

10/29/2014

Final Report for the Mobile Bay National Estuary Program- Evaluating Gains in Ecosystem Services with Coastal Restoration Project- Part 1: Monitoring restoration activities

Project Period: 7/1/2012-9/30/2014

Amount: \$58,650

Project Description:

Field Component: We monitored three restoration projects previously carried out in partnership with the Mobile Bay National Estuary Program. The three projects vary in design, implementation, and restoration focus, but all of them have the common goal of restoring fringing and degraded coastal communities and the services therein provided. One project involved the stabilization of the shoreline and planting of riparian vegetation at Luscher Park in Dog River (Fig. 1.). A second project has focused on restoring a native grass marsh in Helen Wood Park at the mouth of Dog River (Fig. 1). A third project involved the construction of a combination of pre-designed offshore and intertidal reefs composed of riprap across private property on the western shore of Mobile Bay (Fig. 1). This project was built with the intention of reducing coastline erosion and favoring the consolidation of healthy fringe communities.

In all three restoration sites, we established three control transects (locations adjacent to the restored area where no restoration activities had been carried out) and an equal number of transects in restored locations. The transects ran from upland (i.e. landward border of the fringing habitat to the subtidal). Quarterly over two years we quantified the following metrics in a number of stations along each transect:

- diversity and abundance of plant species from the upland to the subtidal
- diversity and abundance of nekton in the intertidal and subtidal
- intertidal benthic invertebrate communities and sediment organic content
- water quality parameters
- shoreline elevation profile and intensity of erosion or stability

Materials and Methods:

Sampling at each site

- 1.) Dog River Park (aka Luscher Park; 30°37'40"N, 88°06'06"W)- restored native grasses riverine

Two years post restoration, three transects were set within the native plant restored area of Dog River Park. These transects are different from the other two sites due to park maintenance procedures that keep the planted vegetation within a narrow border along the shoreline. Seaward transects typically only extend out ~5m because of the extreme depth increases due to boat action at this popular boat launch site. Therefore, plant abundance and community composition counts were conducted solely at the waterline to maintain a constant quadrat that is comparable over time. Nekton community sampling was conducted by using a 5m wide seine and seining parallel to the shoreline for ~10m to capture nekton utilizing the shore vegetation. Water samples were taken mid transect for water quality comparisons. The control transects were set up ~60m to the north of the restored transects in an area cluttered with debris from an older seawall structure for habitat comparisons. Little to no vegetation occurs here, however quadrats are also set along the shoreline to monitor any potential vegetation

growth or community changes. Seining and water samples were conducted at these transects in similar fashion to the restored area transects.

2.) Mon Louis Island(30°26'30"N, 88°06'20"W)- offshore reef construction

Post construction, sampling was conducted at all 40m long control transects(20m shoreward, 20m seaward) perpendicular to the shoreline, located ~250m North of reefs and at reef adjacent transects of the same length within one 24 hour period. Currently at this site, there is no vegetative growth along the transects that are completely located on sandy beach substrate. Therefore, we conducted surveys of shoreward vegetative growth only if sediment accrual allows for establishment of any new vegetation. At all transects, we collected water samples and 15cm diameter sediment cores at 10m seaward, measuring distance from the waterline, for a total of 6 samples. We also surveyed the nekton community with a 5m wide seine net, beginning at the end of the seaward transect and seining shoreward 20m for a total area seined of 100m². Elevation profiles were measured using Real Time Kinematic (RTK) satellite navigation with a 1cm level of accuracy. When possible, these measurements were compared statistically among each transect and treatment, as well as chronologically. These measurements were compared with a control (i.e. not influenced by offshore reefs) site located approximately 380m to the North of the reef influenced site. Both sites were located directly in front of privately held properties, with the sole difference being the influence of the offshore reef structures.

3.) Helen Wood Park (30°34'13"N, 88°05'08"W)- restored native grasses marsh

Two years post restoration, three intertidal transects were set perpendicular to shoreline at variable lengths to compensate for the irregular shape of the marsh that is bordered by a parking lot to the east and a major road to the west. The transects were set at lengths of 35m, 45m, and 50m from west to east with four stationary 1m² quadrates along each transect to measure plant height, abundance, and species diversity. Nekton sampling was conducted with seining, however the seaward transects are also irregular due to the installation of oyster reefs approximately 10 to 15m offshore. Therefore, the seaward transects measure 10m, 15m, and 15m in length from west to east. Sediment cores and water samples will be taken in the center of each seaward transect. A fourth back marsh transect at 50m length was installed with four stationary quadrates to measure this area's plant species community and any changes over time. Control transects were stationed ~780m north of the restored marsh in an area dominated by sandy beach and *Phragmites* vegetation for an unrestored comparison. This control site was also a disturbance prone shoreline, with private property to the North and a water treatment plant to the Southwest. Shoreward transects were 20m in length with plant height, abundance, and species composition measured. Seaward transects are 10 to 15m in length in order to be comparable to the restored marsh seaward transects and the same metrics are sampled in a similar fashion (i.e. seining, water samples, and sediment cores). RTK measurements were taken at both control and marsh restored sites once a year to measure shore height and potential sediment accrual/ erosion. When possible, these measurements were compared statistically among each transect and treatment, as well as chronologically.

