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Historical Changes in the Mississippi-Alabama Barrier-Island Chain and the Roles of Extreme Storms, Sea Level, and Human Activities

Robert A. Morton

U.S. Geological Survey
10100 Burnet Road, Building 130
Austin, TX 78758, U.S.A.
rmorton@usgs.gov

ABSTRACT

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Barrier-island chains worldwide are undergoing substantial changes, and their futures remain uncertain. An historical analysis of a barrier-island chain in the north-central Gulf of Mexico shows that the Mississippi barriers are undergoing rapid systematic land loss and translocation associated with: (1) unequal lateral transfer of sand related to greater updrift erosion compared to downdrift deposition; (2) barrier narrowing resulting from simultaneous erosion of shores along the Gulf and Mississippi Sound; and (3) barrier segmentation related to storm breaching. Dauphin Island, Alabama, is also losing land for some of the same reasons as it gradually migrates landward. The principal causes of land loss are frequent intense storms, a relative rise in sea level, and a sediment-budget deficit. Considering the predicted trends for storms and sea level related to global warming, it is certain that the Mississippi-Alabama (MS-AL) barrier islands will continue to lose land area at a rapid rate unless the trend of at least one causal factor reverses. Historical land-loss trends and engineering records show that progressive increases in land-loss rate correlate with nearly simultaneous deepening of channels dredged across the outer bars of the three tidal inlets maintained for deep-draft shipping. This correlation indicates that channel-maintenance activities along the MS-AL barriers have impacted the sediment budget by disrupting the alongshore sediment transport system and progressively reducing sand supply. Direct management of this causal factor can be accomplished by strategically placing dredged sediment where adjacent barrier-island shores will receive it for island nourishment and rebuilding.

ADDITIONAL INDEX WORDS: *Sediment budget, barrier restoration, channel dredging, human modifications.*

INTRODUCTION

Barrier-island chains worldwide are being recognized as finite natural resources with high social value for recreation and storm protection, but with uncertain futures (Pilkey, 2003). The uncertainty comes from the fact that some barrier-island chains are disintegrating rapidly as a result of combined physical processes involving sediment availability, sediment transport, and rising sea level. Accelerated rates of land loss and decreases in area should be expected for these ephemeral features, because present physical conditions are different from those that existed when many of the barrier islands first formed (Bird, 2003). In many coastal areas during the past few thousand years, sediment supply has diminished, rates of relative sea-level rise have increased, and hurricanes and winter storms have been frequent events that generate extremely energetic waves capable of permanently removing sediment from the island chains.

Recent attention has focused on the accelerated land loss and morphological changes of barrier-island chains in the north-central Gulf of Mexico that resulted from impacts of Hurricane Katrina (Sallenger *et al.,* 2006). Barrier islands at greatest risk of further degradation, the Chandeleur-Breton Island, Grand Terre Island, Timbalier Island, and Isle Dernieres chains in Louisiana, are associated with the Mississippi River delta (McBride and Byrnes, 1997). These chains of transgressive barrier islands have progressively diminished in size as they migrated landward and/or disintegrated in place (McBride *et al.,* 1992; McBride and Byrnes, 1997). In contrast, the MS-AL barrier islands (Figure 1) are not migrating landward as they decrease in size. Instead, the centroids of most of the islands are migrating westward in the direction of predominant littoral drift through processes of updrift erosion and downdrift deposition (Byrnes *et al.,* 1991; Otvos, 1970; Richmond, 1962). Although the sand spits and shoals of the MS-AL barriers are being transferred westward, the vegetated interior cores of the islands remain fixed in space.

The objectives of this investigation were to document the historical changes in position and land area of the MS-AL barrier islands, examine the physical factors that are most

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Figure 2. Morphological and spatial changes in Dauphin Island between 1847 and 2007.

