Sediment Exchange between a Marsh and an Adjacent Submersed Aquatic Vegetation (SAV) bed in Chincoteague Bay, MD

by

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Abstract

In recent years, coastal marshes and submersed aquatic vegetation (SAV) beds in the Chesapeake Bay have been shrinking in area with rising sea level and warming of the bay. Understanding the factors that affect sediment deposition in the marshes could help the efforts being made to preserve them, and sediment provided from offshore SAV diebacks could be playing a major role. A transect of sediment cores, one within an SAV bed and four within an adjacent marsh, were collected and analyzed for grain size and organic matter content. These parameters, along with ^{210}Pb dating, were used to assess possible linkages between the SAV bed and the marsh. The SAV core is characterized by large median grain size (1-2 phi) and low organic content (<10%), with two separate dieback events indicated in the core. These events occurred from 2004-2006 and 2009-2011 and thinned out landward of the SAV bed. Prior to 2004 there were no SAV dieback events to be seen, but SAV diebacks due to recent increases in ocean temperature are now providing a large amount of sediment to the marsh.

Keywords: Marsh, Submersed Aquatic Vegetation Bed

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Introduction

The Chesapeake Bay is the largest estuary in the United States and contains many marshes that serve as the habitat for a host of different organisms. Hundreds of different species rely on marshes for food and shelter. With a direct connection to the ocean these marshes are significantly affected by change in sea level. If sea level rises too quickly the marsh will be flooded and the sediment will be eroded, replacing the marsh with open shallow water (Thom 1992). Accounting for land subsidence as well as global sea level rise, relative sea level rise in the Chesapeake Bay from 1940 to 1980 was 2.5 mm yr^{-1} (Davis 1987) and this rate is projected to increase 2 to 5 times that by 2100 due to global warming (Titus and Narayanan 1995). In order to survive in the rising sea, marshes must accrete sediment at at least the same rate that sea level is rising (Chmura and Hung 2004). Sea level rise is not the only problem facing marshes; human population growth is playing a large part as well. Many historical marsh sites have been converted to developed property and farmland. Examining how and when sediment is deposited in marshes will suggest strategies for preservation and restoration in the face of these changes.

Marshes accrete vertically by both biomass accretion and mineral sediment deposition. Biomass accretion occurs in two separate ways, with either autochthonous or allochthonous material (Neubauer 2008). During a flood a network of autochthonous aquatic roots develops just above the surface of the sediment eventually becoming indistinguishable from the pre-existing marsh surface (Nyman et al. 2006). Both materials have been found to play an important role in vertical accretion.

Mineral sediment deposition rates in marshes have been found to rely on several variables. The most significant of these are habitat differences and interannual climate variability (Pasternack and Brush 1998), proximity to tidal creek (Neubeuer et al. 2002), elevation (Pasternack et al. 2000), river suspended sediment (Darke and Megonigal 2003), and mean tidal range (Chmura and Hung 2004). One variable that has not yet been examined closely is proximity to submersed aquatic vegetation (SAV) habitats. A stable SAV habitat typically contains sandy sediment with low organic content (Palinkas and Koch in review). The sand trapped in nearshore SAV beds adjacent to marshes is a potential source of mineral sediment for them.

The sandy sediment of SAV beds is generally deposited in an environment of lower water-energy (Hine et al. 1987). This occurs because the SAV reduces the current velocity by slowing the momentum of the water. This slower velocity allows particles to deposit that would otherwise have stayed suspended (Koch 2001). The rhizomes and roots of the SAV anchor the substrate around them and the sediment is protected from erosion by the decreased current velocity (Scoffin 1970).

In the lower Chesapeake Bay and in the Coastal Bays, the seagrass *Zostera marina* is one of the prominent SAV that exists, despite the fact that it has declined in population since 1973 (Orth 1976). It is a cooler weather plant and the Chesapeake Bay is located on the warmer extent of its limits. Once the water temperature reaches approximately 30°C photosynthesis and biomass can be limited. This can cause massive diebacks of the SAV beds (Marsh Jr. et al. 1986), which also affect the other organisms living within them (Orth 1976).

The death of an entire SAV habitat can be caused by an increase in temperature or by a massive sediment erosion or deposition event. After a die-off event, the sandy substrate is no longer anchored by the SAV and it can be eroded and redistributed. This situation occurred in Florida when over-grazing of seagrass beds redistributed sand onto a barrier island (Hine et al. 1987).

In 2005 a massive dieback, witnessed by Dr. Eve Koch, of a previously healthy SAV bed occurred at the same time as a thick sand layer was deposited in a nearby marsh in our study area. Rhizomes and roots of the SAV, which are typically buried, were observed above the surface of the sediment, indicating sediment erosion due to this dieback. This relationship could indicate that marshes and SAV beds interact via sediment redistribution. The SAV beds may be trapping sediment that would otherwise be deposited in the marsh. When the SAV die, the sediment is no longer trapped by vegetation and the sand that was stored in the SAV is now transported onto the marsh. This could benefit the marsh, not only by supplying sediment, but the relative coarseness of the sand may be more resistant to erosion. This exchange also likely occurs in the other direction, with marsh erosion being a possible source of sediment to SAV beds.

