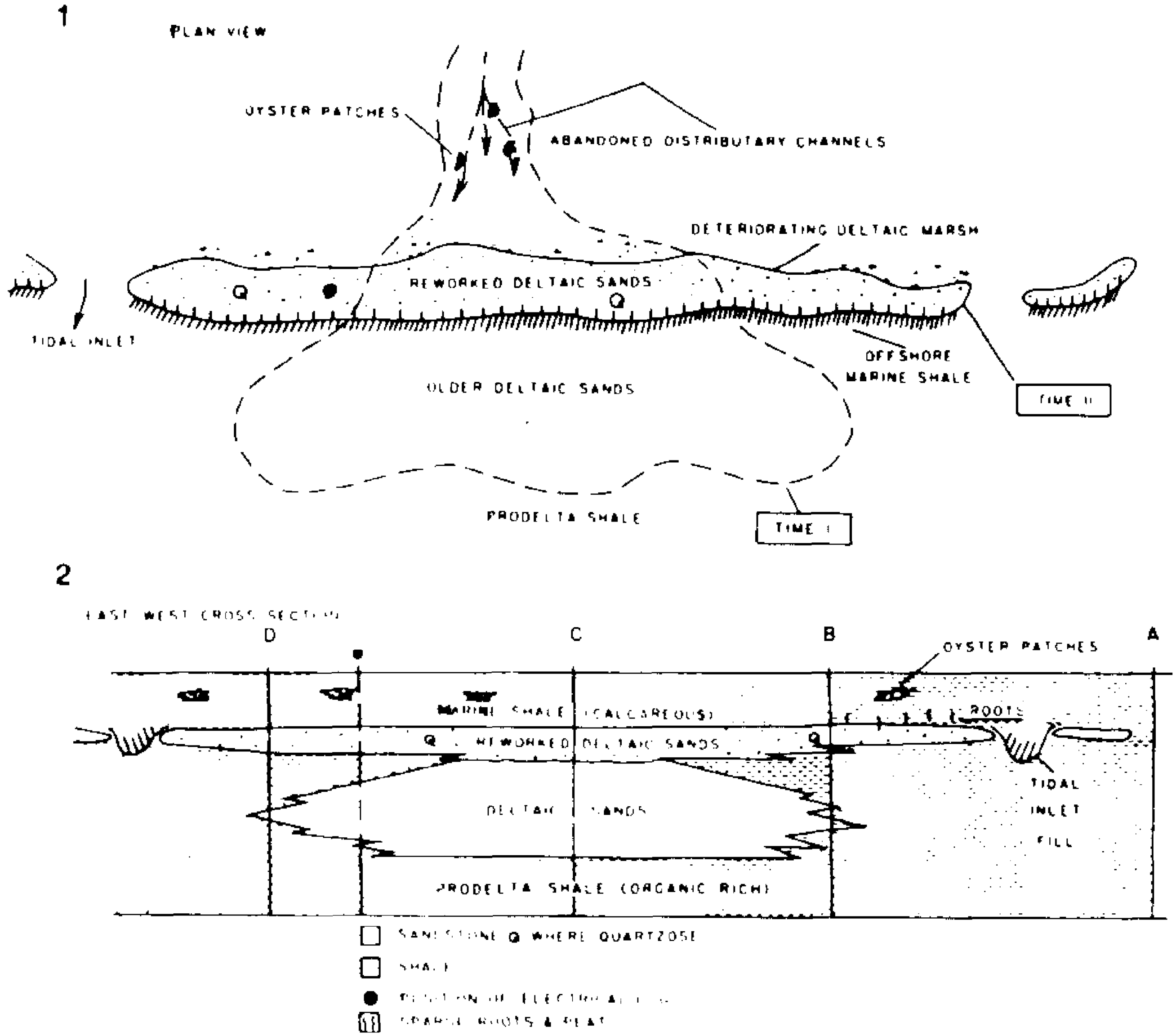


Figure 11. Transgressive barrier island stratigraphy showing the formation of flanking sandy spits (Nummedal, 1983).

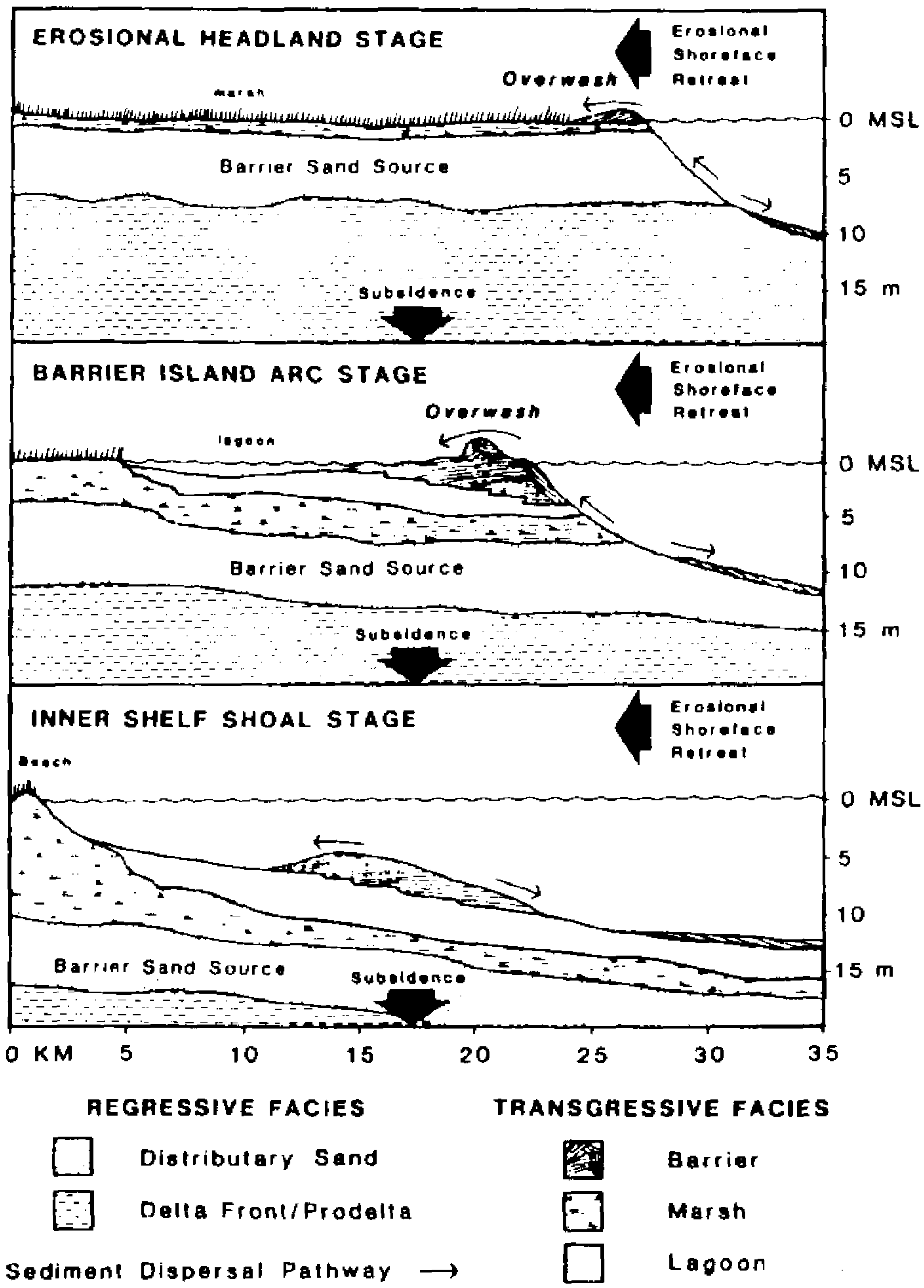


Figure 12. Cross-sectional view of the deltaic barrier cycle showing the transition through the transgressive barrier arc stage (Boyd and Penland, 1984).

4. Having a lobate, crenulate, or cuspate lagoon margin.

Within this context Oertel (1985) characterizes typical barrier systems (Figure 13) as consisting of:

1. A mainland, with a corresponding lithology, slope, and drainage,
2. A backbarrier lagoon, with associated depositional environment,
3. Inlets and inlet deltas, which separate island elements and move and rework island sediments,
4. A Barrier island, which exists as a subaerial expression of an accumulation of sediments between two inlets and between the shoreface and the mainland,
5. A barrier platform, a stratigraphic substructure primarily related to the origin and evolution of the barrier system, and
6. A shoreface, which extends through the shore zone of the ocean floor beyond the low tide line, bounded on the upper end by the area of shoaling and breaking waves (just beyond the area of storm breakers), and on the lower end by its merger with the inner shelf.

Barrier islands change and evolve with changing energy and geologic settings (Riggs, 1976). Their existence depends on a variety of factors. Hayes (1979) described the energy conditions under which barriers would normally exist:

1. Tidal range and wave energy effects interact to produce a characteristic morphology,
2. In areas of low wave energy ($H < 60$ cm) smaller tidal ranges are necessary to produce tide dominated morphology,
3. Barrier islands do not occur on macrotidal coasts (tidal range >4 m),

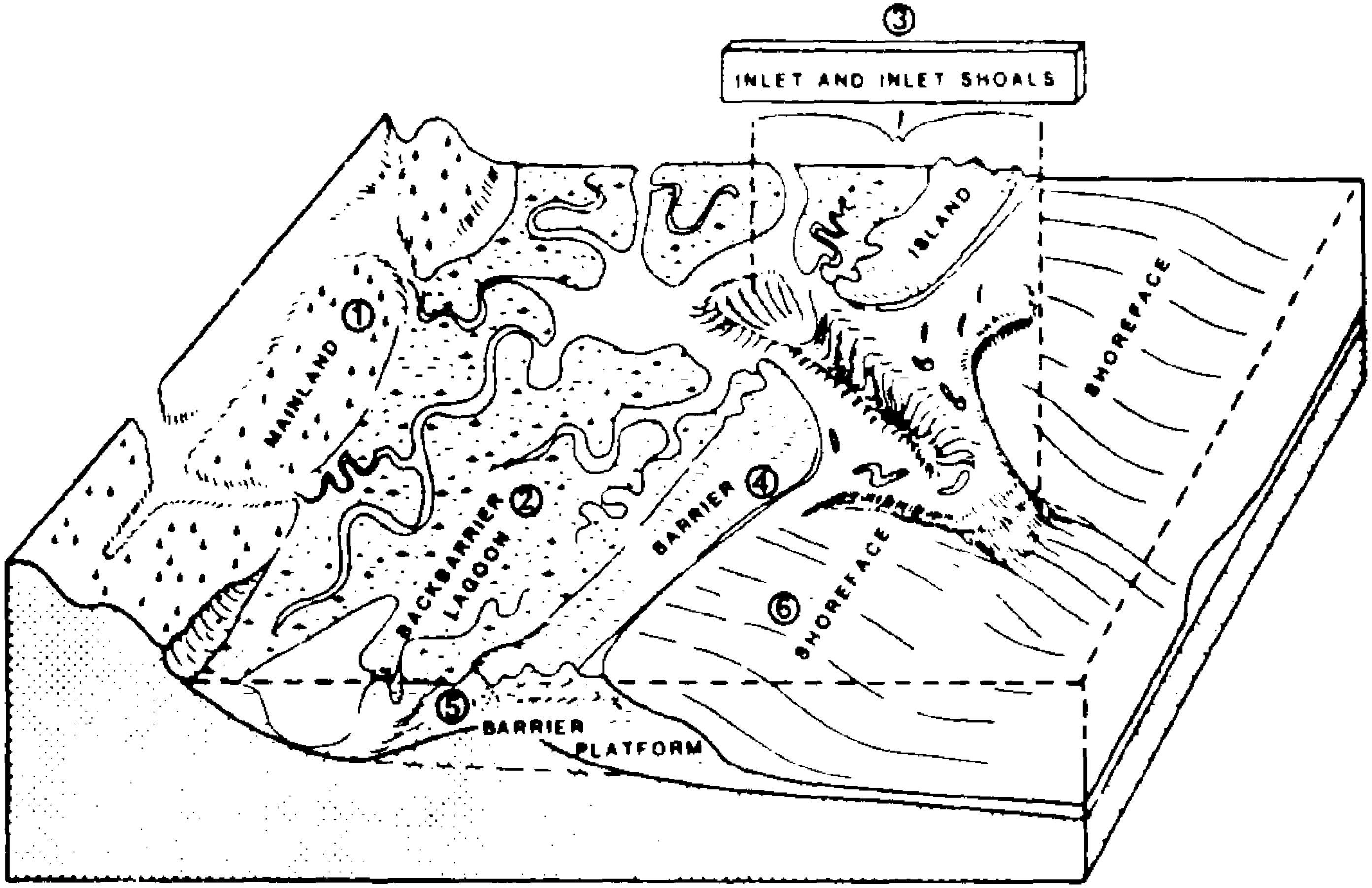


Figure 13. Interactive barrier island sedimentary environments (Oertel, 1985).

4. Barriers are most abundant on microtidal coasts (tidal range <2 m) and are long and linear with a predominance of storm washover influences,
5. Barriers and river deltas are best developed on microtidal coasts, and
6. On mesotidal coasts, barrier islands are short and stunted, with a characteristic "drumstick" shape.

A discussion of barrier island dynamics requires the use of terms which could be somewhat ambiguous. For this reason, Schwartz (1973) prepared a list of commonly used terms and a formal definition for each.

Overwash: the mass of sediment laden water which overtops a barrier during strong storm surges.

Washover: the sediment deposited on the barrier during an overwash event.

Backbarrier: the area of a barrier island between the foredune ridge and the subtidal boundary of the bay or lagoon shoreline.

B. Climate

The Louisiana coast is a storm dominated environment. Storm surges accompanying winter cold fronts and tropical and extra-tropical cyclones can be from 0.5 m to over 8 m (Boyd and Penland, 1984). Modal wave conditions in deeper Gulf waters are 1 m and 5-6 sec, however, modal conditions occur only 4% of the time in inshore waters (Boyd and Penland, 1984). Normal coastal tides are mixed, predominantly diurnal, with a microtidal range of 36 cm (Penland et al., 1985). Winter frontal passages (10-25 per winter) increase the range up to 120 cm (Penland et al., 1985).

Baumann et al. (1984) describe hurricanes and winter cold fronts as the major depositional and erosional agents in the northern Gulf. They report the passage of an average of 5.7 fronts through the area each winter month, and an annual probability of a hurricane passing within 80 km of a given area as 12% (one every 8.3 years). These storms elevate water levels and resuspend sediments. Nummedal (1982) reports the occurrence of tropical storms (winds in access of 63 km/hr) every 1.6 years and hurricanes every 4.1 years. Hurricanes can generate surge elevations 2-7 m above mean sea level, occasionally overwashing entire barrier shorelines (Boyd and Penland, 1981).

The tendency is for storms to move sand offshore and fair weather conditions to return it (Figure 14). However, according to Boyd and Penland (1984), the low wave energy of the northern Gulf is incapable of sediment transfer at a rate comparable to that of landward shoreline displacement. Significant non-storm sediment transport is limited to the upper shoreface landward of the 5 m isobath (Penland and Boyd, 1982). Sediment can be transported offshore well below the -10 m isobath during storms. As transgression of the Gulf continues shoreward over the very low Louisiana coastal gradient, (typical Gulf slopes are 0.5-1.5%, Shepard, 1960). There is a nearly equal increase in depth of water on both the lagoon and Gulf shorefaces. Therefore, since barrier sands are constantly being lost to deeper water, these barrier islands will be gradually transformed into subaqueous shoals (Boyd and Penland, 1984).

According to Dolan (1972; 1973; 1976) the natural condition for mid-Atlantic barriers is a range of sand deposit responses to various wave conditions. One response is an adjustment in beach cross-section to accommodate wave runup. During high storm surges the slope of the active beach is reduced and spread out absorbing wave energy over a greater extent. When wave runup is low the beach contracts to its pre-storm profile. During extreme storm events the extension can be beyond the outer bar seaward and inland through the dunes and sand flats. Leatherman (1979c) states that in these mid-Atlantic barriers short,

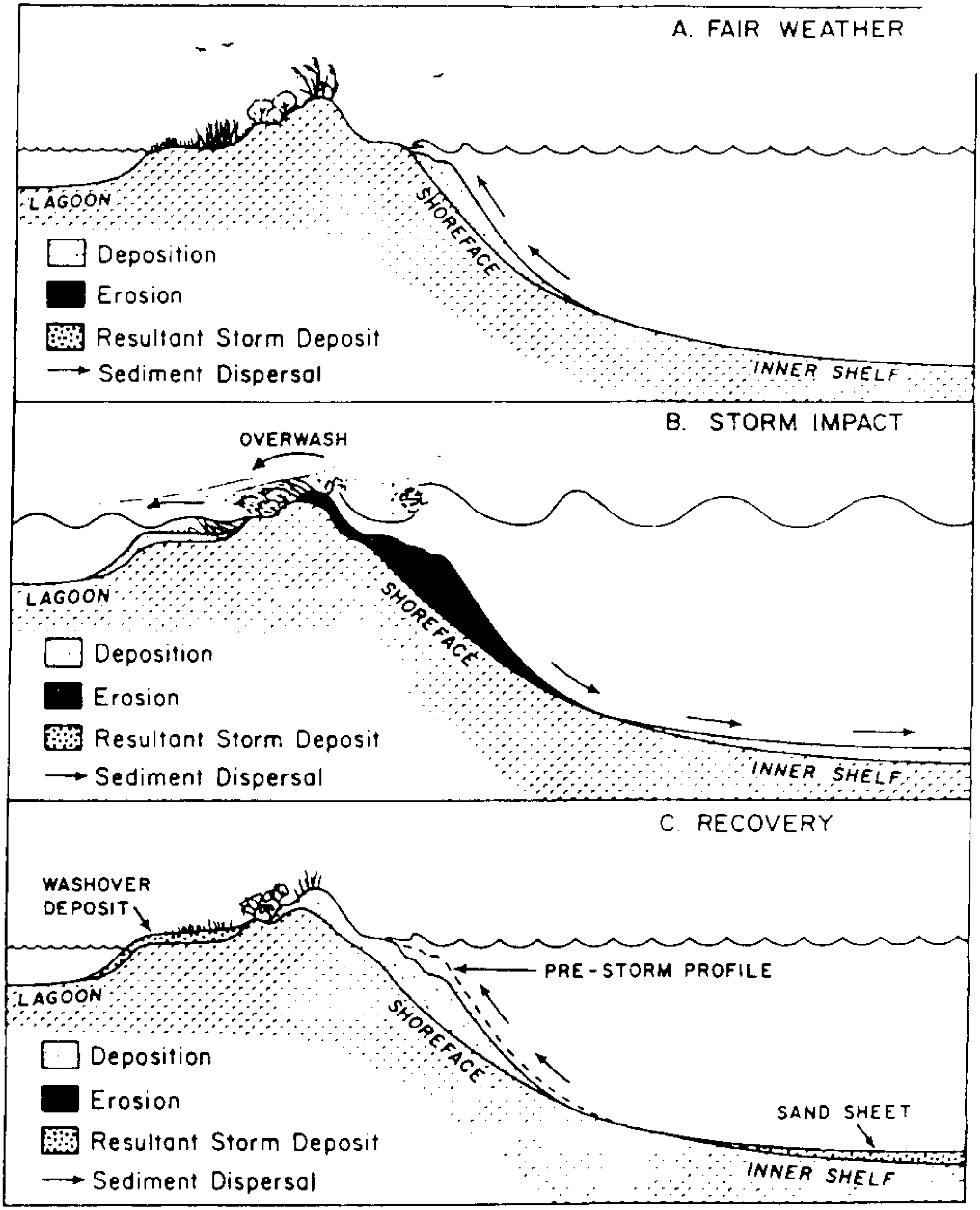


Figure 14. Response of barrier island shoreline to overwash events (Penland, et al., 1985).

intense pulses of energy (50-100 year storms) accomplish the major portion of geologic work. In the northern Gulf of Mexico, Otvos (1979) notes that island segmentation resulting from hurricane surge is at least as important as littoral drift.

C. Relative Sea Level

The rise in the surface elevation of the Gulf of Mexico relative to that of the land is contributing to high rates of erosion among Louisiana's barrier islands. The change in relative sea level is the result of a combination of sediment accretion, compaction and subsidence of underlying seabed materials, and the eustatic world-wide rise of sea level due to continued glacial retreat.

DeLaune et al. (1978) used Cesium-137 horizons to measure recent sediment accretion in Barataria Bay. They determined that accretion rates since 1963 were on the order of 1.1 cm/yr. Baumann et al. (1984), using an artificial white clay marker horizon in Fourleague and Barataria Bays, found rates to range from 0.9 cm/yr inland to 1.5 cm/yr at streamside. Salinas et al. (1986) measured accretion in backbarrier marshes on Grand Isle and Grand Terre, Louisiana, at 0.55 to 0.78 cm/yr.

Subsidence of unconsolidated deltaic sediments has been estimated to be as high as 4 cm/yr (Morgan, 1967), although more recent studies have estimated average rates of 1.1 to 1.7 cm/yr (Swanson and Thurlow, 1973; Salinas et al., 1986). This would suggest that accretion rates are nearly equivalent to subsidence. However, subsidence rates vary greatly depending on the age and thickness of underlying sediments (Swanson and Thurlow, 1973).

Added to the equation of subsidence and accretion is the absolute or eustatic increase in sea levels world-wide. McGee (1890) first suggested a trend of rising seas as a cause of shoreline erosion. The oceans have apparently been rising since the end of the last ice age (8000-10,000 years BP) (Figure 15). This change in sea level seems to

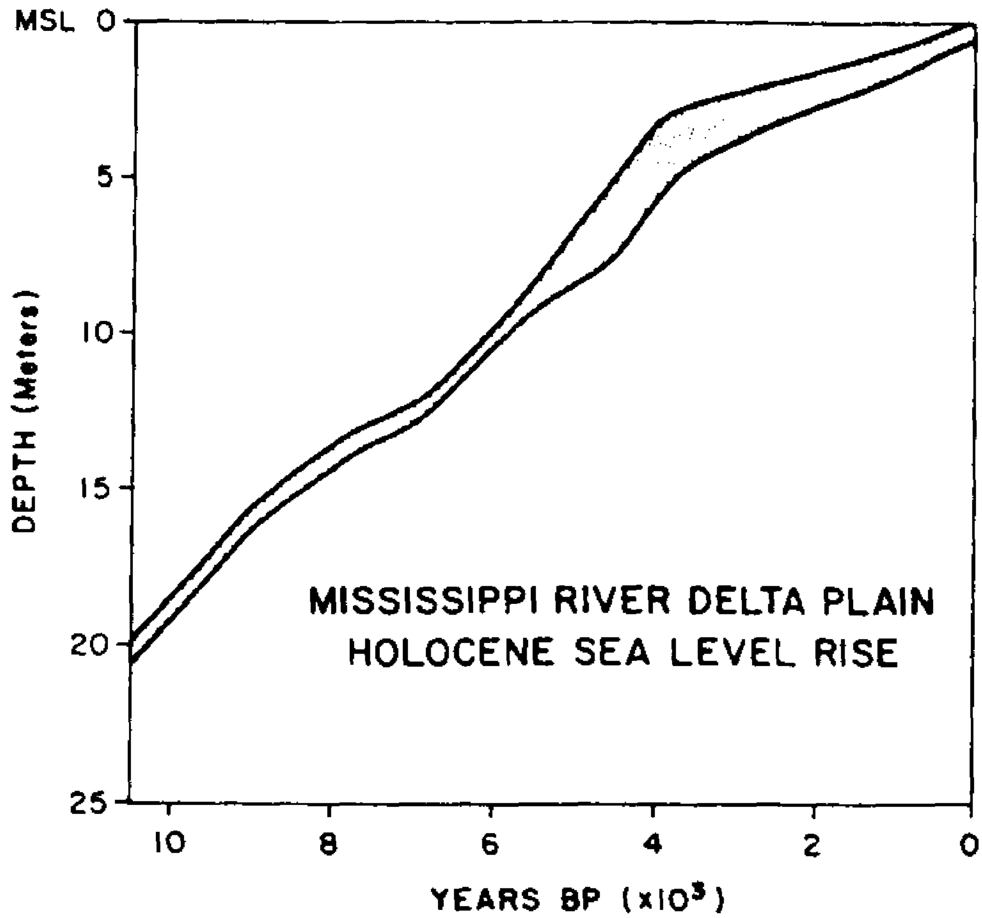


Figure 15. Plot of eustatic rise of sea level in the northern Gulf of Mexico. Grey area indicates range of estimates (Boyd and Penland, 1984).

have occurred quite rapidly at first, and then appears to have slowed to a relatively stable state approximately 3000-4000 years BP (Otvos, 1979). Milliman and Emery (1968) studying sea levels over the previous 35,000 years estimated a rise of 30 cm/100 yrs for the last 5000 years. Hicks (1972) measured a change of 8 cm from 1960 to 1970 (0.8 cm/yr), indicating an acceleration in the rate of eustatic sea rise. However, Gornitz et al. (1982) estimated current global rates averaging as low as 0.12 cm/yr. Bruun (1962) measured a sea level rise of 3-4 mm/yr in the Gulf of Mexico between 1930 and 1960. He theorized that a rise of 0.3 m within 50 to 100 years should cause a general shoreline recession of 35 m with much greater loss on low lying coasts. Schwartz (1965) using an experimental wave basin essentially substantiated Bruun's hypothesis. He also found that:

1. There was a shoreward displacement of the entire beach profile as the upper beach was eroded,
2. The material eroded from the upper beach is equal in volume to the material deposited on the nearshore bottom,
3. There is a rise in the nearshore bottom equal to the rise in sea level, thus maintaining a constant water depth.

The combination of eustatic rise, subsidence, and accretion results in a relative or apparent rise of sea level. Morgan (1967) estimated relative sea level rise of 1 m/100 yrs for the northern Gulf of Mexico. Swanson and Thurlow (1973) found rates as low as 7.5 cm/100 yrs for old delta complexes, and greater than 400 cm/100 yrs for the Modern Birdsfoot delta. More recent estimates indicate a range of values from 0.5-1 cm/yr (Penland et al., 1987) through 1.2 cm/yr for Barataria Bay (Baumann et al., 1984), to 1.8 cm/yr for the backbarrier marshes of Grand Isle and Grand Terre, Louisiana (Salinas et al., 1986).

The increase in relative sea level for the Mississippi River deltaic plain translates into a net rate of shoreline retreat for the Louisiana barrier islands which is the highest in the nation (Monteferrante et al., 1982). Shoreline erosion has been estimated at 5

to 20 m/yr (van Beek and Meyer-Arendt, 1982; Penland and Boyd, 1981; Penland and Boyd, 1982; Penland et al., 1985), with extremes in excess of 50 m/yr during high storm years (Penland and Boyd, 1981). These rates compare to rates of 6.7 km for the previous 7000 years (0.96 m/yr) for Core Banks, North Carolina (Moslow and Heron, 1979).

The response of barrier islands to increases in sea level are usually a landward recycling of sediments through shoreface retreat (Bruun, 1962; Schwartz, 1965; Hoyt and Henry, 1967; Pierce, 1970; Godfrey and Godfrey, 1973; Leatherman, 1979b; Boyd and Penland, 1984). This can occur through storm surges overtopping the island and redepositing shorefront sediments towards the rear of the island (Godfrey and Godfrey, 1973), through the cutting of inlets and redistribution sediments behind the island in the form of flood deltas (Leatherman, 1979b), or through aeolian distribution of sand by onshore winds (Rosen, 1979).

D. Inlet Dynamics

Barrier islands which are narrow and have no tidal flats are most often breached through the formation of inlets. Pierce (1970) studying the mechanisms of inlet formation, migration, and closure, determined that inlets do not occur due to direct frontal wave attack, since the energy would be evenly distributed along the beach front and, therefore, rapidly dissipated by the shallow nearshore slope. During strong overwash events, however, this energy will be concentrated into lower areas which channel the flood waters. Depending on the size of the island and conditions in the backbarrier and lagoon, these flood channels can erode down into the island cutting new inlets. The determinant factors are the slope of the barrier surface, the island width, and the depth of the lagoon, as well as the strength of the storm tide. Where the barrier is narrow and lagoon flats are absent the resulting slope will produce relatively high velocities during overwash

events. According to Pierce, this facilitates the removal of island sediments to the deeper lagoon water adjoining the barrier, thus the back of the island is not elevated and the slope, in fact, is increased.

Pierce (1970) pointed out that rapid wind reversal during frontal storm passage can create large storm surges on the lagoon side of an island. This can be channeled up tidal creeks and into low areas of the backbarrier and dune field. If the water tops the storm beach ridge, the remaining beach slope would be very steep, allowing water velocities to become quite high, with the potential to cut through wide low relief islands with well developed tidal flats.

Once opened, barrier island inlets tend to migrate in the direction of dominant sediment transport (Hoyt and Henry, 1967). This process can cause the movement of the entire island as erosion occurs at one end and accretion at the opposite due to longshore sediment transport. Inlets also move large quantities of sand and sediment through the island forming tidal deltas. When these inlets close, a rapid vegetational succession may occur, from submerged beds of *Zostera* and *Ruppia* to *Spartina alterniflora* and eventually *S. patens* (Godfrey and Godfrey, 1973). Inlet dynamics have, therefore, been suggested as being responsible for the highest rates of island migration (Leatherman, 1979b; 1979c).

E. Migration

Migration of barrier islands is a commonly recognized phenomenon (Leatherman, 1985). Dillon (1970), studying Rhode Island barriers, theorized that shoreward migration occurs when the islands are unable to maintain a profile of equilibrium by building upward during periods of rising sea level. He stated that, since the profile of equilibrium remains essentially the same, the volume of sand which must be added for each increment of vertical growth will constantly increase. Otvos (1979) noted that the Chandeleur Islands of Louisiana migrated from

500-2100 m/century through redistribution of overwash and inlet sediment, as well as post-storm reemergence landward of prior positions. Boyd and Penland (1984) suggested that, in the Louisiana deltaic environment, shoreface retreat becomes less effective as a means of maintaining island profiles as sand is continuously lost to sediment sinks such as spits, tidal inlets, and the inner shelf.

F. Overwash

Where barriers are sufficiently wide and adjoin areas of extensive tidal flats, washover fans are likely to be formed during overwash events. According to Pierce (1970), this is because the slope of the combined backshore and barrier flat will be low on a wide barrier so that the water cannot attain a high potential energy or velocity and, therefore, will not erode deeply. Deposition of entrained sediments on the tidal flats results in a further reduction of the slope.

Pierce (1969), used sediment budgets to quantify gains and losses to a North Carolina barrier coast as a result of overwash. Sources of data included experimental dune building and detailed topographic surveys over a short time span. The object was to compare material eroded from the shorefront with amounts gained on the backshore (washover). Half of all short term surveyed sections showed a net accretion and half showed erosion, resulting in no net overall change. However, the long term trend is one of accretion. He suggests an offshore source such as that implied by Zenkovitch's (1962) transverse drift.

Dillon (1970), first used the term barrier island "rollover" to describe a process which he observed in Rhode Island barriers. He theorized that, because of inadequate material, as sea levels rise a shoreward migration is produced. This occurs through the erosion of barrier sands which are washed back onto the shallow lagoon sediments. This elevates the island and reestablishes a beach slope which will

dissipate wave energy without loss or gain of sediment (an equilibrium profile). This process is evidenced by large chunks of peat, remains of old backbarrier marshes, which are now exposed on the ocean side of the Rhode Island barriers.

The small tidal range and high storm frequency in the Core Banks of North Carolina results in numerous overwash events (Godfrey et al., 1979). Godfrey and Godfrey (1973) described the impacts of overwash events in the Core Banks and Outer Banks. During overwash, sand is transported from beach and berm crest onto and across the berm to the interior, where it is deposited as a veneer of sand, forming a fan or terrace. Winds sort and redistribute the finer grained sands from the fan into dunes, leaving coarser grains and shell fragments behind. These layers occur in regular stratigraphic profiles, providing a record of overwash events.

As sand is moved onto the island through overwash, and into the dunes through aeolian transport, the elevation of the island is increased, maintaining pace with the rise of sea level (Godfrey and Godfrey, 1973; Rosen, 1979). Godfrey and Godfrey (1973) found an increase in elevation of 8.4 cm from 1960 to 1970 in the North Carolina Core Banks. They also noted that storm waves help to maintain a wide berm. Dunes and vegetation which become established on the berm during periods of low storm frequency are generally destroyed by strong storm surges. However, dunes sufficiently inland from the beach may survive. Overwash sediments also provide a substrate for new marsh formation when the sediments completely cross the island and form a shallow fan on the lagoon floor.

Godfrey and Godfrey (1974) attempted to formalize the concept of barrier island retreat by characterizing barrier islands as having vegetation, soils, and hydrology adapted to the physical forces which drive this process. These forces include rising sea level, wave driven currents, and wind. They elaborate on Dillon's (1970) concept of barrier island "rollover" as occurring through the basic mechanisms of:

1. Overwash,
2. Inlet dynamics, and
3. Dune migration.

Overwash drives water over the beach and through the dunes, depositing sediment on the vegetation and lagoons behind the beach. Inlets move sand through the barrier system, depositing shoals in the form of ebb and tidal deltas, and eventually closing to form new substrate over which the islands will retreat.

Dunes form where vegetation is present to capture wind driven sand (Figure 16). The three major factors which determine the degree to which dunes will form sufficient height to resist overwash are orientation relative to the prevailing winds, sand supply, and storm exposure. The dunes form a sand reservoir and are the most obvious component of the island movement, as they yield sand to the back marsh and lagoon during overwash and inlet formation, and regain their elevation slightly shoreward of their previous position. In this manner the island continues to move shoreward, while maintaining approximately the same profile, shape, and size.

Jeffery (1984) investigated the relationship of frontal storm systems to barrier beach overwash along the Caminada coast of Louisiana. He determined that the highest frequency of occurrence was during the passage of winter cold fronts. This indicates that potential washover conditions can occur 10 to 30 times per year in the northern Gulf of Mexico. According to Boyd and Penland (1981), sediments accumulated through washover events account for over 50% of barrier island sediments in parts of Louisiana.

IV. Management of Barrier Islands

Management of barrier systems can range from the purely administrative control of land use through the issuance of permits, to

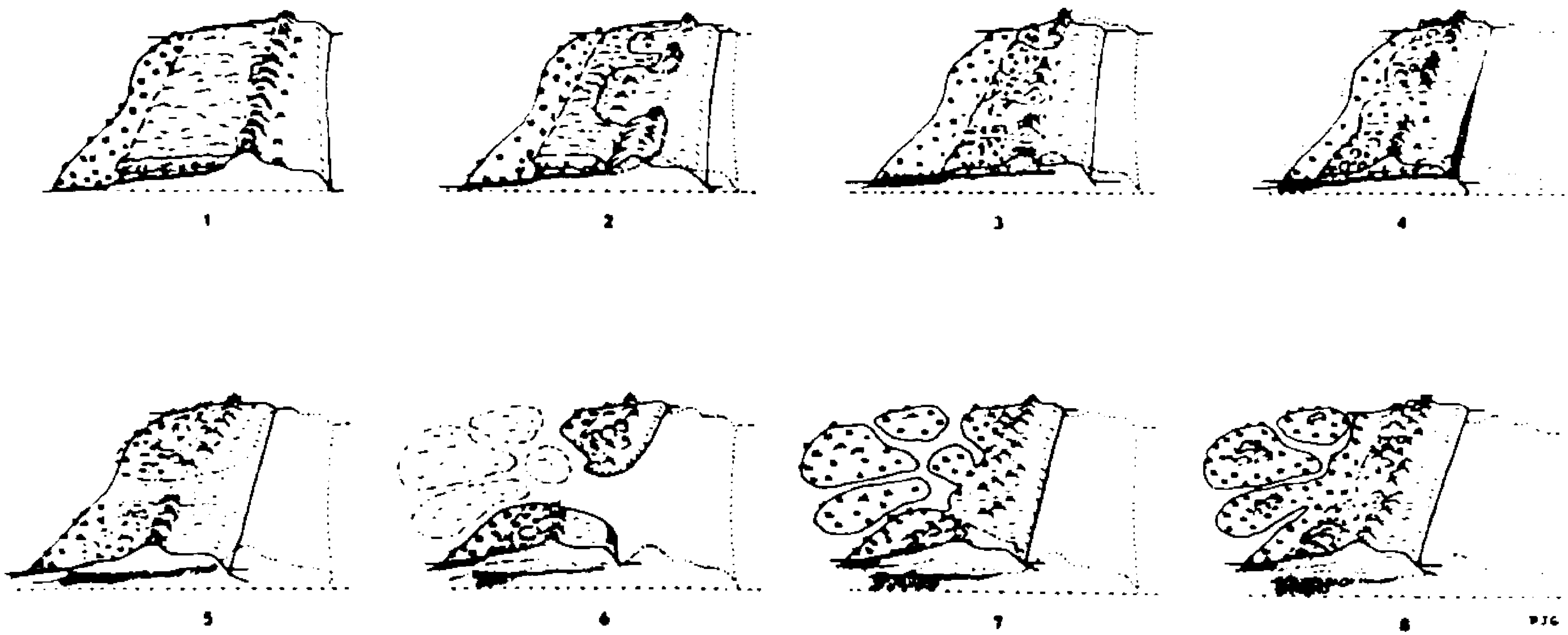


Figure 16. Barrier island rollover cycle showing shoreward displacement through sequential overwash events (Godfrey and Godfrey, 1974).

active manipulation of the environment such as the introduction of dune stabilizing plants or construction of groins and jetties. In order to achieve the desired management objectives, however, it is essential that we have a thorough understanding of the factors which influence the manner and rate at which these islands change.

The many factors involved in island change provide a wide range of opinions as to which are most important within a given set of circumstances. Leatherman (1979a) lists inlet dynamics, aeolian transport, and washover as the factors most important in controlling island migration. Dolan (1976) states that beach stability is determined by energy, sediment, and sea level. That is, the amount and type of materials making up the beach, the intensity of natural forces, and sea level stability are the primary controlling factors.

According to Nummedal (1983), stratigraphy and morphology are controlled most importantly by Holocene sea level history, longshore distribution of sediment sources and sinks, volume of water being exchanged through flanking tidal passes (tidal prism), and nearshore wave energy. He notes that transgressive barrier stratigraphy typically has developed near erosional headlands while a regressive strategy may prevail some distance away. These patterns may alternate over time, due to fluctuations in sea level and sediment supply.

Penland et al. (1985), discussing Louisiana deltaic barrier arcs, suggest that the shape and position of these islands are controlled by shoreface translation, age of the transgression, and thickness of the barrier sediment package. Young island arcs such as the Isles Dernieres are thin and exhibit limited landward retreat. Older arcs, such as the Chandeleur Islands, are thicker and exhibit significant landward transgression.

A. Vegetative Stabilization

Barrier island vegetation plays an important role in mitigating the

effects of currents, wind, and storms by binding the existing sand substrate, accelerating sediment accretion, absorbing incipient wave energy, and increasing the organic content of the soil (Godfrey and Godfrey, 1974). Godfrey and Godfrey describes barrier islands as being typified by grasslands, with shrub savannas and thickets forming where protected by dunes or where recent overwash has not occurred (Figure 17). In the northern Gulf of Mexico this can also include mangroves, which tend to colonize and stabilize the zone from below mean low water level to mean high water level (Dodd and Webb, 1975).

Godfrey et al. (1979) suggested that it is not possible to take a model of barrier island dynamics derived from one area and universally apply it to other barrier systems. However, regional variation in barrier island morphology can be partially explained by differences in plant species. For instance, northeastern barrier dunes, characterized by *Ammophila breviligulata*, show a sharp demarcation between dune, salt marsh, and washover sands. However, southeastern barrier dunes, dominated by *Uniola paniculata*, form initially as scattered mounds and hummocks. These also exhibit a higher proportion of washover sediments in the marsh. In addition, *Spartina patens* tends to be killed by overwash in the north, but survives in the south.

Godfrey (1976) noted that barrier island vegetation is uniquely adapted to harsh and dynamic physical environments. Dune vegetation is generally able to survive burial by sand, near drought conditions, extreme heat, and salt spray, and is able to rapidly recolonize large areas following dune breaching and overwash. Backbarrier marsh vegetation must withstand not only a high saline environment, but also low soil oxygen levels, frequent inundation, and the constant encroachment of sand from dune overwash. Even under such hostile conditions barrier islands often have a dense vegetative cover and can produce deep organic peat layers.

The presence of grasslands can make overwash a constructive process, since *Uniola paniculata* and *Spartina patens*, common dune species, have good sand burial recovery and are both rapid dune builders

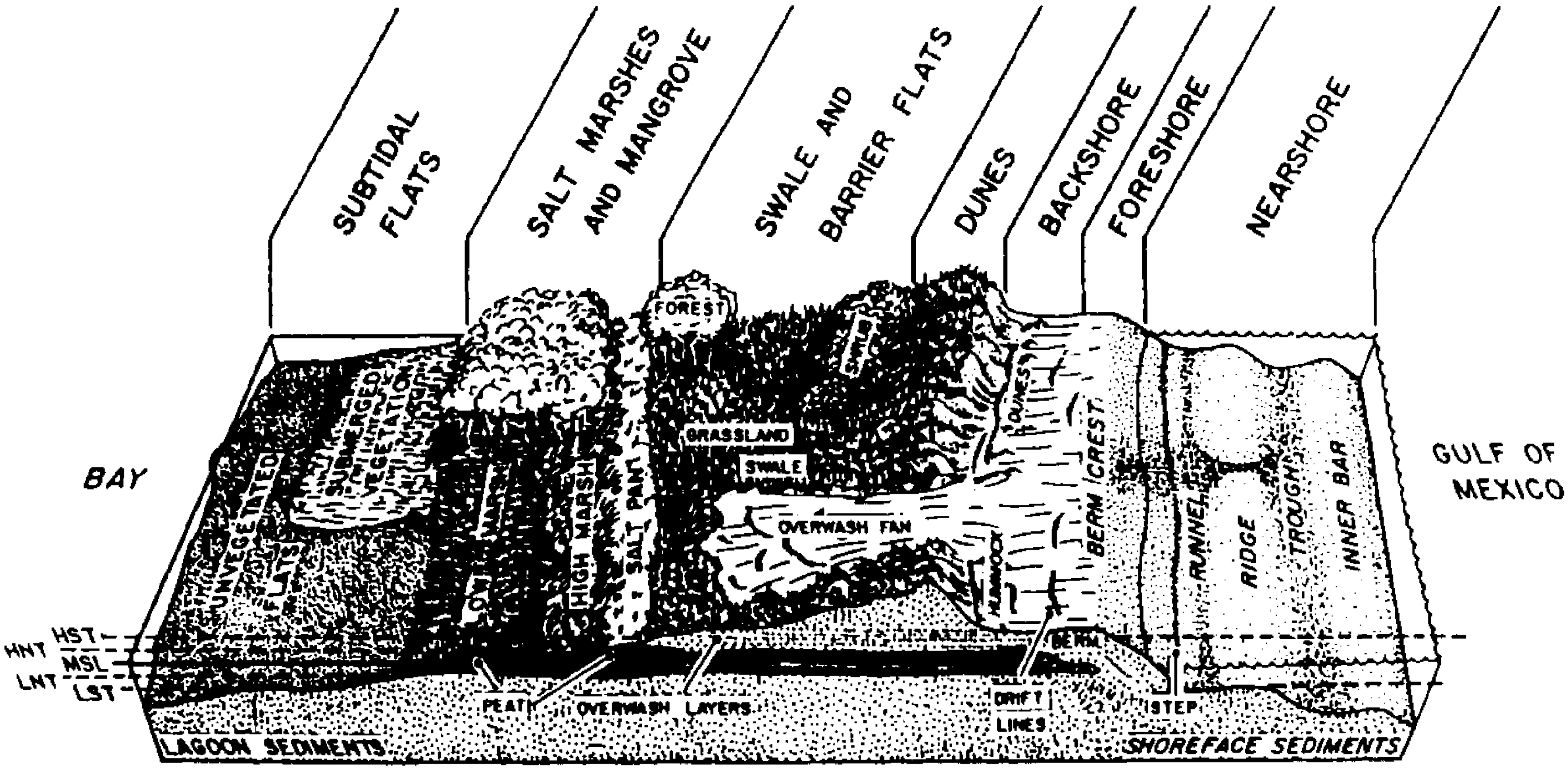


Figure 17. Barrier island vegetation zones (Mendelssohn et al., 1987, after Godfrey, 1976b).

(Godfrey and Godfrey, 1973). According to Godfrey (1976), *Spartina patens* can survive complete burial by overwash deposits and rapidly recolonize, thus preventing excessive loss of sand by deflation or transport back into the dunes. Godfrey et al. (1979) cite one incidence of *Spartina patens* recovering to near pre-washover densities within one year from 0.5 m burial, exclusively from buried vegetation. *Spartina alterniflora* can quickly colonize new lagoon overwash and inlet deposits. Godfrey and Godfrey (1973) reported *Spartina alterniflora* productivity on new washover marsh at three times that of adjacent older marshes on the Core Banks of North Carolina.

1. Dune Stabilization

Barrier island dune systems play a significant roll in barrier island dynamics. Dunes prevent overwash from occurring so frequently that interior vegetation cannot recover (Godfrey, 1976). During storm surge the dunes provide resistance and constrict the flow of overwash, slowing and dissipating its energy (Pierce, 1970). Dunes also act as sand reservoirs during severe storms, supplying material to the berm and beach and thereby broadening and flattening the wave approach (Leatherman, 1979c).

Dolan (1972) suggests that dunes are a "response element of the system, not a forcing element." He notes that efforts at stabilization of the dunes are intended to contain the upper limit of storm attack and prevent overwash and inlet channel formation. Problems with this strategy are due to the continuous shoreface erosion of barriers and the gradual eustatic rise of sea level. He contends that, if the dunes are static, they cannot adjust to such changes, and that the entire system will be forced out of equilibrium. The result is a steepening of the run-up profile and a winnowing out of finer sand grains, leaving coarse, narrow beaches (Figure 18). He describes this as an accelerating process which can cause major loss of beach material.

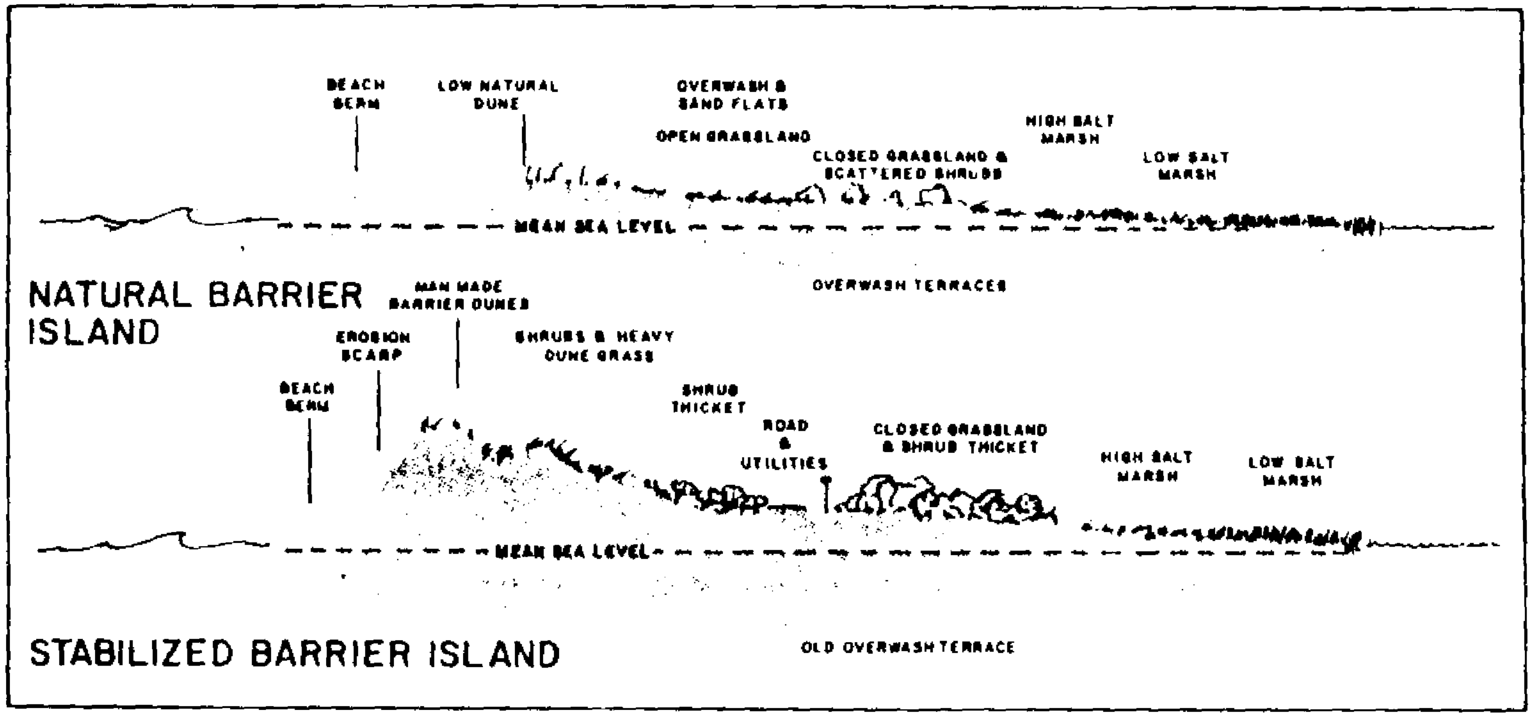


Figure 18. Comparison of profiles of natural barrier island to barrier with stabilized dunes (Dolan, 1973).

Godfrey and Godfrey (1973), working with artificially stabilized versus natural island dune systems note that hurricanes are relatively frequent along the North Carolina coast. During these events little damage occurs on the natural islands, while on the stabilized islands overwash is usually prevented, with a resultant loss of the sand eroded from the beaches and dunes. Dolan (1972) observed that the distance between the dunes and the shoreline of the Outer Banks has decreased from 100-125 m to 70-100 m in 13 years since major stabilization efforts, reducing the dunes by 10% and the active sand zone from 42% to 22% of the total island width. He later (1973) compared a stabilized dune system (Hatteras Island), with a more natural system (Core Banks). Beach widths of the altered islands were reduced to 30 m or less, while the natural island beach widths averaged 150 m (Figure 19).

Godfrey et al. (1979) suggests that the best barrier island management scheme is to leave the dunes in a more or less open and natural state. He recommends encouraging the growth of *Spartina patens* on the overwash flats, thereby building the backbarrier regions. Leatherman (1979a), however, counters that in contrast to this contention, stabilized dunes provide a source of sand during storm events through which the nearshore profile is altered by formation of a storm bar (Figure 20). The net effect is a reduction of erosional effects, since this sand is returned to the beach and dune during normal conditions.

2. Backbarrier Stabilization

The shoreward migration of barrier islands is at least partially dependent on the characteristics of the backbarrier lagoon. Some management efforts have focused on the planting and stabilization of the nearshore lagoon and backshore area. Dodd and Webb (1975) experimented with the use of coastal vegetation for shoreline stabilization in Galveston Bay, Texas. They tested 12 species under a variety of

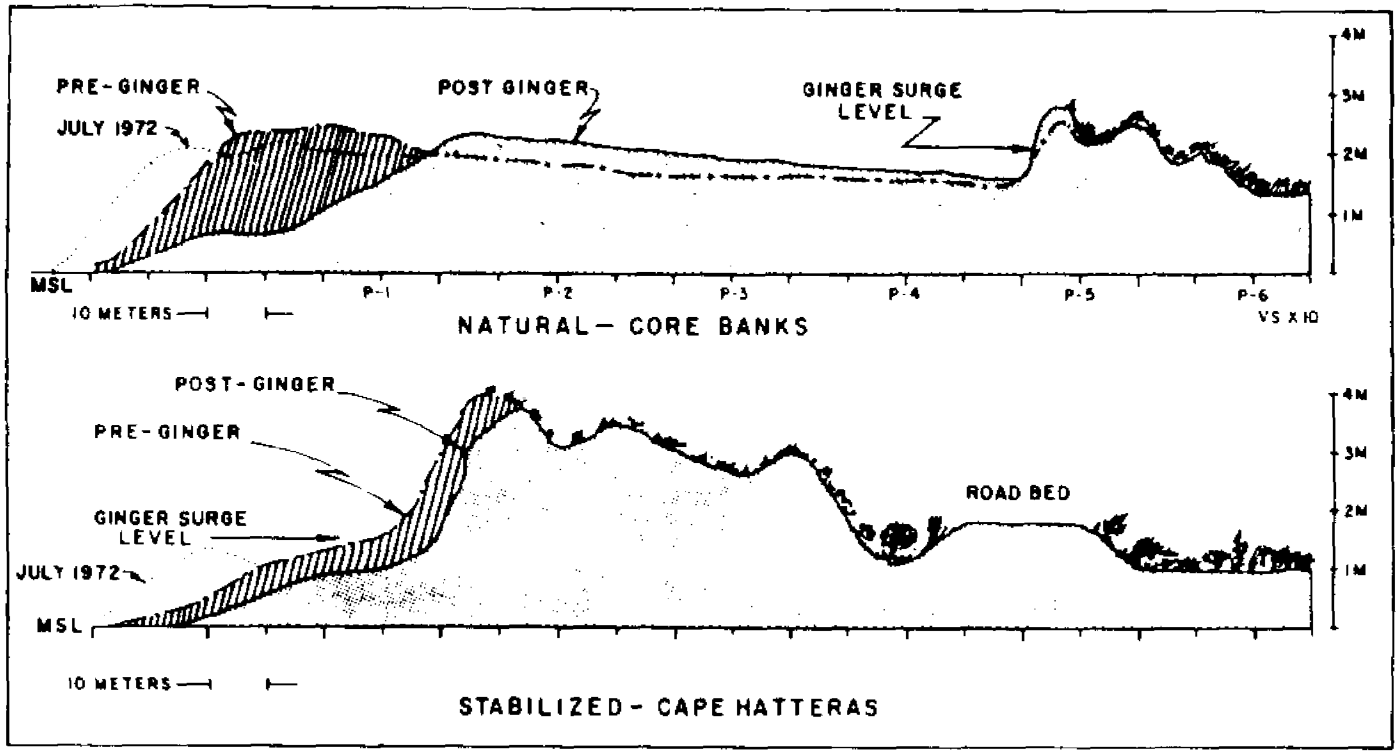


Figure 19. Effects of hurricane Ginger (1972) on a natural barrier island (Core Banks, North Carolina) compared to a dune stabilized island (Cape Hatteras, North Carolina) (Dolan, 1973).

