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Accretion, Sediment Deposition and Suspended Sediment Dynamics in  
Mugu Lagoon, a Southern California Coastal Estuary

A thesis submitted in partial satisfaction  
of the requirements for the Master of Science  
in Environmental Health Science

by

Jordan Alexander Rosencranz

2012



## ABSTRACT OF THE THESIS

Accretion, Sediment Deposition and Suspended Sediment Dynamics in  
Mugu Lagoon, a Southern California Coastal Estuary

By

Jordan Alexander Rosencranz

Master of Science in Environmental Health Science

University of California, Los Angeles, 2012

Professor Richard F. Ambrose, Chair

Vertical accretion, the aggregation of material on a wetland surface, depends on organic matter accumulation and mineral sedimentation. We measured suspended sediment concentrations by total suspended solids (TSS), sediment deposition and vertical accretion rates in four marsh zones in the central basin of Mugu Lagoon, a salt marsh dominated by *Salicornia pacifica*. Mean TSS was  $21 \pm 1 \text{ mg l}^{-1}$  (Mean  $\pm$  SE) between February and May 2012, which is within the middle of the range of other salt marshes. Mean sediment deposition ranged from  $0.00 \text{ g m}^{-2} \text{ day}^{-1}$  to  $1.29 \text{ g m}^{-2} \text{ day}^{-1}$ , which is in the low end of the range of other salt marshes. No net vertical accretion was observed between August 2011 and May 2012. Our results indicate that for high and high-mid marsh zones, sedimentation was highest adjacent to the creek. Interestingly, organic matter concentration in TSS varied with tide height, but mineral content did not. While more data are needed to confirm whether these trends occur over longer time periods, our study is one of the first to characterize spatial and temporal variation in sediment dynamics for a salt marsh dominated by *Salicornia* species.

The thesis of Jordan Alexander Rosencranz is approved.

Peggy M. Fong

Irwin H. Suffet

Richard F. Ambrose, Committee Chair

University of California, Los Angeles

2012

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## INTRODUCTION

Among a myriad of ecosystem services, salt marshes provide nursery habitat for fisheries, trap pollutants, mitigate wave disturbance during storms, and store more carbon per unit area than any ecosystem on earth (Costanza et al. 1997, Chmura et al. 2003). Despite their intrinsic value, past and current anthropogenic destruction and predicted sea-level rise (SLR) threaten these invaluable resources (Morris et al. 2002, Rahmstorf 2007, Mudd 2011). In southern California, nearly 75% of the historical 200 km<sup>2</sup> of coastal wetlands have been lost (PERL 2000, SCCWRP 2010). In addition to SLR and anthropogenic disturbance, lack of riverine sediment can contribute to the disappearance of coastal salt marsh (Day et al. 2000, Mudd 2011). Therefore to protect, preserve, and restore salt marsh, there is a fundamental need to understand vertical accretion, the aggregation of material on a wetland surface, and associated sediment dynamics in salt marsh ecosystems.

Vertical accretion is a key factor in determining how marshes maintain elevation above mean sea level and is dependent on the interaction between organic processes and inorganic sedimentation. Once mobilized from a sediment source, inorganic sediments are delivered to the marsh surface via a tidally influenced water source such as a creek (Reed et al. 1999). In general, trapping and settling of mineral sediments on the marsh surface depends on the reduction of surface water velocity, which is tied to the amount of organic matter present above and biomass processes below the marsh surface (Mudd et al. 2010, Day et al. 2011, Moskalski and Sommerfield 2012). Vegetation causes a reduction in tidal velocity, allowing sediment in the water column to adhere to organic matter and above ground biomass and eventually settle on the marsh surface.

Total suspended solids (TSS; an estimate of suspended sediment concentrations (SSC)), which also include organic material, are useful estimates of inorganic sediment available in the water column (i.e. tides) for deposition to the marsh surface (Stumpf 1983, Moskalski and Sommerfield 2012). Reed et al. (1999) determined that spatial patterns of sedimentation were influenced by tidal creeks. For example, SSC declines with distance from the edge of a tidal creek (Reed et al. 1999, Moskalski and Sommerfield 2012). Spatial variation may also be dependent on direct trapping and flow obstruction by vegetation (Li and Yang 2009). Studies investigating TSS often deploy sediment traps, consisting of flat surfaces such as filter paper or plastic material with a known diameter, in conjunction with siphon samplers to quantify how effective the marsh is at trapping suspended sediment and how sediment transport and deposition are correlated (Leonard 1997, Reed et al. 1999, Leonard et al. 2002, Moskalski and Sommerfield 2012).

Mineral deposition is an episodic process, highly dependent on storm events (Reed 1989, Cahoon et al. 1996). Reed (1989) examined the effect of winter storms on mineral deposition, showing that sediment mobilization from winter storms was the primary driver of sedimentation on the surface in a Louisiana marsh. Similar to Reed's (1999) study, researchers have observed similar patterns in southern California marshes and rivers with infrequent storm events leading to lasting changes in marsh hydrology and geomorphology (Onuf 1987, Cahoon et al. 1996, Mertes et al. 1998, Wallace et al. 2005, Zedler 2009). Wind-driven waves and direct precipitation on the marsh surface may also be responsible for elevated mineral sediment deposition (Mwamba and Torres 2002, Wallace et al. 2005, Moskalski and Torres 2012). All of these mechanisms influence mineral sediment deposition within a marsh, which ultimately affects vertical accretion and, thus, the long-term stability of a marsh.

Studies by Wallace et al. (2005), Weis et al. (2001) and Cahoon et al. (1996) highlight the impact of infrequent storm driven sedimentation events on accretion rates in southern California, as well as the fact that the majority of information on sedimentation in southern California comes from the Tijuana Estuary. Cahoon et al. (1996) determined that marsh zones ranging from high marsh (dominated by *Salicornia pacifica*) to poorly drained low marsh zones (dominated by *Spartina foliosa*) respond differently to sedimentation events. Cahoon et al. (1996) observed that low marsh zones were the most responsive to episodic stream flows, while high marsh zones received little to no sedimentation during heavy storm inputs. While this information from Tijuana Estuary is useful for predicting sedimentation patterns in southern California, sedimentation processes in Tijuana Estuary may not be representative of other southern California salt marshes because of past and current land management practices.