The hypothesis that marshes and SAV beds interact with each other has not yet been explored. They have each been looked at separately in many different studies on sedimentation and accretion, but the idea that there is an interaction between them is new. This study looked to find whether sand layers are deposited within a marsh due to SAV diebacks. The evidence of SAV diebacks within the marsh will be represented by distinguishable sand layers with a low organic content that will pinch out landward of the SAV bed. We dated sediment cores from the marsh and SAV bed using ^{210}Pb and ^{137}Cs methods, in combination with sedimentological observations. With those dates, we could infer when SAV dieback events occurred, and we estimated sediment accumulation rates in the various locations.

Research Methods

Field Measurements and Sample Methods

A series of cores were taken along a transect from the SAV bed through the fringing marsh. One of the cores was taken in the SAV bed and 4 were taken in the marsh.

A vibracorer (~3 m) was used to take the core in the SAV bed and a peat corer (~60 cm) was used to core within the marsh. The cores taken in the marsh were cut into 1-2 cm increments in the field, while the other vibracore was taken back to Horn Point Lab and frozen prior to cutting.

Sample Analysis

Every second interval was analyzed in each core. For grain size analyses, samples were wet-sieved at 63 μm to separate sand- and mud-sized particles. The mud component was analyzed using the Sedigraph 5120, while the sand component was dried and sieved from 1-4 phi (500-62.5 μm) at 1/4-phi increments. The data from each component was combined to calculate the median diameter. Organic content was also determined for each interval by combustion at 450°C for 4 hours.

^{210}Pb analysis was done using alpha spectroscopy, following the methods of Palinkas and Nittrouer (2006). The constant flux/constant sediment accumulation model was used. A 1 g sample of each interval was given a Po spike and digested first in a concentrated nitric acid, then in concentrated hydrochloric acid multiple times. Samples were plated for 24 hours on silver planchets, and then Po and Pb activities were counted for 24 hours. Activities were normalized to the mud content to remove the effects of variations in grain size. The ^{210}Pb activities were plotted on a logarithmic scale with depth and the point where background levels were reached was used to calculate accumulation rates.

The ^{137}Cs activity was determined by gamma counting of the dried sample.

Geologic Setting

Samples were taken in early June from the south side of Tizzard Island (Figure 1), located in Chincoteague Bay along the eastern edge of Maryland. Chincoteague Bay is a

Figure 1: These maps show the location of Tizzard Island within Chincoteague Bay as well as the core locations at Tizzard Island.

lagoon connected to Sinepuxent Bay to the north and these are separated from the Atlantic Ocean by Assateague Island (a barrier island). There are two outlets that connect the bays to the Atlantic Ocean located at their northern and southern extent. This is located along a passive continental margin. The effects of the tides on the bay are greatly reduced by Assateague Island. The bay bed is made up of about 50% sand and 50% mud (Bartberger, 2006).

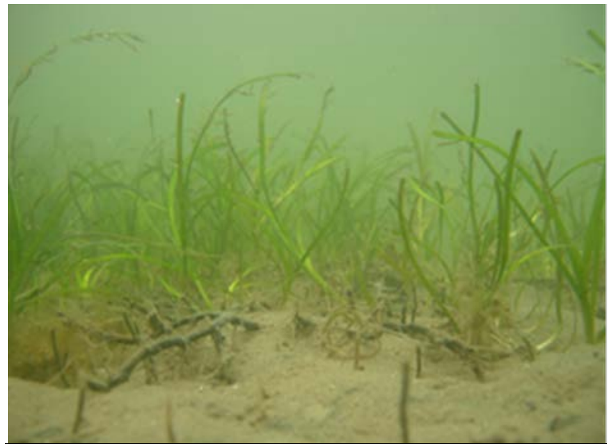

Figure 2: This is an image of our SAV bed in the spring of 2011. A recent dieback is indicated by the visibility of the roots and rhizomes of the SAV.

The climate in the area varies greatly ranging from -30ºC to 40ºF. Hurricanes can have a major impact on the area in the summer months, which cause large changes in wave energy.

The Bay is roughly 40 km long and 5 km wide while Tizzard Island is roughly 1 km^2 (Figure 1). There is a marsh on the eastern side of Tizzard Island and a SAV bed to the south of that. The SAV bed is located in roughly meter deep water and is in the process of recovering from a recent dieback (Figure 2). The marsh is made up of mostly peaty sediment with a visible layer of sand deposited on the south side. There is also some erosion to the east of our sample area.