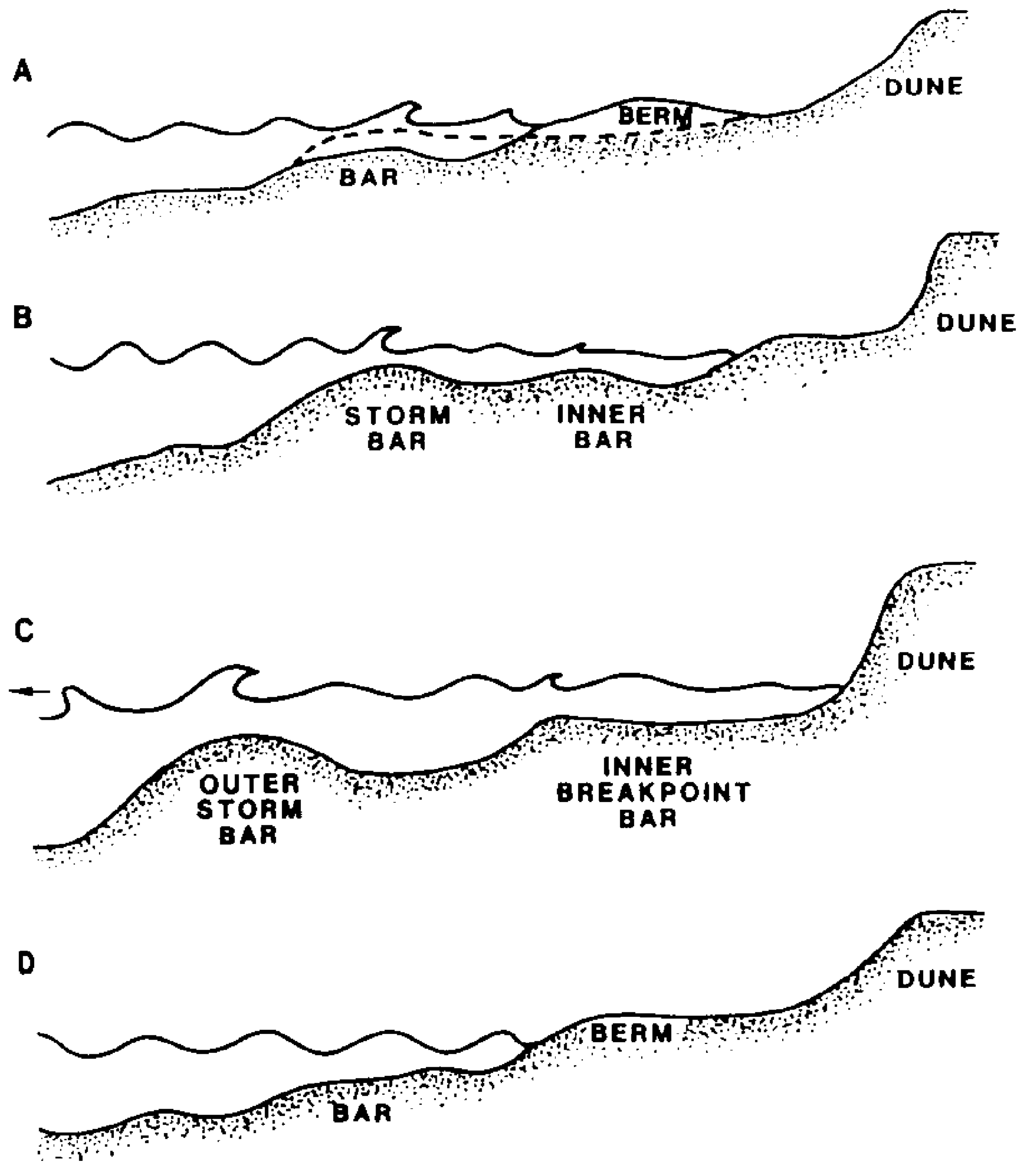


Figure 20. Beach recovery cycle following storm impact (Mendelssohn et al., 1987, after Leatherman, 1979c).

flooding profiles, including bare mud, tidal inlet banks, and shorelines. *Spartina alterniflora* and *Avicennia germinans* were shown to be well adapted for colonizing and stabilizing the zone from below mean low water to mean high water. They noted that for *Spartina alterniflora* transplants performed better than seeds.

A. Beach Nourishment

The choice of barrier island management strategies depends to a great extent on the type of demands to be made of the island system. Dolan (1976) suggests the following as a basic list of management options:

1. Sand stabilization - which stalls the inland penetration of storm surge,
2. Seawalls and breakwaters - which temporarily protect localized areas at the expense of adjacent areas,
3. Groins - which rob downdrift beaches while replenishing updrift beaches, and
4. Beach nourishment - The best solution if large quantities of sand are available. This technique provides:
   a. A beach suitable for recreation,
   b. A supply of sand for adjacent beaches, and
   c. An effective check on erosion.

Dolan also envisions that sources for future beach nourishment will probably come from offshore.

I. Data Collection and Processing

The acquisition of information about an object without physical contact with the object is termed remote sensing (Colwell, 1983). This

usually refers to the gathering and processing of information relating to the earth's surface through the use of photographs and related data acquired from aircraft and satellite platforms (Simonett et al., 1983). The process of acquiring remotely sensed data involves the use of chemical emulsions or electronic sensors sensitive to reflected and/or emitted energy along various portions of the electro-magnetic spectrum (Suits, 1983). These variations in electromagnetic energy can be used to help determine patterns specific to certain cover categories and plant species or assemblages.

Bartlett and Klemas (1981) were able to discriminate 'low marsh' and 'high marsh' communities in Delaware using hand held radiometers. They noted a seasonal variation in spectral reflectance based on monthly samples of various marsh areas. They were able to obtain some separability of 'high' and 'low' marsh during most months, but discovered that the spectral signatures converged during the spring and summer, particularly in the visible range. They suggested that the optimum time for discrimination of marsh communities would be during the month of December.

A. Aerial Photography

Aerial photography is the most accepted and familiar form of remote sensing. Many improvements have been made in the quality and precision of aerial cameras and lenses since 1859 when the first aerial photographs were taken from tethered balloons (Simonett et al., 1983). The film used in aerial photography has undergone a similar refinement. Color infrared film has become widely accepted for mapping and monitoring coastal vegetation (Knipling, 1969). Pestrong (1969) compared color infrared film to color, black and white panchromatic, and nine-lens multiband photography. He found color infrared film to be the most useful in differentiating vegetative assemblages in California salt marshes.

According to Knipling (1969), the spectral range of aerial color infrared film is 500-900 nm, when using a minus-blue (deep yellow) filter. Image color formation is dependent on reflected energy in the green and red portions of the visible spectrum, as well as the near-infrared. The emulsions are layered so that green reflected light exposes the yellow-forming emulsion, red light exposes the magenta-forming emulsion, and infrared exposes the cyan-forming emulsion layer, resulting in blue, green, and red images, respectively. Healthy plant foliage characteristically appears a bright red or magenta, with different species often exhibiting recognizable variation in shades. Unhealthy, damaged, or dying vegetation tends to deviate from the bright red pattern.

1. Barrier Island Photography

Aerial photography has been used extensively in recent years for barrier island research (Zeigler and Ronne, 1957; Pierce, 1970; Pierce and Colquhoun, 1970; Stafford and Langfelder, 1971; Godfrey and Godfrey, 1973; Gallagher, 1974; Fisher and Simpson, 1979; Otvos, 1979; Leatherman, 1979b; Cleary and Hosier, 1979; Boyd and Penland, 1981). Photographs provide a wealth of information as well as an instantaneous view of many island features.

Aerial photographs are often the only accurate and reliable sources of detailed spatial information. Otvos (1979) notes that changes in the configuration of shoals and islands, and the correct identification of these features are often missing from the regularly updated, published U.S. Coastal Geodetic Survey (USCGS) charts. Published maps may lag behind field conditions by 10-25 years.

Stafford and Langfelder (1971) compared the advantages and disadvantages of using aerial photography compared to traditional ground survey methods for surveying coastal erosion. Among the advantages they

list:

1. Coastal features are permanently recorded,
2. Detail is much greater than on charts or maps,
3. Coastal areas are frequently reflown, and
4. Information acquisition is economical and less labor intensive.

As a disadvantage they note that the record is of a specific fixed point in time which may be atypical (i.e., beaches are transient and change seasonally). They suggest that fall conditions usually approximate the average beach location.

2. Sequential Photography

Time series photography provides a means of observing and measuring small scale changes in vegetation and terrain over relatively long or short periods (Weismiller et al., 1977). Zeigler and Ronne (1957) were among the first to use sequential aerial photography for barrier island research. They conducted aerial photographic flights along the South Carolina and Georgia Sea Islands in 1953, 1956, 1957, and 1958 and used this information to record changes in island surface features. Moffitt (1969) used aerial photographs as historical records in investigating changes in the Monterey Bay shoreline.

Cleary and Hosier (1979) used aerial photography from 1938 to 1977 to determine areas of barrier islands influenced by cutting/infilling and consequent spit elongation. Transects were drawn on the photographs perpendicular to the beach line. Measurements made from these transects included total island width, herbaceous vegetation width, arborescent vegetation width, and shoreface erosion rates. Standardized sums of these values were inversely correlated with washover history ($r=-0.9597$). Significant washovers occurred in 1954-1955 and 1962. They found that recovery from washover events depends on sand grain size

distribution, with coarse grained sediments slowing vegetation and physiographic redevelopment.

3. Photogrammetry

Stafford and Langfelder (1971) used photogrammetrically rectified sequential aerial imagery, enlarged to a common scale and referenced to stable ground points to measure coastal changes in North Carolina. A total of 1400 reference points were selected at approximately 1000 ft intervals for each date. Measurements were made from each reference point to the dune line and the high water line. The high water line was assumed to best record shoreline change because it records loss and gain equally well, whereas the dune line takes longer to reestablish after washover. Problems using the high water line include variations due to wind tides and variable wave runup. In North Carolina, the highest erosion rates were correlated with hurricanes.

In one of the first studies to quantify backbarrier shoreline change, Fisher and Simpson (1979) used a photogrammetric grid point-count technique to measure washover and tidal sedimentation rates on a transgressive barrier shoreline. Variable scale aerial photography dating from 1939 to 1975 was ratioed to ground control points using a Bausch and Lomb Zoom Transfer Scope. They were unable to distinguish aeolian from overwash transport but considered overwash the most significant of the two. Mapping accuracy was within 2.1% of field reference data.

4. Stereo Coverage

Gallagher (1974) notes the advantages of using stereo (three dimensional) photography for delineating coastal vegetation. He was able to differentiate pure stands of *Spartina alterniflora* and *Juncus*

roemerianus, and mixed *Salicornia virginica, Distichlis spicata,* and *Limonium nashii* using color and color-infrared aerial photographs in stereo. Stereo coverage is obtained by using 60% end lap and 30% side lap when acquiring aerial photographs. He also suggests that flights be conducted at sun angles of less than 70° to avoid reflection from wet surfaces. Higher altitudes also help to reduce sun shadow differences across the image. Best species separation was in late summer and poorest was in February.

B. Geographic Information Systems (GIS)

A geographic information system is a computer implemented data structure which supports the management, analysis and manipulation of spatially referenced information in a problem solving synthesis (Fisher and Lindenberg, 1989). These are usually implemented as geographically linked multiple data sets in which the component attributes are retrievable by a common set of map coordinates. A coastal management GIS, incorporating land use and associated wetlands habitat maps with transportation and population density overlays is an example.

1. Spatial Relationships

Hill et al. (1985), established a GIS for coastal Lafourche Parish, Louisiana, to facilitate the issuance of land use permits by the Louisisna Department of Natural Resources, Division of Coastal Zone Management. Landsat MSS scenes and U.S. Fish and Wildlife Service (FWS) digitized habitat maps were combined with information pertaining to the location of existing permits, flood plain contours, environmental management units (EMU), and special ecological and cultural features. This provided simultaneous access to both geographic and textual information, such as the number and location of environmentally

sensitive areas within a user-specified radius of proposed permit request sites.

Johnston et al. (1988), developed a GIS to assess the cumulative impact of wetland abundance, type, and location on downstream water quality. Spatial analysis indicated that proximal wetlands were most beneficial to water quality maintenance.

Hodgson et al. (1988), created a GIS in order to assess the foraging activities of wood stork populations relative to the proximity, size, and change in wetlands habitat. They found that the storks tended to utilize a similar location and foraging range during wet and dry years.

2. Change Analysis

Change detection is accomplished by comparing the areas of the same image category in time sequential images. This requires that the two images be geometrically referenced to one another. This is often difficult since a number of atmospheric, object, and sensor calibrations and corrections are required. Weismiller et al. (1977) describe several methods for ascertaining change in temporal data sets. They emphasize that image classifications must be standardized and of sufficient accuracy to produce meaningful results. The procedure involves digital subtraction of one image from another to produce a change image, consisting of all corresponding pixels which have different values on each image. This provides not only the amount or rate of change, but the type of change, such as mangrove areas becoming open beach.

Scaife, et.al. (1983), using 1956 and 1978 FWS habitat maps concluded that canals were a major factor contributing to land loss in coastal Louisiana. They found that the effects were greatest near the coast and in younger abandoned deltas.

Dozier et al. (1983) established a temporal data set for a portion of Barataria Basin, in southern Louisiana. This was derived from large

format aerial photography over southern Lafourche Parish, Louisiana, for the years 1945, 1956, 1969, and 1980. The photographs were interpreted to determine landcover categories and percent open water within each minimum mapping unit. This information was used to create a series of thematic maps which were then manually digitized to 50 meter cells thus providing a synoptic and temporal view of a marsh landscape spanning 35 years. Hill and Worthy (1985) overlaid coastal salinity zone maps (Chabreck et al., 1968) to the data base of Dozier et al. (1983) to determine rates of land loss in fresh versus saline marsh areas. They found that the rate of loss was greater in the area which was originally freshwater marsh, apparently due to the construction of oil and gas canals.

Spatial and temporal analysis of environmental data is, therefore, greatly facilitated through the implementation of a digital geographic information system. A GIS furnishes a means for combining and correlating information pertaining to type, proximity, and size of cover categories. Changes in these relationships can then be observed over time, providing insight into causal mechanisms. For these reasons the creation of a GIS was considered an important step towards the understanding of barrier island change.

METHODS

I. Study Areas

Two adjacent Louisiana Barrier islands, Timbalier Island and the Eastern Isles Dernieres, were selected for this study (Figure 1, page 2). Both have similar habitats and are influenced by the same environmental forces. However, the Eastern Isles Dernieres remains relatively undisturbed while Timbalier Island has undergone major modifications related to oil and gas activities. Both islands are characterized by mixed stands of *Avicennia germinans* (black mangrove) and *Spartina alterniflora* (salt marsh cordgrass) in the backbarrier marshes, large mixed stands of *S. patens* (marsh hay cordgrass) with *Cakile fusiformis, Croton punctatus, Sporobolis virginicus*, and *Borrichia frutescens* in the dune and swale, and on Timbalier Island *Iva frutescens* and *Myrica cerifera* in the higher spoil elevations (Chabreck et al., 1968; Mendelssohn et al., 1987). These islands are located near the limits of the northernmost range of black mangrove within the Gulf of Mexico (Lugo and Zucca, 1977; Johnston, 1983). Due to a series of hard freezes during the last years of this study, both islands experienced extensive mangrove die-backs.

A. Timbalier Island

Timbalier Island is a relatively narrow barrier island centered at 29°4′ north latitude, 90°28′ west longitude, and is oriented approximately east-southeast to west-northwest (Figure 1, page 2). It is approximately 13 km long and varies in width from less than 50 meters to over one and a half kilometers.

Timbalier Island is a transgressive barrier island formed from the reworked downdrift sediments of the last Lafourche delta (15th

Mississippi lobe; Figure 3, page 8) which was active from 1800 Years Before Present (Y.B.P.) until it was dammed in 1904 (Peyronnin, 1962; Frazier, 1967). Timbalier Island first formed as a flanking barrier spit to the west of the Caminada-Moreau headland. It continues to transgress westwardly as it erodes on the eastern end and accretes on the western end (Penland et al., 1987).

Timbalier Island is the site of major oil and gas exploration and extraction activities. Much of the island has been dredged for access to well drilling sites and spoil banks are common, as are drilling rigs and platforms. Efforts have been made to protect portions of the Gulf shoreline by constructing riprap and by attempting to increase and stabilize the island dunes. Some older spoil areas have reverted to swale and marsh and now support typical barrier island vegetation. In addition, large expanses of marsh, dune, and swale remain intact.

B. Eastern Isles Dernieres

The Eastern Isles Dernieres is the easternmost island of an east to west barrier chain centered at 29°3′ north latitude, 90°39′east longitude (Figure 1, page 2). The island is approximately six kilometers long and varies in width from less than 50 meters to just over 500 m. The western third of the island consists primarily of low sand and overwash sediments with scattered patches of *Spartina patens*. The central third of the island is characterized by a narrow beach and dune line backed by marsh (predominantly *S. alterniflora)* and black mangrove (*Avicennia germinans*). The eastern third contains a broad washover fan with a large relatively diverse swale and dune environment to the east, terminated by a north and westwardly recurved sandy spit.

The Isle Dernieres were formed from sediments laid down during the fourth Lafourche delta activity period (14th Mississippi lobe; Figure 3, page 8) dating from 3000 to 2800 Y.B.P. until 800 Y.B.P. (Peyronnin, 1962; Frazier, 1967; Penland et al., 1981). Since then the effects of

subsidence, tides, wind, and wave action have worked to reshape the outer deltaic edge, causing a gradual disappearance of the seaward marshes and the formation of a barrier rim.

Prior to a devastating hurricane in 1856, the island served as a summer recreation area for wealthy New Orleanians (Peyronnin, 1962). The island chain remained intact after this event until another major storm in 1887. It has since diminished in size due to erosion and subsidence, and has separated into a number of smaller islands, including the Eastern Isles Dernieres (Kwon, 1970). These remaining islands have transgressed landward from 750 to 900 m since 1890, while the backbarrier marshes continued to subside (Peyronnin, 1962).

The island has been the site of limited mineral extraction operations. There is a small oil separator and facilities platform on the eastern end, as well as the remnants of an abandoned containment pond near the center. Otherwise, the island is in a relatively natural state.

II. Data Acquisition

Large format (240 mm x 240 mm), vertical aerial photography was selected as the primary data source for this study. Aerial imagery provides an instantaneous and synoptic record of surface features. Large format aerial mapping cameras produce photographs of high resolution and geometric accuracy, and when acquired vertically, reproduce the precise spatial relationships of those features. Color-infrared film provides an advantage over normal color or black-and-white film for coastal land cover mapping, since land/water boundaries are readily distinguished and vegetation more easily differentiated.

A shoreline change analysis of the Louisiana coast had been conducted in 1978 for the LSU Center for Wetlands Resources (CWR) by Robert Dolan, of Coastal Research Associates, Charlottesville, Virginia (Dolan, 1978). He used a sequence of archival, large format, vertical

aerial photographs dating back to June 6, 1934, combined with then-recent aerial photography obtained on October 15, 1978. In order to extend the data from Dolan's study, archival photography from November, 1978 was selected as the earliest image data for the current study. Archival aerial imagery was available from a variety of sources, at differing photographic scales and for several years of coverage. In addition, beginning in 1983, original imagery was available at preselected photographic scales, through the Louisiana Department of Natural Resources.

A. Environmental Protection Agency (EPA) Photography - 1978

High altitude, large format (240 mm x 240 mm), color-infrared photographs were acquired over coastal Louisiana on November 10, 1978, by the National Aeronautics and Space Administration (NASA) for the United States Environmental Protection Agency (EPA). Contact copy transparencies were available at the Louisiana State University Remote Sensing and Image Processing Laboratory (RSIP). The photographs were at a scale of 1:70,000 and were of good image quality and resolution.

In addition to the RSIP copies, 1:24,000 quadrangle-centered enlargements of the 1978 EPA photographs were available at the Louisiana State University (LSU) School of Forestry. Although these enlargements were in an uncontrolled format and did not provide stereographic coverage, they were very useful for visually checking maps produced from the contact transparencies.

B. National High Altitude Photography (NHAP) - 1982

Large format (240 mm x 240 mm) photographic imagery was acquired over portions of the Louisiana Coast during 1982 and 1983 as part of the NASA National High Altitude Photography Program (NHAP). This imagery

was available for use as controlled, quadrangle-centered, color-infrared enlargements (prints) at a scale of 1:24,000, through the Louisiana Department of Natural Resources, Office of Coastal Zone Management (DNR-CZM). Two of these enlargements, photographed on November 24, 1982, served as the source for one of the Timbalier Island data sets. The imagery used was of very good quality, although stereographic coverage was not available, making the task of photointerpretation somewhat more difficult.

C. Louisiana Environmental Monitoring System (LEMS) Photography - 1983 and 1984

Between February, 1982, and April, 1985, Louisiana's DNR-CZM, in cooperation with RSIP, operated an aircraft-based environmental monitoring system (LEMS), including a large format (240 mm x 240 mm) aerial mapping camera. Local control of mission planning allowed photographic imagery to be acquired at optimal altitudes (900 m to 3100 m) for coastal land cover feature mapping. The 1984 LEMS imagery was selected as the reference imagery for photointerpretation due to overall superior image quality and resolution.

A LEMS coastal monitoring flight was flown over the Eastern Isles Dernieres during the fall of 1983 using color-infrared film. The purpose of this flight was to provide imagery to establish an initial data source for proposed island restoration efforts. The mission was flown on November 16, 1983, at an altitude of 1100 m, providing a photographic scale of 1:7200. The imagery was somewhat underexposed, but acceptable.

A follow-up to the 1983 Eastern Isles Dernieres flight was planned for the fall of 1984. This mission included Timbalier Island and the entire Isles Dernieres barrier chain. The mission was flown on December 8, 1984. Imagery was acquired over all sites at an altitude of 3050 m, for an image scale of 1:20,000. Additional passes were made over the

Eastern Isles Dernieres at altitudes of 1830 m and 915 m, providing image scales of 1:12,000, and 1:6000, respectively. The additional altitudes were intended to provide a variable resolution data set for calibrating the relative information content of an onboard digital scanner. However, they provided an excellent means of assessing the accuracy of the photointerpretation from smaller scale imagery (1:20,000). The resulting color-infrared photography was of very high quality.

D. NASA Louisiana Coastal Mission - 1985

In 1985 the NASA U-2 High Altitude Aircraft Program acquired large format (240 mm x 240 mm) color-infrared imagery over southern Louisiana. The mission was flown December 5, 1985, just over a month following hurricane Juan (Oct 26-Nov 1985). The photographs were acquired at a scale of 1:70,000 and were of variable interpretative quality due to flood stage water levels inshore and very high sun angles, causing strong sun glint off the water and wet terrain.

Water levels of the Gulf of Mexico in the vicinity of both Timbalier Island and the Eastern Isles Dernieres were acceptable, but image quality was poor. The islands were overexposed and well off center in their respective photographic frames. The overexposure problem was apparently due to light metering over open water rather than over the much more reflective land areas. The imagery was usable, but considerable effort was required to adequately interpret and map land cover detail.

E. Hurricane Data

The Louisiana coast is a storm dominated environment (Hayes, 1979). Normal wave energies are low, but can increase dramatically during

passage of winter cold fronts and the occurrence of extra-tropical and tropical cyclones (Penland and Ritchie, 1979). In Louisiana, tropical storms (winds greater than 63 km/hr) occur on an average of once every 1.6 years, while hurricanes (sustained winds exceeding 118 km/hr) occur every 4.1 years (Nummedal, 1982). Major storms can generate wave heights of seven meters or greater, capable of overwashing entire barrier islands (Boyd and Penland, 1981). Such events play a major role in the dynamics of coastal systems (Peyronnin, 1962; Dolan, 1973; Riggs, 1976; Leatherman, 1979c; Nummedal, 1982).

Due to the length of elapsed time between the photographic images and the lack of wind data for the specific region of Timbalier Island and the Eastern Isles Dernieres, the impact of lesser storm events could not be determined. However, all major tropical storms are plotted by date and position, and their effects more readily determined. North Atlantic Hurricane Tracking Charts for 1978 through 1985 (NWS, 1978-1985) were reviewed to determine the proximity of major tropical storms to the study area. The National Weather Service wind summary data for New Orleans was compared for dates during which nearby tropical disturbances were occurring to determine the local impact in terms of changes in wind velocity and duration.

III. Map Production

In order to provide useful information, photographic imagery must be interpreted and recorded in a manner in which both the categorical interpretations and their spatial relationships are preserved. Land cover classification maps, on which surface features were interpreted and categorized based on a standardized classification scheme, constitute the information source for island change analysis.

A. Base Maps

Portions of United States Geological Survey (USGS) 1:24,000 scale topographic maps covering Timbalier Island (1980 photorevised Timbalier Island and Cat Island Pass quadrangles) and the Eastern Isles Dernieres (1980 photorevised Eastern Isles Dernieres quadrangle) were photoenlarged using a vacuum frame enlarger. The enlargements were printed on heavy (0.1 mm) mylar sheets to serve as stable base maps for scaling and rectifying the aerial photographic imagery. The Timbalier Island mylar was printed at a scale of 1:12,000 (2X enlargement) and the Isles Dernieres mylar was printed at a scale of 1:6000 (4X enlargement).

B. Scale Adjustment and Image Rectification

The 1984 LEMS photography was selected as the reference imagery for photointerpretation due to its larger photographic scale and overall superior image quality. The 1984 photography for each island was registered to the mylar base map, rectified, and adjusted to a common mapping scale using a Bausch and Lomb Stereo Zoom Transfer Scope (ZTS). Individual corrections for image tilt, rotation, warp, and scale were possible for each of the mounted photographs through a combination of mechanical and optical adjustments.

For each subsequent map created, the previously interpreted map was used as the base map in order to correctly relocate common features. This proved to be more accurate than attempting to register each new image to the USGS base map, since much of the detail of the USGS maps had apparently been generalized from previous revisions. In some cases the USGS maps did not accurately represent the islands as they existed during this study. Therefore, tying the initial (1984) photointerpreted maps to the USGS enlargements, and the remainder of the maps to each previously completed map, proved to be a good method for ensuring an accurate final map product.

C. Photointerpretation

The interpreted land cover categories were limited primarily by the 1985 NASA photography. This did not prove to be a major problem, however, since all of the categories necessary to complete this study were discernable. Features were determined on the basis of a combination of color, texture, tone, pattern, relief, location and by comparison with earlier or later photography. This process was aided by frequent trips to the islands and by surface and low level aerial oblique 35 mm photographs acquired during these trips and on two observation flights.

The Eastern Isles Dernieres was mapped to a scale of 1:6000, and Timbalier Island, which was roughly two and one half times larger, was mapped to a scale of 1:12,000. This resulted in final map products of approximately the same physical dimensions, close to the maximum practical size for the Zoom Transfer Scope. Due to the differences in scale, and in order to attain similar sized databases, the digital resolution was established at 2x2 m pixels (individual picture elements) for the Eastern Isles Dernieres and 5x5 m pixels for Timbalier Island. The minimum mapping units (MMU) were selected at 10 m by 10 m (100 m^2) for the Eastern Isles Dernieres and 25 m by 25 m (625 m^2) for Timbalier Island, corresponding to 25 pixels in each of the final computer images. Linear features less than the MMU in width, but greater than two units in length were also recorded. Templates were created to aid in the decision to record or ignore features near the minimum size. The following categories were delineated based on the accompanying characterizations.

Category	Color-Infrared Photographic Characteristics
1. Gulf	Extensive water body. Smooth, reflective, dark blue (clear), or green (turbid). Adjacent to Gulf-side shoreline.
2. Bay	Extensive water body. Smooth, reflective,

	dark blue or green. Adjacent to bay shoreline.
3. Ponds	Small, enclosed, inland water bodies. Smooth, reflective, dark blue or green. Usually associated with marsh or swale.
4. Canals	Long, linear, inland water bodies. Smooth, reflective, dark blue or green. Often accompanied by spoil banks.
5. Beach	Dry, low to medium relief terrain. Smooth, bright white to pale yellow. Generally at or near Gulf water boundary. The beach line was taken as the dry line, as described by Dolan et al. (1978), usually somewhat above the swash or tide line.
6. Wet Sand	Wet, linear, low relief terrain. Smooth, dark grey or brown. This category was later combined with beach and water categories. Those ares inland from and adjacent to beach or spoil were reclassified as beach. Areas adjacent to water bodies were reclassified as the neighboring water body.
7. Vegetated Beach	Dry, vegetated, often sparse or widely scattered, low relief terrain. Irregularly textured, dark red or brown. Adjacent to or surrounded by beach.
8. Dune	Dry, vegetated, narrow, linear, elevated relief terrain. Darker in tone than adjacent beach, Yellow to light brown, becoming brown to dark red in vegetated areas. Roughly parallel to and bordering

	the beach. Usually vegetated on side opposite beach.
9. Swale	Dry, vegetated, usually low relief terrain. Highly variable texture, red to red-brown. Generally inland of dunes and/or bordering marsh zones.
10. Marsh	Usually wet, vegetated, low relief terrain. Smooth, very dark red to dark brown. Often adjacent to water bodies. Usually on or near the bay side of island.
11. Mangrove	Usually wet, vegetated, low relief terrain. Rough mottled texture. Very bright, consistent magenta-red. Usually associated with marsh. Often adjacent to water bodies. Usually on or near the bay side of island.
12. Spoil	Dry, often vegetated, very high relief terrain. Highly variable texture. Bright white to tan, or red to red-brown when vegetated. Usually associated with canals or nearshore dredging.
13. Shell	Dry, unvegetated, medium to low relief terrain. Smooth, very bright white. Associated with man-made features such as buildings or levees.
14. Riprap	Dry, unvegetated, linear, medium relief terrain. Coarse, dark grey. On beach/water boundary. Associated with canals or other structures near the waters edge.

15. Other — Buildings, roadways, drilling platforms, holding tanks, and other man-made structures (this category was eliminated from final analysis, since it represented less than 1% of the image data).

D. Field Verification

Several trips were made to both islands between 1984 and 1985 to become familiar with the vegetation, habitat, and conditions of the islands. Prints of the 1983 Isles Dernieres photography and later the 1984 Isles Dernieres and Timbalier Island photography were sealed in clear plastic covers and used to aid in field orientation. Colored permanent ink felt-tipped pens were used to make notes of surface features, vegetation types, and object sizes and distances directly on the plastic covers. Color 35 mm photographs were taken and plants collected from representative locations to aid in the delineation of cover categories.

Two physical transects were run across each island perpendicular to the Gulf shoreline in areas which would encompass all major island cover categories. Transects locations were selected near points easily identifiable both in the field and on the photographic imagery so that direct reference could be made to these transect in the final map product. Distances were measured inland from the beach front to and across each cover feature on each of the transects using a hand-reeled 500 m tape. These measurements were used to determine the final map scale, and to calibrate distance information in the computer generated transects.

IV. Geographic Information System (GIS) Development

A geographic information system is a computer implemented data structure which supports the management, analysis and manipulation of spatially referenced information in a problem solving synthesis (Fisher and Lindenberg, 1989). Geographically linked, multiple-date, classified data sets can be a powerful tool for investigating coastal processes.

A. LSU Remote Sensing and Image Processing Laboratory

All photointerpretation, map creation, digitization, and image processing for this study was accomplished at the Remote Sensing and Image Processing Laboratory (RSIP) at LSU. The RSIP image processing equipment used included:

1. Bausch and Lomb Stereo Zoom Transfer Scope (ZTS),
2. Perkin Elmer 8/32 32-bit minicomputer,
3. Sperry CCI 4000 UNIX based superminicomputer,
4. Comptal 8000-S color display system,
5. I²S Model 75 display controller,
6. Talos 72x48 digitizing table,
7. Matrix film recorder,
8. NASA Earth Resources Laboratory Applications Software (ELAS),
9. Tape drives, printers, light tables, and other miscellaneous equipment.

B. Software

The RSIP version of ELAS (Earth Resources Laboratory Applications Software; NASA, 1980) was used during this study for all image processing, Geographic information system (GIS) development, and data

extraction. ELAS is an interactive, modular, and comprehensive image processing software system. The ELAS version implemented at RSIP had been modified to run under the UNIX operating system on the Sperry CCI 4000 and other UNIX based computer systems. ELAS was designed to work with raster based image data in a line by line and element by element process. This method of image storage and retrieval is ideally suited to area change assessment such as that performed in this study.

C. Map Digitization

The photointerpreted mylar maps were manually digitized using a Talos digitizing table and the ELAS digitizing module DGTZ, which converts coordinate X-Y positions on the Talos table to computer code representing the scaled point locations. This method involved taping one of the mylar maps to the surface of the digitizing table and initializing the map by positioning the cross-hairs of a magnetic cursor over a sequence of Universal Transverse Mercator (UTM) control points (grid marks) precisely recorded onto the map. Once initialized, each cover category was traced with the cursor, creating a sequence of digitized points along the category boundaries. These points defined the vertices of polygons within the image data space created by the computer, each polygon corresponding to an individual cover feature.

The initial vector data was converted to raster format by assigning all pixels within the borders of a given polygon a count value corresponding to the cover/change category represented by the enclosed area. The digital resolution was set at two meters per pixel for the Eastern Isles Dernieres and five meters per pixel for Timbalier Island, due to the different map scales. Decreasing the pixel size causes a directly proportional increase in the number of pixels. The resultant digitized maps contained eight million pixels per image date, or a total of 32 million pixels per data set.

As each map was completed the composite of polygons forming the

computer map image was reviewed on a color image display device. Different colors were assigned to each of the interpreted land cover categories. Each polygon was observed and checked for correct classification and boundary accuracy. Discrepancies noted during this review were corrected directly on the digitizing table before removing the current map.

With the completion of the digitizing, review, and editing of each map, a new map was installed and initialized, and the process repeated. With the completion of all map digitization and editing, each series of maps were again reviewed to determine the accuracy of sequential map registration. Errors were corrected by referring back to the original photographic imagery and remapping and redigitizing the revised features.

D. Field Agreement Sampling

Once digitization of the maps had been completed, sample areas were selected to test the agreement between the digitized map categories and the actual surface features. Test sites were determined using the ELAS module RANS, which provides a user-designated number of random site locations for each selected cover category. A site location consisted of a 25 pixel area (minimum mapping unit) of similarly classified (single category) pixels. Fifty sites were selected for each island. The number of sites chosen for each category was based on the relative surface area, with each major category (other than open water bay and Gulf) represented.

Clear acetate sheets were attached to contact prints of the 1984 LEMS photography. The locations of the selected sites were precisely recorded on these photographs using permanent ink felt-tipped pens. These photographs were carried into the field and used to locate the test sites. A helicopter was employed for the agreement sampling. All test sites on both islands were identified and closely observed on

August 5, 1986. Test sites were considered correctly classified if at least 50% of the features within the site matched the interpreted category.

Agreement was defined as the sum of the correctly classified test sites divided by the total test sites and expressed as a percentage (Evans, 1986). This was determined to be 84% for Timbalier Island and 86% for Eastern Isles Dernieres (Tables 1 and 2). On both islands the transition zones between marsh and swale were areas of greatest confusion, accounting for 41% of the total error. Other sources of error included small recovering patches of mangroves which were identified as marsh due to limited foliage.

On the Eastern Isles Dernieres a new category, shell, was differentiated from the beach category due to observation of relatively large areas on the bay side of the island. The assumed difference in erosional resistance compared to sandy beach substrate combined with a distinguishably brighter appearance on the infrared photography provided sufficient justification for separating the two categories. This was not a true error of classification, since it had been properly identified within the constraints of the original cover categories. Therefore, the field agreement for the Eastern Isles Dernieres cover classification was 86% rather than 82%. In addition, no sampling was attempted for Gulf or bay water areas, due to their ease of identification. Therefore, the reported agreement values are somewhat conservative.

All discrepancies noted during the sampling were corrected and the maps edited and redigitized. Fewer than 10% of the mapped areas were affected by these changes.

E. Data Compression

The original digital images consisted of 32 Mb of data for each island (4000 elements, 2000 lines, and 4 image dates). Subtractive

Table 1. Field verification agreement table for Timbalier Island surface feature classification map.

MAP SAMPLES	FIELD IDENTIFICATION Pond	Canal	Beach	Dune	Swale	Marsh	Mangrv	Spoil	RipRap
Ponds (5)	5								
Canal (5)		5							
Beach (10)			9			1			
Dune (5)			1	4					
Swale (10)					8	2			
Marsh (5)					2	7	1		
Mangrove (2)							2		
Spoil (2)					1			1	
RipRap (1)									1

8 samples out of 50 in error:
Overall Agreement = 84%
Land/Water Agreement = 100%
Wetlands/Non-Wetlands Agreement = 88%

Table 2. Field verification agreement table for the Eastern Isles Dernieres surface feature classification map.

MAP SAMPLES	FIELD IDENTIFICATION Pond	Unveg Beach	Veg Beach	Dune	Swale	Marsh	Mangrv	Spoil	Shell
Ponds (5)	5								
Unveg.Beach (10)		10							(2)
Vegetated Beach(5)			4	1					
Dune (5)				4	1				
Swale (10)				1	7	2			
Marsh (10)					1	8	1		
Mangrove (4)							4		
Spoil (1)								1	

9 samples out of 50 in error
Overall Agreement = 86%
Land/Water Agreement = 100%
Wetlands/Non-Wetlands Agreement = 93%

change images essentially doubled these amounts, resulting in a data storage requirement of 128 Mb. However, each raw image pixel contained one of only 15 possible values (representing each of the various cover categories, with water split between Gulf and bay), while being capable of representing any of 256 discrete values. Each pixel, therefore, was capable of displaying all possible change combinations between any two image dates ($15^2 = 225$).

The original 15 values were reduced by eliminating the "other" category, since it represented less than 1% of the image data. These were further reduced by using the same value for "riprap" and "shell," since these each represented data on only one island ("shell" on Eastern Isles Dernieres and "riprap" on Timbalier Island). The resulting 13 image values were converted to values which simultaneously represented two image dates, as well as the changes between the two dates. For example, Value 149 represented an area which was swale in the first year and dune in the second year and, therefore, represented change in the form of loss of swale and gain of dune area. Count Value 85 represented beach in both years and, therefore, no change. The data for each island was, thereby, reduced from eight to four image channels, the same as the original raw data. The resulting four channels represented:

1. Year 1, Year 2, and Change from Year 1 to Year 2,
2. Year 2, Year 3, and Change from Year 2 to Year 3,
3. Year 3, Year 4, and Change from Year 3 to Year 4, and
4. Year 1, Year 4, and Change from Year 1 to Year 4.

Data storage was further conserved by eliminating portions of the images which contained only open water in all four years and which lay outside a rectangular boundary containing all image land pixels. This reduced overall data size to 28 Mb for the Eastern Isles Dernieres and 24 Mb for Timbalier Island. A major advantage of these data compression techniques was that more information could be extracted with each data query.

F. Baseline Area Polygon Creation

The transect baselines originally established by Dolan (1978) parallel to and offshore from Timbalier Island and the Eastern Isles Dernieres (Figures 21 and 22) were retained in order to facilitate comparison with his results. Each baseline extended 3600 m parallel to the shoreline and was located at approximately 3400 m intervals. These provided an offshore reference from which measurements could be made to the shoreline and inland to other island areas.

The baselines were numbered from east to west. The five corresponding to Timbalier Island were numbered 23 through 27, while the two Eastern Isles Dernieres baselines were numbered 28 and 29 (Figures 21 and 22). These numbers were retained, but the prefix "D" and "T" (for Dernieres and Timbalier) were added to help avoid confusion. Timbalier Island's T23 paralleled the easternmost end, while D29 paralleled the Eastern Isles Dernieres' western end.

The endpoints of each of Dolan's baseline were carefully registered and digitized. Baseline area polygons were then created by combining the baseline endpoints with points directly opposite, on the bay side of the island (Figures 21 and 22). Each resultant rectangular polygon enclosed a portion of one of the islands, providing localized regions within which category area extraction and area change analysis could be performed. This facilitated the investigation of spatial variation and provided the framework to continue and extend Dolan's transect data.

V. Data Extraction

With the GIS fully implemented, information queries were executed based on whole data sets, existing polygons, and batch-file input of sequential transect coordinates. These were performed utilizing existing ELAS modules, original modules created for this study, and 'C' language executable code. The information extracted consisted of pixel

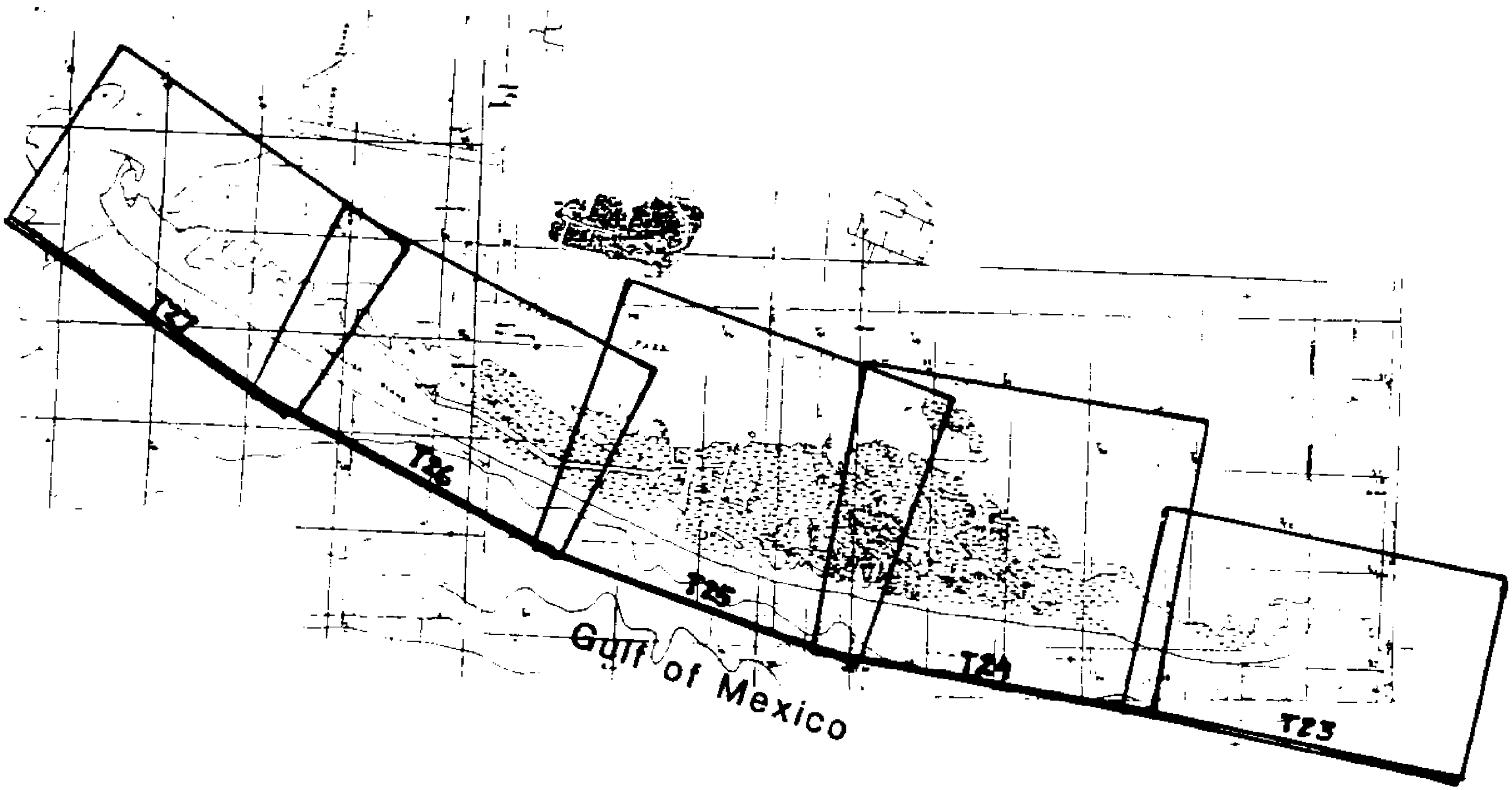


Figure 21. Portions of 7½' USGS topographic maps for Timbalier Island, Louisiana, showing location of transect polygons. The offshore Gulf side of the eastern end transect area is equivalent to Dolan's (1978) transect baseline #23, and the offshore side of the western end transect area is equivalent to Dolan's baseline #27.

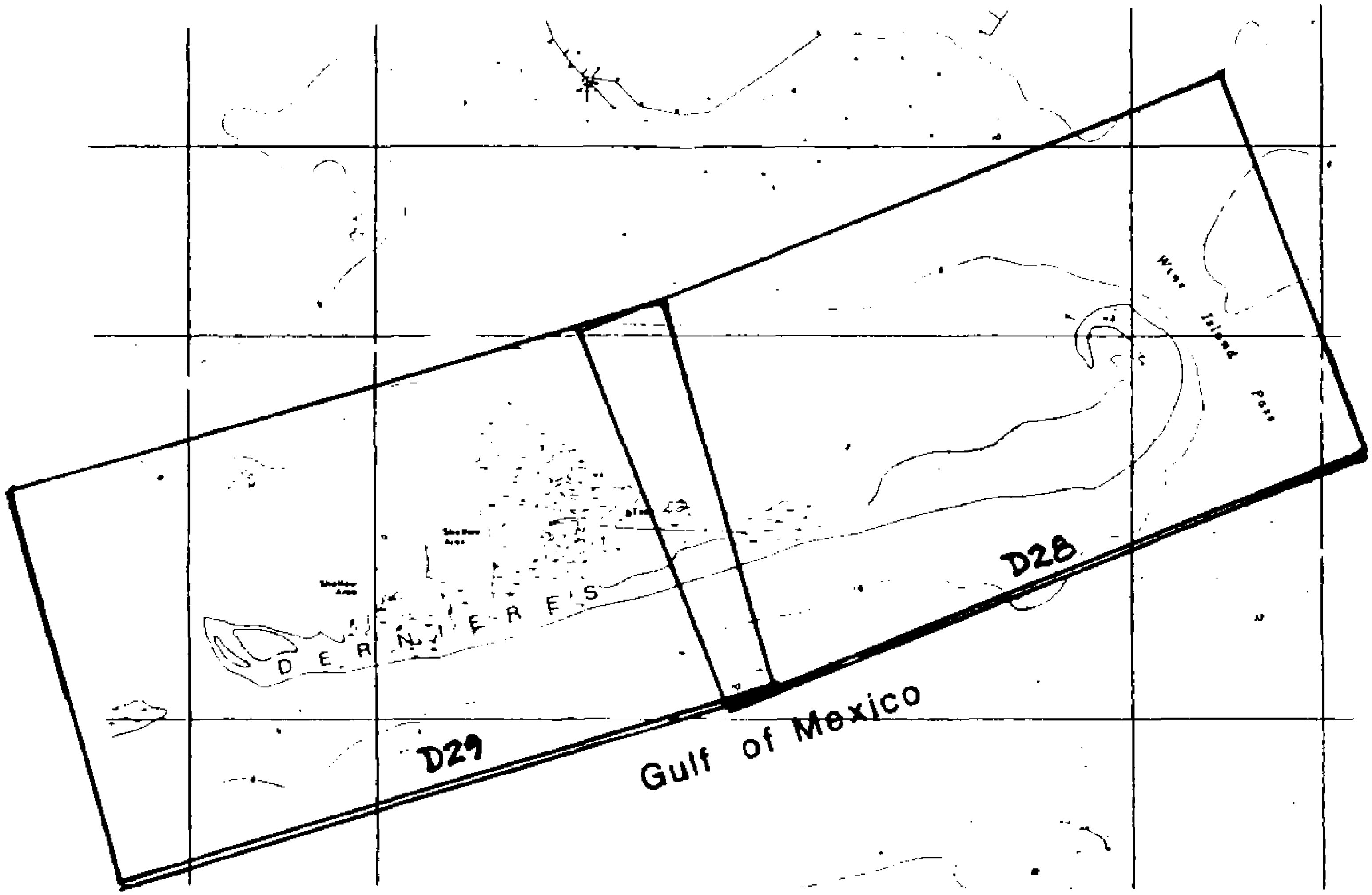


Figure 22. Portion of 7½′ USGS topographic map for the Eastern Isles Dernieres, Louisiana, showing location of transect polygons. The offshore Gulf side of the eastern transect area is equivalent to Dolan's (1978) transect baseline #28 and the offshore side of the western transect area is equivalent to Dolan's baseline #29.

counts, tabulated by assigned image count values. For each data querry, the total number of pixels recorded for a given count value corresponded to either the polygon area or transect distance within which each type of land cover change had occurred. This provided a means for determining land cover category areas and widths for each sample date, as well as the amount and type of change which occurred within and among each category.

The frequency of occurrence of all values within each image channel and within each defined polygon boundary were determined using the ELAS module PLYA (Polygon Acreage). Output was selected for cumulative frequency (number of pixels) and hectares for each classification value. This provided total area values for each cover category within each island data set as a whole, as well as within each of the baseline polygons.

In order to determine the lateral shoreline displacement, as well as the displacement of cover categories relative to Dolan's (1978) preestablished baselines, it was necessary to create an ELAS module which could measure these distances. The module TSEC was developed by the programming staff of RSIP to compute the Pythagorean distance between boundaries of image cover categories lying along a line described by beginning and ending image coordinates.

A separate program was written to automatically orient each transect perpendicular to the appropriate baseline (Figure 23). Each transect ran inland across the island to a point behind the island. This provided an arbitrary Gulf distance value, determined by the offshore location of the beginning transect coordinate (lying along Dolan's baseline) and the location of the first island land value. Absolute distance values were recorded for each incidence of each cover category intersected. An arbitrary Bay value, determined by the location of the last land coordinate and the transect end coordinate were also determined.

It was technically possible to generate transects for each point (pixel) along the baselines. However, data processing and storage

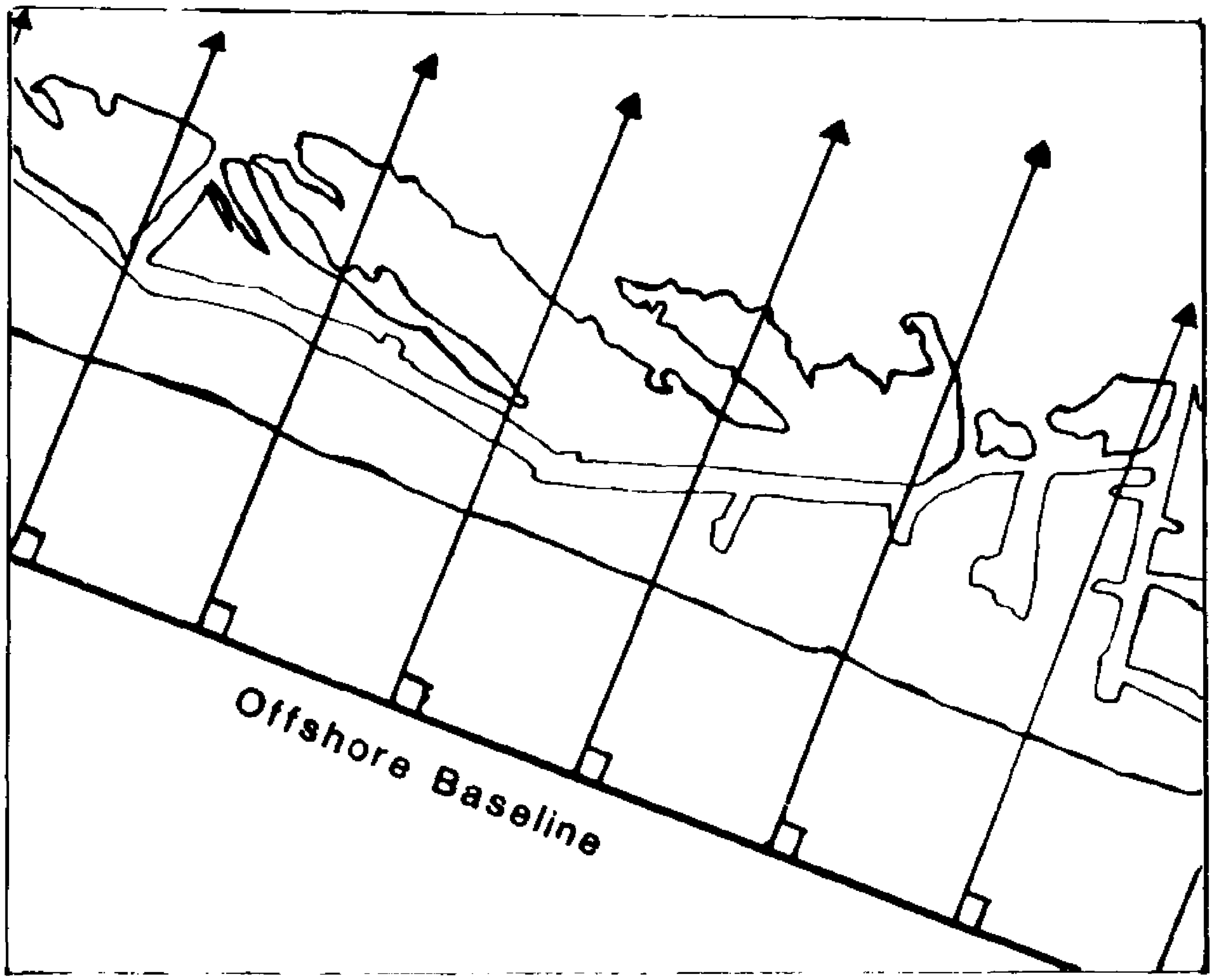


Figure 23. Perpendicular transect generation from offshore Gulf-side baseline. Each transect is oriented at right angles to the baseline and runs onshore and across the island to the bay. Width and distance values are determined by tallying the number of pixels of each category contacted during the transit of the island.

limitations necessitated a subsampling of transects. In order to assure coverage, transects were generated for every tenth pixel, corresponding to intervals of 20 m for the Eastern Isles Dernieres and 50 m for Timbalier Island. In order to track lateral migration, 100% sampling was performed within 50 m of the eastern ends of both islands and the western end of Timbalier Island. The western end of the Eastern Isles Dernieres exhibited such relatively large gains and losses that individual pixel sampling was impractical. Approximately 250 transects were sampled from each island data set.

A program was written which could selectively accumulate output from the ELAS TSEC module. The distances to each cover category within a transect were summed separately to provide a total width value for each category. In similar fashion, the total distance from the shoreline to the first inland water body pixel was summed, as was the total distance from the baseline to the first dune pixel and first marsh or mangrove pixel. This provided information needed to test portions of the Godfrey and Godfrey (1974) "rollover" model.

VI. Data Analysis

The purpose of most statistical analyses are prediction and estimation of population parameters, based on the variability within the population, and determined through relatively small representative samples. However, with digitized photointerpreted data sets, a given land cover category is assigned a discrete numerical identity and all variability within that category is eliminated. The data set becomes a simplified model of the real world whose parameters can be determined directly and entirely.

Accuracy of a classified data set depends on how well the real features are interpreted and digitized. This can be estimated by comparing classified data values with the actual features using traditional statistical sampling. Once this determination has been

made, assuming that the interpretation is acceptably accurate, the population and subpopulations can be queried as a whole. This means that, within the classified data set, the total area of each category and the exact degree and nature of changes can be determined.

The amount of information inherent in a classified data set is directly proportional to the number of categories. However, the degree of accuracy is inversely proportional. A data set which consisted exclusively of a single land cover category would have the greatest probability of correct classification, but would provide little useful information. Conversely, a classification which differentiated every potential habitat and every species within each habitat might provide a wealth of information. However, precisely and accurately determining and locating such species/habitat combinations is beyond the normal limitations of aerial photography, photointerpretation, or field investigations. Therefore, interpreted data sets are usually a compromise between the amount of classification detail possible and that which can be efficiently and accurately deduced from available imagery.

Changes in total land area and area of each cover category were determined for both Timbalier Island and the Eastern Isles Dernieres. This methodology involved running the ELAS PLYA module to extract the cumulative hectares for each data category within each entire two-date data file. Those compressed data values which represented change were totaled and converted to their respective gain (positive) and loss (negative) values for each category. Data was reported as total area (hectares) for each category. Categories were ranked as to:

1. Total surface area,
2. Surface area lost, and
3. Surface area gained.

The same extraction and conversion procedures performed for total island areas were performed for each of the polygons corresponding to Dolan's (1978) baselines. The total area of each cover category contained within each baseline polygon, as well as changes in those

areas, were reported. This provided a means for evaluating the spatial variability of cover categories.

Gulf shoreline change analysis was performed in a fashion similar to area change extractions, except that the TSEC output formed the data source and the values extracted were distances. Gulf shoreline change was determined by totaling the distance through which a data code representing Gulf the first year and land the second year (shoreline accretion) or land the first year and Gulf the second year (shoreline erosion) was recorded. Bay shoreline change was determined using the same procedure.

Island width was considered to be the total distance across the island, from shoreline to shoreline, at a given point along the length. Cumulative land width was the total of all distances across all land values from shoreline to shoreline. Total island width exceeded cumulative land width wherever an inland water body comprised a portion of the islands width. Cumulative land width is an important parameter in areas where subsidence and erosion have resulted in patchy scattered terrain features surrounded by large areas of open water. Island width was determined by totaling all non-Bay and non-Gulf values corresponding to a given year. Cumulative land width was determined by subtracting the respective canal and pond values from the width value. Changes were determined by subtracting the first year values from the second year.

Widths and changes in widths of individual cover categories were determined in a manner similar to that for shoreline change. The coordinates of each change in cover category within a transect were used to compute the width for each category encountered. Multiple encounters of a given category within a transect were accumulated to provide a total width value for each category within each transect.

