Getting to the Core of the Matter
STUDENT PAGES

Key Questions
How Does Elevation Affect Carbon Storage in Salt Marshes?
Are Our Salt Marshes Keeping Up with Sea Level Rise?

Background

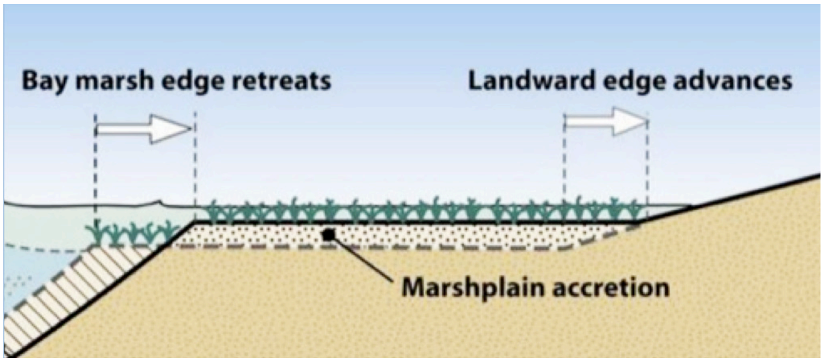
Vertical accretion is the rate at which a salt marsh gains elevation as sediment is deposited and plants grow. Contributions to salt marsh growth can come from various sources: incoming tides can carry sediments and deposit them as the salt marsh is covered by water; rivers can bring sediment to the salt marsh area; and plant growth can build up organic material that is preserved in the oxygen poor peat below the surface of the marsh. The potential of a salt marsh to grow vertically is an important factor in their ability to adapt to the current rapid rate of sea level rise that is the consequence of climate change.

If a salt marsh does not gain in elevation rapidly enough, the increased frequency of tidal flooding caused by sea level rise can cause erosion of marsh sediments and loss of salt marsh habitat. However, if the rate of salt marsh build-up over time keeps up with the rate of sea level rise, the marsh can continue to function ecologically.

Dr. Meagan Gonneea and a colleague with a marsh core.

Carbon sequestration The term "climate change" refers to the relatively rapid rise in global average temperature since 1880, mainly caused by a large increase in the amount of the heat-trapping gas carbon dioxide (CO_2) in the atmosphere. Research has shown that most of the additional CO_2 in the atmosphere came from human activities that involve burning coal, oil, gas, and wood during the past 150 years. Salt marshes may help to reduce the effects of climate change because they have the potential to remove large amounts of CO_2 from the atmosphere through photosynthesis, and then keep that carbon stored in sediments for centuries or more. This long-term burial is called **carbon sequestration**.

Research Project The Bringing Wetlands to Market (BWM) project was a collaborative research project led by Waquoit Bay National Estuarine Research Reserve (WBNERR). As part of the study, scientists collected data to study vertical accretion and carbon burial rates in salt marshes. In 2014, sediment cores were collected from the salt marsh at the main study site located at Sage Lot Pond near South Cape Beach in Mashpee, MA. The sediment cores were cut into one centimeter pieces and analyzed for lead-210, a radioactive form of lead, from which sediment ages of each section of the core were calculated. This method is limited to the past 100 years, since after that time all the lead-210 in the soil has decayed. The length of time each sediment slice represents depends on how quickly the sediment is deposited in the marsh. Since the high marsh deposits sediment at a lower rate, each interval represents a longer time period than the same interval in the low marsh. Because of this, we calculate the age of the sediment across the different marsh environments from the lead-210 isotopes, rather than comparing sediment at the same depth.



Accretion allows a salt marsh to increase in elevation. If the land at the upper edge of the marsh has a gradual slope, the marsh can move inland as well. Image by Jeremy Lowe, SERC.

Based on the sediment ages at different depths, scientists were able to determine how fast the sediment is growing vertically. This is called vertical accretion rate and it is measured in units of distance divided by time, or millimeters/year. For example, between 1982 and 1988, the marsh gained 7.98 mm in elevation, meaning the rate of accretion was an average of 1.33 mm per year. (7.98/six years)

Illustrations courtsey ian.umces.edu

The scientists also analyzed the amount of carbon in the sediment. This information was combined with the soil vertical accretion rate and density of the soil particles to determine how fast carbon is buried in the marsh. For example, in 2009 the high marsh grew at 2.14 mm/year, and the sediment had 0.027 grams of carbon in each cubic centimeter, resulting in carbon burial of 58 grams of carbon in a square meter each year.

