Geologic Site of the Month

March, 2008

Tombolo Breach at Popham Beach State Park Phippsburg, Maine

43° 44‘ 11.63“ N, 69° 47‘ 46.20“ W

Text by
Stephen M. Dickson

Introduction

Popham Beach State Park is one of the State's most popular parks. It has a large natural dune system and a long stretch of natural beach composed of fine- to medium-grained sand. During the summer, the park is so popular that the parking lot can fill with cars by mid-morning. Views offshore from the park are scenic with several islands including Seguin Island with its high lighthouse.

Figure 1. A view of Popham Beach State Park in Phippsburg, Maine taken from an aircraft. The park is bound on the westerly side by the Morse River (not shown in the lower edge of the photo) and on the east by the arcuate Hunnewell Beach that is developed with homes. The Kennebec River forms the eastern limit of the beach and dune system. The Fox Islands are in the lower right corner and opposite the State Park parking lot.

Popham Beach State Park

A walk east along the beach from the State Park leads across the developed Hunnewell Beach to the mouth of the Kennebec River about a mile away (Figure 2). Walking north along the river for another three quarters of a mile ends up at Fort Popham State Park (DOC, 2008) and the site of early Colonial settlement on the Maine coast (Popham Colony, 2008).

Figure 2. An oblique air photo of Popham Beach with the Kennebec River in the foreground and Fort Popham in the lower right corner.

Popham Dunes, Beach, and Tombolo

Popham Beach has a long history of shifting shorelines. Historical maps and air photos have been used to trace former shorelines and overlay them on a map (Figure 3).

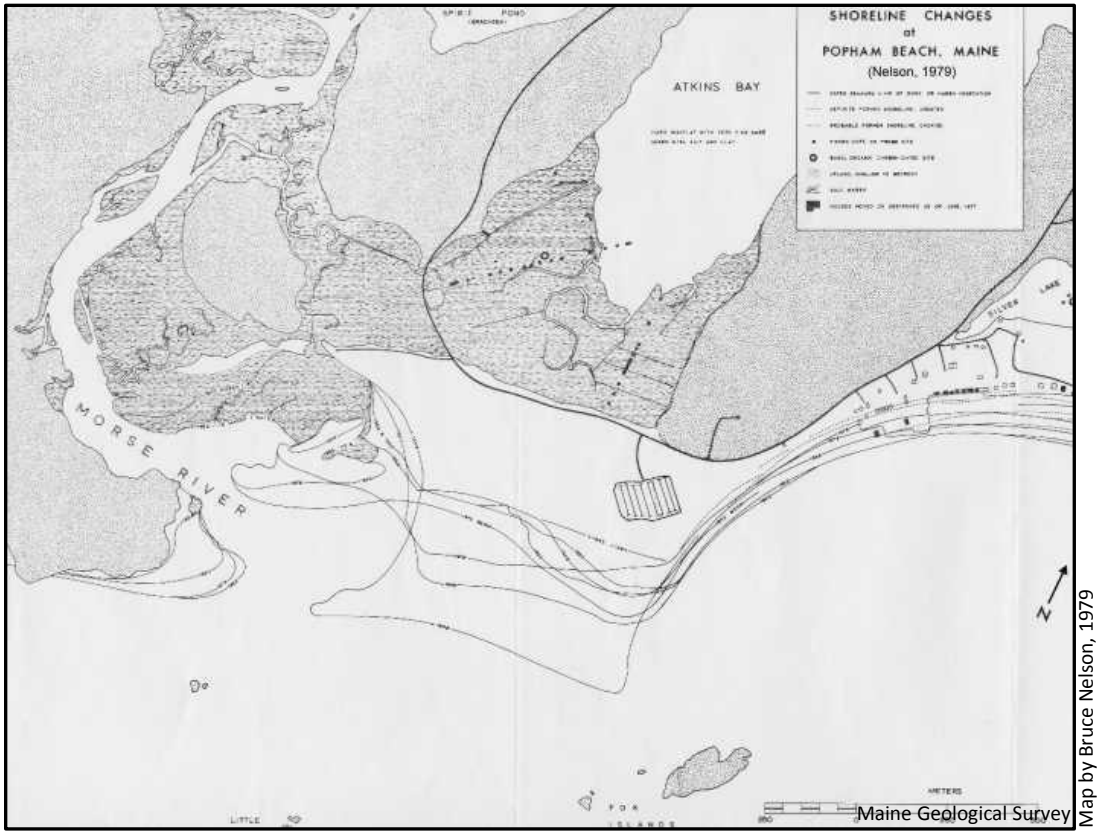

Figure 3. A portion of a map of historical shorelines created by Bruce Nelson (1979). The greatest amount of shoreline change around the State Park is to the west of the Fox Islands. Note how the shoreline fluctuates both landward and seaward over time.