Sample Processing:

a) Plant communities-

At each permanent quadrat, a 1m² area is identified down to plant species and counted. The most abundant species from each quadrat is then measured in length for up to 20 individuals. These community processes will be tracked and statistical methods used to monitor changes in plant density, height, and composition among transects, treatments, and over time.

b) Nekton communities-

Each nekton sample was similarly identified down to species and counted with length measurements of up to 20 individuals per species. Each seine sample will then be separated by species into a pre-weighed tin, dried in an oven at 70°C for >24hr period and a dry weight will be measured. The samples were then placed in a muffle furnace and burned at 500°C until all volatiles and organic matter consumed, then an ash free dry weight (AFDW) measured. These measurements were used with graphing and statistical methodologies to compare community composition and nekton biomass metrics among transects, treatments, and over time.

c) Water quality parameters

A 1L water sample was taken at each transect and filtered using glass fiber filters (GFF) type A/E at pore size 1µm to measure the following parameters:

- Water column chlorophyll- 100mL of sample water was filtered and then the filter is frozen to preserve chlorophyll structure until sent to DISL's onsite analytical lab for analysis of total chlorophyll content per volume of sample.
- Total suspended solids(TSS)- a pre-muffled, pre-weighed filter is used to filter 200mL of sample water, dried at 45°C for 24hrs, and then re-weighed for a final measurement.
- Total dissolved nitrogen (TDN)- 50mL of filtered water will be frozen until sent to the onsite analytical lab for analysis of TDN per volume of sample. This sample will also be used to quantify dissolved inorganic nitrogen (DIN) and orthophosphate content (PO₄³⁻).
- Water sample will also be used to determine salinity at each site.

d) Sediment cores

Cores were examined for invertebrate community composition with individuals identified down to taxonomic group (e.g. gastropod, bivalve, etc.). Biomass of the cores was then placed in a pre-weighed tin, dried at 45°C for 24hrs and re-weighed. The remainder of the core sample was dried, weighed, and then placed in a muffle furnace for AFDW measurements to obtain the percent composition of organic material.

(*Special case- seagrass samples) In the event that seagrass is found at any of the sites, a minimum of 10 shoots will be collected for morphometrics and biomass measurements.

Sampling schedule:

Preliminary scouting of sites and control site search was conducted in August and September of 2012. This was followed by the determination of transects and stations to be monitored at each site. Transect and station determination could not be completed for Mon Louis Island (MLI) sites until the construction of offshore and intertidal reefs was completed in early spring of 2013. Following transect and station determination, the seasonal sampling scheme was conducted for all restored sites and respective control sites, with exact dates found in Table 1.

Table 1. Sampled dates at all monitoring sites.

| SITE | YEAR | SAMPLED DATES |
|------------------------|------|-----------------------|
| DOG RIVER PARK (DR) | 2012 | 9/19 |
| | 2013 | 3/14, 6/5, 10/22 |
| | 2014 | 3/4 |
| HELEN WOOD PARK (HWP) | 2012 | 9/19 |
| | 2013 | 3/14, 6/5, 10/22 |
| | 2014 | 2/27, 5/3 |
| MON LOUIS ISLAND (MLI) | 2013 | 3/15, 5/3, 6/7, 10/31 |
| | 2014 | 2/27, 5/3 |

Results for biological metrics:

Restoration monitoring project #1: Dog River Park

Vegetation monitoring-

Restored vegetation was monitored at the waterline when possible, however extensive park maintenance prevented this on multiple occasions. As evidenced in Figure 2, when left untrammelled, the restored native vegetation regrew to dominate the waterline stations. The 2.5m stations of transects were mowed continuously following the first sampling round and therefore could not be monitored. Alternatively, the control stations were dominated with invasive and/or disturbance related vegetation species that persisted throughout the monitoring timeline (Table 2). In addition to the persistence of native emergent vegetation at the restored transects, the submerged aquatic vegetation species *Vallisneria americana* began to colonize a submerged portion of transect 1 (the southernmost transect). Pre-restoration colonization of this species has not been measured and so it can not be determined whether or not this is a new patch, or conversely a sporadically occurring patch.

Table 2. Vegetation species encountered at monitored sites

| SITE | STABLE/ NATIVE | DISTURBANCE AND/OR INVASIVE | INTERMEDIATE |
|---------------------|---|--|--|
| DOG RIVER PARK (DR) | | | |
| RESTORED | <i>Zizania aquatica</i> , <i>Spartina patens</i> , <i>Juncus roemerianus</i> , <i>Schoenoplectus californicus</i> , <i>Schoenoplectus robustus</i> , <i>Vallisneria americana</i> | <i>Mitreola petiolata</i> , <i>Colocasia esculent</i> | <i>Sagittaria lancifolia</i> , <i>Solidago fistulosa</i> |
| CONTROL | <i>Spartina patens</i> | <i>Mitreola petiolata</i> , <i>Calamintha georgiana</i> , <i>Hedera</i> sp., <i>Ipomea</i> sp., <i>Colocasia esulent</i> , <i>Panicum repens</i> | <i>Sagittaria lancifolia</i> , <i>Distichlis spicata</i> |