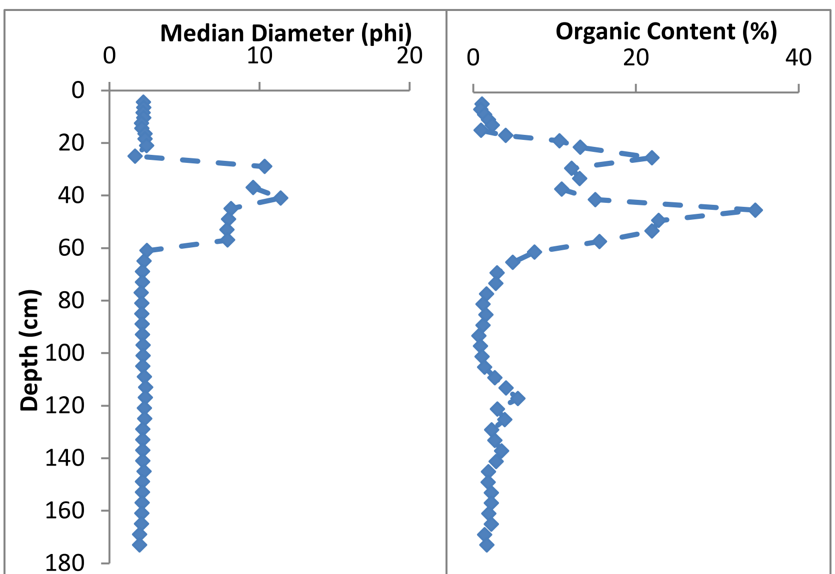

Figure 3: Graphs showing median grain size diameter and organic content for Core SAV. Large gain sizes generally correspond with low organic content and this is the type of sediment used to indicate diebacks in the marsh cores.

Results

General Sediment Description

The SAV core (Figure 3) has a consistent median grain diameter of about 2 phi (250 µm) for the entire length except from 20 to 60 cm. Within that interval the diameter decreases to 7 to 10 phi (7.8-0.98 µm) and then increases to 2 phi again for the rest of the core. Organic content for this core follows this same trend by remaining steady at 1-2% for the first 20 cm, increasing from 20 to 60 cm, and then lowering to 1-2% once again for most of the remainder of the core. Within the 20 to 60 cm range there are two peaks with a larger organic content than the area in between them. At about 120 cm the organic content begins to vary more than the 1-2% previously seen, but still remains under 10%.

The first marsh core, M4 (Figure 4), taken just within the tidal zone, shows large fluctuations in grain-size (about 4 phi, 63 µm) with an overall slightly decreasing trend from top to bottom (from 1 to 6 phi, 500-16.6 µm). The organic content in this core also shows large fluctuations that in most cases have an inverse correlation with fluctuations in the median grain size; intervals of larger grains occur at the same time as low organic content, and vice versa. Although this is what is happening in the majority of the core, there are some intervals where this pattern does not take place.

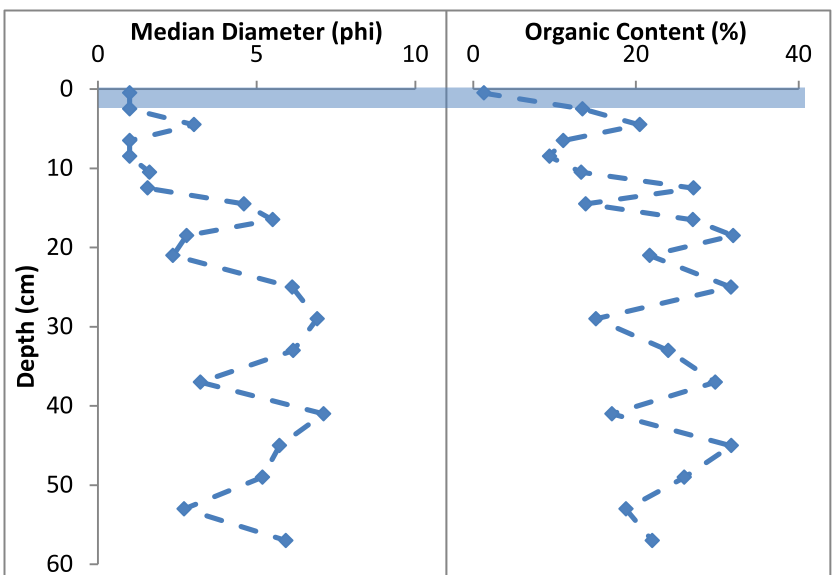

Figure 4: The median grain size diameter and organic content of Core M4 are shown. The box highlights the layer of sediment that indicates a dieback.

Core M1 (figure 5) was taken at the thickest part of the recently deposited sand layer. This layer made up 20 cm of the core having >500 µm median grain size. That section also had overall low organic matter content. Below that there are two instances where grain-size decreases, one larger than the other in both thickness and magnitude. During these changes in grain size organic content increases and stays at a moderate level until it begins to decrease again in the last 10 cm.

