The Rate of Accretion and Spatial Distribution of Sediments In the Great Sippewisset Salt Marsh

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Salt marshes provide many important ecosystem services, yet they are endangered directly and indirectly by human activity. Maintaining an accretion rate greater than the accelerating rate of mean sea level rise is necessary for marshes to avoid "drowning." In this project, I estimated the accretion rate of Great Sippewisset Marsh and observed the effects of location relative to the sediment source and tidal channel, elevation, tide magnitude, and marsh grass coverage on the spatial distribution of sediments in the system. I also quantified the importance of inorganic and organic contributions to marsh accretion. I found that the GSM is accreting at a rate that surpasses the rate of sea level rise. The data revealed a positive correlation of sediments deposited with hours of tidal flood coverage and negative correlations with distance from the sediment source (the Falmouth coast) and distance from the tidal channel. There was no correlation of sedimentation with *Spartina patens* density. The availability of inorganic sediment decreased with distance from the source. I determined the biggest contributor to marsh accretion to be the below ground biomass of *S.patens*.

Key Words: *marsh accretion, sedimentation, tidal flooding, lead and* ^{137}*Cs dating*

Introduction

While resilient to seasonal and tidal changes, coastal marshes have long been threatened by human activity. In addition to directly destroying these habitats by dredging and filling marshes, there are indirect anthropogenic impacts. Global climate change is accelerating the rate of mean sea level rise, possibly faster than marshes can grow vertically. Sediment retention by various forms of coastal armoring is depriving marshes and other coastal ecosystems of the inorganic fill required to maintain optimum heights above sea level. Salt marshes are valuable habitats that offer many ecosystem services. The shallow waters of salt marshes offer a protected nursery to fishes and crustaceans. Salt marshes provide the primary production that supports fisheries in the form of vascular plants and algae. Concerning rates of production, marshes are similar to rainforests (Boesch and Turner 1984). An additional ecosystem service marshes offer is the storage, dilution, and stabilization of pollutants.

Relative sea-level rise (RSLR) has been occurring since the last ice age, altering coastal ecosystems. In the last half century, RSLR has accelerated with the additions of ice sheet melting and thermal expansion of the oceans. The NOAA station at Woods Hole documented the mean sea level trend as 2.59 mm yr^{-1}, based on monthly data from 1932 to 1999 (NOAA 2005). Historically, marsh accretion rates, or the net vertical growth of marsh soils from a datum like sea level, have approximated RSLR (Orson 1998). The marsh substrate is a complex matrix of mineral soil, living roots and rhizomes of marsh grasses, mostly-intact dead roots, refractory organic matter and water (Bricker-Urso and Nixon 1989). Marshes accrete through a combination of mineral and organic matter accumulation. Sedimentation is the deposition of mineral and organic matter on marsh substrate (Bryant and Chabreck 1998). Sediment that enters salt marshes comes from coastal erosion, brought in by flooding tides and high energy storms. The inorganic sediment load to marshes may be limited by coastal development. According to the Coastal Resources Working Group's 2003 report on the status of Falmouth's south shore, the construction of jetties, groins, and coastal armoring have disrupted the natural processes that build and maintain beaches because continued erosion is no longer offset by an upstream supply of sediment. In a study conducted by the USGS, WHOI Sea Grant, and the Mass Office of

Coastal Zone Management on Falmouth shoreline, erosion rates increased substantially around the 1930s-1960s when the hard stabilization of this shoreline began. Although the armoring of a few properties has little impact, a proliferation of bulkheads, revetments, and sea walls can change the coastal environment and ecosystem function (OSB 2006). In the wake of RSLR, accretion rates determine the fate of coastal marshes. If sediment accretion is not sufficient, then the salt marshes will become open water habitat (Turner et al 2006).

The purpose of this project was to estimate the accretion rate of Great Sippewisset Marsh and to determine if this growth rate is sufficient to maintain optimum marsh height above sea level. I studied the formation of the marsh over the past forty years by analyzing sediment cores. I studied the weekly sediment inputs to the surface of the marsh. Another objective of this work was to understand the relative importance of sediment deposits on the marsh surface versus below surface plant contributions as well as is the relative quantities of organic and inorganic material in deposited particles and within the peat. Studying the spatial distribution of sedimentation to find relationships with distance from sediment source, distance from the tidal channel, hours of tidal flooding, and grass coverage was another aspect of sedimentation I explored.

Methods

Study Site

Great Sippewissett Marsh (GSM) is a salt marsh protected by barrier beaches on the Western shore of Falmouth, MA. The dunes to the north and south of the beach are armored to retain sediment and groins stop alongshore movement of sand (Schwarzman 2002). Development encroaches on the marsh: an abandoned railroad corridor passes through the western edge it is surrounded by residences. Covering about….km^2, GSM is a typical Southern New England pocket salt marsh dominated by *Spartina patens* on the high marsh and *Spartina alterniflora* along channels and in the pannes. A main tidal channel brings water from Buzzard’s Bay into the marsh with rising tides. I studied the deposition on the marsh surface at four transects, T1-T4 (Fig.1), each farther from the mouth of the marsh to establish a gradient from the sediment source. At each of these transects, I monitored a range of elevations by locating sites at 3m (A), 15m (B), and 30m (C) from the main channel. These sites experienced different levels of flooding.

Tidal Flood Duration

To estimate the total hours of tidal flooding at each site, a group of 4 students simultaneously measured the depth of the water at each site during the highest tide of the month. All but one of the sites was submerged. Knowing the height of the tide at Chapaquoit Point, West Falmouth Harbor (WFH) at the time we took these measurements allowed me to calculate the minimum tide height in WFH for each site to experience flooding. By adding up the hours that the tides exceeded these heights each week, I was able to estimate the monthly coverage for each site (Table 1).

In addition to characterizing the sites by relative elevation, I also measured the vegetation covering each site. To approximate stem density and average above ground biomass, I gathered all of the grass (*S. patens* at all sites except for T1 A, where there was *S. alteriflora.*) in a 0.09 m^2 quadrat. I recorded the number of stems at each site and the dry weight.