Popham Dunes, Beach, and Tombolo

Topography or the elevation of the dunes at Popham Beach State Park was mapped by aircraft in 2004 using Light Detection and Ranging (LIDAR; NOAA, 2007). With buildings removed, the data show the high-relief back dune field and a pitch pine maritime forest (Figure 4).

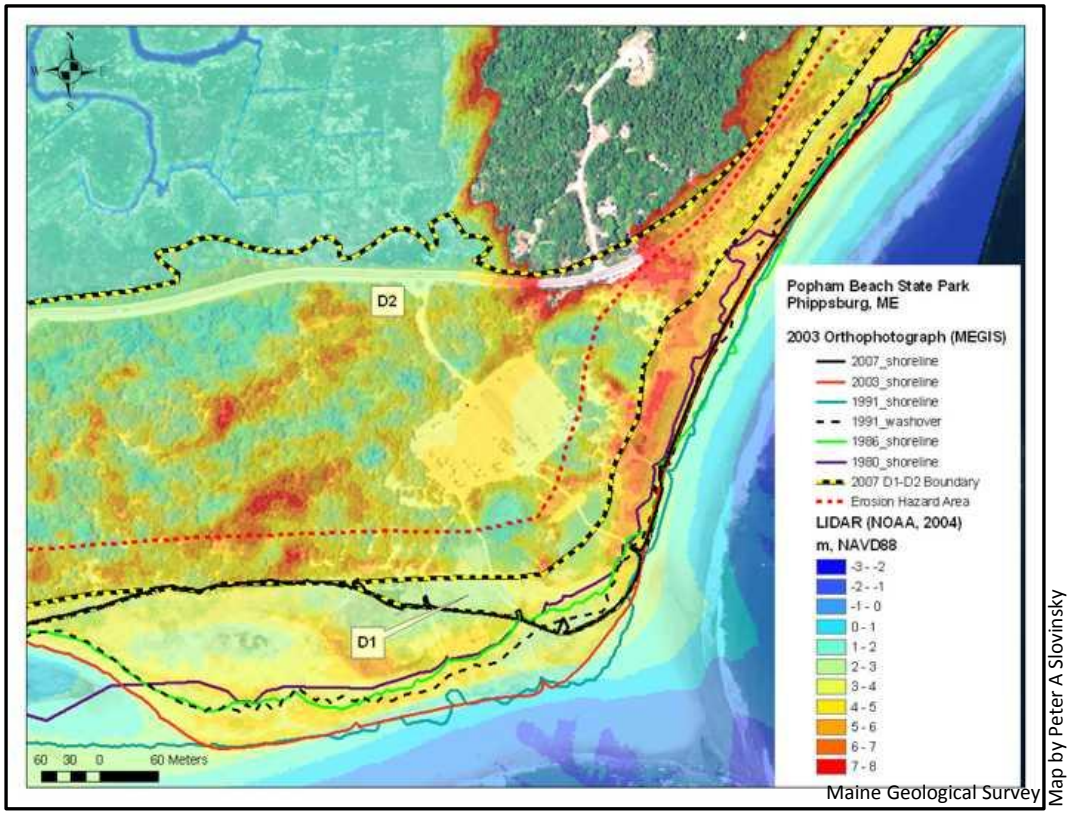

Figure 4. This map shows elevations of the beach and dunes (in meters) in shaded colors superimposed on a 2003 aerial photograph (courtesy of the Maine Coastal Program and Office of GIS).

