ECOLOGICAL EFFECTS OF MARSH EROSION ON BENTHIC COMMUNITIES AT PASTURE POINT, INDIAN RIVER BAY, DE

by

Gail Huckins

A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Honors Bachelor of Science in Biological Sciences with Distinction.

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ABSTRACT

Marsh erosion is an important natural process of sediment transport that can have detrimental effects on both human interests and the ecology of salt marshes, especially when exacerbated by human action. Thus, the quantitative measurement of erosion and study of nearby and unique benthic communities can help researchers understand the impact of erosion on these communities. The Pasture Point marsh in Indian River Bay, DE was studied for erosion and for the abundances of benthic fauna on the nearby marsh blocks. The rate of erosion did not differ significantly between the Eastern sides of the marsh or between the near and far ends presumably because of similar wave action around of the marsh. The benthic community on the Eastern marsh blocks was dominated by Geukensia demissa, while the Western marsh blocks were dominated by species of amphipods. In these communities, both differed from the types of benthic fauna that typically dominate Indian River Bay. Thus, this benthic community is a new type of habitat in Indian River Bay that increases the diversity of the bay. Also, the benthic communities’ abundance and composition was not clearly related to erosion rate, which indicates that the sedimentation from the erosion does not adversely affect the communities to the extent hypothesized.
Chapter 1

INTRODUCTION

1.1 Salt marsh

Salt marshes are coastal intertidal wetlands typically located on temperate and low-energy coasts and which are characterized by salt tolerant plants, such as *Spartina* cord grasses. These marshes are divided into different zones based on the vegetation and elevation. The first zone is the low marsh, which occurs in the intertidal zone and is characterized by tall Smooth Cordgrass, *Spartina alterniflora*. The next zone is the high marsh, which occurs above the level of the mean neap high tide and has a shorter form of *Spartina alterniflora* because of the higher salinity and fewer nutrients, which is caused by a lower tidal exchange rate than the low marsh. Above high marsh, the *Spartina alterniflora* is no longer present and is replaced by salt meadow cordgrass, *Spartina patens*, and saltgrass, *Distichlis spicata*, which characterizes the salt meadow zone. As the marsh elevation increases, the salt meadow is replaced by species of black grass, *Juncus roemerianus and Juncus gerardi*, and marsh elder, *Iva frutescens*, forming the shrub zone of the marsh (Long and Mason 1983).

1.2 Ecological contributions of salt marshes

While these marshes were once considered unimportant wastelands, now they are recognized as valuable ecosystems that are biologically and geologically
important. Like rain forests, marshes are one of the most productive ecosystems on
the planet with a net primary production of approximately 812 g C m⁻² yr⁻¹ (Fahey and
Knapp 2007). In addition to housing many invertebrates, like annelids, arthropods,
and mollusks, salt marshes act as nurseries to the juveniles of several fish species,
including the spot, *Leiostomus xanthurus*, pinfish, *Lagodon rhomboids*, and Atlantic
croaker, *Micropogon undulates*, protecting the fish from predation (Reed, 1990; Van
Dijkeman et al., 1990, Shenker and Dean 1979).

1.3 Geologic contributions of salt marshes

Geologically, salt marshes are invaluable in protecting the coastline by
acting as a buffer zone against storm surges and other eroding wave action. The
marsh is able to lessen the force of brief storm surges on the coast because of the
tough fibrous roots of the *Spartina* cord grasses, which bind the marsh sediments
together and thus prevent excess erosion of the coastline (Odum, 1988). The fibrous
root system also prevents erosion by trapping sediments from rivers and preventing
them from being carried offshore. By the same means, the salt marshes are able to
prevent inland pollutants from reaching the ocean by filtering and lowering the
amounts of pollutants carried in freshwater streams and rivers towards the estuaries.