Ship Island between 1848 and 1986. Their bathymetric comparisons for successive periods revealed the alterations in Mississippi Sound related to dredging of the Gulfport Ship Channel. Byrnes *et al.* (1991) compared the island shapes and calculated subaerial change rates. McBride, Byrnes, and Hiland (1995) developed a morphological classification of lo2sifirtedhanpedsh2(of341.21))-bar7(lo2sifirte.8(Ba241.2(is3the)-341.2(chade,)-inclu

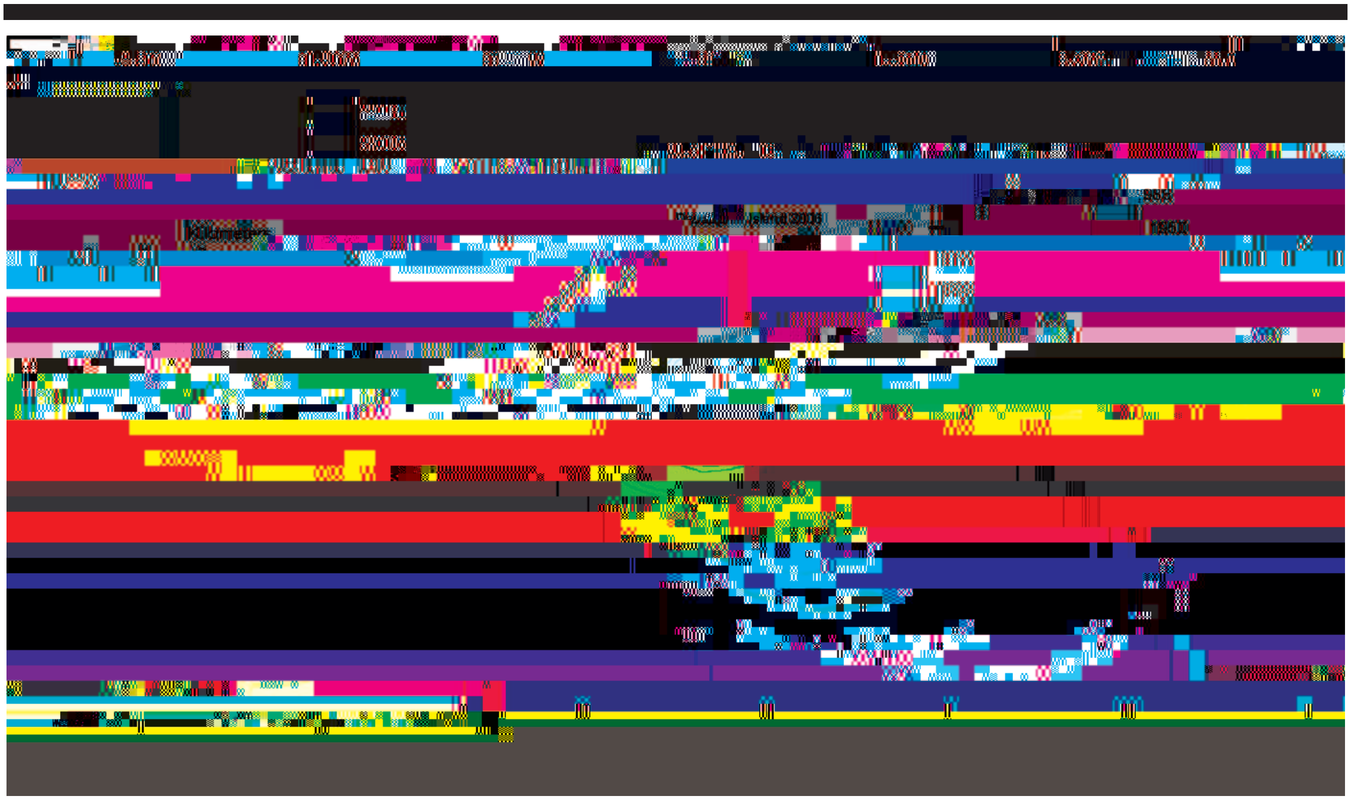

Figure 3. Morphological and spatial changes in Petit Bois Island between 1848 and 2007.