Therefore, in order to improve our understanding of spatial and temporal patterns of sediment transport and deposition in southern California, we should investigate sedimentation patterns at other wetlands. With increased knowledge of these patterns, we can strengthen our predictions of how southern California marshes will respond to drought and storms. Our study examined how physical and spatial characteristics of tidal creeks and marsh zones, delineated by an elevation gradient from the seaward side of the marsh to the upland area, may impact sediment transport (TSS), sediment deposition patterns and long-term patterns such as vertical accretion at a southern California natural reference site at Mugu Lagoon. Our study compared sedimentation patterns between a high order creek, or main tidal channel, and its lower order branches. We were also interested in the variation of TSS across seasonal timescales and between tidal heights. Therefore, we tested the following hypotheses:

- 1) TSS, sediment deposition, and vertical accretion rates vary inversely with respect to creek order (low to high), distance from tidal creek (edge to interior), and marsh zone. (low marsh to the upland transition zone)
- 2) TSS, sediment deposition, and vertical accretion rates increase with respect to storms and relatively high tides, which scour tidal channels at greater velocities and slow storm inputs down during storm events.

Our study is one of the first to characterize spatial and temporal variation in sediment dynamics for a salt marsh dominated by *Salicornia* species.

## METHODS

### *Study Site*

Located within Naval Base Ventura County at Pt. Mugu, Mugu Lagoon (34° 06'N, 119° 05'W) is a branched estuary with three open water basins bordered by approximately 380 ha of salt marsh with a network of tidal channels and lower-order creeks (Figure 1). Our study focused on four representative marsh strata, zones defined by characteristic vegetation patterns and relative elevation (although our low marsh plots were not dominated by *Spartina* species), along a dendritic tidal creek approximately 1.1 kilometers in length within the central basin of the estuary (Figure 1). This site was chosen to study the physical properties of the tidal creeks since it is one of the least impacted regions of the lagoon.

### *Monitoring Stations*

In addition to being an ideal southern California reference site, the study location was chosen based on its appropriate size and accessibility for this type of investigation. The tidal creek we studied meanders the extent of the four representative marsh zones of interest – low (closest to the mouth of the estuary), mid, high-mid, and high (near the upland transition zone;

Figure 1). Figure 1 shows a representative set of fixed point monitoring stations within the low marsh zone. We marked the location of plots with gray polyvinyl chloride (PVC) conduit piping at the edge, 5m, 10m and 20m from the tidal creek of interest (Figure 1).

### *Total Suspended Solids*

Sixteen single-stage siphon samplers (11; (Inter-Agency Committee on Water Resources 1961)) were deployed among 32 fixed point stations during over-marsh flood tides from February to April 2012, such that the 5m and 10m stations were sampled during one flood tide and the edge and 20m stations were sampled during the following or previous flood tide of similar height. This was done to avoid carrying excessive amounts of water. Samplers were collected the following day, transported in a cooler on ice and refrigerated at 4°C for no longer than a week before analysis. Blank 50mm pall/Gellman A/E glass fiber filters were washed with distilled water and dried for one hour at 103-105°C, then cooled in a desiccator. The 1l sample was mixed using a magnetic stir plate. Then a 500ml subsample was passed through the clean pre-weighed filter using a vacuum hose filtration set-up. Samples were dried at 103-105°C for one hour, cooled in a desiccator and weighed in mg. Samples were dried for another 20-30 minutes, cooled in a desiccator, and re-weighed to confirm original weights. We also filtered 500 ml of distilled water through three method blank filters, which were oven dried with the other samples and reweighed. All filters were heated in crucibles in a muffle furnace at 450°C for 10 hours to determine weight of inorganic and organic solids (Day et al. 2011).

### *Sediment Deposition*

Sediment deposition was measured using a rubber jar opener method (Callaway et al. 2009), which consisted of a stack of two slightly textured rubber disks approximately 11.4cm diameter secured to a double light switch plate. Similar to Reed's (1989) filter paper method,

each instrument was secured to the marsh surface with four 10.5cm long nails with a uniform head diameter (Figure 2). Prior to installation, the top rubber disk was washed with distilled water, dried at 70°C for at least 48 hours, cooled in a desiccator and weighed to the nearest 0.000g.

We deployed 32 sediment deposition disks at fixed-point stations for two-week periods from February 2012 to April 2012. During collection, the top disk was removed and placed in a Ziploc bag, while the nails were wiped clean. Any debris or feces (usually rodent or bird) was removed from the top sediment deposition disk before it was put in the Ziploc bag. Any sign of physical disturbance such as pecking by birds was noted. Sediment on the bottom disk was removed and a clean pre-weighed rubber disk was secured on top of the bottom disk with four 10.5 cm nails. Although we sampled for five two-week periods from February 21, 2012 to May 3, 2012, we only included the initial sample of these sampling periods in the results due to field degradation of re-used sediment deposition disks and consequent weighing errors.

Samples were brought back to the lab on ice and oven dried at 70°C for 48 hours, cooled in a desiccator for 20 minutes, and weighed to the nearest 0.000g. We conducted a second weighing after 30 more minutes of oven drying to ensure the sample was completely dry. We used method blanks for each part of the lab analysis. After weighing, disks were cleaned with a wire brush, rinsed with distilled water and reused. Sediment deposition rates were calculated by dividing the number of grams by the surface area of the disk (minus the surface area of the nail head) and the number of days in the field (~two weeks).

### *Vertical Accretion*

Feldspar marker horizons were installed in August 2011 in duplicate along at 32 fixed point stations (Cahoon and Turner 1989). Using a 200ml scoop, we sprinkled 6-8 scoops full of

dry Custer Feldspar clay within the perimeter of a 0.5m by 0.5m quadrat, shaking the vegetation thoroughly after each scoop. Corners of the plots were staked with a gray PVC pipe.

