Marine Extension Bulletin

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Woods Hole Sea Grant Program
Cape Cod Cooperative Extension

The Effect of Sea Level Rise on the Barrier Beaches of Cape Cod, Martha's Vineyard, and Nantucket

In Massachusetts a barrier beach is defined by the state Wetlands Protection Act (310CMR10.29) as a narrow low-lying strip of land generally consisting of coastal beaches and coastal dunes. According to the CZM Barrier Beach Inventory Project there are ~680 designated barrier beaches in Massachusetts, ~460 (70%) are on the Cape and Islands. They are typically separated from the mainland by a narrow body of water or a marsh system (Figure 1). A barrier beach may be joined to the mainland at one or both ends, while a barrier island is separated from the mainland.

The dynamic nature of barrier beaches protect landward areas providing a buffer to storm waves and storm surge. Barrier beaches protect upland private property as well as salt marshes, estuaries, salt ponds, etc., which are essential to juvenile marine fisheries. In addition, these beaches are also important to the protection of upland wildlife habitat and productive shellfish beds. Barrier beaches are also some of the locations most favored by locals and tourists alike and bring significant income to the economy.

Although barrier beaches may seem relatively stable, they are constantly changing. Some people may wonder if barrier beaches can survive the effects of sea level rise, or will simply disappear. This bulletin describes how barrier beaches are formed and how they respond to the forces of sea level rise, tides and storm events. This understanding will help us to know what barrier beaches might look like in years to come and whether there are steps we can take now to preserve barrier beaches.

Figure 1. Aerial photograph of the barrier beach protecting Pleasant Bay taken near Nauset Beach (Orleans) looking south.

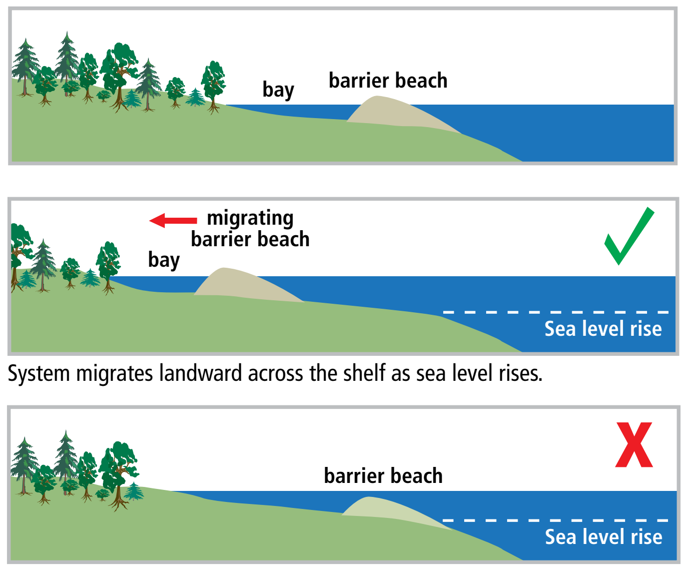

Figure 2. Sea level rise has been occurring for thousands of years. During this time barrier beaches have migrated landward through natural coastal processes and have avoided "drowning in place".

Geological History

Most of the barrier beaches on Cape Cod and the Islands are "transgressive," migrating landward and upward (in the long term) and cover the water body or salt marsh that lies behind it (Figure 2). This process has been occurring on most beaches on Cape Cod and the Islands for thousands of years. The driving mechanisms behind this shoreline movement are sea level rise and occasional storm events. Sea level has been rising globally since the end of the last ice age when glaciers started melting more than 20,000 years ago. (Fairbanks, 1989). During this time when a significant amount of water was sequestered in the glaciers, sea level was ~450 feet lower than it is today and our ocean coastline was ~100 miles offshore of its present position land (see left panel of Figure 4). The added water forced the shoreline to move up the gently sloping continental shelf. Eleven thousand years ago there were no glaciers in the immediate area, but there were still very large glaciers on land further north. During

Scenario	2025	2050	2100
Highest	0.49′	1.81′	6.83′
Intermediate High	0.36′	1.19′	4.20′
Intermediate Low	0.24′	0.65′	1.91′
Lowest (Historic Trend)	0.18′	0.39′	0.81′