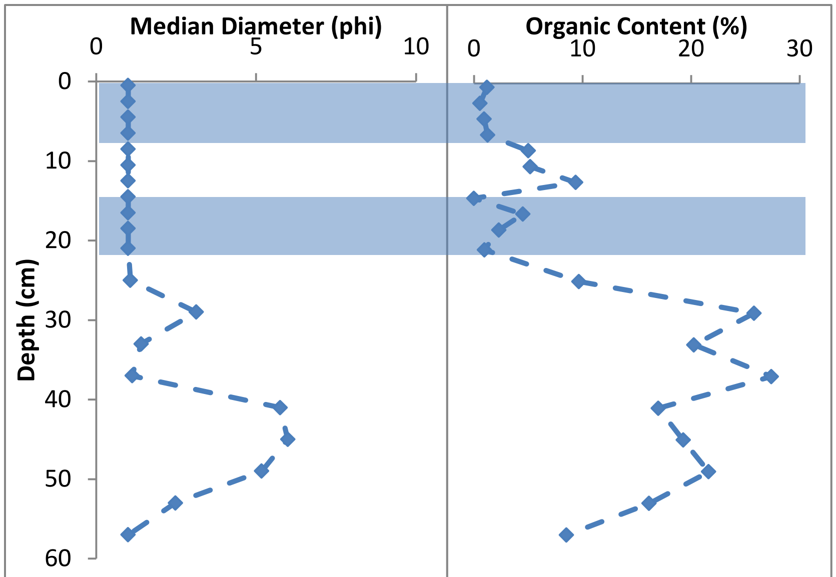

Figure 5: The median grain size and organic content of core M1 are shown. The two intervals that indicate separate dieback events are shown in the boxes with the interval of higher organic content separating them.

Further inland the core, M3 (Figure 6) becomes more variable again. Grain size is larger near the top of the core and decreases with depth. Organic content once again follows the grain size for the majority of the core.

The furthest inland core, M2 (Figure 7) continues to show a variety of grain sizes but an overall larger organic content than previously seen. The grain size also shows fewer patterns than previous cores.

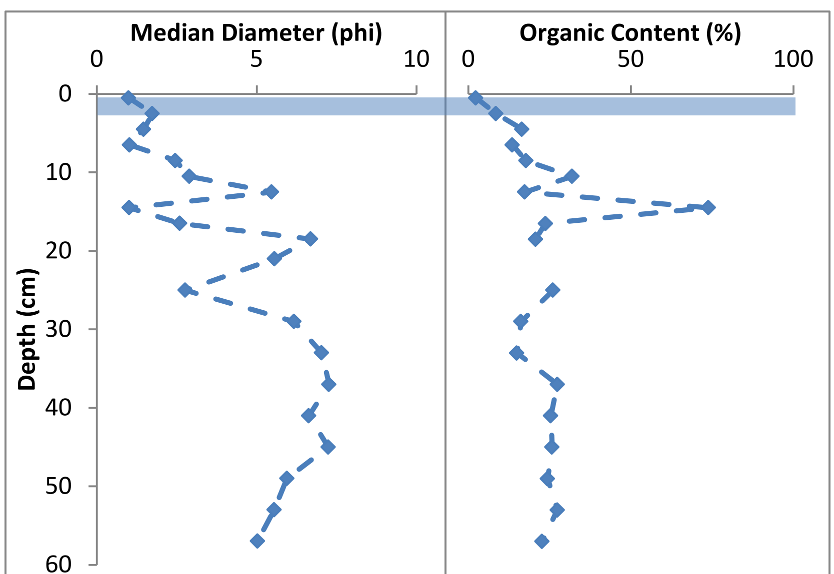

Figure 6: The median grain size diameter and organic content for core M3 are shown. The box is highlighting the layer that indicates an SAV dieback event.

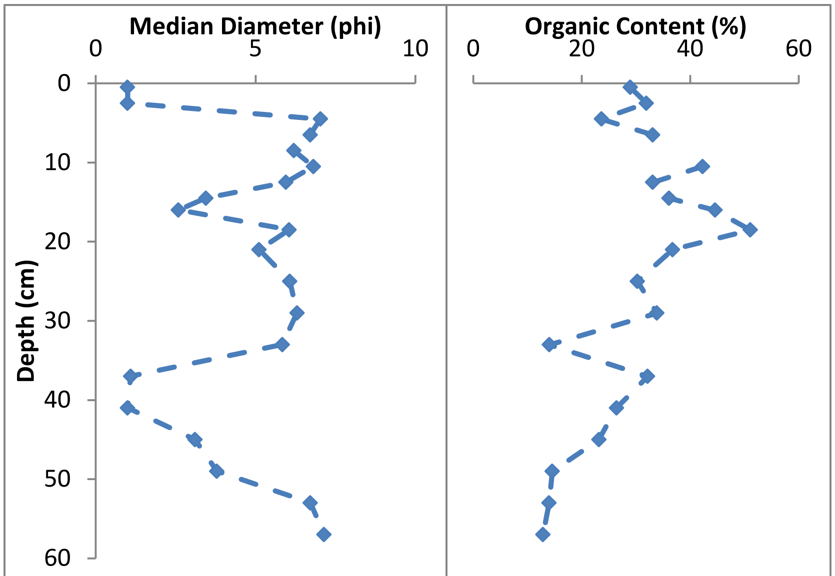

Figure 7: The median grain size diameter and organic content for core M2 are shown. There was no interval indicating a dieback even in our most inland core due to the high organic content throughout.

It does not show the overall grain-size decrease with depth. The organic content is also opposite the other cores with larger percent at the surface.

