A Coast for All Seasons:

A Naturalist's Guide to the Coast of South Carolina

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FIGURE 10. Cross-section illustrating the collision of continental and oceanic plates. At the collision point, the continental plate rides over the oceanic plate, creating a high, young mountain range. Shorelines along the collision juncture tend to be dominated by rocky shores, wave-cut cliffs, and relatively short pocket beaches (e.g., coasts of western North and South America). Coastlines on the trailing edge of the continental plate are dominated by coastal plains that contain abundant estuaries and barrier islands (e.g., east coast of the United States). Modified after Davies (1973, Fig. 3) and Inman and Nordstrom (1971).

FIGURE 11. Generalized models of the three basic types of depositional coasts – (A) Microtidal [tidal range (TR) = < 6 ft., usually wave-dominated], (B) Mesotidal (TR = 6-12 ft., usually mixed energy), and (D) Macrotidal (TR = > 12 ft., usually tide-dominated). The red lines in A represent offshore, submerged wave-formed sand bars, and those in B and C indicate intertidal sand deposits. The South Carolina shoreline is a classic example of a mesotidal (mixed-energy), depositional coast.

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FIGURE 23. The recurved spit at the southern end of Kiawah Island, South Carolina at low tide on 10 June 1976 (infrared photograph by Dennis K. Hubbard). Because of the consistent movement of sand along the shore from northeast to southwest (see arrow; view looks northeast), the tidal inlet just beyond the bottom of the photo (Captain Sam's Inlet) is forced to migrate to the south at rates of around 200 ft/year. As a result, the waves moving sand along the beach and into the inlet produce a curve in the beach that extends much of the way around the end of the island on the inside of the inlet. As this pulsating process continues, the spit continues to migrate to the southwest with the curving beach ridges marking the different stages of this advancement. Around 1948, a new inlet channel was formed at the narrow neck of the recurved spit, after which the inlet resumed its unceasing migration to the southwest. Therefore, the entire spit form shown in this photograph, which was more than 5,000 ft long at that time, had been formed in the past 28 years.

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FIGURE 30. The section of the coast between Charleston Harbor (to the southwest) and Bulls Bay (to the northeast). Vertical infrared image acquired on 23 October 1999. Note the drumstick shape of the two larger islands, Bull Island and Isle of Palms. All of the inlets, except Price Inlet at the southwest end of Bull Island, have distinct downdrift offsets (Figure 31).

FIGURE 31. View looking southwest from the southwest end of Bull Island. Inlet in foreground is Price Inlet and the Isle of Palms is visible in the distance. The two tidal inlets in the middle distance, Dewees and Capers, show distinct downdrift offsets. Infrared photograph taken circa 1978.

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The bar in the foreground (arrow C) gradually moved landward, allowing a large packet of sediment to bypass the inlet and weld to the beach, a process called bar-bypassing (Sexton and Hayes, 1982). As a result of these types of bars welding to the beach, the downdrift offset of the beach south of the inlet developed. The light colored bulge of sand behind the beach (in the foreground) had been formed in this manner within the past few years before this photograph was taken (at low tide in December 1979). The bright red vegetation (wax myrtle – Myrica cerifera) was growing on older deposits.

FIGURE 35. Vertical infrared image of Kiawah Island and vicinity acquired on 23 October1999, courtesy of Earth Science Data Interface (ESDI) at the Global Land Cover Facility. The locations of inlets originating by three different mechanisms are shown on this image. Captain Sam's Inlet was cut most likely during a hurricane storm surge in the middle to late 1940s. Stono and North Edisto Inlets were formed by barrier islands converging over lowstand valleys, as is illustrated in Figure 33. A number of small tidal inlets were formed south of North Edisto Inlet as a result of a chain of landward-migrating barrier islands moving landward across major tidal channels (as is illustrated in Figure 27).

FIGURE 36. General model of the morphology of tidal inlets.

FIGURE 37. Typical morphology of ebb-tidal deltas in mesotidal settings (after Hayes, 1980). Arrows indicate dominant direction of tidal currents. This model was derived for the ebb-tidal deltas of the New England area, but it applies equally well to the inlets of South Carolina and other barrier-island systems around the world.

FIGURE 38. Examples of ebb-tidal deltas on the South Carolina coast. (A) North Edisto Inlet. Arrows indicate the dominant orientation of bedforms generated by tidal currents (e.g., megaripples) and wave-generated currents (e.g., ripples). Compare this diagram with the general model given in Figure 37. Note the dominance of landward–directed sand transport in the marginal flood channels and seaward-directed transport in the main ebb channel. Arrows are based on actual field observation through several tidal cycles (Imperato, Sexton and Hayes, 1988). (B) The ebb-tidal delta of Price Inlet, South Carolina at low tide in the winter of 1975. Compare this ebb-tidal delta with the model in Figure 37. Note the symmetrical ebb-tidal delta, with a clearly defined main ebb channel, terminal lobe, several well-developed swash bars, and two marginal flood channels.

FIGURE 39. Effect of tides on the mixing of salt and fresh water in estuaries (modified after Biggs, 1978).

FIGURE 40. Estuaries. (A) Plan view of a typical estuary in South Carolina. (B) Cross-section of a typical estuary showing predominant processes and circulation patterns. Especially noteworthy is the formation of a zone of the turbidity maximum where the clay particles brought in by the river undergo a process called flocculation.