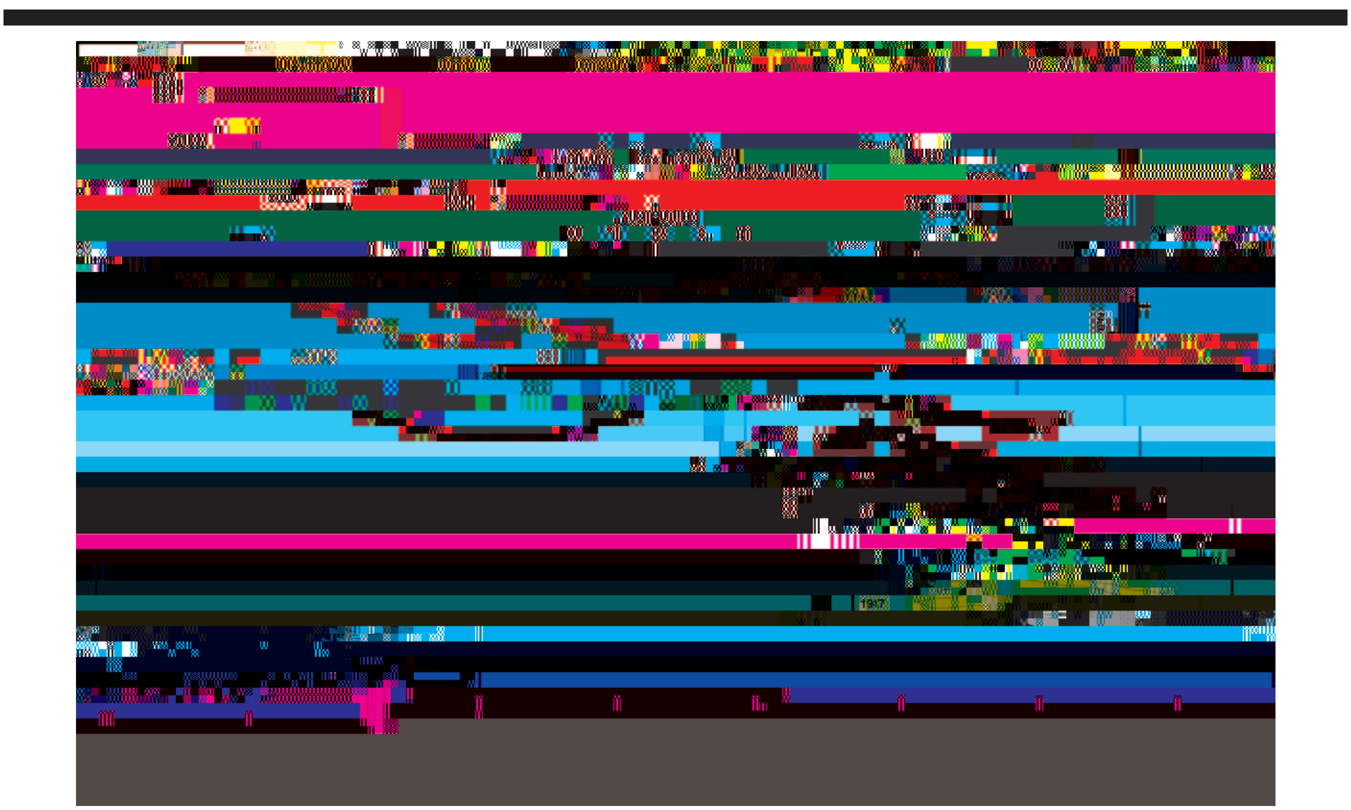

Figure 4. Morphological and spatial changes in Horn Island between 1849 and 2007.

Figure 5. Morphological and spatial changes in Ship Island between 1848 and 2007.

Figure 6. Morphological and spatial changes in Cat Island between 1848 and 2007.

