# Portland Causeway Marsh Restoration – Preconstruction Assessment

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**Final Report**

**March 1, 2010**

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## Acknowledgements

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**Portland Causeway Marsh Restoration – Baseline Assessment**

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## Executive Summary

The purpose of this study was to provide a baseline assessment of flora and fauna inhabiting Nueces Bay, TX prior to the construction of a new salt marsh habitat by the Coastal Bend Bays and Estuaries Program. We completed a survey of vegetation density as well as nekton and benthic community structure, and water quality parameters within the planned restoration site and within existing, adjacent natural marsh areas that border the site of the planned marsh restoration. The goals of this project were to a) provide a baseline assessment of flora and fauna for future comparisons after the restoration is completed and to b) compare existing marshes to the area where the restoration is planned. This comparison is important to establish that nekton in this site are dependent upon salt marsh habitat. Further, the contrast between natural and restored areas documented here will be an important component of future studies examining the effectiveness of the restoration. That is, future surveys will be able to determine if the restored marsh contains similar communities as natural marshes and measure synergy between the natural and restored areas. In this report, we provide extensive species lists from benthic and nektonic samples, water quality parameters, and vegetation density collected in existing marshes and planned restoration areas, these data comprise the baseline assessment.

Our data indicate that the existing marshes harbor a significantly higher abundance and diversity of nekton than the non-vegetated, mud bottom areas that predominate in Nueces Bay. Furthermore, our data suggest that nekton in marsh areas consume benthic organisms in the marsh sites, and resultantly benthic abundance was significantly less in existing marshes. Water depth was significantly deeper in the planned restoration area than in the existing marshes. Resultantly, we found no vegetation present in the planned restoration area as the water was too deep to support emergent plants. Submerged vegetation (seagrasses) was not found in our samples, but we cannot determine why this pattern occurred. Abiotic conditions (e.g., salnity, DO) were consistent across marsh and restoration sites, and thus differences in vegetation presence and nekton and benthic abundance could not be attributed to differences in water quality. Rather, the presence of vegetation significantly increased nekton abundance and diversity, and the presence of vegetation was seemingly limited only by water depth.

In summary, marsh sites in Nueces Bay harbor an abundance of nekton, including commercially important species such as blue crabs (*Callinectes sapidus*). Our findings suggest that the planned restoration will have a significant, positive effect on nekton abundance in Nueces Bay, and will most likely increase abundance of commercially and recreationally important species.

## Introduction

Salt marshes provide essential habitats for many estuarine organisms including economically important fisheries (Turner 1976, Turner and Boesch 1988, Pennings and Bertness 2001). They also protect coastal areas from flooding, filter sediments and minerals from the water column, and enhance habitat quality and biodiversity of adjacent marine habitats (e.g., oyster reefs Bertness 1999, Pennings and Bertness 2001, Grabowski et al. 2005). Due to their importance, salt marshes are designated as coastal natural resource areas (CNRAs) by the Texas General Land Office.

Salt marshes in Nueces Bay, Texas are limited to shallow-water areas near the shoreline and on several smaller islands created from dredge fill. Much of the bay is too deep to support salt marsh vegetation (McKee and Patrick 1988), but it was traditionally inhabited by extensive oyster reef communities. In the mid 20$^{th}$ century, oysters in Nueces Bay and many other Texas estuaries were dredged and the shells used for road construction (Doran 1965). Since this anthropogenic disturbance, Nueces Bay has lost much of its structured habitat and the bay remains largely uninhabited by oyster reefs, seagrasses, and salt marshes and contains vast expanses of unstructured sand and mud bottom. To compensate for the habitat loss, the Coastal Bend Bays and Estuaries Program (CBBEP) will be restoring ~150 acres of salt marsh in Nueces Bay to provide structured, vegetated habitat and bring many ecosystem services into the bay that salt marshes provide. Salt marshes are home to many commercially and recreationally important species including blue crabs (*Callinectes sapidus*) and red drum (*Sciaenops ocellatus*), and the planned restoration should increase populations of these and other nektonic species.

The purpose of this study was to document the existing flora and fauna in natural marshes in Nueces Bay and in the planned restoration site, and area that lacks vegetation and structured habitat. Here, we provide a comparison between the natural marsh and planned restoration sites to illustrate the potential effects the restoration will have in Nueces Bay. We also generate species lists, vegetation analysis, and water quality data to provide a baseline for later comparisons after the restoration is complete.

## Methods

The survey of conditions for the baseline assessment in Nueces Bay, TX was performed on August 19, 2009. The methods described below commenced at 10:00 AM and were completed by 4:00 PM. The tide was high during the morning but began to ebb during the afternoon. The wind and waves made estimating water levels and tidal stage difficult. The weather was warm, with air temperatures ranging from 28$^{o}$C to 33$^{o}$C and wind was blowing from the southeast at 10-15 mph with gusts up to 20 mph. All tasks described below were performed in the planned marsh restoration area and in natural marshes that surround the restoration area at depths less than 1.0 m. Our equipment is limited to this depth. Vegetation surveys and nekton sampling were performed in the same area. Benthic samples were collected within 5.0 m of the vegetation and nekton samples. GPS coordinates of each sampling area were recorded and are presented in table 1 below.

**Table 1.** GPS location of each site sampled. Sites labeled marsh are within existing marshes and those labeled restoration and within the planned restoration area. Depth (cm) is also listed.

| Site | Water Depth (cm) | Location (GPS) |
|---|---|---|
| Marsh 1 | 23 | N27 51.572 W97 21.185 |
| Marsh 2 | 18 | N27 51.590 W97 21.016 |
| Marsh 3 | 32 | N27 51.676 W97 20.950 |
| Marsh 4 | 17 | N27 51.740 W97 20.904 |
| Marsh 5 | 17 | N27 51.736 W97 20.911 |
| Marsh 6 | 24 | N27 51.736 W97 20.901 |
| Marsh 7 | 31 | N27 51.641 W97 21.274 |
| Marsh 8 | 14 | N27 51.638 W97 21.276 |
| Marsh 9 | 24 | N27 51.633 W97 21.277 |
| Marsh 10 | 30 | N27 51.594 W97 21.194 |
| Restoration 1 | 50 | N27 51.679 W97 21.191 |
| Restoration 2 | 90 | N27 51.608 W97 20.994 |
| Restoration 3 | 85 | N27 51.676 W97 20.952 |
| Restoration 4 | 30 | N27 51.737 W97 20.908 |
| Restoration 5 | 35 | N27 51.734 W97 20.905 |
| Restoration 6 | 98 | N27 51.742 W97 20.893 |
| Restoration 7 | 97 | N27 51.814 W97 20.997 |
| Restoration 8 | 90 | N27 51.812 W97 20.999 |
| Restoration 9 | 97 | N27 51.685 W97 21.246 |
| Restoration 10 | 40 | N27 51.679 W97 21.246 |


**Figure 1**. Map of Study Area. Ten samples were collected in the naturally occurring low marsh habitat shaded in blue. Ten additional samples were taken within the planned restoration area noted by the red circle. GPS coordinates of specific samples are located in table 1 previous page.

