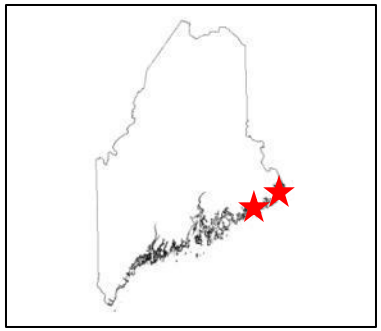
Geologic Site of the Month
January, 2015

Encroachment of Rising Sea Level upon Raised Freshwater Wetlands, Lubec and Jonesport



44° 32’ 25.94” N, 67° 37’ 27.67” W
44° 48’ 41.66” N, 66° 58’ 51.06” W

By
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Introduction

As rising sea level advances across the coastline, bedrock slowly drowns, but more profound changes happen to "soft" coastal environments like beaches, unconsolidated bluffs and wetlands. For examples of these see Coastal Change in Holmes Bay, Whiting, Shoreline Erosion at Western and Ferry Beaches, Scarborough, and The Variety of Maine's Changing Shoreline. Here we focus on wetlands, specifically ombrotrophic bogs. These wetlands are freshwater landforms that derive all of their water and nutrients from precipitation (Davis and Anderson, 2001). Sphagnum mosses are major components of this plant community, although dwarf trees and many other plants also occur in zones distributed around the perimeter of the bogs. The center of the bog grows most rapidly and can be 10-12 feet higher than the rims which is why they are commonly called "raised bogs." Because their highest parts are relatively flat, they are also called "plateau bogs".

Figure 1. View of Hay Creek bog in Jonesport from the south, May, 2010.

Raised Bogs Described

Raised bogs require frequent precipitation (and fog) and mild temperatures in the winter, and so exist only in a 3 mile wide coastal strip from eastern Penobscot Bay (Davis and Anderson, 2001) into Canada. Here cool summers restrict evapotranspiration and lead to frequent foggy days. Winters are also milder than inland. Many of the "downeast" peninsulas possess an abundance of raised bogs. Although some were harvested for their peat in the past, most are pristine. Because of their requirement of abundant fresh water, raised bogs are typically framed by bedrock or glacial sediment. A glacial-marine mud border for the bogs forms an impermeable liner for the bog, while moraines, which are more permeable, can partly surround and trap water to support wetlands.

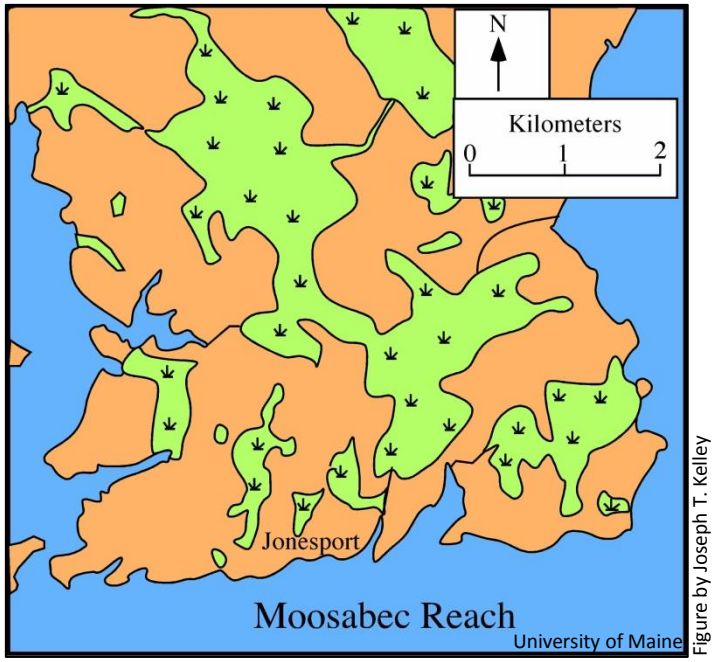


Figure 2. Raised bogs (in green) dominate the coastal landscape on the peninsula near Jonesport.