For all transects containing a specific cover category, a regression analysis was performed to determine the linearity between beginning year category width values and shoreline change, change in island width, and change in cumulative land width. The relationships between category widths and changes in Gulf shoreline, island width, and

cumulative land width (excluding water values) were determined. Change was the dependant variable and the cumulative category width per transect the independent variable. Combinations showing correlations of $R^2=0.5$ and above were graphed.

An analysis of means (Hoel, 1971) was conducted for all transects containing a given category compared to all other transects. This was to determine differences in rates of change of shoreline, island width, and cumulative land width relative to a particular category compared to transects not containing that category. This analysis was repeated for all categories and for each change period, including the total period. The reported test statistic (Z value) is equivalent to the number of standard deviations separating the two populations means, where:

$$Z=\frac{\mu_x-\mu_y}{\sqrt{(\sigma_x^2/n_x)+(\sigma_y^2/n_y)}}.$$

Z values greater than plus two or less than minus two indicate a significant difference between the two means (Z=2 is equivalent to $\alpha=0.05$, or a 95% confidence interval). Values of Z between plus and minus two were not considered significant.

A regression analysis to determine the relationship between the proximity of inland water and shoreline change was performed in a manner similar to that in Section F., above. The distance from the Gulf shoreline to the nearest inland water body was used in place of category widths. If no inland water bodies were encountered within a given transect the distance to the Bay shoreline (island width) was used. Regressions were also run for change in island width and cumulative land width.

The distance and direction of movement of the Gulfward dune and marsh (including mangrove) boundaries were analyzed to test portions of the Godfrey and Godfrey (1974) rollover model. Dune and marsh displacement values were determined relative to the preestablished baselines so that movement could be evaluated on an absolute basis, as

well as relative to the shoreline.

Shoreline data pertinent to Timbalier Island and the Eastern Isles Dernieres were extracted from Dolan's (1978) results and converted to digital format. These data were analyzed for overall change and rates of change. Results were compared with data generated during this study. A linear regression analysis of cumulative shoreline change over time was performed. This data was used to extrapolate current trends in island shorelines and surface area in order to predict future changes.

Therefore, shoreline change data dating from 1934 through 1978 was combined with shoreline position, island width, and land cover data from 1978 through 1985 in order to examine the mechanisms of barrier island change. Table 3 provides a time line detailing the sequence of events related to data aquisition, field sampling, and significant environmental events effecting barrier island dynamics.

Table 3. Time line of relevant events. Included are photo acquisition dates, sampling dates, and significant meteorological events.

Semi-Log Time Scale

1987	
	Aug 5, 1986 - Final Field Agreement Sampling
1986	Dec 5, 1985 - NASA Coastal Photography - Dernieres & Timbalier
	Oct 28-31, 1985 - Hurricane Juan
1985	Early January, 1985 - Hard Freeze
	Dec 8, 1984 - LEMS Photography - Dernieres & Timbalier
1984	Mid January, 1984 - Hard Freeze
	Nov 16, 1983 - LEMS Photography - Dernieres
1983	Nov 24, 1982 - NHAP Photography - Timbalier
1982	
1981	
1980	July 10-11, 1979 - Hurricane Bob
	Nov 10, 1978 - EPA Photography - Dernieres & Timbalier
	Oct, 1978 - Dolan Photography
1975	Oct, 1974 - Dolan Photography
1970	July, 1969 - Dolan Photography
1960	
1950	May and Dec, 1951 - Dolan Photography
1940	
1930	June, 1934 - Dolan Photography

RESULTS

I. Timbalier Island

In 1978, Timbalier Island was characterized by large expanses of sand and swale along the western half and broad stands of marsh and mangrove on the eastern half and backbay areas (Figure 24). The island was extensively traversed by oil and gas access canals, with numerous side branches and outlets to Timbalier Bay. The eastern end of the island consisted of sand bars and mud flats with scattered emergent vegetation and remnant marsh. The western end was characterized by a wide sandy beach, backed by dunes and scattered swale, marsh, and mangrove. Massive die-backs of mangroves due to severely cold weather in the winters of 1983-1984 and 1984-1985 resulted in the conversion of large portions of these areas to marsh and open water (Figure 25).

During this study the majority of the island underwent a narrowing as both the Gulf and bay shorelines eroded (Figures 24 and 25). In addition, the island exhibited a cycle of erosion (shoreline retreat) of the eastern end of the island accompanied by a redistribution of sediment westward, extending the western end. This produced a westward lateral migration of the island perimeter. However, erosion of the eastern end was much greater than the progradation of the west, resulting in a net reduction in island length.

A. Area Change Analysis

Timbalier Island experienced an accelerating loss of surface area during the period of this study (Figure 26). Total surface area declined from 931.7 ha in November, 1978, to 817.9 ha in December, 1985 (Table 4), for a net loss of 113.8 ha or 12.2% of the 1978 surface area. The majority of loss occurred during the final year of the study,

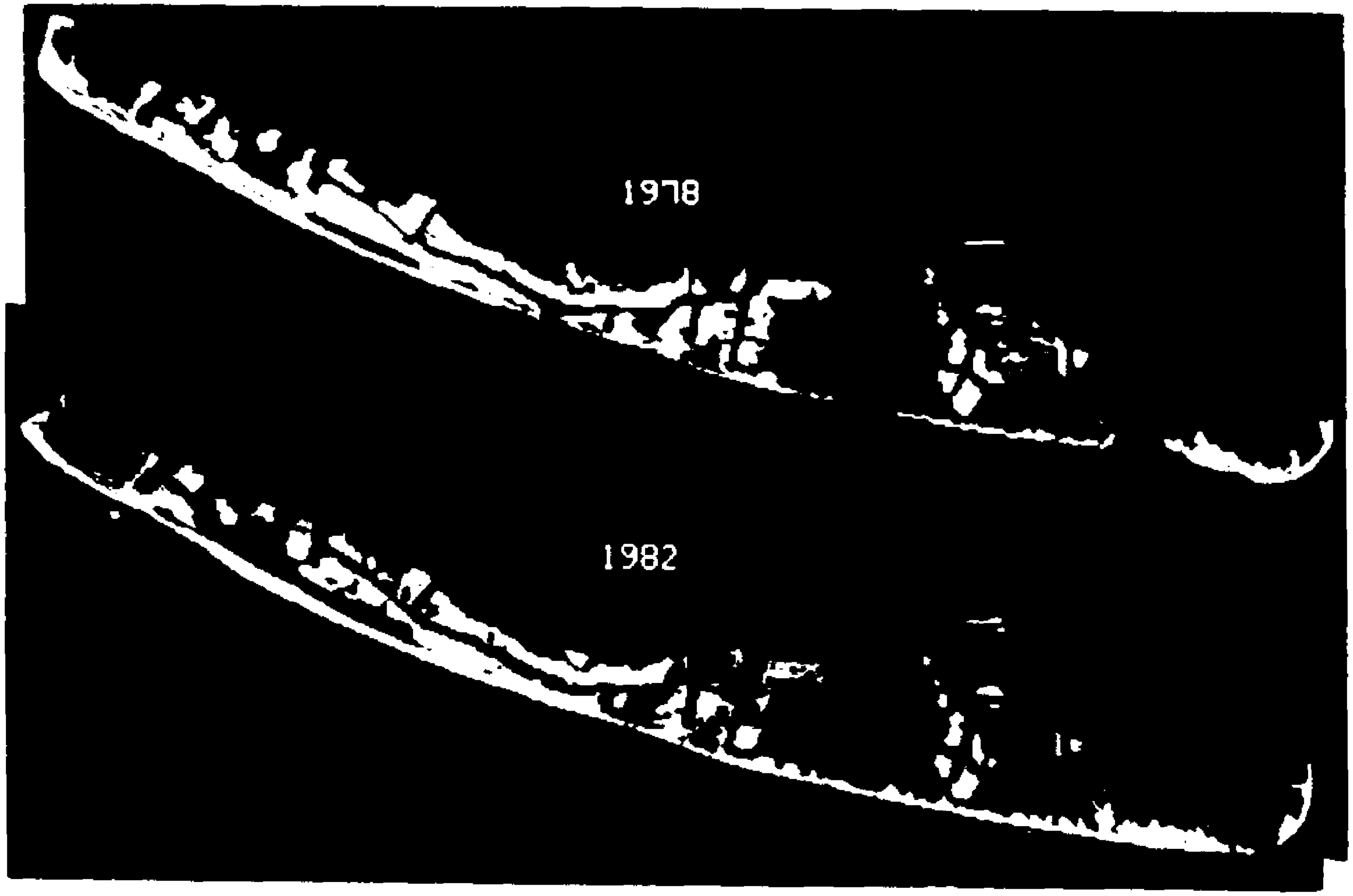


Figure 24. Computer generated images for Timbalier Island cover categories, 1978 and 1982. Beach and sand are white and yellow, dunes are medium green, swale is green, wetlands are dark green and bluegreen, spoil is pink and water is blue and purple.

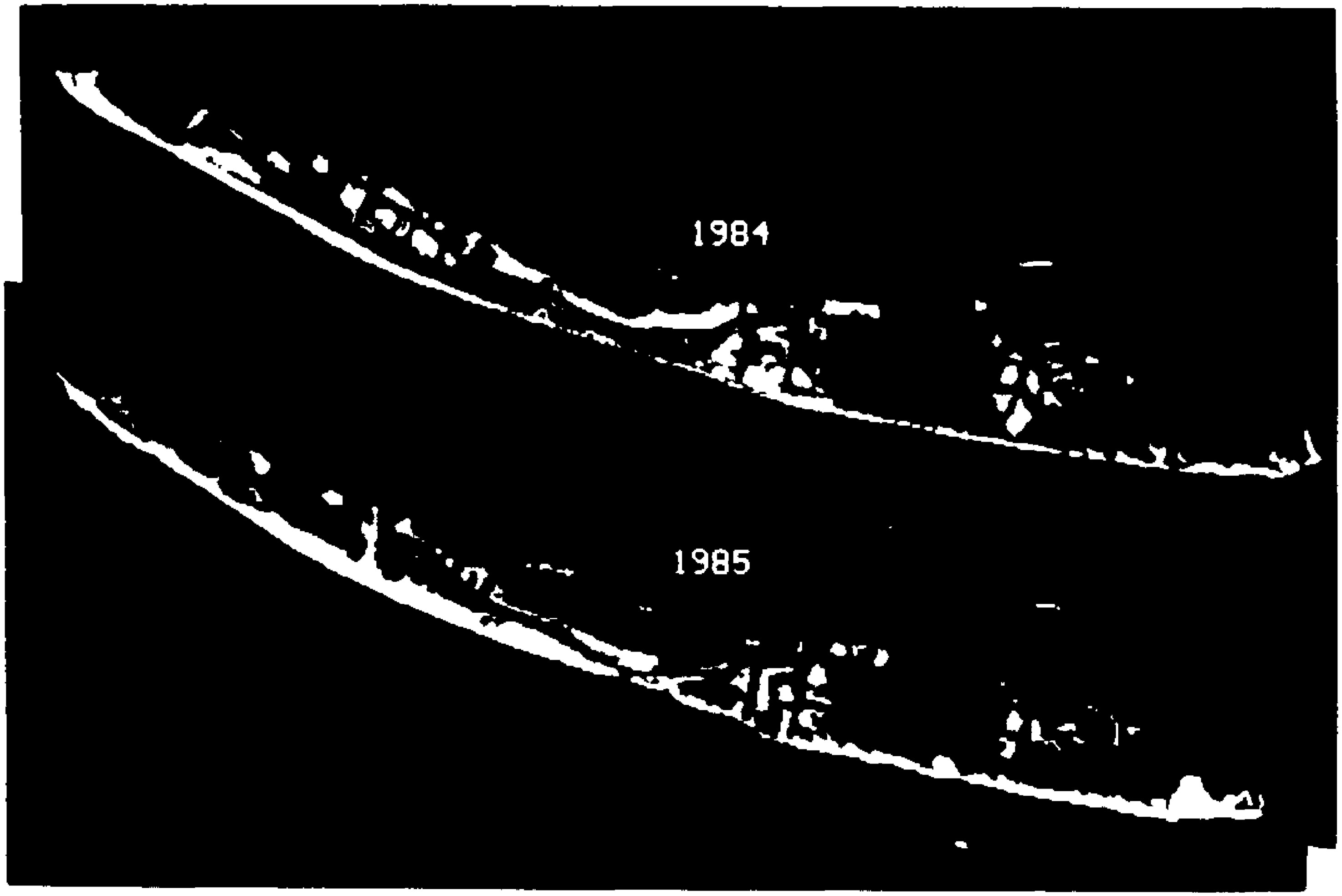


Figure 25. Computer generated images for Timbalier Island cover categories, 1984 and 1985. Beach and sand are white and yellow, dunes are medium green, swale is green, wetlands are dark green and bluegreen, spoil is pink and water is blue and purple.

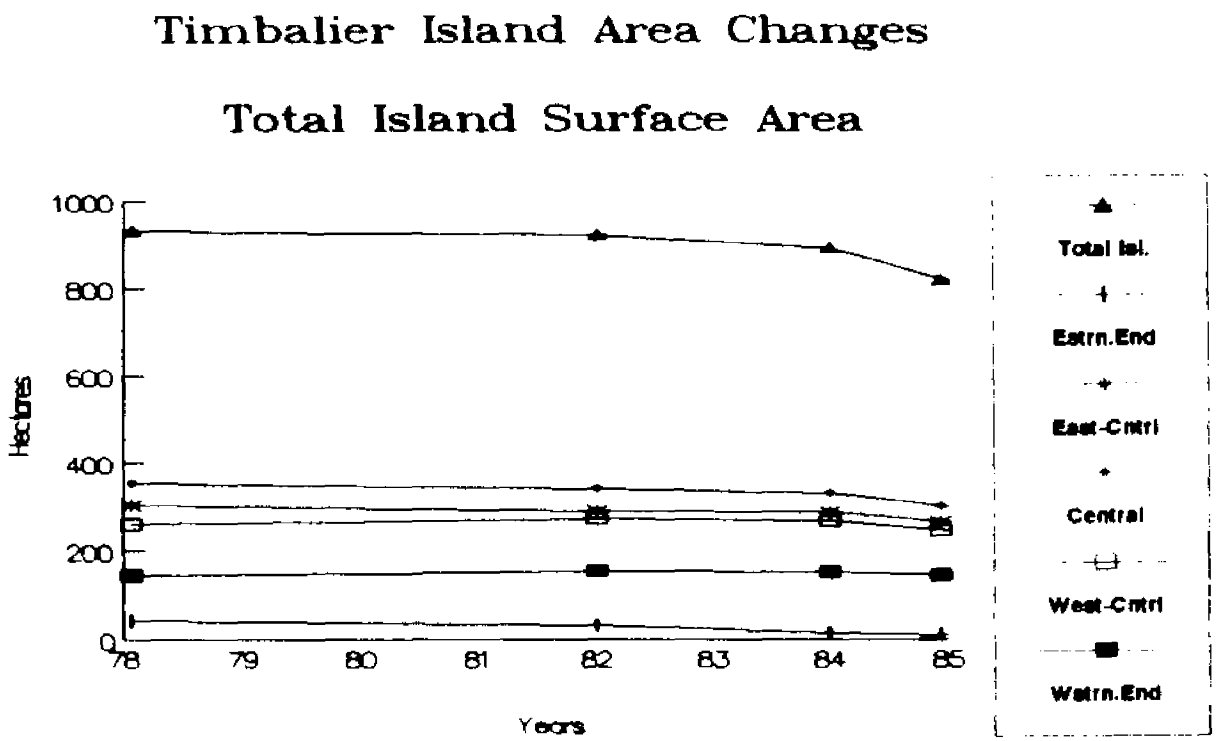


Figure 26. Changes in Timbalier Island surface area for total island and for each transect area polygon, 1978-1985.

Table 4. Total areas (ha) and percent change of Timbalier Island cover categories.

Total Island Category Areas (ha)

Category	1978	1982	78-82	1984	82-84	1985	84-85
Gulf	30.0	43.7	-	73.7	-	147.7	-
Bay	53.7	50.3	-	50.7	-	50.0	
Ponds	78.2	88.5	13.2%	100.2	13.2%	110.2	10.0%
Canal	145.4	137.8	-5.2%	139.6	1.3%	139.4	-0.1%
Spoil	15.7	10.3	-34.4%	4.7	-54.4%	4.6	-2.1%
Beach	90.9	102.4	12.7%	71.6	-30.1%	94.9	32.5%
Dune	40.9	40.5	-1.0%	30.5	-24.7%	28.0	-8.2%
Swale	223.5	232.1	3.8%	234.2	0.9%	181.7	-22.4%
Marsh	111.9	112.9	0.9%	292.7	159.3%	253.5	-13.4%
Mangrove	224.6	196.2	-12.6%	17.2	-91.2%	4.6	-73.3%
RipRap	0.6	0.6	0.0%	0.6	0.0%	1.0	66.7%

Combined Category Areas (ha)

Category	1978	1982	78-82	1984	82-84	1985	84-85	78-85
Inland Water Bodies	223.6	226.2	1.2%	239.8	6.0%	249.6	4.1%	11.6%
Dry Sand Substrate	371.0	385.3	3.9%	341.0	-11.5%	309.2	-9.3%	-16.7%
Wetlands	336.6	309.1	-8.2%	309.9	0.3%	258.2	-16.7%	-23.3%
Total Land Area	708.2	695.0	-1.9%	651.4	-6.3%	568.3	-12.8%	-19.8%
Total Surface Area	931.7	921.2	-1.1%	891.2	-3.3%	817.9	-8.2%	-12.2%

1984-1985. All but the western-most transect area (Figure 21, page 77) underwent a net loss of surface area during this period. The eastern end was reduced by 78% during the seven years of the study, while the mid-island areas lost between 6% and 15% of their surface area. Shoreline erosion was offset by newly deposited sediment within the western portion of the island, resulting in a slight gain in surface area in the western end. However, total surface area declined throughout the study, with the rate of decline most rapid during the final year.

1. Bay and Gulf

Changes in relative bay and Gulf water areas (Figures 27 and 28) indicate that the majority of the loss in island surface area occurred through Gulf shoreline erosion. Land converted to water on the Gulf side (Gulf shoreline erosion) is indicated by increases in Gulf water area. Relatively little net change occurred in the bay water area. A loss of 3.7 ha of bay water area indicated a net gain of backbay surface area (Table 4). This occurred primarily through accumulation of newly deposited island sediments, offsetting a general trend toward erosion of the bay shoreline. Gains in Gulf water area accounted for 117.7 ha of land lost.

2. Ponds and Canals

A slight decline in canal area was more than offset by increases in pond area (Figures 29 and 30). Ponds increased by 32 ha, for an average gain of 41% over the 1978 value of 78.2 ha, accounting for 110.2 ha in 1985 (Table 4). Ponds increased in all but the western end of the island, where they decreased in area by 2.1 ha (within an area of 145 ha). Mangroves comprised the majority of land area reverting to

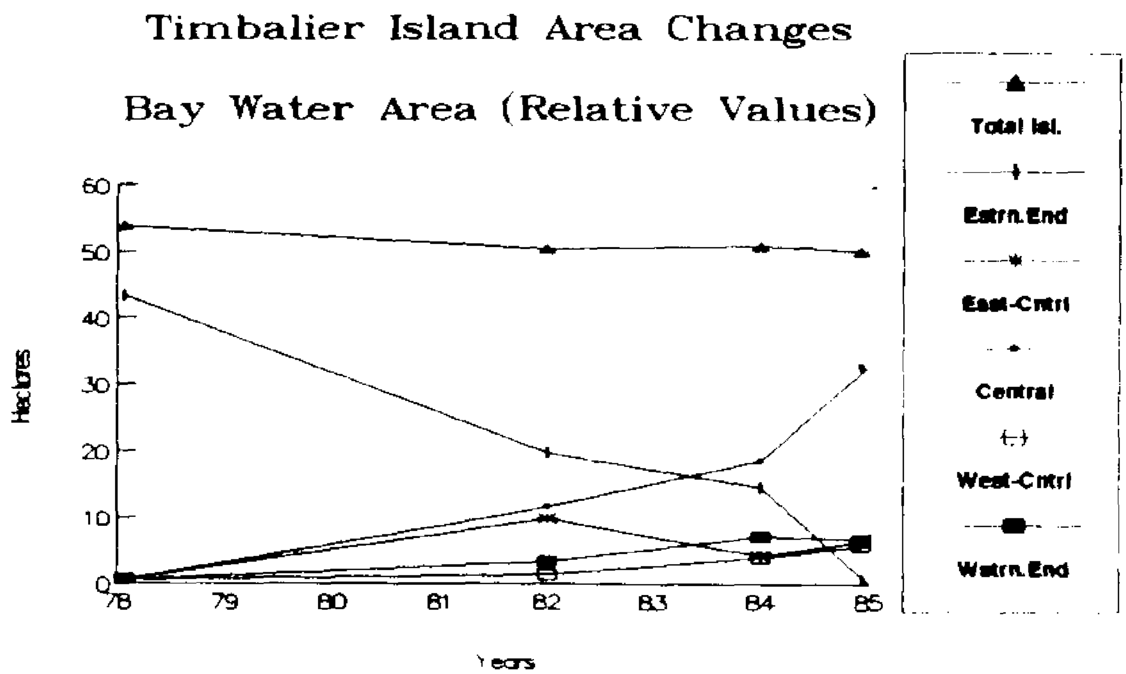


Figure 27. Changes in Timbalier Island bayside water area for total bay shoreline and within each transect area polygon, 1978-1985.

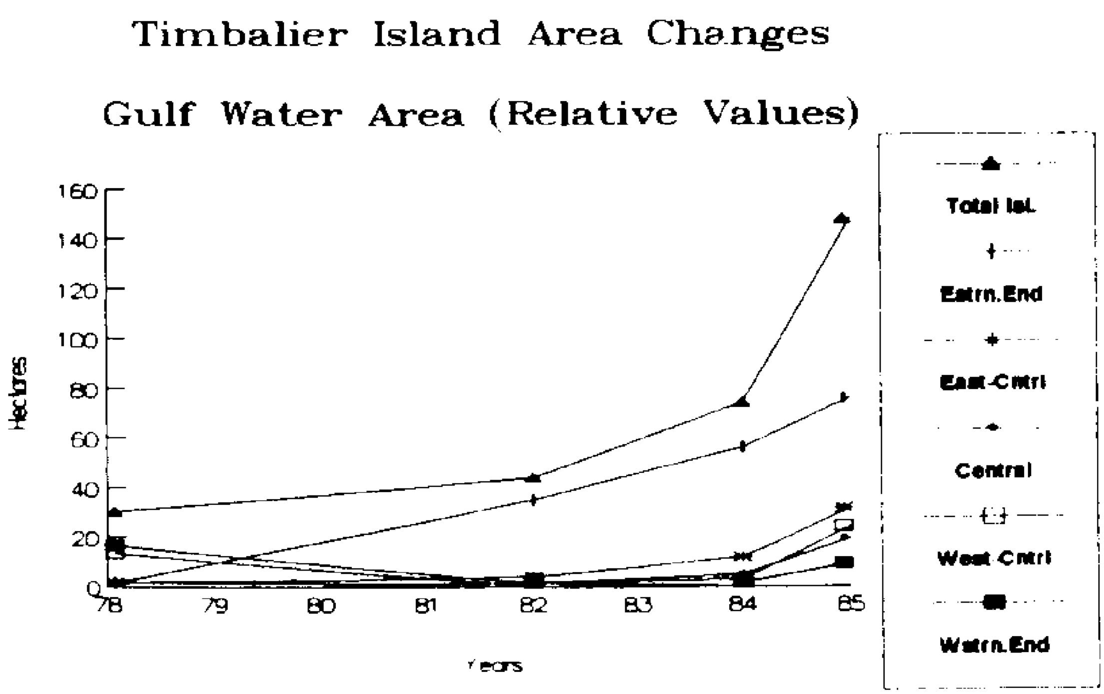


Figure 28. Changes in Timbalier Island nearshore Gulf water area for total Gulf shoreline and within each transect area polygon, 1978-1985.

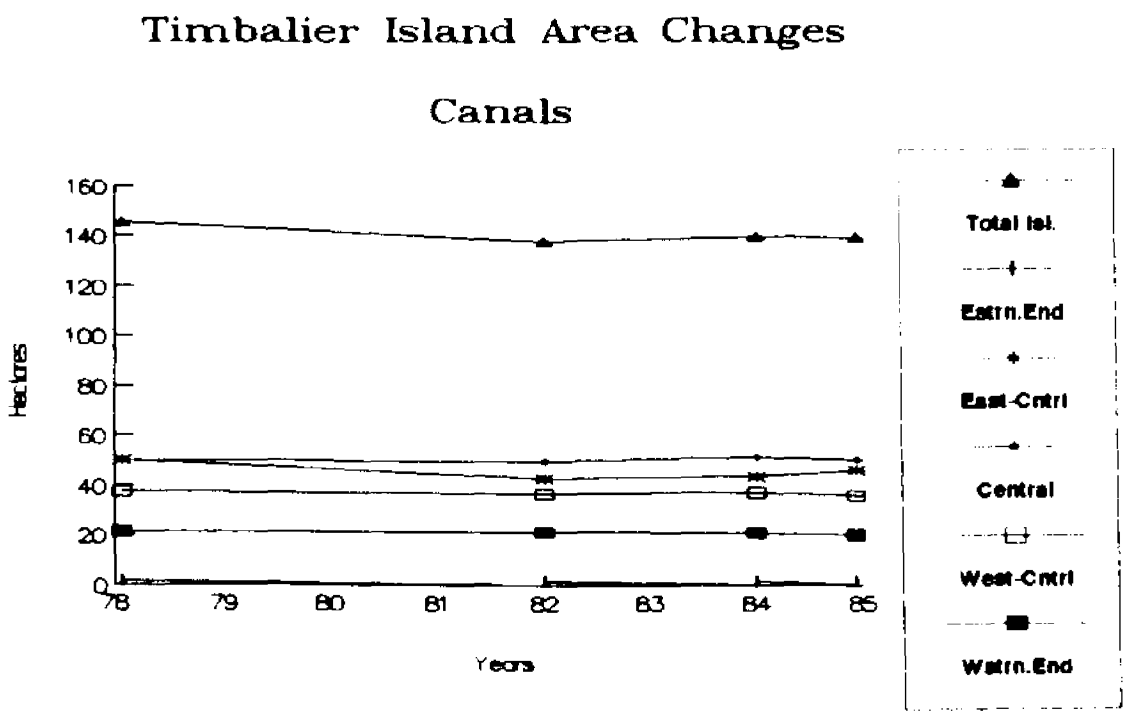


Figure 29. Changes in Timbalier Island canal area for total island and within each transect area polygon, 1978-1985.

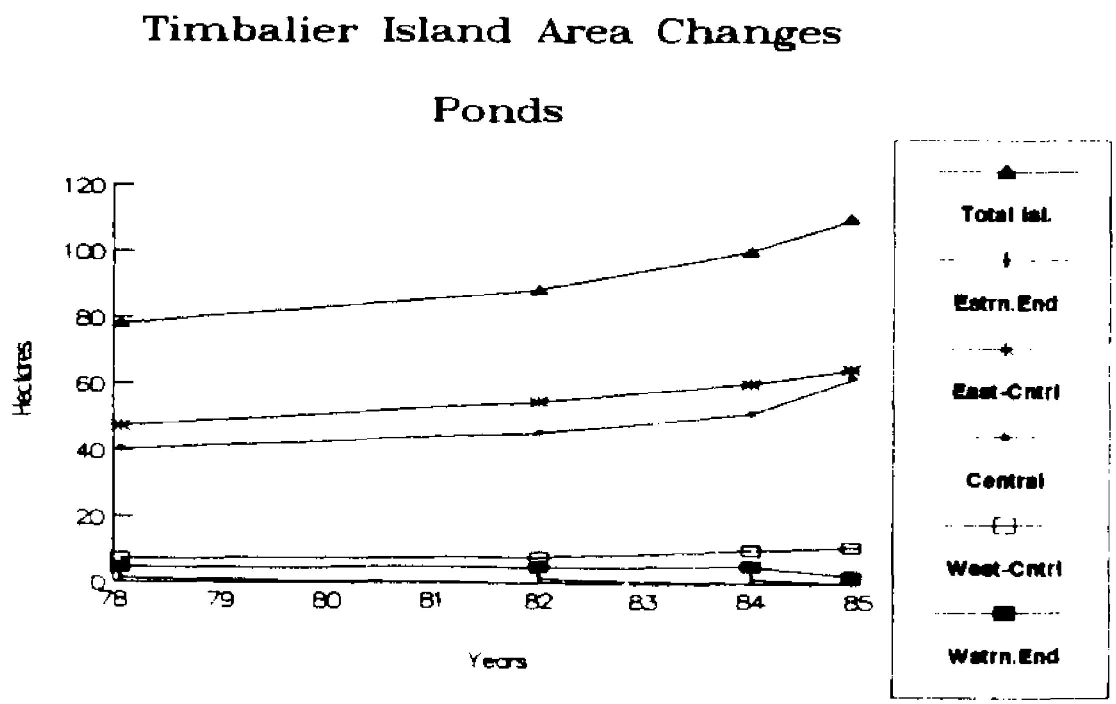


Figure 30. Changes in Timbalier Island pond area for total island and within each transect area polygon, 1978-1985.

ponds (43.2 ha), due to hard freezes and resultant die-backs in the winters of 1983-1984 and 1984-1985 (Table 5). Swale, canals and marsh also contributed to the increases in pond area. Land area gains from ponds included beach (5.1 ha), dune (2.6 ha), swale (2.1 ha), and marsh (1.6 ha). Therefore, canals remained relatively stable, while ponds increased in surface area, primarily through the conversion of frost-damaged mangroves to open water.

3. Total Land Area

An overall decrease in island surface area was accompanied by a similarly accelerating increase in the area of inland water bodies (Figures 31 and 32). This, combined with shoreline erosion (117.7 ha), resulted in a net loss of land area of 139.9 ha, from 708.2 ha in 1978, to 568.3 ha in 1985 (Table 4). This represents a 19.8% loss of land area over the seven years of the study. The majority of this (83.1 ha) occurred within the last year of the study. Shoreline erosion and the conversion of mangroves to ponds accounted for the majority of the overall loss of land area.

a. Combined Dry Sand Categories

Areas consisting of dry or well drained sand substrate (beach, dune, swale, and spoil) underwent a net reduction amounting to 61.8 ha or 16.7% of 1978 totals (Table 4, Figure 33). Losses were recorded in all but the western end of the island. Total dry sand categories accounted for 371 ha in 1978, or 52.4% of land area and 39.8% of surface area. By 1985 this had been reduced to 309 ha, which represents 54.4% and 37.8% of the 1985 land and surface areas, respectively. Therefore, although these areas had diminished substantially from 1978 to 1985, the ratios of dry sand area to total island land and surface area remained

Table 5. Timbalier Island area change matrix, showing beginning categories vertically on the left and ending categories horizontally at the top. Values within the matrix represent the amount of area (ha) from which the category on the left changed to (or remained) the category on the top.

Timbalier Island

1978-1982

Changed From:	Changed To: Gulf	Bay	Pond	Canal	Beach (change values - hectares) Dune	Swale	Marsh	Mangrv	Spoil	RipRap	STARTING TOTALS
Gulf	23.1	0.0	0.0	0.0	25.3	0.9	0.0	0.0	0.0	0.0	0.0	49.4
Bay	8.2	98.9	0.2	0.1	16.7	5.2	0.3	3.4	0.3	0.2	0.0	133.5
Ponds	0.0	1.6	71.3	0.2	1.8	0.8	1.1	1.3	0.2	0.0	0.0	78.2
Canal	0.0	6.1	0.6	133.4	1.8	0.0	1.1	0.9	1.0	0.4	0.0	145.4
Beach	19.8	3.1	0.2	0.1	43.0	17.3	3.3	4.0	0.1	0.2	0.0	90.9
Dune	7.0	0.9	0.4	0.0	8.5	11.1	10.5	2.1	0.2	0.3	0.0	40.9
Swale	0.0	4.6	1.0	2.5	2.2	1.9	195.0	10.3	2.8	3.2	0.0	223.5
Marsh	5.1	1.7	1.0	0.8	1.8	1.3	7.8	86.1	4.2	2.2	0.0	111.9
Mangrove	0.0	11.7	13.8	0.8	1.0	1.9	4.2	3.5	187.5	0.3	0.0	224.6
Spoil	0.0	1.5	0.0	0.1	0.3	0.2	8.7	1.3	0.1	3.5	0.0	15.7
RipRap	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.6
END TOTALS	63.3	130.1	88.5	137.8	102.4	40.5	232.1	113.0	196.2	10.3	0.6	1114.6

1982-1984

Changed From:	Changed To: Gulf	Bay	Pond	Canal	Beach (change values - hectares) Dune	Swale	Marsh	Mangrv	Spoil	RipRap	STARTING TOTALS
Gulf	57.7	0.0	0.0	0.0	5.3	0.0	0.0	0.0	0.0	0.0	0.0	63.1
Bay	6.6	106.5	0.0	0.2	8.9	2.5	0.0	5.1	0.2	0.0	0.0	130.1
Ponds	0.0	0.3	85.6	0.1	0.2	0.1	1.1	1.0	0.0	0.0	0.0	88.5
Canal	0.0	1.5	0.5	134.1	0.0	0.0	0.7	0.8	0.0	0.1	0.0	137.8
Beach	21.8	6.7	0.5	0.6	47.0	12.4	5.2	8.0	0.2	0.1	0.0	102.4
Dune	4.7	2.4	0.7	0.0	5.9	12.9	11.8	2.0	0.1	0.0	0.0	40.5
Swale	0.0	3.4	1.4	2.7	1.5	1.2	203.4	17.4	0.6	0.6	0.0	232.1
Marsh	2.3	1.6	3.0	0.8	1.8	1.1	4.1	97.5	0.7	0.0	0.0	112.9
Mangrove	0.0	8.1	8.6	1.0	0.1	0.0	3.0	160.2	15.1	0.1	0.0	196.2
Spoil	0.0	0.1	0.0	0.1	0.7	0.2	4.7	0.6	0.0	3.8	0.0	10.3
RipRap	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.6
END TOTALS	93.0	130.5	100.2	139.6	71.3	30.5	234.1	292.7	17.1	4.7	0.6	1114.3

1984-1985

Changed From:	Changed To: Gulf	Bay	Pond	Canal	Beach (change values - hectares) Dune	Swale	Marsh	Mangrv	Spoil	RipRap	STARTING TOTALS
Gulf	91.8	0.5	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	93.0
Bay	9.4	106.6	0.0	0.2	11.9	1.4	0.0	0.9	0.0	0.0	0.0	130.5
Ponds	0.0	4.5	83.1	1.1	5.1	2.0	2.5	1.9	0.0	0.0	0.0	100.2
Canal	0.9	1.1	0.1	133.2	1.9	0.1	0.4	0.7	0.0	1.0	0.3	139.6
Beach	33.3	1.6	0.0	0.1	29.2	3.9	1.9	1.6	0.0	0.0	0.0	71.6
Dune	18.7	0.6	0.1	0.0	6.6	3.3	0.9	0.4	0.0	0.0	0.0	30.5
Swale	10.4	0.9	0.6	2.4	22.1	11.2	168.7	16.1	0.0	1.6	0.1	234.2
Marsh	2.1	12.2	25.7	1.9	16.2	6.0	5.7	222.2	0.4	0.3	0.1	292.7
Mangrove	0.0	1.8	0.5	0.4	0.4	0.1	0.0	9.8	4.2	0.0	0.0	17.2
Spoil	0.5	0.1	0.0	0.1	0.7	0.1	1.6	0.0	0.0	1.7	0.0	4.7
RipRap	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.6
END TOTALS	167.1	129.8	110.2	139.4	94.9	28.0	181.7	253.6	4.6	4.7	1.0	1114.8

1978-1985

Changed From:	Changed To: Gulf	Bay	Pond	Canal	Beach (change values - hectares) Dune	Swale	Marsh	Mangrv	Spoil	RipRap	STARTING TOTALS
Gulf	40.0	0.0	0.0	0.0	8.3	0.5	0.5	0.0	0.0	0.0	0.0	49.4
Bay	36.9	70.0	0.0	0.1	18.2	1.6	0.5	6.2	0.0	0.0	0.0	133.6
Ponds	0.4	4.7	61.6	0.5	5.1	2.6	2.0	1.6	0.0	0.0	0.0	78.2
Canal	1.1	8.4	0.8	128.4	3.0	0.2	0.6	1.6	0.0	1.1	0.4	145.4
Beach	49.1	1.0	0.0	0.1	24.0	7.9	6.3	2.5	0.0	0.0	0.0	90.9
Dune	23.0	1.0	0.1	0.0	8.2	2.7	5.3	0.5	0.0	0.0	0.0	40.9
Swale	3.2	8.9	1.4	6.1	10.5	7.5	149.6	34.2	0.0	2.1	0.1	223.5
Marsh	9.5	3.6	3.4	1.7	4.5	1.3	8.1	79.1	0.4	0.5	0.0	112.0
Mangrove	3.2	30.5	43.2	2.4	10.5	3.4	1.3	125.9	4.2	0.1	0.0	224.7
Spoil	0.6	1.6	0.0	0.2	2.5	0.4	7.5	2.1	0.0	0.8	0.0	15.7
RipRap	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.6
END TOTALS	167.1	129.8	110.2	139.4	94.8	28.0	181.7	253.6	4.6	4.7	1.0	1114.7

Timbalier Island Area Changes

Total Land Categories

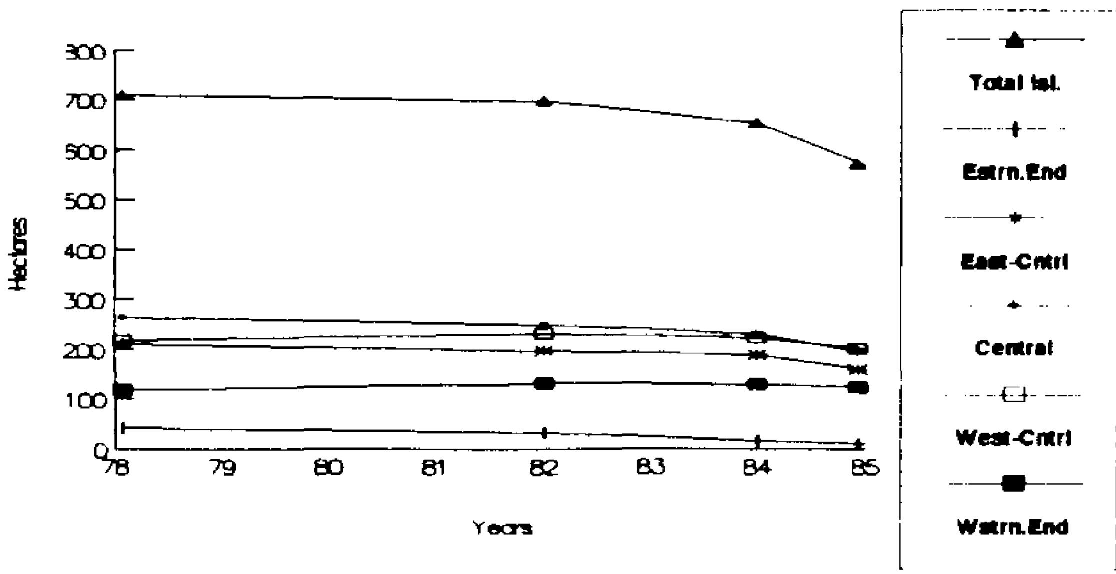


Figure 31. Changes in area of combined Timbalier Island land categories for total island and within each transect area polygon, 1978-1985.

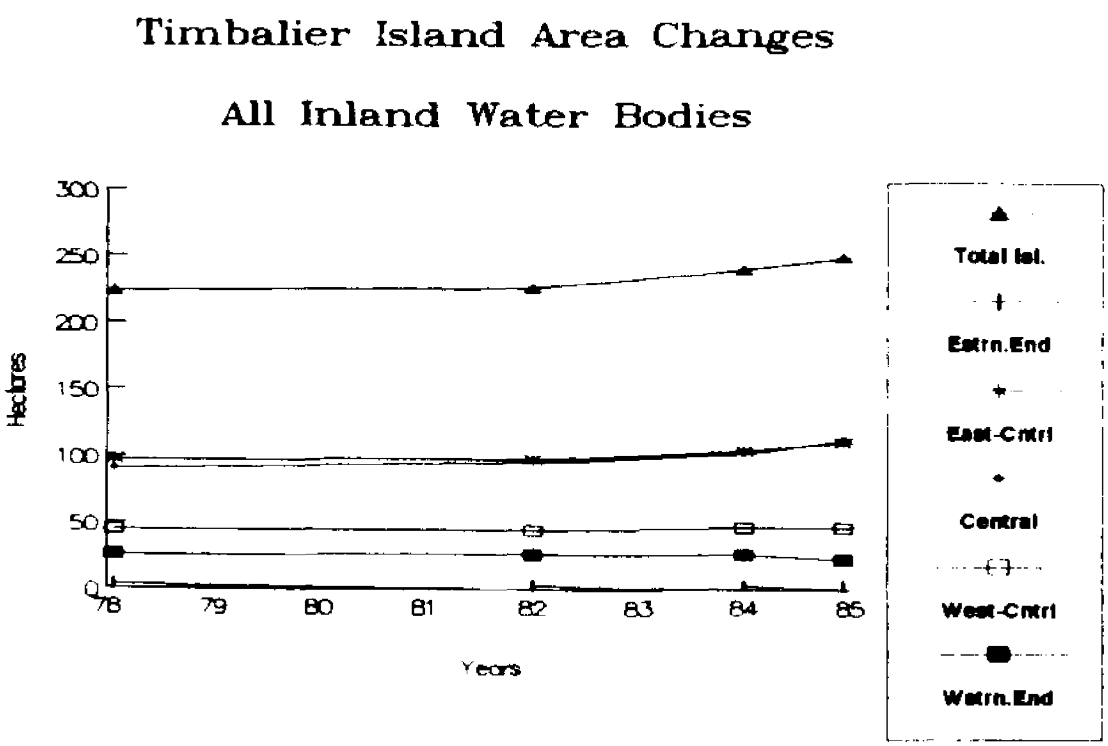


Figure 32. Changes in Timbalier Island inland water area for total island and within each transect area polygon, 1978-1985.

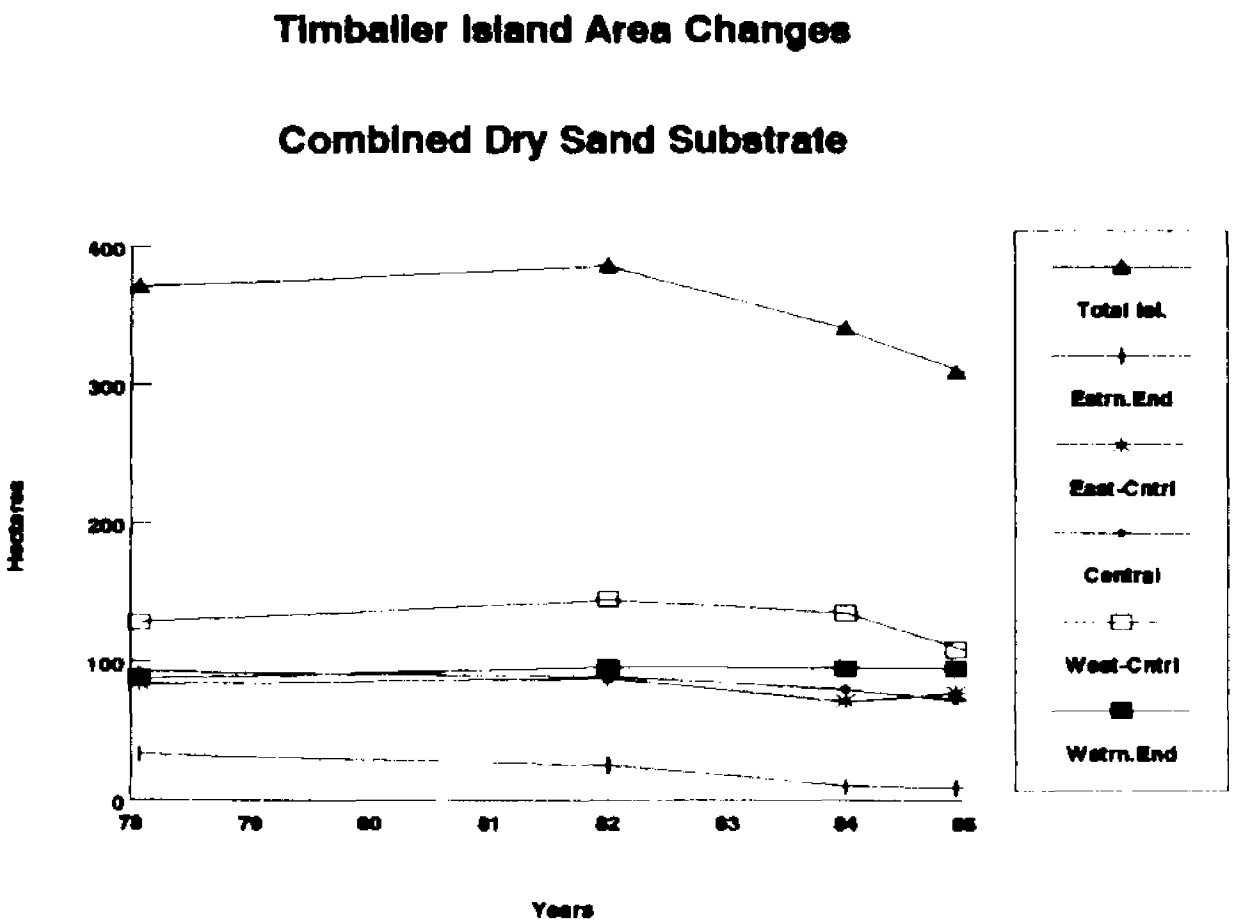


Figure 33. Changes in Timbalier Island combined dry sand substrate area for total island and within each transect area polygon 1978-1985.

essentially the same. In summary, areas of dry or well drained sand substrate underwent an overall reduction in surface area, while retaining the same proportions relative to total island area.

(1) Beaches

Island beaches demonstrated a fluctuating pattern of gain and loss over the period of this study (Figure 34). A net loss of 17.4 ha in the eastern end (Table 4) was offset by net gains in all other areas, resulting in an overall net gain of 3.9 ha or 4.4% of the 1978 beach area. Gulf waters replaced 49.1 ha of beach (Table 5) during the seven years of the study. This indicated that the beach had been displaced landward, while maintaining a relatively consistent aerial extent . Beach replaced 10.5 ha of swale and mangrove, 8.2 ha of dune, 4.5 ha of marsh, and 5.1 ha of ponds, while yielding 7.9 ha to dune, 6.3 ha to swale, and 2.5 ha to marsh. Therefore, total beach area remained relatively constant throughout the study, while being steadily displaced shoreward.

(2) Dunes

Dunes generally declined in area during the study (Figure 35), dropping from 40.9 ha in 1978 to 28.0 ha by 1985 (Table 4). The net loss was 12.9 ha, or 31.5% of the 1978 area. Of these, 23.0 ha were lost to the Gulf of Mexico, while 8.2 and 5.4 ha were replaced by beach and swale, respectively (Table 5). Declines were especially high on the eastern end of the island, where losses amounted to 81%. Partially offsetting the losses were gains from beach (7.9 ha), swale (7.5 ha), mangrove (3.4 ha), and ponds (2.6 ha). Dunes, therefore, decreased in surface area during the study, with losses greatest in the eastern end of the island.

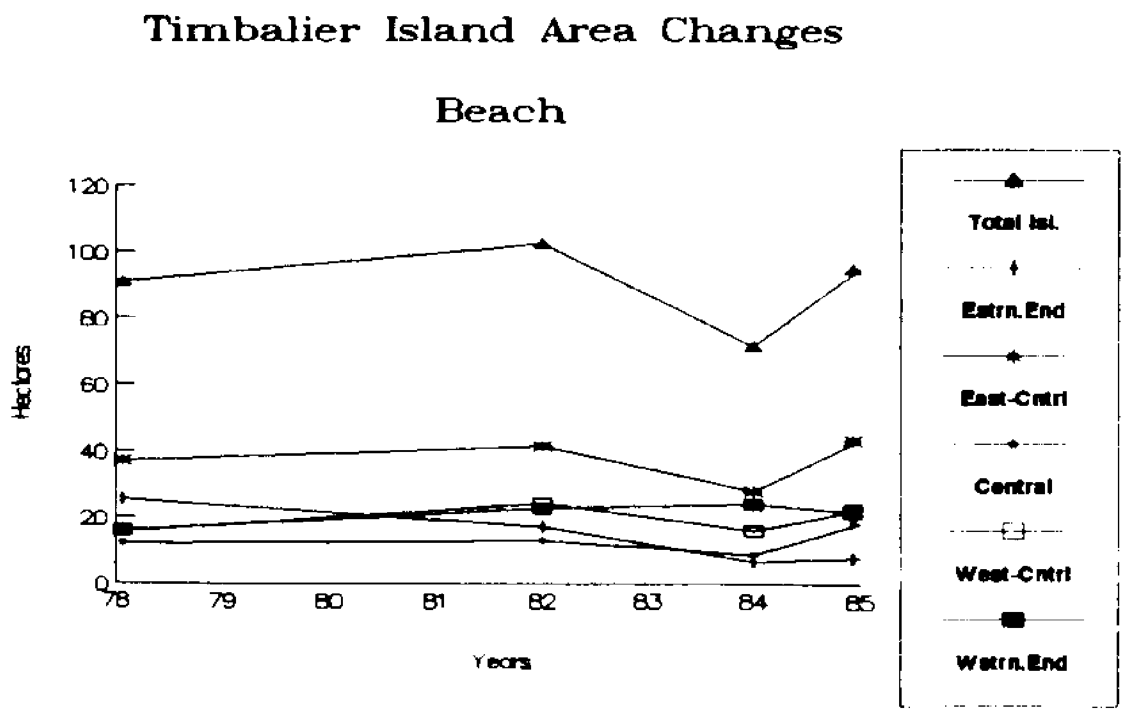


Figure 34. Changes in Timbalier Island beach area for total island and within each transect area polygon, 1978-1985.

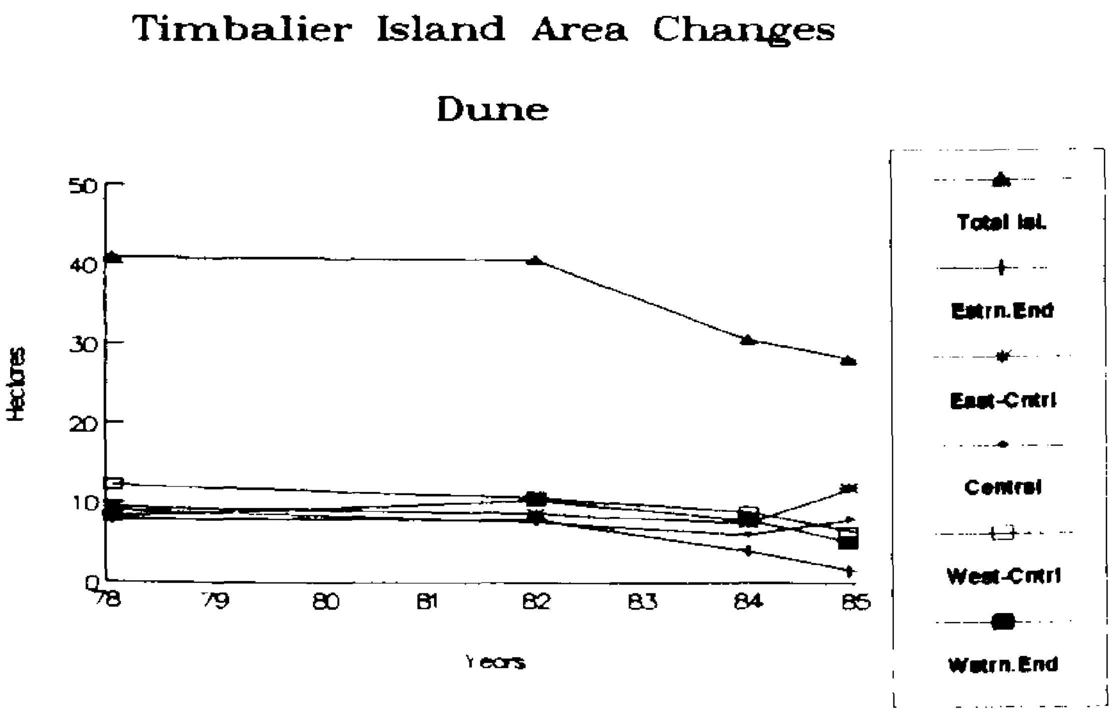


Figure 35. Changes in Timbalier Island dune area for total island and within each transect area polygon, 1978-1985.

(3) Swale

Swale showed a gradual but steady increase between 1978 and 1984 from 223.5 ha to 234.2 ha (Figure 36; Table 4). However, this trend was reversed in the last year of the study in all but the western end of the island, resulting in a net loss of 41.8 ha, or 18.7% of the 1978 area. The western end showed a net gain of 15.5%. Conversion of swale to marsh (34.2 ha) accounted for the majority of the loss of swale (Table 5). Swale gained area primarily from marsh, spoil, beach, and dune. Of the 1978 spoil area, 48% (7.5 ha) had reverted to swale by 1985, and accounted for the primary source of new swale in all but the eastern and western ends of the island. Therefore, although swale increased in surface area during most of the study, losses in the final period resulted in a net overall decline.

b. Combined Wetlands Categories

Total areas of wetlands (mangroves and marsh) showed an overall net loss of area during the study of 78.4 ha representing 23.3% of the 1978 total of 336.6 ha (Figure 37, Table 4). The ratios of wetlands to total island land area and surface area were 47.5% and 36.2%, respectively, for 1978, and 45.4% and 31.6% for 1985. While the ratio of wetlands to total land area remained essentially the same, the greater spread of wetlands area to total surface area is the result of an increase in the extent of enclosed water bodies (ponds). This is an indication of internal breakup due partly to frost damage of island mangroves. The net result was a reduction in surface area of wetlands during the study.

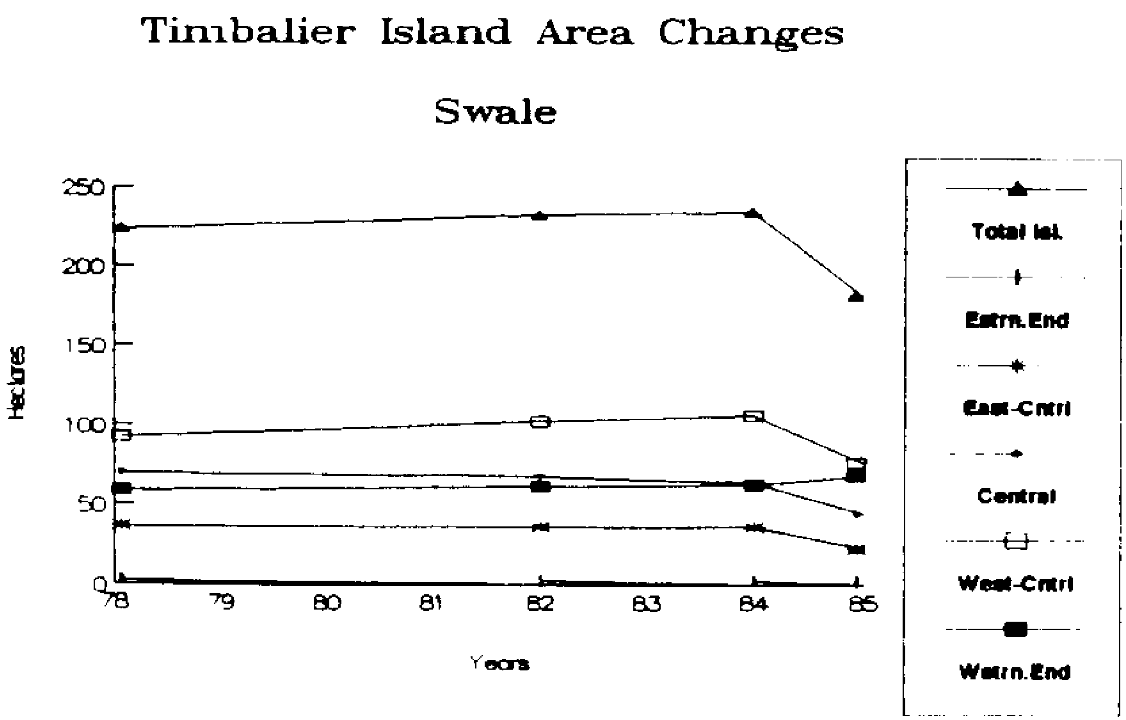


Figure 36. Changes in Timbalier Island swale area for total island and within each transect area polygon, 1978-1985.