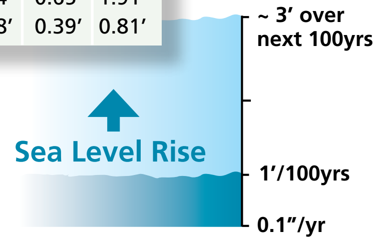

Figure 3. Relative sea level rise estimates adjusted to account for local vertical land movement for Boston, MA. This may match Woods Hole as well, but may underestimate Nantucket (from CZM, 2013).

this time period Georges Bank was not yet submerged and was connected to Cape Cod and the Islands by land (see Figure 4). As the climate continued to warm and ice in the northern glaciers melted, water poured back into the ocean and sea level rose. Approximately 6,000 years ago Georges Bank was inundated and much higher wave energy was now able to strike outer Cape Cod. These stronger waves accelerated erosion of the coastal bluffs, pulling sand away from the mainland and depositing it as barrier beaches across Pleasant Bay and Monomy, in addition to building up Provincetown out of the sea.

The Effects of Sea Level Rise

Along the coastline of Cape Cod and the Islands, sea level is not only rising, the land is also slowly sinking (aka subsiding) due to geologic processes. The rise in the water level that takes into account local effects (subsidence, currents, etc.) with global sea level is known as relative sea level rise. In our area, the average rate of relative sea level has been about a tenth of an inch per year, or about one foot per century (Figure 3). Most of these changes in relative sea level are only significant on a large scale (e.g., state vs state), however even between Woods Hole and Nantucket there is a small (0.25'/100 years) measureable change.

While there are a wide range of sea level rise projections, the state has provided guidance of a relative increase of around 3' by 2100 (range = 0.8–6.8', median = 3', see Figure 3 CZM, 2013). On time scales of hundreds to thousands of years, increased sea level rise could accelerate the migration of barriers landward or even lead to their disappearance altogether if the rise is very fast. The projected increases in sea level could make sections of the ocean coast more vulnerable to erosion over time. However, over typical planning time frames of 30 to 50 years, even increased sea level rise would not significantly change the actual observed rates of shoreline change in those areas experiencing the most severe erosion. On these time scales, sea level rise is of secondary importance compared to other factors in controlling what happens on the coast. On longer time scales and less rapidly eroding shorelines sea level rise has a more dominant impact. The frequency and intensity of coastal storms, and interruptions in the supply of sand available for building the beaches play a greater role (in the short to mid term) in shaping the coast. In most cases, our most severe erosion problems are caused by disruptions in the transport of sand, due to either natural processes or human activities (such as the building of seawalls).

Barrier Beaches — Creation and Migration

The original source of the sand that forms our barrier beaches is from erosion and transport of materials deposited by glaciers thousands of years ago. As sand is deposited in nearshore areas, the combination of wind, waves, and currents distribute sand along the coastline.

There are many mechanisms of dune and barrier beach formation; the one most applicable to our area is spit migration. Barrier beach formation by spit migration is a result of sediment (i.e., cobbles, sand, silt) being transported by waves and currents along the shore, and the progressive deposition of sand resulting in the elongation of a spit of land or dune line, parallel to the shore. A marsh or water body then develops between the mainland and the developing dunes. Tidal inlets often develop along with barrier beaches. These inlets are the pathway for seawater to move back and forth between the near-shore ocean and the back-barrier bays and marshes. Tidal inlets can be transitory environments which may move along a shore at highly variable speeds (Figure 5). The movement of sand along the beach tends to accumulate sand on the updrift side of the inlet and remove sand from the downdrift side, thereby typically forcing the inlet to migrate in the direction of longshore transport.

These barrier beaches retreated (migrated landward) as the ocean continued rising (Figure 6). There are three primary ways that sand can be transported across barrier beach: inlet formation, overwash processes and eolian (or wind) transport. Overwash fans and flood tidal shoals (created by historical inlets) provide the platform that allows the barrier beaches to maintain themselves while moving landward over time in response to rising sea level (Figure 7). Regardless of

Figure 4. The green area in the three maps above indicates an exposed land mass. Over geologic time, the shoreline has retreated landward over the last 18-20,000 years as the glaciers melted and sea level rose. (Adapted from Shaw et al., 2002)

Figure 5. Sediment being transported along the beach drives the tip of the barrier, and thereby the inlet to migrate. The rate at which the barriers migrate varies due to the volume of sand being transported and wave environment. Examples shown above range from 0'/yr at the 2007 inlet of Pleasant Bay in Orleans, to 5'/yr at Sandy Neck in Barnstable, to 750'/yr at the 1987 inlet of Pleasant Bay in Chatham, to 1,150'/yr at Norton Point in Edgartown.