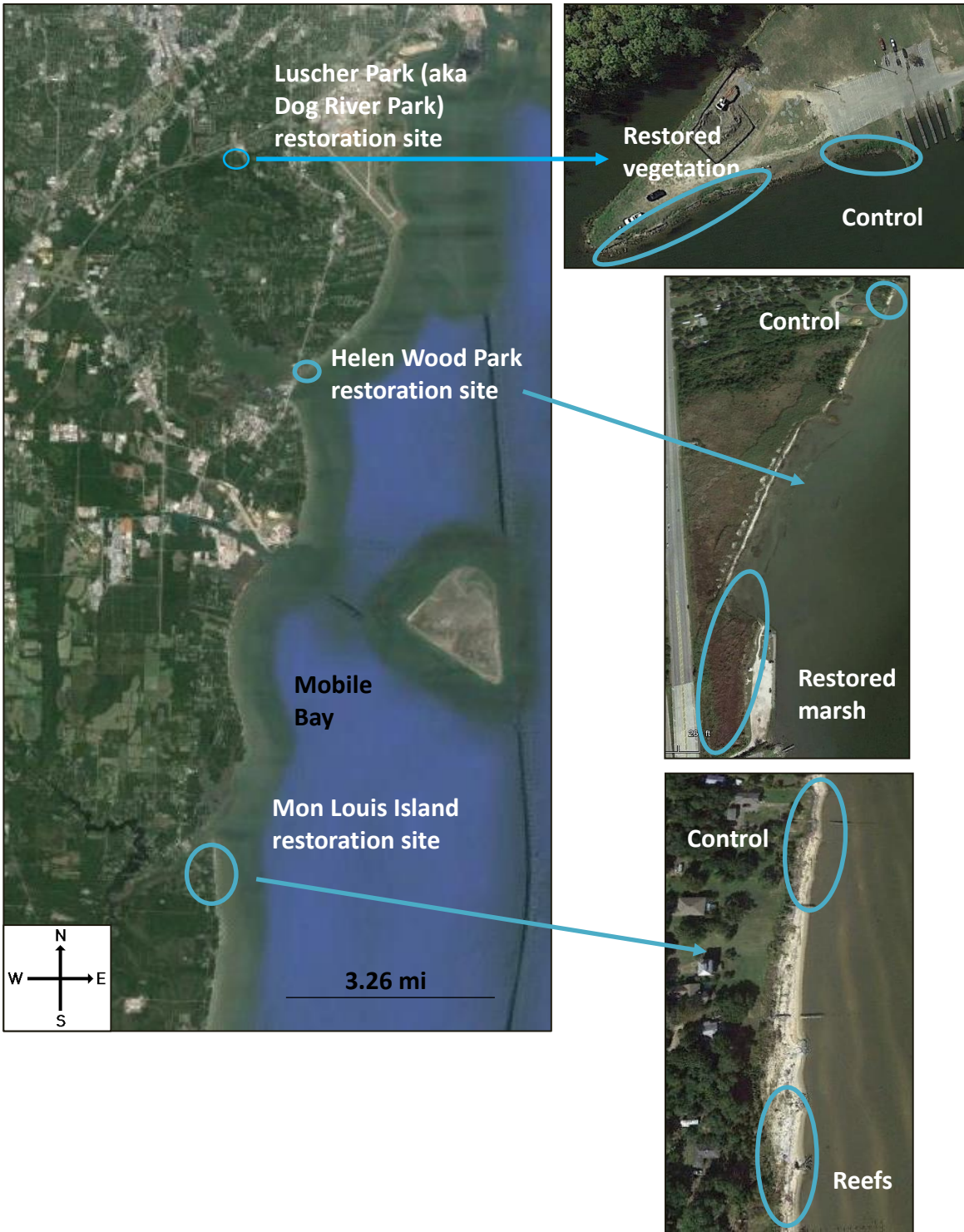


Figure 1. Figure 1. Left, map of Mobile Bay National Estuary Program restoration sites within Dog River and Mon Louis Island, AL. Right, locations of restored and control sites within each monitored restoration.