Salt Marsh Plant Species Different plant species are found in the high marsh (located closer to the uplands) and low marsh (located closer to the sea). The **low marsh** is characterized by plants that can survive being regularly covered by salt water during high tides. Since this part of the marsh is at a lower elevation, it gets flooded by the tides more often than the high marsh. The plant species found in the **high marsh** are less able to survive frequent flooding from tides. In Sage Lot Pond, where the sediment cores in this study were taken, the high marsh is dominated by *Distichlis spicata* (spike grass) and *Juncus gerardii* (black rush), while the low marsh is dominated by *Spartina alterniflora* (cord grass).

Elevation The elevation of the marsh was measured with a very accurate GPS, or global positioning system. The elevation listed in the data table is relative to the North American Vertical Datum of 1988 (NAVD88) rather than mean sea level. Since sea level changes over time, there needs to be an unmoving benchmark data point that isn't fixed to it, so that the changes in sea level can be accurately measured.

The tidal range (difference in water level between low and high tide) is approximately 1 meter here, and the slope of the land is gradual, so a 10 cm difference in marsh elevation may not seem very large but it covers a lot of ground horizontally. The marsh elevation is also important because different species of marsh plants live at different elevations, and the different species can sequester, or store, carbon at different rates.

Gonneea, M.E., O'Keefe Suttles, J.A., and Kroeger, K.D., 2018, Collection, analysis, and age-dating of sediment cores from salt marshes on the south shore of Cape Cod, Massachusetts, from 2013 through 2014: U.S. Geological Survey data release, https://doi.org/10.5066/F7H41QPP

Photo of salt marsh core from Dr. Gonneea's study site.
Photo courtesy Stefanie Simpson.

Interpreting the Results

1) It is useful whenever you look at a data visualization (graph, chart, or diagram) to make sure you understand what the image is all about before you proceed to interpreting the story told by the data in the visualization.

Examine the graphs your teacher assigns to you. For each of the graphs, be sure you know:

a. What is the title of the graph, and what is the graph about?

Graph 1:

Graph 2:

b. What values are on the X and Y axes?

Graph 1: X

Y

Graph 2: X

Y

c. What do the data points represent?

Graph 1:

Graph 2:

2) Look at the vertical accretion graph and write down two or three notes describing how the vertical accretion rate for each of the cores changes through time.

a. High marsh core

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b. Low marsh core

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3) Which core has higher vertical accretion rates for the entire time span?

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4) Calculate the average rate of accretion.

Dr. Gonneea measured the total depth of the core she used for vertical accretion from the high marsh to be 130 mm.
The age of the oldest layer at the bottom of the core was 95.8 years.

Calculate the average rate of accretion. To do this, use the total depth of the core over the whole time span and divide this by the total number of years (rate = depth /time).

Total depth of sediment = 130 mm
Total number of years = 95.8

Average accretion rate ______________________________

Dr. Gonneea measured the total depth of the core she used for vertical accretion from the low marsh to be 260 mm.
The age of the oldest layer at the bottom of the core was 100.6 years.

Calculate the average rate of accretion. To do this, use the total depth of the core over the whole time span and divide this by the total number of years (rate = depth /time).

Total depth of sediment = 260 mm
Total number of years = 100.6

Average accretion rate ______________________________

5) Write down two questions you have about the graph and the patterns you observe.

Graph 1:

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Graph 2:

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6) What factors might affect the rates of vertical accretion and carbon sequestration in the low or high marsh?

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7) Is the high or low marsh system more resilient to sea level rise? Explain why.

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8) Sea level rise in this area is approximately 3 mm/year. Do you think this marsh will be able to keep up with sea level rise? Explain your reasoning.

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9) How might the salt marsh vegetation change as sea level rises?