Sediment Collection

To quantify and look for trends in the sediment deposited on the marsh by tidal flooding, I collected sediment at the 12 sites for four weeks. I set out two pre-weighed 9 cm Whatman glass fiber filters (GF/D) at each site to accumulate sediment. These filters were held on inverted 9 cm plastic Petri dishes with two elastic bands. The dishes were staked into the marsh by means of a nail passing a hole in the center into the marsh substrate. To protect the filters and their collections from heavy precipitation, I covered the filters with tarps made of heavy plastic sheeting held up by wire about 15 cm above the filters, which were nearly flush with the marsh surface. Every seven days, I collected and replaced the filters. In the lab, I carefully placed each filter in a Büchner funnel attached to a vacuum and rinsed it with deionized water to remove salt before drying the filters overnight at 60° C. After weighing total sediment gain I ashed the filters; heating for 4 hours at 450° C, and weighed the inorganic sediment deposit.

Sediment Core Analysis

While the sediment collection method generated information about the spatial patterns in deposition, I took sediment cores to examine the physical characteristics and history of the marsh substrate. Using a cylindrical metal corer with a diameter of 21 cm, I took a single 45 cm sediment core at the middle sites of transects 1, 2, and 4. When using relatively thin-walled, large diameter cylinders (>15 cm), compaction of the sediment is minimal (DeLaune 1978). These cores were sliced with a serrated kitchen knife on a wooden board in the field. I chose the length of my slices based on the consistency of the sediment at each transect. At transect one, I encountered sand saturated with water, which was divided into sections 5 cm long. Transect two was composed of saturated peat, which I was able to cut into 2.5 cm slices. The first 10 cm of core from transect four was more solid peat. Beyond that depth the core was composed rocky soil. Here I made 2 cm slices. The slices were immediately were placed into labeled ziplock bags for transport to the lab, where I weighed the sections and dried them for 24 hours at 60° C. Then I used the dry weight to calculate bulk density, based on the field volume of the slice. To determine percent organic matter at each depth in the cores, I measured the loss on ignition when a portion of each core section was heated for 4 hours at 450° C. To test that all of the organic matter had burned off, I heated the samples to 550° C for an additional hour (DeLaune 1989).

Estimating accretion rates in marsh requires a combination of dating techniques, many of which are based upon the detection of substances associated with human activity. For this project, I chose to examine the distribution of lead (Pb) and ^{137}Cesium (Cs) through the depth of the sediment cores to assign years to the different slices. Once the year of formation has been determined for a certain depth, the depth may be divided by the number of years that have passed since and the quotient is the accretion rate. To prepare for the Pb and ^{137}Cs analysis, I ground the remainder of the core sections from T2, and the T4 peat sections in a coffee grinder.

Lead Content Analysis

Historically, the most significant source of lead (Pb) to the global atmosphere has been the use of leaded gasoline. Other releases are mining, the smelting of ores, and the decimation of lead through industrial processes. The consumption of lead as an additive to gasoline in the United States peaked in 1978 (Miller 1994), though the use of leaded gasoline was already being phased out by as series of national laws (Kitman 2000). By 1988, the use of leaded gasoline had dropped below 1943 levels. The amount of Pb deposited on marsh surfaces is directly proportional to the concentration of Pb in the immediate atmosphere. The changes in Pb emissions over time is documented in sediments as a profile with a peak mg Pb/g sediment value found at a depth formed in 1978.

To extract lead, I added ten mL 10% nitric acid to one gram of sediment from each depth interval in centrifuge tubes and placed the tubes on a shaker table over night. Early the next morning I added an additional 4 mL to the sediment and allowed them to shake for three more hours. I centrifuged the samples to settle the heavy particles and then filtered the samples through paper filters into plastic vials. I measured the concentration of lead extracted in the acid by running the samples through Perkin Elmer 2380 AA spectrophotometer.

Radioisotopic Analysis

A similar dating technique is measuring the ^{137}Cs content of each segment of core. ^{137}Cs is a product of nuclear weapons testing and does not occur naturally. Comparing the activity of ^{137}Cs across sediments at different depths is one of the most widely used dating tools when examining material 40 years old or less (Orson et al 1998). However, radioisotopic methods alone cannot provide accurate accretion rates for shorter time periods due to bioturbation, erosion, and autocompaction of the substrate (Orson et al 1998), but it is helpful to employ in addition to a method that measures deposits directly onto the marsh surface.

The first significant levels of ^{137}Cs were detected in the atmosphere in 1954 when nuclear experimentation began in the United States. Peak quantities were detected in 1963/64 just before an international ban on experimenting. ^{137}Cs accumulates in sediments where it decays exponentially to ^{137}Ba, with a half life of 30 years (DeLaune 1989). This history is typically indicated by a maximum ^{137}Cs activity at 1963 which trails off to a depth equivalent to 1954 when ^{137}Cs was first detectable (DeLaune 1989).

The radioactivity of ^{137}Cs is proportional to the amount present. By counting the radioactive decay of ^{137}Cs in the form of gamma particles in a gamma spectrometer, the relative ^{137}Cs concentrations across depth can be determined. Using a Canberra Germanium dectector (model no. GL2020R), I counted ^{137}Cs decay of the remaining dried and ground sediment in plastic jars in the gamma spectrometer, strategically choosing depths at which I expected to fine elevated levels of the radioactive isotope. I counted each sample until the percent error was about 10%. I scaled these counts up to cps per layer, so different depths could be compared. I then ran each sample with a ^{137}Cs standard, and calculated the percent quenching occurring in each and corrected the cps per layer accordingly.

Results

Comparing the weight of sediment collected on filters across the marsh during different magnitudes of tides revealed a few trends. The filters gained weight in the field due to both sediment and salt deposition. There was a considerable amount of salt on the first set of filters, with heavier loads found at the sites closest to the marsh channel. Once rinsed, I considered only those filters that had gained weight in my analysis. There was a wide range of sediment weights from just over a milligram to 0.056 g, to nearly 1.2 g at T1 only. The average sediment weight collected at the first transect was 0.322 g. At T2, T3, and T4, the average loads over the experimental periods were 0.018g, 0.017g, and 0.009 respectively. I compared these samples by converting to µg sediment per m^2 (Table 2). Usually the sediment weights on the two adjacent filters were similar for a given week but often one sustained some environmental damage which canceled any weight gain in sediment. In general, the greatest sediment loads were found at T1. The particles were much larger than those found at other sites. Here the filters accrued sand, while at the other transects I did not find any sand. The sand was probably blown by wind from the nearby dunes. Because the mechanism of sedimentation occurring at T1 differed from the tidal flood deposition occurring at the other transects and the magnitude was so much larger in many cases, I did not include the T1 data in many of my comparisons.