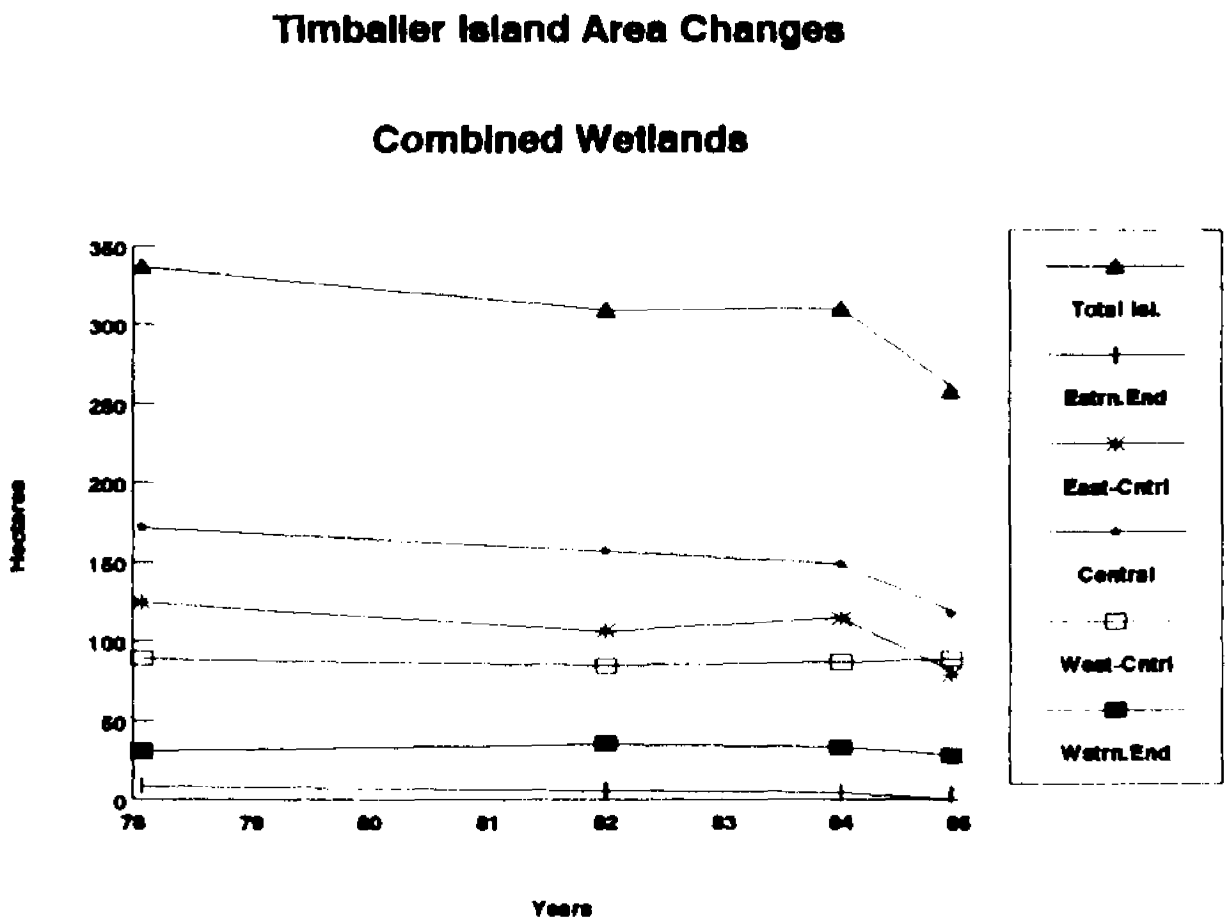


Figure 37. Changes in Timbalier Island combined wetlands area for total island and within each transect area polygon 1978-1985.

(1) Mangroves

Mangroves underwent the most dramatic change of all component island cover categories, declining from the most extensive land cover category at 224.7 ha in 1978 to just 4.6 ha by 1985 (Table 4; Figure 38). The major decrease in mangroves occurred as a result of hard freezes during the winters of 1983-1984 and 1984-1985. The resulting mangrove diebacks provided an opportunity for marsh grasses (primarily *Spartina alterniflora*) which occupy similar environments, to become established within much of the former mangrove areas.

Therefore, the majority of mangrove areas reverted to marsh, resulting in a conversion of 160.2 ha from 1982 to 1985 (Table 5). Destruction of mangroves also resulted in a relatively large loss of land area. Loss from areas occupied by mangroves in 1978 amounted to 79.4 ha by 1985, or 35.3% of the original area. Of the area lost, 3.2 ha became Gulf water, 30.5 ha became bay water, 43.2 ha became ponds, and 2.4 ha was incorporated into canals. Therefore, mangroves declined dramatically during the study, resulting in large increases in island marshes, as well as substantial losses of island land area.

(2) Marsh

Marsh areas remained quite stable in all areas between 1978 and 1982 (Figure 39), but increased from 112.9 ha to 292.7 ha between 1982 and 1984 due to conversion of frost-damaged mangroves to marsh (Table 4). Following this increase, marsh area declined to 253.5 ha by 1985. This represented an overall net increase of 141.6 ha or 126.5% of the 1978 marsh area. Although former mangroves accounted for the most significant source of new marsh, 34.2 ha originated as swale, while beach, spoil, canal, pond, and bay contributed an additional 14.0 ha (Table 5). Despite the overall increase in area, 18.2 ha of the original 1978 marsh area became open water by 1985, while 14.0 ha became

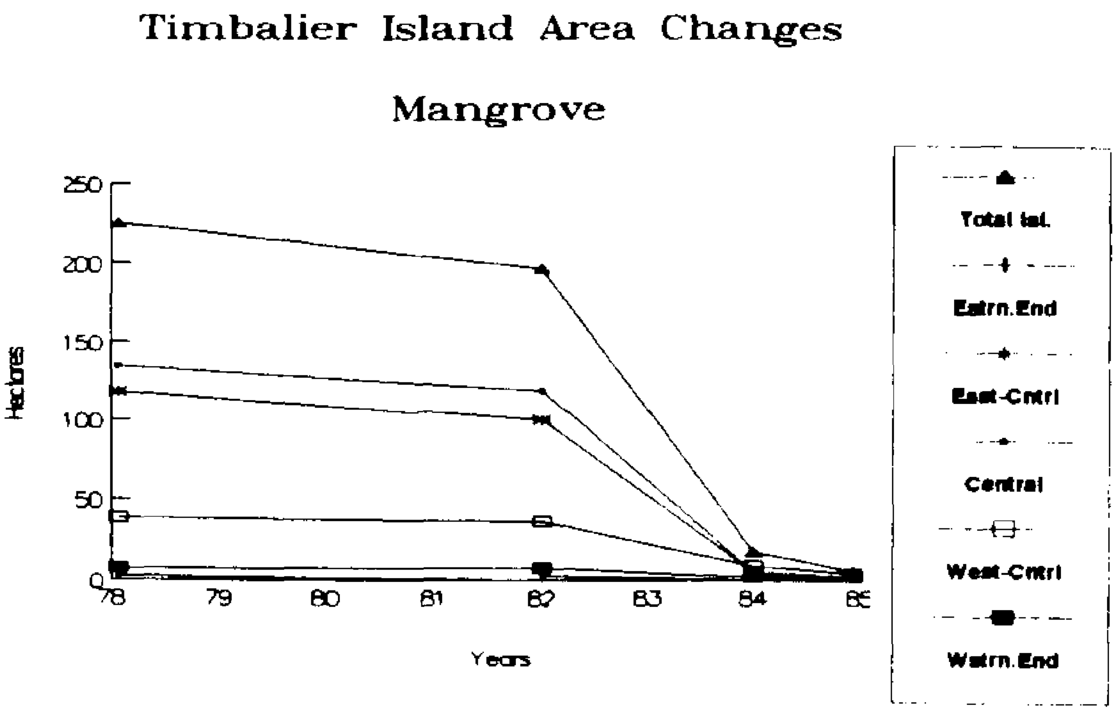


Figure 38. Changes in Timbalier Island mangrove area for total island and within each transect area polygon, 1978-1985.

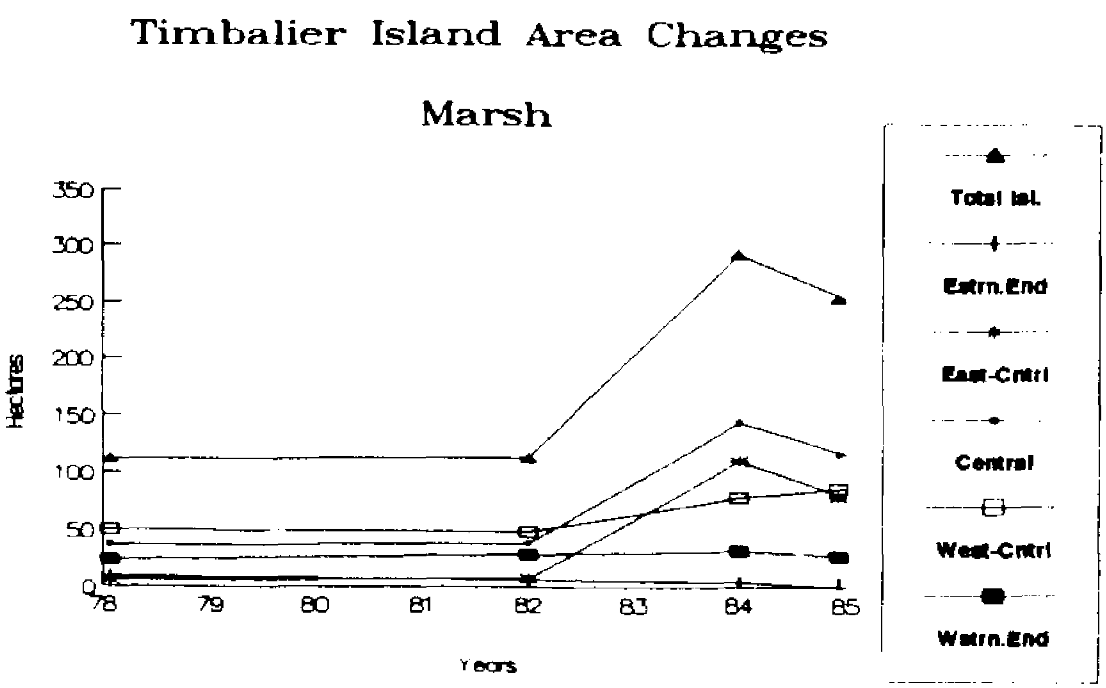


Figure 39. Changes in Timbalier Island marsh area for total island and w.thin each transect area polygon, 1978-1985.

swale, beach, or dune. The net result was an increase in marsh surface area during the study, primarily through the conversion of damaged mangrove areas.

B. Transect Change Analysis

The trends derived from the transect data for Timbalier Island indicated an erosion of the eastern end of the island, accompanied by an extension of the western end (Figures 24 and 25, pages 87 and 88). This occurred while the Gulf shoreline underwent a gradual retreat and the overall width of the island decreased. The generalized trends and trends relative to specific cover categories are discussed below.

1. Gulf Shoreline

The Timbalier Island Gulf shoreline experienced an average rate of erosion of 8 m/yr during the study (Table 6). The lowest rate of loss (2 m/yr) occurred during the first period of the study, from 1978 to 1982. The highest rate (48 m/yr) occurred during the last year, 1984-1985. The sequence of shoreline change can be seen in Figure 40. This series also shows the westward lateral migration of the island through erosion of the eastern end and the buildup and extension of the western end.

Although an average loss of shoreline was recorded during the 1978-1982 period, the majority of the transects sampled (55.8%) experienced a net shoreline gain. The overall average loss for this period was due, to a large extent, to the lateral erosion of the eastern end of the island, where individual shoreline transects averaged losses as high as 114 m/yr. The ratio of gains to losses was reversed for the period 1982-1984, when the percentage of transects eroding exceeded those gaining by 74.1% to 20.7%. This trend increased during 1984-1985,

Table 6. **Timbalier Island transect change summaries, showing average, maximum, and minimum change for each category, as well as the percentage of transects within which the category decreased, increased, or remained unchanged.**

1978-1982	Gulf Shore	Bay Shore	Land Width	Island Width	Combined Dry Sand	Combined Wetlands	Dune Location	Marsh Location
Average Change (m)	-10	-1	-13	-9	9	-21	-9	18
Maximum Gain (m)	193	686	229	229	345	113	197	650
Maximum Loss (m)	-498	-182	-381	-381	-381	-219	-457	-295
Percent Losing	39.9%	54.3%	48.6%	45.7%	39.1%	51.5%	44.2%	36.9%
Percent Unchanged	4.3%	25.4%	1.4%	2.2%	0.7%	10.8%	6.2%	22.5%
Percent Gaining	55.8%	20.3%	50.0%	52.2%	60.1%	37.7%	49.6%	40.5%
1982-1984	**Gulf Shore**	**Bay Shore**	**Land Width**	**Island Width**	**Combined Dry Sand**	**Combined Wetlands**	**Dune Location**	**Marsh Location**
Average Change (m)	-21	2	-30	-22	-29	-1	5	4
Maximum Gain (m)	129	350	268	268	131	460	152	460
Maximum Loss (m)	-391	-76	-452	-452	-452	-183	-156	-459
Percent Losing	74.1%	49.6%	74.1%	74.8%	72.6%	48.0%	33.6%	49.1%
Percent Unchanged	5.2%	20.0%	0.0%	0.0%	0.0%	6.3%	0.9%	0.0%
Percent Gaining	20.7%	30.4%	25.9%	25.2%	27.4%	45.7%	65.5%	50.9%
1984-1985	**Gulf Shore**	**Bay Shore**	**Land Width**	**Island Width**	**Combined Dry Sand**	**Combined Wetlands**	**Dune Location**	**Marsh Location**
Average Change (m)	-54	-8	-65	-56	-22	-47	-48	-31
Maximum Gain (m)	63	271	170	170	221	146	137	322
Maximum Loss (m)	-361	-217	-331	-264	-207	-337	-159	-311
Percent Losing	88.8%	38.8%	86.6%	88.8%	63.4%	62.3%	89.4%	54.8%
Percent Unchanged	3.0%	51.5%	0.0%	0.7%	0.0%	14.8%	7.7%	24.0%
Percent Gaining	8.2%	9.7%	13.4%	10.4%	36.6%	23.0%	2.9%	21.2%
1978-1985	**Gulf Shore**	**Bay Shore**	**Land Width**	**Island Width**	**Combined Dry Sand**	**Combined Wetlands**	**Dune Location**	**Marsh Location**
Average Change (m)	-80	-28	-102	-83	-40	-68	-28	-12
Maximum Gain (m)	164	378	304	304	314	414	280	580
Maximum Loss (m)	-630	-356	-558	-408	-381	-597	-168	-341
Percent Losing	78.0%	68.1%	75.2%	78.7%	65.2%	60.8%	74.5%	56.4%
Percent Unchanged	0.0%	23.4%	0.0%	0.0%	0.0%	7.7%	0.0%	0.0%
Percent Gaining	22.0%	8.5%	24.8%	21.3%	34.8%	31.5%	25.5%	43.6%

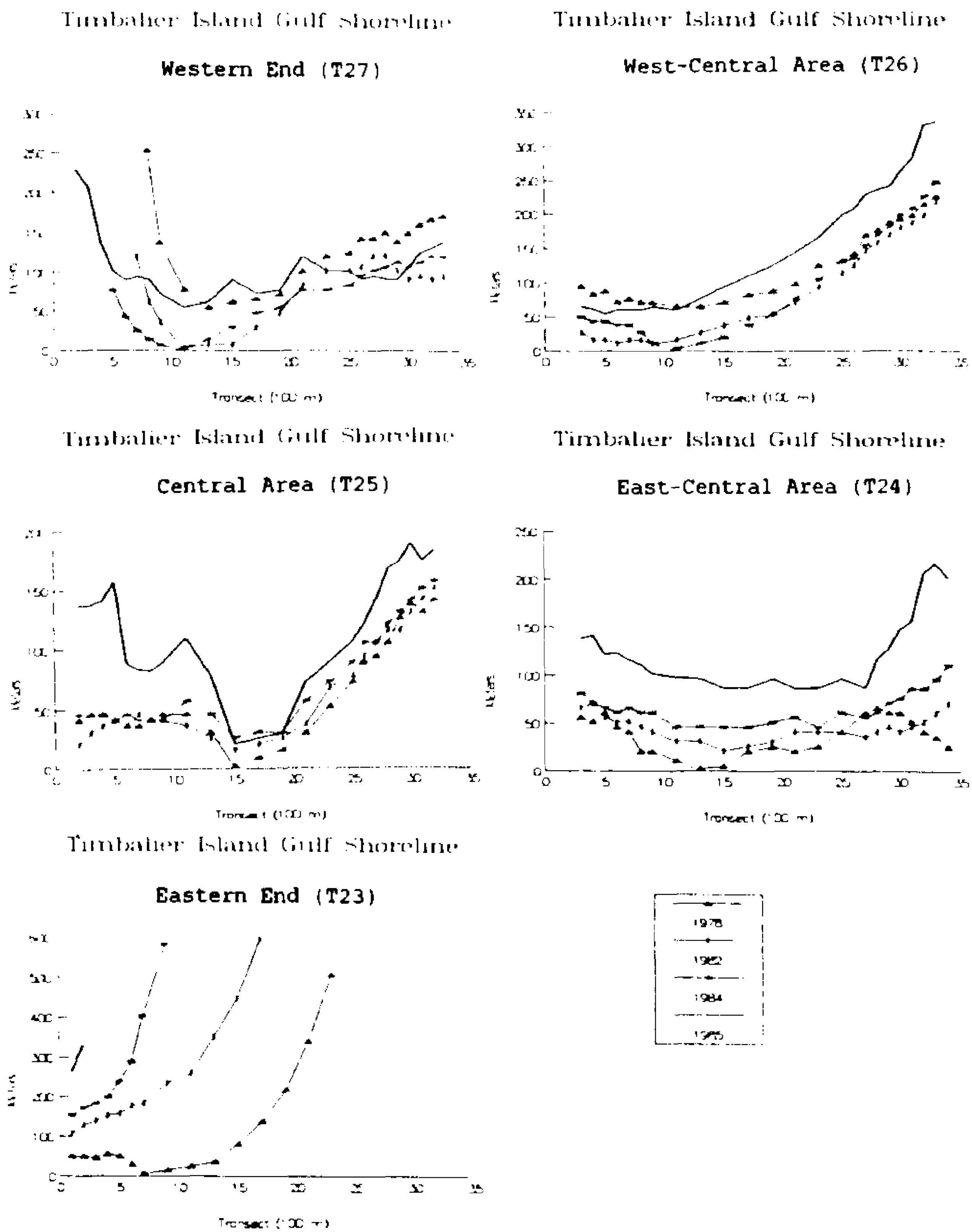


Figure 40. Timbalier Island shoreline change by transect area. Transect area T27 shows shoreline change on the western end, while T23 shows change on the eastern end.

resulting in 88.8% of all transects decreasing and only 8.2% showing an extension of shoreline. The overall ratio was 78.0% eroding and 22.0 gaining, resulting in a net average shoreline loss of 55 m during the seven years of the study.

2. Bay Shoreline

Although exhibiting considerable erosion, the bay shoreline remained one of the more stable features of Timbalier Island during this study. From 1978 to 1985, 23.4% of all transects, remained unchanged with respect to the location of the bay shoreline (Table 6). More than half (51.5%) remained unchanged during the hurricane period of 1984-1985. However, the percentage of transects exhibiting a net bayside erosion exceeded those exhibiting gains in all periods of the study. The highest rate of loss, 8 m/yr, occurred during the 1984-1985 period, despite the majority of transects remaining stable. During the 1978-1982 period there was an slight loss (less than 1 m/yr), while during the 1982-1984 period there was an average gain of 1 m/yr. This resulted in 68.1% of all transects experiencing a loss of bay shoreline, while 8.5% experienced gains. The overall effect was a 4 m/yr average net loss of bay shoreline.

3. Island Width

Island width, including all land categories and inland water categories decreased throughout the study from an average of 702 m in 1978, to 653 m in 1985 (Figures 41, 42, and 43; Table 7). Maximum width declined from 1517 m in 1978 to 1285 m in 1985. The overall average decrease was 12 m/yr, with 78.7% of the sampled transects decreasing in width (Table 6). The greatest loss occurred between 1984 and 1985, with an average decrease in width of 56 m/yr. As with the cumulative land

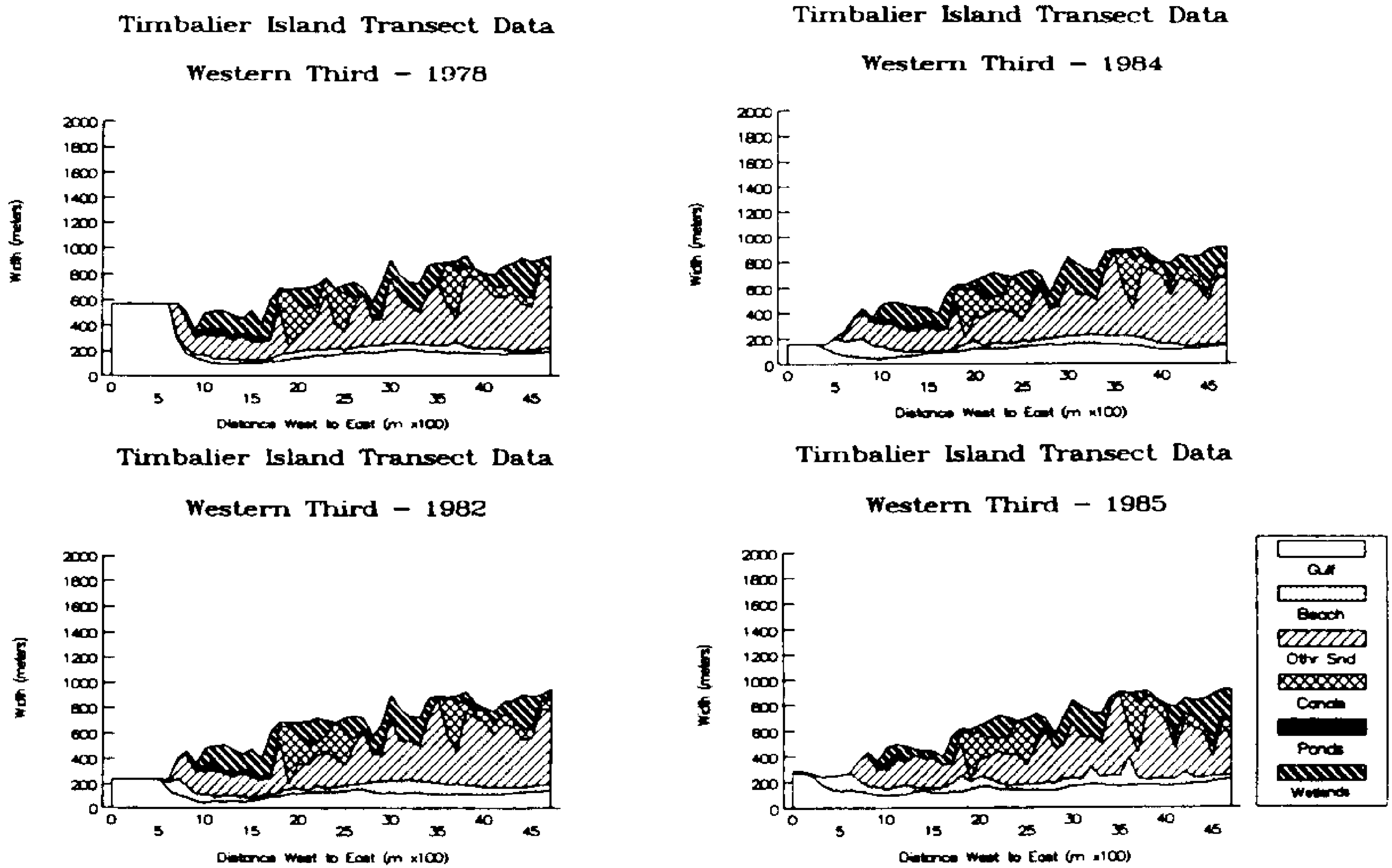


Figure 41. Cumulative widths for the western third of Timbalier Island, 1978-1985. Relative widths of major island components are depicted by individual patterns.

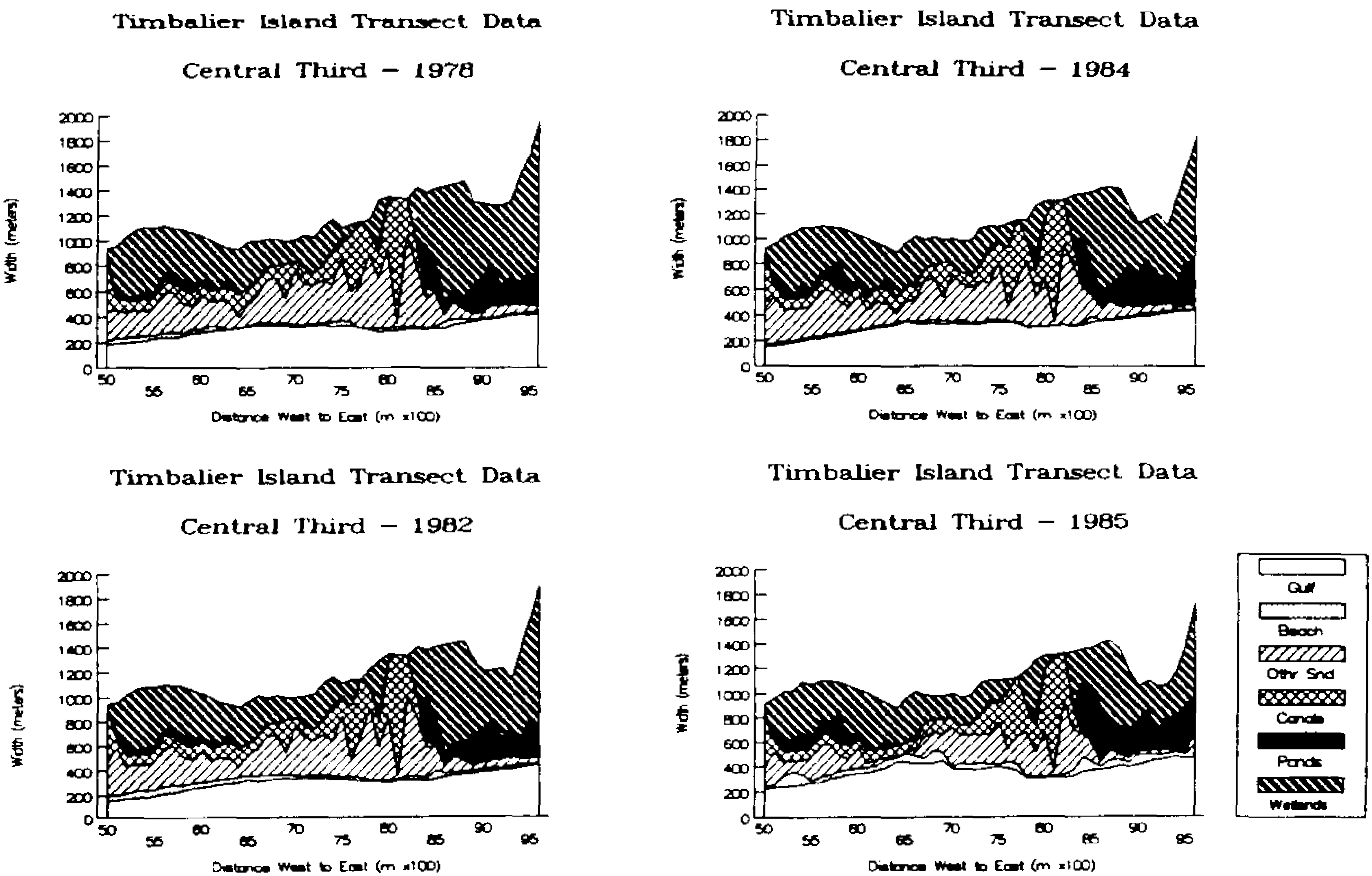


Figure 42. Cumulative widths for the central third of Timbalier Island, 1978-1985. Relative widths of major island components are depicted by individual patterns.

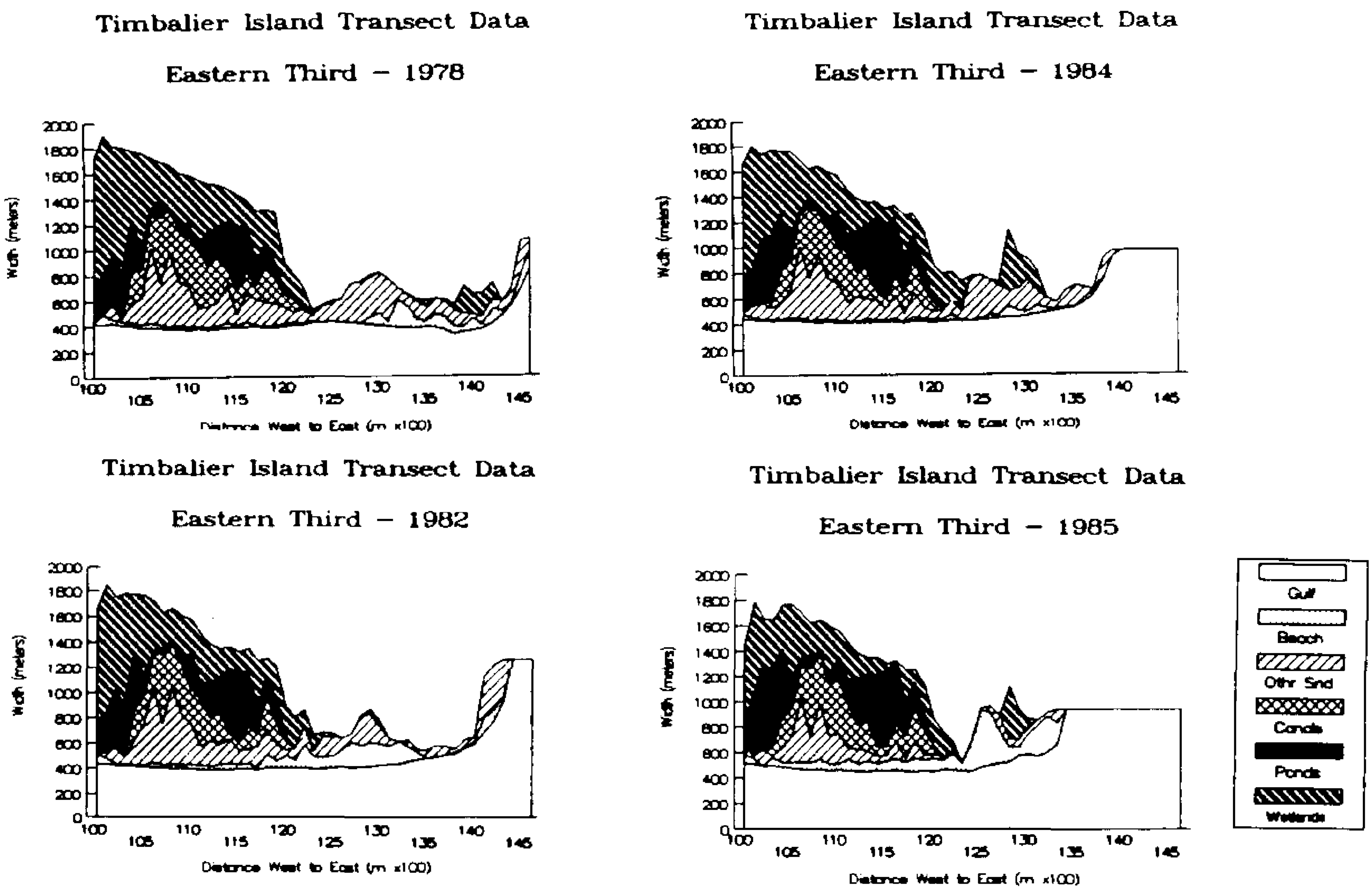


Figure 43. Cumulative widths for the eastern third of Timbalier Island, 1978-1985. Relative widths of major island components are depicted by individual patterns.

Table 7. Timbalier Island transect summaries, showing average and maximum category width, and the percentage of total transects containing each category.

1978	Beach	Dune	Swale	Mngrv	Marsh	Wetlands
Average Width (m)	67	34	208	295	117	306
Maximum Width (m)	412	154	637	1229	354	1229
Percent of Total	99.3%	87.5%	77.9%	59.6%	71.3%	85.2%
	Pond	**Canal**	**Spoil**	**RipRap**	**Land**	**Total**
Average Width (m)	125	194	71	0	532	702
Maximum Width (m)	496	982	264	17	1282	1517
Percent of Total	50.0%	55.1%	19.1%	4.4%	100.0%	100.0%

1982	Beach	Dune	Swale	Mngrv	Marsh	Wetlands
Average Width (m)	76	33	220	262	109	274
Maximum Width (m)	398	305	638	1128	383	1128
Percent of Total	99.3%	88.1%	78.4%	59.7%	77.6%	88.7%
	Pond	**Canal**	**Spoil**	**RipRap**	**Land**	**Total**
Average Width (m)	137	190	55	11	527	703
Maximum Width (m)	553	982	142	16	1176	1449
Percent of Total	53.0%	54.5%	14.2%	4.5%	100.0%	100.0%

1984	Beach	Dune	Swale	Mngrv	Marsh	Wetlands
Average Width (m)	55	25	214	32	271	287
Maximum Width (m)	303	91	631	79	1001	1038
Percent of Total	95.7%	92.4%	84.0%	42.7%	85.5%	85.5%
	Pond	**Canal**	**Spoil**	**RipRap**	**Land**	**Total**
Average Width (m)	143	188	47	11	508	696
Maximum Width (m)	570	955	139	16	1084	1399
Percent of Total	57.3%	56.5%	8.4%	4.6%	100.0%	100.0%

1985	Beach	Dune	Swale	Mngrv	Marsh	Wetlands
Average Width (m)	76	28	196	16	245	249
Maximum Width (m)	446	121	620	34	754	754
Percent of Total	99.3%	83.6%	73.4%	21.9%	82.8%	85.2%
	Pond	**Canal**	**Spoil**	**RipRap**	**Land**	**Total**
Average Width (m)	190	187	32	11	451	653
Maximum Width (m)	672	955	105	16	956	1285
Percent of Total	49.2%	57.8%	12.5%	7.0%	100.0%	100.0%

values, the initial period (1978-1982) provided the lowest rates of loss at 2 m/yr, and highest percentage (52.2%) of transects exhibiting an increase in width. The overall effect was a narrowing of island width during the study.

a. Canals

Transects containing canal values (canal transects) comprised between 54% and 58% of all those sampled (Table 7). Average canal widths ranged from 194 m in 1978, to 187 m in 1985. Compared to transects not containing canal values, canal transects showed consistently lower average rates of loss for Gulf shoreline, island width, and cumulative land width for all periods of the study (Table 8). Differences were statistically significant ($\alpha \leq 0.05$) for Gulf shoreline erosion for 1978-1982, 1982-1984, and 1978-1985. Canal transects averaged shoreline gains of 3 m/yr for 1978-1982, compared to average shoreline losses of 10 m/yr for non-canal transects during the same period. Canal transects averaged shoreline losses of 3 m/yr and 48 m/yr compared to non-canal transect losses of 20 m/yr and 68 m/yr for 1982-1984 and 1984-1985, respectively. Therefore, canal widths decreased slightly, while shoreline erosion in areas containing canals averaged lower than in areas not containing canals.

b. Ponds

Ponds were encountered in 49% to 57% of all sampled transects (Table 7). Transects containing pond values (pond transects) had significantly lower ($\alpha \leq 0.05$) rates of Gulf shoreline erosion than transects not containing ponds throughout the study (Table 9). Gulf shoreline changes for pond transects ranged from a gain of 3 m/yr for 1978-1982, to losses of 5 m/yr and 44 m/yr for 1982-1984 and 1984-1985.

Table 8. Relative influence of Timbalier Island canals on change in Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for canal and non-canal transects, and analysis of means Z values ($Z \geq 2 = \alpha \leq 0.05$).

1978-1982 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	12	-5	5
Transects Decreasing	30.7%	41.3%	45.3%
Transects Unchanged	6.7%	0.0%	4.0%
Transects Increasing	62.7%	54.7%	52.0%
Category Width R^2 Values	0.0827	0.0827	0.0339
Change - Other Transects (m)	-41	-16	-24
Analysis of Means Z Values	2.88	0.53	1.07

Category Encountered in 55.1% of All 1978 Transects

1982-1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	7	-19	28
Transects Decreasing	67.1%	79.5%	78.1%
Transects Unchanged	8.2%	0.0%	0.0%
Transects Increasing	24.7%	20.5%	21.9%
Category Width R^2 Values	0.0487	0.0520	0.0018
Change - Other Transects (m)	-39	-27	35
Analysis of Means Z Values	3.15	0.75	0.62

Category Encountered in 54.5% of All 1982 Transects

1984-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-48	54	62
Transects Decreasing	89.2%	94.6%	94.6%
Transects Unchanged	2.7%	0.0%	0.0%
Transects Increasing	8.1%	5.4%	5.4%
Category Width R^2 Values	0.1610	0.1443	0.0675
Change - Other Transects (m)	-68	-64	74
Analysis of Means Z Values	1.72	0.76	0.76

Category Encountered in 56.5% of All 1984 Transects

1978-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-41	-76	91
Transects Decreasing	84.0%	88.0%	85.3%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	16.0%	12.0%	14.7%
Category Width R^2 Values	0.0086	0.0289	0.0044
Change - Other Transects (m)	-84	-107	-135
Analysis of Means Z Values	2.72	1.39	1.61

Category Encountered in 55.6% of All 1978 Transects

Table 9. Relative influence of Timbalier Island ponds on change in Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for pond and non-pond transects, and analysis of means Z values ($Z \geq 2 = \alpha \leq 0.05$).

1978-1982 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	12	-22	28
Transects Decreasing	45.6%	52.9%	61.8%
Transects Unchanged	0.0%	0.0%	1.5%
Transects Increasing	54.4%	45.6%	38.2%
Category Width R^2 Values	0.2453	0.4092	0.4409
Change - Other Transects (m)	-35	2	1
Analysis of Means Z Values	2.76	-1.90	2.18

Category Encountered in 50.0% of All 1978 Transects

1982-1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-9	-24	-38
Transects Decreasing	80.3%	85.9%	85.9%
Transects Unchanged	5.6%	0.0%	0.0%
Transects Increasing	14.1%	14.1%	14.1%
Category Width R^2 Values	0.0550	0.0902	0.2221
Change - Other Transects (m)	-35	-21	-22
Analysis of Means Z Values	2.56	0.01	0.91

Category Encountered in 53.0% of All 1982 Transects

1984-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-44	-69	-82
Transects Decreasing	93.3%	97.3%	90.7%
Transects Unchanged	1.3%	0.0%	1.3%
Transects Increasing	5.3%	1.3%	9.3%
Category Width R^2 Values	0.0073	0.0905	0.1841
Change - Other Transects (m)	-73	-44	-41
Analysis of Means Z Values	1.42	-2.10	3.41

Category Encountered in 57.3% of All 1984 Transects

1978-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-42	-116	-158
Transects Decreasing	86.8%	92.6%	88.2%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	13.2%	7.4%	11.8%
Category Width R^2 Values	0.1685	0.3700	0.4412
Change - Other Transects (m)	-79	-64	-62
Analysis of Means Z Values	2.52	-2.62	-4.02

Category Encountered in 50.4% of All 1978 Transects

Non-pond transects experienced losses of 9 m/yr, 18 m/yr, and 73 m/yr for these same three periods. Land loss (change from land category to open water body category) rates among pond transects were significantly higher than among transects not containing ponds for 1978-1982, as were width and land loss rates for 1984-1985 and 1978-1985. Average pond width increased steadily throughout the study from 126 m in 1978 to 190 m in 1985. Pond width was found to be somewhat linearly correlated with decrease in island width and cumulative land width during the 1978-1982 period, and overall (1978-1985) with r^2 values of 0.409 to 0.441. Overall, ponds increased in width, while areas containing ponds experienced lower Gulf shoreline erosion but higher rates of decline for land and island width.

c. Change Relative to Proximity of Inland Water

The distance from the Gulf shoreline to the nearest inland water body (ponds and canals) was not found to be linearly correlated with changes in Gulf shoreline, island width, or cumulative land width (Table 10). The investigation was extended by considering the bay as an "inland" water body for transects not containing water bodies, however, no improvement in correlation was obtained. Therefore, no relationship was found between the relative proximity of inland water bodies and changes in island shoreline or width.

4. Cumulative Land Width

Combined land categories (excluding ponds, canals, and embayments) decreased throughout the study from an average width of 532 m in 1978 to 45 m in 1985, with an overall average loss of 15 m/yr (Table 7). Maximum land width also decreased from a high of 1229 m in 1978 to 956 m in 1985. The greatest losses occurred during the period from 1984-1985,

Table 10. Relative influence of the proximity of Timbalier Island inland water bodies on change in Gulf shoreline, island width, and cumulative land width.

		Gulf Shoreline	Island Width	Land Width
1978 Proximity vs 1978-1982 Change	R^2 =	0.0013	0.0170	0.0195
1982 Proximity vs 1982-1984 Change	R^2 =	0.0067	0.0107	0.0025
1984 Proximity vs 1984-1985 Change	R^2 =	0.0079	0.0222	0.0012
1978 Proximity vs 1978-1985 Change	R^2 =	0.0023	0.0112	0.0072

when total land width decreased an average of 65 m/yr. The lowest average losses were recorded during the first period of the study (1978-1982), with an average decrease of 3 m/yr (Table 6). However, transects increasing in width outnumbered those decreasing in width during this period by 50.0% to 48.6%, with 1.4% unchanged. The overall ratio was 75.2% decreasing to 24.8% increasing in cumulative land width. Therefore, the overall trend was of accelerating rates of land loss.

a. Combined Dry Sand Categories

Combined cover categories having a dry or well drained sand substrate (beach, dune, swale, and spoil) exhibited an average decrease in width of 6 m/yr over the study period, although gaining an average of 2 m/yr during the first portion of the study (Table 4, Figures 41, 42, and 43). Width increased in 60.1% of these transects between 1978 and 1982, while 72.6% and 63.4% decreased between 1982-1984, and 1984-1985, respectively. The average loss from 1984-1985 was 22 m/yr. Overall, width of combined dry sand categories decreased in 65.2% of all transects sampled, while 36.6% exhibited an increase.

(1) Beach

Beach values were encountered in 95.7% to 99.3% of all transects sampled. Beach width varied from an average of 67 m in 1978, to 55 m in 1984, and 76 m in 1982 and 1985 (Table 7). Significant linear relationships between beach width and changes in Gulf shoreline, island width, or cumulative land width were not detected (Table 11). Maximum beach widths decreased from 412 m in 1978, to 303 m in 1984, and then increased to 446 m in 1986. The analysis of means statistics for transects containing beach values were not considered valid due to the low number of sample transects (fewer than 10) not containing beach

Table 11. Relative influence of Timbalier Island beach on change in Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for beach and non-beach transects, and analysis of means Z values ($Z \geq 2 = \alpha \leq 0.05$).

1978-1982 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-11	-9	13
Transects Decreasing	40.3%	45.5%	49.3%
Transects Unchanged	4.5%	2.2%	1.5%
Transects Increasing	55.2%	52.2%	49.3%
Category Width R^2 Values	0.0556	0.0143	0.0089
Change - Other Transects (m)	5	-11	5
Analysis of Means Z Values	-1.86	0.26	2.43
Category Encountered in 99.3% of All 1978 Transects			

1982-1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	23	-26	-34
Transects Decreasing	75.4%	76.9%	76.1%
Transects Unchanged	5.2%	0.0%	0.0%
Transects Increasing	19.4%	23.1%	23.9%
Category Width R^2 Values	0.0556	0.0085	0.0012
Change - Other Transects (m)	-46	66	66
Analysis of Means Z Values	4.37	-13.48	14.05
Category Encountered in 99.3% of All 1982 Transects			

1984-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-61	-63	-71
Transects Decreasing	94.8%	91.0%	86.6%
Transects Unchanged	2.2%	0.7%	0.0%
Transects Increasing	3.0%	8.2%	13.4%
Category Width R^2 Values	0.0224	0.0042	0.0129
Change - Other Transects (m)	-3	2	-21
Analysis of Means Z Values	5.81	-5.31	-4.6[illegible]
Category Encountered in 95.7% of All 1984 Transects			

1978-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-60	-90	111
Transects Decreasing	81.3%	82.1%	78.4%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	18.7%	17.9%	21.6%
Category Width R^2 Values	0.2048	0.0285	0.0360
Change - Other Transects (m)	-48	-74	-70
Analysis of Means Z Values	-1.70	-1.55	-3.24
Category Encountered in 99.3% of All 1978 Transects			

values. Beach profiles remained relatively consistent throughout the study width while undergoing a continuous shoreward displacement.

(2) Riprap

Prior to 1985, transects containing riprap values (riprap transects) experienced a gradual erosion of beach area immediately shoreward of their location. These transects lost an average of 3 m/yr between 1978 and 1984 (Table 12). This trend was reversed during the 1984-1985 period, resulting in an average gain of 4 m while virtually all other Gulf shoreline transects eroded. Erosion of Gulf shoreline among transects not containing riprap averaged 59 m/yr during this final period, while the Gulf shoreline along the area of riprap remained quite stable. Relatively high r^2 values were obtained for regressions of riprap width and change in both shoreline and cumulative land width for 1978-1982, and change in island width for 1984-1985. However, these results are somewhat ambiguous due to the uniform width and limited extent of riprap. The strong analysis of means results ($\alpha \le 0.05$) for 1982-1984, 1984-1985, and 1978-1985 indicate that the presence of riprap in these areas significantly reduced rates of shoreline erosion. The overall observed results were, therefore, that areas containing riprap experienced lower rates of shoreline erosion and land loss than those areas not containing riprap.

(3) Dune

Dunes were encountered in 88% to 93% of all sampled transects during the study (Table 13). Average dune width ranged from a high of 34 m in 1978 to a low of 25 m in 1984, increasing to 28 m by 1985. Transects containing dunes (dune transects) showed significantly ($\alpha \le 0.05$) higher rates of Gulf shoreline erosion, decrease in island

Table 12. Relative influence of Timbalier Island riprap on change in Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for riprap and non-riprap transects, and analysis of means Z values ($Z \geq 2 = \alpha \leq 0.05$).

1978-1982 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	9	13	24
Transects Decreasing	83.3%	83.3%	83.3%
Transects Unchanged	16.7%	0.0%	0.0%
Transects Increasing	0.0%	16.7%	16.7%
Category Width R^2 Values	0.3415	0.2231	0.5864
Change Other Transects (m)	-12	10	-13
Analysis of Means Z Values	0.71	-0.29	-0.69

Category Encountered in 4.4% of All 1978 Transects

1982-1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-9	41	48
Transects Decreasing	100.0%	100.0%	100.0%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	0.0%	0.0%	0.0%
Category Width R^2 Values	0.1680	0.0023	0.0011
Change Other Transects (m)	-22	22	30
Analysis of Means Z Values	2.45	1.88	1.45

Category Encountered in 4.5% of All 1982 Transects

1984-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	4	2	-22
Transects Decreasing	0.0%	33.3%	83.3%
Transects Unchanged	33.3%	0.0%	0.0%
Transects Increasing	66.7%	66.7%	16.7%
Category Width R^2 Values	0.2609	0.8530	0.7964
Change - Other Transects (m)	-59	-61	-70
Analysis of Means Z Values	11.38	7.37	4.29

Category Encountered in 4.6% of All 1984 Transects

1978-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-13	-53	-94
Transects Decreasing	100.0%	100.0%	100.0%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	0.0%	0.0%	0.0%
Category Width R^2 Values	0.2814	0.0002	0.0630
Change - Other Transects (m)	-63	-92	-111
Analysis of Means Z Values	6.21	[illegible]	0.66

Category Encountered in 4.4% of All 1978 Transects

Table 13. Relative influence of Timbalier Island dunes on change in Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for dune and non-dune transects, and analysis of means Z values ($Z \geq 2 = \alpha \leq 0.05$).

1978-1982 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-10	9	1.
Transects Decreasing	37.0%	43.7%	46.2%
Transects Unchanged	4.2%	0.0%	2.5%
Transects Increasing	58.8%	53.8%	52.1%
Category Width R^2 Values	0.0552	0.0645	0.0378
Change - Other Transects (m)	-21	-21	-26
Analysis of Means Z Values	0.84	0.77	0.88
Category Encountered in 87.5% of All 1978 Transects			

1982-1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-18	-26	-34
Transects Decreasing	72.9%	77.1%	76.3%
Transects Unchanged	5.9%	0.0%	0.0%
Transects Increasing	21.2%	22.9%	23.7%
Category Width R^2 Values	0.1742	0.3123	0.2215
Change - Other Transects (m)	48	5	-6
Analysis of Means Z Values	1.26	0.28	0.62
Category Encountered in 88.1% of All 1982 Transects			

1984-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-59	-62	-71
Transects Decreasing	95.0%	93.4%	89.3%
Transects Unchanged	0.8%	0.0%	0.8%
Transects Increasing	4.1%	5.8%	10.7%
Category Width R^2 Values	0.1759	0.0000	0.0000
Change - Other Transects (m)	-20	-14	-21
Analysis of Means Z Values	3.49	3.28	3.47
Category Encountered in 92.4% of All 1984 Transects			

1978-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-55	-99	-118
Transects Decreasing	78.8%	83.1%	78.8%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	21.2%	16.9%	21.2%
Category Width R^2 Values	0.1039	0.0389	0.0044
Change - Other Transects (m)	-97	-29	-55
Analysis of Means Z Values	1.92	2.03	-1.65
Category Encountered in 87.4% of All 1978 Transects			

width, and land loss from 1984 to 1985, and decrease in island width for 1978-1985, compared to non-dune transects.

The Timbalier Island beach/dune boundaries were displaced an average of 28 m inland of the 1978 locations during the seven years of the study (Table 6). The changes in dune location were relatively minor during the first two periods of the study, averaging 2 m/yr inland during 1978-1982, and 3 m/yr shoreward during 1982-1984. This was followed by an average inland displacement of 48 m for 1984-1985, as a result of hurricane Juan. A lateral westward movement of dunes was also observed in conjunction with the westward migration of the entire island. Dunes generally maintained a consistent profile relative to the Gulf shoreline and beach. Therefore, dunes were displaced inland during the study, while areas containing dunes experienced greater reduction in island width than areas not containing dunes.

(4) Swale

Transects containing swale values (swale transects) accounted for 78% to 84% of all those sampled (Table 7). Swale widths averaged 208 m in 1978, increasing to 220 m in 1982, and decreasing through 214 m in 1984, to 196 m by 1985. Maximum swale width was 637 m. Swale transects showed significantly lower Gulf shoreline erosion rates ($\alpha \leq 0.05$) than transects not containing swale for all three periods of the study (Table 14). Swale transects averaged a shoreline accretion of 5 m/yr for the first period of the study (1978-1982), compared to an average loss of 30 m/yr in transects not containing swale. Swale width was apparently not correlated to changes in island width, cumulative land width, or shoreline erosion. Overall, swale maintained a relatively constant width, while areas containing swale experienced lower rates of Gulf shoreline erosion than areas not containing swale.

Table 14. Relative influence of Timbalier Island swale on change in Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for swale and non-swale transects, and analysis of means Z values ($Z \geq 2 = \alpha \leq 0.05$).

1978-1982 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	19	-3	6
Transects Decreasing	31.1%	40.6%	45.3%
Transects Unchanged	5.7%	0.0%	2.8%
Transects Increasing	63.2%	56.6%	52.8%
Category Width R^2 Values	0.0056	0.0655	0.0372
Change - Other Transects (m)	-120	36	-39
Analysis of Means Z Values	4.75	1.13	1.12

Category Encountered in 77.9% of All 1978 Transects

1982-1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	8	-22	33
Transects Decreasing	71.4%	82.9%	81.9%
Transects Unchanged	6.7%	0.0%	0.0%
Transects Increasing	21.9%	17.1%	18.1%
Category Width R^2 Values	0.0226	0.0173	0.0330
Change - Other Transects (m)	72	24	-24
Analysis of Means Z Values	3.28	0.25	-0.10

Category Encountered in 78.4% of All 1982 Transects

1984-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-42	-57	-68
Transects Decreasing	90.0%	93.6%	91.8%
Transects Unchanged	2.7%	0.0%	0.9%
Transects Increasing	7.3%	5.5%	8.2%
Category Width R^2 Values	0.0125	0.0945	0.0594
Change - Other Transects (m)	-129	-65	-62
Analysis of Means Z Values	3.53	0.30	-0.24

Category Encountered in 84.0% of All 1984 Transects

1978-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-30	-82	-105
Transects Decreasing	76.4%	84.0%	80.2%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	23.6%	16.0%	19.8%
Category Width R^2 Values	0.0209	0.1430	0.0784
Change - Other Transects (m)	-173	-120	129
Analysis of Means Z Values	7.42	1.06	0.59

Category Encountered in 78.5% of All 1978 Transects

(5) Spoil

Spoil values were encountered in less than 20% of all sampled Timbalier Island transects (Table 7). Average width of spoil declined throughout the study from 71 m in 1978, to 32 m in 1985, primarily through gradual reduction in spoil elevation and colonization by swale vegetation (Table 5). Rates of Gulf shoreline erosion for transects containing spoil (spoil transects) averaged significantly lower ($\alpha \leq 0.05$) than for non-spoil transects during the 1978-1982 and 1982-1984 periods, and 1978-1985 (Table 15). This may have been the result of an increased resistance to overwash due to their slightly higher elevations. In addition, spoil transects had significantly lower overall (1978-1985) rates of land loss than non-spoil transect, due perhaps, to thier gradually yielding sediment to surrounding land categories. Although changes in topographic relief were apparent during the photointerpretation and map creation process, no quantative measurements were attempted due to lack of surveyed elevation data. No correlation was detected between spoil width and change in shoreline, island width, or cumulative land width. Therefore, spoil width decreased throughout the study, while areas containing spoil experienced lower rates of shoreline erosion and land loss.

b. Combined Wetlands Categories

Combined wetlands cover categories (marsh and mangrove) were encountered in 85% to 89% of all transects during the study. They exhibited an overall average decrease in width of 10 m/yr (Table 6). Losses were recorded for all periods of the study, and ranged from a low of 1 m/yr, during the 1982-1984 period, to a high of 47 m/yr for 1984-1985. Transects with decreasing wetlands width outnumbered those with increasing width in all periods of the study. Of all transects containing wetlands (wetlands transects), 60.8% decreased and 31.5%

Table 15. **Relative influence of Timbalier Island spoil on change in Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for spoil and non-spoil transects, and analysis of means Z values ($Z \geq 2 = \alpha \leq 0.05$).**

1978-1982 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	20	5	3
Transects Decreasing	26.9%	38.5%	38.5%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	73.1%	61.5%	61.5%
Category Width R^2 Values	0.0219	0.0035	0.0035
Change - Other Transects (m)	-19	-14	-16
Analysis of Means Z Values	3.32	1.33	0.93

Category Encountered in 19.1% of All 1978 Transects

1982-1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	6	-15	19
Transects Decreasing	57.9%	68.4%	68.4%
Transects Unchanged	5.3%	0.0%	0.0%
Transects Increasing	36.8%	31.6%	31.6%
Category Width R^2 Values	0.0131	0.0000	0.0100
Change - Other Transects (m)	-24	-24	-33
Analysis of Means Z Values	2.87	1.08	1.32

Category Encountered in 14.2% of All 1982 Transects

1984-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-57	-62	-72
Transects Decreasing	100.0%	100.0%	100.0%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	0.0%	0.0%	0.0%
Category Width R^2 Values	0.0541	0.0199	0.0061
Change - Other Transects (m)	-56	-58	-67
Analysis of Means Z Values	-0.06	-0.43	-0.32

Category Encountered in 8.4% of All 1984 Transects

1978-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-21	-57	96
Transects Decreasing	65.4%	76.9%	80.8%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	34.6%	23.1%	19.2%
Category Width R^2 Values	0.0110	0.0283	0.0083
Change - Other Transects (m)	-70	-98	-114
Analysis of Means Z Values	4.11	2.30	0.67

Category Encountered in 19.3% of All 1978 Transects

increased in width between 1978 and 1985, while 7.7% remained unchanged. Transects containing wetlands experienced significantly higher ($\alpha \leq 0.05$) rates of land loss than non-wetland transects during the final period of the study (1984-1985) and overall (1978-1985; Table 16). Wetlands width was found to be somewhat linearly correlated with land loss for these same periods, with r^2 values of 0.402 and 0.499 (Figure 44), respectively. Therefore, wetlands declined in width during the study and were associated with increased rates of land loss.