1.4 Marsh erosion

Marsh erosion is a naturally occurring process generally caused by wave
action, herbivory, and bioturbation, which can be accelerated by human action and sea
level rise (Schwimmer, 2001; Morton et al., 2003). The erosion of salt marshes will
likely cause severe consequences for the ecology of salt marshes, such as decreases in
nearby faunal populations. Marsh erosion has been shown to convert marsh
environment into an open water environment, which can decrease the diversity and abundance of the local fauna because as erosion increases, the sedimentation and turbidity of the surrounding water increases, which can result in the loss of nearby sea grass beds and therefore a loss in fish species in the area (Stevenson et al., 2002). Additionally, the loss of salt marsh could result in a decrease in survivorship of juvenile fish due to predation. Furthermore, the marsh is a major food source for these juvenile fish, since it houses many of the benthic invertebrates the fish prey on; therefore, the loss of the marsh would decrease the juvenile fish food supply. Also, salt marshes are valuable nesting sites for coastal birds and provide nutrients to the birds’ invertebrate prey, so a loss of this habitat could result in a decrease in bird populations and an increase in the nearby marine invertebrate populations (Hughes 2004).

1.4.1 Types of marsh erosion at Pasture Point

There are two types of marsh erosion present at the marsh study area. The first is overhang erosion. This kind of erosion occurs when the wave action erodes the base of the marsh, leaving the top vegetative layer intact. Overhang erosion causes the top layer of the marsh to slump, which eventually results in the vegetative layer of the marsh breaking off and forming marsh blocks, which lie on the bottom of the Bay. The second kind is cleft formation, which occurs when narrow channels in the marsh are eroded away, resulting in U-shaped clefts.

1.5 Project Objectives

This study will quantitatively measure the erosion in the Pasture Point marsh, specifically comparing erosion on the Eastern and Western sides of the marsh.
Furthermore, the abundance and diversity of epifauna on the marsh blocks will be quantified and will be compared to the erosion rates to see if there is a correlation between faunal abundance and amount of erosion. Unfortunately, no studies have been conducted on marsh blocks, and therefore, the effects of the blocks on the abundance of the benthic fauna are essentially unknown. Additionally, while the processes and rates of erosion in Rehoboth Bay have previously been examined (Schwimmer 2001), the rates and most prevalent areas of erosion have not been examined in Indian River Bay, more specifically Pasture Point.

I predict that the erosion rates found in this study will be comparable to those found in previous erosion studies in the Delaware area (Schwimmer, 2001) and that the amount and rate of erosion will not differ significantly from the Eastern side of the marsh to the Western side of the marsh because the main cause of erosion at Pasture Point appears to be wave action and based on personal observation, there does not appear to be a significant difference in wave action between the two sides of the marsh. I also predict that high amounts of erosion (i.e. greater than 50 cm of erosion total) will result in a low abundance of fauna on the marsh blocks because a high amount of erosion indicates that sediment should be depositing on the blocks, which would prevent the settlement of benthic invertebrates, as well as decreasing the available food source for the invertebrates (Wantzen 2006).
Chapter 2

EXPERIMENTAL METHODS

2.1 Study site

Pasture Point is a salt marsh found in the South-East region of Indian River Bay in Lower Delaware (Figure 1 and 2). This marsh is found within the James Farm Ecological Preserve, and atypically, Pasture Point forms a peninsula into the bay, in contrast to most marshes in the Indian River Bay, which lie along the shoreline behind a sandy beach. Also, Pasture Point has a large number of broken off pieces of marsh, here termed marsh blocks, which range from 0.55 m to 4.1 m in length and from 0.63 m to 1.5 m in width. Aside from its unusual geography, Pasture Point is a typical Atlantic salt marsh, mainly populated with the tall form of Smooth Cordgrass, \textit{Spartina alterniflora}, fiddler crabs (\textit{Uca} spp.), marsh snails (\textit{Littorina} spp.), and ribbed mussels, \textit{Geukensia demissa} (Personal observation).