Popham Dunes, Beach, and Tombolo

The map in Figure 4 also shows historical shorelines that are based on a series of orthophotographs and a July 2007 field survey with a precise RTK-GPS by the Maine Geological Survey. Both the computer digitizing and surveying methods trace the seaward edge of dune vegetation along Popham Beach. Over time the dunes have built seaward and also eroded landward in a cyclic process. This give-and-take in the shoreline position is very unusual for a Maine beach and due to the influence of rocky islands offshore, the outflow of sand on the bottom of the Kennebec River, and more immediately the movement of the Morse River channel at the west end of Popham Beach. Note the base air photograph shows the large area of dunes in 2003 that have since eroded by the summer of 2007.

Dune boundaries were mapped on a 1986 air photo and show the position of the frontal dune, the seaward and most active dune ridge (Figure 5). The back dunes are the more stable and older dune field which includes the pitch pine maritime forest (Nelson and Fink 1980; Trudeau and others, 1977). Some of the dune shapes are a result of old shoreline positions and erosion. Walking from the parking lot to the beach, through any of the several paths, it is possible to spot a dramatic drop in elevation - a scarp - cut by waves and tides, perhaps in the Blizzard of February 1978. Over the last 4,600 years, the dunes have been building and yet have also experienced episodes of severe erosion (Buynevich and FitzGerald, 2003; Buynevich and others, 2004; Nelson, 1979).

Popham Dunes, Beach, and Tombolo

Figure 5 shows a map of Popham Beach and dunes based on conditions in 1986, when the Morse River was farther west than today and Popham dunes were more expansive. The frontal dune (D1) is the seaward-most ridge of sand and the most active portion of the dune system. Most of the 1986 frontal dune is now gone (compare this photo to Figure 4). The back dune (D2) is more stable, has older vegetation including pitch pine trees, and less dense American beachgrass. The sand beach (B1) fringes the dunes. Historical shoreline mapping by the Maine Geological Survey uses the seaward edge of vegetation (the B1-D1 boundary line) to calculate erosion and accretion rates. For a more complete description of map units see Dickson (2001).

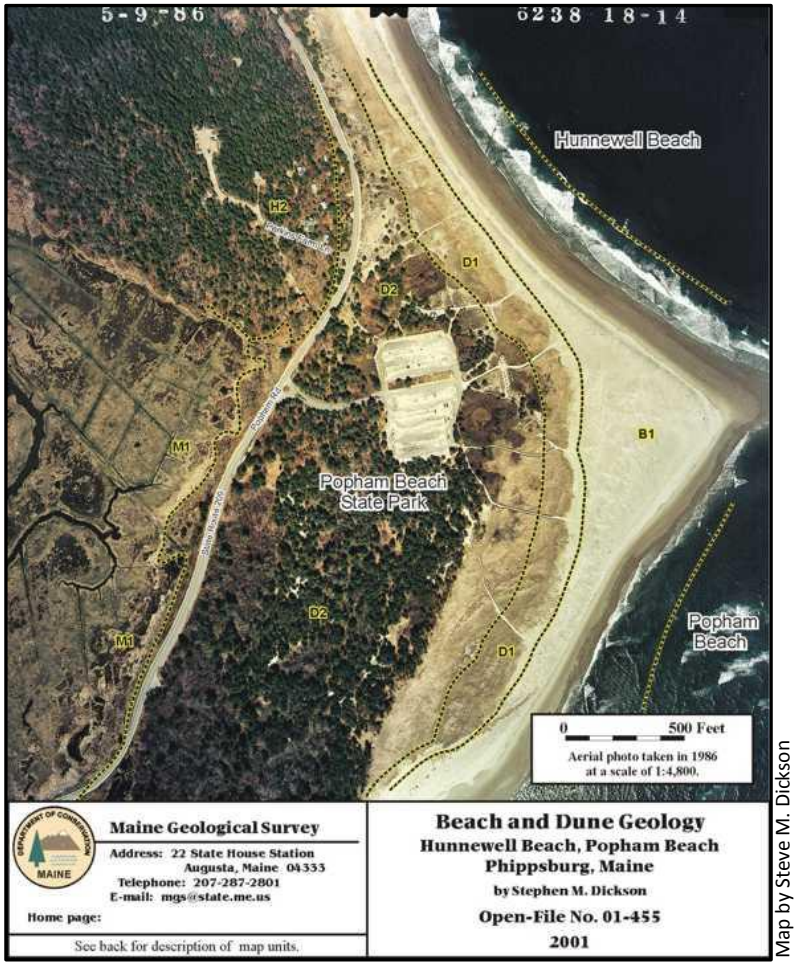

Figure 5. Map of Popham Beach and dunes in 1986.