(1) Mangrove

Mangroves were encountered in 60% of all sampled transects in 1978 and 1982 and averaged between 262 m and 295 m in width (Table 7). By 1984 mangroves were encountered in only 43% of sampled transects and by 1985, only 22%. Average widths for these last two years were 32 m and 18 m, respectively. Maximum widths declined from a high of 1229 m in 1978 to a low of 33.5 in 1985.

Transects containing mangrove (mangrove transects) showed significantly lower rates of Gulf shoreline erosion ($\alpha \leq 0.05$) than those not containing mangrove during both the 1978-1982 and 1982-1984 periods (Table 17). However, mangrove transects averaged significantly greater decreases in island width and land width than non-mangrove transects for the interval 1978 to 1985. This was due to the greater number of transects containing mangroves in 1978 relative to the interim periods, since change was based on the presence of a category at the beginning of the period. This implies higher rates of land loss and decline in island width during the interim periods (1982-1984 and 1984-1985) within former mangrove transects (mangrove in 1978, some other category from 1982-1985).

Mangrove width was somewhat linearly correlated with decrease in island width and cumulative land width during the 1978-1982 period, and for 1978-1985, with r^2 values as high as 0.687 (Figures 45 and 46).

Table 16. Relative influence of Timbalier Island combined wetlands on change in Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for wetlands and non-wetlands transects, and analysis of means Z values ($Z \geq 2 = \alpha \leq 0.05$).

1978-1982 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	0	-5	-9
Transects Decreasing	38.3%	43.5%	47.8%
Transects Unchanged	5.2%	2.6%	1.7%
Transects Increasing	56.5%	53.9%	50.4%
Category Width R^2 Values	0.0010	0.1792	0.2561
Change - Other Transects (m)	-70	32	-36
Analysis of Means Z Values	1.73	0.95	0.94
Category Encountered in 85.2% of All 1978 Transects			

1982-1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	18	20	29
Transects Decreasing	78.3%	81.[illegible]	80.9%
Transects Unchanged	6.1%	0.0%	0.0%
Transects Increasing	18.3%	20.9%	21.7%
Category Width R^2 Values	0.0137	0.044[illegible]	0.13[illegible]4
Change - Other Transects (m)	-57	55	55
Analysis of Means Z Values	1.30	0.[illegible]	0.[illegible]
Category Encountered in 88.7% of All 1982 Transects			

1984-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-52	-63	-74
Transects Decreasing	88.7%	90.4%	87.8%
Transects Unchanged	2.6%	0.9%	0.0%
Transects Increasing	6.1%	6.1%	9.6%
Category Width R^2 Values	0.0141	0.1769	0.4024
Change - Other Transects (m)	-81	32	-26
Analysis of Means Z Values	1.30	1.68	2.52
Category Encountered in 85.5% of All 1984 Transects			

1978-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-55	-98	-122
Transects Decreasing	83.5%	86.1%	80.9%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	16.5%	13.9%	19.1%
Category Width R^2 Values	0.0004	0.2820	0.4988
Change - Other Transects (m)	-89	-43	-45
Analysis of Means Z Values	1.19	1.56	-2.11
Category Encountered in 85.2% of All 1978 Transects			

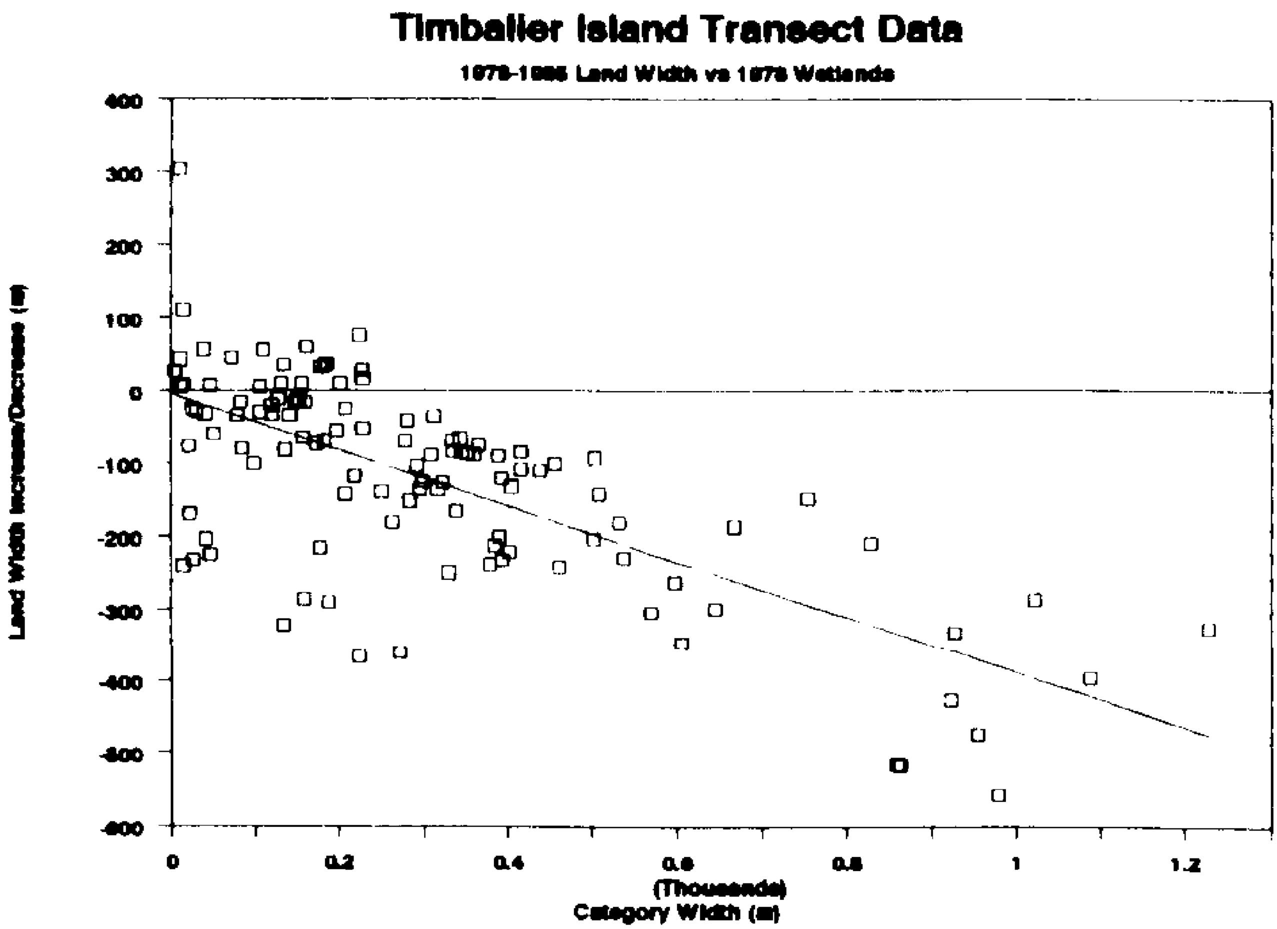


Figure 44. Regression plot of 1978 Timbalier Island combined wetlands width and 1978-1985 change in cumulative land width. Regression r^2=0.499.

Table 17. Relative influence of Timbalier Island mangrove on change in Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for mangrove and non-mangrove transects, and analysis of means Z values ($Z \geq 2 = \alpha \leq 0.05$).

1978-1982 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	11	17	20
Transects Decreasing	40.7%	51.9%	55.6%
Transects Unchanged	6.2%	0.0%	3.7%
Transects Increasing	53.1%	44.4%	4[illegible].0%
Category Width R^2 Values	0.2760	0.3133	0.4646
Change - Other Transects (m)	-44	-0	-4
Analysis of Means Z Values	2.67	-1.21	1.20

Category Encountered in 59.6% of All 1978 Transects

1982-1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	11	[illegible]	41
Transects Decreasing	82.5%	92.5%	90.0%
Transects Unchanged	6.3%	0.0%	0.0%
Transects Increasing	11.3%	7.5%	10.0%
Category Width R^2 Values	0.0002	0.0[illegible]16	0.1574
Change - Other Transects (m)	-37	15	16
Analysis of Means Z Values	2.27	0.58	1.28

Category Encountered in 59.7% of All 1982 Transects

1984-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-54	-65	-68
Transects Decreasing	96.4%	100.0%	94.6%
Transects Unchanged	1.8%	0.0%	0.0%
Transects Increasing	1.8%	0.0%	5.4%
Category Width R^2 Values	0.0733	0.0296	0.0177
Change - Other Transects (m)	-58	-54	67
Analysis of Means Z Values	0.52	1.12	-0.12

Category Encountered in 42.7% of All 1984 Transects

1978-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-48	-114	-149
Transects Decreasing	90.1%	95.1%	90.1%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	9.9%	4.9%	9.9%
Category Width R^2 Values	0.1020	0.5512	0.6874
Change - Other Transects (m)	-79	-53	-53
Analysis of Means Z Values	1.81	2.80	-3.85

Category Encountered in 60.0% of All 1978 Transects

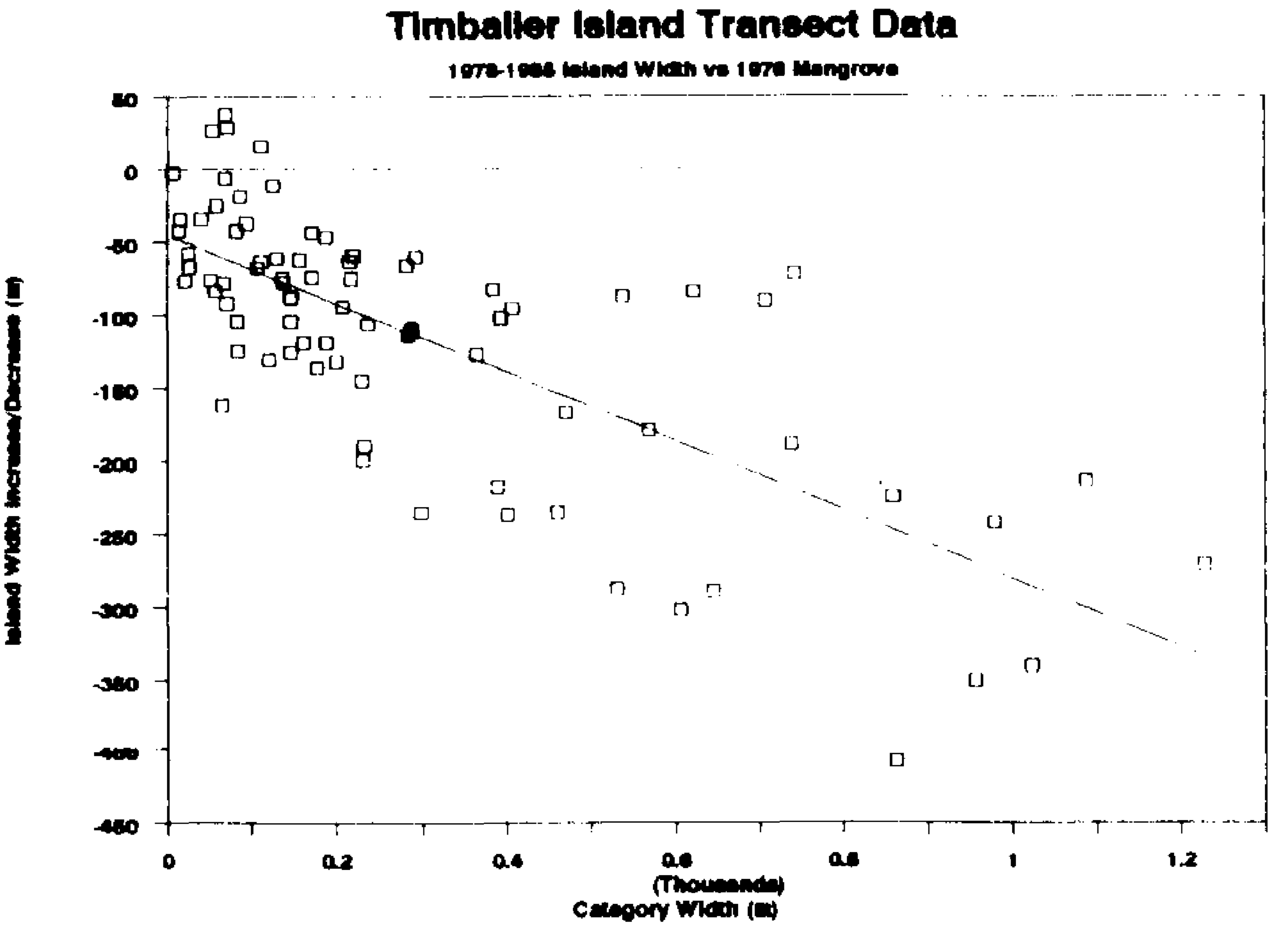


Figure 45. Regression plot of 1978 Timbalier Island mangrove width and 1978-1985 change in island width. Regression r^2=0.551.

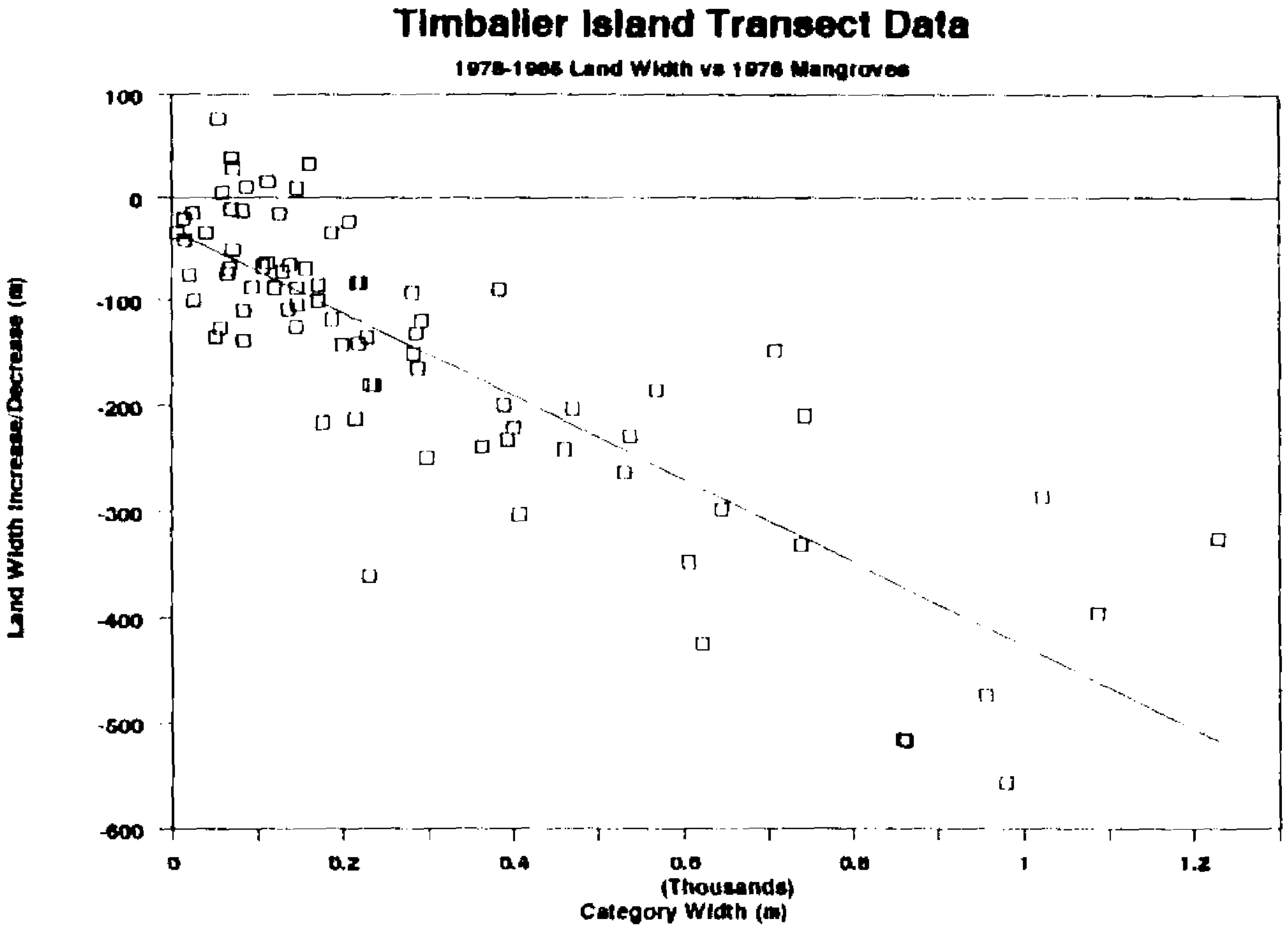


Figure 46. Regression plot of 1978 Timbalier Island mangrove width and 1978-1985 change in cumulative land width. Regression $r^2=0.687$.

Decrease in island width exceeding Gulf shoreline erosion implies erosion of the bay shoreline. The correlation with decrease in island width, therefore, implies a similar relationship to bay-side erosion, although this was not directly tested. Overall, mangroves declined in width and abundance, while areas containing mangroves exhibited greater rates of land loss and reduction in island width compared to non-mangrove areas.

(2) Marsh

Average marsh width decreased from 117 m in 1978, to 109 m in 1982, but increased to 271 m in 1984, due to replacement of mangroves killed during the winters of 1983-1984 (Table 7). Transects containing marsh values accounted for between 71.3% and 85.5% of all transects sampled. Marsh width averaged 245 m by the end of 1985. Maximum marsh width ranged from 354 m in 1978, to 1001 m in 1984.

During the first period of the study (1978-1982), transects containing marsh values (marsh transects) showed significantly less ($\alpha \leq 0.05$) decline in island width, or cumulative land width than transects not containing marsh (Table 18). Marsh transects averaged gains in Gulf shoreline, island width, and cumulative land width, while non-marsh transects averaged losses. During the following period (1982-1984) marsh transects continued to show lower rates of erosion than non-marsh transects, although the differences were not statistically significant. During the last period (1984-1985) declines in cumulative land width averaged significantly higher for marsh transects than non-marsh transects. However, for the overall period of the study, marsh transects had significantly lower rates of land loss than non-marsh transects. Marsh width was found to be somewhat linearly correlated with decrease in cumulative land width (r^2=0.406) during the 1984-1985 period.

Table 18. Relative influence of Timbalier Island marsh on change in Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for marsh and non-marsh transects, and analysis of means Z values ($Z \geq 2 = \alpha \leq 0.05$).

1978 1982 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	1	7	6
Transects Decreasing	32.0%	34.0%	40.2%
Transects Unchanged	6.2%	0.0%	3.1%
Transects Increasing	61.9%	62.9%	57.7%
Category Width R^2 Values	0.0008	0.0000	0.0001
Change - Other Transects (m)	-43	53	-63
Analysis of Means Z Values	1.79	3.28	3.72

Category Encountered in 71.3% of All 1978 Transects

1982 1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	19	18	25
Transects Decreasing	74.0%	76.9%	76.0%
Transects Unchanged	6.7%	0.0%	0.0%
Transects Increasing	19.2%	23.1%	24.0%
Category Width R^2 Values	0.0006	0.0156	0.0132
Change - Other Transects (m)	-30	38	-51
Analysis of Means Z Values	1.01	0.98	1.24

Category Encountered in 77.6% of All 1982 Transects

1984 1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	52	63	74
Transects Decreasing	91.1%	92.9%	90.2%
Transects Unchanged	2.7%	0.0%	0.9%
Transects Increasing	6.3%	6.3%	9.8%
Category Width R^2 Values	0.0160	0.1722	0.4063
Change - Other Transects (m)	-81	32	26
Analysis of Means Z Values	1.30	1.08	2.52

Category Encountered in 85.5% of All 1984 Transects

1978 1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	55	76	90
Transects Decreasing	80.4%	83.5%	77.3%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	19.6%	16.5%	22.7%
Category Width R^2 Values	0.0005	0.0106	0.0408
Change - Other Transects (m)	75	126	163
Analysis of Means Z Values	1.24	1.89	2.19

Category Encountered in 71.9% of All 1978 Transects

The marsh/swale boundaries shifted inland an average of 4 m/yr during the 1978-1982 period and an average of 2 m/yr during the 1982-1984 period (Table 6). However, they were displaced an average of 31 m toward the bay shoreline during the final year of the study. This occurred primarily as a result of hurricane Juan, which overwashed the island in October of 1985, distributing sand and sediment across the island. The marsh/swale boundaries were displaced an average of 12 m toward the bay between 1978 and 1985. Therefore, the overall trend was one increasing marsh widths while the swale/marsh boundaries were displaced shoreward. In addition, marsh areas were associated with reduced rates of land loss compared to areas not containing marsh.

II. Eastern Isles Dernieres

In 1978, the Eastern Isles Dernieres consisted of a relatively narrow and contiguous stretch of land characterized by large expanses of swale near the eastern end and extensive areas of mangrove and marsh in the central and western portions (Figures 47 and 48). Cold weather during the winters of 1983-1984 and 1984-1985 caused massive die-backs of mangroves, resulting in the conversion of large areas to marsh, and a loss of much of the bay side land area to open water.

The island encompassed the remnants of a large abandoned containment pond near the latitudinal mid-point. As of 1978, the banks of this pond were intact on the bay side and it was enclosed on the Gulf side by beach sands. By 1983 the bay side enclosure had been breached, providing direct hydrodynamic communication of the bay with formerly impounded water at the rear of the beach. The deterioration of the pond enclosure contributed to an eventual breach of the island at this point during hurricane Juan, in October of 1985.

During the study the majority of the island underwent a narrowing as the Gulf beaches and the bay shoreline eroded. Much of this was offset by a redistribution of island sediment westward, extending the

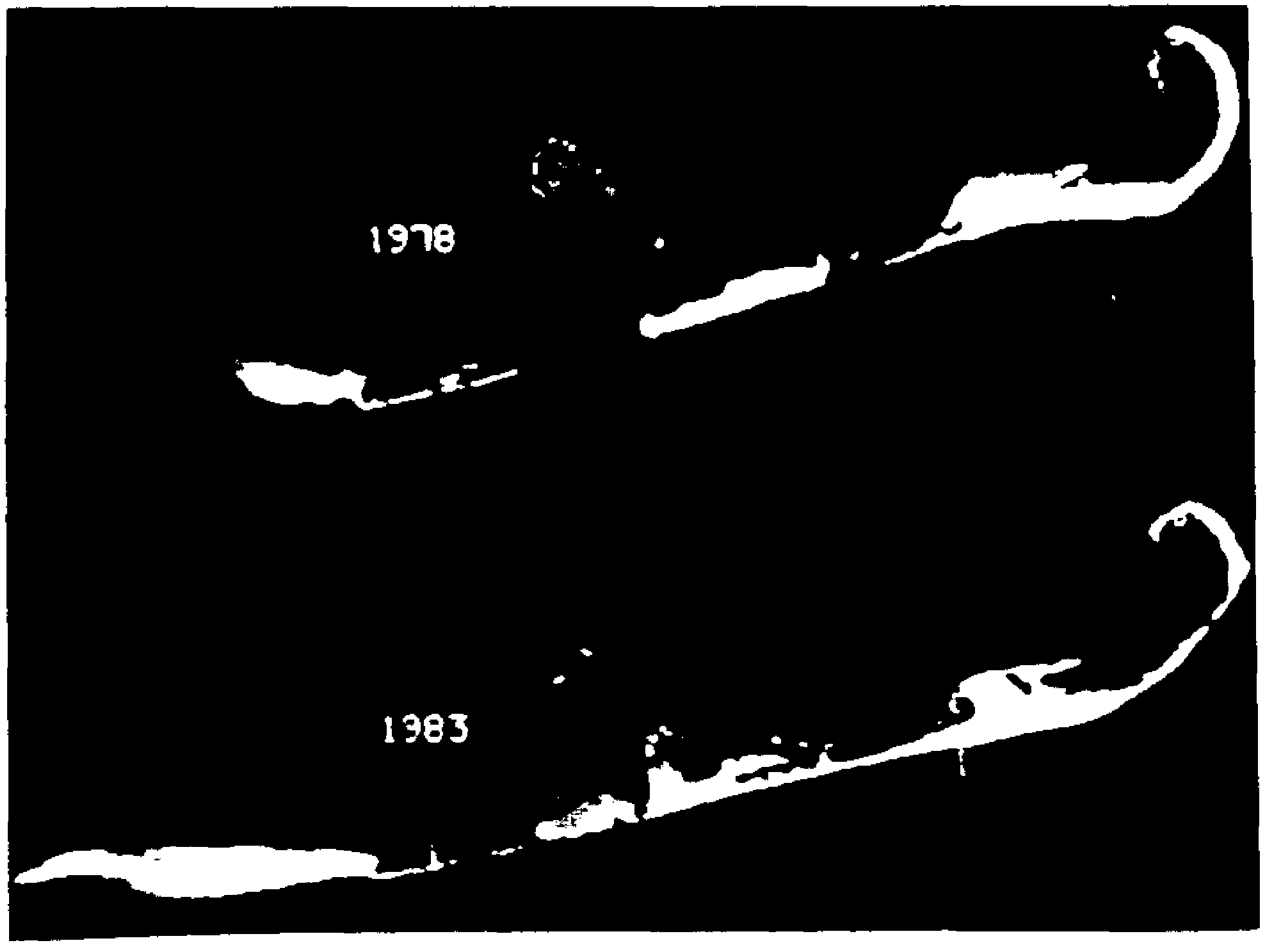


Figure 47. Computer generated images for the Eastern Isles Dernieres cover categories, 1978 and 1983. Beach and sand are white and yellow, dunes are medium green, swale is green, wetlands are dark green and bluegreen, spoil is pink and water is blue and purple.

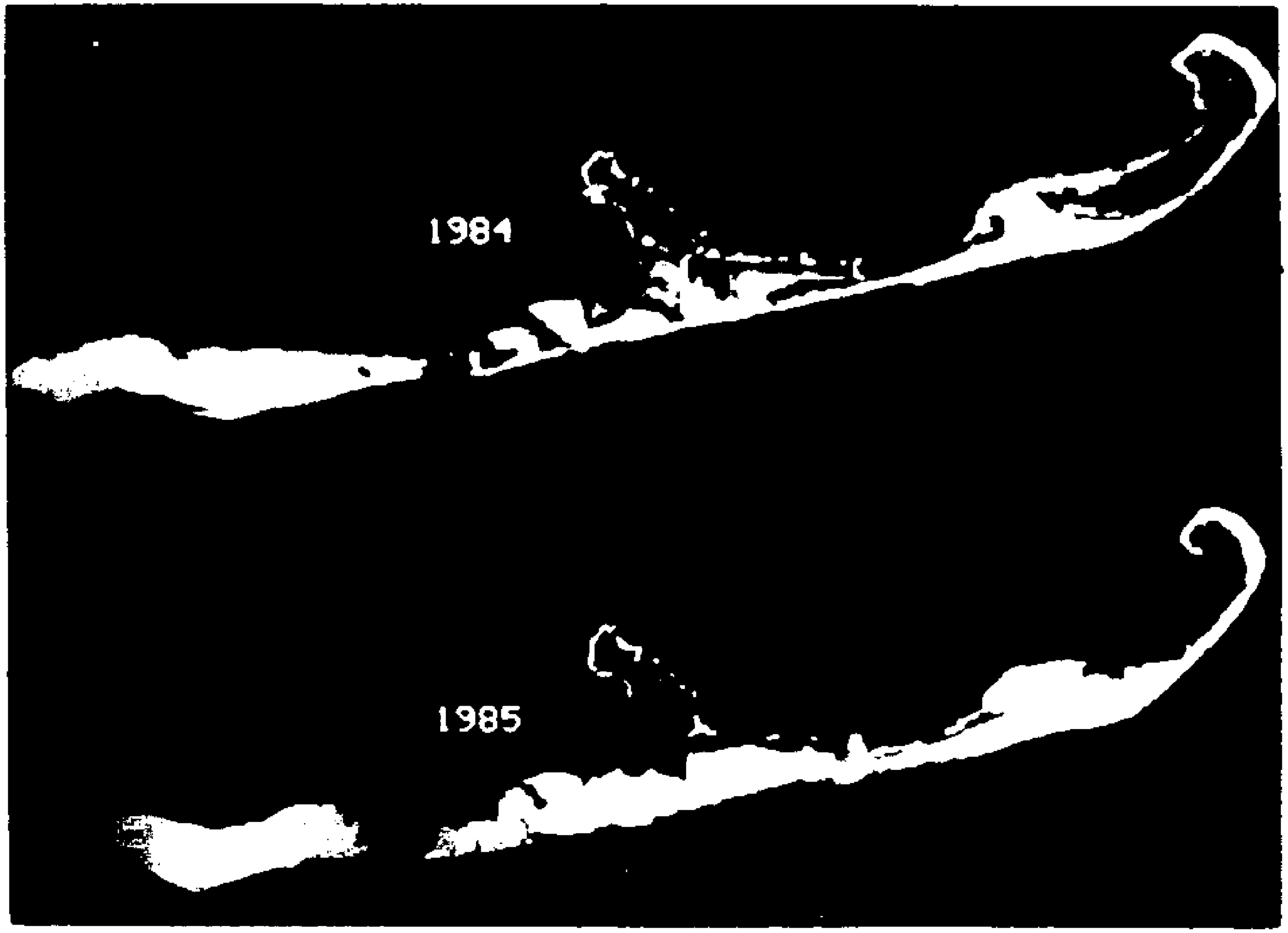


Figure 48. Computer generated images for the Eastern Isles Dernieres cover categories, 1984 and 1985. Beach and sand are white and yellow, dunes are medium green, swale is green, wetlands are dark green and bluegreen, spoil is pink and water is blue and purple.

western end of the island. The loss of mangroves in the central and western portions of the island contributed to a deterioration of the island and resulted in temporary breaches in 1984, and a larger, more permanent breach on the western end of the island in 1985.

A. Area Change Analysis

Surface area diminished steadily from 1978 through 1984 (Figure 49). Total surface area amounting to 141.9 ha in 1978, had been reduced to 117.8 ha by 1983 (Table 19). Of this loss, 15.6 ha was accounted for by the breaching of the large central containment pond which was no longer considered part of the contiguous surface area of the island. Surface area continued to decrease through 1984 to a low of 111.4 ha. As a result of the redistribution of sediments and filling of much of the island back-bay area in 1985, surface area increased to 115.2 ha. Total loss of surface area from 1978 to 1985 was 26.7 ha or 18.8% of the 1978 area. Disregarding the containment pond, the loss of surface area amounted to 8.8% or 11.1 ha.

The most significant changes in surface expression included a near doubling of beach area, the virtual elimination of mangroves, and the drastic reduction of swale, marsh, dunes, and ponds. Beach replaced swale in the eastern half of the island and mangrove in the western half as the predominant cover category by 1985. The majority of these changes occurred during the last period of the study, when hurricanes were prevalent. The overall trend, therefore, was of a reduction in island surface area accompanied by narrowing and elongation.

1. Bay and Gulf

Changes in the area of nearshore Gulf of Mexico and bay water indicated extensive Gulf shoreline erosion and a balance between gain

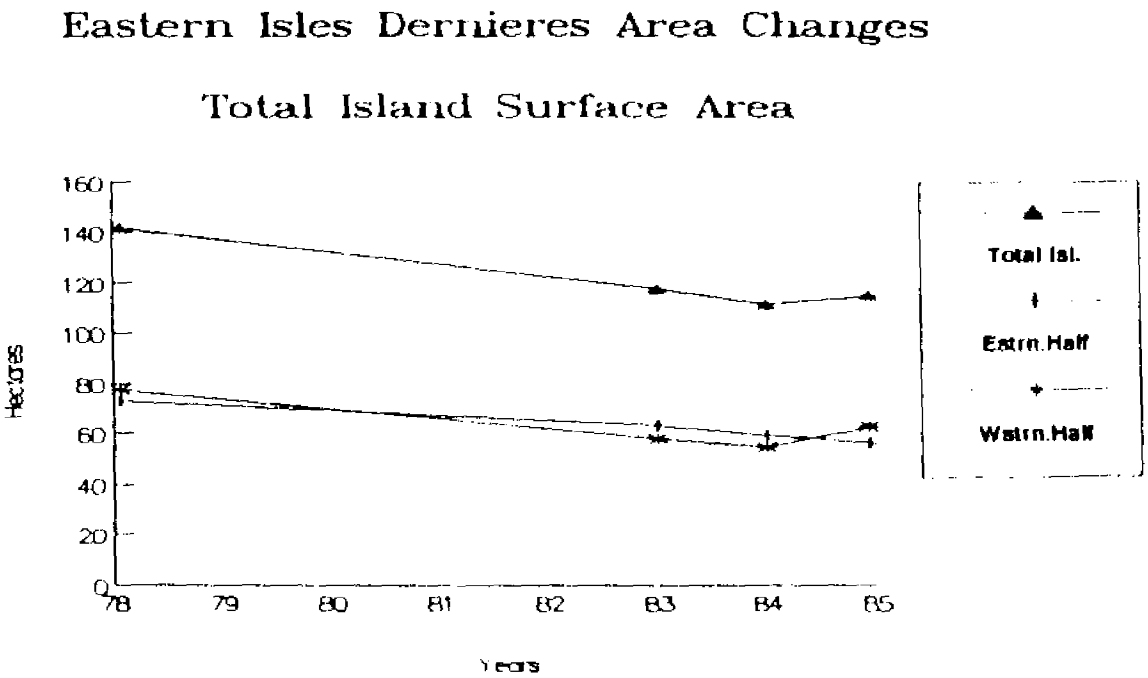


Figure 49. Changes in Eastern Isles Dernieres surface area for total island and for each transect area polygon, 1978-1985.

Table 19. Total areas (ha) and percent change of Eastern Isles Dernieres cover categories.

Total Island Category Areas (ha)

Category	1978	1983	78-83	1984	83-84	1985	84-85
Gulf	0.5	7.0	-	13.0	-	28.7	-
Bay	10.0	29.1	-	29.5	-	20.0	-
Ponds	22.5	5.9	-73.8%	5.5	-6.8%	2.3	-58.2%
Beach	40.4	34.8	-13.9%	34.5	-0.9%	79.2	129.6%
VegBeach	4.8	11.4	137.5%	9.6	-15.8%	1.2	-87.5%
Dune	10.4	11.6	11.5%	13.2	13.8%	7.8	-40.9%
Swale	26.7	25.3	-5.2%	25.5	0.8%	9.9	-61.2%
Marsh	4.5	4.2	-6.7%	17.3	311.9%	13.9	-19.7%
Mangrove	32.6	24.6	-24.5%	5.7	-76.8%	0.8	-86.0%
Shell	1.2	0.9	-25.0%	1.6	77.8%	1.2	-25.0%

Combined Category Areas (ha)

Category	1978	1983	78-83	1984	83-84	1985	84-85	78-85
Inland Water Bodies	22.5	5.9	-73.8%	5.5	-6.8%	2.3	-58.2%	-89.8%
Dry Sand Substrate	82.3	83.1	1.0%	82.8	-0.4%	98.1	18.5%	19.2%
Wetlands	37.1	28.8	-22.4%	23.1	-19.8%	14.8	-35.9%	-60.1%
Total Land Area	119.4	111.9	-6.3%	105.8	-5.5%	112.9	6.7%	-5.4%
Total Surface Area	141.9	117.8	-17.0%	111.4	-5.4%	115.2	3.4%	-18.8%

and loss of bay side shorelines (Figures 50 and 51). Encompassed Gulf water area increased throughout the study at an accelerating rate. The increase in Gulf water represented shoreline losses of 6.5 ha between 1978 and 1983, 6.0 ha between 1983 and 1984, and 15.7 ha between 1984 and 1985 (Table 19). Total gain in Gulf water amounted to 28.2 ha. Island cover categories experiencing the greatest amount of loss to the encroachment of the Gulf included beaches (25.2 ha), swale (5.9 ha), dune (3.7 ha), and mangrove (1.7 ha; Table 20). Gulf shoreline retreat was greatest in the western half of the island.

Nearshore bay water increased overall by 19.1 ha between 1978 and 1983, but only gained an additional 0.4 ha between 1983 and 1984. From 1984 to 1985 this trend was reversed with a loss of bay water area of 19.5 ha, offsetting the increases posted during the previous six years. The balance occurred through compensating water gains in the eastern half of the island (9.3 ha) and losses in the western half (5.9 ha). Washover sediments, deposited as a result of the impact of hurricane Juan, resulted in the creation of 20.7 ha of new beach in former bay area, 19.1 ha of which occurred in the western half of the island. Land losses to bay water consisted of 8.8 ha of mangrove, 8.6 ha of ponds, 2.8 ha of swale, 2.1 ha of beach, and 1.3 ha of marsh. Therefore, increases in Gulf water area and a relatively consistent bay area indicate a let loss of island surface area through retreat of the Gulf shoreline.

2. Ponds

Since no canals were in existence on the Eastern Isles Dernieres during this study, the inland water bodies consisted only of ponds. These declined in surface area throughout the study (Figure 52). The erosion and breaching of the banks of a large abandoned containment pond in the midsection of the island resulted in the loss of 15.6 ha of pond area between 1978 and 1983 (Table 19). An additional 1.0 ha of pond

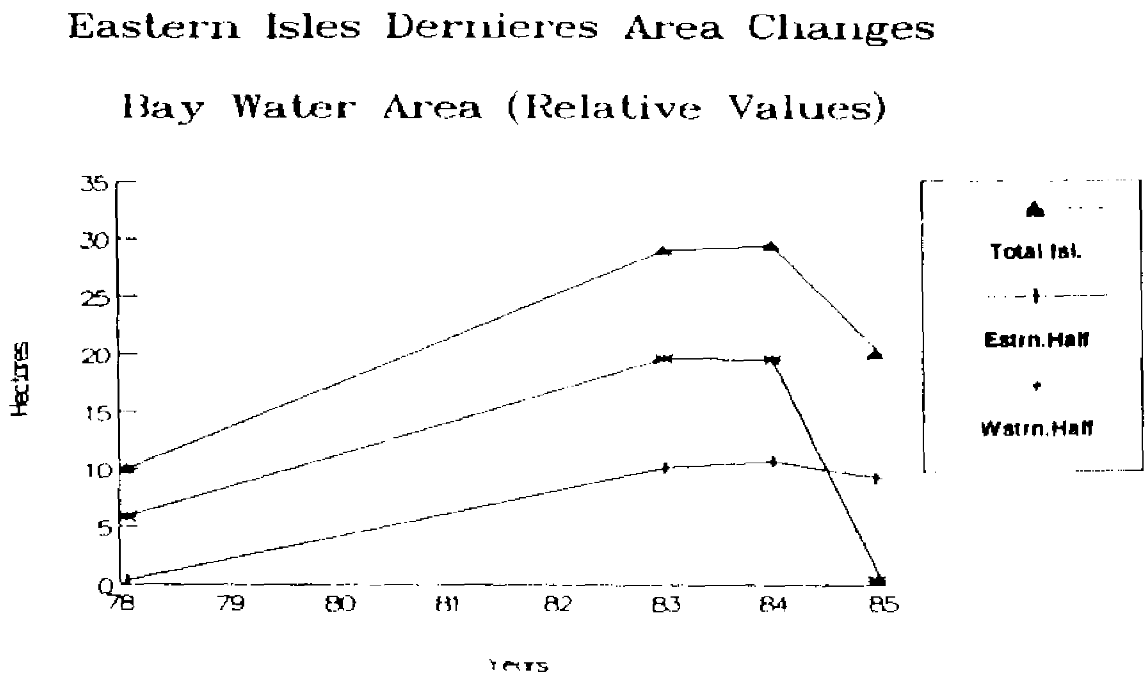


Figure 50. Changes in Eastern Isles Dernieres bayside water area for total bay shoreline and within each transect area polygon, 1978-1985.

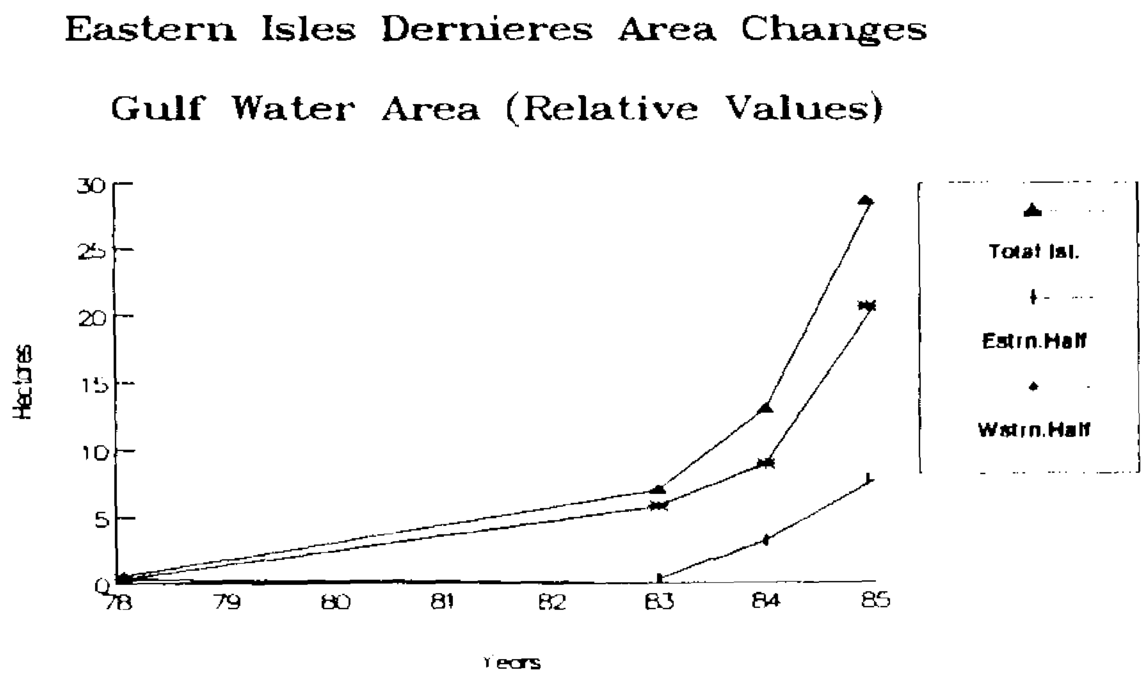


Figure 51. Changes in Eastern Isles Dernieres nearshore Gulf water area for total Gulf shoreline and within each transect area polygon, 1978-1985.

Table 20. Eastern Isles Dernieres area change matrix showing beginning categories vertically on the left and ending categories horizontally at the top. Values within the matrix represent the amount of area (ha) from which the category on the left changed to (or remained) the category on the top.

Eastern Isles Dernieres

1978-1983

Changed From:	Changed To: Gulf	Bay	Pond	Beach	(change values = hectares) Vg.Bch	Dune	Swale	Marsh	Mangrv	Spoil	Shell	STARTING TOTALS
Gulf	57.7	0.7	0.0	11.7	4.9	1.0	0.0	0.0	0.0	0.0	0.0	76.0
Bay	0.1	37.7	0.2	5.9	0.3	0.5	0.1	0.2	0.2	0.0	0.0	45.3
Ponds	0.1	15.0	4.9	1.5	0.2	0.2	0.2	0.1	0.1	0.0	0.1	22.5
Beach	15.6	2.4	0.1	9.6	5.0	4.9	1.0	0.5	0.1	0.0	0.0	39.2
VegBeach	2.2	0.1	0.0	0.6	0.1	0.6	1.2	0.0	0.0	0.0	0.0	4.8
Dune	2.2	0.2	0.0	1.8	0.9	2.6	2.4	0.2	0.0	0.0	0.0	10.4
Swale	2.4	1.9	0.2	0.8	0.0	1.2	19.8	0.3	0.1	0.0	0.1	26.7
Marsh	0.2	0.9	0.1	0.6	0.0	0.1	0.2	2.2	0.3	0.0	0.0	4.5
Mangrove	0.6	4.9	0.3	1.4	0.0	0.5	0.2	0.6	23.9	0.0	0.3	32.6
Spoil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Shell	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.2
END TOTALS	81.0	64.4	5.9	33.9	11.4	11.6	25.3	4.1	24.7	0.1	0.9	263.2

1983-1984

Changed From:	Changed To: Gulf	Bay	Pond	Beach	(change values = hectares) Vg.Bch	Dune	Swale	Marsh	Mangrv	Spoil	Shell	STARTING TOTALS
Gulf	78.2	0.5	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	81.0
Bay	0.8	57.6	0.0	5.0	0.1	0.1	0.1	0.2	0.2	0.0	0.3	64.4
Ponds	0.0	0.8	4.5	0.3	0.0	0.0	0.0	0.1	0.0	0.0	0.1	5.9
Beach	6.2	2.0	0.0	21.0	3.2	1.0	0.2	0.3	0.0	0.0	0.0	33.9
VegBeach	0.0	0.1	0.0	2.0	6.1	3.1	0.1	0.0	0.0	0.0	0.0	11.4
Dune	1.1	0.1	0.0	1.4	0.2	7.8	1.0	0.1	0.0	0.0	0.0	11.6
Swale	0.1	0.5	0.0	0.2	0.0	0.7	23.6	0.0	0.0	0.0	0.1	25.3
Marsh	0.5	0.4	0.1	0.1	0.0	0.2	0.3	2.5	0.0	0.0	0.0	4.2
Mangrove	0.1	2.4	0.8	0.5	0.0	0.3	0.2	14.1	5.5	0.0	0.6	24.6
Spoil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Shell	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.9
END TOTALS	87.0	64.9	5.5	32.8	9.6	13.2	25.5	17.3	5.8	0.0	1.6	263.2

1984-1985

Changed From:	Changed To: Gulf	Bay	Pond	Beach	(change values = hectares) Vg.Bch	Dune	Swale	Marsh	Mangrv	Spoil	Shell	STARTING TOTALS
Gulf	85.3	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	87.0
Bay	0.9	38.1	0.0	24.6	0.1	0.1	0.0	0.9	0.0	0.0	0.2	64.9
Ponds	0.1	0.2	2.1	2.1	0.0	0.2	0.0	0.8	0.0	0.0	0.1	5.5
Beach	10.4	2.6	0.0	19.7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	32.9
VegBeach	1.9	0.0	0.0	6.8	0.8	0.1	0.0	0.0	0.0	0.0	0.0	9.6
Dune	2.2	0.4	0.0	8.3	0.2	2.0	0.1	0.0	0.0	0.0	0.0	13.2
Swale	2.1	0.8	0.0	7.7	0.0	5.3	9.3	0.3	0.0	0.0	0.0	25.5
Marsh	0.0	1.4	0.1	6.3	0.0	0.1	0.3	8.9	0.1	0.0	0.2	17.3
Mangrove	0.0	1.0	0.0	0.7	0.0	0.0	0.1	3.1	0.8	0.0	0.1	5.7
Spoil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shell	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.6	1.6
END TOTALS	102.7	45.3	2.3	77.9	1.2	7.8	9.9	13.9	0.8	0.0	1.2	263.2

1978-1985

Changed From:	Changed To: Gulf	Bay	Pond	Beach	(change values = hectares) Vg.Bch	Dune	Swale	Marsh	Mangrv	Spoil	Shell	STARTING TOTALS
Gulf	61.1	0.1	0.0	14.1	0.6	0.2	0.0	0.0	0.0	0.0	0.0	76.0
Bay	3.6	20.4	0.0	20.7	0.0	0.0	0.1	0.6	0.0	0.0	0.0	45.3
Ponds	0.7	8.6	1.9	9.8	0.0	0.2	0.1	0.6	0.0	0.0	0.5	22.5
Beach	21.7	2.1	0.0	14.3	0.4	0.7	0.0	0.0	0.0	0.0	0.0	39.2
VegBeach	3.5	0.0	0.0	0.9	0.0	0.3	0.0	0.0	0.0	0.0	0.0	4.8
Dune	3.7	0.2	0.0	4.3	0.1	1.7	0.3	0.1	0.0	0.0	0.0	10.4
Swale	5.9	2.8	0.0	4.2	0.0	4.5	8.9	0.3	0.0	0.0	0.1	26.7
Marsh	0.7	1.3	0.0	1.0	0.0	0.1	0.3	1.0	0.0	0.0	0.0	4.5
Mangrove	1.7	8.8	0.4	8.7	0.0	0.1	0.2	11.2	0.8	0.0	0.5	32.6
Spoil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Shell	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.2
END TOTALS	102.7	45.3	2.3	77.9	1.2	7.8	9.9	14.0	0.9	0.0	1.2	263.2

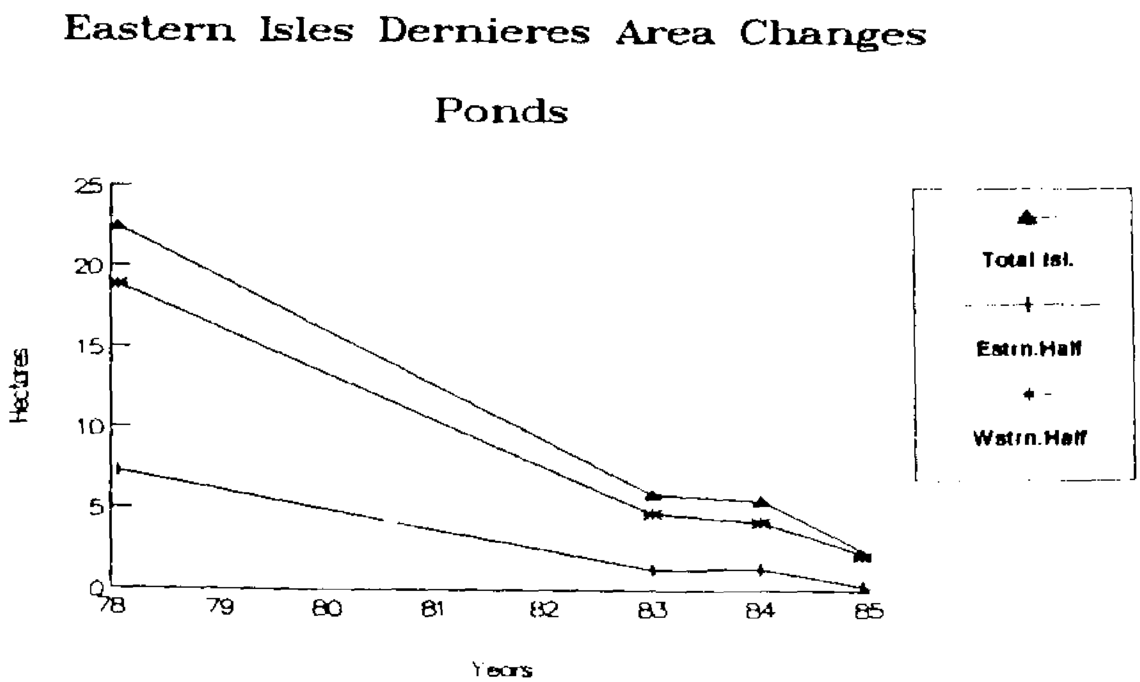


Figure 52. Changes in Eastern Isles Dernieres pond area for total island and within each transect area polygon, 1978-1985.

area was lost during this five year period. Of the 22.5 ha of ponds existing in 1978, only 2.3 ha remained as of December, 1985. The primary changes in pond area were to beach (9.6 ha), due to sediment overwash, and to bay, due to erosion and breaching of enclosing embankments (Table 20). Therefore, ponds decreased in surface area throughout the study.

3. Total Land Area

Total land area decreased from 119.4 ha in 1978 to 111.9 ha in 1983, and 105.8 ha in 1984 (Figure 53; Table 19). Losses were recorded for both the eastern and western halves of the island between 1978 and 1984. Between 1984 and 1985 there was an overall increase in land area of 7.1 ha to a final value of 112.9 ha. This represented an overall net loss of 6.5 ha, or 5.4% of the 1978 land area. The majority of this was recorded in the eastern half of the island, where 9.5 ha were lost, while in the western half a net gain of 2.1 ha was recorded. This occurred as a result of 10.0 ha of new beach being established during the period from 1984 to 1985. Total land area, therefore, declined during the study, with gains in the western half more than offset by losses in the eastern half.

a. Combined Dry Sand Categories

Combined dry or well drained sand substrate categories (beach, dune, swale, spoil, and shell) demonstrated a net overall increase of 15.8 ha from the 1978 total of 81.2 ha (Table 19; Figure 54) The combined areas of dry sand categories remained relatively stable through 1984, decreasing slightly in the eastern half of the island and increasing slightly in the west. The eastern portion continued to decrease slightly through 1985, while the western half increased by

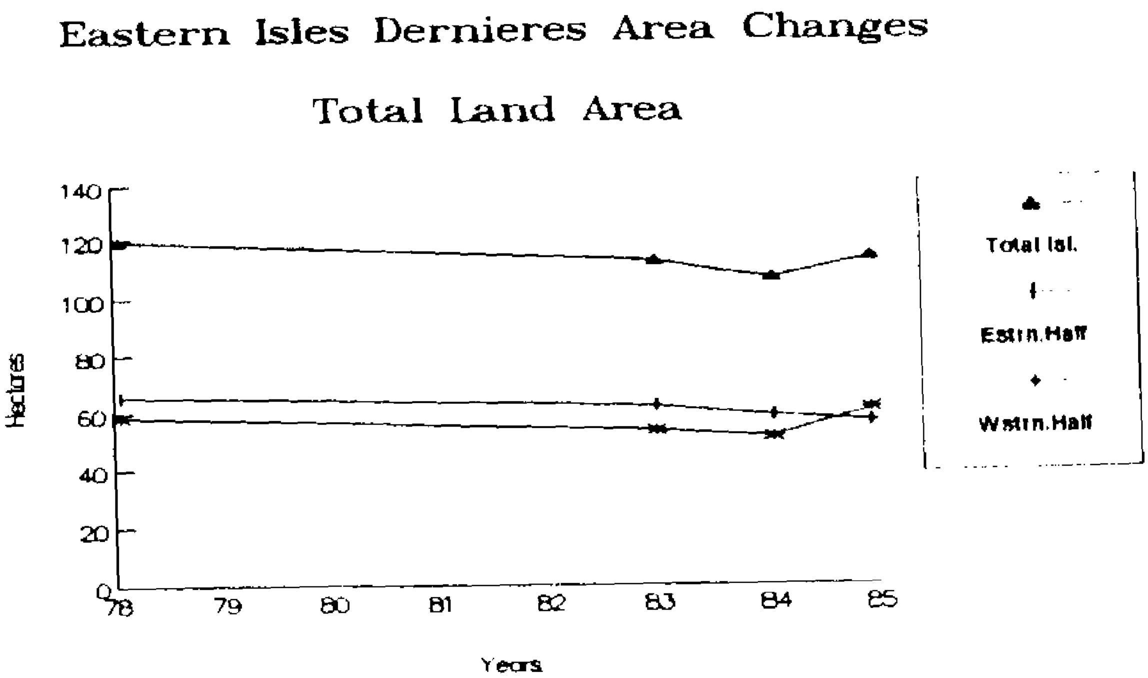


Figure 53. Changes in area of combined Eastern Isles Dernieres land categories for total island and within each transect area polygon, 1978-1985.