*Abiotic Sampling*: Water quality parameters were measured in the existing, natural marshes of Nueces Bay, TX and in the planned restoration area. Four Hydrolab Data Sondes were used for these measurements. Two Sondes were placed in the existing marsh and two in the planned restoration area. Sondes were programmed to sample continuously for 60 seconds for the first minute of each hour during the 48 hr deployment period. Hydrolabs were mounted 20.0 cm above the substratum and programmed to measure the following parameters: water temperature, salinity, dissolved oxygen, turbidity, and pH. The sampling design allowed us to measure each parameter 48 times during the study. Water quality parameters were measured in August 19-21, 2009 and February 22-24, 2010 to compare water quality parameters between marsh areas and planned restoration areas in multiple seasons.

*Vegetation Survey*: Vegetation surveys were performed in 10, 1.0 $m^2$ plots that were randomly selected within both the natural marsh and planned restoration area. A 1.0 $m^2$ metal frame was placed within the respective sampling area and photographed. The only vegetation present in the measurement area was smooth cord grass, *Spartina alterniflora*. The number of shoots within the sampling area was counted as a measurement of vegetation density. GPS coordinates of each plot were recorded as was other relevant information including time, tidal stage, and general weather. No vegetation was present in any samples in the planned restoration area.

*Nekton Sampling:* Nekton samples were collected at each sampling location by placing a 1.0 $m^2$ drop sampler (pictured below in Figure 1) over the sampling area and scooping out all nektonic organisms using a net. This drop sampler consisted of a mesh net and an aluminum foot, which is inserted into the mud to prevent any nektonic organisms from escaping. The net used for organism collection fits exactly within the drop sampler, so that all nekton can be carefully removed from the sampler, regardless of position in the water column (see Rozas and Minello 1997 for detailed description and methods of drop sampling). The net was used to sweep the drop sampler until three consecutive attempts were made and no organisms collected. Samples were then placed in formalin, labeled, and transferred to TAMU-CC. After several weeks, the organisms were placed in 70% ethanol for storage. All organisms were identified, counted, and measured from November 2009 through January 2010. Ten of these samples were randomly taken from the natural marsh and ten from the planned restoration area.

Total abundances of organisms were compared between marsh and planned marsh areas using t-tests (Sokal and Rohlf 1995). Large numbers of grass shrimp were found in the natural marsh and a separate t-test was performed on total abundances of nekton in each area not including the grass shrimp in the total. Additionally, biodiversity was calculated for each plot using the Shannon-Weiner Diversity Index for all nekton samples using the formula $H' = -\sum (p_i * \log_2 p_i)$ where $p_i$ is the percentage of $i^{th}$ species in the plot and H' is summed over all species. Diversity values for plots in the existing marsh were compared to those in the planned restoration area using a t-test (Sokal and Rohlf 1995).

**Figure 2.** Drop sampler used for nekton sampling. James Sanchez (left) and Philip Torres (right) assisted with collection and sorting of samples

*Benthic Sampling*: Benthic sampling was completed using a 10 cm diameter PVC core sampler that was 25 cm in length. Ten benthic samples were randomly collected from the natural marsh and 10 from the planned restoration area. The PVC core sampler was inserted into the sediment to a depth of 10 cm. The core sample was removed and placed into a mesh bag, after which the bag was rinsed to remove sediment. The sample was labeled, placed in formalin and transferred to TAMU-CC. After several weeks, the organisms were placed in 70% ethanol for storage. All organisms were identified, counted, and measured from November 2009 through January 2010. Abundances of benthic infauna were compared between natural marsh and planned restoration areas using t-tests (Sokal and Rohlf 1995). Our analysis detected a lower number of benthic organisms in the natural marsh (see results). Since nektonic species often prey on benthic species, the lower numbers of benthic organisms may be explained by the greater numbers of nekton inhabiting the existing marsh. We performed an additional analysis whereby we compared the number of benthic organisms collected in sites in which the number of nekton collected where less than 20 vs. those greater than 20 using a t-test (Sokal and Rohlf 1995) to determine if nekton abundance affected benthic abundance.

## Results

*Abiotic Sampling*: Water quality parameters are summarized in table 2 (August 2009) and table 3 (February 2010). Two Hydrolab Sondes were deployed in the existing marsh at GPS coordinates N27 51.736 W97 20.901 and N27 51.572 W97 21.185 and are labeled M1 and M2 in Table 2. Two additional Sondes were deployed in the planned restoration area at GPS coordinates N27 51.679 W97 21.246 and N27 51.679 W97 21.246 and are labeled R1 and R2 in table 2.

In fall 2009, the M1 failed in the field and did not record data. Sonde R1 lost power after 10 hrs. The pH and turbidity probes did not function properly in Sonde M2 as the turbidity sensor in Sonde R4 also did not function properly and did not recalibrate correctly. All instruments worked correctly in February 2010 measurements.

**Table 2.** Mean water quality parameters ± SE in August 2009 for each Hydrolab Sonde. * indicates an equipment malfunction which produced unreliable data.

| Site | Depth (cm) | Temperature ℃ | Dissolved Oxygen mg/l | Salinity PSU | pH | Turbidity NTU |
|---|---|---|---|---|---|---|
| M1 | 23 | * | * | * | * | * |
| M2 | 24 | 30.3 ± 0.27 | 13.1 ± 0.1 | 42.5 ± 0.1 | * | * |
| R1 | 97 | 30.4 ± 0.1 | 11.8 ± 0.1 | 41.6 ± 0.1 | 8.0 ± 0.03 | 214.2 ± 140 |
| R2 | 40 | 25.6 ± 0.2 | 7.9 ± 0.2 | 47.5 ± 0.1 | 8.8 ± 0.02 | * |
| ALL Sites | | 28.8 ± 0.2 | 10.9 ± 0.1 | 43.9 ± 0.1 | 8.4 ± 0.02 | 214.2 ± 140 |

**Table 3.** Mean water quality parameters ± SD in February 2010 for each Hydrolab Sonde.

| Site | Depth (cm) | Temperature ℃ | Dissolved Oxygen mg/l | Salinity PSU | pH | Turbidity NTU |
|---|---|---|---|---|---|---|
| M1 | 23 | 12.5 + 0.5 | 9.1 + 0.1 | 24.6 + 0.1 | 7.7 + 0.01 | 19.1 + 2.0 |
| M2 | 24 | 12.9 + 0.6 | 9.3 + 0.1 | 24.8 + 0.5 | 8.4 + 0.01 | 0.1 + .07 |
| R1 | 97 | 13.6 + 0.5 | 8.8 + 0.1 | 25.1 + 0.6 | 8.2 + 0.01 | 2.8 + 0.6 |
| R2 | 40 | 13.2 + 0.5 | 9.1 + 0.1 | 24.6 + .02 | 7.8 + 0.01 | 2.5 + 0.5 |
| All Sites | | 13.1 + 0.5 | 9.1 + 0.1 | 24.8 + 0.3 | 8.0 + 0.01 | 6.1 + 1.1 |

Water depth was also measured in all 20 sites. Mean water depth in the existing marsh was 23.0 cm and was significantly less than the mean depth in the planned restoration area, which was 71.2 cm.0 ($t=5.19$, $p<<0.01$, $n=10$).