FIGURE 41. Classification of river deltas on a ternary diagram, with three factors controlling the delta morphology – 1) river input (amount of sediment delivered to the coast by the river); 2) wave energy flux (how big the waves are); and 3) tidal energy flux (controlled primarily by the tidal range). We have superimposed tidal range on this diagram, which was originally devised by Galloway (1975). The fields within which the three principle types of deltas – river-dominated, wave-dominated, and tide-dominated – would plot are shown. These three delta types are illustrated in Figure 42. Note the approximate location of the Santee/Pee Dee Delta on the diagram, which we refer to as a mixed-energy delta.

FIGURE 42. River delta models. (A) Schematic sketch in plan view of a river-dominated delta. The main lobe of the delta projects far beyond the shoreline of the adjoining coast. During floods, channels (sometimes referred to as crevasses) may be cut across the natural levees and crevasse splays (minor delta-like lobes) are deposited in adjoining waters. (B) Wave-dominated delta. Note prominence of prograded beach ridges throughout the delta plain. (C) Tide-dominated delta. Note the presence of tidal sand ridges at the offshore entrances to the numerous estuarine complexes along the margin of the delta.

FIGURE 43. Zone of dynamic change (ZODC). The area in red depicts sand that may be eroded from the beach area and deposited offshore during storms. Much of this sand is deposited on the offshore bar (colored black). In between storms, much of the eroded sand is returned to the beach/dune area. The yellow arrows indicate the three mechanisms by which the sand bight be lost from this particular ZODC: 1) carried offshore beyond the closure point during large storms, such as hurricanes; 2) blown landward out of the foredune area during periods of high wind activity; and 3) transported alongshore out of the ZODC by beach drift and longshore currents as illustrated in Figure 22.

FIGURE 44. Representative beach profiles from the west (A) and east (B) coasts of the United States.

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FIGURE 46. Ripples and megaripples. (A) Ripples exposed at low tide on a tidal river point bar in South Edisto Estuary. Arrow points to exposed ghost-shrimp burrow. (B) Megaripples exposed at low tide on a sand flat at Hampton Harbor Inlet, New Hampshire. View from bridge. Arrow points to megaripple shown in C. The ebb current that created these megaripples was flowing from the lower left to the upper right. (C) Ground view of the megaripple shown in photograph B. Note the high angle of dip of the beds created by the migration of the bedform by the mechanism illustrated in Figure 47. The machete is about 2.5 ft long. Ebb current that created this bedform was flowing from left to right. Photographs in B and C were taken in November 1965.

FIGURE 47. Mechanism for the movement of megaripples. Compare the implied slip faces of the bedform as it moves along (in the sketch) with the ones exposed in the excavation in the photograph in Figure 46C.

FIGURE 48. Changes in linearity of crests and 3-dimensional shape of ripples under conditions of increasing flow strength. Based on data of Allen (1968), Boothroyd (1969), and numerous field observations by our group on the intertidal bars and sand flats on the South Carolina coast. In all cases, the water was flowing from left to right.

FIGURE 49. Photographs of the ripple types illustrated in Figure 48. (A) Linear ripples. Scale is one foot. The ebb current that created these ripples was flowing from left to right. (B) Ripples with undulatory crests, formed by an ebb current flowing from left to right. Scale is 15 cm (~ 6 inches). (C) Cuspate ripples, formed by an ebb current flowing from the upper right to the lower left. (D) Small rhomboid ripples. Flow is from left to right. Scale is one foot. This ripple form is the last to develop before the bed passes to the flat-bed stage in the transitional zone between lower and upper flow regime.

FIGURE 50. Antidunes. (A) Formation and growth. As the shallow sheet of water flows across the linear form of the antidune, water flowing down the downcurrent side of the antidune tends to erode sand from that slope. As it flows up the slope of the next antidune down current, sand is deposited on that slope, resulting in an upcurrent migration of the form. This bedform is called an antidune, because it moves in the opposite direction to the current. Lower flow regime ripples, on the other hand, move in the same direction as the current (compare this figure with the diagram in Figure 47). However, the sand grains themselves move downstream in both situations. (B) Trench through antidunes on the beach on Seabrook Island, South Carolina (photograph taken at low tide in June, 1975). Water was flowing from right to left when the antidunes were forming. Compare the internal sand layers in the preserved antidune with the sketch in diagram A. Scale is one foot.

FIGURE 51. More antidunes. (A) In the lower left of the image, antidunes are forming in the backwash of a wave. Further up the beach, preserved antidunes are in evidence. This sunset picture was taken on the beach at Seabrook Island, South Carolina in June 1975. (B) Antidunes preserved on the upper beach face on the northern end of Kiawah Island, South Carolina. The return flow that created the antidunes also sorted the sand grains by composition, leaving behind bands of black heavy minerals dominated by magnetite and ilmenite. Scale is 15 cm (~ 6 inches). (Photograph taken circa 1980).

FIGURE 52. Heavy minerals. (A) Beach trench in heavy mineral zone at north end of Kiawah Island. Internal structures in trench indicate that a depositional berm had been truncated by an erosional episode that left a 2-3 cm thick deposit of heavy minerals on the truncation surface. (Photograph taken in May 1978). (B) A 3.5 mm field of view of a sand sample from a heavy mineral layer on a South Carolina beach. The black minerals are dominated by magnetite (Fe_2O_4) and the clear grains are mostly quartz (SiO_2). Courtesy of Ray Torres.

FIGURE 53. Intertidal bars at low tide, central Kiawah Island (infrared photograph taken circa 1978). Waves were slowly moving the bars onshore, with the potential of their welding onto the beachface, forming a wide beach. This process, interrupted at times by major storms, has taken place numerous times over the years.

FIGURE 54. Representative morphology and sedimentary features occurring on the beaches of the prograding, mixed-energy barrier islands of South Carolina. Based on inspection of hundreds of beach trenches. (A) Features found on a typical mid-barrier beach in a constructional mode (modified after Hoyt and Weimer, 1963). (B) Features found on beaches near tidal inlets in a late constructional mode.