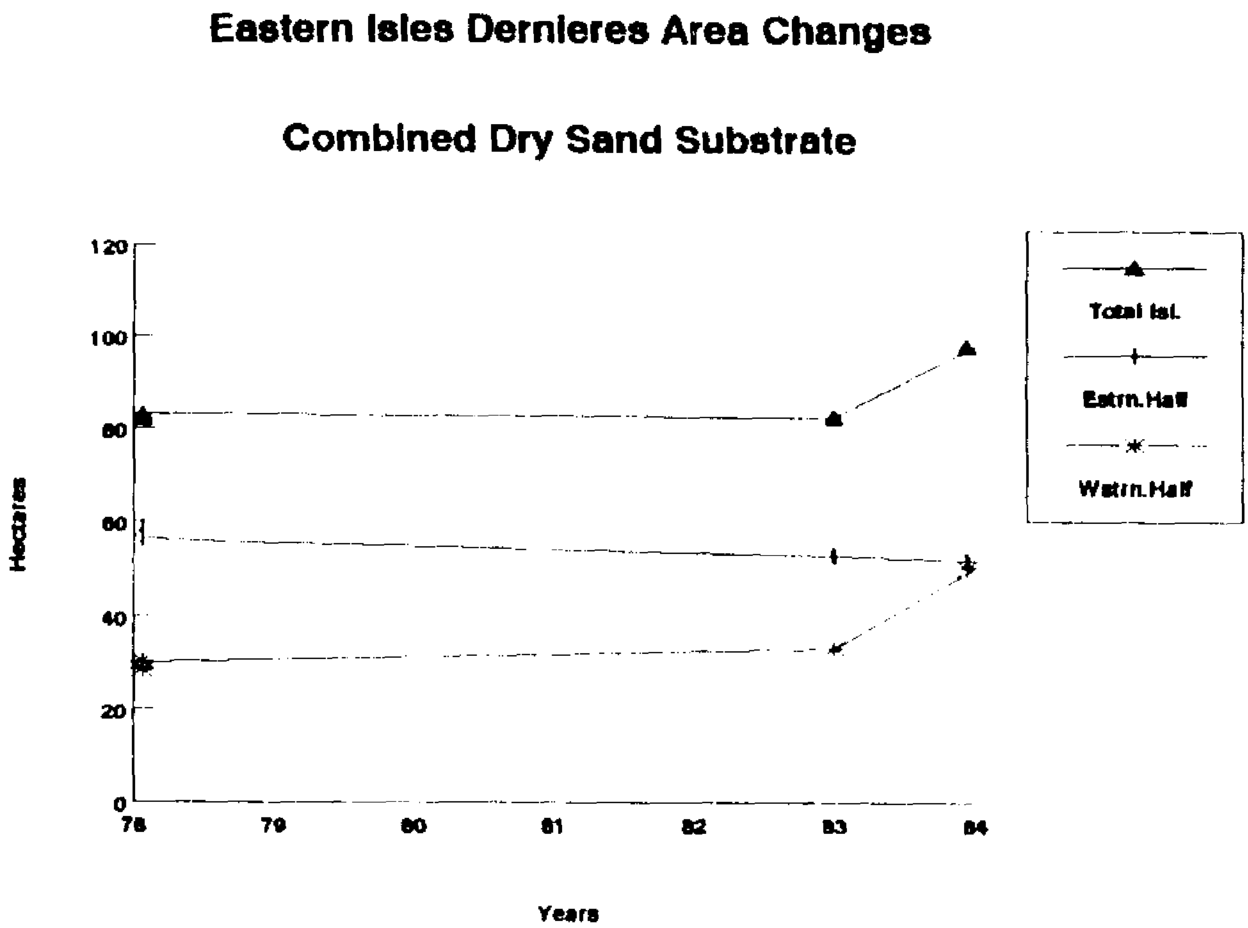


Figure 54. Changes in Eastern Isles Dernieres combined dry sand substrate area for total island and within each transect area polygon 1978-1985.

17.8 ha for a net increase in area of 81.5% over the 1978 value. Total island dry sand categories accounted for 96.9 ha by 1985. Combined dry sand categories, therefore, exhibited an overall increase during the study.

(1) Beaches

Total beach area, including vegetated and nonvegetated beaches, remained relatively constant from 1978 to 1983, decreasing from 44.1 ha to 42.5 ha (Figures 55 and 56; Table 19). However, beach area nearly doubled between 1984 and 1985, increasing to 79.2 ha. This represented a net increase of 35.1 ha or 79.6% overall. The majority of the increase in beach area occurred in the western half of the island, where a gain of 25.3 ha was recorded. These gains occurred while giving up 25.2 ha of beach to the Gulf, indicating a landward and westward displacement of the beaches (Table 20). In 1978, bay and Gulf water accounted for the majority of the area occupied by 1985 beach (20.7 and 14.7 ha, respectively). Other areas converted to beach included 9.8 ha of ponds, 8.7 ha of mangrove, 4.3 ha of dune, and 4.2 ha of swale. The extensive new beach areas in 1985 occurred as a result of overwashing and redistribution of sand and sediments. These sediments covered much of the remaining marsh and mangrove in the western half of the island and formed a large sandy extension of the island to the west. The overall trend was, therefore, one of increase in beach surface during the study, primarily through extension of the western end of the island.

(2) Dunes

Island dunes steadily increased in size from 10.4 ha in 1978 to 13.2 ha in 1984, but were reduced to a total of 7.8 ha by 1985 (Figure 57; Table 19). This resulted in a net loss of 24.6% of the 1978

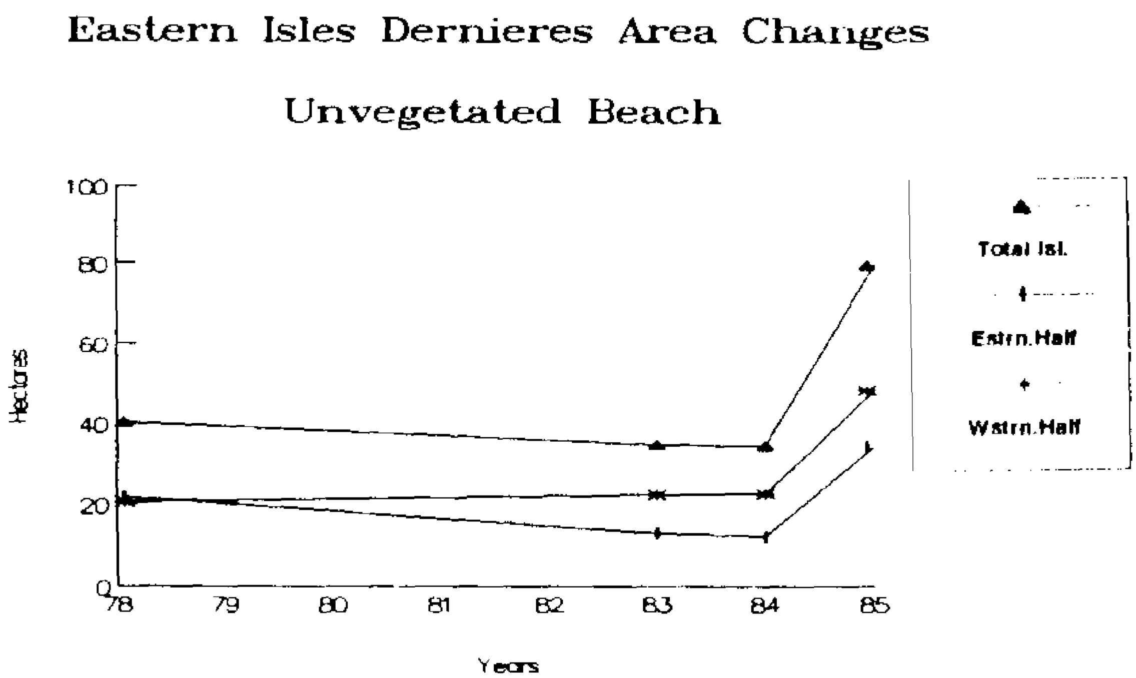


Figure 55. Changes in Eastern Isles Dernieres unvegetated beach area for total island and within each transect area polygon, 1978-1985.

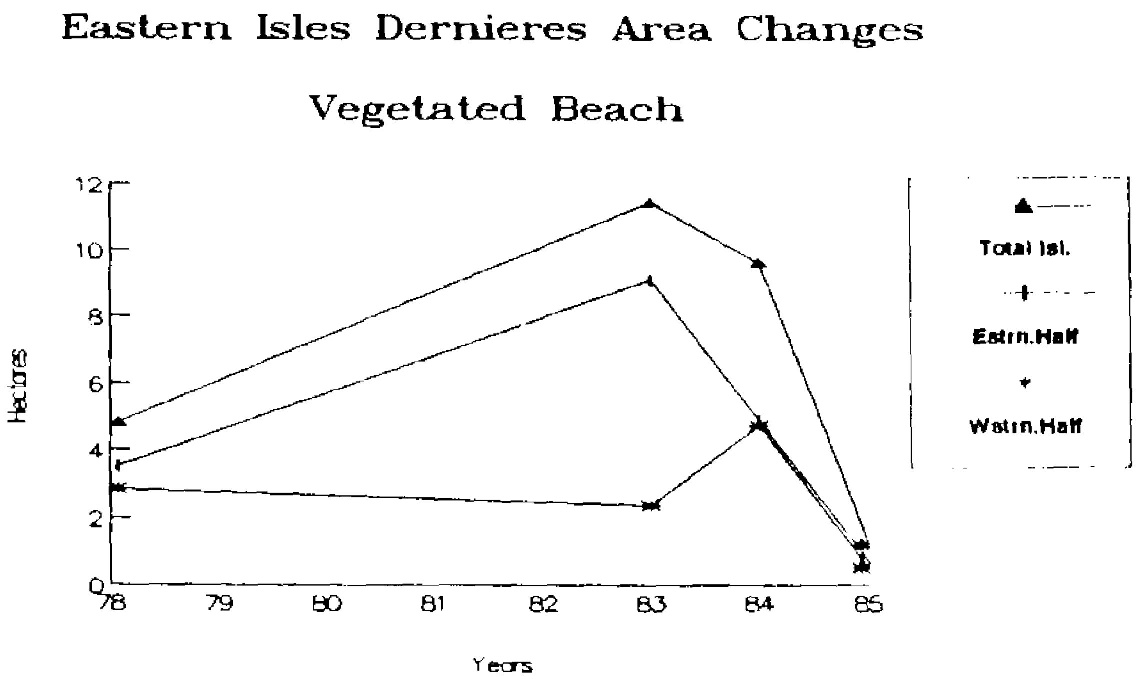


Figure 56. Changes in Eastern Isles Dernieres vegetated beach area for total island and within each transect area polygon, 1978-1985.

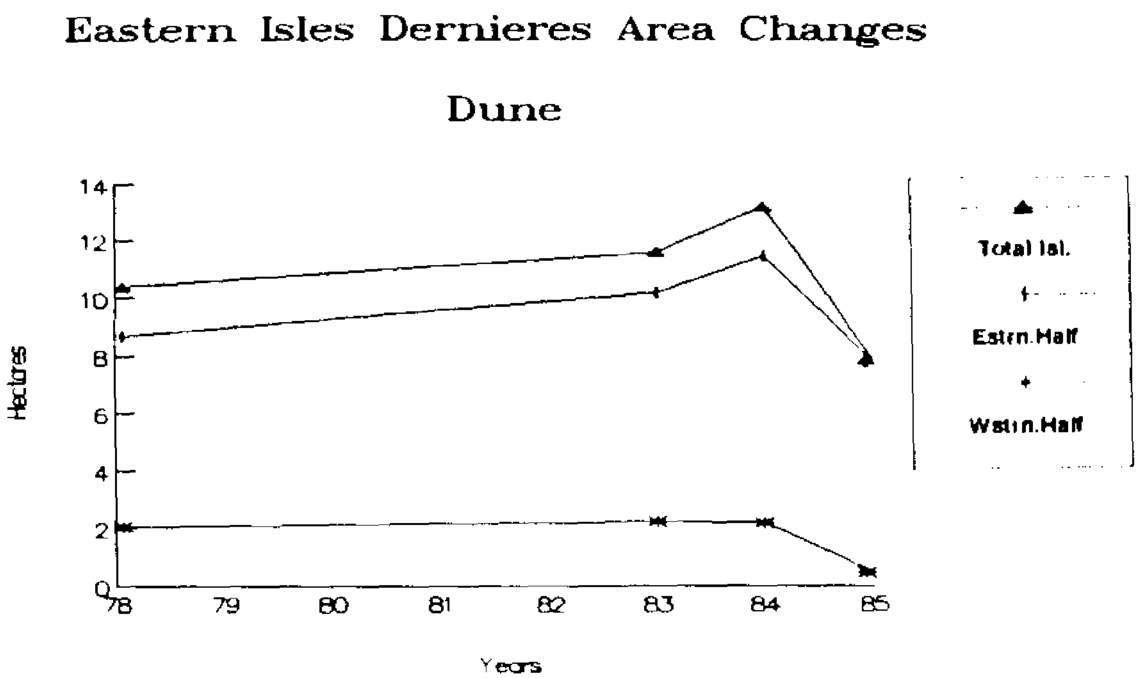


Figure 57. Changes in Eastern Isles Dernieres dune area for total island and within each transect area polygon, 1978-1985.

area. Virtually all dunes were eliminated from the western half of the island by 1985, the majority (1.8 ha of the 2.1 ha present in 1978) having been converted to Gulf water area (Table 20). Overall, the chief replacements of former dune areas were beach (4.3 ha) and Gulf (3.7 ha), while 4.5 ha of swale became dune. Therefore, dunes experienced an overall loss of surface area during the study.

(3) Swale

Swale area remained relatively constant through 1984, declining from 26.7 ha in 1978, to 25.5 ha (Figure 58; Table 19). The loss of swale between 1984 and 1985 resulted in a final total of 9.9 ha, for a net loss of 16.8 ha, or 62.9%. Overall, 5.9 ha was lost to the Gulf of Mexico and 2.8 ha to the bay, while 4.5 ha became dune and 4.2 ha became beach (Table 20). This reversed a trend toward the expansion of swale in the western half of the island. There was little conversion of marsh to swale or the reverse (0.3 ha each direction overall) during the study. The overall trend, therefore, was of a net reduction in swale surface area.

b. Combined Wetlands Categories

Total wetlands (mangrove and marsh) declined steadily throughout the study (Figure 59). In 1978 there were 37.1 ha of combined wetlands, most of which (30.5 ha) was concentrated in the western half of the island (Table 19). By 1985, the remaining wetlands area amounted to 14.8 ha, indicating a net loss of 22.3 ha, or 60.1% of the 1978 total. Hard freezes in the winters of 1983-1984 and 1984-1985 resulted in the near total destruction of island mangroves and the conversion of the majority of these areas to marsh and open water. This, combined with the overwash of the island during hurricane Juan, resulted an overall

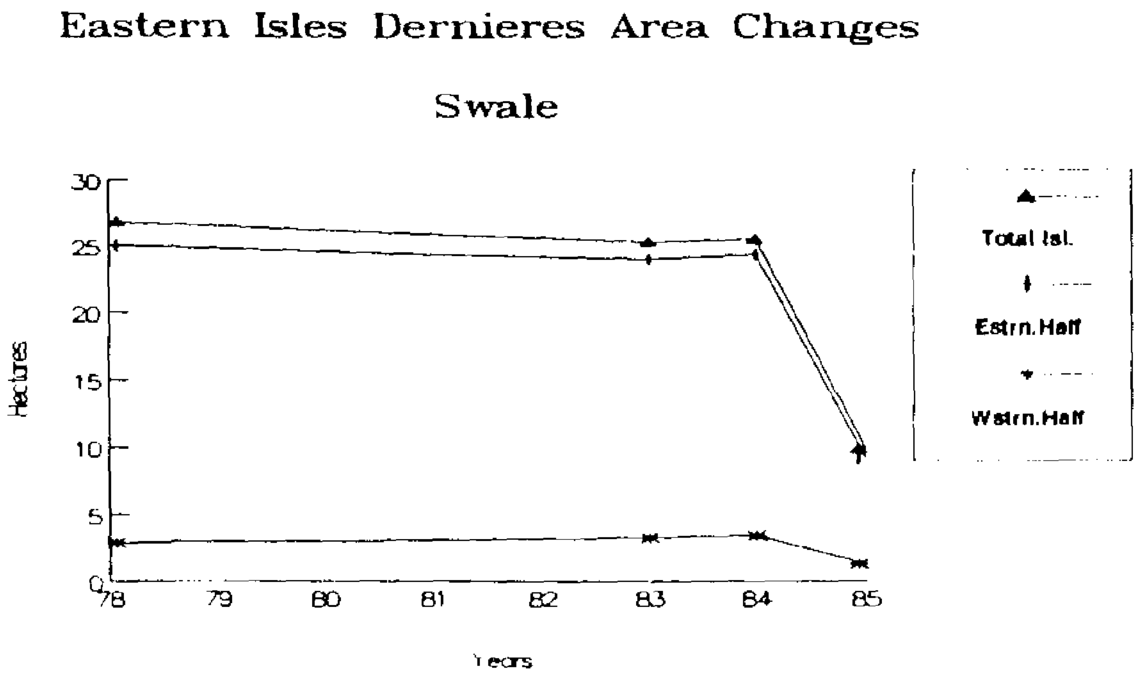


Figure 58. Changes in Eastern Isles Dernieres swale area for total island and within each transect area polygon, 1978-1985.

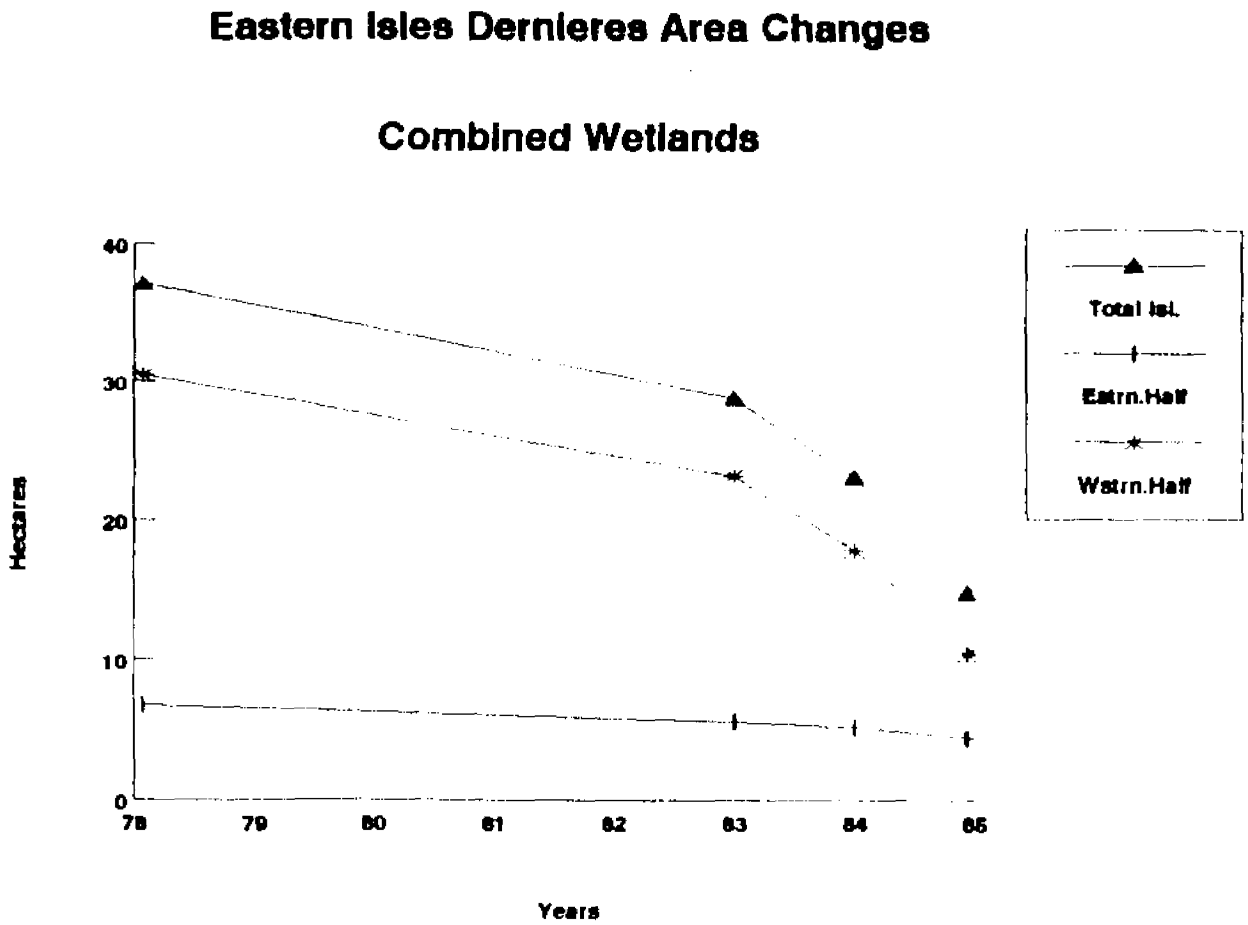


Figure 59. Changes in Eastern Isles Dernieres combined wetlands area for total island and within each transect area polygon 1978-1985.

decrease in wetlands to 14.8 ha by 1985. Therefore, there was a net loss of wetlands during the study, due primarily to frost damage of mangroves and severe storm impact.

(1) Mangroves

In 1978, mangroves, with a total of 32.6 ha, comprised the second largest island cover category after beaches (Table 19). By 1985, less than one hectare remained. Although mangroves had declined between 1978 and 1983, the rate of loss dramatically increased between 1983 and 1985 due to hard freezes and resultant die-backs (Figure 60). 31.7 ha of mangroves representing 97.4% of the 1978 total were lost by 1985. The majority of mangroves killed by the freezes were replaced by marsh (11.2 ha) and beach (8.7 ha), but bay and Gulf claimed 8.8 and 1.7 ha respectively (Table 20). Damage of due to hard freezes resulted in the near elimination of mangroves from the Eastern Isles Dernieres during the study.

(2) Marsh

Total marsh area decreased slightly between 1978 and 1983, from 4.5 ha to 4.2 ha (Figure 61; Table 19). Marsh area increased between 1983 and 1984, to a total of 17.3 ha as a result of massive die-back of mangroves and subsequent replacement by marsh species. Of the 1983 mangrove area, 14.1 ha had become marsh by 1984 (Table 20). Despite an additional conversion of 3.1 ha of mangrove between 1984 and 1985, marsh areas were reduced to a final total area of 13.9 ha by the end of 1985. During the last year of the study 1.4 ha were lost to bay and 6.3 ha became beach. The overall change in marsh area during the study period was an increase of 9.4 ha, representing a net gain of 209.8% of the 1978

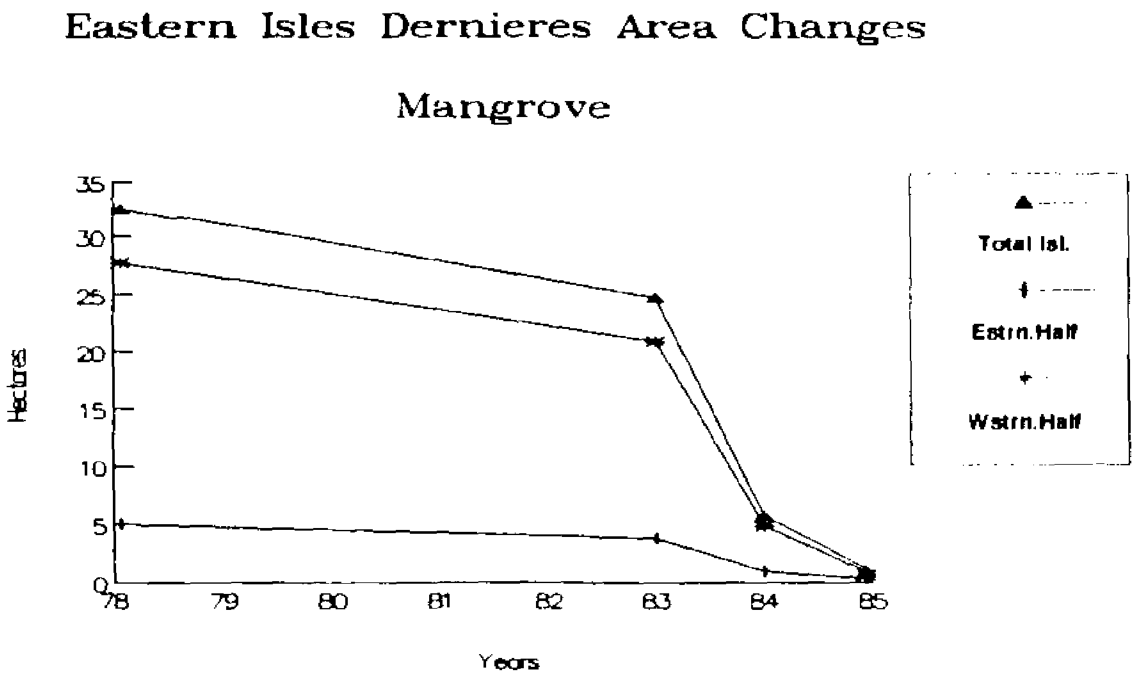


Figure 60. Changes in Eastern Isles Dernieres mangrove area for total island and within each transect area polygon, 1978-1985.

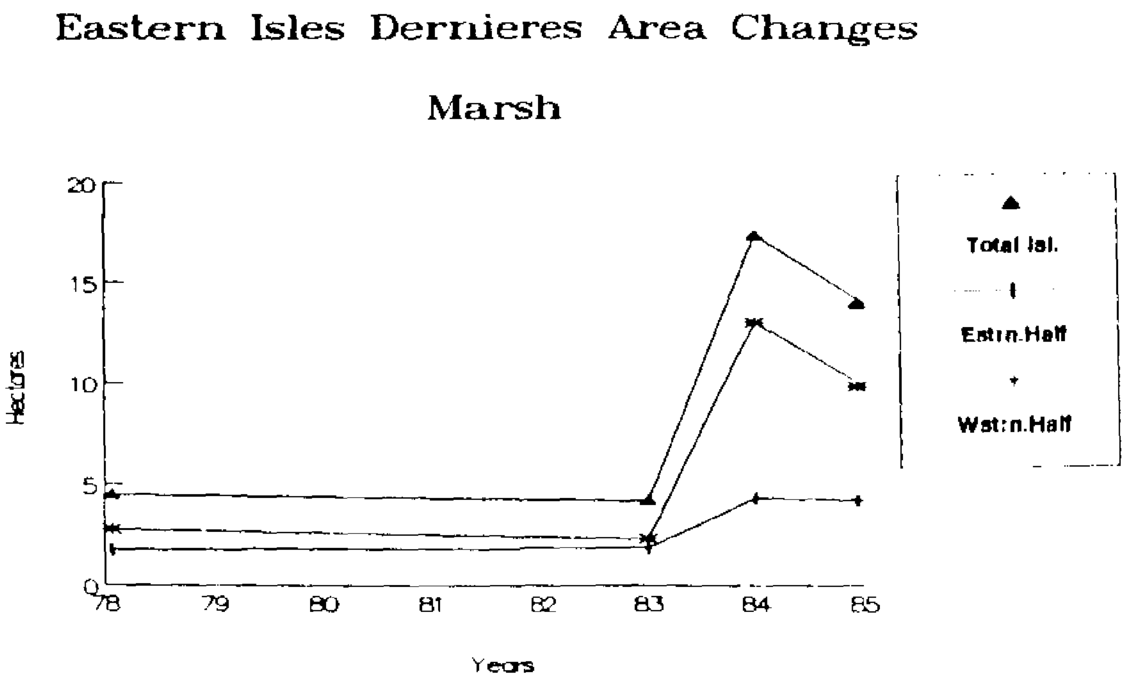


Figure 61. Changes in Eastern Isles Dernieres marsh area for total island and within each transect area polygon, 1978-1985.

total. Therefore, marsh gained in surface area during the study, primarily as a result of the conversion of frost-damaged mangroves.

B. Transect Change Analysis

Trends derived from the transect data for the Eastern Isles Dernieres indicated an overall decrease in island width and cumulative land width over the seven years of the study (Figures 62 and 63). The decrease in island width was accompanied by an extension of the western end of the island while the eastern end remained relatively stable. During the last year of the study (1984-1985) three major breaks occurred in the island, one in the midsection through a former holding pond levee, one in the western marsh/mangrove area and one at the origin of the western extension. The generalized trends and trends relative to specific cover categories are discussed below.

1. Gulf Shoreline

The Eastern Isles Dernieres Gulf shoreline exhibited an increasing erosional tendency, with a minimum of 60% of all sampled transects experiencing shoreline retreat during all periods (Table 21). Rates of erosion increased from 1 m/yr for the 1978-1983 period to 10 m/yr for 1983-1984 and 27 m/yr for 1984-1985. The average overall rate of erosion was 4 m/yr from 1978 to 1985. The sequence of shoreline change can be seen in Figure 64, which also shows the westward lateral migration of the island through the buildup and extension of the western end. The Gulf shoreline, therefore, experienced an average retreat throughout the study, with extension of the shoreline in the western half offset by erosion of the eastern and central areas.

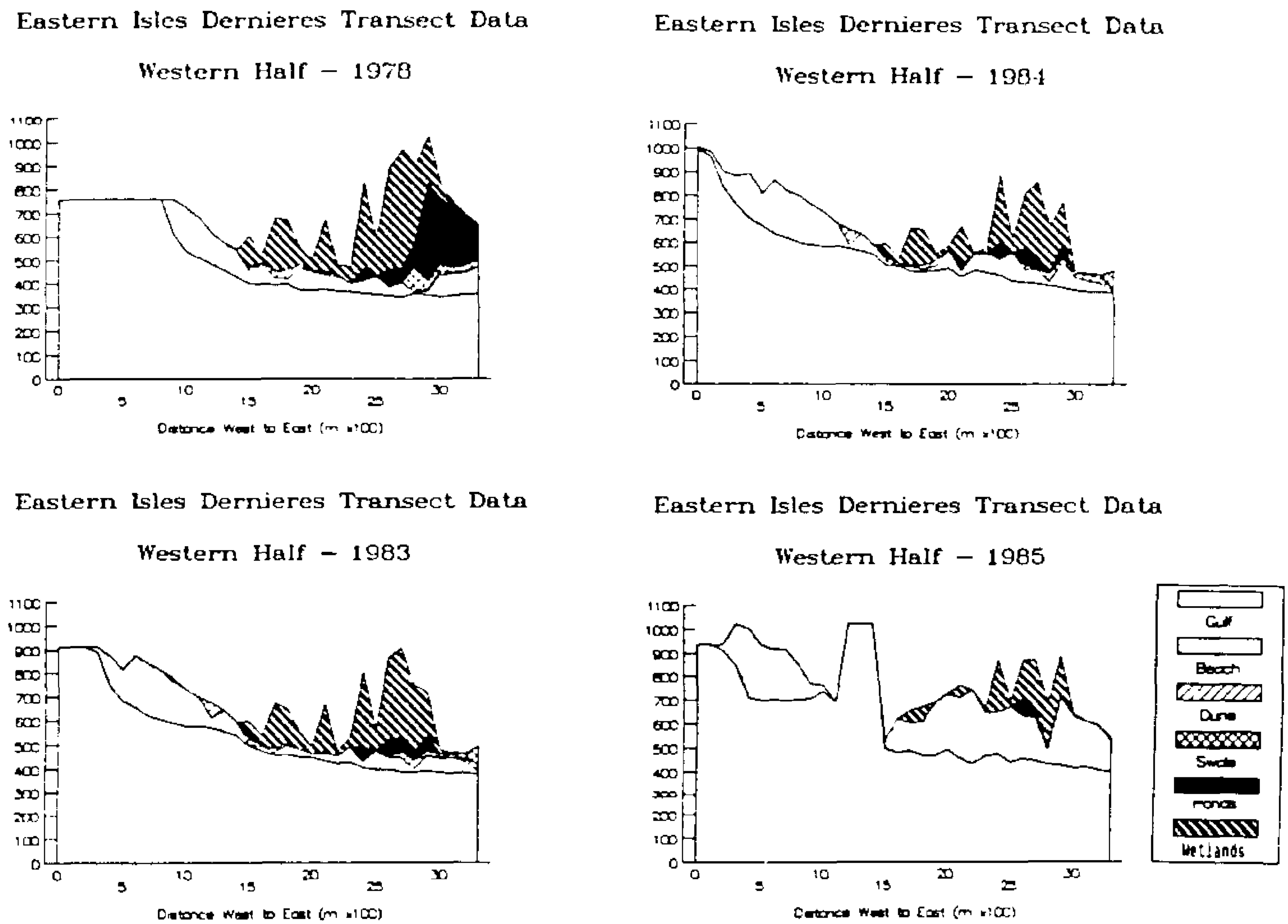


Figure 62. Cumulative widths for the western half of the Eastern Isles Dernieres, 1978-1985. Relative widths of major island components are depicted by individual patterns.

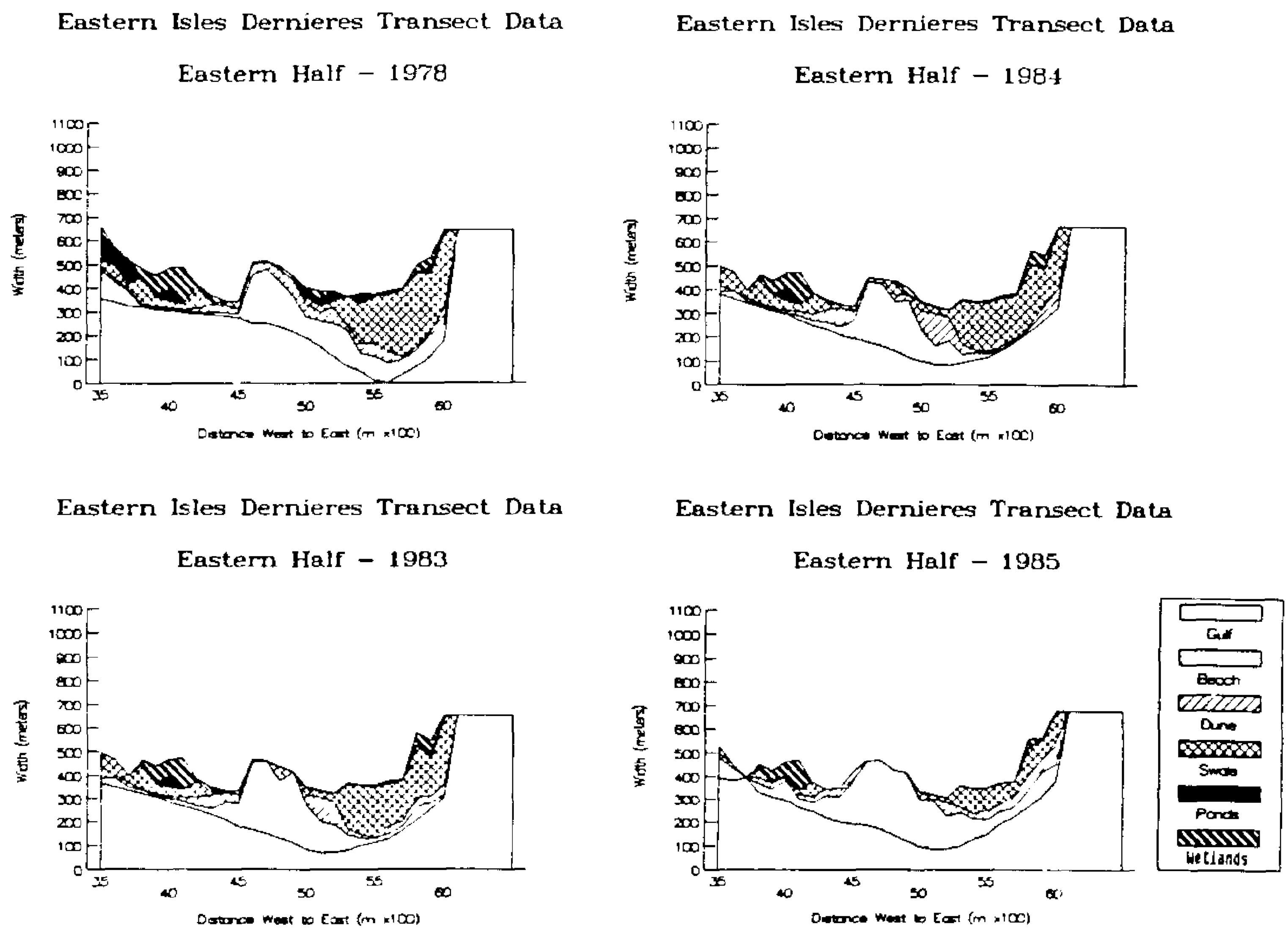


Figure 63. Cumulative widths for the eastern half of the Eastern Isles Dernieres, 1978-1985. Relative widths of major island components are depicted by individual patterns.

Table 21. Eastern Isles Dernieres transect summaries, showing average and maximum category width, and the percentage of total transects containing each category.

1978	Beach	Dune	Swale	Mngrv	Marsh	Wetlands
Average Width (m)	72	24	98	129	28	114
Maximum Width (m)	233	141	323	502	130	530
Percent of Total	98.0%	75.3%	52.0%	52.0%	30.7%	66.0%

	Pond	VgBch	Shell	Spoil	Land	Total
Average Width (m)	89	32	14	12	227	270
Maximum Width (m)	411	82	34	13	584	717
Percent of Total	48.0%	27.3%	14.0%	1.3%	100.0%	100.0%

1983	Beach	Dune	Swale	Mngrv	Marsh	Wetlands
Average Width (m)	59	30	87	111	29	110
Maximum Width (m)	243	113	288	415	127	438
Percent of Total	99.4%	55.7%	47.9%	40.7%	23.4%	47.3%

	Pond	VgBch	Shell	Spoil	Land	Total
Average Width (m)	36	59	11	12	191	201
Maximum Width (m)	178	215	29	13	499	603
Percent of Total	28.7%	33.5%	11.4%	1.2%	100.0%	100.0%

1984	Beach	Dune	Swale	Mngrv	Marsh	Wetlands
Average Width (m)	54	32	87	36	72	94
Maximum Width (m)	210	147	256	176	264	357
Percent of Total	97.2%	60.2%	46.6%	28.4%	40.3%	41.5%

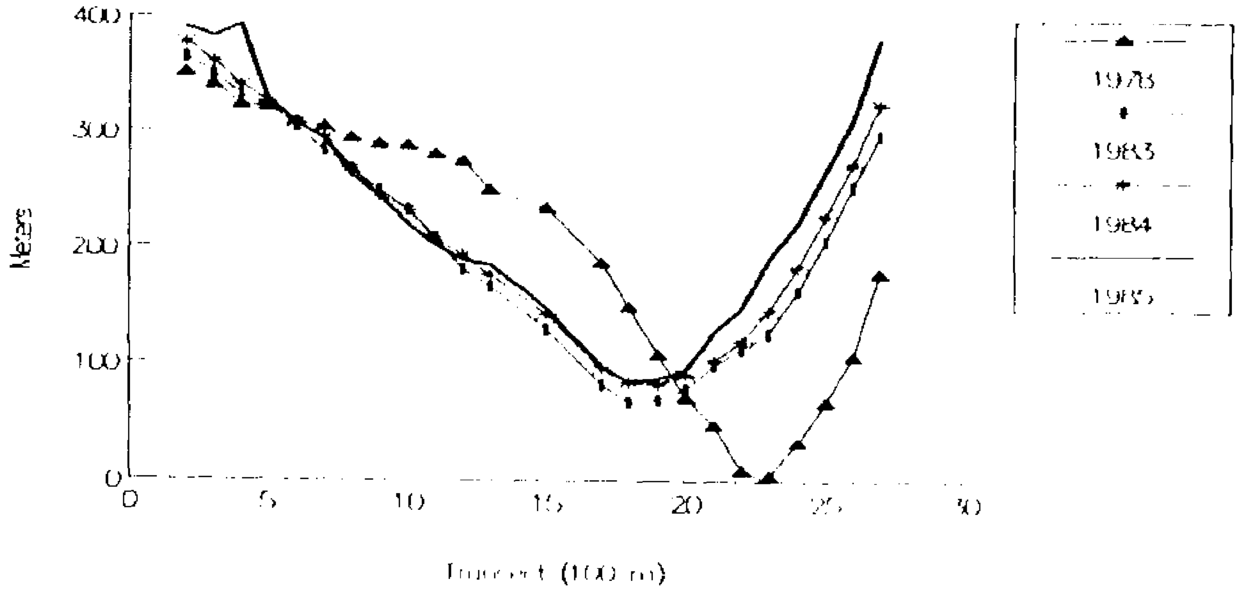
	Pond	VgBch	Shell	Spoil	Land	Total
Average Width (m)	33	54	15	8	172	181
Maximum Width (m)	124	169	31	10	455	547
Percent of Total	27.8%	31.3%	16.5%	1.1%	100.0%	100.0%

1985	Beach	Dune	Swale	Mngrv	Marsh	Wetlands
Average Width (m)	133	36	49	13	76	81
Maximum Width (m)	312	96	135	50	279	279
Percent of Total	92.9%	33.5%	34.1%	12.4%	31.2%	31.2%

	Pond	VgBch	Shell	Spoil	Land	Total
Average Width (m)	39	27	14	8	206	210
Maximum Width (m)	108	58	54	10	456	534
Percent of Total	10.6%	7.6%	14.7%	1.2%	92.9%	92.9%

Eastern Isles Dernieres Gulf Shoreline

Transect Area D-28



Transect Area D-29

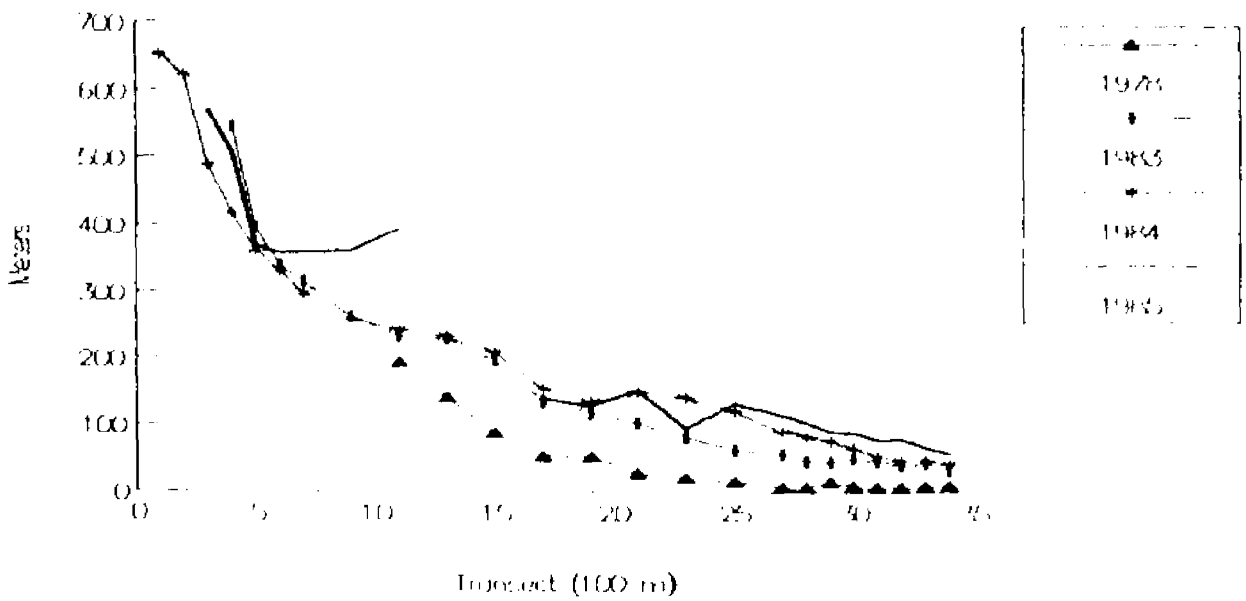


Figure 64. Eastern Isles Dernieres shoreline change by transect area. Transect area D29 shows shoreline change on the western end, while D28 shows change on the eastern end.

2. Bay Shoreline

The bay shoreline experienced an average retreat of 7 m/yr for the five year period 1978-1983, but averaged an overall loss of only 2 m/yr (Table 22). The lower overall rates of retreat were due to the western extension of the island and the occurrence of large areas of overwash during the last period of the study. The bay shoreline averaged a gain of 35 m for the period 1984-1985. The percentage of bay shoreline transects experiencing erosion declined from 66.5% for 1978-1983 to 32.4% for 1984-1985. Overall, 54.7% of sampled transects experienced losses, 26.5% experienced gains, and 18.8% remained unchanged throughout the study. Therefore, the bay shoreline averaged an overall retreat, despite an average gain during the final year of the study.

3. Island Width

Island width, including all land and enclosed water, declined from an average of 270 m in 1978 to 181 m in 1984 (Table 21; Figures 62 and 63). Rates of loss during 1978-1983 and 1983-1984 were 8 m/yr and 10 m/yr, respectively (Table 22). Transects with decreasing widths exceeded those increasing in width by nearly two to one for the 1978-1983 period, and by three to one during the 1983-1984 period. Although the number of transects decreasing in width still exceeded those showing gains, island width for the 1984-1985 period averaged an increase of 8 m/yr, ending at 210 m. Overall, there was an average loss of 7 m/yr, with 60.0% of all transects losing and 40.0% gaining in width. Therefore, island width decreased during the study, resulting in a narrowing of the island, especially in the eastern end, with a redistribution and extension of island sediments westward.

Table 22. Eastern Isles Dernieres transect change summaries, showing average, maximum, and minimum change for each category, as well as the percentage of transects within which the category decreased, increased, or remained unchanged.

1978-1983	Gulf Shore	Bay Shore	Land Width	Island Width	Combined Dry Sand	Combined Wetlands	Dune Location	Marsh Location
Average Change (m)	-5	-36	-13	-41	3	-17	-7	-15
Maximum Gain (m)	229	83	229	229	229	56	94	152
Maximum Loss (m)	-147	-375	-175	-415	-173	-134	-84	-323
Percent Losing	61.7%	66.5%	62.3%	64.1%	54.5%	58.0%	57.0%	59.0%
Percent Unchanged	1.2%	11.4%	0.0%	0.6%	0.0%	33.3%	0.0%	11.5%
Percent Gaining	37.1%	22.2%	37.7%	35.3%	45.5%	8.7%	43.0%	29.5%

1983-1984	Gulf Shore	Bay Shore	Land Width	Island Width	Combined Dry Sand	Combined Wetlands	Dune Location	Marsh Location
Average Change (m)	-10	-0	-9	-10	1	-13	7	-22
Maximum Gain (m)	128	125	110	110	110	29	152	324
Maximum Loss (m)	-73	-116	-106	-145	-41	-109	-32	-270
Percent Losing	80.1%	60.2%	73.9%	74.4%	61.4%	50.8%	59.5%	62.9%
Percent Unchanged	2.8%	5.1%	0.0%	0.0%	0.0%	40.2%	0.0%	0.0%
Percent Gaining	17.0%	34.7%	26.1%	25.6%	38.6%	9.1%	40.5%	37.1%

1984-1985	Gulf Shore	Bay Shore	Land Width	Island Width	Combined Dry Sand	Combined Wetlands	Dune Location	Marsh Location
Average Change (m)	-27	35	13	8	28	-20	-61	-93
Maximum Gain (m)	46	231	244	244	289	17	3	139
Maximum Loss (m)	-152	-62	-119	-119	-119	-108	-176	-537
Percent Losing	72.7%	32.4%	47.7%	54.5%	40.9%	46.2%	96.4%	63.5%
Percent Unchanged	8.0%	11.9%	1.1%	2.3%	1.1%	46.2%	0.0%	30.8%
Percent Gaining	19.3%	55.7%	51.1%	43.2%	58.0%	7.6%	3.6%	5.8%

1978-1985	Gulf Shore	Bay Shore	Land Width	Island Width	Combined Dry Sand	Combined Wetlands	Dune Location	Marsh Location
Average Change (m)	-31	-12	-9	-43	32	-47	-58	-141
Maximum Gain (m)	291	277	291	291	291	31	30	144
Maximum Loss (m)	-229	-349	-249	-427	-217	-327	-193	-584
Percent Losing	63.5%	54.7%	50.6%	60.0%	34.7%	63.3%	71.9%	86.5%
Percent Unchanged	0.0%	18.8%	0.0%	0.0%	0.0%	33.3%	0.0%	0.0%
Percent Gaining	36.5%	26.5%	49.4%	40.0%	65.3%	3.3%	28.1%	13.5%

a. Ponds

Transects containing pond values (pond transects) declined from 48.0% in 1978 to 10.6% by 1985 (Table 21). The large decrease in pond transects was due to overwash and filling of many small ponds in the western portion of the island and the breaching of the remains of a large containment pond levee in the center of the island resulting in a reclassification of those water values from pond to bay. Average cumulative pond width decreased from 89 m in 1978 to 36 m in 1983, and increased to 39 m by 1985. Maximum pond width declined from 411 m in 1978 to 108 m in 1985.

Pond containing transects exhibited significantly higher rates ($\alpha \leq 0.05$) of decline in island width and cumulative land width during the 1978-1983 period compared to non-pond transects (Table 23). Significantly higher rates of Gulf shoreline erosion and decrease in island width were found for the 1983-1984 period. However, gulf shoreline erosion was significantly lower during the 1984-1985 period. For the overall period (1978-1985), decrease in island width was significantly greater among pond transects than among those not containing pond values. Pond width was found to be somewhat linearly correlated with decline in island width during 1978-1983 (r^2=0.693; Figure 65). Therefore, ponds decreased in width and extent during the study, while areas containing ponds experienced higher rates of decline in island width compared to areas not containing ponds.

b. Change Relative to Proximity of Inland Water

The distance from the Gulf shoreline to the nearest inland water body (ponds) was not found to be linearly correlated with changes in Gulf shoreline, island width, or cumulative land width (Table 24). The investigation was extended by considering the bay as an "inland" water body for transects not containing water bodies, however, no improvement

Table 23. Relative influence of ponds on change in Eastern Isles Dernieres Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for pond and non-pond transects, and analysis of means Z values ($Z \geq 2 = \alpha \leq 0.05$).

1978-1983 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	31	-115	-48
Transects Decreasing	76.4%	84.7%	79.2%
Transects Unchanged	1.4%	0.0%	0.0%
Transects Increasing	22.2%	15.3%	20.8%
Category Width R^2 Values	0.0001	0.6932	0.0017
Change - Other Transects (m)	-20	-20	-21
Analysis of Means Z Values	-1.04	6.39	2.61

Category Encountered in 48.0% of All 1978 Transects

1983-1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-22	24	20
Transects Decreasing	93.8%	83.3%	79.2%
Transects Unchanged	4.2%	0.0%	0.0%
Transects Increasing	2.1%	16.7%	20.8%
Category Width R^2 Values	0.0839	0.1232	0.0496
Change - Other Transects (m)	9	9	-9
Analysis of Means Z Values	-4.09	2.53	1.94

Category Encountered in 28.7% of All 1983 Transects

1984-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	15	2	20
Transects Decreasing	65.3%	65.3%	40.8%
Transects Unchanged	12.2%	0.0%	4.1%
Transects Increasing	22.4%	30.6%	59.2%
Category Width R^2 Values	0.0280	0.0004	0.0254
Change - Other Transects (m)	32	10	10
Analysis of Means Z Values	3.87	0.93	0.99

Category Encountered in 27.8% of All 1984 Transects

1978-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	68	-123	-44
Transects Decreasing	79.2%	87.5%	65.3%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	20.8%	12.5%	34.7%
Category Width R^2 Values	0.0009	0.3499	0.1428
Change - Other Transects (m)	-55	30	30
Analysis of Means Z Values	-0.88	5.63	0.87

Category Encountered in 48.0% of All 1978 Transects

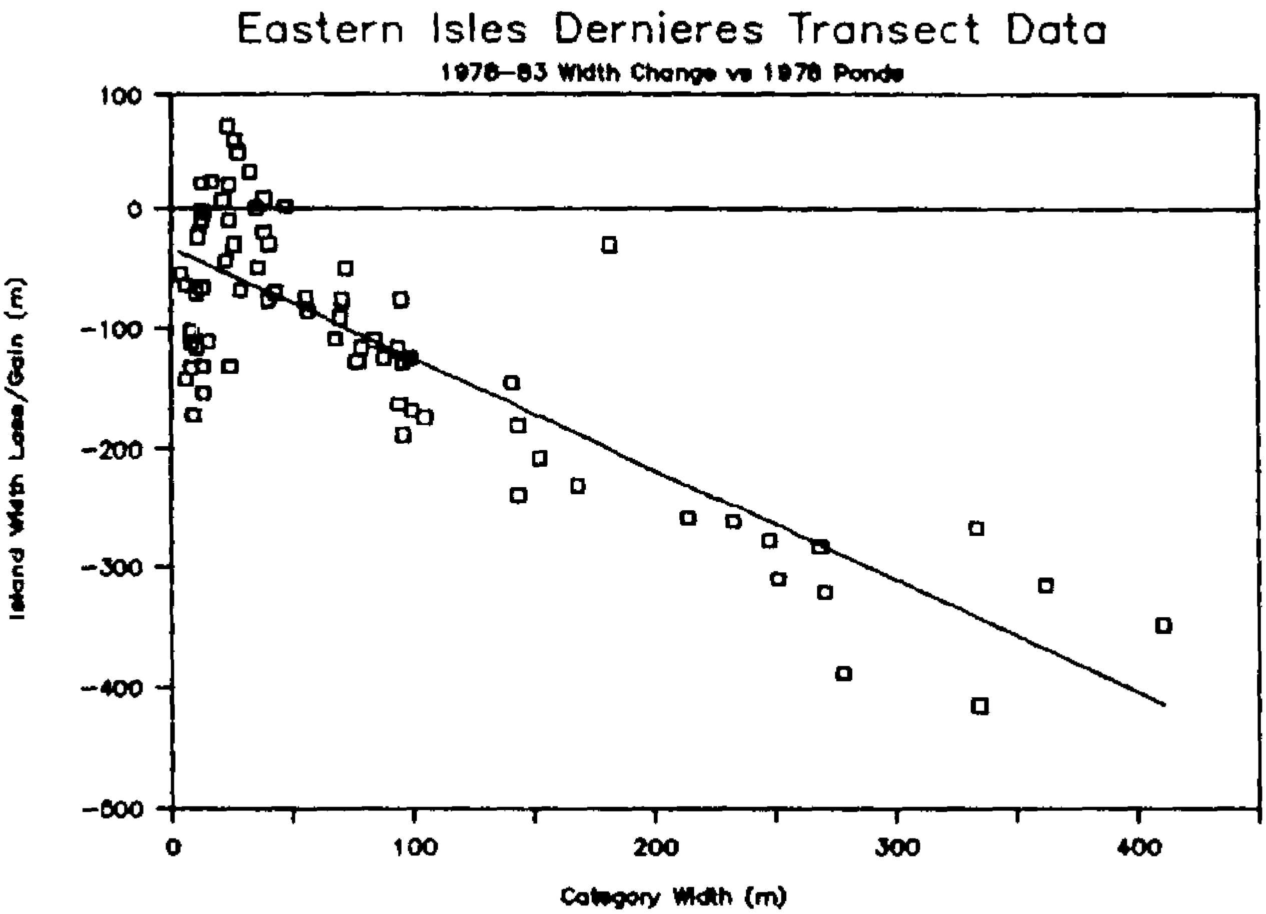


Figure 65. Regression plot of 1978 Eastern Isles Dernieres pond width and 1978-1983 change in island width. Regression r^2=0.693.

Table 24. Relative influence of the proximity of inland water bodies on change in Eastern Isles Dernieres Gulf shoreline, island width, and cumulative land width.