2.2 Erosion measurements

Erosion was quantitatively measured using 24 PVC posts that were implanted around the Pasture Point marsh in August 2006. Thirteen of the posts were placed on the Eastern side of the marsh; the other 11 were on the Western side (Figure 3). Each pipe (or post) was approximately 60 cm in length and was pushed approximately 40 cm into the marsh, and each post was placed in the marsh about 240 cm from the edge (range from 185 cm to 295 cm). The measured distance from the
post to the marsh edge in 2006 was used as initial distance, with decreases in this measurement indicating marsh shoreline erosion. One post on each side of the marsh was designated a control post; these posts were placed at the base of the marsh, where the geology of the marsh was similar to other Indian River Bay marshes along the shoreline.

2.2.1 Erosion data collection and analysis

On eight occasions in 2006 through 2008, erosion data were collected by measuring the distance from the post to the edge of the marsh with a transect tape (Figure 4). The nearest perpendicular edge of the marsh will be used in the measurements. Undercutting of the marsh was measured as well with a collapsible meter stick by measuring from the edge of the top vegetative layer to the base of the marsh. The state of the marsh around each post was recorded, documenting whether the marsh has been burrowed by fiddler crabs or was slumped toward the water.

The erosion data were analyzed by calculating the mean erosion rates and determining whether any differences exist, mainly between the Eastern and Western sides of the marsh and between the point of the marsh and the base by conducting a student’s t-test.

2.3 Benthic fauna measurements and community analysis

The epifauna samples were taken from 20 marsh blocks surrounding Pasture Point marsh (Figure 3 and 4). They were collected on July 31, 2008 by scraping all of the epifauna in a 10 cm x10 cm square from the surface of the marsh block with a knife and then preserving the samples collected in 10% buffered formalin. The fauna were identified using a field guide (Gossner, 1999; Lippson,
1997) and dissection microscope. Following identification, the fauna were preserved
in alcohol for further examination.

In order to analyze the community data for similarity between the
communities, standard multivariate statistical methods, such as nonmetric
multidimensional scaling, were used to characterize and compare the benthic
communities. First, the abundances of species found on the blocks were double root
transformed and a Bray-Curtis resemblance matrix was generated using the
multivariate package PRIMER v. 6 (PRIMER-E Ltd., Plymouth Marine Laboratory,
Clarke and Gorley 2006). Then, the matrix was analyzed using non-metric
multidimensional scaling (MDS), which produced an ordination plot (Clarke and
Warwick 2006). Furthermore, the MDS plots were analyzed using ANOSIM tests to
determine if there was a statistical difference in the similarity of fauna on the blocks
depending on which side of the marsh they were from or whether the blocks were in
areas of low or high erosion. Additionally, the raw fauna data was run through
additional PRIMER routines, including the estimators Sobs, Chao1, Chao2,
Jackknife1, Jackknife2, Bootstrap, MM, and UGE, in order to create a species
accumulation plot in order to determine whether enough samples were taken to fully
identify all species found on the marsh blocks. Also, in order to determine whether
there was a difference in the diversity of the Eastern and Western marsh block
communities, the Simpson’s diversity index for each side was calculated.
3.1 Erosion results

Qualitatively, the main types of erosion occurring on the Eastern side of Pasture Point were overhang/undercutting and the subsequent slumping. Slumping occurred primarily near posts E3, E4, E4a, and E7, and undercutting occurred at 9 of 12 Eastern posts. For the Western side, the main erosion types were cleft formation and slumping. Cleft formation occurs mainly at posts W7-W4, the far Western side of the marsh, and slumping at 10 of 11 Western posts.

Over a measurement period from August 2006 through November 2008, the mean amount of erosion on the Eastern side of Pasture Point was not significantly different from the mean amount of erosion on the Western side (t =0.358, p>0.05; Table 1). Based on the mean erosion values and the measurement period of 855 days, the mean erosion rate for the Eastern side was not significantly different from the mean rate for the Western side (t=0.351, p>0.05; Table 2).