Since tidal flooding is the vehicle that brings sediment into the marsh and deposits it, there should be some relationship between the amount of particles deposited and the hours each site is submerged during a week. Two factors control the amount of tidal flooding a site receives: elevation and temporal position in the moon’s monthly cycle. The monitored sites were submerged from 0 to 138.5 hours for the duration of the project. As shown in Figure 2, there is substantial variation in flooding duration over the sites. On a weekly basis, it is difficult to see these trends, but when the sum of flooding at each site for the project is compared to total sediment collected, is a loose positive correlation can be seen (Fig. 3). The increase in sediment with each hour of flooding appears very slight however. The magnitude of the tides, influenced by the phase of the moon, was different each week, so each elevation experienced different periods of flooding each week. This is reflected by the sediment loads, as the week that the most sediment was deposited at each transect was the week with the most flooding due to the full moon (Fig. 4).

As for the distribution of sediments brought into the marsh by the tidal channel, the trends once again were most apparent in when the month’s data for each site was totaled. The sites 3 m from the channel, received more sediment than the sites 30 m away (Fig. 5). There was also a negative correlation between weight of sediment deposited and distance from the mouth of the channel. Of the three inner transects, T2 received the most sediment and T4 the least (Fig. 5). There was no noticeable effect of the *Spartina patens* coverage of the site and the amount of sediment deposited over the month (Fig 6&7).

One way to describe the sediment being deposited is to compare the relative amounts of organic and inorganic matter. The percent of deposited sediment lost on ignition differed across the marsh. At T1, the filters collected nearly all sand. Further into the marsh, the importance of inorganic material relative to the total deposits decreased (Fig. 8). The average percent inorganic material across depth in the sediment cores follows the same trend as the sediment collected from the marsh surface. The core from T1 was quite uniform: mostly sand and each layer was over 99% inorganic. At T2, the sections averaged 50% organic. At T4, the layer ranged from 40 to 93% inorganic, increasing with proximity to the soil. If only the top layer of peat at T4 is considered rather than the entire core, there is a continuous decrease in the amount of inorganic material found in the sediments with increasing distance from Buzzard's Bay (Fig. 9). From the bulk density and percent organic profiles, it is apparent that the composition of the marsh substrate changes drastically at 10 cm deep (Fig.10 &11). I did not notice any layers of sand in the cores, which indicate strong storm activity. Had I seen many bands of sand, I would have quantified the importance of storm events in the accretion of GSM.

Unlike the T4 core, the T2 core was composed entirely of peat, which makes it the most representative of the GSM. Here, the bulk density of the core sections slightly decreased with depth and the water content slightly increased, but on the whole, the core was much more uniform than the T4 core (Fig. 12, 13, &14). Because of this continuity, this core also had the most easily identified maximum Pb and ^{137}Cs contents, clearly shown in the profiles of both elements (Fig. 15-18). I measured the highest lead concentration, 0.051 mg Pb per g dry sediment, in the 15-17.5 cm deep section. The sections directly above and below were similar content followed by Pb concentrations steadily dropped off. The peak cps for ^{137}Cs was also found in this section, but this was a more narrow peak, as the surrounding layers contained half as much radioactivity. At transect four, the lead peak was at 4 -6 cm and the ^{137}Cs peak was at 10 cm. At T1, the highest lead content was also at 15 cm, but the Pb content was 0.01 mg Pb/g dry sediment, while it was 0.05 mg/g at T2 and 0.058 mg/g at T4. This maximum was much less distinguished (Fig. 19). There was also extremely low ^{137}Cs content.

Discussion

While I was able to discern general trends in sediment deposition from the sum of three weeks' sediment accumulations, these were not apparent in the weekly data alone. This is due to the opportunities for sources of error intrinsic to this filter collection method. All of the filters lost some glass fiber, whether it stuck to the Petri dish, the rubber bands, or the foil I dried them on. Some had holes or iron oxide where the head of the nail sat on the dish. Other filters were torn and punctured. Most of the filters remained intact and damage was not apparent, yet it is likely some fiber was lost, lowering the measured sediment weight. I expect some sediment was lost when I rinsed the filters. I do not know if I successfully removed all of the salt from the filters when rinsing. Despite this, I believe the sediment loads are skewed lower than they actually should be. These inaccuracies made it difficult to notice trends on the data from any single week and many of the filters could not be used in the analysis because the filter lost more mass than the sediment deposited on it. Having two filters at each site helped avoid missing data points.

The total amounts of sediment accumulation at each site over three weeks suggest trends relating sediment weight to location in marsh, proximity to tidal creek, elevation, and moon phase. The tidal flood waters are the main mechanism that sediment from the West Falmouth coast reaches the inner GSM. The more time a site is under flood waters, the more sediment bearing water is passes over, slowing and depositing particles as it flows. The time a site spends under tidal floods each week is dependant upon both location and the phase of the moon. Lower elevation sites closer to the channel tend to be submerged the longest and receive the greatest sediment loads. Weeks including the days leading up to and directly after the full moon resulted in greater sediment deposition. Of the three weeks that yielded useful sedimentation data (weeks two, three, and four), week three had the longest total flood time, followed by week four. The full moon occurred with the highest tide of the month at the end of week three and allowed for some flooding early in week four. Week two had the lowest flood time of the three; I put out the filters during the new moon and they remained out until the half moon. This temporal aspect of the moon phases is clearly exhibited in the sediment loads of the two middle transects. In addition to the amount of water passing over a site, the distance the water must travel, both in the tidal channel and over the *S. patens* high marsh zone, is also a factor influencing sediment deposits. The flow of the tidal channel slows as it divides into a network of many channels. The sand that lines the tidal channel ends around T3. This is evidence of sediment falling out of suspension before reaching the edge of the marsh. The tidal waters are slowed further by the high banks covered with *S. alterniflora* and the subsequent spreading out into an unchanneled area. The channel dumps particles as they overflow onto the high marsh. Sites further inland and farther from the tidal channel receive less sediment. This trend, illustrated in Figure 5, is likely to be a result of both location and the consequential lessening of flood time due to locations further inland at higher elevation.

In an experiment conducted on a simulated *S. alterniflora* system, the amount of accretion was positively correlated with stem density (Loisel 1979). The stem density and basal area measurements in my study did not reveal any correlations with *S. patens* coverage in GSM. This could be because *S. patens*, a more flexible and smaller grass, does not slow the current and trap sediment the way the larger, more rigid *S. alterniflora* does. It is also very possible that my sample size was too small to detect any relationship, or that my sites were too similarly vegetated.