Dramatic Shoreline Change

At the center of the park, just south of the parking lot, is a sand bar that connects the dunes to the Fox Islands just offshore. This bar is perpendicular to the overall trend in the beach and is called a tombolo by geologists. At low tide this bar is exposed and park visitors can walk out to explore the bedrock outcrops of the Fox Islands. Around the time of high tide the bar is covered by the ocean for a few hours - so park visitors can become stranded on the Fox Islands if they are unwilling to swim ashore.

Shoreline change at the State Park has been dramatic over the last half century. Using historical air photographs, Peter A. Slovinsky of the Maine Geological Survey georeferenced them to earth coordinates in a geographic information system (GIS) and traced the seaward edge of vegetation (Figure 4). Mapping the historical shoreline positions in a series of photos shows how the dune edge and beach have shifted over time. Precise measurements in the GIS can determine how much the shoreline moved in an interval of time between successive photos and be used to calculate historical erosion rates.

The shoreline at Popham Beach State Park has migrated inland (eroded) and then built back seaward (accreted) significantly over the last half century. Analysis of the historical trends shows that the western beach (west of the Fox Island tombolo) has eroded and accreted more than the eastern beach (Figure 3 and Figure 4). Other geological studies have documented this same trend (Fink and FitzGerald, 1981, 1987; Nelson, 1979).

The beach and dune eroded back 525 feet on the western beach from 2004 to 2007. This loss resulted in a net erosion rate of an astounding 130 feet per year! If not reversed, this trend would consume more and more of the State Park dunes every year. Luckily, the erosion trend has reversed itself in the past and spared more of the pitch pine forest and park buildings and parking lot.

Dramatic Shoreline Change

The current trend is still erosional and pine trees and back dunes continue to be eroded (Figure 6). This photograph was taken just after the Patriots' Day Storm, April 14-16, 2007, but some of the erosion by the Morse River had started to cut into the dunes prior to the storm. The Morse River channel is visible on the left side of the photo.

Figure 6. A photograph of dune erosion and tree loss along the western beach at Popham Beach State Park.

Dramatic Shoreline Change

Shoreline change often happens rapidly during storms. The 100-year storm, based on tidal elevations and flooding was the Blizzard of February 1978. Since that time large storms that have "stalled" in the Gulf of Maine and coincided with large astronomical tides have generally done the most short-term erosion damage to Maine's dunes. After one of these larger storms it can take years for the frontal dune to recover. The Perfect Storm of Halloween 1991 resulted in considerable flooding of the dunes in Maine. The December 2002 northeaster lasted over 3 days and large waves battered the mid-coast. Most recently, the Patriots' Day Storm of April 16-18, 2007 resulted in tides and flooding of the dunes here at Popham Beach (Figure 7) and elsewhere along the coast (Slovinsky and Dickson, 2007; Slovinsky, 2007).

Dramatic Shoreline Change

Sand was deposited in the dunes by the Patriots' Day Storm, April 14-16, 2007. The process of overwash leads to the sand deposit (washover) that helps build the dunes higher (Figure 7). American beachgrass will grow up through the washover and help stabilize the sand in the form of a dune ridge. The Morse River channel is close to the dunes in the right foreground, but turns out to sea and does not cross the Fox Island tombolo.

Figure 7. A view of the frontal dune at Popham Beach State Park from one of the paths to the beach.

The 2008 Tombolo Breach

The Fox Island tombolo was breached in February 2008 and photographed by Brian Murray, the Department of Conservation's park manager (Figure 8). This cut in the sand bar was due to eastward migration of the channel of the Morse River.

Figure 8. View from Popham Beach looking south toward the Fox Islands. The shore-perpendicular sand bar, or tombolo, is being breached by the Morse River (flowing right to left).

The 2008 Tombolo Breach

During a falling tide, the Morse River has a swift current that has been flowing along the western beach for several years (Figure 9). The river channel has continued to migrate north and remove sand from the beach and dunes.

Figure 9. An oblique air photo taken June 30, 2006 over Seawall Beach looking east across the mouth of the Morse River, Popham, and Hunnewell Beaches. The Kennebec River is in the background. Salt marshes of Atkins Bay are just to the left of the State Park parking lot.