The initial sampling date, October 8, 2011, was scheduled to occur before the rainy months of October-April; however, one storm (~3cm of precipitation) occurred on October 5, 2011. While Cahoon and Turner (1989) and Cahoon et al. (1996) used a coring technique to sample feldspar plots, we used a less destructive method since we intended to sample these plots for many years. The sampling method consisted of visually surveying the plot to see if any feldspar was exposed. If feldspar was visible in any area of the plot, we recorded accretion as zero. Since there was often sediment covering some of the feldspar in a portion of the plots, our estimates of accretion are likely conservative. If the plot was 100% covered by sediment, we carefully extracted three soil plugs with a kitchen knife, measuring the newly formed sediment layer with a ruler or calipers to the nearest mm (Figure 3).

#### *Data Analysis*

We calculated total monthly rainfall from data collected at Camarillo Airport Weather Station (KCMA: (Wunderground.com 2012)). All ANOVAs and data transformations were conducted in SYSTAT 13.0. First, we square root transformed all of the data to ensure normality. Two one-way ANOVAs were conducted to determine the effects of NOAA predicted tide height and creek order. We conducted two-factor ANOVAs to investigate the effects of distance from tidal creek and marsh zone. For two-way ANOVAs of the total suspended solid data, we did not include the samples taken from 20m since these samplers did not fill during the sampling period. We used Tamhane's T2 correction for pairwise comparisons of samples with unequal variances (Tamhane 1977).

## RESULTS

### *Rainfall*

Total rainfall between June 2011-May 2012 at Camarillo Airport was 8.8cm, which was below the average of 15.6cm for that time range. October, November and April showed above average monthly precipitation, while all other months, notably February, were well below average (Figure 4). February, which is typically the region's wettest month and when the study period began for monitoring sediment deposition, had a deficit of 9.3cm (Figure 4). Storms with ~3cm or more of precipitation occurred on October 5, November 11, January 21-23, March 26, and April 10-14

### *Total Suspended Solids*

Mean TSS for all stations ( $N=64$ ) was  $21 \pm 1 \text{mg l}^{-1}$  (Mean $\pm$ SE) between February and May 2012. While TSS consisted of predominately mineral content, concentrations of OM were seasonally variable ( $N=64$ ,  $F=30.859$ ,  $P<0.001$ ), with OM concentrations lowest in February (Figure 5a). The higher OM concentrations in March and April were associated with storm events in those months (Figure 4). No other significant seasonal effects were observed in any of the other suspended sediment variables (TSS:  $N=64$ ,  $F=2.034$ ,  $P=0.119$ ; Mineral:  $N=64$ ,  $F=2.108$ ,  $P=0.109$ ).

OM was also influenced by tide height ( $N=64$ ,  $F=15.882$ ,  $P<0.001$ ). Significant differences were observed for OM concentrations during 1.7m and 2.0m tides (Figure 5b). No significant tide effect was found for the other suspended matter variables (TSS:  $N=64$ ,  $F=0.352$ ,  $P=0.788$ ; Mineral:  $N=64$ ,  $F=1.197$ ,  $P=0.319$ ).



Creek order did not appear to influence any of the suspended sediment variables (Figure 6; one-way ANOVAs: TSS:  $N=64$ ,  $F=2.126$ ,  $P=0.150$ ; Mineral:  $N=64$ ,  $F=2.267$ ,  $P=0.137$ ; OM:  $N=64$ ,  $F=0.028$ ,  $P=0.868$ ).

Based on our two-factor ANOVA, we found no significant effects of distance from tidal creek and marsh zone on any of the dependent variables (Table 1). Figure 7 shows high standard error bars characteristic of most of our monitoring stations, making it difficult to detect relationships. However, our results suggest that OM and TSS increase with distance from tidal creek in the mid marsh, and there is a decline in OM and TSS with distance from the edge of tidal creeks (up until 10m since our 20m samplers didn't fill) in the high-mid marsh. More data are needed to confirm whether these trends occur over longer time periods and in other marsh zones. More data are also needed to confirm whether the trend observed in the high-mid marsh continues at 20m.

### *Sediment Deposition*

No effect of creek order was observed for sediment deposition (Figure 8;  $F=0.211$ ,  $P=0.650$ ).

Mean sediment deposition observed in February and March 2012 ranged between  $0.00 \text{ g m}^{-2} \text{ day}^{-1}$  to  $1.29 \text{ g m}^{-2} \text{ day}^{-1}$ . We found no effects of stratum or distance on sediment deposition patterns (Table 1). There is an indication of higher sedimentation at the creek edge for the high and high-mid marsh strata, but there were large differences among replicates for these marsh strata (Figure 9). More data are needed to confirm whether this trend occurs over longer time periods. Lastly, no storms occurred prior to or during the sampling period, which coincided with a relatively low high tide event for the study period.

### *Vertical Accretion*

No measurable accretion was observed in any of the plots surveyed. During both sampling periods, feldspar layers were visible on all of the plots, although portions of some plots showed some sedimentation. No plots were lost due to bioturbation; however, due to extremely dense vegetation cover, we were unable to survey both plots at a high-mid marsh station, which were 20m from a low order creek. Furthermore, all of the low marsh feldspar plots were characterized by patchy algal matting, which didn't appear in the other strata.

### DISCUSSION

Between February and May 2012, TSS at Mugu Lagoon ranged from  $10\text{mg l}^{-1}$  to  $46\text{mg l}^{-1}$ , which was within range of other TSS/SSC values observed in North America and Europe (Leonard 1997, Reed et al. 1999, Moskalski and Sommerfield 2012). Moskalski and Sommerfield (2012) detected between  $10\text{mg l}^{-1}$  and  $190\text{mg l}^{-1}$  over the surface of a Delaware Marsh, observing the highest SSC 1m into a tidal channel. Moskalski and Sommerfield (2012) also noted that erosion and scour of the vertical banks lead to atypical SSC values. In North Carolina, Leonard (1997) measured TSS that ranged from  $8\text{mg l}^{-1}$  to  $38\text{mg l}^{-1}$ , where a similar pattern of decreasing TSS from the tide channel to the marsh interior was observed. Leonard et al. (2002) detected a range of TSS from approximately  $15\text{mg l}^{-1}$  to  $35\text{mg l}^{-1}$  in the Chesapeake Bay (Leonard et al. 2002), with TSS decreasing from the tidal creek to the interior. In eastern England, Reed et al. (1999) observed SSC typically lower than  $20\text{mg l}^{-1}$ . Overmarsh SSC and TSS typically decrease from the edge of a tidal creek to the interior, with the highest values in the tidal channel. While our study was not designed to detect in-channel TSS, we would expect in-channel TSS to be higher than the overmarsh values we observed. Furthermore, since we did not observe any erosion or scour within the immediate area of our stations during the study, we