The relative quantities of organic and inorganic particles on each filter further illustrate the patterns in sedimentation in the GSM. The decrease in percent inorganic matter that accrued on the filters with greater distance up the tidal channel indicates that only the lighter particles may travel to the edge of the marsh. Most of the inorganic sediment settles out as it travels up the channel and there is little resuspension. Sites T3 and T4 are less dependant on inorganic deposits than T1 and T2. These sites are at slightly higher elevations, so large sediment loads are not yet needed for this area to maintain optimal elevation. T4 receives a higher percentage of inorganic sediment than T3 because of its proximity to the edge of the marsh, where the flood waters may come into contact with mineral soils. The transect is also near roads and houses, the construction of which cause erosion, delivering a source of sediment to the marsh via the tidal steam that joins the marsh to a small pond. In percent inorganic matter, the cores strongly resembled the sediment collected at the respective transects. This means that the sediment deposits I analyzed were representative of the sediment these sites have received historically.

More about the formation of the marsh can be learned from the physical characteristics of the cores. The fairly constant percent organic matter content of the T2 core, even to a depth of 45 cm, demonstrates the low rates of decomposition. This limited decomposition allows the *Spartina* to play a substantial role in marsh formation. There was little change in bulk density in this core, which means that compression of peat is also not a major process affecting marsh accretion. The accuracy of the density calculation varies because the core was sliced in the field, and actual volumes of the sections differ. The average bulk density of this core was 0.086g cm^{-3}. I used this ratio to scale up the monthly rate of sedimentation at T2B (0.093 µg sediment m^{-2} $month^{-1}$) to the height of a year's accumulation of sediment. By this calculation, the yearly rate of accretion due to sediment deposits is 1.3 mm yr^{-1}.

Determining the total accretion rate was not as straight forward as I anticipated. The profiles of lead and ^{137}Cs in the peat at Great Sippewisset Marsh offered two different marsh accretion rates. Peak concentrations of both substances were detected at 15 to 17.5 cm deep. If this depth corresponded to the peak ^{137}Cs emission year of 1963, the accretion rate would be about 3.5 to 4.1 mm yr^{-1}. If the 15 cm instead corresponds to 1978, the year of the greatest national consumption of leaded gasoline, then the marsh is accreting more quickly: 5.5 to 6.3 mm yr^{-1}. There are two potential causes for this discrepancy. One is that the peak lead emissions local to GSM occurred earlier than 1978. While Pb emitted by automobiles may volatilize or sorb to aerosols and travel through the atmosphere, much of it is deposited in narrow corridors along roads and highways (Miller 1994) so Pb emissions may be very localized. There are other means of Pb deposition that complicate this dating technique. Boat exhaust is discharged directly into the water and may more easily accumulate in sediments. Lead shot left on the marsh can also contaminate the waters flowing over the surface. The other possibility is that the most Pb was deposited in 1978, but either leached down through the peat or was taken up by marsh grasses and apportioned mainly in roots (Windham 2003), and was transported downward. While salt water makes the K_d of Cs increase, pulses of salt water can transform Pb into a number of slightly soluble forms, like PbSO4. Peaks in Pb concentration can be attributed to the remobiliation and subsequent accumulation of Pb within the zone of water table fluctuation (Vile 1999).

I believe that the actual accretion rate is within the range estimated by the ^{137}Cs technique. Cesium not very mobile and it is unlikely to be resuspended because it adsorbs to clay which is then captured by dense grass. Unlike Pb emissions, ^{137}Cs emissions are linked to a short time period and were not influenced by local occurrences. As the mobility of forms of Pb in sediments is not entirely understood and the local Pb emissions are unknown, the ^{137}Cs method is more reliable in this case, offering an accretion rate of about 3.8 mm yr^{-1}. Unlike the rather homogenous composition of the T2 core, the T4 core exhibited a steep increase in bulk density and decrease in organic matter content at 10 cm. The shallow peat layer indicates that the marsh has spread here relatively recently as part of an ongoing response to RSLR. Soon, GSM will no longer be able to retreat to higher land as the marsh is closely surrounded by homes, roads, and railroad tracks. However, this transect offers insight into the rate of marsh accretion because here the lead peak occurs 6 cm above the ^{137}Cs peak, which is found at the peat soil boundary. If the radioactive Cs was deposited onto soil, and then the peat began to form over it before 1978, then it is possible that 15 years passed as that peat between the peaks was formed. This yields an accretion rate of 4 mm y^{-1}, which is consistent with the other estimate. The Pb may not have leached at this site because of the density of the sediments.

Sediment deposited on the surface of the marsh contributes about 34% of yearly vertical rise of the GSM. At least half of the growth is due to below ground *Spartina* production. The average above ground biomass in the center of the marsh (T2 and T3) was 321 g dry weight *S. patens* m^{-2}. The roots are approximately twice this amount. If all of that root mass was incorporated into the peat, it would scale up to a vertical growth of 7.4 mm yr^{-1}. Some of the root mass is lost, so the actual contribution is not this great, yet the roots of the *Spartina* grasses are the greatest contributor to the peat accretion. Not only do the grasses build the marsh through below ground biomass, but they stabilize the above ground formation. The entrapment and stabilization of suspended inorganic sediment on the marsh surface by vegetation is an important process in helping to maintain the elevation with respect to sea level. The incoming sediment also supplies nutrient for plants which in turn stabilize and enhance the further sediment entrapment (Delaune 1978).

Conclusions

Salt marshes like GSM are maintained by *S. alterniflora* and *S. pattens,* which regulate the elevation of the marsh by forming peat from below ground biomass, accumulating organic matter, and trapping sediment. Patterns in sedimentation are products of distance from the sediment source, distance from the tidal channel, and elevation. Long term, the fate of these ecosystems is determined by the interactions between RSLR, land elevation, primary production, and sediment accretion.