		Gulf Shoreline	Island Width	Land Width
1978 Proximity vs 1978-1983 Change	R^2 =	0.0487	0.0009	0.1273
1983 Proximity vs 1983-1984 Change	R^2 =	0.0313	0.1195	0.0942
1984 Proximity vs 1984-1985 Change	R^2 =	0.0027	0.0091	0.0089
1978 Proximity vs 1978-1985 Change	R^2 =	0.0453	0.0274	0.0072

in correlation was obtained. Therefore, no relationship was found between the relative proximity of inland water bodies and changes in island shoreline or width.

4. Cumulative Land Width

Combined land categories (excluding ponds, canals, and embayments) decreased in average width through the first two periods of the study from 227 m in 1978 to 172 m in 1984, with loss rates of 3 m/yr and 10 m/yr for 1978-1983 and 1983-1984, respectively (Tables 21 and 22). However, during the 1984-1985 period cumulative land width experienced an average increase of 13 m/yr, reducing the overall average loss to 1 m/yr for the seven years of the study. The average width for 1985 was 206 m. Much of the gain in land width during the last year of the study could be attributed to filling in of island water bodies through sediment overwash, as well as the extension of the island westward. Overall, transects showing a decrease in land width just exceeded those showing gains by 50.6% to 49.4%. Therefore, land width averaged a slight increase, due to infilling of inland water bodies and extension of the island westward.

a. Combined Dry Sand Categories

Combined cover categories having a dry or well drained sand substrate (beach, dune, swale, spoil, and shell) averaged between 132 m and 179 m in cumulative width during the study, with maximum widths declining from 457 m in 1978 to 334 m in 1985 (Table 21). Sampled transects exhibited an average increase in width of 32 m during the study, resulting in an overall rate of increase of 7 m/yr (Figure 62; Table 22). Much of this was the result of overwash of wetlands and the extension and emergence of new land area on the island's western end.

Increases in combined dry sand categories were recorded for all periods, with gains of 1 m/yr during the 1978-1983 and 1983-1984 periods and 28 m/yr in the last year of the study, 1984-1985. Transects showing increases outnumbered those showing losses in all but the 1983-1984 period. Therefore, the overall trend was an increase width for combined dry sand categories.

(1) Beach

Average beach width declined from 72 m in 1978 to 54 m in 1984, but increased to 133 m by 1985 (Table 21). Maximum beach width ranged from 210 m to 243 m between 1978 and 1984, and 312 m in 1985. Beach values were encountered in 93% to 99% of all transects sampled (Table 25). Analysis of means test statistics were not considered valid due to the low number (2 to 12) of sample transects not containing beach values. Linear relationships between beach width and changes in Gulf shoreline, island width, or cumulative land width were not detected. Beach, therefore, exhibited a net average gain in width during the study.

(2) Vegetated Beach

Vegetated Beach varied in width from an average of 32 m in 1978, to 59 m in 1983, declining to 27 m by 1985 (Table 21). Vegetated beach was encountered in 27% to 34% of all transects sampled between 1978 and 1984, but only 8% of those in 1985. No correlations were found between width of vegetated beach and changes in shorelines or widths (Table 26). However, transects containing vegetated beach (vegetated beach transects) experienced significantly higher rates ($\alpha \leq 0.05$) of Gulf shoreline erosion and decrease in island width and cumulative land width than transects not containing vegetated beach during 1978-1983 and 1978-1985. Erosion of Gulf shoreline and decrease in island width were four

Table 25. Relative influence of beach on change in Eastern Isles Dernieres Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for beach and non-beach transects, and analysis of means Z values ($Z \geq 2 \Rightarrow \alpha \leq 0.05$).

1978-1983 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-26	67	-34
Transects Decreasing	70.1%	71.4%	69.4%
Transects Unchanged	0.7%	0.7%	0.0%
Transects Increasing	29.3%	27.9%	30.6%
Category Width R^2 Values	0.0627	0.0997	0.0559
Change Other Transects (m)	10	6	-9
Analysis of Means Z Values	3.84	4.88	1.86
Category Encountered in 98.0% of All 1978 Transects			

1983-1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	13	13	13
Transects Decreasing	84.3%	78.9%	78.3%
Transects Unchanged	3.0%	0.0%	0.0%
Transects Increasing	12.7%	21.1%	21.7%
Category Width R^2 Values	0.0705	0.0007	0.0012
Change Other Transects (m)	-22	34	34
Analysis of Means Z Values	5.55	21.34	23.11
Category Encountered in 99.4% of All 1983 Transects			

1984-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	28	8	13
Transects Decreasing	72.5%	55.0%	48.0%
Transects Unchanged	8.2%	2.3%	1.2%
Transects Increasing	19.3%	42.7%	50.9%
Category Width R^2 Values	0.1196	0.0010	0.0027
Change Other Transects (m)	7	26	29
Analysis of Means Z Values	-3.20	0.98	0.83
Category Encountered in 97.2% of All 1984 Transects			

1978-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	62	76	37
Transects Decreasing	72.8%	68.0%	57.1%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	27.2%	32.0%	42.9%
Category Width R^2 Values	0.0123	0.0160	0.0023
Change Other Transects (m)	4	22	17
Analysis of Means Z Values	7.22	3.10	1.19
Category Encountered in 98.0% of All 1978 Transects			

Table 26. Relative influence of vegetated beach on change in Eastern Isles Dernieres Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for vegetated beach and non-vegetated beach transects, and analysis of means Z values ($Z \geq 2 = \alpha \leq 0.05$).

1978-1983 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-70	-175	-73
Transects Decreasing	97.6%	100.0%	95.1%
Transects Unchanged	2.4%	0.0%	0.0%
Transects Increasing	0.0%	0.0%	4.9%
Category Width R^2 Values	0.0017	0.0635	0.0173
Change - Other Transects (m)	-8	-24	-19
Analysis of Means Z Values	-6.04	9.02	5.29

Category Encountered in 27.3% of All 1978 Transects

1983-1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	6	13	13
Transects Decreasing	78.6%	82.1%	83.9%
Transects Unchanged	1.8%	0.0%	0.0%
Transects Increasing	19.6%	17.9%	16.1%
Category Width R^2 Values	0.1322	0.0769	0.0696
Change - Other Transects (m)	-16	-14	12
Analysis of Means Z Values	4.10	0.26	-0.12

Category Encountered in 33.5% of All 1983 Transects

1984-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	39	10	10
Transects Decreasing	83.6%	45.5%	43.6%
Transects Unchanged	9.1%	0.0%	1.8%
Transects Increasing	7.3%	54.5%	54.5%
Category Width R^2 Values	0.0646	0.0023	0.0030
Change - Other Transects (m)	22	7	14
Analysis of Means Z Values	2.65	0.21	0.34

Category Encountered in 31.3% of All 1984 Transects

1978-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-115	181	-73
Transects Decreasing	100.0%	100.0%	73.2%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	0.0%	0.0%	26.8%
Category Width R^2 Values	0.0047	0.0335	0.0519
Change - Other Transects (m)	41	35	-22
Analysis of Means Z Values	5.72	11.21	2.67

Category Encountered in 27.3% of All 1978 Transects

to eight times higher in transects containing vegetated beach than those not containing vegetated beach during this period. Vegetated beach transects showed significantly lower rates of Gulf shoreline erosion during 1983-1984, but significantly higher rates for 1984-1985. Vegetated beach, therefore, underwent an overall reduction in width and distribution, while areas containing vegetated beach experienced higher rates of Gulf shoreline erosion, land loss, and reduction in island width than areas not containing vegetated beach.

(3) Dune

Dunes increased in average width from 24 m in 1978 to 35.6 in 1985 (Table 21). Transects containing dunes (dune transects) accounted for 75% of those sampled in 1978, but only 34% by 1985, declining from 60% in 1984. Comparison of means analysis indicated dune transects experienced significantly less Gulf shoreline erosion ($\alpha \leq 0.05$) during 1978-1983, 1984-1985, and 1978-1985, than transects not containing dunes (Table 27). Dune transects had significantly higher rates of cumulative land loss during the 1983-1984 period, but significantly lower rates for 1978-1983, and 1978-1985. In addition, the decrease in island width was significantly lower for dune transects compared to those not containing dunes for 1978-1985. Transects not containing dunes were approximately three times more likely to experience Gulf shoreline erosion. However, cumulative land loss among dune transects during 1983-1984 was double that for non-dune transects. No relationship was detected between dune width and the amount of shoreline, island width, or cumulative land width change.

The Eastern Isles Dernieres beach/dune boundaries were displaced inland an average of 58 m during the study, (Table 22). They moved 7 m inland from 1978 to 1983, 7 m shoreward between 1983 and 1984, and 61 m inland between 1984 and 1985. Overall, dunes increased in width but decreased in distribution during the study, while being displaced

Table 27. Relative influence of dunes on change in Eastern Isles Dernieres Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for dune and non-dune transects, and analysis of means Z values ($Z \geq 2 \Rightarrow \alpha \leq 0.05$).

1978-1983 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-16	-69	-29
Transects Decreasing	60.2%	65.5%	62.8%
Transects Unchanged	1.8%	0.0%	0.9%
Transects Increasing	38.1%	33.6%	37.2%
Category Width R^2 Values	0.1013	0.1286	0.0805
Change - Other Transects (m)	-53	-54	-50
Analysis of Means Z Values	3.98	1.01	2.12

Category Encountered in 75.3% of All 1978 Transects

1983-1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	12	16	16
Transects Decreasing	92.5%	84.9%	86.0%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	7.5%	15.1%	14.0%
Category Width R^2 Values	0.0022	0.0023	0.0029
Change - Other Transects (m)	-13	10	-7
Analysis of Means Z Values	0.40	1.35	2.12

Category Encountered in 55.7% of All 1983 Transects

1984-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	15	[illegible]	7
Transects Decreasing	64.2%	57.5%	49.1%
Transects Unchanged	10.4%	0.0%	3.8%
Transects Increasing	25.5%	38.7%	49.1%
Category Width R^2 Values	0.0622	0.0035	0.0096
Change - Other Transects (m)	46	17	22
Analysis of Means Z Values	5.30	1.30	1.28

Category Encountered in 60.2% of All 1984 Transects

1978-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-42	-62	-17
Transects Decreasing	62.8%	61.9%	48.7%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	37.2%	38.1%	51.3%
Category Width R^2 Values	0.0761	0.0461	0.0003
Change - Other Transects (m)	118	113	-96
Analysis of Means Z Values	7.18	2.61	4.58

Category Encountered in 75.3% of All 1978 Transects

inland. Areas containing dunes experienced lower overall rates of Gulf shoreline erosion, decrease in island width, and land loss than areas not containing dunes.

(4) Swale

Transects containing swale values (swale transects) accounted for 34% to 52% of all those sampled (Table 21). Average swale width declined from 98 m to 49 m and maximum swale width declined from 323 m to 135 m between 1978 and 1985. Transects containing swale (swale transects) experienced significantly higher ($\alpha \leq 0.05$) rates of decline in island width than non-swale transects during the 1978-1983 period (Table 28). However, Gulf shoreline erosion rates were significantly lower for swale transects than for non-swale transects for 1984-1985 and 1978-1985. Some linear correlations were found between swale width and Gulf shoreline erosion, with r^2 values ranging from 0.304 to 0.673 (Figures 66 and 67). Swale width was also somewhat linearly correlated with decline in cumulative land width for 1978-1983 (r^2=0.502) and 1978-1985 (r^2=0.631; Figures 68 and 69). Therefore, swale width, which was somewhat correlated with Gulf shoreline erosion and land loss, decreased during the study. Areas of the island containing swale experienced greater reductions in island width than areas not containing swale.

(5) Spoil

Spoil values were encountered in less than 2% of all Eastern Isles Dernieres transects (Table 21). The only area interpreted as spoil on the Eastern Isles Dernieres consisted of the levees of a small containment pond located in the eastern end, an area which experienced little change during the study. Spoil was not assimilated into surrounding categories (beach and swale) due to assumed differences in

Table 28. Relative influence of swale on change in Eastern Isles Dernieres Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for swale and non-swale transects, and analysis of means Z values ($Z \geq 2 = \alpha \leq 0.05$).

1978 1983 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-19	-94	-32
Transects Decreasing	60.3%	67.9%	64.1%
Transects Unchanged	2.6%	0.0%	1.3%
Transects Increasing	37.2%	30.8%	35.9%
Category Width R^2 Values	0.6730	0.0088	0.5297
Change - Other Transects (m)	-32	35	-36
Analysis of Means Z Values	1.12	-3.77	0.45

Category Encountered in 52.0% of All 1978 Transects

1983 1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	11	12	-12
Transects Decreasing	92.5%	82.5%	83.8%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	7.5%	17.5%	16.3%
Category Width R^2 Values	0.3044	0.0526	0.0474
Change - Other Transects (m)	-15	-14	-13
Analysis of Means Z Values	1.34	0.46	0.33

Category Encountered in 47.9% of All 1983 Transects

1984 1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-16	2	6
Transects Decreasing	67.1%	63.4%	54.9%
Transects Unchanged	12.2%	0.0%	3.7%
Transects Increasing	20.7%	32.9%	43.9%
Category Width R^2 Values	0.3060	0.2984	0.2769
Change - Other Transects (m)	-37	14	19
Analysis of Means Z Values	4.06	1.25	1.35

Category Encountered in 46.6% of All 1984 Transects

1978 1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	48	-102	-35
Transects Decreasing	64.1%	76.9%	57.7%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	35.9%	23.1%	42.3%
Category Width R^2 Values	0.6674	0.1376	0.6308
Change - Other Transects (m)	76	45	-38
Analysis of Means Z Values	1.98	3.22	0.21

Category Encountered in 52.0% of All 1978 Transects

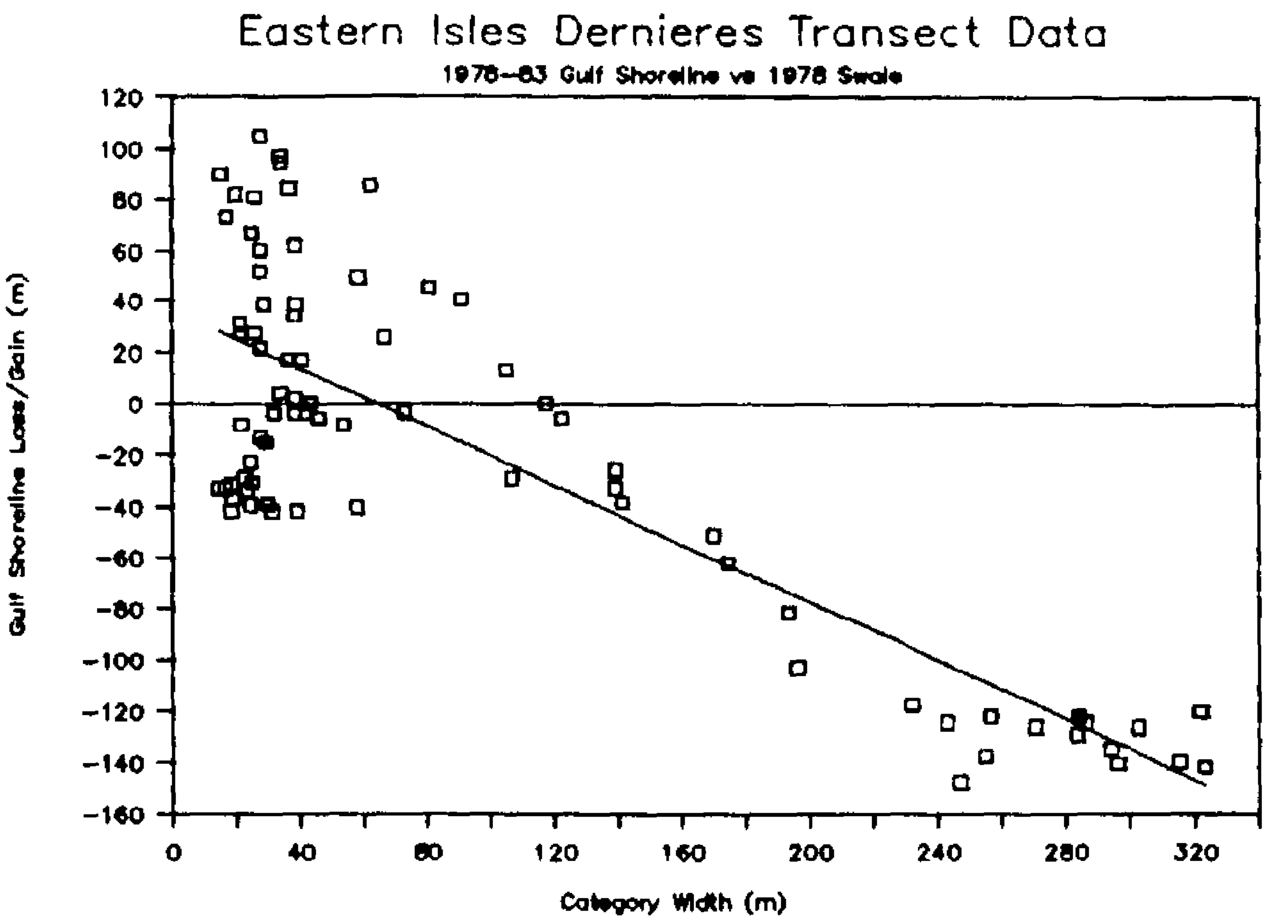


Figure 66. Regression plot of 1978 Eastern Isles Dernieres swale width and 1978-1983 change in Gulf shoreline. Regression $r^2=0.673$.

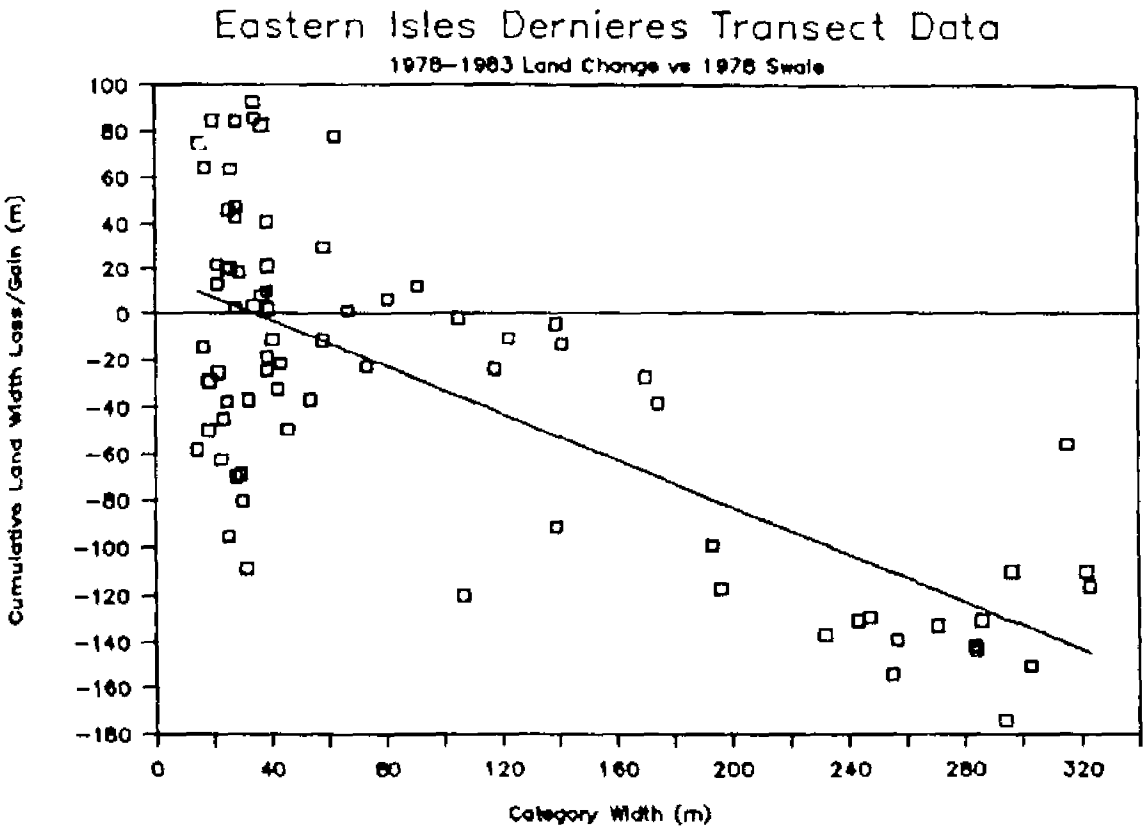


Figure 67. Regression plot of 1978 Eastern Isles Dernieres swale width and 1978-1983 change in cumulative land width. Regression r^2=0.502.

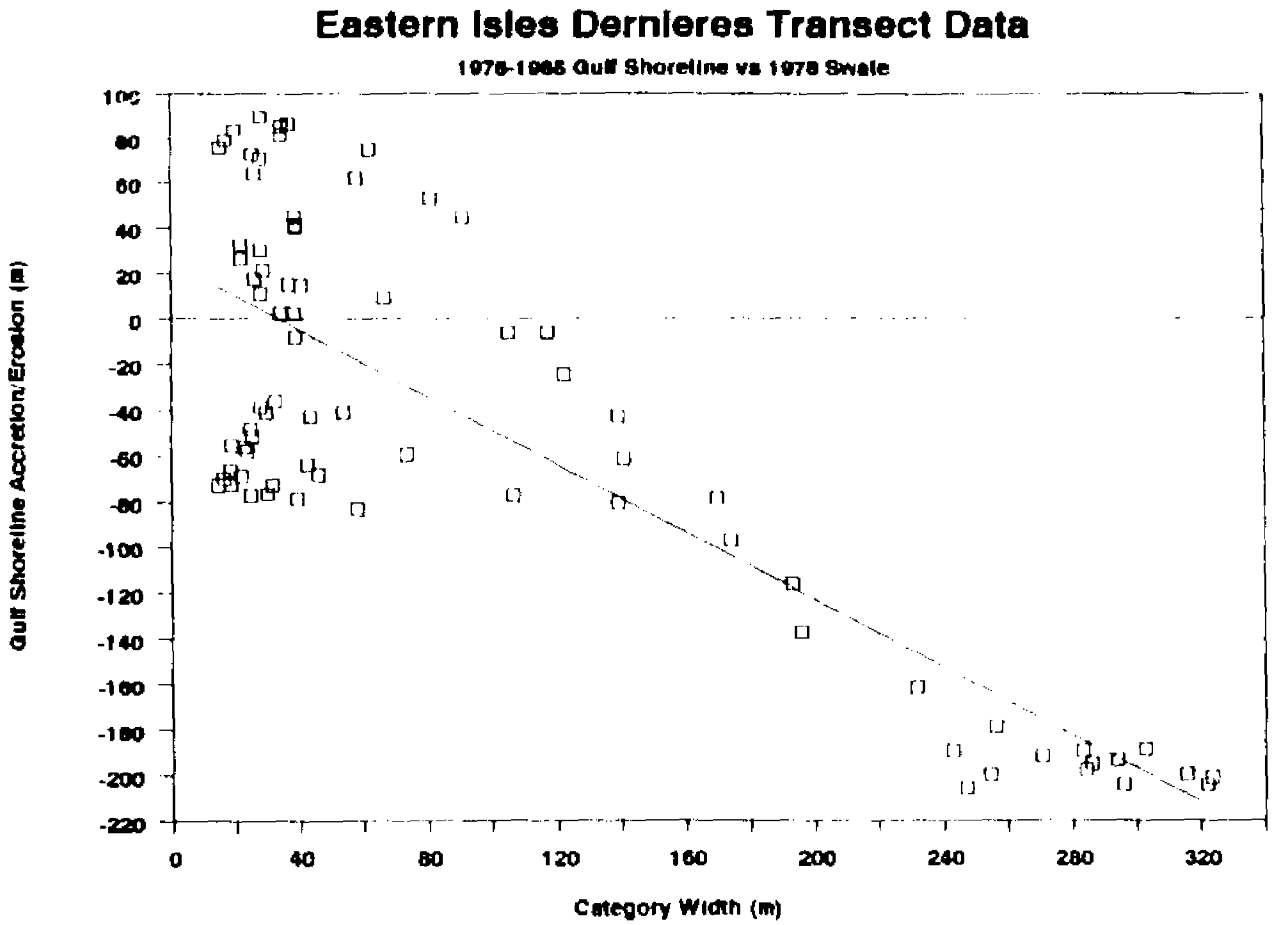


Figure 68. Regression plot of 1978 Eastern Isles Dernieres swale width and 1978-1985 change in Gulf shoreline. Regression r^2=0.667.

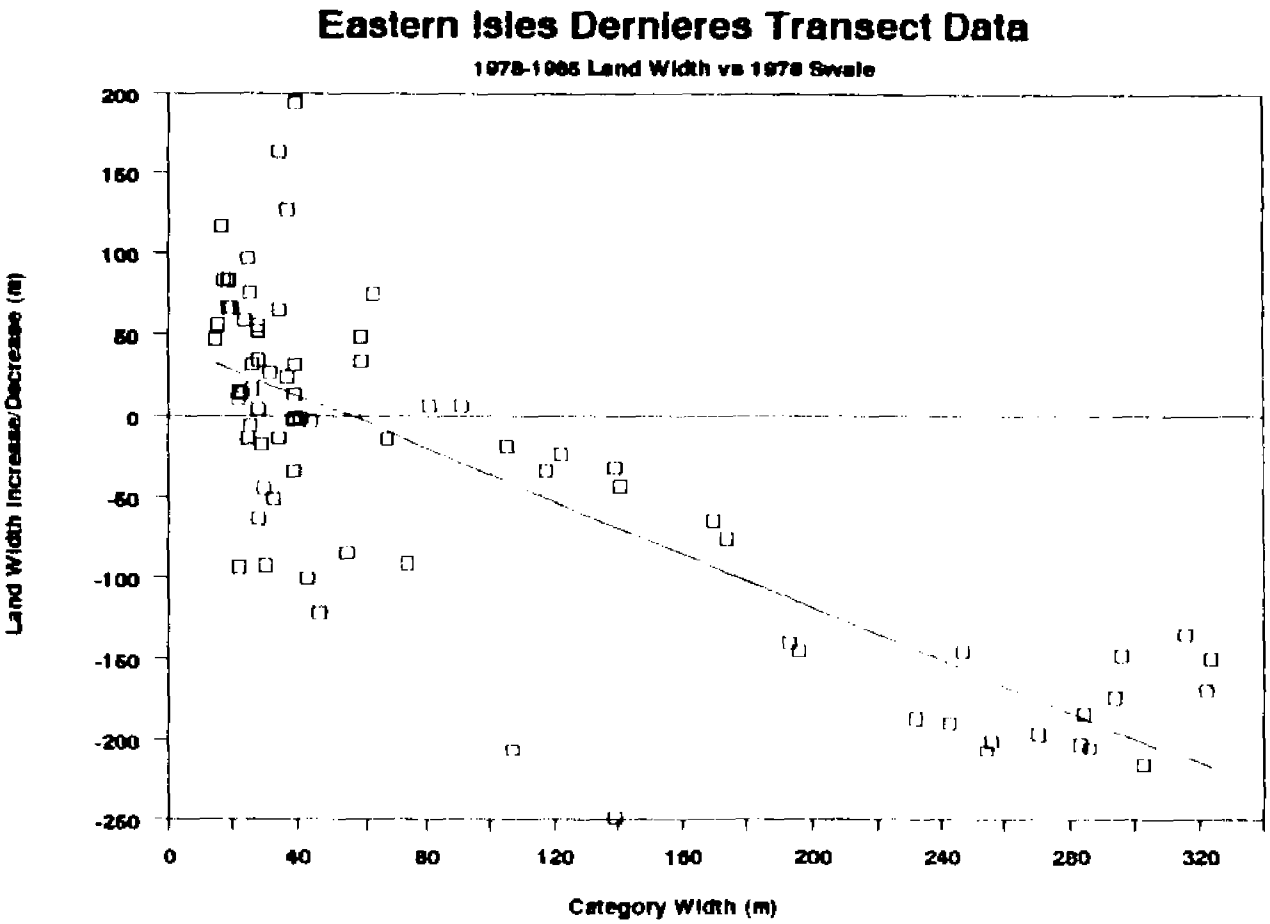


Figure 69. Regression plot of 1978 Eastern Isles Dernieres swale width and 1978-1985 change in cumulative land width. Regression $r^2=0.631$.

effects on island change rates. However, no observable effects were noted.

(6) Shell

Shell values were encountered in 11% to 17% of sampled transects and averaged from 11 m to 15 m in width (Table 21). Transects containing shell (shell transects) experienced significantly ($\alpha \leq 0.05$) higher rates of decline in island width and cumulative land width than non-shell transects during the 1978-1983 period, but lower rates in the 1984-1985 period (Table 29). Shell transects showed significantly greater overall (1978-1985) rates of decline in island width, compared to non-shell transects. The rate of decrease in island width during the first period of study was 42 m/yr for shell transects compared to 8 m/yr for other transects. No correlations were observed between shell width and Gulf shoreline, island width, or cumulative land changes. Therefore, areas containing shell experienced greater overall declines in island width than areas not containing shell.

b. Combined Wetlands Categories

Combined wetlands categories (marsh and mangrove) declined in averaged width from 114 m to 81 m and in maximum width from 502 m to 279 m from 1978 to 1985 (Table 21). Wetlands exhibited an average decrease in width of 47 m from 1978 to 1985 (Table 22). Loss of wetlands was recorded at 4 m/yr, 13 m/yr, and 20 m/yr for 1978-1983, 1983-1984, and 1984-1985, respectively. Transects containing wetlands (wetlands transects) experienced significantly higher rates of Gulf shoreline erosion and land loss during the 1983-1984 period, due in part to die-back of frost damaged mangroves (Table 30). However, Gulf erosion was significantly lower and increases in island width and

Table 29. **Relative influence of shell on change in Eastern Isles Dernieres Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for shell and non-shell transects, and analysis of means Z values ($Z \geq 2 \Rightarrow \alpha \leq 0.05$).**

1978-1983 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-35	-211	-70
Transects Decreasing	100.0%	100.0%	100.0%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	0.0%	0.0%	0.0%
Category Width R^2 Values	0.2011	0.0010	0.1206
Change - Other Transects (m)	-24	42	-28
Analysis of Means Z Values	-1.64	7.39	4.18

Category Encountered in 14.0% of All 1978 Transects.

1983-1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-15	23	20
Transects Decreasing	94.7%	89.5%	89.5%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	5.3%	10.5%	10.5%
Category Width R^2 Values	0.1138	0.0462	0.0418
Change - Other Transects (m)	12	12	-11
Analysis of Means Z Values	-0.93	-1.24	1.13

Category Encountered in 11.4% of All 1983 Transects.

1984-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	25	45	38
Transects Decreasing	100.0%	44.8%	34.5%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	0.0%	55.2%	65.5%
Category Width R^2 Values	0.0057	0.0261	0.0141
Change - Other Transects (m)	27	3	8
Analysis of Means Z Values	0.56	2.54	2.37

Category Encountered in 16.5% of All 1984 Transects.

1978-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-73	180	33
Transects Decreasing	100.0%	95.2%	57.1%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	0.0%	4.8%	42.9%
Category Width R^2 Values	0.1744	0.0343	0.0602
Change - Other Transects (m)	-59	57	37
Analysis of Means Z Values	-1.42	6.25	0.17

Category Encountered in 14.0% of All 1978 Transects.

Table 30. Relative influence of combined wetlands on change in Eastern Isles Dernieres Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for wetlands and non-wetlands transects, and analysis of means Z values ($Z \geq 2 \approx \alpha \leq 0.05$).

1978-1983 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-20	-63	-33
Transects Decreasing	63.6%	68.7%	64.6%
Transects Unchanged	2.0%	0.0%	0.0%
Transects Increasing	34.3%	31.3%	35.4%
Category Width R^2 Values	0.0957	0.0949	0.2102
Change - Other Transects (m)	-36	71	-36
Analysis of Means Z Values	1.35	0.46	0.33

Category Encountered in 66.0% of All 1978 Transects

1983-1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-23	17	17
Transects Decreasing	96.2%	74.7%	75.9%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	3.8%	25.3%	24.1%
Category Width R^2 Values	0.0857	0.2237	0.2069
Change - Other Transects (m)	4	9	-8
Analysis of Means Z Values	-6.67	1.78	2.18

Category Encountered in 47.3% of All 1983 Transects

1984-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	8	22	33
Transects Decreasing	52.1%	50.7%	37.0%
Transects Unchanged	13.7%	4.1%	1.4%
Transects Increasing	34.2%	45.2%	61.6%
Category Width R^2 Values	0.1013	0.0191	0.0032
Change - Other Transects (m)	40	2	-1
Analysis of Means Z Values	6.92	2.37	3.38

Category Encountered in 41.5% of All 1984 Transects

1978-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-50	-56	17
Transects Decreasing	66.7%	59.6%	47.5%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	33.3%	40.4%	52.5%
Category Width R^2 Values	0.1294	0.2045	0.2024
Change - Other Transects (m)	82	110	-74
Analysis of Means Z Values	2.14	3.13	3.45

Category Encountered in 66.0% of All 1978 Transects

cumulative land width significantly higher than among non-wetlands transects during the major hurricane period, 1984-1985, due to the accumulation of overwashed sediments within wetlands areas. Although, wetlands transects averaged overall rates of shoreline erosion, decline in island width, and land loss, these were all significantly lower than transects not containing wetlands, perhaps due to a dampening of washover flow (Webb and Dodd, 1983). Therefore, although wetlands declined in width throughout the study, areas containing wetlands experienced less Gulf shoreline erosion, decline in island width, and land loss than other areas of the island.

(1) Mangrove

Mangroves were encountered in 52.0% of all transects sampled in 1978, but declined to 12.4% by 1985 (Table 21). The average width of mangroves decreased from 129 m to 13 m and the maximum width fell from 502 m to 50 m during the seven years of the study. Much of the decline in mangrove width was due to severe freezes and resultant mangrove die-backs during the winters of 1983-84 and 1984-85. Large areas of dead mangroves reverted to *Spartina alterniflora* and were subsequently classified as marsh.

Transects containing mangroves (mangrove transects) showed significantly higher rates ($\alpha \leq 0.05$) of land loss, decline in island width, and Gulf shoreline erosion than non-mangrove transects during the 1978-1983 period but significantly lower rates of loss during the final 1984-1985 period (Table 31). Erosion of the Gulf shoreline was also significantly higher among mangrove transects during the 1983-1984 survey period. Mangrove width was poorly correlated with decline in island width during this period ($r^2 \leq 0.304$). Rates of shoreline erosion for mangrove transects ranged from 8 m/yr for 1978-1983, to 24 m/yr for 1983-1984, compared to 2 m/yr and 5 m/yr for non-mangrove transects. During the final year of the study mangrove transects experienced an

Table 31. Relative influence of mangroves on change in Eastern Isles Dernieres Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for mangrove and non-mangrove transects, and analysis of means Z values ($Z \geq 2 = \alpha \leq 0.05$).

1978-1983 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-40	89	-51
Transects Decreasing	76.9%	82.1%	78.2%
Transects Unchanged	2.6%	0.0%	0.0%
Transects Increasing	20.5%	17.9%	21.8%
Category Width R^2 Values	0.0204	0.0331	0.1185
Change - Other Transects (m)	-9	-41	-15
Analysis of Means Z Values	-2.78	2.97	-3.61

Category Encountered in 52.0% of All 1978 Transects.

1983-1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	24	17	16
Transects Decreasing	95.6%	70.6%	72.1%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	4.4%	29.4%	27.9%
Category Width R^2 Values	0.0439	0.3043	0.2899
Change - Other Transects (m)	-5	11	10
Analysis of Means Z Values	6.43	1.19	1.55

Category Encountered in 40.7% of All 1983 Transects.

1984-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	7	29	43
Transects Decreasing	48.0%	42.0%	24.0%
Transects Unchanged	14.0%	0.0%	6.0%
Transects Increasing	38.0%	52.0%	74.0%
Category Width R^2 Values	0.2002	0.0024	0.0072
Change - Other Transects (m)	-35	-0	1
Analysis of Means Z Values	6.52	2.79	4.03

Category Encountered in 28.4% of All 1984 Transects.

1978-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-71	-71	24
Transects Decreasing	79.5%	65.4%	52.6%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	20.5%	34.6%	47.4%
Category Width R^2 Values	0.0561	0.1825	0.2018
Change - Other Transects (m)	-50	-78	-50
Analysis of Means Z Values	1.49	0.38	1.58

Category Encountered in 52.0% of All 1978 Transects.

average shoreline erosion rate of 7 m/yr compared to 35 m/yr for other transects.

Declines in island width and cumulative land width among mangrove transects were two to three times the rates for non-mangrove transects during the 1978-1983 period. However, in the final period remaining mangrove transects averaged gains in island width and land width which were twenty to thirty times higher than non-mangrove transects. Island width and cumulative land gains among mangrove transects averaged 29 m/yr and 43 m/yr, respectively, compared to non-mangrove transect losses of less than 1 m/yr and gains of 1 m/yr during this final period. Therefore, although mangroves declined dramatically during the study, areas of remaining mangroves experienced lower rates of Gulf shoreline erosion, decrease in land width, and land loss than areas which did not contain mangroves.

(2) Marsh

Average marsh width increased from 28 m to 29 m between 1978 and 1983, and then jumped to 72 m in 1984 and 76 m by 1985 (Table 21). Maximum marsh widths exhibited a similar expansion, from less than 130 m to over 260 m. The large increase between 1983 and 1984 was largely attributable to the conversion of dead and damaged mangrove stands to marsh. The inland marsh/swale boundaries were displaced toward the bay shoreline an average of 141 m over the seven years of the study (Table 22). The rate of relocation increased from 3 m/yr between 1978 and 1983, to 93 m/yr between 1984 and 1985, for an overall average rate of bayward movement of 20 m/yr.

Transects containing marsh values (marsh transects) accounted for 23% to 40% of those sampled. During the 1978-1983 and 1984-1985 periods, transects containing marsh values experienced significantly lower ($\alpha \le 0.05$) rates of Gulf shoreline erosion, decrease island width, and land loss than non-marsh transects (Table 32). However, marsh

Table 32. Relative influence of marsh on change in Eastern Isles Dernieres Gulf shoreline, island width, and cumulative land width, including regression analyses R^2 values, comparison of average change for marsh and non-marsh transects, and analysis of means Z values ($Z \geq 2 = \alpha \leq 0.05$).

1978-1983 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	5	22	-17
Transects Decreasing	45.7%	50.0%	47.8%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	54.3%	50.0%	52.2%
Category Width R^2 Values	0.0593	0.0875	0.1104
Change Other Transects (m)	-38	-85	-42
Analysis of Means Z Values	3.21	4.10	2.01
Category Encountered in 30.7% of All 1978 Transects			

1983-1984 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	24	24	22
Transects Decreasing	100.0%	79.5%	82.1%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	0.0%	20.5%	17.9%
Category Width R^2 Values	0.1807	0.0100	0.0061
Change Other Transects (m)	-9	10	-9
Analysis of Means Z Values	-4.89	2.07	2.31
Category Encountered in 23.4% of All 1983 Transects			

1984-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	8	21	32
Transects Decreasing	52.1%	52.1%	38.0%
Transects Unchanged	14.1%	0.0%	4.2%
Transects Increasing	33.8%	43.7%	60.6%
Category Width R^2 Values	0.0863	0.0512	0.0207
Change Other Transects (m)	-40	1	1
Analysis of Means Z Values	6.78	2.18	3.09
Category Encountered in 40.3% of All 1984 Transects			

1978-1985 Change Statistics	Gulf Shoreline	Island Width	Land Width
Average Change (m)	-31	-54	-36
Transects Decreasing	47.8%	58.7%	50.0%
Transects Unchanged	0.0%	0.0%	0.0%
Transects Increasing	52.2%	41.3%	50.0%
Category Width R^2 Values	0.0912	0.0339	0.0744
Change Other Transects (m)	75	84	36
Analysis of Means Z Values	2.58	1.64	0.02
Category Encountered in 30.7% of All 1978 Transects			

transects averaged significantly higher rates of Gulf shoreline erosion, decline in island width, and land loss during the 1983-1984 period. For the overall study (1978-1985), marsh transects exhibited significantly lower rates of Gulf shoreline erosion than non-marsh transects. No correlations were detected between marsh width and changes in shoreline, island width, or land width. Therefore, island marshes increased in width throughout the study, primarily as a result of the conversion of frost damaged mangroves areas to marsh. Areas of the island containing marshes experienced lower rates of Gulf shoreline erosion than areas not containing marshes.

III. Comparison of Island Changes

Timbalier Island and the Eastern Isles Dernieres exhibited differing rates of change among land cover categories (Table 33). Total land area decreased nearly 20% on Timbalier Island, but less than 6% on the Eastern Isles Dernieres. Beach areas increased 78% on the Eastern Isles Dernieres, while increasing less than 5% on Timbalier Island. However, many of the larger percent changes recorded for the Eastern Isles Dernieres were due to the smaller surface area relatively to Timbalier Island since a smaller area change resulted in a larger proportional change.

During this study, both Timbalier Island and the Eastern Isles Dernieres experienced overall rates of shoreline retreat, decrease in island width, and decrease in cumulative land width, while undergoing a westward extension (Tables 6 and 22, pages 111 and 170; Figure 70). However, an analysis of means of island transects revealed significant differences (Table 34). Timbalier Island had significantly ($\alpha \leq 0.05$) lower rates of decrease in island width for the relatively calm 1978-1982 period than the Eastern Isles Dernieres had for the similar period of 1978-1983. However, the Eastern Isles Dernieres showed significantly lower rates of Gulf shoreline erosion, decrease in island width, and

Table 33. Comparison of overall (1978-1985) area change values for Timbalier Island and the Eastern Isles Dernieres. Eastern Isles Dernieres vegetated and unvegetated beach categories were combined for comparison with Timbalier Island beach values. Riprap and shell were omitted from the predominant change tabulation since changes to other categories were insignificant.

Combined	Timbalier Island			Eastern Isles Dernieres		
Categories	1978	1985	% Change	1978	1985	% Change
Land Area	708.2 ha	568.3 ha	-19.8%	119.4 ha	112.9 ha	-5.4%
Surface Area	931.7 ha	817.9 ha	-12.2%	141.9 ha	115.2 ha	-18.8%
Dry Sand	371.0 ha	309.2 ha	-16.7%	82.3 ha	98.1 ha	+19.2%
Wetlands	336.6 ha	258.2 ha	-23.3%	37.1 ha	14.8 ha	-60.1%
Inland Water	223.6 ha	249.6 ha	+11.6%	22.5 ha	2.3 ha	-89.8%

Cover	Timbalier Island			Eastern Isles Dernieres		
Category	1978	1985	% Change	1978	1985	% Change
Beach	90.9 ha	94.9 ha	+4.4%	45.2 ha	80.4 ha	+77.9%
Dune	40.9 ha	28.0 ha	-31.5%	10.4 ha	7.8 ha	-25.0%
Swale	223.5 ha	181.7 ha	-18.7%	26.7 ha	9.9 ha	-62.9%
Marsh	111.9 ha	253.5 ha	126.5%	4.5 ha	13.9 ha	+208.9%
Mangrove	224.6 ha	4.6 ha	-98.0%	32.6 ha	0.8 ha	-97.5%
Ponds	78.2 ha	110.2 ha	+40.9%	22.5 ha	2.3 ha	-89.8%
Canal	145.4 ha	139.4 ha	-4.1%	N.A.	N.A.	N.A.
Spoil	15.7 ha	4.6 ha	-70.7%	N.A.	N.A.	N.A.
RipRap	0.6 ha	1.0 ha	+66.7%	1.2 ha	1.2 ha	0.0%
Gulf		117.7 ha			28.2 ha	
Bay		-3.7 ha			10.0 ha	

	Timbalier Island			Eastern Isles Dernieres		
Cover	Predominant	Area	Percent	Predominant	Area	Percent
Category	Change To	Changed	Changed	Change To	Changed	Changed
Beach	Gulf	49.1 ha	54.0%	Gulf	25.2 ha	55.8%
Dune	Gulf	23.0 ha	56.2%	Beach	4.3 ha	41.3%
Swale	Marsh	34.2 ha	15.3%	Gulf	5.9 ha	22.1%
Marsh	Gulf	9.5 ha	8.5%	Bay	1.3 ha	28.9%
Mangrove	Marsh	125.9 ha	56.1%	Marsh	11.2 ha	34.4%
Ponds	Beach	5.1 ha	6.5%	Beach	9.6 ha	42.7%
Canal	Bay	8.4 ha	5.8%	N.A.	N.A.	N.A.
Spoil	Swale	7.5 ha	47.8%	N.A.	N.A.	N.A.
Gulf	Beach	8.3 ha		Beach	14.7 ha	
Bay	Beach	18.2 ha		Beach	20.7 ha	

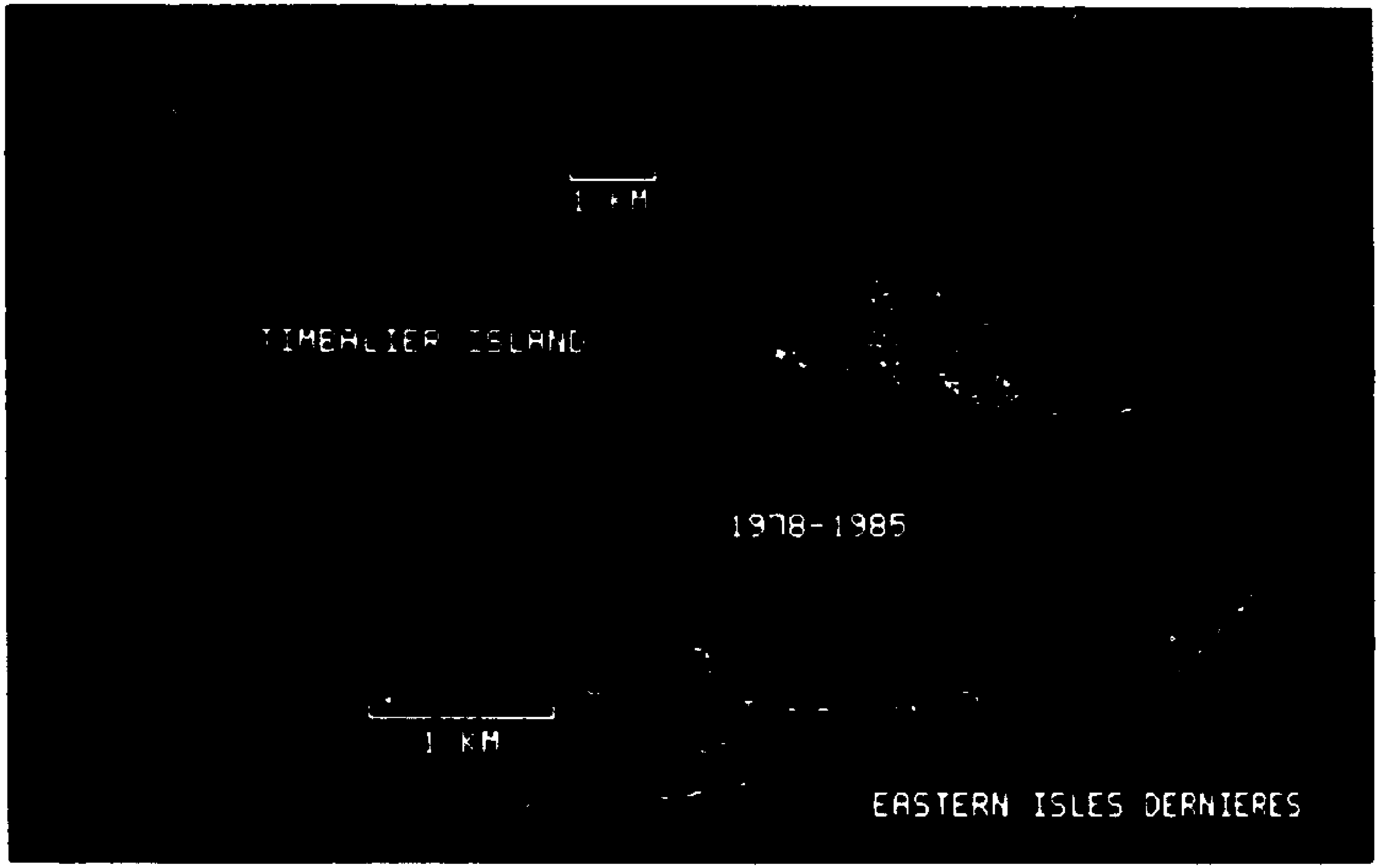


Figure 70 Computer generated change images for Timbalier Island and the Eastern Isles Dernieres, showing areas of loss (red), gain (blue), and no change, (grey-green).

Table 34. Comparison of overall change rates for Timbalier Island and the Eastern Isles Dernieres Gulf shorelines, island widths, and cumulative land widths. Change per year, yearly averaged variance, and analysis of means Z values are reported ($Z \geq 2 = \alpha \leq 0.05$).

		GulfSh	Width	Land
Dernieres 78-83	Mean ch/yr	-5	-13	-7
	Yrly Var/n	6.4	13.8	5.4
Timbalier 78-82	Mean ch/yr	-2	-1	-2
	Yrly Var/n	11.5	8.2	8.8
	Z Value	-0.778	-2.479	-1.241

		GulfSh	Width	Land
Dernieres 83-84	Mean ch/yr	-13	-13	-12
	Yrly Var/n	2.5	5.0	4.1
Timbalier 82-84	Mean ch/yr	-11	-12	-16
	Yrly Var/n	14.2	22.4	24.6
	Z Value	-0.330	-0.263	0.682

		GlfSh	Width	Land
Dernieres 84-85	Mean ch/yr	-27	8	13
	Yrly Var/n	7.8	24.8	25.8
Timbalier 84-85	Mean ch/yr	-56	-59	-67
	Yrly Var/n	27.6	32.4	51.5
	Z Value	4.909	8.809	9.153

		GlfSh	Width	Land
Dernieres 78-85	Mean Chg.	-61	-75	-36
	Var/n	52.1	84.3	67.1
Timbalier 78-85	Mean Chg.	-60	-90	-110
	Var/n	53.9	102.4	159.5
	Z Value	-0.067	1.129	4.925

land loss during the major storm period of 1984-1985. The Eastern Isles Dernieres also showed significantly lower overall rates of land loss than Timbalier Island during the study. Therefore, although exhibiting similar rates of Gulf shoreline erosion, the Eastern Isles Dernieres had lower rates of land loss than Timbalier Island. In addition, the Eastern Isles Dernieres appeared to exhibit fewer negative effects than Timbalier Island from the impact of major tropical storms.

IV. Dolan Coastal Change Analysis - 1934-1978

A comparison of Dolan's (1978) data with that of the present study was undertaken to assess the consistency of current trends, as well as to gain a better understanding of long term changes. Combining data from the two studies reveals that both Timbalier Island and the Eastern Isles Dernieres have been experiencing a continuous retreat of Gulf shorelines since 1934 (Tables 35 and 36). Net losses were recorded for every period observed during both studies. Generally, shoreline erosion rates were higher during the current study than during previous periods. One exception was the interval from May to December 1951, when both Timbalier Island and the Eastern Isles Dernieres experienced much higher rates of erosion. The reasons for this are unclear, since no major meteorological events were reported during those dates.

Regression analysis of cumulative shoreline change (dependent variable) over time (independent variable) produced r^2 values better than 0.910 for both Timbalier Island and the Eastern Isles Dernieres (Table 37). Plotting the cumulative Gulf shoreline change from 1934 through 1985 reveals a relatively linear trend (Figures 71 and 72). Erosion rates showed a gradual increase through 1974, when the Timbalier Island shoreline retreated an average of 5 m/yr and the Eastern Isles Dernieres retreated 6 m/yr. Although both islands experienced an accretion and extension of their western ends, the rates of net shoreline retreat increased throughout the present study.

Table 35. Timbalier Island shoreline change, 1934-1985. Comparison of change rates derrived from Dolan's (1978) survey and data from the current study.

	DOLAN (1978): Average Change/yr (m)					**WORTHY:** Average Change/yr (m)		
Transect Area	6/34-5/51	5/51-12/51	12/51-7/69	7/69-10/74	10/74-10/78	11/78-11/82	11/82-12/84	12/84-12/85
East End	-11	-221	-10		-15	-49	-59	-135
East Cntr	-8	-115	-4	-8	-18	-2	-9	-54
Central	+5	-59	-5	-9	-1	-1	-5	-34
West Cntr	+19	+8	+5	-6	+16	+9	-3	-59
West End				+2	+30	+12	+2	-30
TOTALS:	-12	-76	-48	-25	-13	-8	-24	-48
PER YEAR:	-1	-113	-3	-6	-3	-2	-12	-48

Cumulative Loss 1934-1978 = 175 m   Average Loss/yr 1934-1978 = 4 m/yr
Cumulative Loss 1978-1985 = 80 m   Average Loss/yr 1978-1985 = 11 m/yr
Cumulative Loss 1934-1985 = 255 m   Average Loss/yr 1934-1985 = 5 m/yr

Table 36. Eastern Isles Dernieres shoreline change, 1934-1985. Comparison of change rates derrived from Dolan's (1978) survey and data from the current study.

	DOLAN: Average Change/yr (m)					**WORTHY:** Average Change/yr (m)		
Transect Area	6/34-5/51	5/51-12/51	12/51-7/69	7/69-10/74	10/74-10/78	11/78-11/83	11/83-12/84	12/84-12/85
East Half	-8	-13	-1	-4	8	1	-10	-14
West Half	0	-17	-4	-9	-7	-11	-12	-33
TOTALS:	-60	-11	-43	-33	-8	-5	-10	-27
PER YEAR:	-4	-16	-3	-6	-0	-1	-10	-27

Cumulative Loss 1934-1978 = 155 m   Average Loss/yr 1934-1978 = 4 m/yr
Cumulative Loss 1978-1985 = 42 m   Average Loss/yr 1978-1985 = 6 m/yr
Cumulative Loss 1934-1985 = 197 m   Average Loss/yr 1934-1985 = 4 m/yr

Table 37. Cumulative Gulf shoreline change rates, including estimates of subaerial duration of Timbalier Island and the Eastern Isles Dernieres, based on linear regressions of Gulf shoreline changes (1934-1985), and changes in island widths and surface areas (1978-1985).