*Vegetation Survey*: No vegetation was present in the planned marsh restoration area. *Spartina alterniflora* was the only plant species observed in the natural marsh. Vegetation density was estimated by counting the number of *Spartina* shoots within the 1.0 $m^2$ sampling area. Shoot density was 28 $\pm$ 11.4 (mean density $\pm$ SE). Shoot density for each plot can be found in table 4 along with GPS coordinates.

**Table 4**. Site name, location, and number of shoots in the 1.0 $m^2$ sampling area.

| Site | Location (GPS) | # shoots $m^{-2}$ |
|---|---|---|
| Marsh 1 | N27 51.572 W97 21.185 | 42 |
| Marsh 2 | N27 51.590 W97 21.016 | 19 |
| Marsh 3 | N27 51.676 W97 20.950 | 14 |
| Marsh 4 | N27 51.740 W97 20.904 | 28 |
| Marsh 5 | N27 51.736 W97 20.911 | 28 |
| Marsh 6 | N27 51.736 W97 20.901 | 16 |
| Marsh 7 | N27 51.641 W97 21.274 | 21 |
| Marsh 8 | N27 51.638 W97 21.276 | 48 |
| Marsh 9 | N27 51.633 W97 21.277 | 38 |
| Marsh 10 | N27 51.594 W97 21.194 | 26 |
| Mean $\pm$ SE | | 28 $\pm$ 3.6 |

*Nekton Sampling:* We collected 31 total nektonic organisms from the unvegetated plots within the planned marsh restoration area. In contrast, 519 organisms were collected from the natural marshes fringing the planned restoration area (Table 5). A t-test revealed significantly more nekton in the natural marshes ($t=4.11$, $p<<0.01$, $n=10$, Figure 2). However, of the 519 organisms collected from the natural marsh sites, 431 were grass shrimp (*Palaemonetes sp.*). An additional t-test was performed to compare total abundances between natural marsh and restoration sites without counting grass shrimp in the total. This t-test also revealed significantly more organisms in the marsh sites ($t=2.29$, $p<0.05$, $n=10$, Figure 2). A summary of all nektonic organisms collected in each site can be found in appendix I. Figure 3 illustrates the total numbers of shrimp, fish, and crabs collected from marsh and planned restoration sites. Shannon-Weiner Index values of diversity were calculated for the nekton collected in each plot. As with total abundances, a t-test revealed significantly greater species diversity in the natural marsh sites ($t=2.27$, $p<0.05$, $n=10$, Table 5, figure 4).

**Table 5.** GPS location of each nekton sample collected. Marsh sites refer to the existing marsh and restoration sites refer to samples collected in the planned restoration area. Number of nekton species are reported from each sample as is the Shannon-Weiner Diversity value (H') for each site.

| Site | Location (GPS) | Nekton Density (# $m^2$) | Nekton Diversity (H') |
|---|---|---|---|
| Marsh 1 | N27 51.572 W97 21.185 | 3 | 0.92 |
| Marsh 2 | N27 51.590 W97 21.016 | 41 | 1.31 |
| Marsh 3 | N27 51.676 W97 20.950 | 71 | 0.22 |
| Marsh 4 | N27 51.740 W97 20.904 | 37 | 0.41 |
| Marsh 5 | N27 51.736 W97 20.911 | 38 | 0.63 |
| Marsh 6 | N27 51.736 W97 20.901 | 99 | 0.80 |
| Marsh 7 | N27 51.641 W97 21.274 | 39 | 1.17 |
| Marsh 8 | N27 51.638 W97 21.276 | 61 | 0.41 |
| Marsh 9 | N27 51.633 W97 21.277 | 123 | 0.62 |
| Marsh 10 | N27 51.594 W97 21.194 | 9 | 1.53 |
| Restoration 1 | N27 51.679 W97 21.191 | 7 | 1.26 |
| Restoration 2 | N27 51.608 W97 20.994 | 3 | 0.00 |
| Restoration 3 | N27 51.676 W97 20.952 | 1 | 0.00 |
| Restoration 4 | N27 51.737 W97 20.908 | 2 | 0.00 |
| Restoration 5 | N27 51.734 W97 20.905 | 12 | 1.00 |
| Restoration 6 | N27 51.742 W97 20.893 | 0 | 0.00 |
| Restoration 7 | N27 51.814 W97 20.997 | 0 | 0.00 |
| Restoration 8 | N27 51.812 W97 20.999 | 0 | 0.00 |
| Restoration 9 | N27 51.685 W97 21.246 | 3 | 0.92 |
| Restoration 10 | N27 51.679 W97 21.246 | 3 | 0.00 |

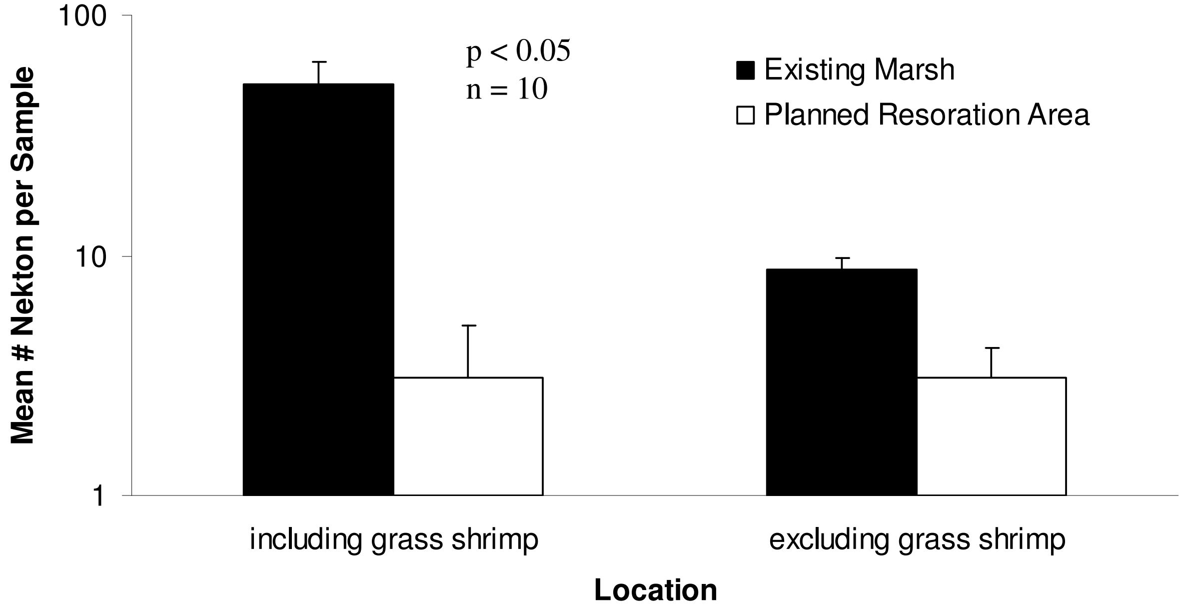


**Figure 3**. Mean number of nektonic organisms ± SE collected in samples from the existing marsh and planned restoration area with and without grass shrimp included in samples. A t-test detected significant differences in nekton regardless of whether grass shrimp were included.