The 2008 Tombolo Breach

Sand eroded from the beach then is carried east and reworked by waves into sand bars that are elongated parallel to shore (Figure 10). In 2007 there were two large bars offshore separated by a trough and the Morse River channel up against the beach. At low tide it was possible to wade across the channel and trough and walk over 500 feet to reach the surf zone.

Figure 10. An oblique air photo taken June 30, 2006 with Popham Beach State Park in the foreground. The wide dune to the right of the parking lot is now gone and the shoreline is up to and into the dark green maritime forest.

The 2008 Tombolo Breach

These shore parallel sand bars also confine the Morse River along the dunes and make it difficult for the river to cut across the large bars to have a straighter course to the sea. Research at Boston University first documented the influence of the Morse River on Popham Beach (Goldschmidt, 1989) and the field evidence suggests a clockwise circulation cell along the beach and offshore (Figure 11; FitzGerald and Fink, 1981, 1987; Goldschmidt and others, 1991).

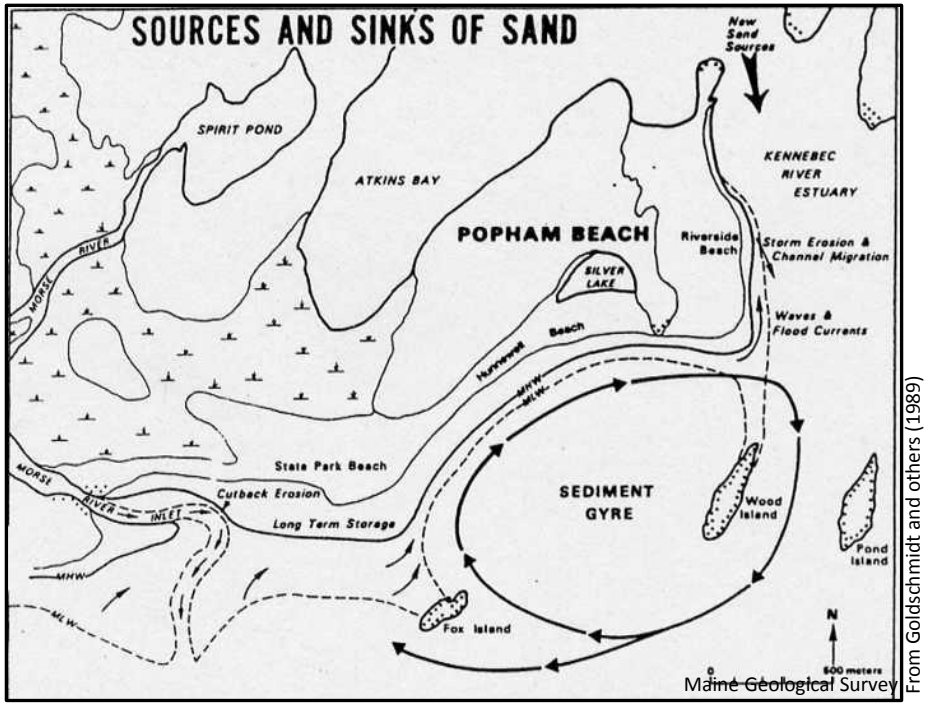

Figure 11. Map illustrating the clockwise circulation gyre that moves sand east of the Fox Islands from Popham Beach to Hunnewell Beach and eventually the Kennebec River. The map also suggests some sand bypasses the Fox Islands, moving in a westerly direction, on the seaward side to come ashore in the vicinity of the Morse River.

The 2008 Tombolo Breach

Goldschmidt and others (1991) documented a January 1987 breach of the Fox Island tombolo that occurred about 4 months after the Morse River began to cut a new channel on a straighter course out to sea. Historical air photos show evidence of the Morse River cutting into the pitch pine forest in 1953 (Figure 12). The tombolo was breached by the Morse River in or around the fall of 1964, 1972, and 1987. This series of events suggests a period of about 10-15 years between breach events and thus a cycle of river meandering on the order of a decade or more from one extreme to the other.

Figure 12. This vertical air photo from 1953 shows Popham Beach before the State Park facilities and parking lot were built. The Morse River has a very easterly course that, until 2007, may have been the most recent time erosion reached the pitch pine maritime forest. Note at this time the river channel does not breach through the Fox Island tombolo.