The E-Control post had much higher erosion than the rest of the Eastern erosion posts, so the total amount of erosion and erosion rate were calculated for the Eastern side, excluding the E-Control post. While the mean amount of erosion and mean erosion rate decreased for the Eastern side, they were still not significantly different from the mean erosion values of the Western side (t=0.248, p>0.05; Table 1).
3.2 Fauna results

Based on the fauna samples taken July 31st, 2008, a total of 11 species were found on 20 marsh blocks (Table 3). The most abundant species on the Eastern marsh blocks were *Geukensia demissa*, and several species of amphipods that are designated *Gammarus A*, *Gammarus B*, and *Gammarus C* (Table 3). The most abundant species on the Western marsh blocks were *Gammarus A*, *Gammarus B*, *Gammarus C*, and *Ilyanassa obsoleta* (Table 3). Overall abundance was greater in the East than the West for all species except two, *Nereis succinea* and *Ilyanassa obsoleta*. The MDS ordination plot showed three main groupings in fauna abundance: the Eastern marsh blocks, the Western marsh blocks, and block W1 (Figure 4). When erosion factor (high vs. low erosion, i.e. >50 cm vs. ≤ 50 cm) was applied to the MDS plot, the high and low erosion points were randomly interspersed and showed no discernable groupings or patterns (Figure 5).
4.1 Marsh erosion rates

The similarity of the erosion rates between the Eastern and Western sides indicates that the different types of erosion that occur at Pasture Point result in approximately the same amount of erosion; however, the calculated Western erosion rate may be lower than the actual erosion rate because the posts were located in between the clefts. Therefore, to the extent that erosion may have occurred at a greater rate in the clefts, rates reported here may be conservative. Based on personal observations of the wave action at Pasture Point, the erosion was expected to be similar on both sides because the wave heights and periods during sampling were observed to be the same during erosion measurements.

The erosion rate at post E-Control was much higher than the rates at other Eastern posts (Table 1). Based on the current patterns, it appears that waves directly strike E-Control, instead of obliquely striking the post, which occurs at the other Eastern posts (Janzen and Wong 1998).

Also, post W1a experienced a negative erosion rate, which could be a result of the extreme amount of slumping occurring at that post (Table 2). During measurements, the distance from the edge of the marsh to the post; however, in the case of slumping, the distance between the edge of the marsh and the post became
artificially increased because of the curve of the marsh, which could explain the negative erosion rate.

4.1.1 Erosion rates in comparison to Rehoboth Bay

The calculated annual rates of erosion (Eastern – 27 cm/yr; Western – 30 cm/yr) are comparable to those found at other locations such as the marshes on Horsehead Island in Rehoboth Bay (23 ± 4 cm/yr) (Schwimmer 2001); however, they are much less than those seen in Marsh Island in Rehoboth Bay, which are at least 1.4 times higher (43 ± 4 cm/yr) than the erosion rates for either side of Pasture Point (Schwimmer 2001). The conclusions on wave power from Schwimmer (2001) suggest that the wave power around Pasture Point is comparable to the wave power near Horsehead Island, but is less than the wave power at Marsh Island, assuming that wave action is the only cause of erosion. Furthermore, it is expected that the islands would have similar rates of erosion because, like Pasture Point, they are being eroded from all sides, unlike traditional salt marshes, which are only eroded from one side.

4.2 Marsh block fauna

According to the species-sample curves in Figure 9, the asymptote indicates that enough faunal samples were taken and that nearly all the species present on the marsh blocks were detected. The species accumulation curve was composed of the estimators Sobs, Chao1, Chao2, Jackknife1, Jackknife2, Bootstrap, MM, and UGE. The Sobs curve represents the number of species observed in the sampling. Chao1 curve is a non-parametric estimator that represents the number of rare species found in a sample (i.e. less than 3 individuals); while, Chao2 curve is a non-parametric, incidence based estimator that represents the distribution of species among
the samples (i.e. number of species that occur in only one sample and the number of species that occur in exactly two samples). Similarly, Jackknife1 curve is a non-parametric curve that is based on the number of species occurring in only a single sample, and Jackknife2 is a non-parametric curve that is based on the number of species occurring in only one sample as well as the number of species that occur in exactly two samples. Additionally, Bootstrap is a resampling estimator. MM curve is a parametric Michaelis-Menten richness estimator that computes the mean accumulation curve and UGE is the mean curve of all of the estimators. All the curves agreed that enough samples were taken to detect nearly all species on the blocks.