would not expect to see high SSC/TSS similar to Moskalski and Sommerfield (2012). With more severe storms than occurred during our study, we would likely see more erosion and scour along the vertical banks within the marsh and, therefore, TSS would increase beyond the range we observed. Lastly, depending on the intensity of the storm, we would also expect an influx of sediment from the Calleguas Creek watershed that would alter TSS.

The effect of tide height on TSS is less clear in Mugu and may not follow similar patterns shown in other marshes (Leonard 1997, Reed et al. 1999, Moskalski and Sommerfield 2012), where TSS increases with higher tides. While we observed a significant difference in OM between tide heights (Figure 5b), TSS and mineral content did not vary with respect to tide height. Significant differences in OM between 1.7m tides to 1.8m tides could be explained by the effect of a storm on March 26, since 1.7m tides were sampled prior to this storm and immediately following a prolonged dry period in February and early March. However, it is surprising that TSS did not vary with respect to tide height in the same way OM did. More data from different tide heights are needed to explain the differences between OM and TSS over longer time periods. Since we did not sample directly after storms, we were unable to observe direct impacts of these storm inputs. However, storms (~3 cm of precipitation) in March and April could have caused scouring and erosion within the Calleguas Creek watershed delivering sediment to the estuary. The storms could also have caused scouring and erosion within the marsh itself, especially along vertical creek banks, increasing the amount of sediment available for re-suspension by tidal action.

Considering below average rainfall and the extended dry periods between the five storms (~3cm of precipitation) during the study period, it is not unexpected that we observed no net accretion. Cahoon et al. (1996) determined that accretion rates in the low marsh zone of Tijuana

Estuary, which is dominated by *Spartina foliosa*, ranged from 1.5-4.5cm yr<sup>-1</sup> and were almost entirely dependent on storm inputs. However, despite extensive sedimentation in the low marsh, only ~0.1cm yr<sup>-1</sup> accreted in the high marsh zone dominated by *Salicornia* during their 17-month study period. Our experimental design did not incorporate low marsh areas dominated by *Spartina*, but our plots would compare to feldspar plots installed by Cahoon et al. (1996) in high marsh dominated by *Salicornia*. While our results indicate that accretion at Mugu Lagoon was zero during our study period, more long-term data are needed to compare accretion in high marsh zones at Tijuana and our study area.

On a longer time scale than Cahoon et al. (1996), Weis et al. (2001) found that accretion rates in Tijuana Estuary caused a total elevation increase of 17.0cm throughout the marsh over a 35-year period, for an average accretion of 0.5cm yr<sup>-1</sup>. Wallace et al. (2005) measured vertical accretion rates in Tijuana Estuary of 1.3cm yr<sup>-1</sup> during a five-year study period. At Mugu Lagoon, Chan and Ambrose (unpublished data) found accretion rates of 0.2cm yr<sup>-1</sup> over a 13-year period. Our sampling method for accretion is conservative and could have underestimated accretion at Mugu Lagoon, but it is also likely that accretion was relatively low during our study, especially since the study occurred during a low-rainfall year. During exceptionally high rainfall years at Mugu Lagoon, storm events increased stream flows and the led to the direct discharge of Calleguas Creek sediments into the central basin and eastern arm (Onuf 1987). These episodic storm events deposited extensive amounts of sediment into what was a vast expanse of open water at Mugu Lagoon, effectively lowering the water level by 42% (Onuf 1987). While Onuf (1987) predicted that similar storm inputs would cause Mugu to continue to fill with sediments until it resembled an alluvial fan, we have yet to see a similar sedimentation event at Mugu Lagoon, despite some years of exceptionally high rainfall. Onuf's (1987) report illustrates the

episodic nature of sedimentation events in southern California. More data are needed to determine accretion rates that are representative of accretion on longer time scales.

While our sediment deposition data were limited to a two-week period, our sediment deposition values, ranging from  $0.00 \text{ g m}^{-2} \text{ day}^{-1}$  to  $1.29 \text{ g m}^{-2} \text{ day}^{-1}$ , fall within the lower range of what previous studies have found. In June 2007, in the St. John's River estuary, Moskalski and Sommerfield (2012) observed a range of sediment deposition values from  $0.45 \text{ g m}^{-2} \text{ day}^{-1}$  to  $56.93 \text{ g m}^{-2} \text{ day}^{-1}$ . Leonard (1997) observed sediment deposition rates for a year using petri dish sediment traps, which ranged between  $13.8 \text{ g m}^{-2} \text{ day}^{-1}$  and  $63.7 \text{ g m}^{-2} \text{ day}^{-1}$ , in a marsh zone adjacent to Bradley Creek in southeastern North Carolina marsh. Leonard (1997) found that sediment deposition in the Bradley Creek site exhibited a significant seasonal trend, with greater sediment deposition in the summer months following storms, compared to the winter months. Our sediment deposition disks were deployed in mid-February, which typically receives the most precipitation in Southern California; however, rainfall before and during the sampling period was minimal. In addition, tide heights were relatively low for this period, limiting other mechanisms by which sediment deposition could occur. It is not surprising that our sediment deposition rates were lower than Leonard's (1997) and within the lower range of Moskalski and Sommerfield's (2012) sediment deposition rates. Furthermore, since there was little sedimentation, it is also expected that short-term sediment deposition did not vary with respect to distance from tidal creek or any other spatial factor measured, which is different from the patterns observed in other studies (Leonard 1997, Reed et al. 1999, Moskalski and Sommerfield 2012).