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Figures

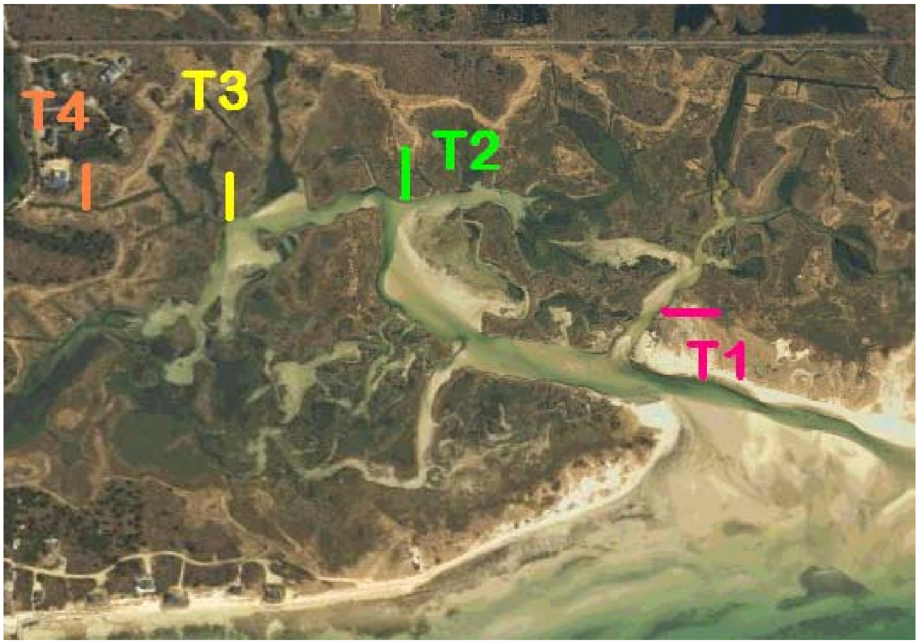


Figure 1: An aerial view of Great Sippewisset Salt Marsh. The transects of sediment collection sites are along the lines drawn onto the digital image. T1 is the closest site to the sediment source, the offshore sand. T4 is the furthest site from this source and is located at a site that the marsh has expanded into in the past 30 years due to sea level rise.

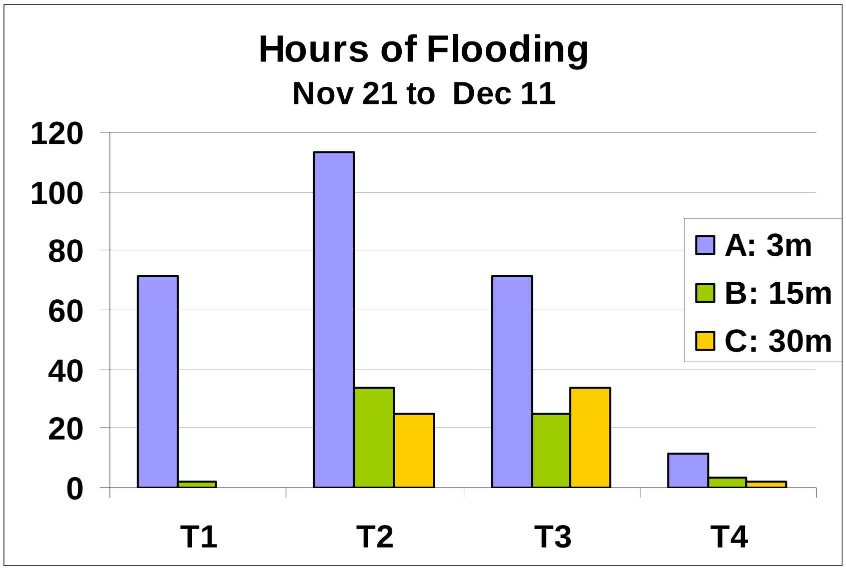


Figure 2: This chart compares the hours of tidal flooding each site experienced during the three week period that useful sedimentation data was collected. This chart may be used to compare the elevations of the sites.

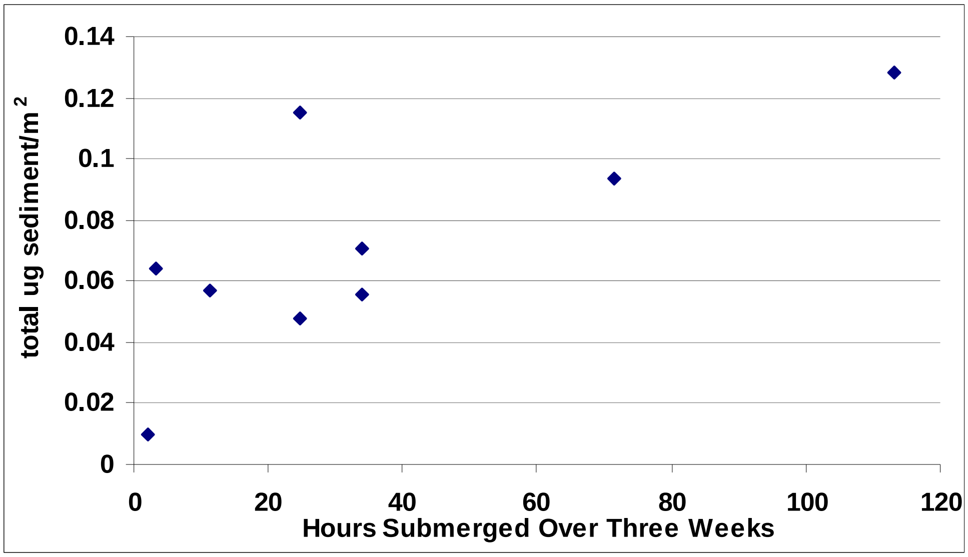
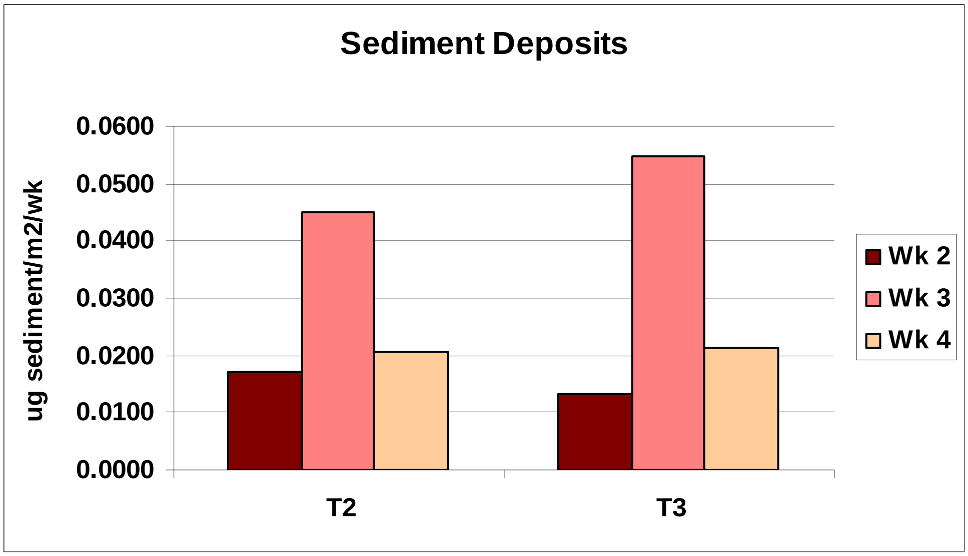


Figure 3: Effect of duration of site flooding. There is a loose positive correlation between total sedimentation over three weeks and the amount of time under tidal floods during that period.