Study Area

Because of their proximity to the coast, raised bogs are threatened by rising sea level. In some locations, waves erode the glacial barrier and salt water enters the streams draining the bog. When this happens, it might appear that the freshwater bogs would quickly succumb to salt-water intrusion, but our coast provides three distinct settings that result in differing coastal environments. Although there are about 100 raised coastal bogs along the Downeast coast, we focus on two of them that show the range of outcomes to wetland-ocean interaction (Figure 3; Mansfield, 2012).

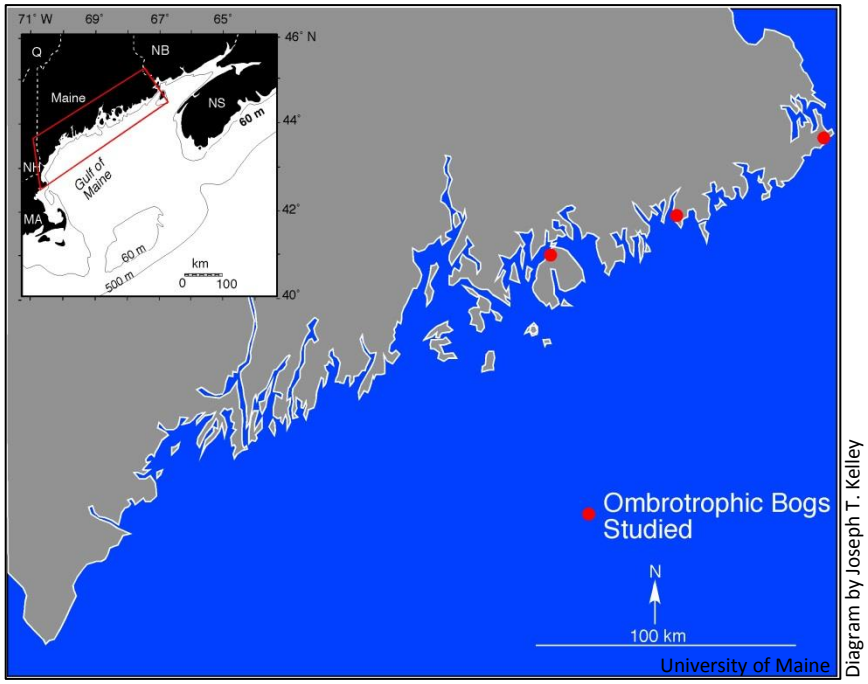


Figure 3. Map of the Maine coast showing raised bogs studied in Downeast Maine. The two eastern red points, in Jonesport and Lubec, are the focus of this article.

Lubec Heath

Near the easternmost point of the United States, the Lubec Bog (also called the Lubec Heath) is a small, but extraordinary wetland. An aerial view (Figure 4) shows a tidal flat along its sheltered northern (left) side, with a sand and gravel "pocket" beach on the southern border with the open Atlantic Ocean.

Figure 4. Aerial view of eroding Lubec Heath taken May, 1987, looking east. State Route 189 crosses over the bog. There is a coastal dune with a beach spit on the left side of the photo.

Lubec Heath Erosion

Time-series aerial photographs have shown that the sand spit on the north (far left side of Figure 4) has been growing at about 1 meter per year southward (Kelley et al., 2015). The entire embayment has experienced significant shoreline change since the 1700s. (Kelley, 1998). The heath has also eroded southward at about 1 meter per year between 1957 and 2008.