Storms during the study period did not affect accretion. Our study period had five storms (~3cm of precipitation), but the storms were separated by extended dry periods and no storm yielded more than 4cm of precipitation. Our results would have likely been different had we

received more storms of greater intensity. Similar to Cahoon et al.'s (1996) study, we likely would have observed significantly higher sediment inputs in the low marsh zone compared to the high marsh. It's also likely that the effect of distance from tidal creek and marsh zone would have been significant for all of our dependent variables. However, these predictions are not certain as the low marsh in our study area at Mugu is not dominated by *Spartina* and accretion rates still might be uniform across all marsh zones if vegetation is the dominant mechanism driving accretion in southern California.

With predictions of sea level rise and increasing extreme weather patterns, it is clear that coastal salt marsh is extremely vulnerable to climate-induced changes. Particularly in southern California, where development has buried, fragmented and encroached on the borders of nearly 75% of salt marsh habitats, the remaining ecosystems will likely drown or become filled with sediment if we do not make watershed-level management decisions based on good science. With an improved understanding of sediment transport and deposition, we can effectively manage, enhance and restore these invaluable resources, preserving their ecosystem services and functions for the future.

Table 1: Results of a two-factor ANOVA of TSS, mineral content, organic matter, and sediment deposition as dependent on stratum and distance from tidal creek.

Variable	Ss	Df	F	P
TSS				
Strata	0.001	3	0.600	0.619
Distance	0.000	2	0.166	0.847
Strata X Distance	0.003	6	0.702	0.650
Error	0.027	45		
Mineral content				
Strata	0.001	3	0.601	0.617
Distance	0.000	2	0.351	0.706
Strata X Distance	0.002	6	0.622	0.712
Error	0.027	45		
Organic matter				
Strata	0.000	3	0.089	0.966
Distance	0.003	2	2.280	0.114
Strata X Distance	0.003	6	0.931	0.482
Error	0.027	45		
Sediment deposition				
Strata	2.862	3	0.469	0.709
Distance	4.880	3	0.800	0.516
Strata X Distance	15.700	9	0.858	0.582
Error	26.443	13		

Figure 1: Regional location map of Mugu Lagoon (bottom), location map of monitoring stations in relation to marsh stratum within the central basin (top right) and approximate locations of fixed point monitoring stations in each marsh stratum (top left).

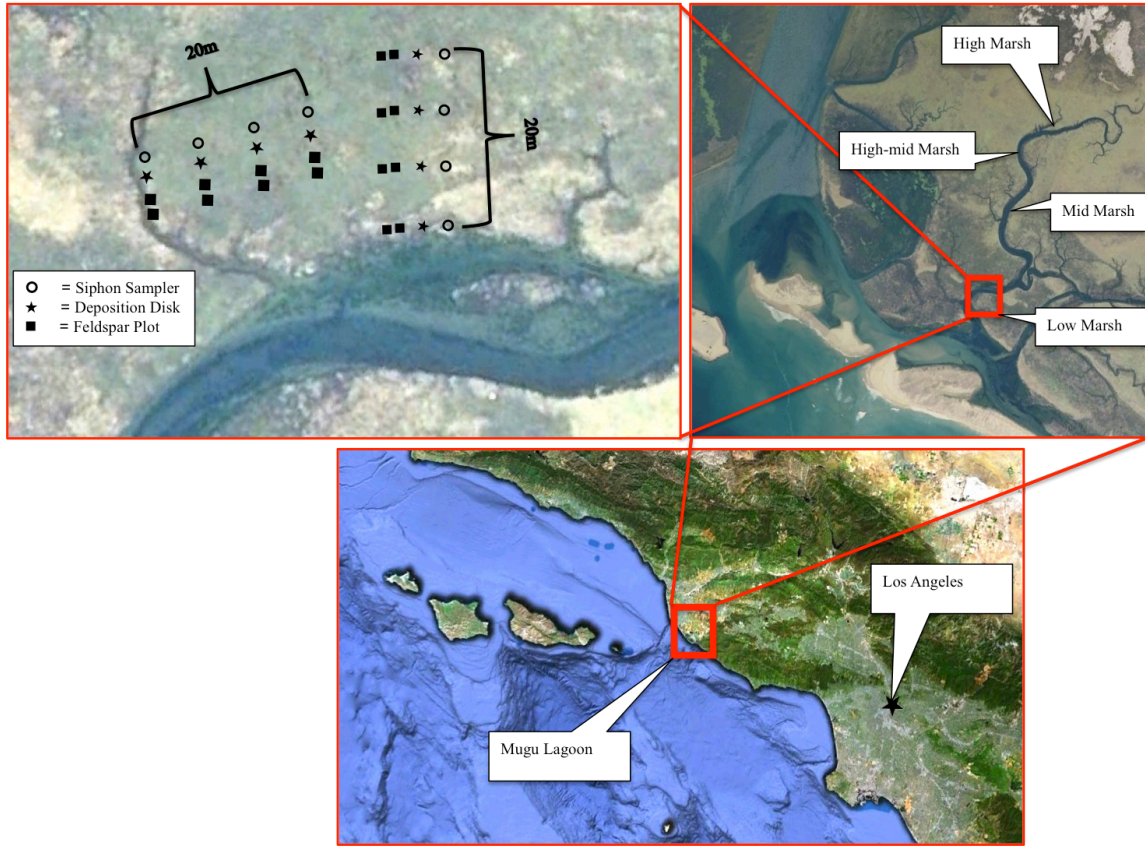




Figure 2: Sediment deposition disk placed in low marsh zone.



Figure 3: Soil plug with visible white feldspar layer (note top of feldspar layer is reddish).