29.15	50.55	33.4		16.5	31.95	23

Figure 4: Sediment deposition compared to hours of flooding at T2 and T3 (average of A, B, and C) for each week. The amount of sediment deposited per week is dependent upon the phase of the moon. There was a full moon during week three.

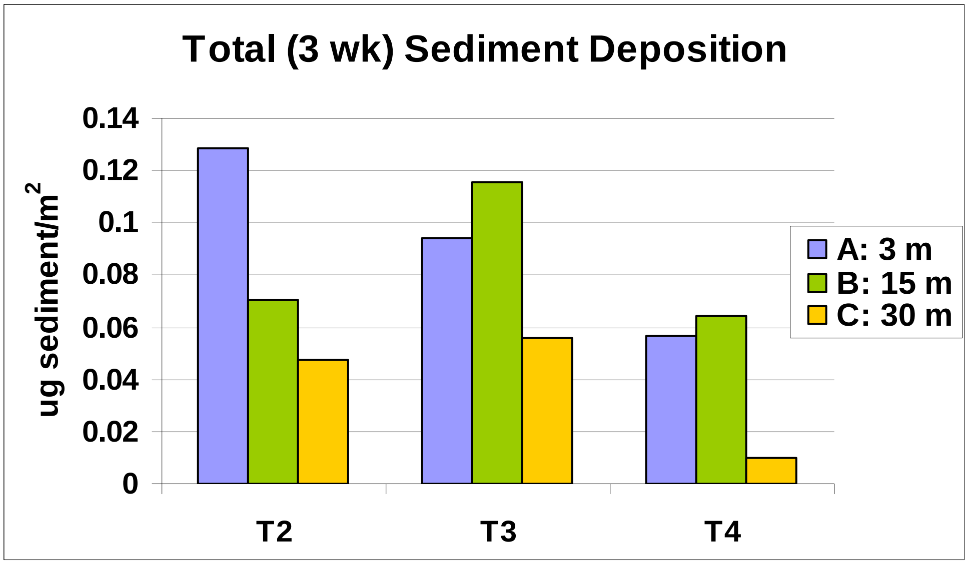
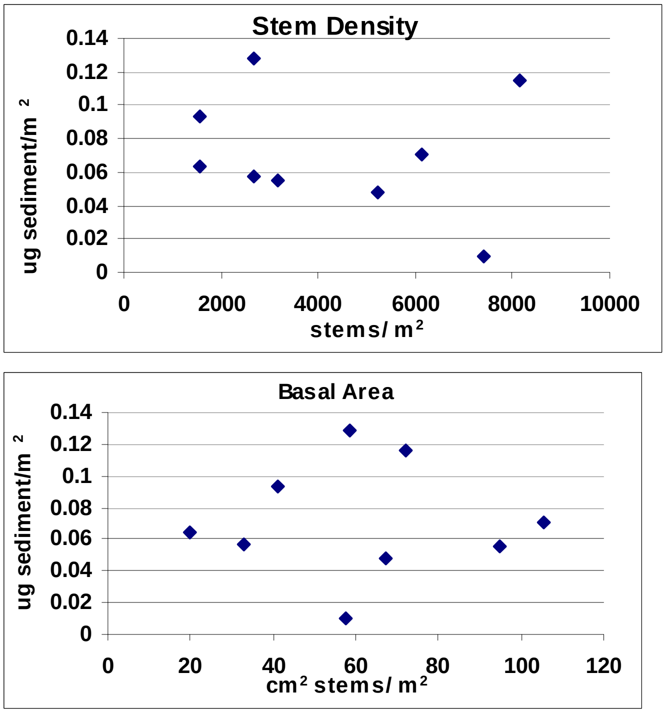


Figure 5: Spatial distribution of sediments. The sum of three weeks of sediment collection decreased with greater distance from the sediment source. More sediment accumulated at the 3 m and 15 m from the channel sites than at the 30 m sites.



Figures 6 & 7: The effect of *Spartina patens* coverage on sediment deposited. Within this dataset, there were no apparent trends.

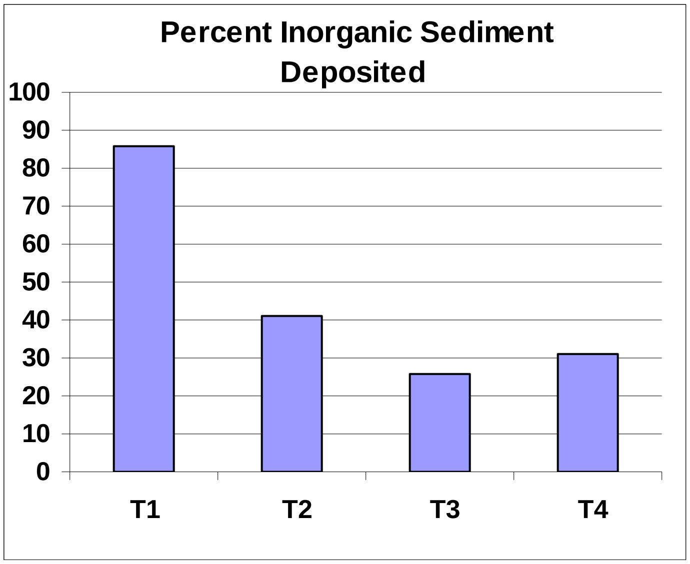


Figure 8: The average percent inorganic content of all of the sediment collections. As the sites get further from the sediment source, the percent inorganic sediment decreases. This shows that resuspension of inorganic matter is not prevalent.