FIGURE 55. Model for evolution of foredune ridges on a prograding, recurved spit in South Carolina (see photograph of one such recurved spit in Figure 23).

FIGURE 56. Shoreline changes associated with tidal inlets in South Carolina. (A) Large swash bars detaching from the ebb-tidal delta at Stono Inlet and merging with the beach. Upper – Early stage of detachment in 1977. Middle – Attached to shore in 1983. Lower – A new swash bar detached in 1986, which attached to the beach in 1990. From Kana, Hayter, and Work (1999). (B) Illustration of the three stages of bar welding from the same article.

FIGURE 57. Groins (arrows) at Edisto Beach, South Carolina (photograph taken by Tim Kana on 10 February 2006). This extensive groin field was installed between 1948 and 1975.

FIGURE 58. Seawalls and beach erosion. (A) Illustration of erosion in front of and on downdrift side of a seawall as a result of waves reflecting from the seawall (highly modified after Silvester, 1977, Figure 8). The approaching wave crests meet the reflecting wave crests at approximately right angles, generating a flow parallel with the shore in the downdrift direction. This current scours a channel a few yards seaward of the wall. The beach downdrift of the seawall will also erode due to loss of sand in the scour zone, which would normally accrete on the beach in the absence of such a strong current in the nearshore area. (B) Waves reflecting off a seawall at Hampton Beach, New Hampshire. Wide arrow indicates approaching wave and dashed arrow indicates reflected wave moving away from the seawall at a 90-degree angle to the approaching wave. Photograph taken by A. D. Hartwell in circa 1969.

FIGURE 59. Offshore breakwaters (arrows) near Port Fourchon, Louisiana (photograph taken in the spring of 2005). The effectiveness of these breakwaters is hindered by the fact that the land is sinking at a relatively rapid rate, because of the abandonment of a lobe of the Mississippi delta several hundred years ago.

FIGURE 60. Hurricane Hugo approaching SC coast on 21 September 1989. Image courtesy of National Oceanic and Atmospheric Administration.

FIGURE 61. Oblique southeasterly view of the central shoreline of the Isle of Palms taken a few days after Hurricane Hugo (11 October 1989). Arrows point to locations where beachfront houses were completely removed from their foundations and transported landward.

FIGURE 62. Isle of Palms erosion during hurricane Hugo (1989). Arrows show path of migration of a house formerly on the front row of beach houses that was deposited in a neighbor's yard during the storm surge of the hurricane.

FIGURE 63. Southern end of Pawleys Island showing closely spaced houses on the washover terrace of the southern spit. Photograph taken by Tim Kana on 2 January 1987, two years and eight months before hurricane Hugo (1989).

FIGURE 64. Erosion at Pawley's Island during hurricane Hugo (1989). (A) Schematic showing location of displaced houses. (B) House in new channel cut by the storm. Photograph by Bill Jordan.

FIGURE 65. Image of southern end of Pawleys Island acquired 2006, courtesy of SCDNR. Many of the houses on the spit were built back after hurricane Hugo (1989).

FIGURE 66. Damage to the trees in the forests of South Carolina as a result of hurricane Hugo (1989). Courtesy of the South Carolina Forestry Commission.

FIGURE 67. Generalized model for the expansion of tidal inlets observed on the South Carolina coast as a result of hurricane Hugo (1989).

FIGURE 68. Typical topographic profile of tidal channel and associated habitats of the backbarrier and lower estuary regions in South Carolina.

FIGURE 69. Marsh plants. (A) Occurrence of the most conspicuous plants in the marshes of the upper (fresh), middle (brackish), and lower (saline) parts of the estuaries of South Carolina. Modified after Stalter (1974). (B) Sketches of some of the more common marsh plants in South Carolina.

FIGURE 70. Typical profile of the salt marshes of the Georgia Bight (modified after Teal, 1958). The “Minax marsh” zone is named after the dominant species of fiddler crab found there, Uca minax. The dominant plant is extremely short Spartina alterniflora.

FIGURE 71. Ground view of salt marsh surface in the backbarrier region of Kiawah Island. Note zonation of plants, with Borrichia occupying the high ground on the right and Spartina alterniflora occupying lower ground in the distance. Salicornia occupies the middle zone. Bass Creek, the major tidal creek landward of the north end of Kiawah Island, can be seen to the far right. Photograph taken in October 1978.

FIGURE 72. Intertidal sand flat exposed at low spring tide. This sand flat, located at the entrance to St. Helena Sound, is several hundred yards wide. Linear streaks in lower portion of image are plumes of suspended sediment being transported out of the Sound by ebb currents. The multiple parallel sand bars in the middle of the image are evidence that this tidal flat is subject to some wave action. The mouth of the Ashepoo River is a short distance beyond the upper left corner of the image. Infrared photograph taken in December 1979.

FIGURE 73. Horseshoe crabs (Limulus polyphemus) on the sand flat illustrated in Figure 72 during the spring mating season (April/May). In both cases, these horseshoe crabs were stranded on the flat at low tide. (A) Overturned on its back to show the underparts. This one was carried down to the waters edge and released. (B) Male mounted on top of a larger female, a typical mating arrangement. The female burrowed into the sand a small distance after the tide went out. Photographs taken circa 2003.

FIGURE 74. Extensive mud flat in the North Edisto Estuary at low tide. View looks northwest. Arrow points to line of oyster mounds. This flat is several hundred yards across. Infrared photograph taken on 2 May 1981.