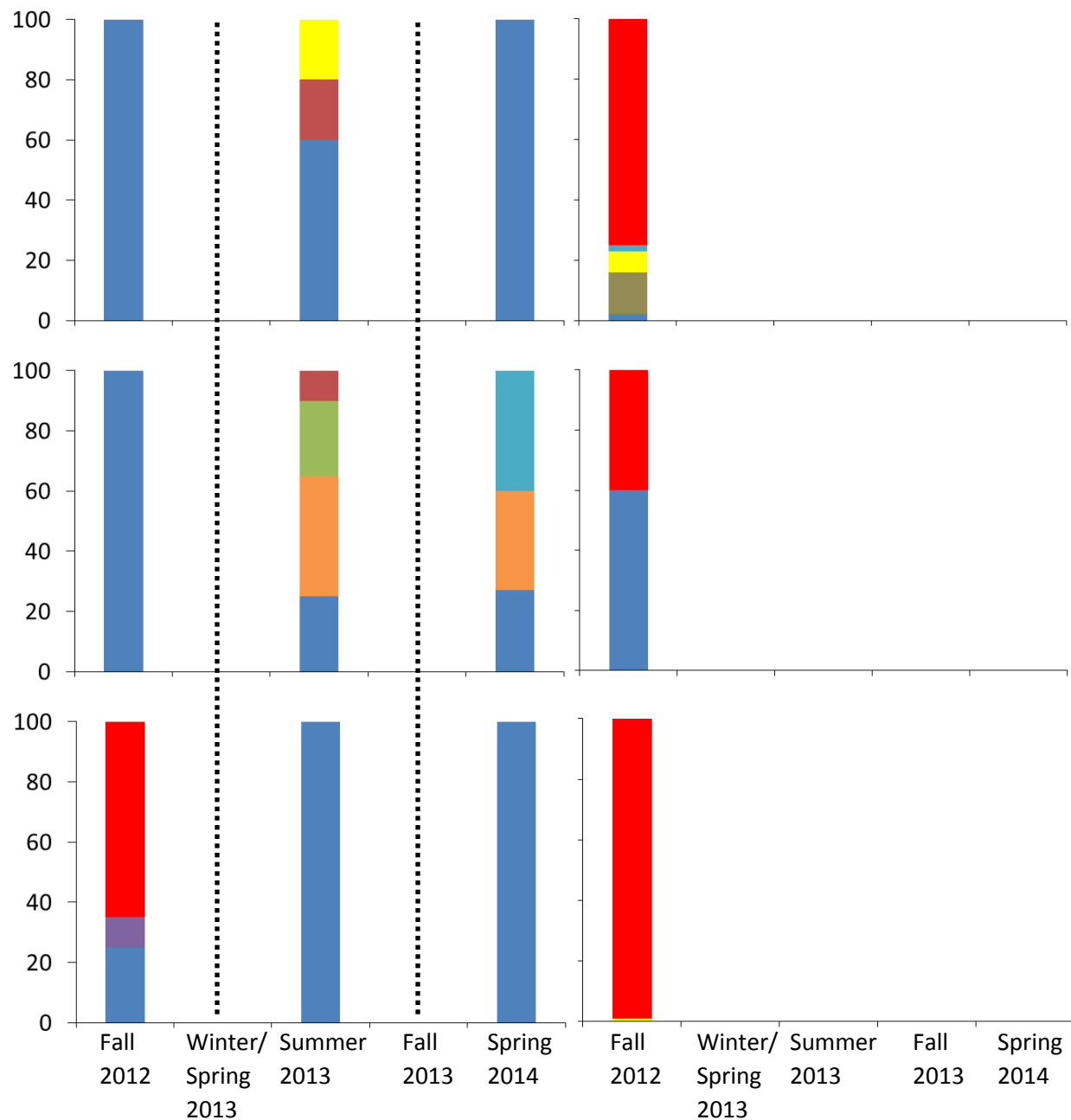


Figure 2. DR park restored vegetation species percent contribution of transects 1 through 3 (top to bottom) and at 0m and 2.5m (left and right).

Legend:

Stable species:

- Z. aquatica*
- S. patens*
- J. roemerianus*
- S. californicus*
- S. robustus*

Disturbance species:

- M. petiolata*
- C. esculenta*

Both:

- S. lancifolia*
- S. fistulosa*
- Park maintenance mowed to waterline

Nekton monitoring-

Total biomass of nekton (Fig. 3) was only variable among dates sampled (seasonally, $p=0.012$) and not between control and restored vegetation transects ($p=0.379$). Seines conducted in summer and fall of 2013 had a higher biomass content than any other time sampled. Species composition of the control and restored vegetation transects was similar, with only two species unique to the control concrete slab habitat and six species unique to the restored vegetation habitat (Table 3). Unique control habitat species (*T. maculatus*, *H. jaguana*, and *L. setiferus*) are generally classified as structure independent and often prefer sandy/muddy bottom sediments. Three of the five nekton species unique to the restored vegetation habitat (*G. robustum*, *L. oculatus*, and *P. pugio*) are generally classified as structure dependent species, for at least one part of their life cycle, and the other two species are less associated with structure (i.e. *M. cephalus* and *E. argenteus*). In the control transects, the largest biomass was from a single largemouth bass (*M. salmoides*, Table 3) and the largest number of individuals was approximately 11,000 bay anchovies (*A. mitchilli*). In the restored vegetation transects, the greatest amount of nekton biomass was attributed to a single spotted gar (*L. oculatus*, Table 3) and the most abundant species was approximately 5,800 bay anchovies. Relative differences between species composition changes over time are represented in Figure 4.