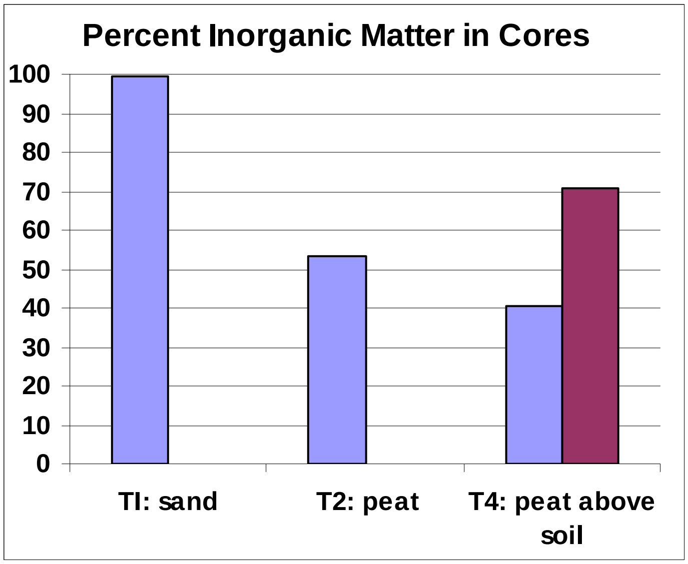
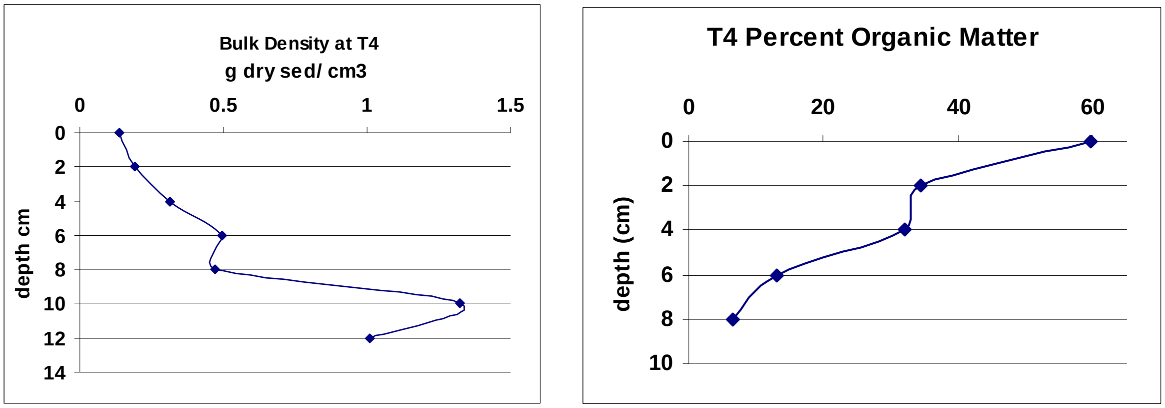
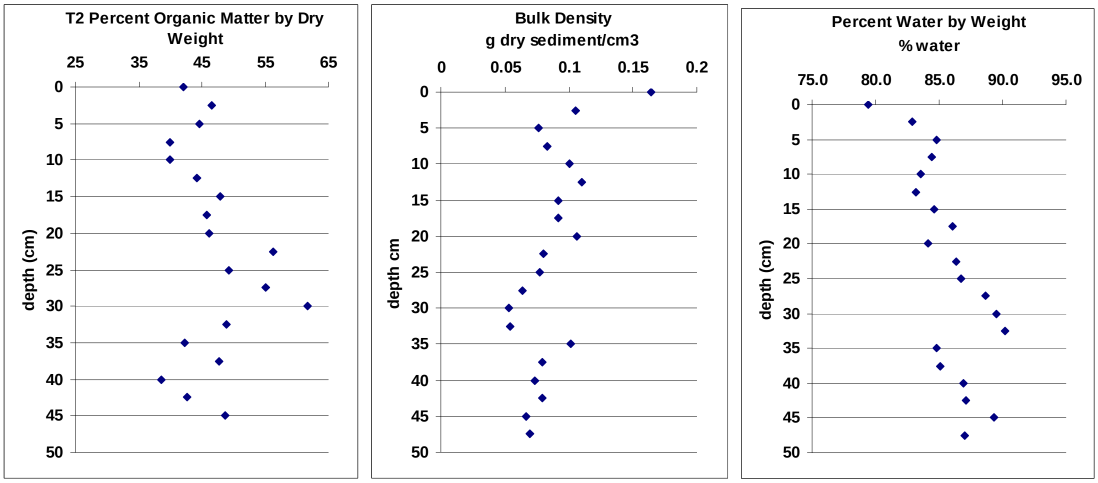


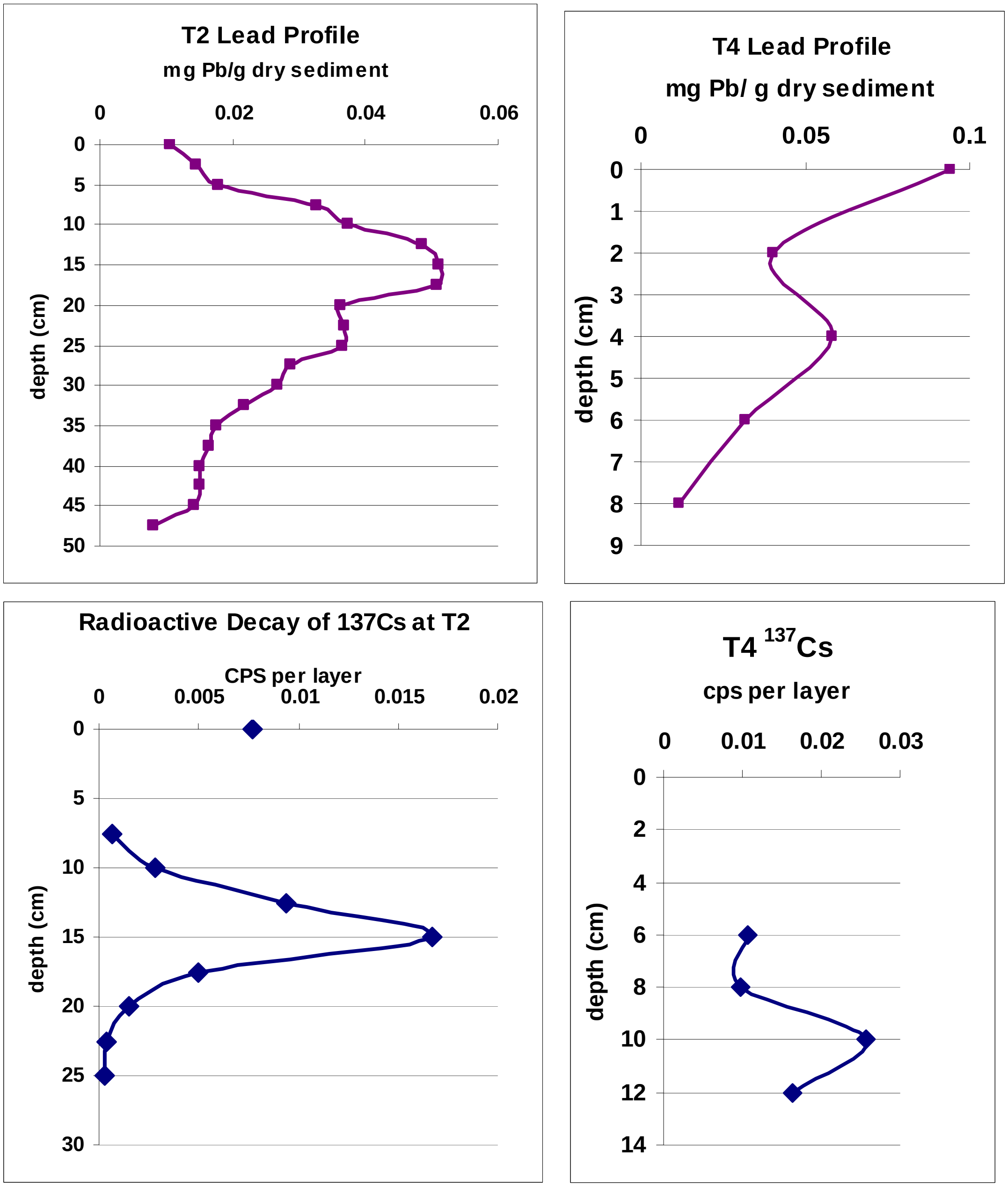
Figure 9: The average percent inorganic material found in the sediment follows the same trend as the sediment collected from the marsh surface if only the top layer of peat at T4 is considered rather than the entire core, which included soil (the purple bar).