Figure 4: Annual precipitation totals as recorded at Camarillo Weather Station (KCMA). Sampling dates are denoted by black stars (TSS), solid line (sediment deposition) and dashed lines (vertical accretion), while the white stars represent storm events (~3cm of precipitation)

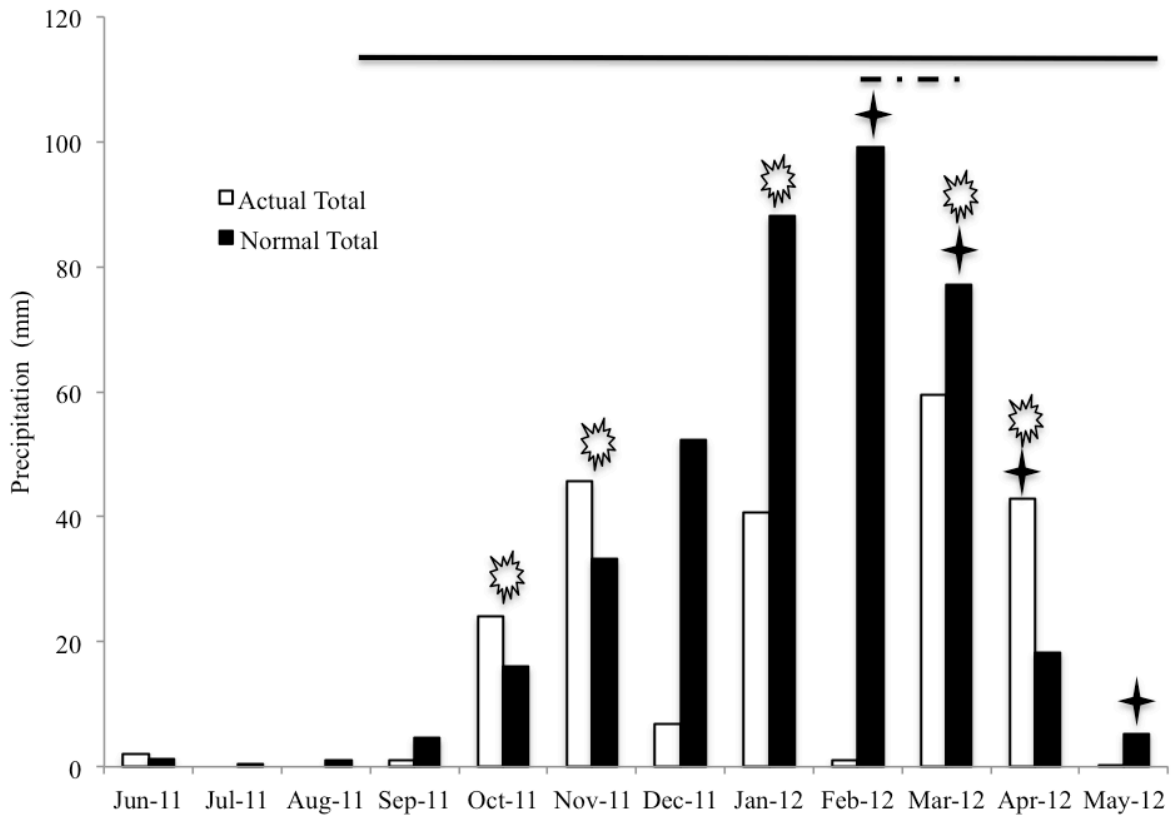
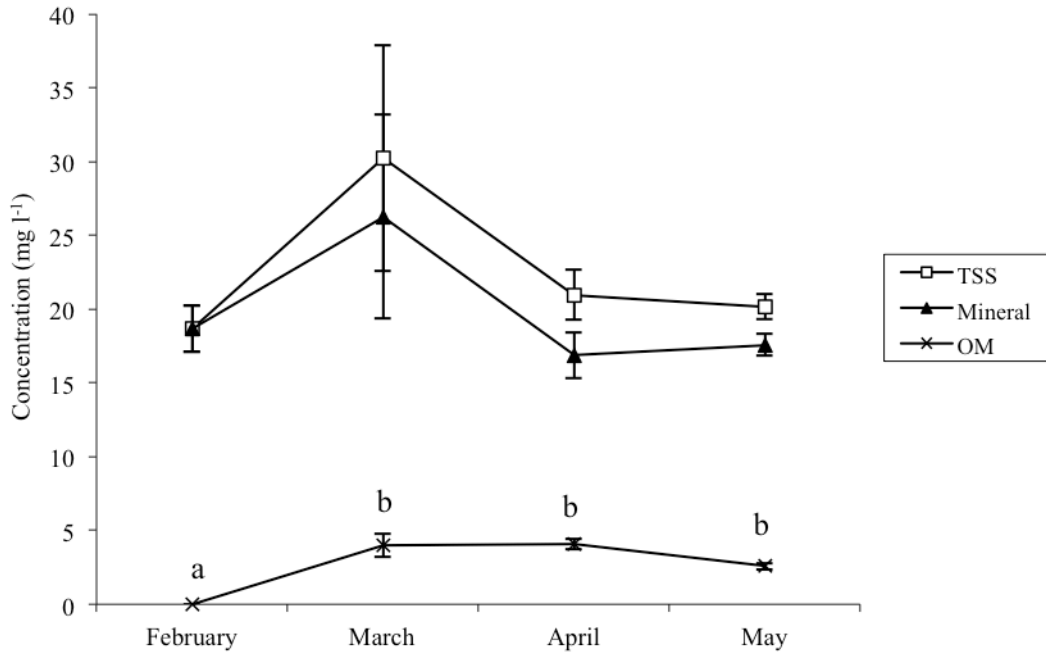


Figure 5: TSS, OM, mineral content and the effects of a) month in 2012 and b) tide height predicted by NOAA at Mugu Ocean Pier. Letters represent significant differences based on Tamhane's T2 correction for pairwise comparisons. We did not do pairwise comparisons between OM, mineral, and TSS. Error bars represent  $\pm 1$  SE.

a)



b)