FIGURE 75. Location of “bare spots.” (A) General model for the formation and location of “bare spots.” (B) Location of “bare spot” in the lee of Bull Island (arrow). Image taken in 2006, courtesy of SCDNR.

FIGURE 76. Tidal creek in the Kiawah Island backbarrier region. (A) Meandering channel. Note how the former meander bed had truncated an older beach ridge, probably around 3,000 years old. Since the meander shown in this photograph was cut off, approximately 20 years before the photograph was taken, the abandoned oxbow had filled in with fine-grained sediment (arrow). Infrared photograph by L. G. Ward in the spring of 1978. (B) Ground view of the abandoned oxbow cutoff shown in photograph A. Note the abundance of fine-grained mud sediments that had filled in the oxbow. Marsh grass (Spartina alterniflora) fringes the channel. Photograph by A.W. Duc in May 1979.

FIGURE 77. Burrowing characteristics of four of the more common organisms on the tidal flats of the South Carolina coast.

Ba –The iodine worm (Balanoglossus), which has an open u-shaped burrow. Note the excreted sand pile, a conspicuous feature on the sandy tidal flats where this organism lives.

Dc – The periscope worm)Diapatra cuprea), which lives in a vertical chitinous tube with a periscope-like entrance.

Om – The soda straw worm (Onuphis microcephala), which lives in a vertical mucoid tube covered with sand grains.

Cm – The ghost shrimp (Callianassa major), which lives in a complex vertical to horizontal catacomb-like network of burrows lined with mud-rich fecal pellets. This burrow is analogous to Ophiomorphia of the Cretaceous deposits of the Rocky mountain region.

(Modified after Howard and Dorjes, 1972)

FIGURE 78. Channel types. (A) Classified as to whether they are straight or sinuous and whether they are single channels or a complex divided channel (after Rust, 1978). (B) Contrasting steep and flat channels.

FIGURE 79. Confluence of Congaree and Wateree Rivers (central South Carolina). Note complex meander belt of the Wateree River in the foreground. Arrow points to the bridge where US 601 crosses the Congaree River. Infrared photograph taken in September 1979.

FIGURE 80. Vertical infrared image of upper May River, South Carolina acquired in 1994. Arrow points to location where the meandering channel has eroded into the adjacent Pleistocene upland. Image courtesy of SCDNR.

FIGURE 81. General model of the morphology of tidal channels in the estuaries of South Carolina. (A) Upper estuary. (B) Middle estuary.

FIGURE 82. Oblique infrared photograph at low tide of a tidal river point bar located on the Wadmalaw River south of Charleston. The ebb-tidal current flows from left to right (arrow). Elevated channel on side of sand spit away from the main channel is dominated by flood currents (arrow; note flood-oriented sand waves in channel; arrow points in direction of the flood current at high-water level). Compare this image with the diagram in Figure 81B. The gray sediment between the marsh and the flood channel (lower half of image) is soft mud. Photograph taken circa 1982.

FIGURE 83. An eroding bluff on the shoreline of the May River, South Carolina. The location of this bluff is indicated by the arrow on the image in FIGURE 80. Photograph taken around mid tide on 30 October 2003.

FIGURE 84. Major piedmont and coastal plain river systems occurring within the Georgia Bight region. (A) Piedmont Rivers – Pee Dee (1), Santee (2), Savannah (3), and Altamaha (4). (B) Coastal Plain Rivers – Waccamaw (5), Little Pee Dee (6), Black (7), Cooper (8), Edisto (9), and Combahee (10). Coastal plain rivers in Georgia are not named.

FIGURE 85. The three zones of the direct transfer of sediments from the uplands to the coast. Zone 1 – The watershed or drainage basin located in the Piedmont and Blue Ridge Physiographic Provinces. Zone 2 – The alluvial valley that cuts across the Coastal Plain Physiographic Province. Zone 3 – The coastal zone where most of the sediments accumulate in the deltas and estuaries. Note that the fall line is the boundary between Zones 1 and 2. The physiographic provinces in South Carolina are mapped in Figure 6.

FIGURE 86. Plan view sketch of the morphology of the flood plain of a typical major piedmont river where it crosses the Coastal Plain of South Carolina. These flood plains are typically several miles across.

FIGURE 87. Hydrographs for two piedmont rivers (Broad and Tyger) and one coastal plain river (South Edisto) in South Carolina during four separate months in 1991. Note the flashy discharge of the piedmont rivers compared with the relative steady nature of the coastal plain river during the same time frame.

FIGURE 88. Topographic cross-section illustrating the components of typical bottomland hardwood ecosystems in the southeastern United States. Modified after Clark and Benforado (1981), Mitsch and Gosselink (1986), and Taylor et al. (1990).

FIGURE 89. Examples of bottomland hardwood ecosystems. (A) Upper bottomland hardwoods. Note the abundance of dwarf palmetto (Sabal minor) in the understory. (B) Cypress/tupelo swamp. The closest tree in the center of the photo is a water tupelo (Nyssa aquatica) and the large tree in the middle distance is a bald cypress (Taxodium distichum). Note the abundant cypress knees around the cypress tree.

FIGURE 90. Bathymetry of the continental shelf off the central coast of South Carolina. (A) This complex offshore bathymetry is thought to be the result of changes of the position of the mouths of the Santee and Pee Dee Rivers at different times and stages of sea level. The old delta lobe seaward of Bulls Bay is particularly significant, as we believe it to be the source of the sands of the barrier islands to the southwest. The rectangle outlines the shelf area studied in detail by Sexton (1987) and shown in diagram B. (B) Detailed bathymetric map of the seafloor in the vicinity of the Cape Romain shoal. Note the steep scarp at the seaward end of the shoal.