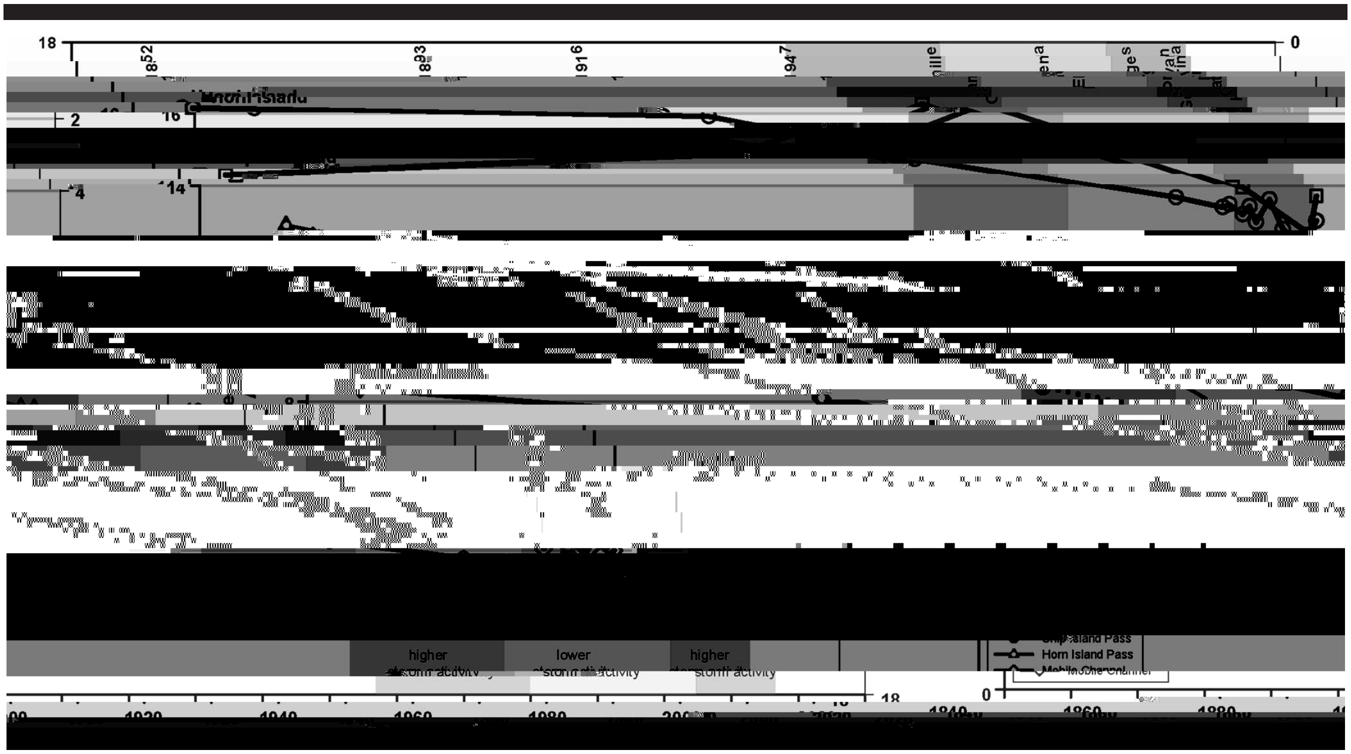

Figure 7. Historical land-loss trends for the Mississippi-Alabama barrier islands relative to the timing of major hurricanes that impacted the islands, cycles of variable storm intensities, and depths of shipping channels dredged through the outer bars at three tidal inlets within the barrier-island chain.

Table 1. *Average rates of land-area change for Dauphin Island for selected periods. Rates are in ha/y. Positive numbers indicate land gain, and negative numbers indicate land loss.*

1847–1917	1847–1940	1940–1958	1958–1996	1996–2007	1847–2007
*	+0.73	+7.17	−		

Table 2. *Average rates of land-area change for the Mississippi barrier islands for selected periods. Rates are in ha/y. Negative numbers indicate land loss.*

	Petit Bois
Period	

breached by hurricanes in 1853, 1947, and 1969 (Camille). The 1950 USGS topographic map and the 1958 U.S. Department of Agriculture air photos (Waller and Malbrough, 1976) indicate that Ship Island was separated into east and west segments either continuously or for long periods before Hurricane Camille. However, the pre-Camille breaches eventually shoaled, and the narrow barrier segments were rebuilt by constructive non–storm waves that reworked sand from the surrounding platform, enabling the narrow barrier segments to become subaerial once again. Since 1969, Ship Island has been separated into east and west segments.