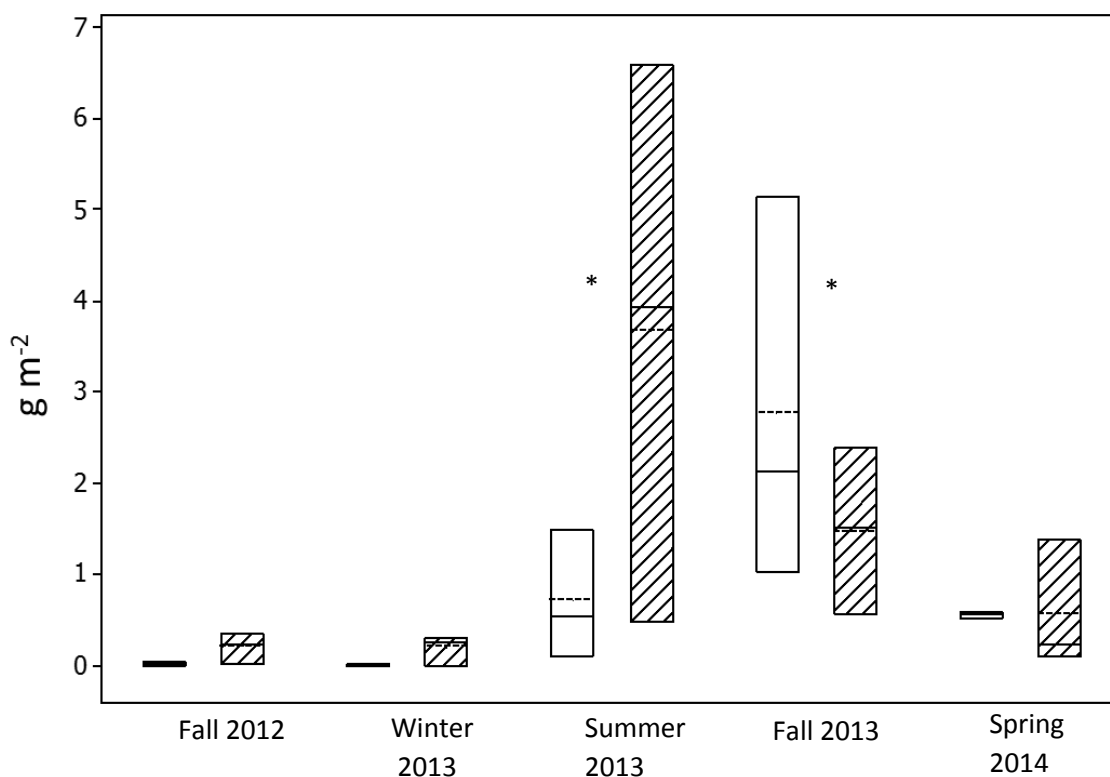


Figure 3. DR nekton biomass for control (open) and restored (diagonal slash). Dashed line represents mean and asterisks represent differences among sample date.

Table 3. Nekton species present at DR park monitoring sites. Bold species indicate unique presence at listed habitat type.

| | Control habitat site species | Biomass gAFDW | Number of individuals | Restored habitat site species | Biomass (gAFDW) | Number of individuals |
|---------------|-------------------------------------|---------------|-----------------------|--------------------------------------|-----------------|-----------------------|
| Fish | <i>Menidia beryllina</i> | 28.4836 | 103 | <i>Menidia beryllina</i> | 66.6571 | 231 |
| | <i>Anchoa mitchilli</i> | 89.1271 | 10,914 | <i>Anchoa mitchilli</i> | 38.4258 | 5,770 |
| | <i>Ctenogobius boleosoma</i> | 0.1211 | 58 | <i>Ctenogobius boleosoma</i> | 0.067 | 4 |
| | <i>Leiostoma xanthurus</i> | 6.5344 | 2 | <i>Leiostomus xanthurus</i> | 4.567 | 2 |
| | <i>Achirus lineatus</i> | 0.1001 | 3 | <i>Achirus lineatus</i> | 1.4397 | 4 |
| | <i>Micropterus salmoides</i> | 148.2966 | 8 | <i>Micropterus salmoides</i> | 6.1317 | 18 |
| | <i>Strongylura marina</i> | 0.0931 | 1 | <i>Strongylura marina</i> | 0.2013 | 2 |
| | <i>Lepomis macrochirus</i> | 2.3518 | 1 | <i>Lepomis macrochirus</i> | 32.1218 | 7 |
| | <i>Lepomis microlophus</i> | 23.23 | 1 | <i>Lepomis microlophus</i> | 59.88 | 3 |
| | <i>Syngnathus scovelli</i> | 0.2629 | 2 | <i>Syngnathus scovelli</i> | 0.5557 | 9 |
| | <i>Fundulus grandis</i> | 0.1427 | 15 | <i>Fundulus grandis</i> | 3.5251 | 205 |
| | <i>Syngnathus louisianae</i> | 0.0032 | 1 | <i>Syngnathus louisianae</i> | 0.5598 | 5 |
| | <i>Lagodon rhomboides</i> | 0.7957 | 17 | <i>Lagodon rhomboides</i> | 9.9534 | 53 |
| | <i>Micropogonius undulates</i> | 0.5256 | 35 | <i>Micropogonius undulates</i> | 0.6569 | 35 |
| | <i>Trinectes maculatus</i> | 0.116 | 12 | <i>Mugil cephalus</i> | 6.72 | 1 |
| | <i>Harengula jaguana</i> | 0.7102 | 142 | <i>Gobiosoma robustum</i> | 0.1192 | 1 |
| | | | | <i>Eucinostomas argenteus</i> | 6.8571 | 4 |
| | | | | <i>Lepisosteus oculatus</i> | 122.66 | 1 |
| Shrimp | <i>Litopenaeus setiferus</i> | 0.3008 | 3 | <i>Paleomentes pugio</i> | 0.9819 | 87 |
| Crab | <i>Callinectes sapidus</i> | 0.7957 | 1 | <i>Callinectes sapidus</i> | 82.8637 | 13 |