SECTION II: Major Compartments. The boundaries of the four major morphological compartments of the coast (Grand Strand, Santee/Pee Dee Delta Region, Barrier Islands, and Low Country). Landsat image mosaic acquired 1999-2001, courtesy of U.S. Geological Survey.

FIGURE 91. Vertical infrared image of Grand Strand compartment acquired on 11 May 2000, courtesy of Earth Science Data Interface (ESDI) at the Global Land Cover Facility. Note that this compartment consists mostly of a narrow beach abutted against the Pleistocene upland, with barrier island systems present only near the SC/NC border and at Murrells Inlet.

FIGURE 92. The northernmost portion of the Grand Strand compartment. The smallish, drumstick-shaped barrier island located just west of the jetties is Waties Island. The river in the middle of the image (Little River) is the South Carolina/North Carolina border. Infrared image acquired in 2006, courtesy of SCDNR.

FIGURE 93. Views from the fishing pier at Myrtle Beach State Park. (A) Southerly view at near low tide. Arrow points to salt-pruned shrubs and trees behind the beach. (B) Northerly view. Photographs taken on 14 January 2007.

FIGURE 94. Carolina bays (arrows) in the Lewis Ocean Bay Heritage Preserve, which is located on Figure 91. Image acquired in 2006, courtesy of SCDNR.

FIGURE 95. Origin of Carolina bays. (A) General model for their origin emphasizing the role of opposing wind directions. Wind rose is for the last 10 years at the Wilmington, North Carolina airport. Lines in wind rose indicate directions from which the wind blows, a distinct northeast/southwest bimodal trend. Compare this model with the real bays shown in Figure 94. (B) Modern analogs of bays like Carolina bays on the northern side of the Alaska Peninsula. In this case, only one side of the bays has developed the arcuate shoreline, because there is only one dominant wind direction (indicated by the arrows). Photograph taken in August 1976.

FIGURE 96. Beach at Huntington Beach State Park. View looks southwest. Photograph taken at low tide on 14 January 2007.

FIGURE 97. Murrells Inlet on 10 July 1989. Arrow points to large intertidal bar system on the downdrift side of the jetties.

FIGURE 98. Vertical infrared aerial photographic mosaic of Pawleys Island acquired in 2006. Courtesy of SCDNR.

FIGURE 99. Vertical infrared image of the Santee/Pee Dee Delta compartment acquired on 11 May 2000, courtesy of Earth Science Data Interface (ESDI) at the Global Land Cover Facility.

FIGURE 100. Watersheds of the rivers that empty into Winyah Bay.

FIGURE 101. Vertical infrared image of the North Inlet area acquired in 2006, courtesy of SCDNR. Note the huge ebb-tidal delta and small flood-tidal delta, a characteristic of mesotidal coasts like South Carolina. Like several other tidal inlets in South Carolina, the main ebb channel of the ebb-tidal delta has been oriented to the south as a result of the dominant northeasterly waves.

FIGURE 102. Satellite image of the Santee/Pee Dee delta region. Three major tidal inlets are marked, as well as the designated delta components.

FIGURE 103. Abandoned oxbow lake in the upper delta plain of the Santee portion of the Santee/Pee Dee Delta located just off the main channel of the North Santee River. Since this oxbow was cut off, probably at least a few hundred years ago, it has filled with over 30 feet of fine-grained sediment (clay and silt). Note the freshwater marsh plants (arrow; mostly saw grass, Cladium jamaicenci) that have grown on the surface of the muddy sediment. Infrared photograph taken in April 1977.

FIGURE 104. Former rice ponds in the lower delta plain of the Santee portion of the Santee/Pee Dee Delta that are presently maintained for waterfoul by the U.S. Fish and Wildlife Service. Photograph taken on 5 May 1997.

FIGURE 105. Oblique aerial views of the delta front of the Santee/Pee Dee Delta. (A) Infrared photograph taken by Peter J. Reinhart between mid and high tide in October 1979. Note the development of beach ridges along the seaward margin of this mixed-energy delta (arrows). The channel in the middle ground is the North Santee River. Note the slightly exposed swash bar at the river mouth. Winyah Bay can be seen in the far distance, and the south Santee channel is visible in the lower left. (B) Photograph of the mouth of the North Santee River at low tide on 5 May 1997, eleven years after the rediversion of approximately 50% of the river flow back into the main channel of the river. The huge swash bar in the middle distance, which eventually welded onto the beach, probably derived much of its sand from the revitalized river.

FIGURE 106. Vertical infrared image of delta front portion of the Santee/Pee Dee Delta acquired on 11 May 2000, courtesy of Earth Science Data Interface (ESDI) at the Global Land Cover Facility. The path of a recommended driving tour through the area of the multiple Pleistocene beach ridges is shown.

FIGURE 107. Plantation houses. (A) Hampton House, in the Santee/Pee Dee delta region. (B) Grove Plantation, in the ACE Basin. Both photographs were taken in the winter of 2006/2007.

FIGURE 108. Typical configuration of the cuspate forelands of North Carolina (called capes), showing the importance of two opposing wind directions. In the case of the North Carolina capes, the northeast wind is the dominant one, creating waves that erode the northern flank of the headlands.

FIGURE 109. Vertical infrared image of Cape Romain, an arrow-shaped cuspate foreland, acquired in 2006, courtesy of SCDNR. Each flank of the cape is made up of a landward-migrating

(transgressive) washover terrace system that terminates in a recurved spit complex. Arrows indicate that longshore sediment transport is to the north on the northeast flank of the foreland and to the west on the southwest flank. The landward-migrating islands of the foreland are presently retreating at the rate of several tens of yards per year.