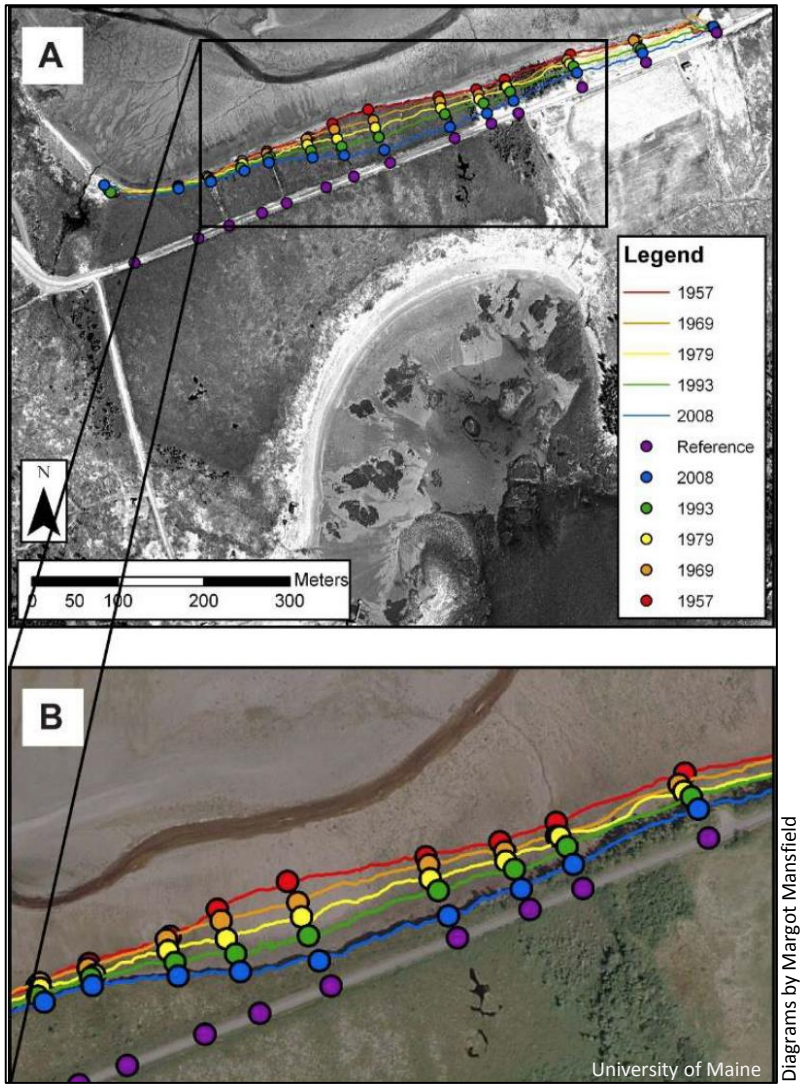


Figure 5. Time series aerial photographs were traced to show the changing position of the shoreline at the Lubec Heath. Figure A shows shorelines superimposed on a 1957 photo. Figure B shows an enlargement on a 2008 photo. From Mansfield, 2012

Lubec Heath Bluff Margin Retreat

The reason for the rapid retreat of the bluff margin is that at high tide it is directly exposed to the dominant direction of wind-generated waves (northwest). The waves, coupled with blocks of ice in the winter months, separate 6-9 foot high blocks of peat at a time from the main body of the bluff. This peat is then dispersed across the tidal flat where it becomes an important addition to the local food web.

Figure 6. Large blocks of dark brown peat eroded from the north side of the Lubec Heath (May, 1987).

Lubec Heath Seawall

Unfortunately, the erosion threatens the only road to West Quoddy Head State Park and several houses. To protect the road, the Army Corps of Engineers placed a rip-rap seawall in the most rapidly retreating section. While the wall offers some protection from waves to the heath directly behind it, wave energy becomes focused on the edges of the wall, which will likely see enhanced erosion in the future.

Figure 7. Rip-rap wall on the bluff at the north side of the Lubec Heath, October, 2014. Note that the heath embankment next to the nearby end of the riprap is farther landward than on the left side of the image. This suggests increased heath erosion and shoreline retreat from waves interacting with the wall.

Lubec Heath Beach Movement

On the Atlantic Ocean side of the peninsula, waves have reworked the underlying sediment, glacial till. This produced a sand and gravel beach that was pushed landward onto the southern/eastern margin of the Lubec Heath. This is a pocket beach that is set into a small cove with erosion-resistant rock headlands at either end, and some rock outcrops in the center. A lack of landmarks and a likely slow rate of landward movement here precluded measurement of the rate of encroachment of the beach on the wetland.

Figure 8. The beach on the Atlantic side of the Lubec Heath where waves drove the beach up and over the raised bog.