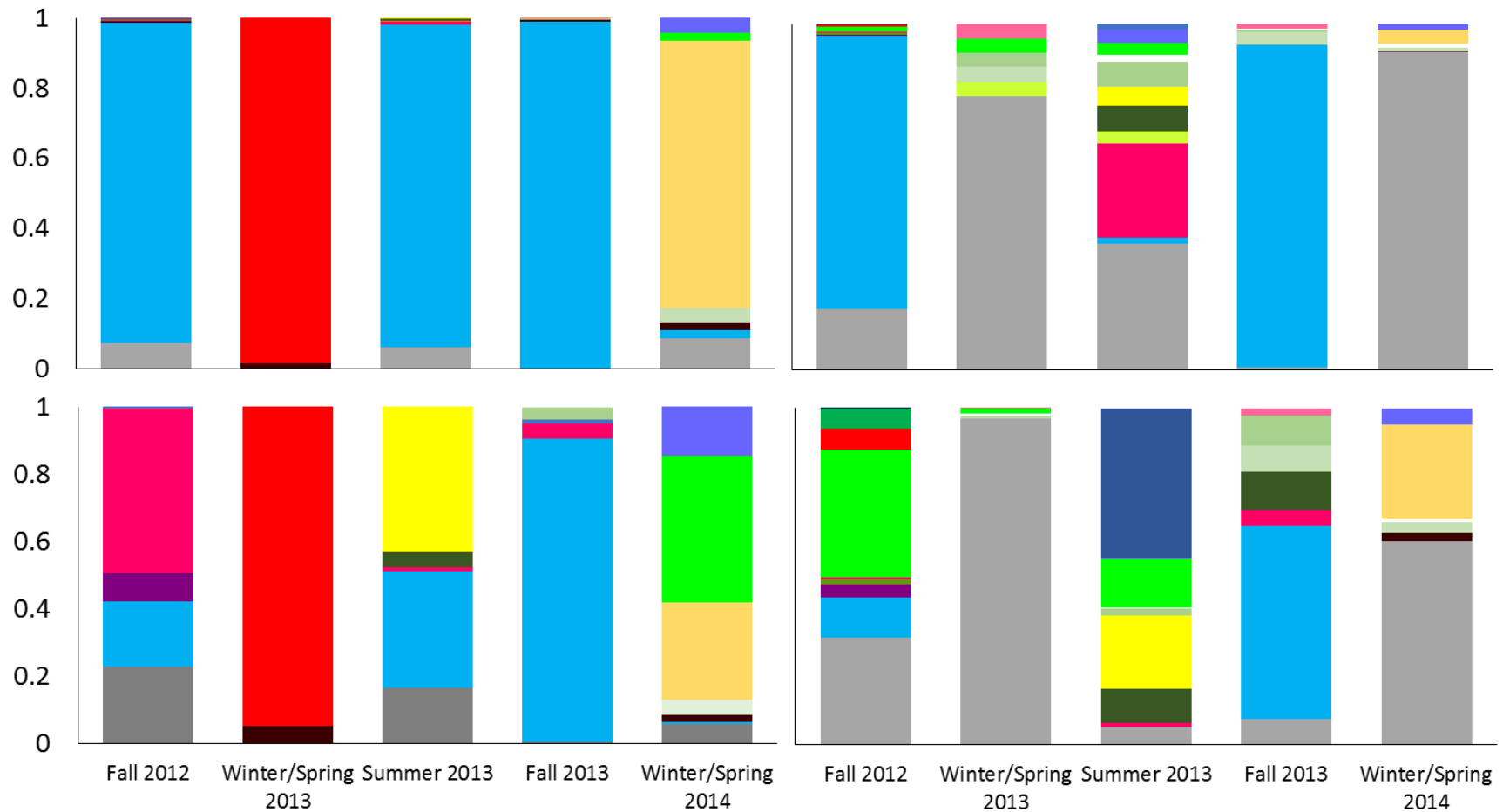
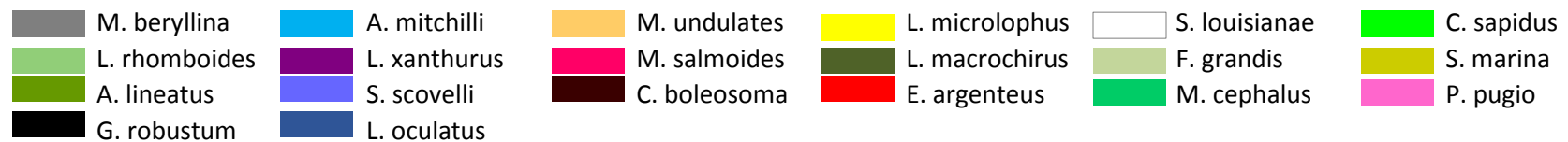


Figure 4. Nekton species % contribution to total number of individuals (top) and total biomass (bottom) for DR Park control (left) and restored vegetation (right).