**Figure 4**. Total number of shrimp, fish, and crabs collected in marsh sites and in planned restoration sites.


**Figure 5**. Mean diversity (H') values + SE calculated from nekton samples in the existing marsh and planned restoration area. A t-test revealed significantly higher species diversity in the existing marsh ($p < 0.05$, $n = 10$).

*Benthic Sampling:* Polychaetes were the most abundant benthic organisms collected. We collected 456 total benthic organisms from the unvegetated plots within the planned marsh restoration area. In contrast, 198 organisms were collected from the natural marshes fringing the planned restoration area (Table 6). A t-test revealed significantly more benthic organisms in the planned restoration area than in the existing marshes ($t=2.22$, $p<0.05$, $n=10$, Figure 5). A summary of all organisms collected in each site can be found in appendix II. The lower number of benthic organisms in the existing marsh may seem counter intuitive. However, we noted a negative relationship between the numbers of benthic and nektonic species collected in each site (Figure 6). We then compared the number of benthic organisms collected in sites where we collected > 20 nektonic species vs. sites where < 20 nektonic species were collected. Significantly more benthic organisms were collected in sites when the number of individual nekton was < 20 ($t = 1.73$, $p<0.05$, $n = 12 < 20$ and $8 > 20$, Figure 7).

**Table 6.** GPS location of each benthic sample collected. Marsh sites refer to the existing marsh and restoration sites refer to samples collected in the planned restoration area. Numbers of benthic species are reported from each sample and GPS location of collection.

| Site | Location (GPS) | # Organisms |
|---|---|---|
| Marsh 1 | N27 51.572 W97 21.185 | 67 |
| Marsh 2 | N27 51.590 W97 21.016 | 0 |
| Marsh 3 | N27 51.676 W97 20.950 | 1 |
| Marsh 4 | N27 51.740 W97 20.904 | 18 |
| Marsh 5 | N27 51.736 W97 20.911 | 37 |
| Marsh 6 | N27 51.736 W97 20.901 | 34 |
| Marsh 7 | N27 51.641 W97 21.274 | 4 |
| Marsh 8 | N27 51.638 W97 21.276 | 2 |
| Marsh 9 | N27 51.633 W97 21.277 | 23 |
| Marsh 10 | N27 51.594 W97 21.194 | 12 |
| Restoration 1 | N27 51.679 W97 21.191 | 82 |
| Restoration 2 | N27 51.608 W97 20.994 | 53 |
| Restoration 3 | N27 51.676 W97 20.952 | 7 |
| Restoration 4 | N27 51.737 W97 20.908 | 12 |
| Restoration 5 | N27 51.734 W97 20.905 | 46 |
| Restoration 6 | N27 51.742 W97 20.893 | 29 |
| Restoration 7 | N27 51.814 W97 20.997 | 40 |
| Restoration 8 | N27 51.812 W97 20.999 | 25 |
| Restoration 9 | N27 51.685 W97 21.246 | 62 |
| Restoration 10 | N27 51.679 W97 21.246 | 99 |

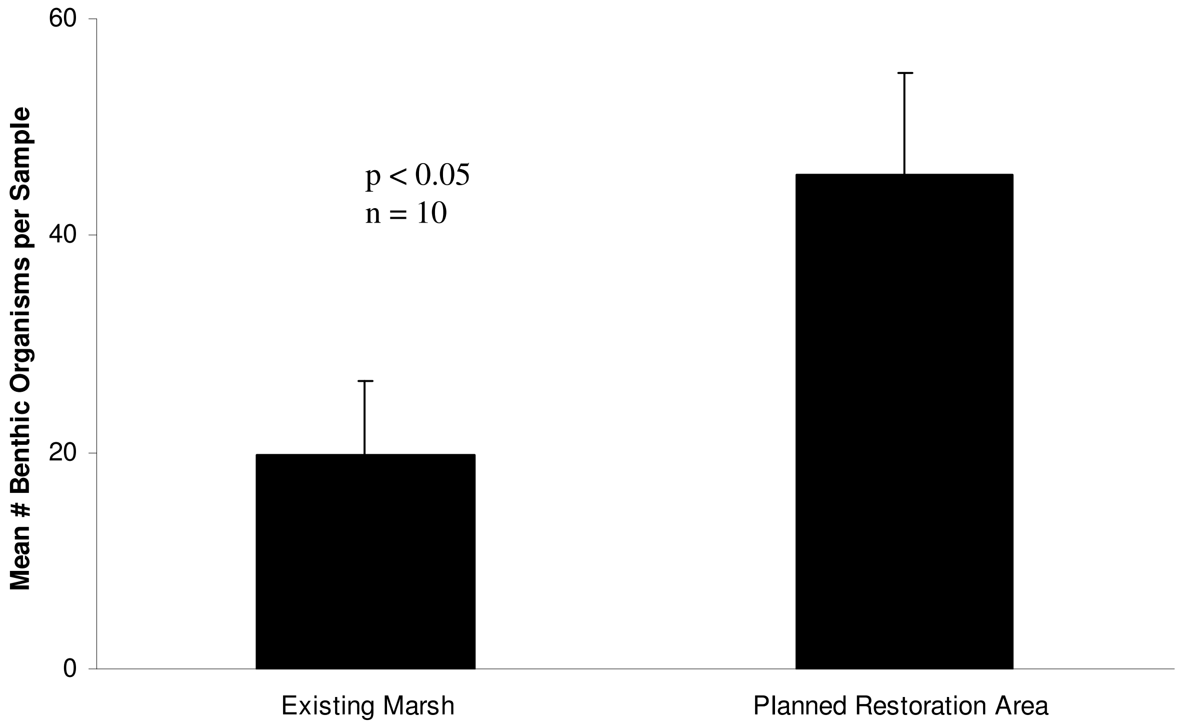


**Figure 6.** Mean number of benthic organisms ± SE collected in samples from the existing marsh and planned restoration area. A t-test indicated significantly greater number of benthic organisms in the planned restoration area ($p < 0.05$, $n = 10$).