^{210}Pb Activities

In this study, sediment cores from a marsh and adjacent SAV bed were dated with ^{210}Pb analyses in order to determine rates of sediment accumulation. ^{210}Pb accumulates in sediments from a combination of sources. It can be supplied through precipitation and runoff as well as from the in situ decay of its parent ^{226}Ra. ^{210}Pb produced from this in situ decay is constantly being renewed so there is always a small amount of "background" levels. Once the supply of ^{210}Pb from runoff and precipitation is cut off it begins to decay to its daughter isotope ^{206}Pb. After 5 half-lives (22.3 years per half-life) only the background ^{210}Pb remains.

The ^{210}Pb activities are all plotted on a logarithmic scale. An ideal activity profile would show a small amount of vertical mixing at the top of the core, which would be shown as activities with identical values. Deeper in the profile activities would decrease and eventually reach

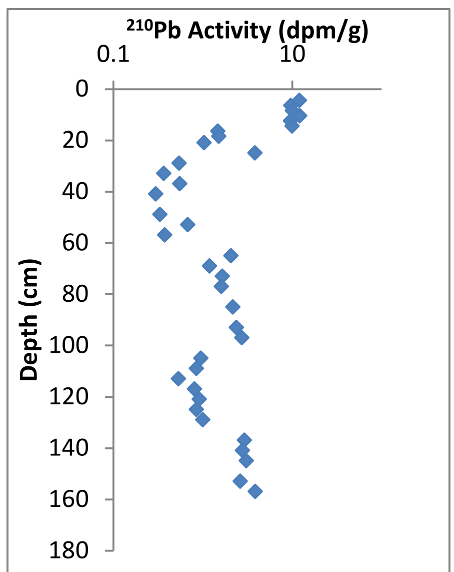

Figure 8: The ^{210}Pb activities for core SAV show no clear decline to background level. There is significant variability throughout the core.

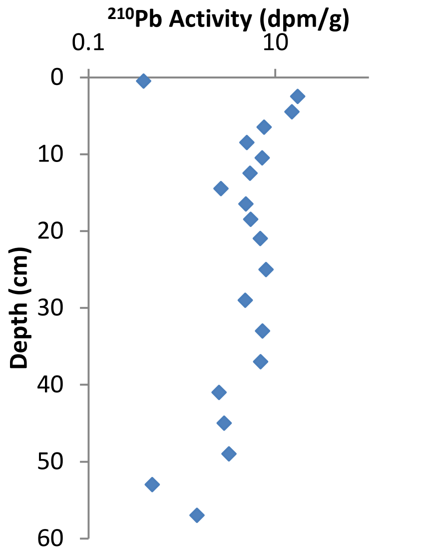

Figure 9: The ^{210}Pb data for core M4 show a decrease in activity throughout the core. An approximate accumulation rate of 0.3 cm/yr can be calculated if background is estimated to be at 37 cm.

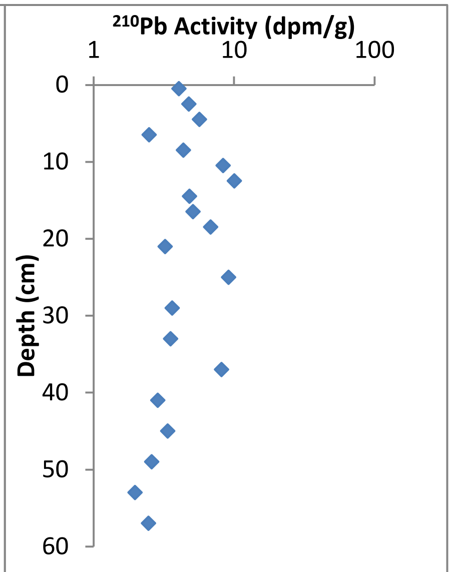

Figure 10: The ^{210}Pb activities for core M1 have a large amount of variability with depth and never appear to reach background levels. A minimum accumulation rate of 0.4 cm/yr is calculated based on some assumptions.

constant background ^{210}Pb levels near the bottom of the core.

The SAV core (figure 8) has very similar activities down to 12.5 cm. This is followed by a slight decrease in the activities going down to 21 cm. Below this there are four sections of the core having constant activities. The first, ranging from 29 to 57 cm, has activities around 0.5 dpm/g. The next section, from 65 to 97 cm, has activities of 2 dpm/g. From 105 to 129 cm, the activities are roughly 0.8 dpm/g. The last section, from 137 to 157 cm, has activities of about 3 dpm/g.

Core M4 (figure 9) has very low activities for the first interval, but then shows an overall decrease from 2.5 to 14.5 cm. After this the ^{210}Pb activities are roughly identical from 16.5 to 37 cm with values of around 5 dpm/g. After this interval the activities decrease again to values ranging from 0.5 to 3 dpm/g for the rest of the core. Core M1 (figure 10) has ^{210}Pb activities ranging from 3 to 10 dpm/g for the first 37 cm of the core. After that there is a slight, moderately steady decrease in the activities for the rest of the core. Core M3 (figure 11) begins with an 8.5 cm section of around 10 dpm/g. After that there is a section with a large amount of variability, but an overall decreasing activity from 10.5 to 33 cm. For the rest of the core the ^{210}Pb activities stay approximately identical with the very last interval decreasing. Core M2 (figure 12) has an overall decrease in ^{210}Pb activity for the whole core with some variability from 18.5 to 33 cm. There is one interval that has a very high activity at 41 cm.