Legend:



Water column monitoring-

1.) chlorophyll- Similar to nekton biomass, water column chlorophyll a content was also only variable among dates sampled ($p < 0.01$, Fig. 5) and no evidence of differences between control and restored vegetation ($p = 0.25$). The fall 2013 sampling had the highest chlorophyll content, while the spring 2014 had the lowest and the other dates equal.

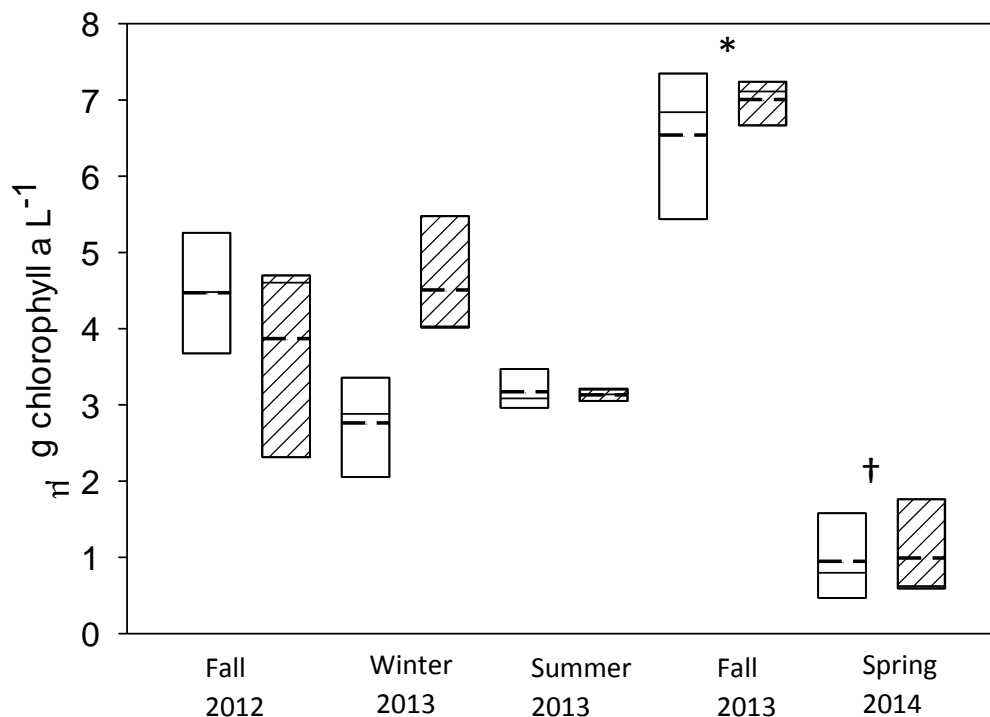


Figure 5. Chlorophyll a concentrations of water samples from DR control (open) and restored vegetation transects (diagonal slash). Dashed lines represent mean and symbols note significantly distinct measurements.

2.) TSS- There was no evidence of differences in amount of total suspended solids (g L^{-1}) between control and restored transects ($p = 0.56$; Fig. 6). The highest amount of total suspended solids was in the March 2013 sampling round, which was significantly greater than any other sampling round ($p = 0.027$).

3.) TDN- Similar to TSS, the total dissolved nitrogen content of water sampled was similar between transects ($p = 0.94$), but dissimilar among dates ($p < 0.01$; Fig. 7). DIN measurements were also only variable seasonally, with the May 2014 having significantly larger concentrations of inorganic nitrogen than any other date ($p < 0.001$).

4.) PO_4^{3-} - There was a significant interaction between transect site (control or restored) with date sampled for orthophosphate concentrations ($p < 0.01$; Fig. 8).