Between 1848 and 2007, Ship Island lost about 60% of its initial land area (Table 3), and the land loss rates generally increased. Average losses of −0.6 ha/y between 1848 and 1917 increased to −2.8 ha/y between 1917 and 1950 (Table 2). A slight decrease to −2.4 ha/y occurred between 1950 and 1986, when approximately 20 ha of land were artificially added to the island near Fort Massachusetts. Land loss rates subsequently increased to 6.4 ha/y between 1986 and 2007. Within that period, land losses averaged −12.1 ha/y between 2000 and 2007, because Hurricane Katrina severely eroded Ship Island and recovery was relatively minor.

Cat Island

The island that changed the least morphologically was Cat Island, which has remained a relatively stable landform throughout its recent history. This is because interior elevations and the orientation of Cat Island prevent breaching and overwash by storm waves except along spits of the eastern shore. Although the core of the island has not moved, the island perimeters have shifted as a res-341.70.6(was)-S.6(when(segmeab-358.8(of)-4uui417.6(except)i417.6(exc6vuui417.6(except)i417.6(exc6ar

ated between 1950 and 1960 such that average annual dredging from Horn Island Pass increased from about 26,000 m^3/y to about 394,000 m^3/y; average annual sediment volumes removed from Ship Island Pass increased from 33,000 m^3/y to about 443,000 m^3

1976). In the mid-1800s, the natural controlling depths of tidal inlets connecting Mississippi Sound with the Gulf of Mexico were from 4.5 to 5.7 m. Since then, the outer-bar channels have been repeatedly dredged to depths well below their natural depths and that of the surrounding seafloor. The initial shallow dredging would have had minimal effect on sediment transport, but the cumulative effects of nearly simultaneous deepening of the navigation channels through the outer bars would eventually prevent the sediment-transport system from transferring sand to the downdrift barriers. This temporal progression is consistent with observations at Ship Island Pass that shoaling was substantially greater than maintenance dredging by the 1950s (Knowles and Rosati, 1989), and at Horn Island Pass and Ship Island Pass that trapped sediment volumes increased exponentially as channel dimensions increased (Rosati *et al.,* 2007).

The channel modifications eventually disrupted the littoral system and rendered it incapable of transferring sand across the ebb-tidal deltas. Most of the sand in transport along the available for platform construction as sea level continues to rise and storms modify the island geometries. Petit Bois and Ship Islands are prevented from migrating westward because the dredged channels maintained near their downdrift ends intercept sand that would have either forced westward inlet migration or filled the channel margin, constructing an inlet-margin platform and promoting lateral island extension. The presence and ages of large shoals preserved on the inner continental shelf off the Texas and Louisiana coasts are reminders that conditions favorable for drowning some barrier islands occurred previously in the northern Gulf of Mexico as a result of rapid sea-level rise during the late Holocene. Also, the demise of the Isle of Caprice and Dog Keys shoals provides historical evidence of total island destruction (Rucker and Snowden, 1988).

Prediction of future morphological and land-area changes perhaps is easiest for Dauphin Island, because it is still anchored to the Pleistocene core that provides stability to its eastern end. Armoring of the eastern end with bulkheads on the sound side and a riprap revetment along the inlet margin provides additional protection from erosion, thus minimizing additional land loss and mobility. The primary sand source of the island, the ebb-tidal delta at the Mobile Bay Entrance, is still attached and periodically supplies additional sediment to the gulf shores of the island. This sand eventually becomes the beach and dune sand that supplies downdrift spit growth and island extension. It would also supply storm-washover deposition, which enables the barrier to maintain mass as the western three-fourths of the island migrates landward. The future of the Ivan/Katrina breach through Dauphin Island is an uncertainty that will significantly influence future land-loss trends and island position. The island has been breached repeatedly west of the island core near the shallow subsurface contact between Holocene and Pleistocene sediments (Otvos and Giardino, 2004) and at other locations about 10–20 km from its eastern end. Historical documents show that wide storm breaches through Dauphin Island eventually shoaled and the beach and alongshore transport systems

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