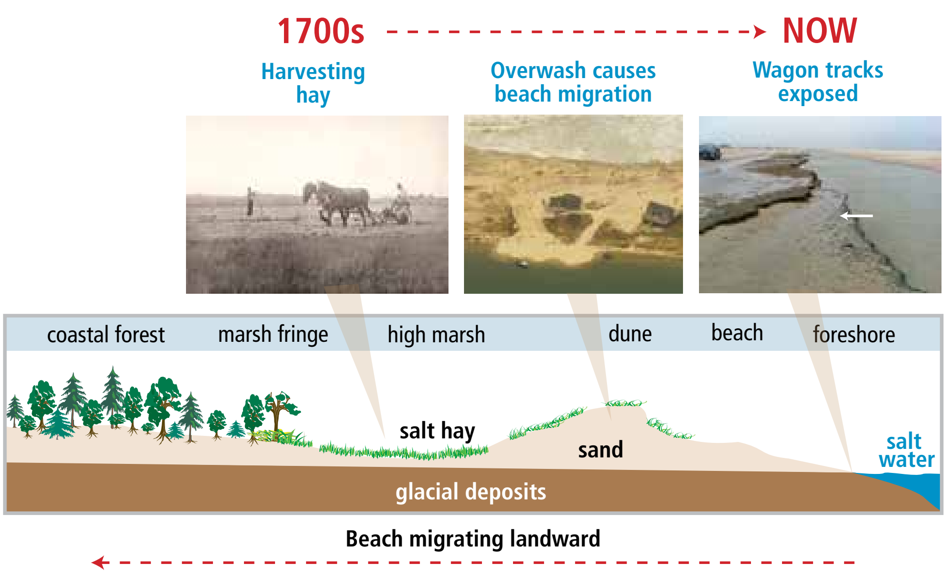

Figure 6. Most of our beaches are "transgressive," which is defined as a beach migrating landward and upward (in the long term) and covering the water body or salt marsh that lies behind it. One example of evidence of this migration is wagon tracks observed in peat exposed at the foreshore beach. Hundreds of years ago salt hay was harvested by wagon in marshy areas landward of the dune, and the barrier beach migrated these areas got covered (typically by the transport of sediments over the beach and dune system by storm waves which deposits a fan of sediments on the landward side aka overwash) until erosion exposed these tracks in their current environment.
"Harvesting Hay" photograph from *Sand Dunes and Salt Marshes*, by Charles W. Townsend (1913).

the actual mechanisms by which the barriers move in response to the rise in sea level, they have moved landward over the historical time frame of thousands of years.

How Management Practices Affect Barrier Beaches

The coastline of Cape Cod and the Islands is a remarkably diverse and complex place. It is this diversity and complexity that provide the many environmental, recreational and economic benefits the coast has to offer. This area is also very dynamic and, in many ways, very fragile. The shoreline we value and enjoy today was created by a variety of forces and processes operating on time scales ranging from hours to millennia. The result is a coastline that is naturally changing all the time.

Proper management of this important area requires a solid understanding of the factors affecting shoreline, how the shoreline responds to these factors, and the desired uses of the area. *Guidelines for Barrier Beach Management in Massachusetts*. A report of the Massachusetts Barrier Beach Task Force, CZM, 1994, was designed as a reference tool for those charged with the responsibility of preparing, reviewing, and implementing barrier beach management plans. Some have attempted to alter barrier beach inlet systems with limited success. In 2007, during the same Patriot's Day storm that opened the second inlet of Pleasant Bay, a new inlet formed in the barrier beach connecting Katama Bay to the Atlantic Ocean. This natural opening closed with no intervention in 2015, however historically this area has seen multiple attempts at significant human intervention. The first (of many) known attempts to open occurred in 1873, in order to "refresh the bay for shellfish" and for commercial fishermen to have a shortcut to Wasque Point, at the eastern end of Chappaquiddick. It was quickly closed by a storm. Only one failed attempt was made to artificially close the inlet. In 1976, cranes and bulldozers piled up dunes and sandbags to try to plug the inlet. This was attempted in order to stop the shifting sand from burying shellfish beds and to reduce the wild currents in Edgartown Harbor. After four months of attempts they gave up, and a year later the inlet closed natu-