Morse River Avulsion

At some point, perhaps in 2008, when the bars get lowered or migrate farther ashore and choke the channel, the Morse River will be so long and sinuous that the river outflow will back up and then will manage to wash over and cut down through the bars, creating a shorter channel to the sea (Goldschmidt and others, 1991). This shorter channel to the sea will then be flooded by the incoming tide and most likely remain open. The old channel next to the State Park will infill over a period of months to a year as sand is pushed ashore by the surf. There will also be an infusion of sand into the longshore drift to the east past the tombolo and toward Hunnewell Beach (Figure 11).

Morse River Avulsion

This process of channel switching is called avulsion is also common in sandy rivers and at river deltas where they enter the sea. Popham Beach State Park is the only beach in Maine where avulsion occurs on a regular basis across the ebb-tidal delta. In fact, with the exception of the Scarborough River in southern Maine, most Maine beaches have very small ebb-tidal deltas due to high wave energy. At Popham Beach and the mouth of the Morse River, the Fox Islands act to break waves and shelter the beach to some extent. So it is the combination of rock islands offshore, bedrock at the mouth of the river on the western shore, and the abundant sand supply at the mouth of the Morse River that contribute to the process of avulsion and also the easterly extension of the channel across the Fox Island tombolo every 10 to 15 years and much to the detriment of the Popham Beach and the natural dune field.

After the avulsion takes place, sand migration ashore will widen the beach at the state park and allow dunes to grow seaward. Dune vegetation in areas of rapid dune recovery is primarily American beachgrass (*Ammophila breviligulata*; NRCS, 2008) and Dusty Miller (*Artemisia stelleriana*; Nelson and Fink, 1980). In more mature back dunes one can find pitch pine, red oak, red maple, white birch, aspen, white spruce, red spruce, fir, and beach heather in a large area that is uncommon elsewhere in Maine (Nelson and Fink, 1980; Trudeau, 1979; Trudeau and others, 1977).

What to check before heading to Popham Beach State Park

A visit to Popham Beach State Park can be an educational experience to see coastal processes in action. Before heading to the beach, check the tide tables in the newspaper, on the weather radio broadcasts, or on the web (NOS, 2008). Portland tides are very similar to Phippsburg's so they are adequate. Also check the wave conditions offshore at the Portland buoy (NDBC, 2008) to see how high they are and how far apart they are spaced (swells tend to have a period of 8 seconds or more between crests while wind waves are shorter and usually smaller in height). Consider packing a camera to take a picture of a favorite place (and then repeat it each trip to document the changes). For more information on Popham Beach State Park visit the State Parks and Public Lands website.

What to look for on your next visit to Popham Beach

At the beach watch the ebb and flood of the tides from the banks of the Morse River. Examine the width of the wet and dry beach areas at high and low tide. See where the Morse River channel is in relation to historical positions (bring along some of these figures). Check the seaward edge of dune vegetation - is it cut by a small scarp (or cliff) or is gradually sloping toward the beach. Notice if the dune vegetation appears sparse and young or thick and dense (mature). When the tide is falling, walk out across the Fox Island tombolo and look for sand ripples that indicate which way the waves were flowing (the steep side of the ripple is "downstream" of the flow and creates cross-bedding in the sand). From the Fox Islands look around and examine how the waves break on the seaward side of the rocks and then wrap around the island. See how many sand bars there are breaking waves seaward of the west beach compared to the east beach. At low tide count the number of bar-and-trough complexes there are - or at high tide observe the number of wave breaks offshore - each bar may create its own small surf break.

A word of caution

The complex flow of tides, river flow, and waves can make swimming difficult at times. Walking in the ocean can be challenging due to the softness of the sand, speed of the currents, and surging power of breaking waves. Walking or swimming can be particularly dangerous for children or inexperienced swimmers since one can encounter steep drop-offs from a bar into a trough. You can experience this sudden change in water depth on both the western and eastern beaches. Check with lifeguards and heed warning signs for bathers posted at the State Park. There can be many safe and enjoyable places to swim and play, and based on the ever-changing history of the beach, each experience could be different and educational!