FIGURE 110. General model of how the growing ends of cuspate spits in a lagoon might eventually meet, causing the formation of circular bays. Based on observations made by Zenkovitch (1967) on the Chukchi Sea coast of Russia.

FIGURE 111. View of the southwest end of Cape Romain (Sandy Point) a few days after hurricane Hugo (11 October 1989). The white band of sediment, a mixture of sand and shell, is a washover terrace that advanced landward several 10s of feet during the storm. The dark layer seaward of the washover terrace is exposed backbarrier muddy sediments. As a result of the landward migration of this barrier island, a new tidal inlet was created where it intersected the large tidal channel in the foreground.

FIGURE 112. Low-tide morphology of the landward-migrating (transgressive) barrier island on the southwest end of Cape Romain (at Sandy Point; see photograph in Figure 111), based on observations made during the late 1990s. At that time, a wide wave-cut platform composed of salt-marsh sediments was exposed at low tide (also visible in the photograph in Figure 111). A scarp displaying a remarkable array of erosional features was eroded into the outer edge of the exposed salt-marsh sediments. As the shoreline retreated, tidal creeks and oyster reefs were exposed along the eroding platform. The beach face was steep, because of an abundance of coarse-grained shell material in the beach sediment, and the washover terrace was terminated in a 3-ft-high slip face on top of the living marsh surface (this abrupt margin is also visible in Figure 111). Steep storm berms composed mostly of oyster shells were present in places along the top of the beach face. Continued landward migration results in loss of the top 9-12 ft. of the stratigraphic record and the deposition of a shell lag on top of a transgressive surface of erosion. According to Walter J. Sexton, this landward-migrating barrier island at Sandy Point was nearly gone in 2007 and probably will have been completely washed away by the date of publication of this book, the sediments being deposited into the deep tidal channel on its landward side that is shown in Figure 111.

FIGURE 113. Vertical infrared image of Bulls Bay acquired on 11 May 2000, courtesy of Earth Science Data Interface (ESDI) at the Global Land Cover Facility. Arrow A points to what appears to be an embryonic barrier island (Bird Island) and arrow B is in approximately the same location from which the oblique aerial photograph in Figure 111 was taken. In the eleven years between the date of hurricane Hugo (September 1989) and the time this image was taken (May, 2000), the shoreline of the southwest end of Cape Romain (vicinity of arrow B) had continued to retreat in a dramatic fashion.

FIGURE 114. Vertical infrared image of the Barrier Islands compartment acquired on 23 October 1999, courtesy of Earth Science Data Interface (ESDI) at the Global Land Cover Facility.

FIGURE 115. Vertical infrared image of the Bull Island subcompartment acquired in 2006, courtesy of SCDNR.

FIGURE 116. The Bull Island subcompartment. (A) Oblique infrared photograph, the bottom of which shows the northeast end of Bull Island. The top of the photo marks the southwest end of the Isle of Palms. Compare this view with the images in Figures 30 and 115. Photograph taken by Walter J. Sexton at low tide on 23 November 1981. (B) True color view of the same area as is

shown in A, but at a lower altitude. Note the well developed intertidal bar system exposed at low tide. The white sand in the vegetation behind the beach (arrows) is dune sand deposited by hurricane Hugo (1989). Photograph taken at low tide on 5 May 1997.

FIGURE 117. Price Inlet and Capers Island. The position of Price inlet in 1822 is shown. Note the truncated beach ridges at north end of Capers Island (middle distance; see also Figures 115 and 116). These ridges were truncated by the tidal inlet when it was at that position in 1822. Since then, the inlet has reoriented to the north and the old channel has become filled in with fine-grained sediments, creating a clay plug in the old channel. The stratigraphy of this section was studied by R.S. Tye (1981; 1984). Photograph taken at low tide in the winter of 1975.

FIGURE 118. Vertical infrared image of the Isle of Palms/Sullivans Island subcompartment. Acquired in 2006. Courtesy of SCDNR.

FIGURE 119. The mesotidal barrier island system to the immediate north of Charleston. (A) Oblique view looking northeast in April 1975. Sullivans Island is in the foreground. Note drumstick shape of the Isle of Palms, and the downdrift offset at Breach Inlet (compare with Figure 118). (B) Huge intertidal bar welding onto the beach on the northeast end of the Isle of Palms (arrow). Compare with Stage 2 in Kana's model given in Figure 56B. Photograph taken at low tide on 5 May 1997.

FIGURE 120. Hooded mergansers at the Pickett Recreation Area in Mt. Pleasant. Photograph taken on 13 January 2007.

FIGURE 121. Vertical infrared image of Morris and Folly Islands. Image acquired in 2006. Courtesy of SCDNR.

FIGURE 122. 1779 map of Charleston Harbor made by the British military. Note how the large ebb-tidal delta off the entrance to the Harbor is deflected far to the south. Compare this map with the image of the ebb-tidal delta of North Inlet shown in Figure 101.

FIGURE 123. Historical shoreline changes, Morris Island to Kiawah Island. Morris and Folly Islands eroded hundreds of feet and Kiawah Island prograded more than 3,000 ft during this time period. This diagram was created in 1974, but the trend in shoreline changes shown has continued into the 21st century.

FIGURE 124. Lighthouse Inlet, which separates Folly and Morris Islands, at low tide in October 1978. The main ebb channel of the inlet cuts obliquely across the center portion of this infrared image. Note waves breaking around the seaward extent of the ebb-tidal delta. A large swash bar complex had developed on the northern channel margin linear bar of the ebb-tidal delta (compare photograph with model in Figure 37). A well-defined marginal flood channel (arrow) was situated between the swash bar complex and the beach. The Morris Island Lighthouse, which was constructed 1200 ft landward of the high-tide line in 1876, was located far off the severely eroding beach when this photograph was taken.