The most abundant fauna found on the Eastern blocks was the ribbed mussel, *Geukensia demissa*; whereas the most abundance fauna found on the Western blocks was three species of amphipods. Additionally, the most abundant species on block W1 was *Ilyanassa obsoleta*, a very common species on the James Farm sandflat (personal observation); this was unexpected because based on previous personal observations during sampling, it appeared that the Western marsh blocks were composed of basically the same types of fauna. One possible explanation for the differences between the other 8 Western marsh blocks and W1 could be that there was a type of algae (*Porphyra umbilicus*) present on W1, which was not present on any other marsh blocks (Lubchenco 1978). Another possible explanation is that the current coming from the middle of Indian River Bay hits Pasture Point around the site of block W1 and the impact of the current could result in a different type of fauna for W1, since none of the other blocks are as greatly impacted by the current (Janzen and Wong 1998).
Based on the environmental data for the area, there are no clear
temperature or salinity differences between the Eastern and Western sides, which
might explain the discrepancy in abundance of *Geukensia demissa* (Tables 1 and 2).
One possible hypothesis for the presence of *G. demissa* on the Eastern marsh blocks
and the lack on the Western marsh blocks is that *G. demissa* larva prefer to settle
among established adult populations; therefore, the difference can be explained if the
Eastern marsh blocks have established *G. demissa* populations when they break off
from the marsh and the Western marsh blocks do not (Nielsen and Franz 1995). Also,
the current around Pasture Point flows from the current of the bay towards the
Southeast; therefore, when the current hits Pasture Point, it most likely flows down the
Western side and around the tip toward the Eastern side (Janzen and Wong 1998).
This type of current flow would prevent any *G. demissa* larvae from travelling to the
Western side from the Eastern side.

The MDS plots indicated that the faunal composition on the marsh blocks
was not affected by the amount of erosion occurring near the location of the block
(Figure 7), but that the location of the block most affected the abundance of fauna
(Figure 8). It was predicted that high levels of erosion would result in a decrease in
fauna abundance because of the increased amount of sedimentation on the marsh
blocks (Wantzen 2006). Since the amount of erosion had no effect on the abundance
of fauna, either the erosion did not produce a high enough amount of sediment to
disrupt benthic fauna or the sediment was deposited farther away from the marsh
blocks.
4.2.1 Comparision to other Indian River Bay marsh communities

The 3 most abundant species on the Pasture Point marsh blocks were *Geukensia demissa*, and several species of amphipods. However, previous studies of benthic marsh communities have found that the three dominant species are *Nereis succinea*, *Streblospio benedicti*, and *Heteromastos filiformis* (Daiber 1975). Furthermore, Daiber (1975) found that 89.2% of individuals found on the marsh were annelids, 6.3% were mollusks, and 3.6% were arthropods, while at Pasture Point, 52.1% of individuals found were arthropods, 39% were mollusks, and 6.8% were annelids. The differences between the marsh and marsh blocks could indicate that the marsh blocks are creating a new kind of habitat. However, another reason for the difference in community composition could be the difference in sampling techniques. Daiber (1975) measured infauna as well as epifauna in Indian River Bay, while the focus of this study was on epifauna. Perhaps, if cores of the marsh blocks were taken, there would be a higher percentage of annelids found since most polychaetes are burrowing worms.

4.2.2 Comparision to other Indian River Bay communities

The benthic community composition of the marsh blocks at Pasture Point also differs greatly from the community composition of Indian River Bay overall (Maurer 1977), as well as lagoon and bay areas. The top three species in the Bay overall were *Streblospio benedicti*, *Capitella capitata*, and *Heteromastus filiformis*. For the lagoon areas of the Bay, the top three species were *Streblospio benedicti*, *Heteromastus filiformis*, and *Capitella capitata*. For the bay areas, the top three species were *Streblospio benedicti*, *Glycinde solitaria*, and *Heteromastus filiformis* (Maurer 1977). Since all of the top species in these areas are annelids, more
specifically polychaetes, this indicates that benthic communities in Indian River Bay are typically dominated by annelids. However, since the most dominant species on the marsh blocks is *Geukensia demissa*, the marsh blocks are likely a qualitatively different habitat than the rest of Indian River Bay because they are characterized by bivalves rather than annelids.