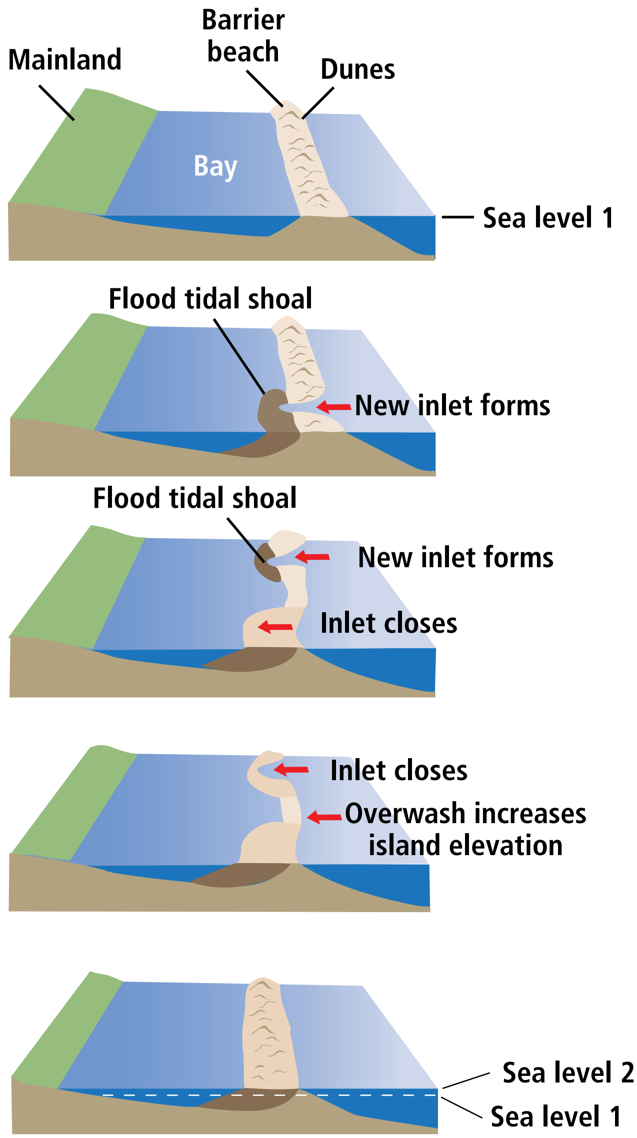

Figure 7. Simplified schematic of barrier island migration in response to sea level rise. Inlets transport sand to bays in the form of flood tidal shoals which provides the platform that allows the island to move landward. Overwash processes then raise the elevation of the island. This migration is a slow process occurring over periods of hundreds to thousands of years. (Illustration adapted from John Norton in Tanski, 2012)

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rally on its own (*Man's Efforts to Open – and Close – Norton Point*, Tom Dunlop, Martha's Vineyard Magazine, 5.1.11).

In some areas, the best management strategy may be to do nothing and let the natural processes continue unimpeded. The Cape Cod National Seashore manages a portion of the barrier beaches and islands protecting Pleasant Bay and has a strict ban on human intervention (coastal engineering structures, sand nourishment, inlet relocation, etc.). These types of invasive beach management are not allowed by National Park Service policies, which require the preservation of natural processes, including erosion, overwash, deposition, inlet formation, and shoreline migration.

While some intervention may be warranted, whatever management strategy is employed, efforts to mitigate erosion problems should work in concert with, and not against, natural processes. Management strategies need to be adaptable to changing conditions to ensure preservation for future generations.

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Additional information:

http://tidesandcurrents.noaa.gov/sltrends/sltrends.html
www.mass.gov/eea/docs/czm/stormsmart/slr-guidance-2013.pdf
http://www.mass.gov/eea/agencies/czm/program-areas/stormsmart-coasts/barrier-beaches/

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