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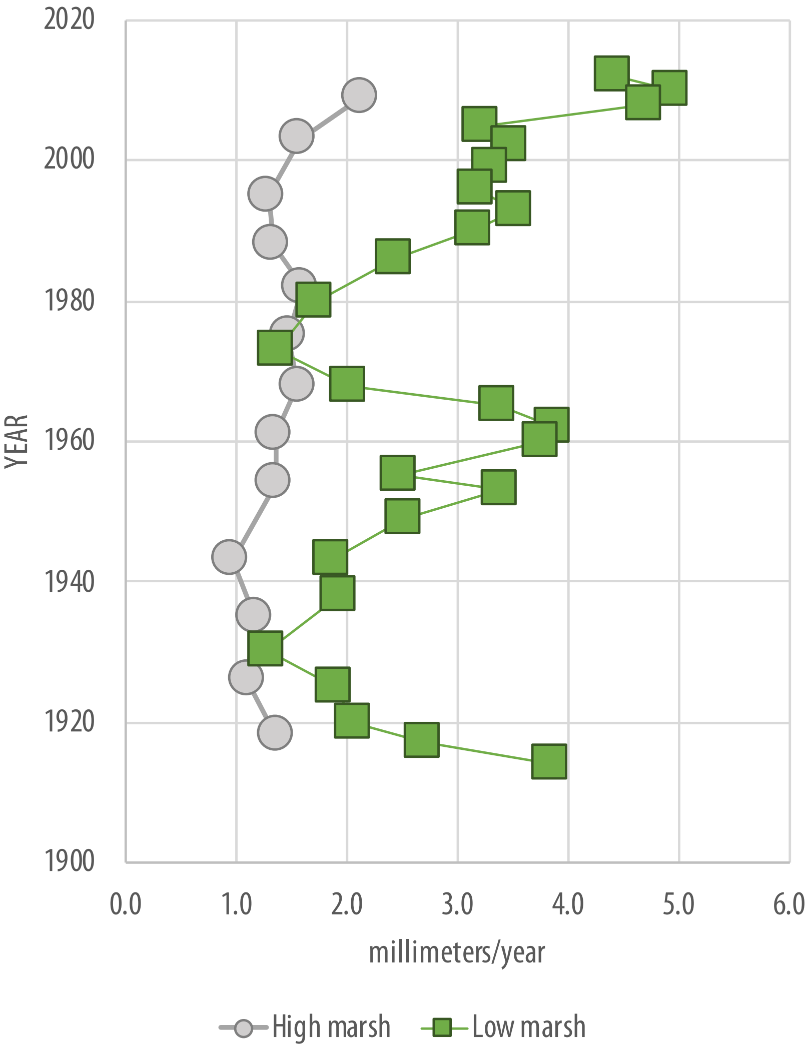
Vertical Accretion Rates in High and Low Marsh