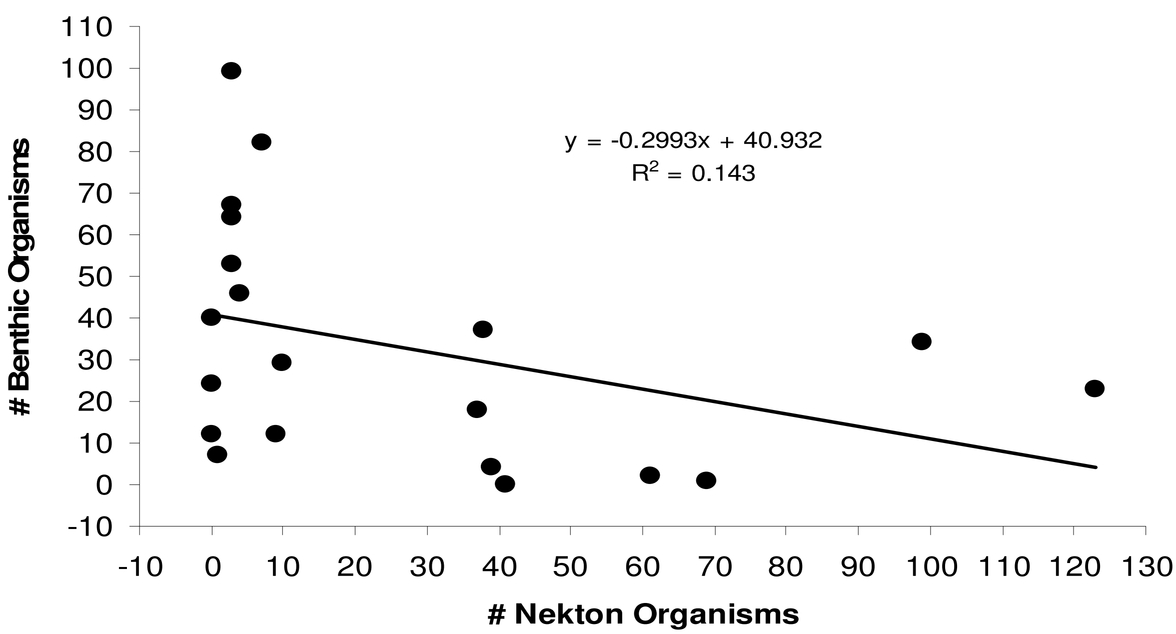


**Figure 7**. Relationship between number of benthic and nektonic organisms collected in each site.

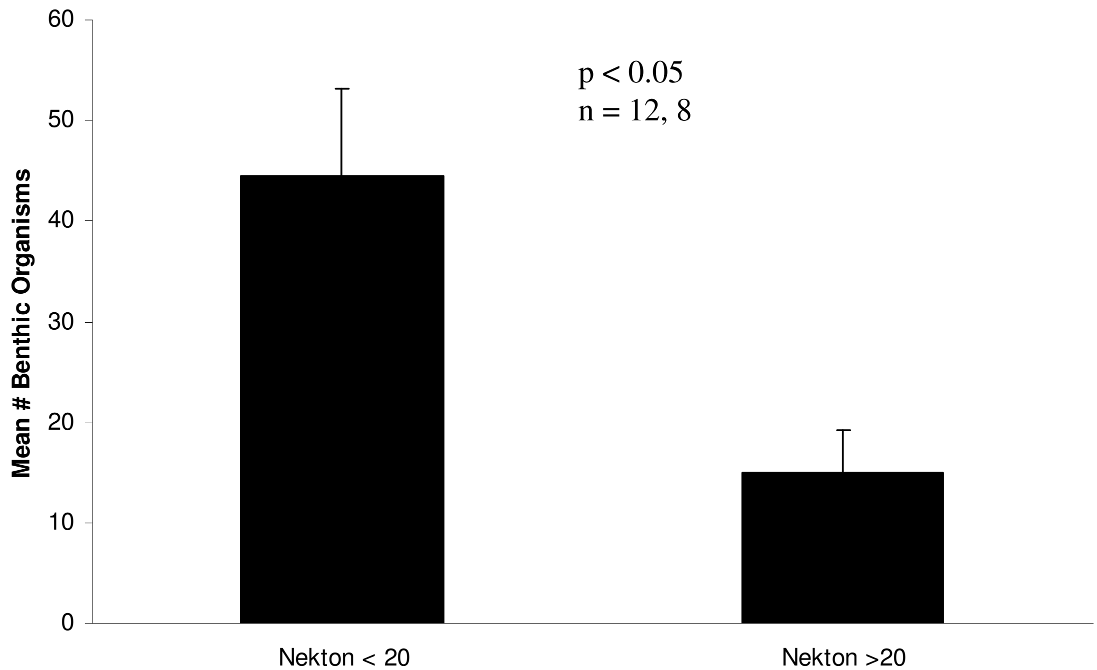


**Figure 8.** Mean number of benthic organisms + SE collected in when nekton density is < 20 $m^{-2}$ vs. when nekton is > 20 $m^{-2}$. A t-test indicated a significantly higher number of benthic organisms present when nekton density is < 20 $m^{-2}$ ($p < 0.05$, n = 12 and 8 for < 20 and > 20).

## Discussion

Abiotic conditions in Nueces Bay were within a range tolerable to most native nektonic and benthic species. Water quality parameters were similar between marsh and restoration sites in August 2009 and February 2010. Abiotic conditions can vary significantly across small spatial scales (e.g., Montagna and Ritter 2006), but we did not find community differences in this study to be caused by differences in water quality between natural marshes and planned restoration sites. Rather, the presence of vegetation seemed to drive the observed patterns of species abundance and diversity, and the presence of emergent vegetation was driven primarily by water depth. Vegetation was completely absent from the planned marsh restoration area, probably due to the average depth at these sites (McKee and Patrick 1988), and we only found *S. alterniflora* in the existing marshes fringing the planned restoration site. *Spartina alterniflora* is an intertidal species, and its distribution is limited by water inundation (McKee and Patrick 1988). The planned restoration sites were too deep to support *Spartina*, but, we did not find seagrass in our samples. The absence of seagrass may be due to the high turbidity levels common in Nueces Bay, but more studies will be needed to verify this supposition.

Significantly more nekton (Figures 2&3) were found in the existing marsh, which was perhaps unsurprising given many nektonic species prefer vegetated and/or structured habitats, especially *S. alterniflora* (Turner 1976, Turner and Boesch 1988, Bertness 1999). Numerous studies suggest that nektonic organisms will select vegetated habitats over unvegetated substrates, especially when predators are present (e.g., Zimmerman et al. 1984, Micheli 1997). We observed numerous red drum, *Sciaenops ocellatus*, while performing this survey, and the presence of red drum and other predators likely influences the distribution of the nektonic species collected. In addition to abundance, we noted a significantly higher diversity of nektonic organisms in the existing marsh samples (Figure 5).

In contrast to the nekton samples, we found significantly fewer benthic organisms in the existing marsh sites. We examined the relationship between the number benthic organisms and number of nektonic organisms collected in each site and noted a negative relationship (Figure 6). We performed an additional analysis to compare the number of benthic organisms collected when the number of nektonic organisms collected was less than vs. greater than 20. We found that significantly fewer benthic organisms were collected when nekton was greater than 20 (Figure 7). This finding is perhaps unsurprising given that benthic organisms such as polychaetes and oligochaetes that were common in our surveys are frequently eaten by nektonic organisms such as blue crabs (*Callinectes sapidus*). Still, we cannot clearly determine the pattern for benthic abundance and alternative mechanisms may account for our results. For example, wrack build up in the vegetated area may cover the substrate, creating hypoxic conditions that are not conducive to benthic organisms (Montagna and Ritter 2006). The increased nekton found in marsh sites be an attempt by these organisms to avoid their predators (Irlandi and Peterson 1991, Micheli 1997), and thus the benthic and nektonic abundances may not be related. However, previous studies in soft-sediment communities have found that nektonic predators strongly influence benthic community structure (Virnstein 1977, Posey and Hines 1991). Moreover, we did not find excessive amounts of wrack in the vegetated sites, and thus we feel strongly that predation by fishes, shrimp, and crabs drives the benthic community composition in Nueces Bay, TX. Additional empirical work may be needed to determine the factors driving benthic community structure in Nueces Bay.