Timbalier Island

Dolan + Present Study Shoreline Change Estimates (m)				Estimates From Present Study Data Only				
DATE	Change	Cumltv Change	Adj.Avg. Width	DATE	Surface Area(ha)	Land Area(ha)	Avg. Width(m)	Max. Width(m)
1934.5			907.7	1978.9	931.7	708.2	702	1517
1951.4	-12.4	-12.4	895.3	1982.9	921.2	695	703	1449
1951.9	-75.6	-87.9	819.7	1984.9	891.2	651.4	696	1399
1969.6	-48.3	-136.2	771.5	1985.9	817.9	568.3	653	1285
1974.8	-25.3	-161.5	746.2	Est.=	2026	2010	2042	2024
1978.9	-13.3	-174.8	732.9	Years=	40.2	23.6	55.9	38.0
1982.9	-7.6	-182.3	725.3		±3.2	±3.1	±4.1	±1.9
1984.9	-24.1	-206.4	701.3	r^2=	0.6389	0.6725	0.4309	0.8301
1985.9	-48.3	-254.7	653.0					
	Est. Final Year =		2124					
	Years from 1985 =		138.2	±53.8	r^2=0.9116			

Estimate of Subaerial endurance from current study data = 20-60 Years from 1985
Estimate of Subaerial endurance from combined data = 90-190 Years from 1985
Combined Best Estimate of Subaerial endurance = 40-190 Years from 1985

Eastern Isles Dernieres

Dolan + Present Study Shoreline Change Estimates (m)				Estimates From Present Study Data Only				
DATE	Change	Cumltv Change	Adj.Avg. Width	DATE	Surface Area(ha)	Land Area(ha)	Avg. Width(m)	Max. Width(m)
1934.5			407.2	1978.9	141.9	119	270	717
1951.4	-60.4	-60.4	346.8	1983.9	117.8	111.9	201	603
1951.9	-10.9	-71.3	335.8	1984.9	111.4	105.8	181	547
1969.6	-43.3	-114.6	292.6	1985.9	115.2	112.9	210	534
1974.8	-32.8	-147.4	259.8	Est.=	2010	2032	1999	2006
1978.9	-7.8	-155.2	252.0	Years=	24.0	46.4	13.1	19.6
1983.9	-5.1	-160.2	246.9		±1.4	±3.3	±2.6	±0.8
1984.9	-9.8	-170.0	237.1	r^2=	0.9359	0.6050	0.7923	0.9787
1985.9	-27.1	-197.2	210.0					
	Est. Final Year =		2050					
	Years from 1985 =		64.3	±13.7	r^2=0.9784			

Estimate of Subaerial endurance from current study data = 10-50 Years from 1985
Estimate of Subaerial endurance from combined data = 40-80 Years from 1985
Combined Best Estimate of Subaerial endurance = 20-80 Years from 1985

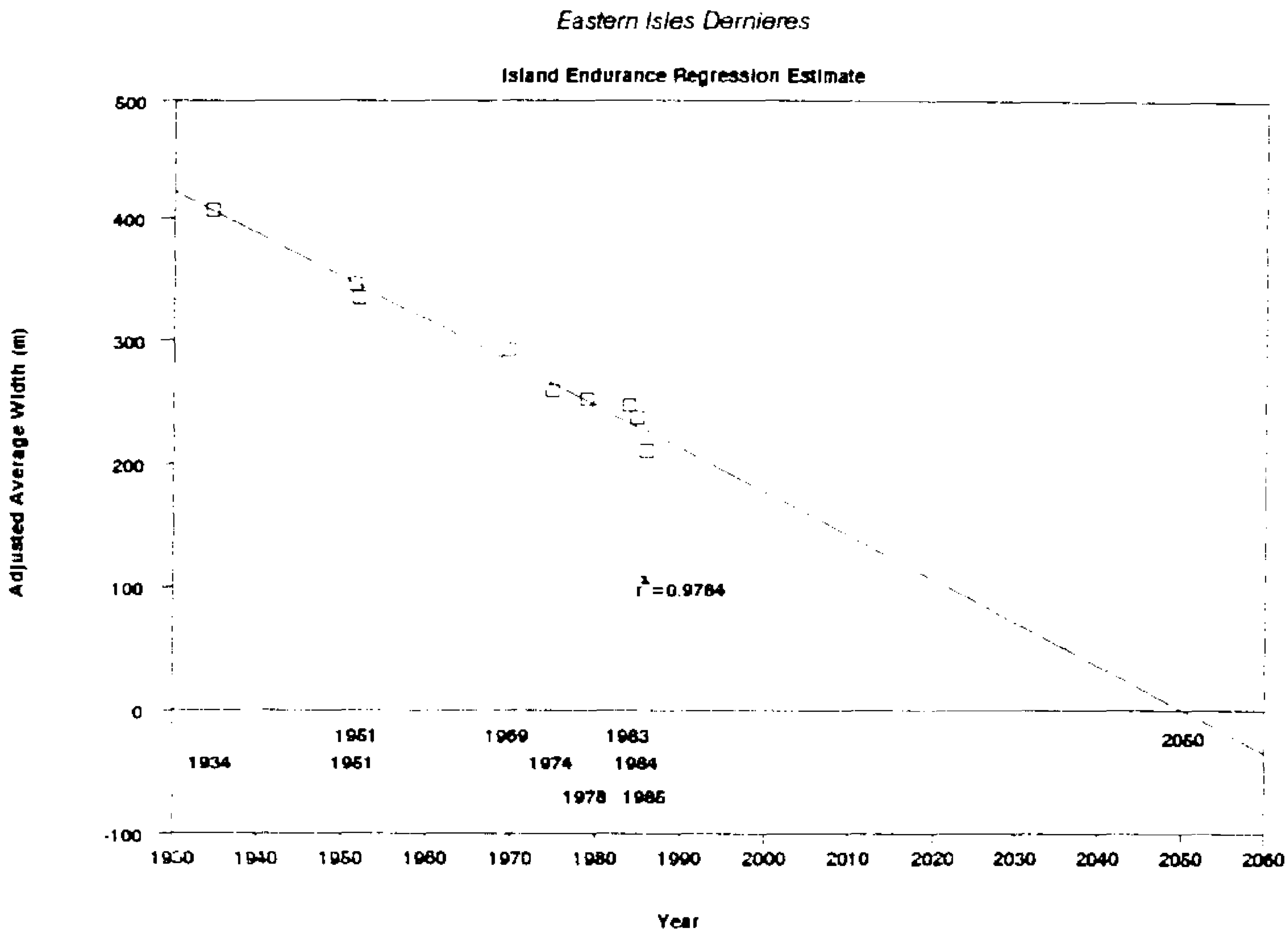


Figure 71. Regression plot of Eastern Isles Dernieres cumulative shoreline change,1934-1985. Values adjacent to data points indicate average change since last data point (meters). Years below the zero width line are photo acquisition dates.

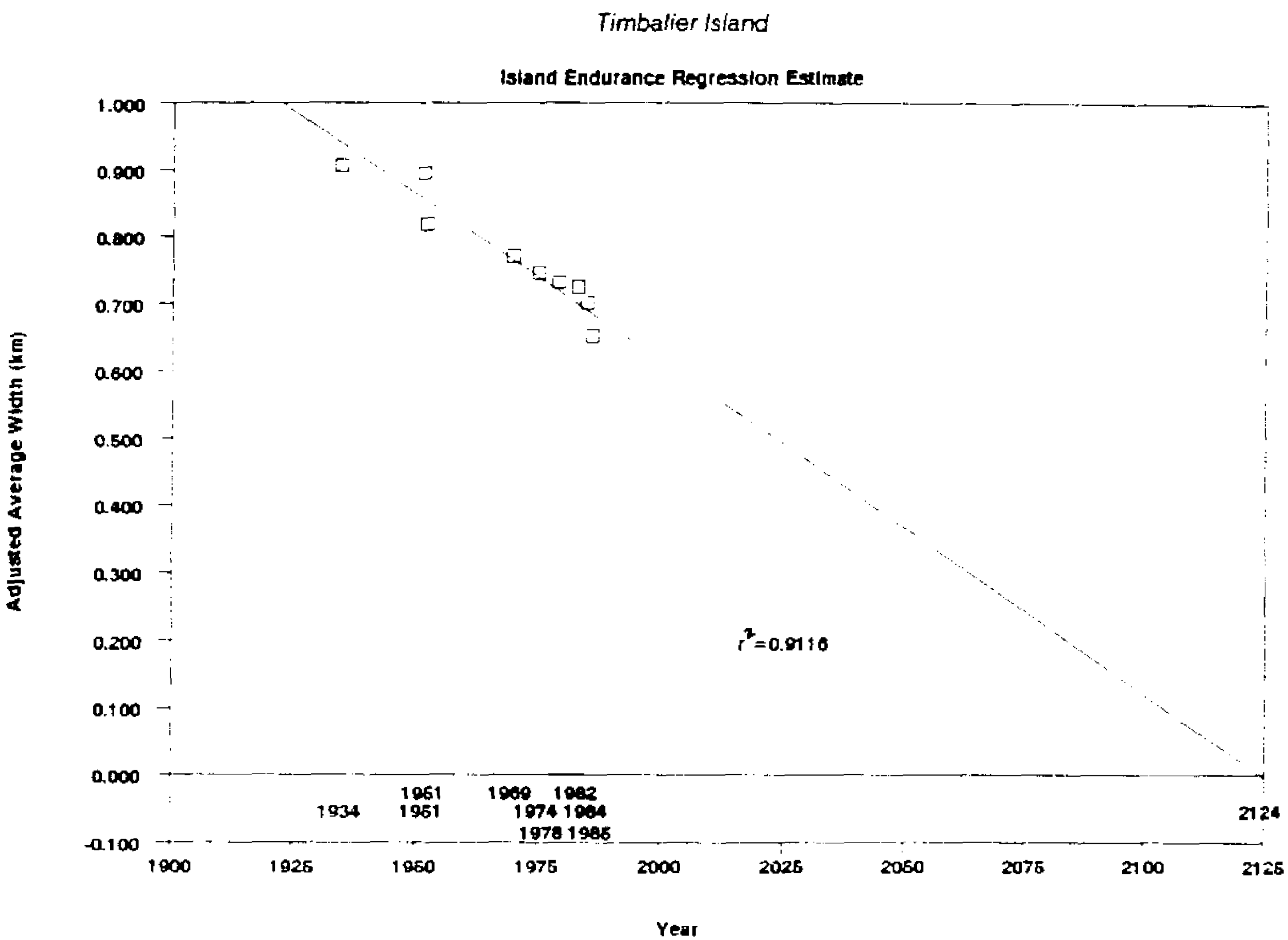


Figure 72. Regression plot of Timbalier Island cumulative shoreline change, 1934-1985. Values adjacent to data points indicate average change since last data point (meters). Years below the zero width line are photo acquisition dates.

Both Timbalier Island and the Eastern Isles Dernieres experienced somewhat similar rates of change up to the last year of the current study (1984-1985), when the Timbalier Island shoreline eroded at a much higher rate than that of the Eastern Isles Dernieres. During this period, both islands were directly impacted by hurricane Juan. The resistance to overwash provided by canals, spoil banks and the overall greater width of Timbalier Island may have increased scouring of the beach berm and foredunes. Another possibility is that the center of the hurricane may have passed closer to Timbalier Island than to the Eastern Isles Dernieres. In either case, it may be expected that some of the beach would be regained during a return to normal weather. The overall trend for both islands, therefore, is one of accelerating shoreline erosion accompanied by occasional brief periods of severe loss.

A. Timbalier Island

Dolan's (1978) transect data for Timbalier Island indicated the highest rates of shoreline erosion occurred in the eastern end of the island (Table 35). Erosion decreased to the west, with an average shoreline gain in the western end. This trend was consistent through the present study, with the exception that, during the final period (1984-1985), the western end experienced a net loss.

Timbalier Island exhibited an average retreat of the Gulf shoreline for all periods examined from 1934 through 1985. The average rates of erosion between 1934 and 1978 were 4 m/yr, for a cumulative Gulf shoreline retreat of 175 m. In the interval from May, 1951 to December, 1951 the island experienced a shoreline retreat of 76 m, for a rate of 113 m/yr. The causes for this remain unclear. The combined rate of erosion from 1934 through 1985 was 5 m/yr, with a total average shoreline retreat of 255 m. Timbalier Island, therefore, exhibited a continuous trend of Gulf shoreline retreat, characterized by erosion of the eastern end and accretion of the western end.

B. Eastern Isles Dernieres

Following the initial 1934-1951 period, the Eastern Isles Dernieres experienced greater rates of Gulf shoreline erosion in the western half than in the eastern half of the island. This is the opposite of the trend for Timbalier Island (Tables 35 and 36). However, the Eastern Isles Dernieres and the Central Isles Dernieres formed a single contiguous island until 1972 (Dolan, 1978). Therefore, prior to the 1969-1974 data period, shoreline change rates for the area which became the western half of the island were based on mid-island shoreline fluctuations, rather than those of a generally more dynamic island end.

From 1934 through 1985 the Gulf shoreline exhibited a continuous average trend of shoreline retreat. The rate of erosion averaged 4 m/yr from 1934 to 1978, for an overall retreat of 155 m. During the 1974-1978 interval, losses in the western half were nearly offset by gains in the eastern half of the island resulting in an average loss of less than 1 m/yr. The greatest rates of shoreline retreat prior to the current study, 16 m/yr, occurred during the May, 1951 to December, 1951 period for unknown reasons. Combining results from the current study with those of Dolan (1978) provided an overall retreat of 197 m from 1934 to 1985, for an average rate of shoreline erosion of 4 m/yr. Therefore, the Eastern Isles Dernieres Gulf shoreline has undergone a continuous trend of retreat. This has been characterized by relative stability of the eastern end and breaching and later progradation of the western end.

C. Change in Island Length

Transects generated in the vicinity of the ends of each island furnished a means for determining lateral change. Combining the lateral changes observed at each end of each island provided a means of determining lateral displacement or migration. Dolan's (1978) data was

reported in 100 m increments, while the present results are in 2 and 5 m increments for the Eastern Isles Dernieres and Timbalier Island, respectively. Both islands have experienced a westward extension during this study. However, Timbalier island has shown an overall westward displacement while the location of the eastern end of the Eastern Isles Dernieres has remained relatively stationary, resulting in an overall lengthening of the island.

1. Timbalier Island

Timbalier Island underwent a net westward lateral migration during all periods examined from 1934 through 1985 (Table 38). This was effected through erosion of the eastern end of the island accompanied by deposition and extension of the western end. The net erosion of the eastern end was nearly double the extension of the western end between 1978 and 1985, resulting in an average reduction in length of the island of 93 m/yr. Prior to this, Dolan's (1978) data indicated the island had averaged a gain in length of 40 m/yr (1934-1978).

During the current study, the rate of westward progradation increased from 35 m/yr during the 1978-1982 period, to 85 m/yr for 1982-1984, and reached a high of 310 m/yr during the 1984 to 1985 period. From 1978 to 1985, total extension of the western end amounted to 620 m, for an overall rate of extension of 89 m/yr. Lateral erosion of the eastern end of Timbalier Island also increased from 65 m/yr for 1978-1982, to 190 m/yr for 1982-1984, and 630 m for 1984-1985. Total erosion of the eastern end amounted to 1270 m, for an overall rate of 181 m/yr. This resulted in decreases in island length of 30 m/yr, 105 m/yr, and 320 m/yr, for 1978-1982, 1982-1984, and 1984-1985, respectively. Total reduction of island length amounted to 650 m during the current study, for an average rate of decline of 93 m/yr. Combining Dolan's data with that from the current study produced an average gain in island length of 20 m/yr, and a total gain of 1040 m between 1934 and

Table 38. Timbalier Island longitudinal changes, 1934-1985. Change in island length and position of island ends. Plus signs indicate an extension or accretion, minus signs indicate a retreat or erosion.

		Change from Previous Date:		
Year	Length	Western End	Eastern End	Total
1934	11,600 m	-	-	-
1951	12,500 m	+1100 m	-200 m	+900 m
1969	10,500 m	-500 m	-1500 m	-2000 m
1978	13,290 m	+3090 m	-300 m	+2790 m
1982	13,170 m	+140 m	-260 m	-120 m
1984	12,960 m	+170 m	-380 m	-210 m
1985	12,640 m	+310 m	-630 m	-320 m
Dolan's (1978) Study:		+3700 m	-2000 m	+1700 m
This Study:		+620 m	-1270 m	-650 m
Overall Changes:		+4310 m	-3270 m	+1040 m

1985. Therefore, despite the reduction in island length during the current study, the overall trend has been towards an increase in length, accompanied by a net westward migration of the island.

2. Eastern Isles Dernieres

Prior to 1972 the western end of the Eastern Isles Dernieres was contiguous with the Central Isles Dernieres (Dolan, 1978). In addition, the eastern end maintained the same location as far back as 1934. Therefore, prior to the breach which separated the two islands there was no lateral movement or change in island length. However, during the current study, the Eastern Isles Dernieres underwent a net westward progradation while the eastern end remained stable (Table 39). A westward redistribution of island sediments was accompanied by an overall narrowing of the island. This reduction in width contributed to breaching of the island during the last year of the current study. Gains in island length were recorded in all but the final period (1984-1985), for an overall increase of 22 m/yr from 1978 to 1985.

The eastern terminus remained relatively stable throughout the first six years of the study, but retreated 30 m during the final year. The western end, however, gained 588 m between 1978 and 1983, for a rate of increase of 118 m/yr. The progradation continued through the 1983-1984 period, with an additional gain of 276 m. However, the western end eroded 228 m during the 1984-1985 period, for an overall western extension of 636 m. Two breaches in the island of 80 m and 380 m during the 1984-1985 period contributed to a net reduction of island length of 718 m during this last year. Overall, the island gained 246 m in length during the study. Although the length of the island increased through progradation of the western end, there was little westward relocation, since the position of the eastern end remained relatively constant.

Table 39. Eastern Isles Dernieres longitudinal changes, 1934-1985. Change in island length and position of island ends. Plus signs indicate an extension or accretion, minus signs indicate a retreat or erosion.

		Change from Previous Year:		
Year	Length	Western End	Eastern End	Total
>1972*				
1974	5100 m		-0-	
1978	5204 m	+100 m	-0-	+100 m
1982	5792 m	+588 m	-0-	+588 m
1984	6068 m	+276 m	-0-	+276 m
1985	5350 m**	-228 m	-30 m	-718 m**
Overall Changes:		+736 m*	-30 m	+246 m

*Contiguous with Central Isles Dernieres prior to 1974
**Two breaches of 80 m and 380 m occurred between 1984 and 1985

D. Estimates of Island Endurance

Island endurance can be estimated through extrapolation of the regression curves derived from the combination of Dolan's Gulf shoreline data and island width data from the current study (Figures 71 and 72). These provide an estimated endurance of subaerial expression for Timbalier Island of 140 years (±50 years) from the conclusion of the study in 1985 (Table 37). This assumes that overall conditions remain similar to those observed since 1934, and that there is no significant change in rates of bayside erosion or accretion. Current study predictions derrived from changes in average island width and surface area are 40 years (±5 years) and 55 years (±5 years) respectively, although correlation coefficients were relatively poor. Therefore, the best estimate for persistence of Timbalier Island appears to be between 40 and 190 years from 1985.

Repeating the Gulf shoreline regression calculations for 1934-1985 for the Eastern Isles Dernieres provides an estimated endurance of 65 years (±15 yrs) from the conclusion of the study in 1985. This estimate assumes that overall conditions remain similar to those occurring since 1934, and that there is no significant change in bayside erosion or accretion. Predictions based on changes in average island width and surface area observed during the current study are 15 years (±3 years) and 25 years (±2 years), respectively. However, the correlation coefficient for change in average width was relatively poor. Therefore the best estimate of endurance for the Eastern Isles Dernieres appears to be between 20 and 80 years from 1985.

V. Hurricane Data

Severe storms occur frequently along the Louisiana Gulf coast. These usually originate in the warm waters of the tropical Atlantic, gaining strength as they enter and transit the Gulf of Mexico (Muller,

1977). Under the right conditions these may develop into very strong and destructive systems, occasionally reaching hurricane force. There were eight major storms, five of them hurricanes in the vicinity of the northern Gulf of Mexico during the span (1978-1985) of this study (Table 40; NOAA, 1978-86). One of these (tropical storm Debra, August, 1978) occurred just prior to the first image data.

Hurricanes Bob (July, 1979) and Juan (October, 1985), directly impacted Timbalier Island and the Eastern Isles Dernieres (Figures 73 and 74). The consequences of hurricane Bob are less obvious than those of hurricane Juan. Sufficient time may have elapsed prior to subsequent image acquisition to obscure the immediate effects. Both 1980 and 1981 were mild storm years and the first images acquired following hurricane Bob were for November 1982 for Timbalier Island and November 1983 for the Eastern Isles Dernieres. Little damage directly attributable to hurricane Bob was visible. The impact of hurricane Juan (late October, 1985) was much more obvious and dramatic than that of hurricane Bob, since the imagery was acquired shortly after the storm. Hurricane Juan may have had a greater impact than other previous storms due to it's duration within the immediate vicinity of the central Louisiana Gulf coast.

Table 40. Northern Gulf of Mexico severe storm events, 1978-1985.

Year	Event	Dates of Impact	Area(s) Most Affected
1978	Tropical Storm Debra	August 28-29	Lake Charles, La.
1979	**Hurricane Bob***	**July 10-11**	**Cocodrie, La.**
	Tropical Storm Claudett	July 24-25	Port Arthur, Tex.
1980	Tropical Storm Danielle	September 4-5	50-100 mi. Offshore
1981	Calm		
1982	Tropical Storm Chris	September 11-12	Port Arthur, Tex.
1983	Hurricane Alicia	August 17-18	Galviston, Tex.
1984	Calm		
1985	Hurricane Danny	August 15-16	Grand Chenier, La.
	Hurricane Elena	September 12	Gulfport, Miss.
	Hurricane Juan*	**October 28-31**	Intercoastal City, La. Morgan City, La. **Cocodrie, La.** Venice, La.

*Direct impact on Timbalier Island and Isles Dernieres (storm center tracked within 10 km of islands)

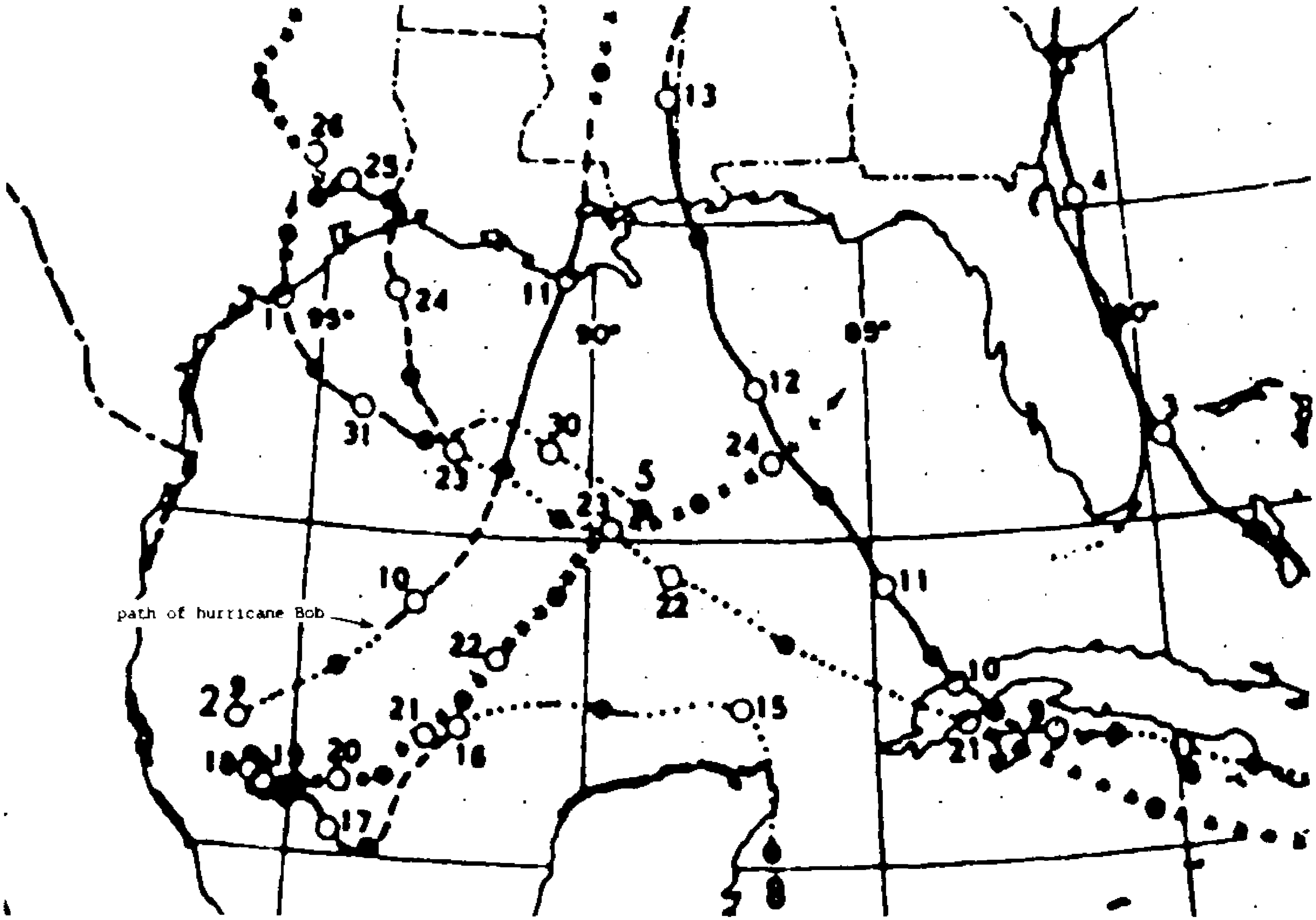


Figure 73. Portion of National Weather Service 1979 North Atlantic Hurricane Tracking Chart showing the path of hurricane Bob, July 9th through 16th.

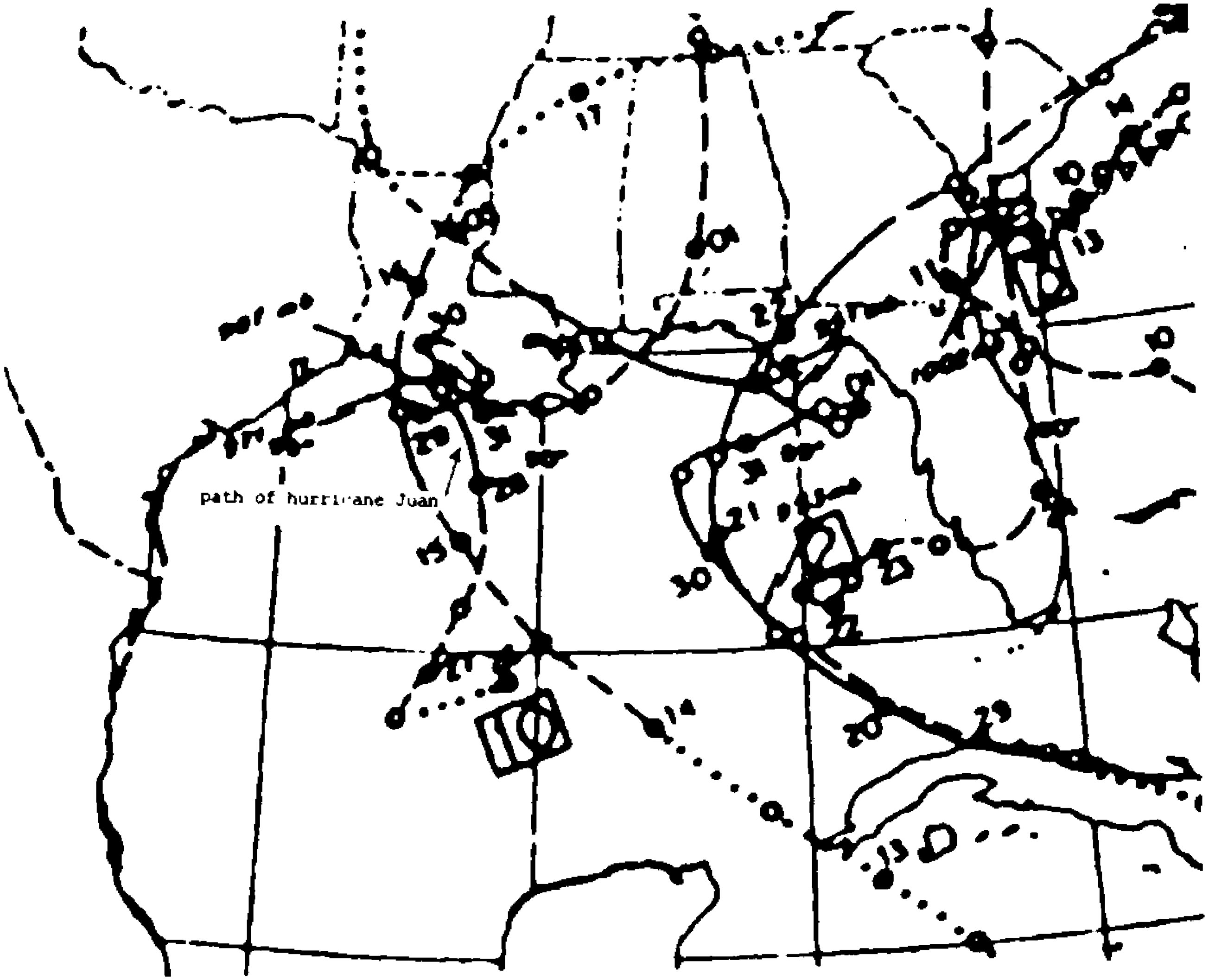


Figure 74. Portion of National Weather Service 1985 North Atlantic Hurricane Tracking Chart showing the path of hurricane Juan, October 26th through November 1st.

SUMMARY AND CONCLUSIONS

I. Surface Features and Island Change

A GIS was implemented to investigate spatial and temporal patterns within selected Louisiana barrier islands. Timbalier Island and the Eastern Isles Dernieres were selected as contrasting examples of Louisiana barriers. Among the major differences were the relative makeup of island surface features. The predominant categories on the Eastern Isles Dernieres, in descending order were beach (vegetated and unvegetated), wetlands (marsh and mangrove), and swale. Together, these accounted for 83% of the total surface area. On Timbalier Island, wetlands (marsh and mangroves) comprised the predominant surface feature, followed by swale, and beach, accounting for a total 68% of the surface area. Timbalier Island also contained a relatively extensive network of oil and gas canals and associated features. No canals were present on the Eastern Isles Dernieres.

1. Timbalier Island

The beaches on Timbalier Island were not as wide as those of the Eastern Isles Dernieres, especially in 1985. This could be due to the existence of longitudinal canals and associated spoil banks on Timbalier Island which may limit inland beach expansion. These same canals and spoil banks may contribute to the predominance of marsh on the island, since they may also block the transport of sediment across the island during overwash events. Subsidence without periodic replenishment of sediments would prevent succession from marsh to swale (Salinas et al., 1986). This would favor the conversion of swale to marsh and marsh to open water, which appears to have been happening on Timbalier Island. An average of 10% of marsh and mangrove area reverted to open water

during each period of the study (28% overall), while only 3% was converted to swale. At the same time, an average of 7% of swale became marsh during each period, while only 3% became beach or dune.

The conservation of swale appears to be of particular importance on Timbalier Island. Lateral transects through areas containing swale showed significantly lower rates of Gulf shoreline erosion than portions of the island not containing swale. Interestingly, pond area transects also showed significantly lower Gulf shoreline erosion compared to areas not containing ponds. However, ponds were associated with significantly higher declines in land area during the first period of the study, and both ponds and marsh were associated with significantly greater declines in island width during the final 1984-1985 period. Increasing widths of both ponds and marsh were found to be correlated with declines in island width and land area.

2. Eastern Isles Dernieres

The relationship between marsh and swale is more complicated on the Eastern Isles Dernieres. Although smaller isolated areas of swale were located through the midsection of the island, only one large contiguous area of swale existed during this study. This was located near the eastern end of the island in an area which was heavily eroded during hurricane Bob (July, 1979). In addition, nearly 40% of the swale in this area was eroded or covered by overwashed sands during hurricane Juan (October, 1985). Despite the occurrence of these two major overwash events, less than 2% of the existing marsh areas were converted to swale during the course of the study.

The eastern area of the island occupied by swale has a higher elevation than the central or western portions. This may have contributed to a scouring of the beach, since all but the highest storm tides would be forced around to the east and west. Supporting this was the finding that swale width was correlated with Gulf erosion during all

periods of the study, but especially during the first period. During this first period, the portions of the island containing swale showed significantly higher rates of Gulf shoreline erosion, as well as land loss and overall reduction in island width than other areas of the island. However, during the final period this area experienced significantly less erosion of the Gulf shoreline than areas not containing swale.

The majority of the Eastern Isles Dernieres marshes and mangroves were located in the center and western portions of the inland. In most cases these were bounded immediately on their Gulf sides by dunes and beach. Although a large proportion (16%) of these marsh and mangrove areas were lost to the Gulf or Bay during the study, 9% were claimed by retreating beaches and dunes. The narrowness and low profile of the island in these areas may account for the lack of significant amounts of swale, as well as the high losses to open water.

Mangroves comprised 88% of the Eastern Isles Dernieres wetlands in 1978, but were badly damaged during successively severe winters between 1983 and 1985. This may have contributed to significantly higher rates of Gulf shoreline erosion and declines in overall island width and land area during the first two periods of the study. Most of the mangroves on the Eastern Isles Dernieres extended from the bay shoreline forward to a narrow line of beach and dunes. Since a large proportion of the damaged mangroves reverted to open water, the dunes and beach in these areas would have been more easily breached. However, most of the damaged mangroves were replaced by marsh, which comprised 75% of the combined area by 1984, and 95% by 1985. During the last period, the loss rates of land, island width, and Gulf shoreline were significantly lower in wetlands areas than in areas not containing marsh or mangrove. These differences may be due to higher stem density and surface area of marsh vegetation compared to mangrove, enhancing their ability to slow the flow of water and trap sediments (Godfrey, 1973; Dodd and Webb, 1975).

Areas of the Eastern Isles Dernieres containing dunes were found to

have significantly lower rates of Gulf shoreline erosion than areas without dunes during the two most severe storm periods (1978-1983 and 1984-1985). This implies that the dunes may have contained sufficient sand reserves to help reduce the impact of overwash events. By contrast, areas containing vegetated beach showed significantly higher erosion rates during the 1978-1983 and 1984-1985 periods, but significantly lower erosion during the 1983-1984 period, compared to other areas of the island. This may indicate that beach vegetation may not be able to bind the sand nor amass sufficient quantities to aid in resisting major storm surges. It may also be an indication of insufficient quantities of sand in these areas to build dunes.

II. Islands Status

Both Timbalier Island and the Eastern Isles Dernieres experienced erosion of their Gulf shorelines during all periods examined from 1934 to 1985. During the current study (1978-1985) Timbalier Island declined in length, width, and surface area. The Eastern Isles Dernieres increased in length during the study, but averaged a decline in island width and surface area despite increases during the final period. During the last period, the Eastern Isles Dernieres experienced significantly lower rates of land loss than Timbalier Island, and appeared better able to resist the effects of major storm events.

Assuming that past conditions and observed rates of change prevail, some estimates can be made concerning the future of these islands. Shoreline change (1934-1985) and changes in island width and island surface area (1978-1985) were extrapolated from 1985 area and width totals for Timbalier Island and the Eastern Isles Dernieres. These provided an estimated duration of subaerial expression for Timbalier Island of 40 to 190 years from the conclusion of the study in 1985, indicating a probable persistence through the year 2120. Combining and extrapolating the Eastern Isles Dernieres change data provided an

estimated duration of subaerial expression of 20 to 80 years from 1985. This would indicate a probable endurance of the Eastern Isles Dernieres through the year 2050 without any delaying management activity.

III. Barrier Island Models

Two models of barrier island dynamics were investigated in order to determine their applicability to the Louisiana coastal environment. In addition, the relationships of surface features to island change rates were examined to ascertain the degree of positive or negative influence which these features might exert on island changes. The Godfrey and Godfrey (1974) *rollover* model describes island responses to rising sea levels, while the Penland and Boyd (1981) *deltaic barrier cycle* deals more specifically with the dynamics of barrier islands originating and existing in large river delta environments. Inconsistencies were detected between these models and actual observations, and, based on these differences, a modified model is suggested.

A. Barrier Island "Rollover"

The salient characteristic of the Godfrey and Godfrey (1974) *rollover* model is that barrier islands gradually migrate towards the mainland while maintaining a relatively constant surface area in response to rising sea level. This process is described as occurring through washover events which erode the sea shoreline and redistribute sediments across the island. During calmer periods, the dunes rebuild and overwashed sediments are consolidated and colonized by plant communities. This should result in a sequential retreat of the sea shoreline and an extension of the bay shoreline. The final stage is the reestablishment of an equilibrium beach/dune profile at a location inland from that previously occupied. In this manner the island "rolls" toward the mainland. The major assumptions of the *rollover* model are:

1. There are relatively plentiful and mobile supplies of sand;
2. The sea floor slopes upwards from the island toward the mainland; and
3. Relative sea level increases over time to a point at which high storm tides overwash the island.

Eustatic sea level rise combined with compaction and subsidence of Mississippi deltaic sediments produces a relatively rapid increase in the relative sea level along the Louisiana coast (Morgan, 1967; Swanson and Thurlow, 1973; Salinas et al., 1986; Baumann et al., 1984). Estimates range from 1 cm/yr (Morgan, 1967; Penland et al., 1987) to as high as 4.3 cm/yr (Swanson and Thurlow, 1973). Increase in relative sea level for the North Carolina coast, where the *rollover* model was conceived, has been estimated at 0.8 cm/yr (Godfrey and Godfrey, 1973). In addition, major storm events are particularly common within The Louisiana coast. Both Timbalier Island and the Eastern Isles Dernieres experienced at least two major washover events during the time encompassed by this study. However, there is little slope to the seabed in the vicinity of the southern Louisiana barriers (Shepard, 1960). Therefore, sediments washed over the island have no "ramp" which they can ascend in order to maintain elevation and surface area. In addition, the only mobile sand sources are the former Mississippi delta headlands which are currently undergoing erosion. Timbalier Island, which is downdrift from the Caminada headland, may have an adequate sand supply, due to continued erosion of the headland and redistribution of its sediments (Boyd and Penland, 1981). However, no readily available source is evident for the Eastern Isles Dernieres.

1. Timbalier Island

The Timbalier Island Gulf shoreline averaged a net retreat of 8 m/yr between 1978 and 1985. During this period beach width fluctuated between 34 m and 55 m, increasing from 1978 to 1982, declining from 1982

to 1984, and increasing again in 1985. The position of the dunes paralleled these changes, moving 29 m landward, despite a Gulfward displacement during the 1982-1984 period. Similarly, total beach area increased from 1978 to 1982, declined in 1984, and increased again to 95 ha by 1985.

The narrowing of Timbalier Island beaches effected by a combination of Gulf shoreline retreat and Gulfward advance of the dunes, as well as the overall reduction in beach area between 1982 and 1984 indicate a steepening of the beach profile during a period of relatively mild storm activity. By contrast, despite a landward shoreline retreat, increases in beach area and width occurred during both periods of major washover events, accompanied by proportionate displacements of the dune line. These details appear to be consistent with the Godfrey and Godfrey (1974) model.

There were only minor changes in the Timbalier Island Bay shoreline between 1978 and 1984, with slight losses in the first period being offset by similar gains in the second period. During this time there was an inland expansion of wetlands boundaries. However, this expansion was reversed during the final year, concurrent with an increase in Bay shoreline erosion of 1 m/yr, resulting in a decline in total marsh area of 80 ha between 1978 and 1985.

Combined changes in the Gulf and Bay shorelines resulted in a decrease in island width of 50 m between 1978 and 1985, from 702 m to 653 m. The majority of the overall loss occurred during the final year of the study. Total island surface area also declined from 932 ha in 1978 to 818 ha by 1985, for an overall decrease of 114 ha.

Although the Timbalier Island Bay shoreline and the overall island width changed only slightly during the first two periods of the study, the width and surface area of marsh and mangrove declined, as did the overall island surface area. During the final period, in response to a major overwash event, the Bay shoreline eroded, marsh area and width declined, and the overall island width and surface area decreased. These responses are inconsistent with the Godfrey and Godfrey (1974)

model, whereby the bay shoreline should accrete and the total surface area should remain relatively constant.

2. Eastern Isles Dernieres

Erosion of the Eastern Isles Dernieres Gulf shoreline averaged 6 m/yr between 1978 and 1985. Dunes exhibited minor rates of shoreward relocation similar to those of the Gulf shoreline during the first two periods of this study, However, many of the dunes were eliminated during hurricane Juan in 1985, declining from 60% of all transects sampled in 1984 to just 34% by 1985. Dunes remaining after the 1984-1985 period were displaced an average of 61 m inland from the average 1984 location, while the shoreline retreated an average of 27 m.

Beach width decreased between 1978 and 1983, but increased 84 m between 1984 and 1985 to an average of 138 m. Total beach area, including vegetated beach, remained relatively constant between 1978 and 1984, then nearly doubled to a total of 80 ha by 1985. This was the result of sandy overwash deposits covering and eliminating much of the mid-island marshes, greatly extending the beach in these areas.

The Eastern Isles Dernieres total beach area remained relatively constant during the first two periods of the study, but increased dramatically during the final period as a result of overwash deposits covering much of the mid-island marshes. The net effect was an extension of the bay shoreline and an overall increase in total land and surface area during the final period of the study (1984-1985). During this last period, 27 ha of the Bay were filled by overwashed sediments. The inland marsh/swale boundary was displaced bayward an average of 141 m during the study (93 m during the final year). This, combined with the steady retreat of the Gulf shoreline and the parallel landward relocation of the dunes appears to be consistent with the Godfrey and Godfrey (1974) barrier island model. However, these increases were offset by losses between 1978 and 1984. Overall, the bay shoreline

averaged a retreat of 12 m, decreasing the width and surface area of island wetlands.

Total island width and surface area of the Eastern Isles Dernieres declined during the first two periods of the study and increased in the last. The average island width decreased from 270 m in 1978, to 210 m in 1985, while total island surface area decreased from 142 ha to 115 ha. The overall change in surface area amounted to a loss of 27 ha, the majority of which occurred during the 1978-1983 period.

The surface area and Bay shoreline gains of the final study period may be artificially high due to the short period of time which had elapsed between hurricane Juan in 1985, and the final study imagery. Much of these gains may have been temporary, since the overall history of the Eastern Isles Dernieres Bay shoreline, as well as island surface area was one of loss. These losses included an earlier major washover period, that of hurricane Bob in 1979. In addition to the overall losses in island surface area and Bay shoreline there was a steady reduction of marsh area throughout the study. The loss of the Eastern Isles Dernieres marsh and surface area and overall retreat of the Bay shoreline are inconsistent with the Godfrey and Godfrey (1974) model.

3. Model Evaluation

The fundamental inconsistency with the Godfrey and Godfrey (1974) model in the Louisiana coastal environment seems to be the inability of Louisiana barriers to extend beyond their bayside shoreline (Table 41). In the case of Timbalier Island the presence of canals and/or spoil banks along virtually the entire length of the island may impede the flow of sediments over the island. In addition, dredging activities on the Bay side of the island may eliminate much potential accretion. The Eastern Isles Dernieres is not directly effected by canals or dredging activities. However, although evidence of sediment overwash exists, no long term extension of the Bay side was found.

Table 41. Barrier Island Rollover Model agreement/disagreement.

	Eastern Isles Dernieres	Timbalier Island
I. Assumptions:		
A. Relatively Plentiful and Mobile Sand Supply.	no	no
B. Sea Floor Slopes Up to Mainland.	no	no
C. Relative Sea Level Increases.	yes	yes
D. Washover Events Occur.	yes	yes
II. Dynamics:		
A. Island Migrates Toward Mainland:		
1. Sea Shoreline Erodes.	yes	yes
2. Beach and Dunes Move Landward.	yes	yes
3. Bay Shoreline Accretes.	minor	minor
4. Marsh Colonizes Accretion.	some	some
B. Island Maintains Surface Expression.	no	no

One of the most obvious differences between the Louisiana coastal environment and other North American coasts is the relatively high rate of subsidence of Mississippi River deltaic sediments. In addition, the unconsolidated nature of the nearshore sediments tends to average out the slope of the sea floor (Shepard, 1960). This eliminates the ramp effect of hard bottomed gradually sloping shorelines over which many barriers exist (Gilbert, 1885; Zenkovitch, 1962; Leontiev and Nikiforov, 1965; Godfrey and Godfrey; 1974). The net effects is that sand and sediment which is washed over the island is essentially lost. Therefore, since sand is in diminishing supply the islands will likely continue to decline in surface area.

B. Deltaic Barrier Cycle

The *deltaic barrier cycle* described by Penland and Boyd (1981) was hypothesized for environments such as those of the Louisiana coast. This model assumes a sequence of events characterized by:

1. Active delta land building during river occupation; followed by
2. River abandonment and subsequent disintegration of the delta marshes; accompanied by
3. Winnowing and reworking of the abandoned headland sediments.

As this material progrades to either side of the headland, a series of *flanking sandy spits* are formed. Eventually these separate from the headland to form *transgressive flanking barrier* islands. With a continuous source of sand from the eroding headland, supplied through nearshore currents, these flanking barriers will continue to "move" downdrift. This process occurs through erosion of their updrift ends and accretion and progradation of their downdrift ends. Eventually, total submergence of the marshes backing the headland will isolate the headland shoreface and the flanking barriers. These would remain as a *transgressiv barrier arc* of islands, which would continue to spread away from the central headland/island while transgressing shoreward through

overwash processes. Eventually the combined effects of subsidence of the underlying sediments and depletion of the remaining sand supply will result in the submergence of the island arc, forming a series of *subaqueous shoals*. The entire process would begin again with the eventual reoccupation of the area by the river system.

1. Timbalier Island

Timbalier Island has been described as representative of the *transgressive flanking barrier* stage of the *deltaic barrier cycle* (Penland and Boyd, 1981; Penland et al., 1981). Timbalier Island lies to the west of the Caminada headland, from which it apparently originated. The Caminada headland, a recently abandoned distributary of the Mississippi River, is currently undergoing erosion and reworking. Timbalier Island has undergone a steady westward lateral migration since the earliest charts of its location. The island has moved a total of 4300 m since 1934 through a combination of erosion on the eastern end and accretion on the western end. This has been accompanied by an increase in length of 1700 m between 1934 and 1978, although the island has decreased in length since 1978. The decline in island width has been associated with modifications such as jetties and breakwaters which have been constructed upstream from Timbalier Island (Penland and Boyd, 1981). However, the lateral relocation appears to be consistent with the *flanking barrier* stage of the *deltaic barrier cycle*.

2. Eastern Isles Dernieres

The Isles Dernieres have been described as representative of the *transgressive barrier arc* stage of the *deltaic barrier cycle* (Penland and Boyd, 1981). As such they should be moving landward as they spread laterally away from the central islands, decreasing in surface area and

width as they move. Therefore, the western islands in the arc should move westward and the eastern islands should move east, and all should be retreating shoreward. However, a trend of westward lateral migration of the eastern portion of the Isle Derniere (later the Isles Dernieres) is evident in the historical charts. These show westward movement of the eastern and western ends of the Isles Dernieres of nearly 2 km between 1853 and 1974 (Penland and Boyd, 1981), and a westward shift of Isle Derniere and Wine Island, immediately to the east, of 4 km between 1845 and 1947 (Kwon (1969). The Eastern Isles Dernieres has also undergone an extension of its western end since the breach which separated it from the Central Isles Dernieres in 1972 (Dolan, 1978). It gained a total of 736 m between 1978 and 1985. However, the eastern end has apparently remained in essentially the same position since 1934, retreating 30 m in the final year of the current study.

The Gulf shoreline of the Eastern Isles Dernieres, has continued to retreat shoreward. This could be considered consistent with the *transgressive barrier island arc* stage of Penland and Boyd's (1981) model. However, the Eastern Isles Dernieres lies to the southeast of it's origin in the Caillou headland (Shepard, 1960; Kwon, 1969) and is the easternmost island in the Isles Dernieres barrier arc (Peyronnin, 1962). According to the *deltaic cycle* model, the island should be prograding eastward. Despite this, it is prograding in a westward direction, which is inconsistent with the model.

3. Model Evaluation

Timbalier Island has exhibited a net westward migration since 1934. This lateral relocation appears to be consistent with the *flanking barrier* stage of the *deltaic barrier cycle* (Table 42). The Gulf shoreline of the Eastern Isles Dernieres, has continued to retreat inland, resulting in an overall narrowing of the island. This is consistent with the *transgressive barrier island arc* stage of Penland

Table 42. Deltaic Barrier Cycle Model agreement/disagreement.

	Eastern Isles Dernieres	Timbalier Island
I. Active Deltaic Environment.	yes	yes
II. Associated with Abandoned and Eroding Deltaic Headland.	yes	yes
A. 1. Connected to Headland.	no	no
2. Laterally Prograding.	yes	yes
Flanking Barrier Spit	no	no
B. 1. Detached from Headland.	yes	yes
2. Migrating Laterally Away from Headland.	no	yes
3. Laterally Prograding.	yes	yes
Flanking Barrier Island	no	yes
C. 1. Detached from Headland.	yes	yes
2. Laterally Prograding Away from Center.	no	yes
3. Forming an Arc Around Subsiding Headland.	yes	no
4. Migrating Shoreward.	no	no
Barrier Arc	no	no
D. 1. Subaqueous Shoal.	no	no
2. In Vicinity of Former Deltaic Headland.	yes	no
Subaqueous Shoal	no	no

and Boyd's (1981) model. However, the Eastern Isles Dernieres lies to the southeast of it's deltaic origin but is prograding in a westward direction. This is inconsistent with the model. Therefore, the *deltaic barrier cycle* appears to describe the dynamics of Timbalier Island but does not adequately describe the Eastern Isles Dernieres.

C. Modifications to Existing Models

Although the Godfrey and Godfrey (1974) *rollover* and Penland and Boyd (1981) *deltaic cycle* models appear to describe most of the major events recorded during this study, neither was found to be entirely accurate nor complete with regards to Timbalier Island or the Eastern Isles Dernieres. The Godfrey and Godfrey (1974) model may be useful in describing the impact of major storm events on the beach and Gulf shorefront. However, this model fails to predict or account for the continued subsidence and erosion of the backbarrier area within the Louisiana barriers investigated. Penland and Boyd's (1981) model is in much closer agreement with observed changes. The one inconsistency was an inability to predict the direction of lateral drift of older deltaic barrier parcels. Since Penland and Boyd essentially include the major components of the Godfrey and Godfrey (1974) model in modified and expanded form, discussion of further modification will be limited to their *deltaic barrier cycle*.

The predicted decline of Timbalier Island and the Eastern Isles Dernieres seems to support their presumed respective ages in the deltaic cycle, as well as confirm their imminent transition to the *subaqueous shoal* stage of Penland and Boyd's (1981) model. The one observed shortcoming was the westward, rather than eastward lateral migration of the Eastern Isles Dernieres. This may indicate that at a certain point in the decay of the islands and headlands the symmetry of the lateral drift is replaced by an overall linear drift determined by prevailing nearshore currents. The early symmetric flanking spit formations might

result from localized nearshore currents generated through tidal flushing of the marshes to either side of the headland (Nummedal, 1983). As these marshes subside and are separated from the remaining spits and barriers, the flushing effects would be proportionately diminished. Eventually the influence of the prevailing longshore currents may predominate, resulting in a unidirectional drift of the entire barrier system.

In the case of the Isles Dernieres, no countercurrent spread is evident, even from charts dating back to times when the island was in close proximity to the headland marshes (Penland et al., 1987). This may be due to inaccuracies in the early charts or it may indicate that the spreading arc may be a special, rather than a general case in this stage of deltaic barrier island development. Determination of local nearshore currents would, therefore, be essential prior to attempting modification of the barrier island environment for management purposes.

IV. Management Recommendations

Assuming that the Louisiana barrier islands are expressions of stages in a pattern of deltaic building and deterioration, efforts intended to sustain or prolong their longevity must be considered ultimately futile. Nevertheless, there may be circumstances which could warrant the enhancement or protection of these islands. Ccver categories which appear to provide the best possibilities for prolonging or improving the present status of the islands include beach, swale, and marsh. Swale forms as a result of the vegetative colonization of accumulated overwashed beach and dune sediments, while in these islands, new marsh appears to result from the gradual submergence of backbarrier swale. On Timbalicr Island 15-28% of newly accreted sand was colonized by marsh, while only 3-12% was colonized on the Eastern Isles Dernieres. The beaches and dunes are themselves maintained by reworking and accumulation of island and nearshore sediments through a combination of

longshore drift, tides, and aeolian transport. Increasing the available supply of sand would, therefore, constitute the best method for enhancing both beach and swale.

The marshes investigated in this study have distinctly different origins. The Eastern Isles Dernieres marshes are predominantly remnants of the original deltaic headlands over which the swale and beach have been retreating (Peyronnin, 1962; Frazier, 1967; Penland et al., 1981). The marshes on Timbalier Island have formed from subsided beach ridges and swales resulting from the islands lateral migration (Peyronnin, 1962; Frazier, 1967). Enhancement of marshes on Timbalier Island would, once again, appear to require supplementing the supply of sand to beaches and swale. However, maintenance or reestablishment of marshes on the Eastern Isles Dernieres does not seem to be as likely a prospect, since a sufficiently shallow and stable Bay platform does not appear to exist. Backfilling of the nearshore Bay area may be possible, however, the unconsolidated nature of the back barrier and Bay sediments would greatly increase the amount of material required to maintain marsh over any length of time. Since the Gulf shoreface has an existing sand base, subsidence there might be less than in the backbarrier or Bay areas.

The best prospect for reducing erosion on both Timbalier Island and the Eastern Isles Dernieres appears to be beach sand nourishment. In addition, due to the westward drift of both islands, if such an undertaking were to be considered, the greatest benefits should be derived from augmenting beaches and swale in the eastern portions of the two islands, since this would assure the maximum distribution of the sediments over time.

V. Suggestions for Further Investigation

The information used in this study represents only a fraction of that potentially available for analysis. Additional data processing recommendations include the implementation, within the existing GIS, of

a dynamic computer model based on observed relationships and rates of change. This could be used to predict the outcome of various management strategies prior to their implementation. However, for such a model to accurately represent the dynamics of these islands, more information is needed.

New photography, as well as additional archival imagery should be acquired and maps produced in order to fill in gaps and update the existing data. This would provide highly useful information relative to the long term effects of hurricane impacts, since the last imagery used in this study immediately followed hurricane Juan. In addition, a sequence of aerial photographs shortly prior to and following a major winter frontal passage would help answer some of the questions concerning the relative impact of such events. The majority of effort involved in this study was in establishing the database. This involved:

1. selecting appropriate study areas,
2. obtaining available photographic imagery,
3. acquiring additional recent imagery,
4. creating photointerpreted maps registered to a standard map projection,
5. verifying the accuracy of the maps through field investigations, and
6. manually digitizing the final map products.

Adding additional photographic dates would still require registering and interpreting the imagery, but the process would be one of updating existing maps rather than creating entirely new ones. Many features or portions of features would remain unchanged and would only require verification.

Timbalier Island and the Eastern Isles Dernieres are not entirely representative of the Louisiana barrier coast. The Chandeleur islands are remnants of older deltaic headlands and apparently respond in fashion more typical of the *rollover* model (Penland et al., 1981). Louisiana Environmental Monitoring System (LEMS) imagery exists for portions of the northern Chandeleurs, as does the 1978 EPA photography

and the 1982 NHAP and 1985 NASA imagery. Extending the database to include one or more of the Chandeleurs would provide a more complete picture of the dynamics of the Louisiana barrier coast.

Another suggestion is to add coring data to the transect analysis, to determine possible relationships between the subsurface strata and observed surface changes. Patches of old marsh have been observed in the beach front of the Eastern Isles Dernieres as the beach retreats landward. Such features may have a significant influence on shoreline erosion.

In addition, the inclusion of nearshore current, storm surge, and sediment transport data would greatly aid in quantifying the mechanisms of shoreline erosion, accretion, and longitudinal drift. Such information would be essential for creating a computer simulation model of barrier island dynamics. The implementation of such a model could provide valuable insight into the results of various management strategies prior to actually committing time or resources to these activities.

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VITA

Lionel Dorsey Worthy, Jr. was born on January 19, 1947, in Fort Payne, Alabama. His father is a retired electrical engineer and his mother a retired elementary school teacher. He is married to Susan Filley, a professional porcelain ceramicist, and has a son, Gabriel Alexander, born in January of 1988.

He first attended college in 1965, at Auburn University, in the mechanical engineering program prior to enlisting in the U.S. Air Force. After serving four years in Italy and Germany as a finance and accounting specialist, he returned to academics. He obtained an A.S. from Northern Virginia Community College in 1972, a B.S. in Forestry from West Virginia University in 1974, and an M.S. in Fisheries Science from Virginia Polytechnic Institute in 1977.

Dorsey joined the Peace Corps in 1978, and worked with the government of St. Lucia, West Indies. There, he initiated a statistics program for island fisheries, and helped in the establishment of an underwater national park. In 1980, he returned to Virginia and worked with an environmental engineering firm as a field biologist and director of their water and soils testing laboratory. In 1983, Dorsey and his wife, Susan, moved to Baton Rouge, Louisiana, where he completed the course work and research for his PhD, at Louisiana State University. He is currently president of Harbinger Associates, an environmental mapping and assessment firm in Charlottesville, Virginia.

He holds commercial, multi-engine and instrument pilot ratings, and open water and research SCUBA certificates. His favorite activities are woodworking, whitewater canoeing, fishing, and playing music.

DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Lionel Dorsey Worthy, Jr.

Major Field: Marine Sciences

Title of Dissertation: Louisiana Barrier Island Change Analysis Derived From A Geographic Information System (GIS) Based on Sequential Aerial Photography

Approved:

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

Date of Examination:

April 25, 1990