Graph 1



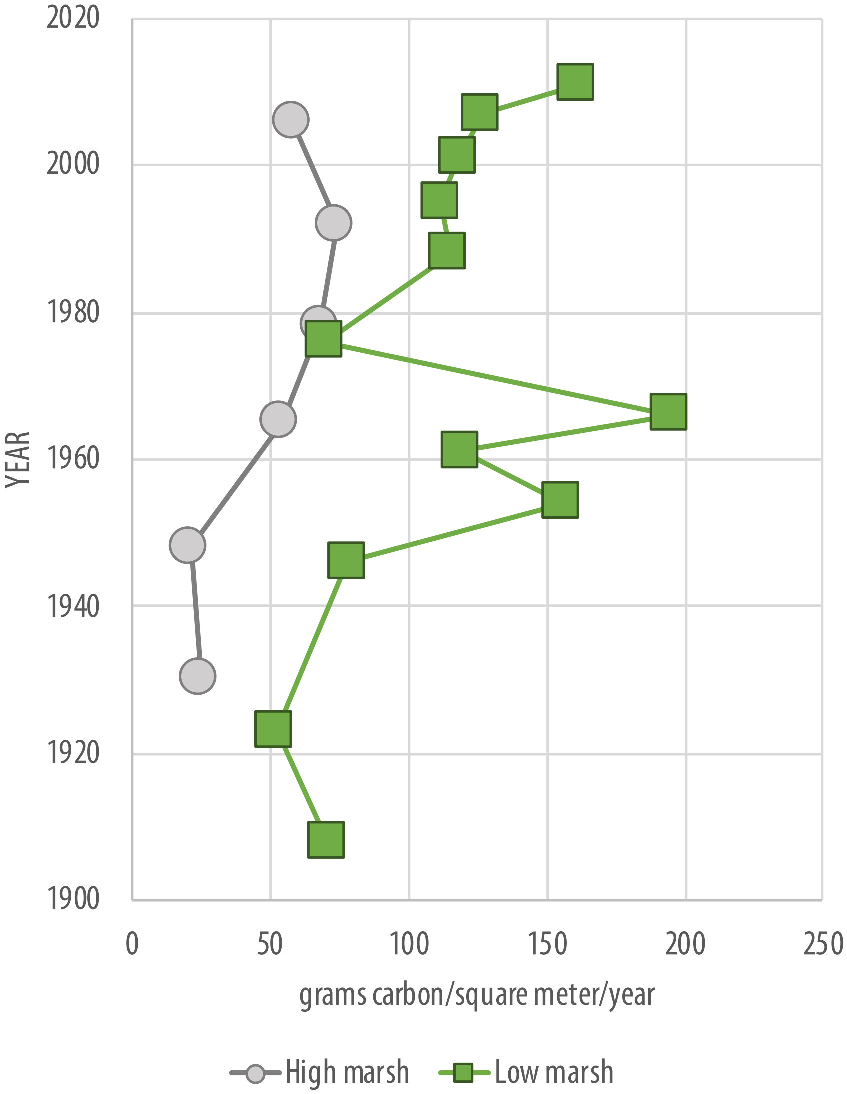
Elevation is reported relative to the North American Vertical datum of 1988

Table 1

HIGH MARSH: Collected January 2014 Elevation: 24 cm NAVD88				LOW MARSH: Collected December 2013 Elevation: 14 cm NAVD88		
Age (years)	Year	Vertical accretion rate (mm/y)	Sedient depth interval (cm)	Age (years)	Year	Vertical accretion rate (mm/y)
4.7	2009	2.1	0-1	2.3	2012	4.4
11.1	2003	1.6	1-2	4.3	2010	4.9
18.8	1995	1.3	2-3	6.4	2008	4.7
26.3	1988	1.3	3-4	9.5	2005	3.2
32.6	1982	1.6	4-5	12.4	2002	3.5
39.4	1975	1.5	5-6	15.4	1999	3.3
45.8	1968	1.6	6-7	18.6	1996	3.2
53.1	1961	1.4	7-8	21.4	1993	3.5
60.5	1954	1.4	8-9	24.6	1990	3.2
70.9	1943	1.0	9-10	28.7	1986	2.4
79.5	1935	1.2	10-11	34.5	1980	1.7
88.5	1926	1.1	11-12	41.8	1973	1.4
95.8	1918	1.4	12-13	46.8	1968	2.0
			13-14	49.7	1965	3.4
			14-15	52.3	1962	3.9
			15-16	55.0	1960	3.8
			16-17	59.0	1955	2.5
			17-18	62.0	1953	3.4
			18-19	65.9	1949	2.5
			19-20	71.2	1943	1.9
			20-21	76.4	1938	1.9
			21-22	84.2	1930	1.3
			22-23	89.4	1925	1.9
			23-24	94.3	1920	2.1
			24-25	98.0	1917	2.7
			25-26	100.6	1914	3.9

Carbon Burial Rates in High and Low Marsh

Graph 2



Elevation is reported relative to the North American Vertical datum of 1988

Table 2

HIGH MARSH: Collected January 2014 Elevation 24 cm NAVD88			LOW MARSH: Collected December 2013 Elevation 14 cm NAVD88	
Year	**Carbon burial rate ($gC/m^2/y$)**	**Sediment depth interval (cm)**	**Year**	**Carbon burial rate ($gC/m^2/y$)**
2006	58	0-2	2011	161
1992	74	2-4	2007	127
1978	68	4-6	2001	118
1965	54	6-8	1995	112
1948	21	8-10	1988	115
1930	25	10-12	1976	70
		12-14	1966	195
		14-16	1961	119
		16-18	1954	156
		18-20	1946	78
		22-24	1923	52
		24-26	1908	71