## Conclusions

Salt marshes provide a host of ecosystem services including slowing coastal erosion, filtering sediments and nutrients as well as providing habitat for many species of fish and invertebrates (Bertness 1999, Pennings and Bertness 2001). Our data suggests that the existing marshes in Nueces Bay, TX harbor a greater abundance and diversity of nekton, including commercially important species like blue crabs, than the expansive mud bottom habitats common in this bay. Abiotic conditions were variable in the study site, and we did not find a relationship between abiotic variables and species abundance or diversity. Patterns of nektonic abundance were driven by the presence of vegetation, and vegetation distribution was determined by water depth. Thus, it is likely that by changing the substrate elevation in Nueces Bay, the CBBEP will be able to successfully restore marsh habitat in this site. Based on these findings, and other published works (reviewed by Pennings and Bertness 2001), we conclude that the planned restoration in Nueces Bay will provide essential habitat and increase the abundance of nekton, including many commercially and recreationally important species. Moreover, our data suggest that the abiotic conditions in Nueces Bay will support *Spartina* and associated marsh communities, but these communities do not develop in the majority of the bay due to water depth. By decreasing depth, we anticipate the planned restoration to lead to the creation of salt marsh habitats in Nueces Bay.

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## Appendix I. Nekton Collections by Site with Depth and GPS Coordinates

| Call # | Sample # | Common Name | Latin Name | Type of Organism | Length | Density ($m^{-2}$) |
|---|---|---|---|---|---|---|
| 1 | Restoration 1 | Goby Unknown | | Fish | 9.1 | 1 |
| 2 | Restoration 1 | Naked Goby | *Gobiosoma bosc* | Fish | 15.4 | 2 |
| 3 | Restoration 1 | Naked Goby | *Gobiosoma bosc* | Fish | 10.2 | |
| 4 | Restoration 1 | Brown Shrimp | *Farfantepenaeus aztecus* | Shrimp | 27.1 | 4 |
| 5 | Restoration 1 | Brown Shrimp | *Farfantepenaeus aztecus* | Shrimp | 20.5 | |
| 6 | Restoration 1 | Brown Shrimp | *Farfantepenaeus aztecus* | Shrimp | 12.7 | |
| 7 | Restoration 1 | Brown Shrimp | *Farfantepenaeus aztecus* | Shrimp | 16.6 | |
| 8 | Restoration 2 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 56.4 | 3 |
| 9 | Restoration 2 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 51.2 | |
| 10 | Restoration 2 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 36.0 | |
| 11 | Restoration 3 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 16.8 | 1 |
| 12 | Restoration 4 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 24.7 | 2 |
| 13 | Restoration 4 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 18.6 | |
| 14 | Restoration 5 | Blue Crab | *Callinectes sapidus* | Crab | 17.2 | 2 |
| 15 | Restoration 5 | Blue Crab | *Callinectes sapidus* | Crab | 16.5 | |
| 16 | Restoration 5 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 22.3 | 10 |
| 17 | Restoration 5 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 25.1 | |
| 18 | Restoration 5 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 24.8 | |
| 19 | Restoration 5 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 28.7 | |
| 20 | Restoration 5 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 19.6 | |
| 21 | Restoration 5 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 19.0 | |
| 22 | Restoration 5 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 18.7 | |
| 23 | Restoration 5 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 13.3 | |
| 24 | Restoration 5 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 16.8 | |
| 25 | Restoration 5 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 11.5 | |
| 26 | Restoration 6 | | | | | |
| 27 | Restoration 7 | | | | | |
| 28 | Restoration 8 | | | | | |
| 29 | Restoration 9 | Blue Crab | *Callinectes sapidus* | Crab | 10.5 | 1 |
| 30 | Restoration 9 | Brown Shrimp | *Farfantepenaeus aztecus* | Shrimp | 30.8 | 2 |
| 31 | Restoration 9 | Brown Shrimp | *Farfantepenaeus aztecus* | Shrimp | 21.1 | |
| 32 | Restoration 10 | Brown Shrimp | *Farfantepenaeus aztecus* | Shrimp | 40.3 | 3 |
| 33 | Restoration 10 | Brown Shrimp | *Farfantepenaeus* | Shrimp | 29.0 | |

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|---|---|---|---|---|---|---|
| | | | *aztecus* | | | |
| 34 | Restoration 10 | Brown Shrimp | *Farfantepenaeus aztecus* | Shrimp | 22.4 | |
| 35 | Marsh 1 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 15.8 | 2 |
| 36 | Marsh 1 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 19.6 | |
| 37 | Marsh 1 | Pipefish | *Syngnathus sp.* | Fish | 103.1 | 1 |
| 38 | Marsh 2 | Blue Crab | *Callinectes sapidus* | Crab | 16.0 | 7 |
| 39 | Marsh 2 | Blue Crab | *Callinectes sapidus* | Crab | 10.1 | |
| 40 | Marsh 2 | Blue Crab | *Callinectes sapidus* | Crab | 11.3 | |
| 41 | Marsh 2 | Blue Crab | *Callinectes sapidus* | Crab | 10.5 | |
| 42 | Marsh 2 | Blue Crab | *Callinectes sapidus* | Crab | 10.2 | |
| 43 | Marsh 2 | Blue Crab | *Callinectes sapidus* | Crab | 11.1 | |
| 44 | Marsh 2 | Blue Crab | *Callinectes sapidus* | Crab | 9.8 | |
| 45 | Marsh 2 | Bay Anchovy | *Anchoa mitcheli* | Fish | 25.1 | 7 |
| 46 | Marsh 2 | Bay Anchovy | *Anchoa mitcheli* | Fish | 23.5 | |
| 47 | Marsh 2 | Bay Anchovy | *Anchoa mitcheli* | Fish | 17.9 | |
| 48 | Marsh 2 | Bay Anchovy | *Anchoa mitcheli* | Fish | 14.7 | |
| 49 | Marsh 2 | Bay Anchovy | *Anchoa mitcheli* | Fish | 14.3 | |
| 50 | Marsh 2 | Bay Anchovy | *Anchoa mitcheli* | Fish | 12.4 | |
| 51 | Marsh 2 | Bay Anchovy | *Anchoa mitcheli* | Fish | 16.0 | |
| 52 | Marsh 2 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 70.3 | 7 |
| 53 | Marsh 2 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 66.7 | |
| 54 | Marsh 2 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 48.2 | |
| 55 | Marsh 2 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 27.4 | |
| 56 | Marsh 2 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 25.9 | |
| 57 | Marsh 2 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 24.0 | |
| 58 | Marsh 2 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 13.6 | |
| 59 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 9.8 | 20 |
| 60 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 23.9 | |
| 61 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 23.4 | |
| 62 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 18.2 | |
| 63 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 17.0 | |
| 64 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 18.7 | |
| 65 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 22.5 | |
| 66 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 23.3 | |
| 67 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 21.2 | |
| 68 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 13.6 | |
| 69 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 13.3 | |
| 70 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 17.7 | |
| 71 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 10.1 | |
| 72 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 18.6 | |
| 73 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 19.4 | |
| 74 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 21.3 | |
| 75 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 16.1 | |
| 76 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 22.8 | |