Hay Creek Wetlands

In the Jonesport area, wetlands around Hay Creek present a different manner in which a freshwater wetland encounters the sea. Here a tidal creek has advanced along the side of the wetland to where it merges with a small stream emerging from beneath the heath. The seaward side of the bog is protected from the ocean by a fringing salt marsh and brackish water peat.

Figure 9. Aerial view of Hay Creek in Jonesport. The sphagnum bog is a darker color while the salt marsh is a light yellow.

Hay Creek Salt Marsh Islands

Within the salt marsh are “islands” of freshwater bog. The contact between the marine environments and freshwater bog is abrupt and the bog rises half a meter above mean high water in a short distance.

Figure 10. Close up view of an “island” of freshwater peat surrounded by brackish water marsh. This looks like a very dynamic situation, but we were not able to detect any change here exceeding 5 meters over the past 50 years.

Hay Creek Ground-Penetrating Radar Study

A ground-penetrating radar (GPR) device sent radar waves through the peat that are reflected back by deposits according to their differing electrical properties (salt content, water content). Saltwater completely attenuates the radar because of its high conductivity so that no energy passes through it. Thus, on the seaward side of a GPR line, there is very little signal returned. Landward of the transition from brackish water to freshwater wetland on the ground surface, the GPR shows saltwater penetrates several meters beneath the sphagnum bog. In close association with this is a peculiar reflection from the freshwater bog that we interpreted as "rotting peat" formed from the interaction of saltwater and freshwater peat. Cores showed this peat to be more macerated (softened by soaking in a liquid) and finer grained than adjacent areas of peat. Landward of this, the freshwater peat is observed to rest upon glacial-marine mud, which is impermeable and supports the wetland.

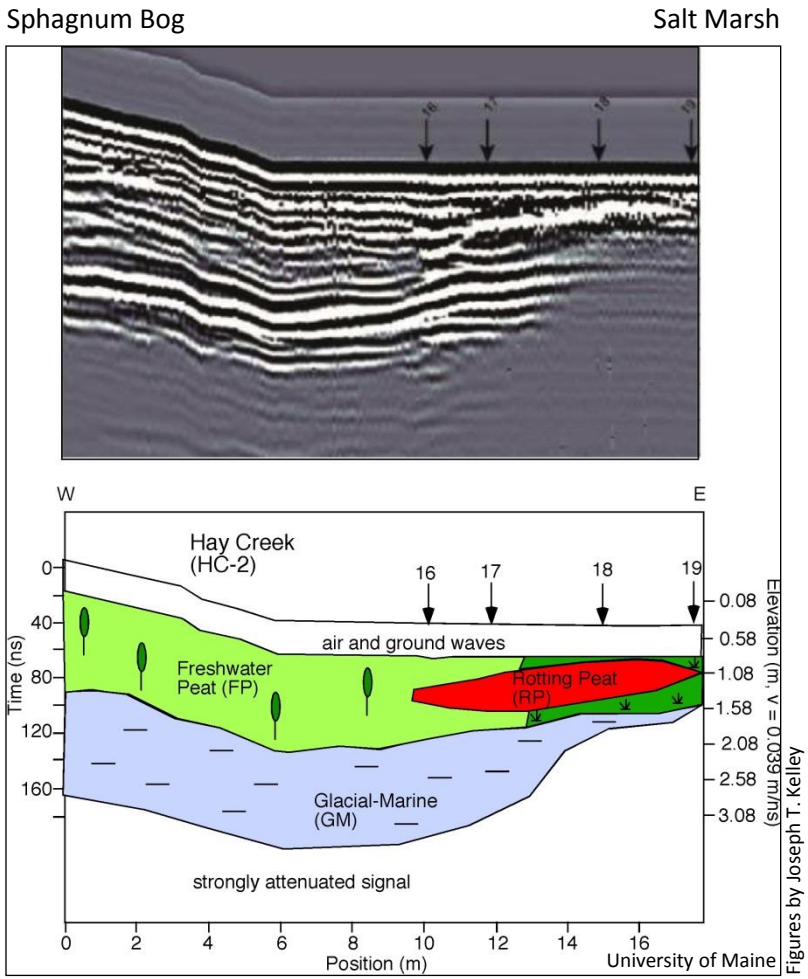
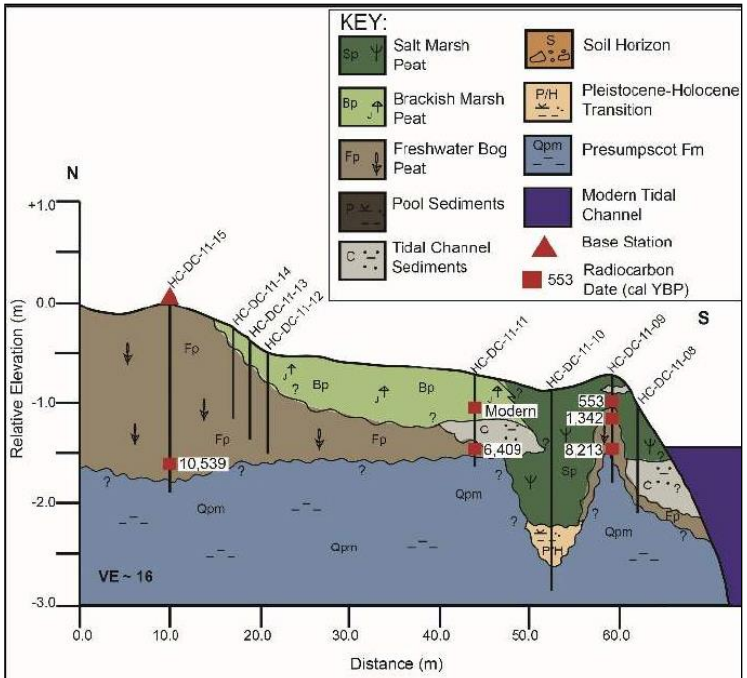