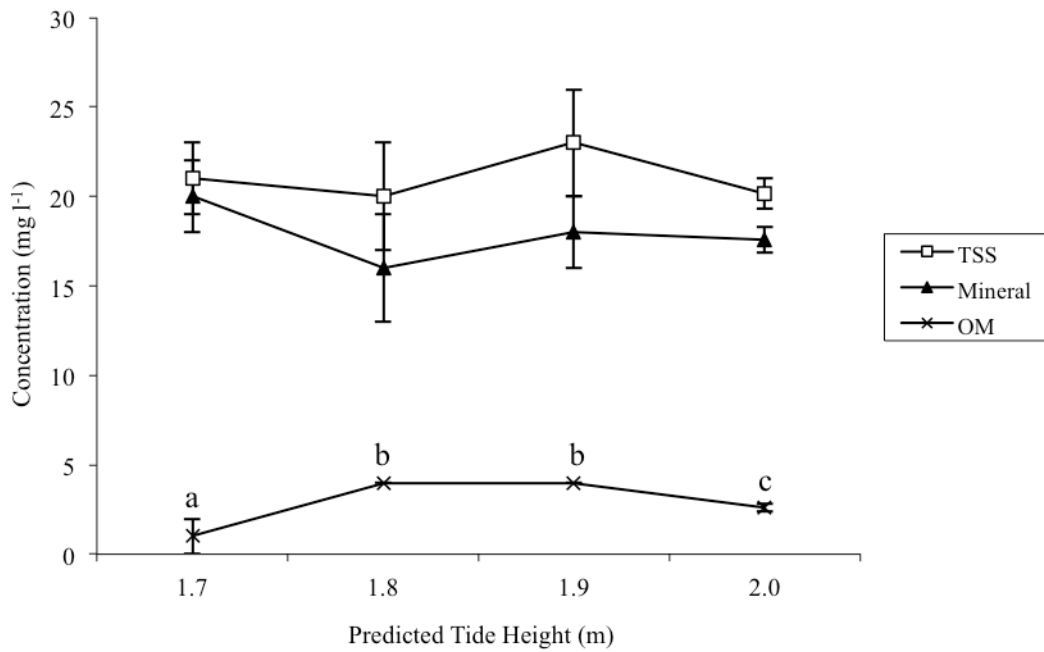


Figure 6: The influence of creek order on TSS, OM, and mineral concentrations. Error bars represent  $\pm 1$  SE.

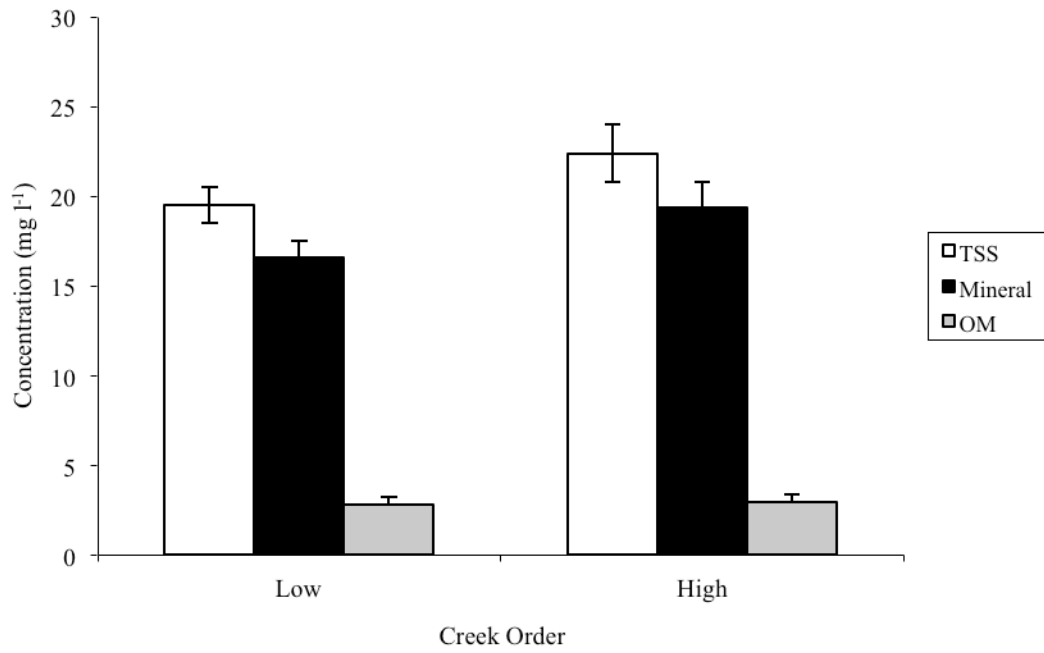
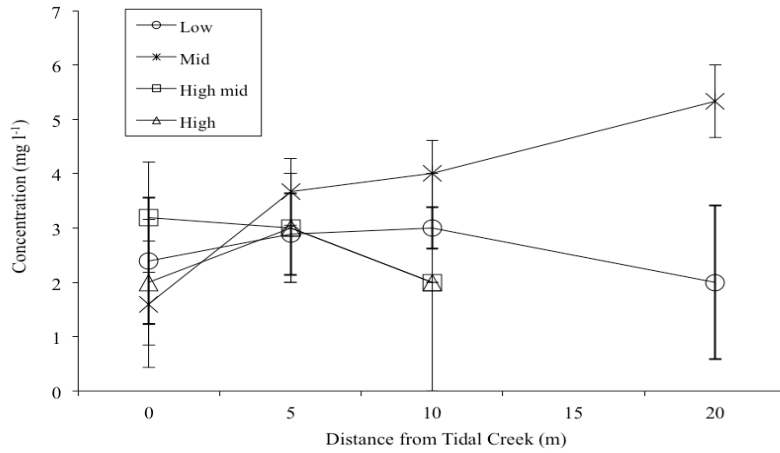
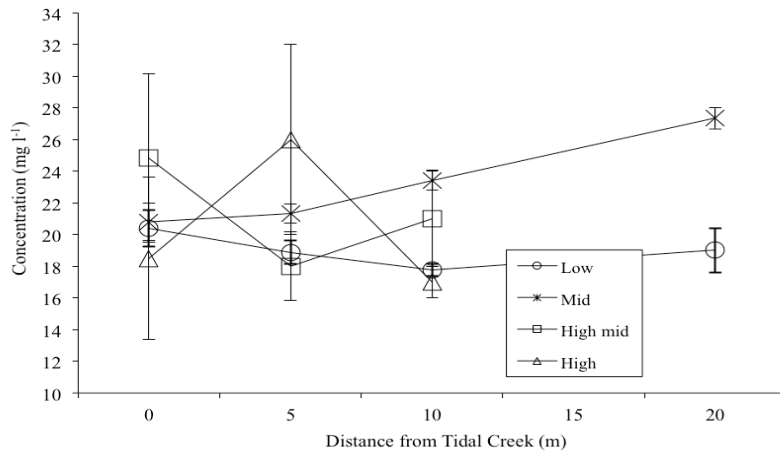