Figures 10 & 11: It is apparent that the composition of the marsh substrate changes drastically at 10 cm deep. This indicates that this site is located in a place that the marsh has spread into relatively recently.



Figures 12, 13, & 14: In contrast to T4, at T2 the water content and bulk density were fairly uniform throughout the core. There was a slight increase in percent water with depth and a slight decrease in density. There was a slight decrease in percent organic matter with depth. These data emphasize how slow the decomposition process occurring in the marsh is.



Figures 15, 16, 17, & 18: At T2, peak concentrations of both Pb and 137Cs were more easily identified than at T4. At T2, the peak Pb and 137Cs concentrations clearly are found at a depth of 15-17.5 cm.

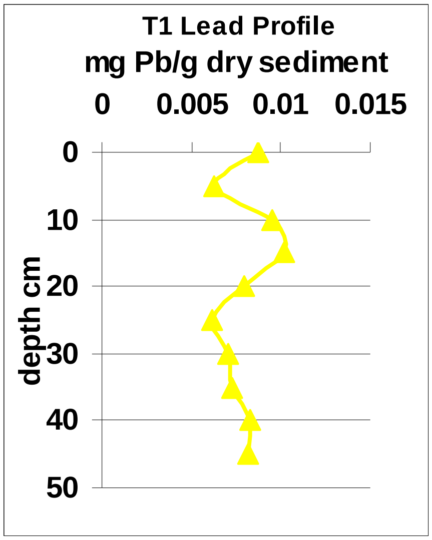


Figure 19: The concentrations of lead found in the T1 core were much lower than those in the other two cores and the maximum is less distinguished.

Tables

Hours of Tidal Coverage Experienced at Each Site

Transect, site	Measured water height (cm)	Min WFH tide height (cm)	(ft)	Hours of flood coverage
T1 A	**46**	**113**	**3.7**	**86.9**
T1 B	**3**	**155**	**5.1**	**2**
T1 C	**0**			
T2 A	**56**	**102**	**3.4**	**138.5**
T2 B	**37**	**121**	**4**	**40.4**
T2 C	**32**	**127**	**4.2**	**28.3**
T3 A	**46**	**112**	**3.7**	**86.9**
T3 B	**30**	**128**	**4.2**	**28.3**
T3 C	**37**	**121**	**4**	**40.4**
T4 A	**16**	**143**	**4.7**	**11.3**
T4 B	**7**	**152**	**5**	**3.3**
T4 C	**4**	**154**	**5.1**	**2**

Table 1: Calculating the hours of flood coverage at each site, Nov. 16-Dec 11. The depths at each site were measured during the highest tide that occurred during the sediment collections on December 5th, 7:40 AM.

Total and Inorganic Sediment Deposits μg/ m^2 by site and week

		T1	T2	T3	T4
Wk 2 sed	**A**	**0.028**	**0.036**	**0.020**	**0.008**
	B	**1.730**	**0.014**	**0.015**	**0.014**
	C	**0.914**	**0.001**	**0.005**	**0.002**
Wk 2 inorg	**A**	**0.017**	**0.022**	**0.008**	**0.005**
	B	**1.679**			**0.006**
	C	**0.868**		**0.005**	
Wk 3 sed	**A**	**0.149**	**0.081**	**0.057**	**0.023**
	B	**0.859**	**0.032**	**0.077**	**0.021**
	C	**0.088**	**0.022**	**0.030**	**0.000**
Wk 3 inorg	**A**	**0.119**	**0.012**		**0.001**
	B	**0.760**	**0.009**	**0.002**	**0.004**
	C	**0.075**	**0.015**	**0.004**	
Wk 4 sed	**A**	**0.051**	**0.012**	**0.018**	**0.027**
	B	**0.449**	**0.025**	**0.023**	**0.029**
	C	**0.055**	**0.024**	**0.022**	**0.008**
Wk 4 inorg	**A**	**0.031**	**0.003**	**0.007**	**0.014**
	B	**0.426**	**0.007**	**0.003**	**0.010**
	C	**0.040**	**0.024**	**0.011**	**0.002**
Total 3 wks	**A**	**1.057**	**0.048**	**0.058**	**0.010**
	B	**3.038**	**0.071**	**0.115**	**0.064**
	C	**1.057**	**0.048**	**0.058**	**0.010**
Total inorg	**A**	**0.168**	**0.037**	**0.015**	**0.021**
	B	**2.866**	**0.016**	**0.005**	**0.020**
	C	**0.983**	**0.039**	**0.019**	**0.002**

Table 2: Sediment deposition weighed on filters, scaled up to μg/ m^2, total and inorganic. Averages of 2 replicates are represented when possible.