Figure 11. Ground-penetrating radar image (top) through the sphagnum bog-salt marsh transition. Diagram (bottom) of materials inferred from GPR image.

Hay Creek Material Ages

Cores through the peat support the GPR interpretations. Radiocarbon dates demonstrate that the freshwater peat began at least 10,500 calendar years ago, although nearer the edge of the bog, the oldest date was only 6,400 years old. Salt marsh and brackish marsh are much more recent deposits, suggesting that the process of converting freshwater peat to salt marsh peat is a slow one.



Core Site	Core Name	Sample Depth (cm)	Weight (g)	Description	Age ± Error	Calibrated Age ± Error (2-sigma range)
Hay Creek	HC-9	28	1.4362	Salt marsh (upper core)	490 ± 45	553 ± 153 (474 – 632)
		34	0.4618	Freshwater bog material just below unconformity	1,450 ± 25	1,342 ± 80 (1,302 – 1,382)
		69	1.0546	Base of freshwater bog above Presumpscot Fm	7,410 ± 45	8,213 ± 267 (8,069 – 8,356)
	HC-11	39	2.3105	Brackish marsh	Modern	—
		68	0.7051	Freshwater bog material just below unconformity	5,650 ± 30	6,409 ± 173 (6,322 – 6,495)
	HC-15	157	0.4238	Base of freshwater bog above Presumpscot Fm	9,330 ± 40	10,539 ± 246 (10,416 – 10,662)

Figures from Margot Mansfield (2012) University of Maine

Figure 12. Cross section of the Hay Creek wetlands developed from a series of cores. The radiocarbon dates (in calendar years before present) demonstrate the great age of the sphagnum bog. The salt marsh is much younger.

Hay Creek Marsh Movement

Examination of aerial photographs leads to an ambiguous interpretation about the modern rate of wetland change because there are very few fixed points with which to compare images, and the oldest images are of low resolution. Our interpretation of ambiguous changes is that within the resolution of the images, we can see no change in the boundary between freshwater bog and salt marsh exceeding 5 meters (16 feet) since the 1950s. There is little likelihood that the freshwater bog is growing seaward.