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|---|---|---|---|---|---|---|
| 77 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 20.5 | |
| 78 | Marsh 2 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 22.6 | |
| 79 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 23.3 | 67 |
| 80 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 9.0 | |
| 81 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 15.0 | |
| 82 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 15.9 | |
| 83 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 14.0 | |
| 84 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 16.0 | |
| 85 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 14.6 | |
| 86 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 18.9 | |
| 87 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 19.0 | |
| 88 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 21.6 | |
| 89 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 20.2 | |
| 90 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 19.2 | |
| 91 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 19.4 | |
| 92 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 19.4 | |
| 93 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 20.6 | |
| 94 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 17.4 | |
| 95 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 23.1 | |
| 96 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 22.2 | |
| 97 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 16.4 | |
| 98 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 20.9 | |
| 99 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 15.7 | |
| 100 | Marsh 3 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 11.8 | |
| 101 | Marsh 3 | Penaeid Shrimp | | Shrimp | 16.9 | 1 |
| 102 | Marsh 3 | Blue Crab | *Callinectes sapidus* | Crab | 13.3 | 1 |
| 103 | Marsh 3 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 75.6 | 2 |
| 104 | Marsh 3 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 44.0 | |
| 105 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 24.5 | 34 |
| 106 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 10.9 | |
| 107 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 20.0 | |
| 108 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 21.1 | |
| 109 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 15.7 | |
| 110 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 20.7 | |
| 111 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 22.3 | |
| 112 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 22.9 | |
| 113 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 20.5 | |
| 114 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 22.6 | |
| 115 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 14.9 | |
| 116 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 19.5 | |
| 117 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 22.0 | |
| 118 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 21.7 | |
| 119 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 17.4 | |
| 120 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 20.7 | |
| 121 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 20.0 | |
| 122 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 21.6 | |
| 123 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 19.5 | |
| 124 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 20.9 | |
| 125 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 15.0 | |

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|---|---|---|---|---|---|---|
| 126 | Marsh 4 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 18.3 | |
| 127 | Marsh 4 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 60.6 | 3 |
| 128 | Marsh 4 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 56.6 | |
| 129 | Marsh 4 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 34.4 | |
| 130 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 129.5 | 32 |
| 131 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 13.4 | |
| 132 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 28.6 | |
| 133 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 13.6 | |
| 134 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 23.0 | |
| 135 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 27.6 | |
| 136 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 19.3 | |
| 137 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 18.1 | |
| 138 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 22.6 | |
| 139 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 20.8 | |
| 140 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 16.7 | |
| 141 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 24.8 | |
| 142 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 16.7 | |
| 143 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 24.5 | |
| 144 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 23.0 | |
| 145 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 18.0 | |
| 146 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 22.5 | |
| 147 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 19.2 | |
| 148 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 23.6 | |
| 149 | Marsh 5 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 24.7 | |
| 150 | Marsh 5 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 19.7 | 6 |
| 151 | Marsh 5 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 20.0 | |
| 152 | Marsh 5 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 16.2 | |
| 153 | Marsh 5 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 16.5 | |
| 154 | Marsh 5 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 15.5 | |
| 155 | Marsh 5 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 13.6 | |
| 156 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 29.6 | 82 |
| 157 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 10.4 | |
| 158 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 24.0 | |
| 159 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 23.5 | |
| 160 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 18.8 | |
| 161 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 16.4 | |
| 162 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 14.6 | |
| 163 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 16.7 | |
| 164 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 16.9 | |
| 165 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 17.2 | |
| 166 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 16.9 | |
| 167 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 15.0 | |
| 168 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 14.8 | |

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|---|---|---|---|---|---|---|
| 169 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 14.0 | |
| 170 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 14.9 | |
| 171 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 27.4 | |
| 172 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 18.9 | |
| 173 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 26.1 | |
| 174 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 21.3 | |
| 175 | Marsh 6 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 16.9 | |
| 176 | Marsh 6 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 24.0 | 14 |
| 177 | Marsh 6 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 26.1 | |
| 178 | Marsh 6 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 29.8 | |
| 179 | Marsh 6 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 12.8 | |
| 180 | Marsh 6 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 14.9 | |
| 181 | Marsh 6 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 15.7 | |
| 182 | Marsh 6 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 13.1 | |
| 183 | Marsh 6 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 33.8 | |
| 184 | Marsh 6 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 29.0 | |
| 185 | Marsh 6 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 27.9 | |
| 186 | Marsh 6 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 29.2 | |
| 187 | Marsh 6 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 28.4 | |
| 188 | Marsh 6 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 36.4 | |
| 189 | Marsh 6 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 50.0 | |
| 190 | Marsh 6 | Blue Crab | *Callinectes sapidus* | Crab | 17.2 | 1 |
| 191 | Marsh 6 | Inland Silverside | *Menidia beryllina* | Fish | 54.5 | 2 |
| 192 | Marsh 6 | Inland Silverside | *Menidia beryllina* | Fish | 56.3 | |
| 193 | Marsh 7 | Spotted Seatrout | *Cynoscion nebulosus* | Fish | 52.1 | 1 |
| 194 | Marsh 7 | Blue Crab | *Callinectes sapidus* | Crab | 18.2 | 2 |
| 195 | Marsh 7 | Blue Crab | *Callinectes sapidus* | Crab | 11.3 | |
| 196 | Marsh 7 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 68.2 | 8 |
| 197 | Marsh 7 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 51.4 | |
| 198 | Marsh 7 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 49.8 | |
| 199 | Marsh 7 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 49.4 | |
| 200 | Marsh 7 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 33.6 | |
| 201 | Marsh 7 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 22.7 | |
| 202 | Marsh 7 | White Shrimp | *Litopenaeus* | Shrimp | 26.4 | |