References and Additional Information

Buynevich, I. V. and FitzGerald, D. M., 2003, High-resolution subsurface (GPR) imaging and sedimentology of coastal ponds, Maine, USA: Implications for Holocene back-barrier evolution: Journal of Sedimentary Research, v. 73, p. 559-571.

Buynevich, I. V., FitzGerald, D. M., and van Heteren, S., 2004, Sedimentary records of intense storms in Holocene barrier sequences, Maine, USA: Marine Geology, v. 210, p. 135-148.

DOC, 2008, Popham Beach State Park: Bureau of Parks and Lands, Maine Department of Conservation.

Dickson, S. M., 2001, Beach and Dune Geology, Hunnewell Beach, Popham Beach, Phippsburg, Maine: Maine Geological Survey, Open-File No. 01-455.

FitzGerald, D. M., and Fink, L. K., 1981, Field guide to Popham Beach, Phippsburg, Maine: 1981 SEPM (Northeast Section) Field trip to Maine Coast, May 22-24, 1981.

FitzGerald, D. M., and Fink, L. K., Jr., 1987, Sediment dynamics along an indented coast; Popham Beach-Kennebec River, Maine: in Kraus, Nicholas C. (editor), Coastal sediments '87: American Society of Civil Engineers, New York, New York, p. 2047-2061.

Goldschmidt, P. M., 1989, Sediment dynamics at the mouth of Morse River Inlet, Maine: M.S. thesis, Department of Geology, Boston University, Boston, Massachusetts, 116 p.

Goldschmidt, P. M., FitzGerald, D. M., and Fink, L. K. Jr., 1991, Processes affecting shoreline changes at Morse River inlet, central Maine coast: Shore and Beach, v. 59, no. 2, p. 33-40.

NDBC, 2008, National Data Buoy Center of the National Oceanic and Atmospheric Administration, Portland Buoy, Station 44007, outer Casco Bay.

Nelson, B. W., 1979, Shoreline Changes and Physiography of Maine's Sandy Coastal Beaches: M.S. Thesis, Department of Oceanography, University of Maine, Orono, 302 p.

References and Additional Information

Nelson, B. W., and Fink, L. K., Jr., 1980, Geological and botanical features of sand beach systems in Maine: Maine Sea Grant Publications, Bulletin 14, 163 p. (originally published by Maine State Planning Office, Critical Areas Program, Planning Report 54).

NOAA, 2007, Remote sensing for coastal management, Coastal Services Center.

NOS, 2008, National Ocean Service, Tides Online.

NRCS, 2008, PLANTS Profile, *Ammophila breviligulata* Fernald American beachgrass: Natural Resources Conservation Service,

Popham Colony, 2008, Wikipedia.

Slovinsky, P. A., 2007, The Patriots' Day Storm at Willard Beach: Maine Geological Survey.

Slovinsky, P. A. and Dickson, S. M., 2007, State of Maine's Beaches in 2007: Maine Geological Survey, Open-File Report 07-99, 117 p.

Trudeau, P. N., 1979, Ecology of barrier beaches in south-central Maine (Popham Beach State Park, Reid State Park, and Small Point Beach): Ph.D. dissertation, University of Massachusetts, Amherst, Massachusetts, 412 p.

Trudeau, P., Godfrey, P. J., and Timson, B. S., 1977, Beach vegetation and oceanic processes study of Popham State Park beach, Reid State Park beach, and Small Point beach: Maine Department of Conservation and U. S. Department of Agriculture, Soil Conservation Service, Resource Conservation and Development Project, 144 p.

van Heteren, S., FitzGerald, D. M., McKinlay, P. A., and Buynevich, I. V., 1998, Radar facies of paraglacial barrier systems; coastal New England, USA: Sedimentology, v. 45, no. 1, p. 181-200.

Wikipedia, 2008a, Avulsion, accessed 3/7/08.

Wikipedia, 2008b, Cross-bedding, accessed 3/7/08.

Related MGS Websites

MGS Virtual Tour of Maine's Coastal Marine Geology (PDF 2.1 Mb)

Slovinsky, P.A. and Dickson, S. M., 2006, Impacts of Future Sea Level Rise on the Coastal Floodplain: Maine Geological Survey, Open-File Report 06-14.

Erosion and flood maps

Popham Beach is part of the Coastal Barrier Resources System