Figure 7: The influence of distance from edge of tidal creek and marsh stratum to a) OM b) mineral content and c) TSS. Samplers located 20m from edge of tidal creek did not fill in high-mid and high marsh stations. Error bars represent  $\pm 1$  SE.

a)



b)



c)

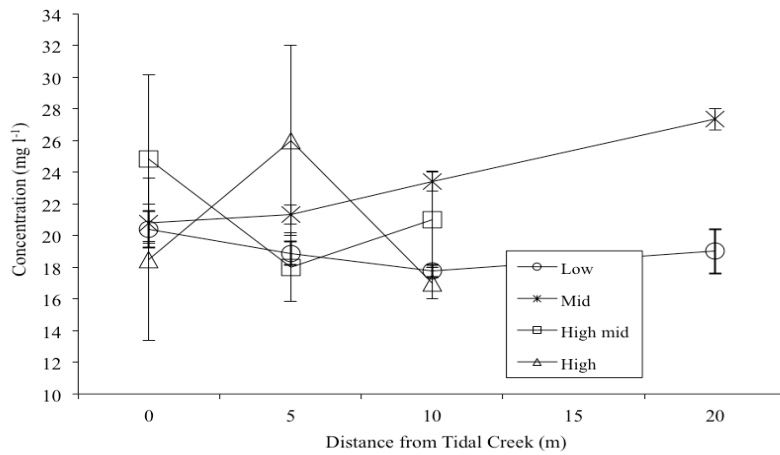


Figure 8: The influence of creek order on sediment deposition. Error bars represent  $\pm 1$  SE.

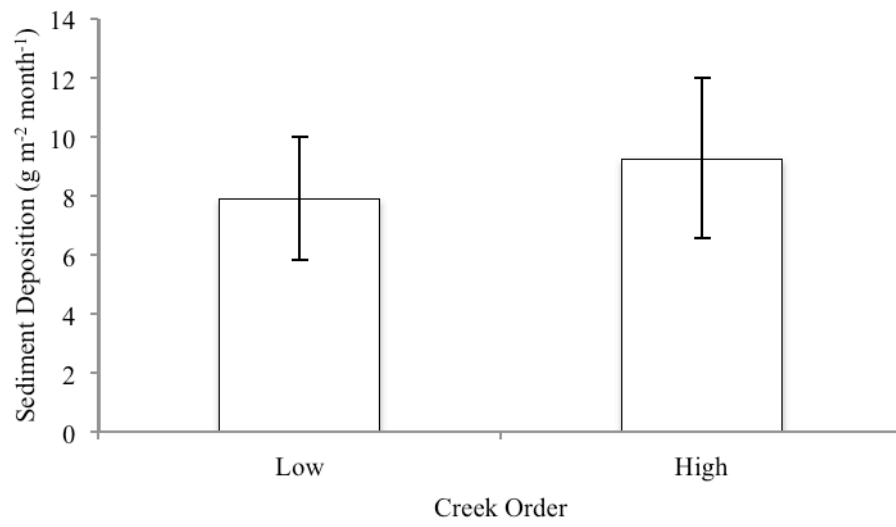
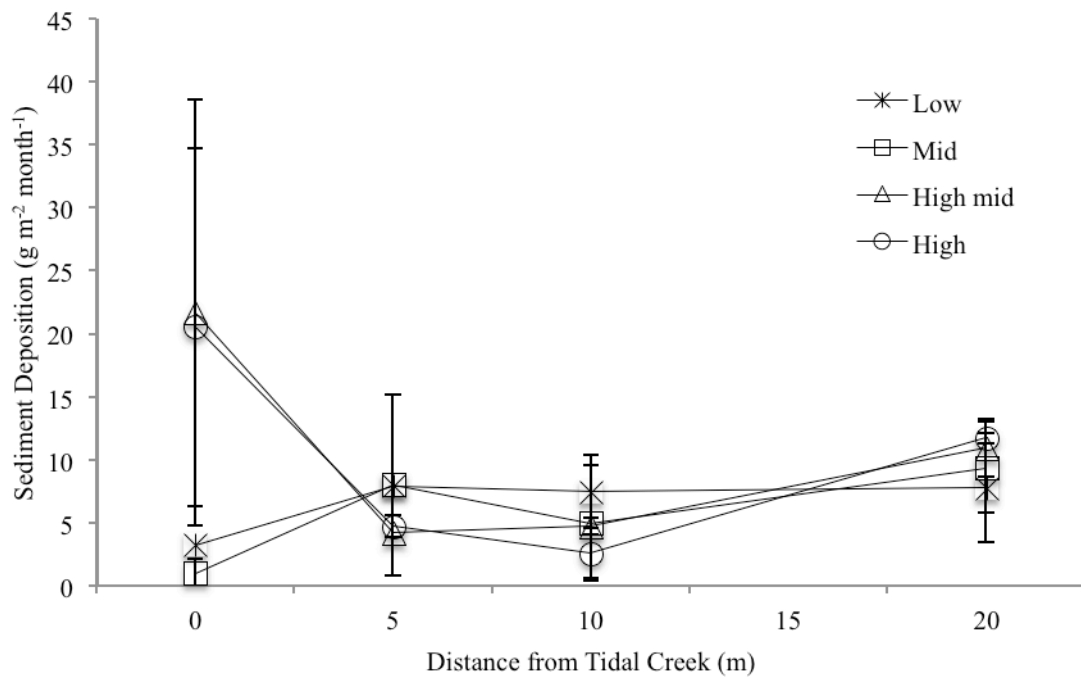


Figure 9: The influence of distance from edge of tidal creek and marsh stratum on sediment deposition. Error bars represent  $\pm 1$  SE.





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