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|---|---|---|---|---|---|---|
| | | | *setiferus* | | | |
| 203 | Marsh 7 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 25.0 | |
| 204 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 17.0 | 28 |
| 205 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 27.3 | |
| 206 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 26.7 | |
| 207 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 23.8 | |
| 208 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 20.7 | |
| 209 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 18.9 | |
| 210 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 21.2 | |
| 211 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 23.8 | |
| 212 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 25.3 | |
| 213 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 18.3 | |
| 214 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 18.1 | |
| 215 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 17.6 | |
| 216 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 18.7 | |
| 217 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 19.2 | |
| 218 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 21.5 | |
| 219 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 17.2 | |
| 220 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 18.8 | |
| 221 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 22.4 | |
| 222 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 23.9 | |
| 223 | Marsh 7 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 25.4 | |
| 224 | Marsh 8 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 46.8 | 5 |
| 225 | Marsh 8 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 34.6 | |
| 226 | Marsh 8 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 27.3 | |
| 227 | Marsh 8 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 24.2 | |
| 228 | Marsh 8 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 16.4 | |
| 229 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 8.9 | 56 |
| 230 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 27.8 | |
| 231 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 20.1 | |
| 232 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 22.5 | |
| 233 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 24.0 | |
| 234 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 21.4 | |
| 235 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 20.7 | |
| 236 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 22.0 | |
| 237 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 23.2 | |
| 238 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 19.6 | |
| 239 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 11.1 | |
| 240 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 12.0 | |
| 241 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 21.3 | |
| 242 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 20.6 | |
| 243 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 15.8 | |
| 244 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 19.3 | |
| 245 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 20.2 | |
| 246 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 24.5 | |
| 247 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 23.4 | |

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|---|---|---|---|---|---|---|
| 248 | Marsh 8 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 21.2 | |
| 249 | Marsh 9 | Blue Crab | *Callinectes sapidus* | Crab | 36.7 | 1 |
| 250 | Marsh 9 | Striped Mullet | *Mugil cephalus* | Fish | 79.7 | 1 |
| 251 | Marsh 9 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 41.4 | 13 |
| 252 | Marsh 9 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 34.2 | |
| 253 | Marsh 9 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 41.7 | |
| 254 | Marsh 9 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 40.2 | |
| 255 | Marsh 9 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 31.7 | |
| 256 | Marsh 9 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 38 | |
| 257 | Marsh 9 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 29.1 | |
| 258 | Marsh 9 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 26.8 | |
| 259 | Marsh 9 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 26.1 | |
| 260 | Marsh 9 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 28.8 | |
| 261 | Marsh 9 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 20.8 | |
| 262 | Marsh 9 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 27.3 | |
| 263 | Marsh 9 | White Shrimp | *Litopenaeus setiferus* | Shrimp | 22.5 | |
| 264 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 13.3 | 108 |
| 265 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 26.3 | |
| 266 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 24.2 | |
| 267 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 22.4 | |
| 268 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 25.5 | |
| 269 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 26.2 | |
| 270 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 17.8 | |
| 271 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 21.0 | |
| 272 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 23.7 | |
| 273 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 24.1 | |
| 274 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 18.5 | |
| 275 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 25.2 | |
| 276 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 22.6 | |
| 277 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 18.9 | |
| 278 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 21.9 | |
| 279 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 25.8 | |
| 280 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 24.5 | |
| 281 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 25.4 | |
| 282 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 20.7 | |
| 283 | Marsh 9 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 24.2 | |
| 284 | Marsh 10 | Inland Silverside | *Menidia beryllina* | Fish | 47.1 | 3 |
| 285 | Marsh 10 | Inland Silverside | *Menidia beryllina* | Fish | 44.6 | |
| 286 | Marsh 10 | Inland Silverside | *Menidia beryllina* | Fish | 39.3 | |
| 287 | Marsh 10 | Blue Crab | *Callinectes sapidus* | Crab | 16.1 | 4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 288 | Marsh 10 | Blue Crab | *Callinectes sapidus* | Crab | 14.7 | |
| 289 | Marsh 10 | Blue Crab | *Callinectes sapidus* | Crab | 9.8 | |
| 290 | Marsh 10 | Blue Crab | *Callinectes sapidus* | Crab | 10.4 | |
| 291 | Marsh 10 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 14.1 | 2 |
| 292 | Marsh 10 | Grass Shrimp | *Palaemonetes sp.* | Shrimp | 13.9 | |

**Appendix II. Benthic Collections by Site with Density**

| Site | Families Present | Density |
|---|---|---|
| Marsh 1 | Hesionidae | 1 |
| | Spionidae | 13 |
| | Capitellidae | 15 |
| | Oligochaete | 1 |
| | Gastropod | 1 |
| | Polychaete fragment | 36 |
| Marsh 2 | | |
| Marsh 3 | Nereididae | 1 |
| Marsh 4 | Spionidae | 4 |
| | Capitellidae | 8 |
| | Polychaete fragment | 6 |
| Marsh 5 | Capitellidae | 6 |
| | Spionidae | 8 |
| | Eunicidae | 1 |
| | Polychaete fragment | 22 |
| Marsh 6 | Nereididae | 6 |
| | Spionidae | 13 |
| | Capitellidae | 2 |
| | Eunicidae | 1 |
| | Polychaete fragment | 12 |
| Marsh 7 | Eunicidae | 1 |
| | Capitellidae | 1 |
| | Polychaete fragment | 2 |
| Marsh 8 | Staphylinidae larvae | 1 |
| | Polychaete fragment | 1 |
| Marsh 9 | Capitellidae | 11 |
| | Eunicidae | 4 |
| | Polychaete fragment | 8 |
| Marsh 10 | Nereididae | 5 |
| | Spionidae | 3 |
| | Capitellidae | 1 |
| | Polychaete | 3 |

| | | |
|---|---|---|
| | fragment | |
| Restoration 1 | Spionidae | 27 |
| | Capitellidae | 8 |
| | Pilargidae | 1 |
| | Polychaete fragment | 46 |
| Restoration 2 | Pilargidae | 3 |
| | Spionidae | 2 |
| | Capitellidae | 9 |
| | Polychaete fragment | 39 |
| Restoration 3 | Spionidae | 3 |
| | Polychaete fragment | 4 |
| Restoration 4 | Pilargidae | 1 |
| | Spionidae | 5 |
| | Capitellidae | 2 |
| | Polychaete fragment | 4 |
| Restoration 5 | Oligochaete | 1 |
| | Capitellidae | 12 |
| | Spionidae | 6 |
| | Polychaete fragment | 27 |
| Restoration 6 | Hesionidae | 1 |
| | Spionidae | 13 |
| | Capitellidae | 4 |
| | Polychaete fragment | 11 |
| Restoration 7 | Eunicidae | 1 |
| | Pilargidae | 2 |
| | Capitellidae | 8 |
| | Spionidae | 6 |
| | Maldanidae | 1 |
| | Polychaete fragment | 22 |
| Restoration 8 | Eunicidae | 1 |
| | Capitellidae | 3 |
| | Pilargidae | 1 |
| | Polychaete fragment | 18 |
| | Spionidae | 1 |
| | Nereididae | 1 |

| | | |
|---|---|---|
| Restoration 9 | Pilargidae | 2 |
| | Eunicidae | 2 |
| | Spionidae | 12 |
| | Capitellidae | 10 |
| | Polychaete fragment | 38 |
| Restoration 10 | Capitellidae | 21 |
| | Spionidae | 30 |
| | Eunicidae | 1 |
| | Polychaete fragment | 47 |