### 4.2.3 Comparison to nearby oyster reef

While there are no quantitative results for benthic species present on the nearby oyster reef, there is some qualitative data taken in the summer of 2007. Some of the epifaunal species found on the oyster reef are *Nereis succinea*, *Mitrella lunata*, *Mytilus edulis*, several species of *Gammarus*, *Botrylloides violaceus*, and *Botryllus schlosseri* (personal observation). Most of these species were also found on the Pasture Point marsh blocks, except for *B. violaceus* and *B. schlosseri*, which are 2 species of tunicates. Also, *G. demissa* was missing from the oyster reef. Based on the amount of overlap between the two communities, the marsh block benthic communities and the oyster reef benthic communities are similar, which was not expected based on the differences in substrates; however, the similarity is most likely caused by the proximity of the two areas.

### 4.3 Future of Pasture Point

The total erosion rate for Pasture Point was calculated by combining the mean erosion rates of the Eastern and Western sides and the combined erosion rate is approximately 57 cm/yr. The narrowest part of Pasture Point is approximately 11 m wide. Assuming the erosion rate does not change, the narrowest part of the marsh will completely erode after approximately 20 years, which would separate Pasture Point
from the shoreline (Figure 1). The widest part of the marsh is approximately 74 m wide and based on a uniform erosion rate would completely erosion after about 137 years, which would result in the disappearance of Pasture Point marsh. However, this is a conservative estimate based on previous shorelines of Pasture Point (Figure 10). Using previous shorelines as a basis, past erosion rates from 1938 to 2002 were calculated and the rate of erosion from 1938 to 1968 was .76 m/yr, while the rate of erosion from 1968 to 1997 was 1.2 m/yr and the rate of erosion from 1997 to 2002 was 1.8 m/yr (Figure 10). The past rates indicate that the overall erosion rate of Pasture Point has been increasing over the past 70 years. The amount of erosion occurring possibly will cause a change in the sediment composition in the nearby area. Since sediment composition is linked to the types of benthic communities present (Daiber 1975; Maurer 1977), this could change the benthic communities around Pasture Point from being arthropod and mollusk dominated to being annelid dominated like the rest of Indian River Bay, which would decrease the overall diversity of the bay (Maurer 1977, Watling 1975).

4.4 Future studies

The main area that appears to demand future study is the difference between East and West sides of the marsh in abundance of *G. demissa*. Since benthic species are typically affected by environmental conditions and sediment composition, an extensive study of the conditions on both sides of the marsh and the sediment composition of the blocks should be undertaken. Additionally, since current flow is a possible hypothesis for the *G. demissa* difference as well as the presence of *Ilyanassa obsoleta* on W1 and the high erosion at post E-Control, current meters should be placed around the marsh at the Western base, Eastern base, and the tip. Furthermore,
only the epifauna of the marsh blocks were studied. In order to get a more complete picture of the fauna present on the marsh blocks, a study should be performed on the infauna, in order to determine if the whole benthic community is similar to the majority of benthic communities in Indian River Bay.