FIGURE 125. Folly Beach before and after hurricane Hugo (1989). (A) Photograph taken circa 1980. Arrow points to the Atlantic House Restaurant. (B) Arrow points to former location of the Atlantic House Restaurant. Photograph taken 11 October 1989, 19 days after the passage of hurricane Hugo.

FIGURE 126. Beach view looking southwest on the northeast sector of Folly Beach. The line of dune sand trapped by the snow fence is topped by sea oats (Uniola). Photograph taken on 13 January 2007.

FIGURE 127. Map of the geomorphology of Kiawah Island, using a 1971 aerial photograph as a base. The line labeled A-A' gives the approximate location of the stratigraphic section shown in Figure 132.

FIGURE 128. Historic changes Captain Sam's Inlet between 1661 and 1973, based on a combination of historical charts and aerial photographs. These maps and photos show three periods of breaching of the spit: 1822, 1922, and 1949. Breaches occurred at numerous other times, of course, at intervals we estimate to be about every 40-50 years. From Hayes et al. (1976).

FIGURE 129. Oblique view of north end of Kiawah Island, showing a large swash bar welding to the beach. This is the main mechanism by which such prograding barrier islands attain their drumstick configuration (see also Figures 28, 29, and 56). Infrared photograph taken at low tide on 29 May 1980.

FIGURE 130. The Ocean Course on the north end of Kiawah Island. This photograph was taken by Tim Kana at low tide on 13 July 2006, after the completion of an erosion remediation effort by his company, Coastal Science and Engineering, LLC. A few months earlier, a very large swash bar complex similar to the one shown in Figure 129 diverted to the south the flow from a tidal creek (arrow A) draining a marsh system such that it hugged the beach for several hundred yards, allowing the front dune line to erode. The remediation involved cutting a new channel across the welded swash bars (arrow B) so that the channel would no longer impact the beach, as well as moving part of the mass of sand toward the beach. Eventually, most of the sand in the upper right hand part of the photograph will weld to the beach.

FIGURE 131. Beach morphology of the middle of Kiawah Island, a typical prograding, mixed-energy barrier island. (A) Three-dimensional view of the beach at low tide, illustrating a low intertidal bar and trough and prograding foredune ridges (on 10 June 1974). Diagram is based on five beach profiles spaced at 150-yard intervals and plotted at a 5:1 vertical exaggeration. BLS = stake near the high-tide line. (B) Oblique aerial view of the beach at low tide in July 1974, looking northeast. This area is approximately 1.5 miles north of the one mapped in A.

FIGURE 132. Generalized stratigraphy of Kiawah Island. Modified after Moslow (1980). This cross-section is located (approximately) on Figure 127.

FIGURE 133. The painted bunting. Photograph courtesy of the Friends of Hunting Island.

FIGURE 134. Sketch showing the different aspects of the beach on the recurved spit on the south end of Kiawah Island.

FIGURE 135. The ghost crab (Ocypode quadrata). (A) A rare view of one on the surface in the daylight. (B) Sand castings outside one of their burrows.

FIGURE 136. Outlets of ghost shrimp burrows on the lower intertidal beach on Kiawah Island. Scale is in centimeters.

FIGURE 137. The ghost shrimp (Calianassa major). (A) Live ghost shrimp with its large "digging claw" exposed. (B) Fecal pellets accumulated around a burrow outlet. Photographs A and B courtesy of Bill Frank, Jacksonville, Florida. (C) Corncob-like burrows exposed by erosion that were fortified with fecal pellets like the ones shown in B. These dense and spectacularly

displayed burrow remnants were originally formed in the lower intertidal zone of a Pleistocene barrier island that is now exposed along the banks of the St. Marys River on the Georgia/Florida border.

FIGURE 138. Beach Club on Seabrook Island. (A) Eroding dune scarp west of the Beach Club. This scarp retreated over 20 ft during a single high tide. Photograph taken at low tide on 12 October 1974. (B) Revetment composed of riprap constructed to prevent erosion of the type illustrated in A. This photograph was taken in July 1978 a little further away from the Beach Club than the one in A.

FIGURE 139. Beach erosion at the golf course on Seabrook Island. (A) Infrared photograph taken at low tide on 17 October 1978. Note the erosional arc that was developing in front of the golf course (arrow). (B) Photograph taken on 28 January 1983. Arrow A points to sandbag revetment in front of the golf course and arrow B points to riprap revetment in front of houses in the lower right.

FIGURE 140. Vertical image of the relocated Captain Sams Inlet on 28 March 1983. Relocation of the new inlet was completed 24 days earlier, on 4 March 1983.

FIGURE 141. Sand added to Seabrook Island as result of relocating Captain Sams Inlet in 1983. (A) Photograph of Seabrook Island taken by Tim Kana at low tide on 25 February 1986, two years and eleven months after Captain Sams Inlet was relocated. Note the welding and landward migration of swash bars composed of sand released from the abandoned ebb-tidal delta after the inlet was relocated. (B) Photograph taken by Tim Kana on 10 February 2006. The beach in front of the golf course had built out 985 feet in the 23 years since the inlet was originally relocated. It was relocated again in the spring of 1996. Note the position of the 1983 shoreline (compare with photograph in Figure139B).

FIGURE 142. Vertical infrared image of Edisto Beach subcompartment. Image acquired in 2006. Courtesy of SCDNR.

FIGURE 143. Vertical image of Edisto Beach taken in 1939. Note the curving beach ridges, which mark the progressive southwesterly growth of the spit.