^{137}Cs Activities

Sediment cores were also dated with ^{137}Cs analyses, because the use of ^{210}Pb in the Chesapeake Bay to calculate sediment accumulation rates is not well-tested and a second dating method can ensure accuracy. This is done using the year of maximum fallout of ^{137}Cs from atmospheric testing of nuclear weapons. ^{137}Cs is a bomb-derived radionuclide that has

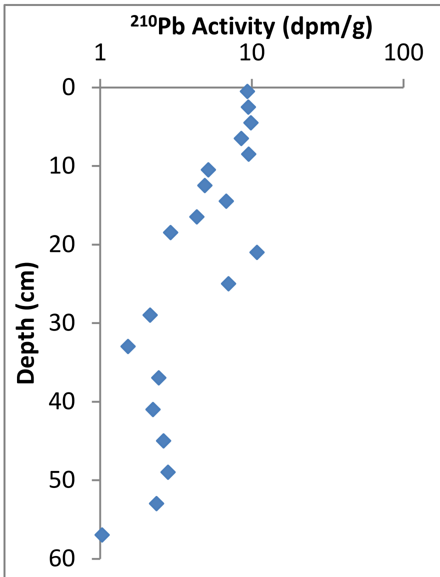

Figure 11: The ^{210}Pb activities for core M3 show the best decline to background levels. At 33 cm there is a decrease in the activities so an accumulation rate of 0.33 cm/yr is calculated.

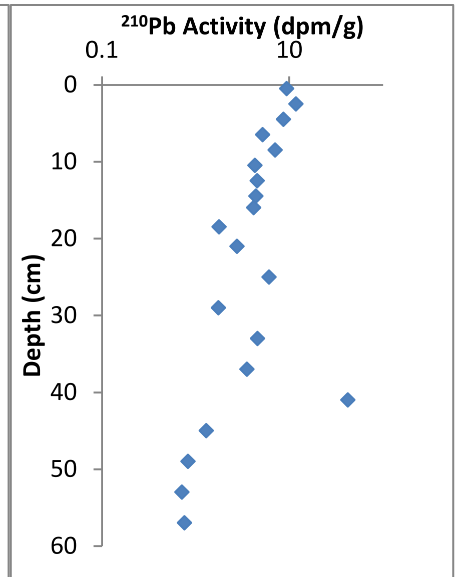

Figure 12: The ^{210}Pb activities for core M2 steadily decrease. With a possible achievement of background levels at 14.5 cm an accumulation rate of 0.15 cm/yr can be calculated.

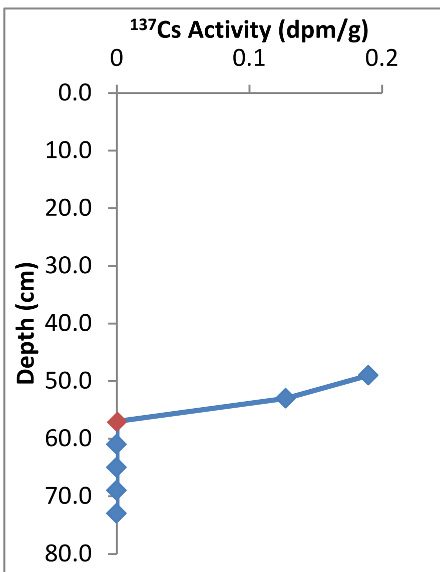

Figure 13: The ^{137}Cs data for core SAV show the appearance depth at 57 cm, shown by the red point. With this point an accumulation rate of 1 cm/yr is calculated.

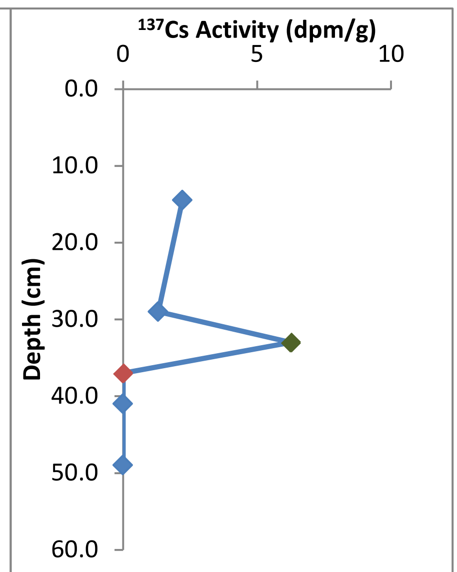

Figure 14: The ^{137}Cs activities for core M4 show the appearance date at 37 cm (shown by the red point) and the peak activity at 33 cm (shown by the green point). There is an accumulation rate of 0.4 cm/yr from 1954-1963 as well as from 1963-2011.