4.5 Project summary

Overall, this study has confirmed that erosion is occurring at Pasture Point marsh at an increasing rate based on rates calculated from Figure 10, which will eventually result in the complete erosion of the marsh in less than 150 years. While the erosion of the marsh causes the creation of marsh blocks, there is no correlation between the amount of erosion occurring in a region and the abundance and type of benthic fauna present on the marsh blocks. Instead, the type and abundance of benthic fauna on the marsh blocks is most likely related to the spatial location of the blocks and possibly the environmental conditions around the blocks. The types of dominant fauna on the blocks differed greatly from the dominant fauna in other areas of Indian River Bay, but were similar to the fauna present on a nearby oyster reef. In conclusion, the erosion at Pasture Point may indirectly affect the benthic communities surrounding it, resulting in a less diverse benthic population in Indian River Bay as the benthic populations are lost.
Figure 1 Aerial photograph of Indian River Bay
Figure 2  Image of Pasture Point marsh from Google Earth. Open ocean is to the East.
Figure 3  Map of Pasture Point marsh with erosion post locations
Figure 4  Measurement of distance from post to marsh edge
Figure 5  Map of Pasture Point marsh with marsh block locations
Figure 6  Image of a marsh block found at Pasture Point
Table 1  Erosion and erosion rate data for Eastern marsh posts with the mean erosion and mean erosion rate values ± standard deviation. From August 2006 to November 2008, mean salinity = 26.4 ppt; mean temperature = 24.2 °C

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<th>10-Jul-07</th>
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Mean not including Control: 56.25 ± 15.29 cm, 0.066 ± 0.018 cm/day
Mean including Control: 63.46 ± 29.84 cm, 0.074 ± 0.035 cm/day
Table 2  Erosion and erosion rate data for Western marsh posts with the mean erosion and mean erosion rate values ± standard deviation. From August 2006 to November 2008, mean salinity = 26.4 ppt; mean temperature = 24.2 °C

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<th>10-Aug-06</th>
<th>20-Dec-06</th>
<th>16-May-07</th>
<th>12-Jun-07</th>
<th>10-Jul-07</th>
<th>4-Jul-08</th>
<th>19-Sep-08</th>
<th>21-Nov-08</th>
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| W-Contro| 250 | 225 | 240 | 240 | 215 | 260 | 268 | 235 | 15 | 0.018 |

Mean not including Control 76.2 ± 54.09 cm 0.089 ± 0.063 cm/day

Mean including Control 70.64 ± 54.54 cm 0.083 ± 0.064 cm/day
Table 3  Abundances of benthic fauna per marsh block of the 11 species found at Pasture Point. Temperature at time of sampling = 29.0 °C; salinity at time of sampling = 23.4 ppt

<table>
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<tr>
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<th>Geukensia demissa</th>
<th>Nereis succinea</th>
<th>Mitrella lunata</th>
<th>Gammarus C</th>
<th>Mytilus edulis</th>
<th>Gammarus A</th>
<th>Brania clavata</th>
<th>Ilyanassa obsoleta</th>
<th>Boreotrophon clathrus</th>
<th>Gammarus B</th>
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Figure 7  Non-metric multidimensional ordination plot of Bray-Curtis resemblance matrix from double-root transformed fauna abundance data indicating side factor by color and symbol. The closer two points are together, the more similar they are. Low stress (0.09) indicates that the plot is an accurate transformation.
Figure 8  Non-metric multidimensional plot of Bray-Curtis resemblance matrix from fauna abundance data depicting erosion rate by color and symbol. Low erosion $\leq$ 50 cm; high erosion $> 50$ cm. The closer two points are to each other, the more similar they are. Low stress (0.09) indicates that the plot is an accurate transformation.
Species accumulation plot of raw fauna data. Sobs curve represents the number of species observed in the sampling. Chao1 curve is a non-parametric estimator that represents the number of rare species found in a sample (i.e. less than 3 individuals). Chao2 curve is a non-parametric, incidence based estimator that represents the distribution of species among the samples (i.e. number of species that occur in only one sample and the number of species that occur in exactly two samples). Jackknife1 curve is a non-parametric curve that is based on the number of species occurring in only a single sample. Jackknife2 is a non-parametric curve that is based on the number of species occurring in only 1 sample as well as the number of species that occur in exactly two samples. Bootstrap is a resampling estimator. MM curve is a parametric Michaelis-Menten richness estimator that computes the mean accumulation curve and UGE is the mean curve of all of the estimators.
Figure 10  Aerial photograph of Pasture Point marsh with superimposed past shorelines.
REFERENCES


Daiber, F.C. 1975. Ecological effects upon estuaries resulting from lagoon construction, dredging, filling, and bulkheading. College of Marine Studies and Department of Biological Sciences, University of Delaware.