FIGURE 144. Map of the Edisto Beach Area subcompartment showing the dominant longshore sand transport directions. Note that transport is to the north in the northern half of the area, presumably because the large ebb-tidal delta of North Edisto Inlet shields the area from the dominant waves approaching the area from the northeast. Refraction of those waves around the ebb-tidal delta is possibly another factor. At the present time, the landward-migrating (transgressive) barrier island complex know as Edingsville Beach (northern half of area; see also Figures 27 and 142) is moving landward at a rate of about 5 yards per year for reasons given in the text. From Kana, White, and McKee (2004; Figure 6).

FIGURE 145. Aerial views of Edisto Beach taken on 10 February 2006 (A) before a major beach nourishment project and after it in June 2006 (B). Note how the nourished sand had buried many of the groins. Photographs taken by Tim Kana.

FIGURE 146. Changes at North Edisto Inlet. (A) Illustration of a major shift to the north of the main ebb channel of the ebb-tidal delta. (B) Erosion of the barrier island to the south of the inlet was caused by the shift in the main ebb channel shown in diagram A, which created a new terminal lobe on the delta that trapped a significant percentage of the sand moving south in the longshore transport system.

FIGURE 147. General pattern of beach cusps. Arrows show the patterns of flowing water (during high stages of the tide) in the bays between the horns of the cusps.

FIGURE 148. Infrared image of Low Country compartment acquired on 23 October 1999, courtesy of Earth Science Data Interface at the Global Land Cover Facility. Note the expansive estuarine marshes and tidal flats that extend up the coastal plain rivers more than 25 miles inland from the coastline.

FIGURE 149. Infrared image of St. Helena Sound. Arrow points to the large sand flat in the entrance to the Sound pictured in Figure 72. Image acquired on 23 October 1999, courtesy of Earth Science Data Interface at the Global Land Cover Facility.

FIGURE 150. Watershed (drainage basin) of the St. Helena Sound estuarine complex. The drainage of the three major rivers of the system, the Edisto, Combahee, and Ashepoo, is confined to the Coastal Plain Province. They are black-water, swamp-draining streams that carry multicycled sand grains reworked from Cretaceous and younger sediments (from McCants, 1982, Fig. 21).

FIGURE 151. Evolution of Snuggedy Swamp peat deposit, according to Staub and Cohen (1979, Fig. 7), from a salt marsh with some fresh water plants on high spots (A) to a continuous peat deposit (D).

FIGURE 152. Infrared image of part of the ACE Basin showing the location of the recommended driving tour of the area. Image acquired on 23 October 1999, courtesy of Earth Science Data Interface at the Global Land Cover Facility.

FIGURE 153. Old Chehaw pond in the Donnelly Wildlife Management Area. (A) General view of the pond from the road on the dam. Note the alligators in the upper right. (B) Closer view of two of the gators in the pond. Photographs taken on 24 November 2006.

FIGURE 154. Vertical infrared image of Hunting/Fripp headland. Image acquired in 2006. Courtesy of SCDNR. The sharp break between St. Helena Island marks location of the shoreline during the last high sea level of the Pleistocene Epoch. All of the marshes, tidal flats and barrier islands seaward of that line were formed during the present highstand of sea level (approximately the last 4,500 years).

FIGURE 155. The exceptionally large ebb-tidal delta at Fripp Inlet. The central channel (main ebb channel) is dominated by ebb currents. Infrared photograph taken at low tide in December 1979.

FIGURE 156. The beach at Hunting Island. (A) View looking north at low tide from near the main parking area. (B) View looking south of the eroding beach near the south end of the island. Both photographs taken on 26 November 2006.

FIGURE 157. Hunting Island. (A) Oblique view looking north at low tide on 30 January 1975. (B) View a little further north along the beach taken soon after a beach nourishment project (on 9 June 2006). Photograph taken by Tim Kana. The arrows, which point to the same location on both images, illustrate the extreme amount of erosion that had occurred on this island within the 31 years between the times the pictures were taken.

FIGURE 158. The salt marsh on the landward side of the southern end of Hunting Island (a few hundred yards north of the bridge across Fripp Inlet). (A) Spartina alterniflora salt marsh. View

looking north from boardwalk. (B) Tidal channel through salt marsh at the end of the boardwalk. Photographs taken on 26 November 2006.

FIGURE 159. Vertical infrared image of Port Royal Sound acquired on 23 October 1999, courtesy of Earth Science Data Interface at the Global Land Cover Facility. Note the large areas of tidal flats intermixed with salt marsh vegetation, which reflects the low rates of mud deposition within this estuary complex.

FIGURE 160. Vertical infrared image of Hilton Head headland acquired on 23 October 1999, courtesy of Earth Science Data Interface at the Global Land Cover Facility.

FIGURE 161. Pond on the Pinckney Island National Wildlife Refuge. Photograph taken on 25 November 2006.

FIGURE 162. Water (A) and suspended sediment discharge in 1909 (B) by the major rivers of the Georgia Bight. Freshwater discharge is based on 1931-1960 U. S. Geological Survey stream records, and suspended sediment discharge is based on data of Dole and Stabler (1909). Diagram is modified from Meade (1969) and Nichols and Biggs (1985).

FIGURE 163. Vertical infrared image of Savannah River Delta acquired on 23 October 1999, courtesy of Earth Science Data Interface at the Global Land Cover Facility.

FIGURE 164. Red-shouldered hawk, the most common hawk in the swamps of South Carolina.

FIGURE 165. View of the cypress/tupelo swamp on the flood plain of the Congaree River from the boardwalk in Congaree National Park. Photograph taken circa 2003.