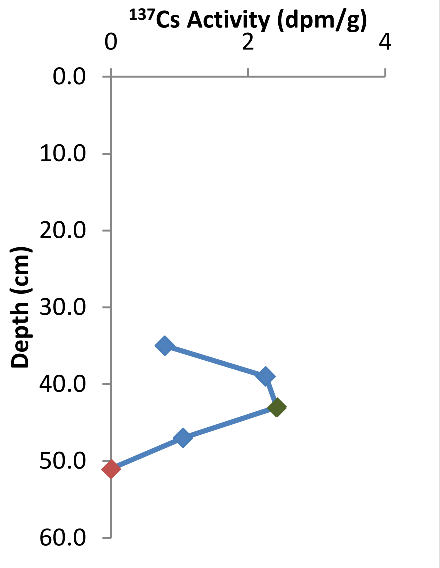

Figure 15: The ^{137}Cs activities for core M1 show the appearance date at 51 cm (shown by the red point) and the peak activity at 43 cm (shown by the green point). There is an accumulation rate of 0.9 cm/yr from 1954-1963 and from 1963-2011.

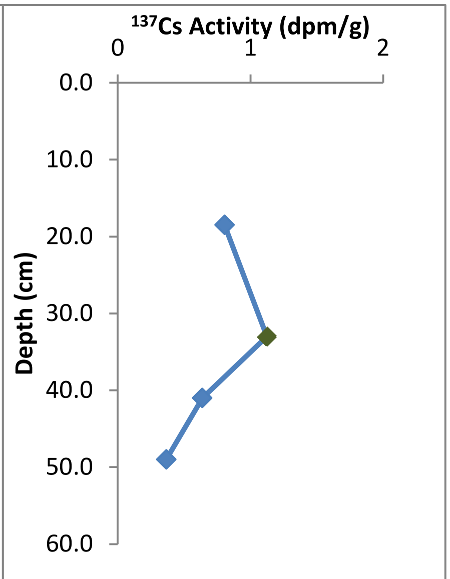

Figure 16: The ^{137}Cs activities for core M3 show only the peak activity at 33 cm (shown by the green point). An accumulation rate of 0.5 cm/yr for 1963-2011 is all that can be calculated with only the peak value.

been present in sediments since 1954 and reaches a peak activity in sediments (and other geologic records) deposited in 1963.

Each ^{137}Cs graph should show a horizon corresponding to the time when ^{137}Cs was first released into the atmosphere (1954) and a peak activity when nuclear testing was at its highest in 1963. Core SAV (figure 13) shows the appearance at 57 cm, but there is not enough data to know where the peak activity is. Core M4 (figure 14) shows the appearance at 37 cm and a peak activity at 33 cm. At 14.5 cm the activity increases slightly as well. Core M1 (figure 15) shows the appearance of ^{137}Cs at 51 cm and a peak at 43 cm. Core M3 (figure 16), the final core that ^{137}Cs analysis was performed on, shows no appearance date but does show a peak at 33 cm.

Sediment Accumulation Rates

The ^{210}Pb activities in the SAV core have a large amount of variability and fail to show an obvious decline to background levels, so ^{210}Pb cannot be used to develop a geochronology for this whole core. An alternate way to develop a chronology is by the existence of a peaty interval from 20-60 cm. According to the Virginia Institute of Marine Science SAV monitoring of the Chesapeake Bay, SAV began to colonize the study area in 1997 and formed a healthy bed until the dieback in 2005. SAV is unable to colonize peaty material, but only a few centimeters of sand are needed to begin colonization (Wicks et al. 2009). Prior to 1997 the area consisted of the peaty material seen in the SAV core from 20-60 cm, but once some sand was deposited the SAV was able to colonize and trap more sand. Using this knowledge it can be assumed that the 1997 occurred at about 29 cm down the core. Using that placemark an approximate accumulation rate of 1.9 cm/yr can be calculated for the SAV core. A third method for dating the core is to use the ^{137}Cs data for the same core (figure 13); using the sediment depth of the year 1963, an accumulation rate of 1 cm/yr can be calculated.

Core M4 (figure 9) does not show an obvious decline to background ^{210}Pb activity levels so a depth can only be estimated where background probably occurred. For the first 10 cm there are two instances where very large grain sizes occur, which can cause irregularities in the activities. From 10-37 cm the ^{210}Pb activities are relatively high until 41 cm, where they decrease. If it is assumed that this decrease is where background levels are reached then we can calculate an approximate accumulation rate of 0.3 cm/yr. The ^{137}Cs data (figure 14) has an accumulation rate of 0.4 cm/yr from 1954-1963 and 0.4 cm/yr for 1963-2011.When looking at both methods it is seen that ^{137}Cs indicates that 1963 occurred at 33 cm, but the ^{210}Pb rates put it at 14 cm.