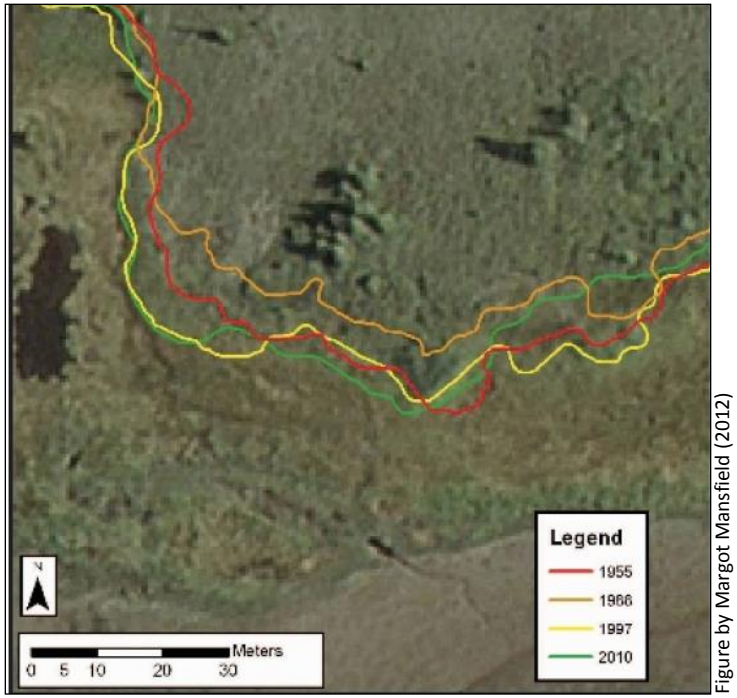


Figure by Margot Mansfield (2012)
University of Maine

Figure 13. Time series of shorelines interpreted from aerial photos at the Hay Creek bog.

General Observations

Our observations on the apparently slow rate of change of the boundary between the Hay Creek sphagnum bogs and salt marsh stands in dramatic contrast to the rapid retreat rate of the Lubec bog when it borders a tidal flat. In the former instance there must be a mechanism that holds the sea at bay for extended periods of time. Probably it is freshwater pouring through the bog that resists the sea's encroachment. Storms come in winter, when the bog is frozen. Salt water enters beneath the bog, as evidenced by the attenuation of the GPR signal under freshwater peat, but the bog survives. The situation where a beach borders the bog remains unknown, but the retreat rate of the beach probably approaches that of the tidal flat because there is no obvious mechanism for the bog to hold back the ocean waves.

Figure 14. View of the raised bog at Lubec as seen from the tidal flat, September, 1989.

References and Additional Information

Davis, R.B. and Anderson, D.S., 2001, Classification and distribution of freshwater peatlands in Maine: Northeastern Naturalist, v. 8, p. 1-50.

Kelley, J.T., Belknap, D.F., and Walsh, J.A., 2015 (in press), Tidal Flat-Barrier Spit Interactions in a Fetch-Limited, Macro-Tidal Embayment, Lubec, Maine, USA. In Randazzo, G., Cooper, J.A.G., and Jackson, D., 2014, Gravel spits, Springer Publishing Company, Berlin, Germany.

Kelley, J.T., 1998, Active Processes in the Lubec Embayment, Maine Geological Survey Web Site, http://www.maine.gov/dacf/mgs/explore/marine/sites/aug98.pdf

Mansfield, Margot Elena, "The Critical Leading Edge of Gulf of Maine Salt Marshes: Interface with Freshwater Wetlands" (2012). Electronic Theses and Dissertations. Paper 1778. http://digitalcommons.library.umaine.edu/etd/1778

Suggested Reading

Maine Natural Areas Program, 2013, Coastal Sedge Bog, Maine Natural Areas Web Site, http://www.maine.gov/dacf/mnap/features/communities/coastalsedgebog.htm

Maine Natural Areas Program, 2013, Jonesport Heaths, Maine Natural Areas Web Site, http://www.maine.gov/dacf/mnap/focusarea/jonesport_heath_focus_area.pdf

Gawler, S. and Cutko, A., 2010, Natural Landscapes of Maine: A Guide to Natural Communities and Ecosystems, Maine Natural Areas Web Site, http://www.maine.gov/dacf/mnap/about/publications/community_classification.htm