When calculating the accumulation rate for core M1 (figure 10) the areas of large grain size need to be disregarded. These occur from 0-25 cm, 37 cm, and 57 cm. With those points ignored there are not many left to work with and calculations must be done based off some assumptions once again. Since almost half the core (the sand layer) was deposited very quickly it can be assumed that activities never reach background. With this a minimum accumulation rate of 0.57 cm/yr is calculated. Using the ^{137}Cs data (figure 15) for this core an accumulation rate of 0.9 cm/yr can be calculated from 1954-1963 and 0.9 cm/yr from 1963-2011. The ^{137}Cs indicates that 1963 is at 43 cm, but the ^{210}Pb rates have it at 19 cm.

Although core M3 (figure 11) has some variability it appears to reach background activity levels at 33 cm. With that depth an accumulation rate of 0.33 cm/yr can be calculated. Since the ^{137}Cs data (figure 16) never reaches the point of appearance an accumulation rate from 1963-2011 is all that can be calculated; this came out to be 0.5 cm/yr. For this core, 1963 should be at 33 cm according to the ^{137}Cs, but the ^{210}Pb rates are off again with 19 cm.

Core M2 (figure 12) has an interval of large grain size that can once again be disregarded from the calculation of the accumulation rate. This interval from 37-41 cm corresponds with an apparent outlier in the ^{210}Pb activity data. With those points disregarded it can be estimated that background levels are reached at 14.5 cm. This then gives an accumulation rate of 0.15 cm/yr.

Discussion

Using the median grain size, organic content and ^{210}Pb data it can be observed in the marsh cores that there have been two SAV dieback events at Tizzard Island. In two cores, M4 and M3, these events were only recorded as one layer of coarser sediment and took place around 2004 and 2006. The break between dieback events in these cores is not visible because core M4 was in the intertidal zone and M3 was too far inland so the layers were too thin to see any separation. In one core, M1, the separate events are clearly seen, but the dates of deposition are not reliable because the large, quickly deposited layers affected the accumulation rate of the core. The fourth and furthest inland core is too far inland to show any evidence of the SAV diebacks. Prior to these two events there are no diebacks recorded in the marsh cores.

The 2 phi median grain size and the 1-10% organic content of the SAV core (figure 3) is the signature for the sand layers we hoped to see within the marsh cores. The interval of smaller grains is likely from sediment provided from increased erosion of the marsh and therefore does not represent times when erosion of the SAV bed was occurring.

Dating of the cores is most reliably accomplished using the ^{137}Cs data. When comparing the dates in each core using both the ^{210}Pb and ^{137}Cs data there are large differences that show the unreliability of the ^{210}Pb data. The accumulation rates for the marsh cores, when calculated using the ^{210}Pb data, are all lower than what is calculated with the ^{137}Cs dates, and some of the cores do not go deep enough to reach background levels. The ^{137}Cs rates are much more reliable since there are known dates and the ^{210}Pb modeling required many assumptions. For these reasons the ^{210}Pb dates will not be used in this analysis, only the ^{137}Cs rates.

The intertidal marsh core, M4 (Figure 4) shows only one instance of coarse sediment with low organic content from 0-2.5 cm. This interval was deposited between 2004-2011, so it can be inferred that there was an SAV dieback during those years. Core M1 (figure 5) shows one large interval of coarse sediment, but two intervals of low organic content. These two intervals were deposited between 1988-1993 and 2004-2011. Since the sand layers in this core were so thick the accumulation rate is most likely not accurate; but, with this core, it can be seen that there are actually two dieback events that have taken place. Core M3 (figure 6) only shows one interval of the coarse SAV-type sediment with low organic content. This was deposited from 2006-2011, but since the peak activity in this core is very wide and there are large spaces in between the measured intervals this date could be different. Core M2 (figure 7), the furthest inland of the cores, does not show any intervals of coarse sediment with a low organic content. The first 2.5 cm have the correct grain size but the organic content is much too high throughout the whole core to have been from the SAV bed. The event layers followed the hypothesis of thinning out further away from the SAV bed with the exception of the first core taken within the tidal zone. The tide affected deposition and caused the beds to be slightly thinner.

If it is assumed that the earliest dieback date (2004) from core M4 is the same dieback event in core M1 that was calculated to have occurred at 21 cm, a new accumulation rate for core M1 can possible be calculated. This new date gives an accumulation rate of 3 cm/yr, which provides new dieback dates of 2004-2006 and 2009-2011.

One question that arises from our data is why the marsh cores do not have evidence of significant sediment accumulation before 1997, at which time there was not yet SAV to sequester sediment? The sand layers in the marsh occur when there is an SAV dieback and previously sequestered sediment is released and brought onto the marsh. Although there was a period of time with no SAV prior to 1997, we infer that no sand deposits are observed in the marsh because there was no sand to be transported there.

Conclusion

This study found evidence of two SAV dieback events recorded in cores taken from Tizzard Island, MD. These events were represented by larger grain sizes (1-2 phi) and lower organic contents (<10%), and were observed to thin out further away from the SAV bed. The earliest of these diebacks took place in 2004 with another possibly occurring in 2009. Prior to these diebacks the SAV bed was thriving and healthy since its colonization in 1997. The observation of these layers shows the clear connection between offshore SAV health and sediment deposition on marshes. The knowledge of this possible feedback between these environments could be very helpful in preserving and restoring both SAV and marshes in the Chesapeake Bay.

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