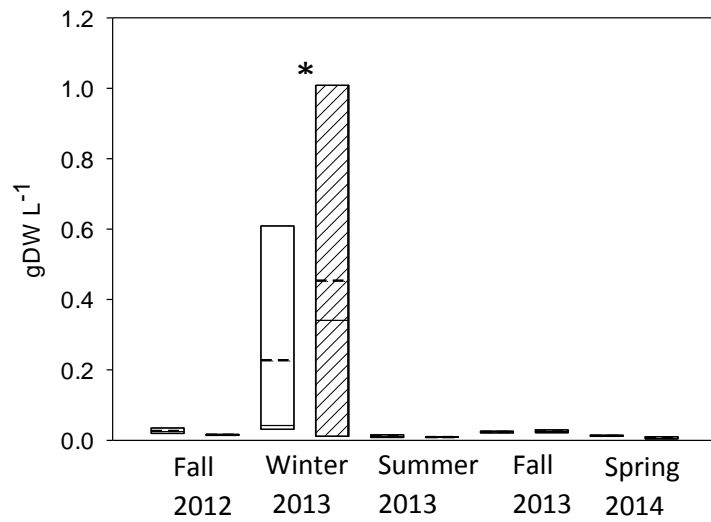


Figure 6. TSS of water samples collected at Dog River Park for control (open) and restored vegetation transects (diagonal slash). Dashed lines represent mean and asterisk notes significantly distinct measurement.

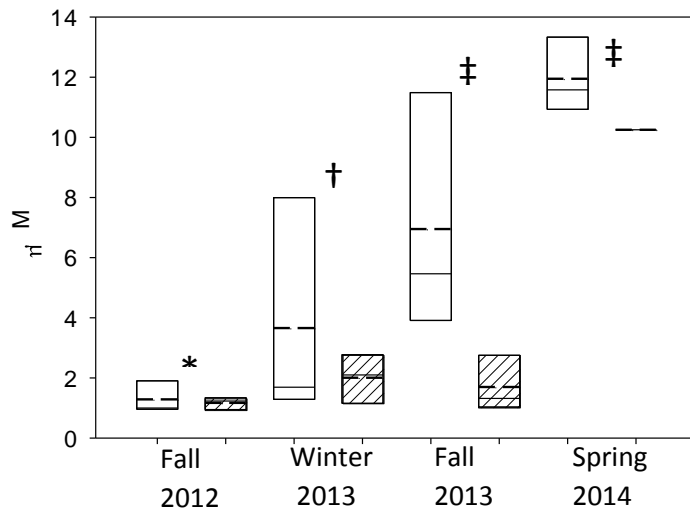


Figure 7. DIN concentrations of samples collected at Dog River Park for control (open) and restored vegetation transects (diagonal slash). Dashed lines represent mean and symbols note significantly distinct measurements.

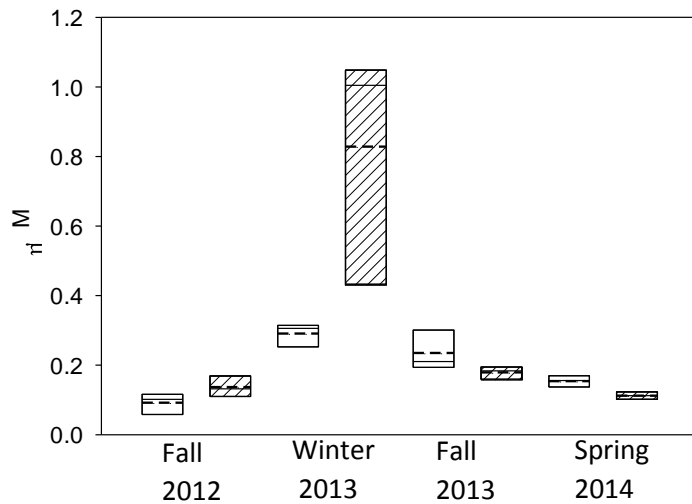


Figure 8. Orthophosphate concentrations of samples collected at Dog River Park for control (open) and restored vegetation transects (diagonal slash). Dashed lines represent mean.

Summary:

- Native, stable emergent vegetation species are capable of surviving and thriving in the restored habitat area, provided the plants are protected from mowing.
- There is evidence that the restoration encouraged the establishment of *V. americana*, however the caveat of no pre-restoration data collection prevents any confirmation.
- No evidence of differences in nekton biomass between control and restored transects (overall average $1.0 \text{ gAFDW m}^{-2} \pm 0.3 \text{ SE}$).
- Nekton community structure differences between transect type indicate that the restored vegetation attracts more structure dependent species when compared with control.
- There is no evidence that the restoration has any impact on water column chlorophyll a content (overall average $3.7 \mu\text{g L}^{-1} \pm 0.4 \text{ SE}$).

Restoration monitoring project #2: Mon Louis Island reef construction

Nekton monitoring-

It should be noted that no nekton species were caught for the first round of sampling (3/15/13), despite seining attempts. We found no discernible differences in nekton biomass (Fig. 9) between sites ($p=0.1$) or among sample dates ($p=0.693$). There were no discernible differences in the number of species between the two site types (Table 4), with the control site having one additional species in total. The species composition did differ between sites, with the control site having six unique species and the reef site having five unique species. The nekton species with the greatest biomass within the control site was the white shrimp (*L. setiferus*, Table 4) and the greatest abundance was the bay anchovy (*A. mitchilli*) with approximately 1200 individuals. The largest biomass within the reef influenced site was from a single southern ray (*D. sabina*) and the largest number of individuals was 700 gulf menhaden (*B. patronus*). Changes in percent composition of nekton species biomass as well as percent contribution to number of individuals is represented in Figure 10.

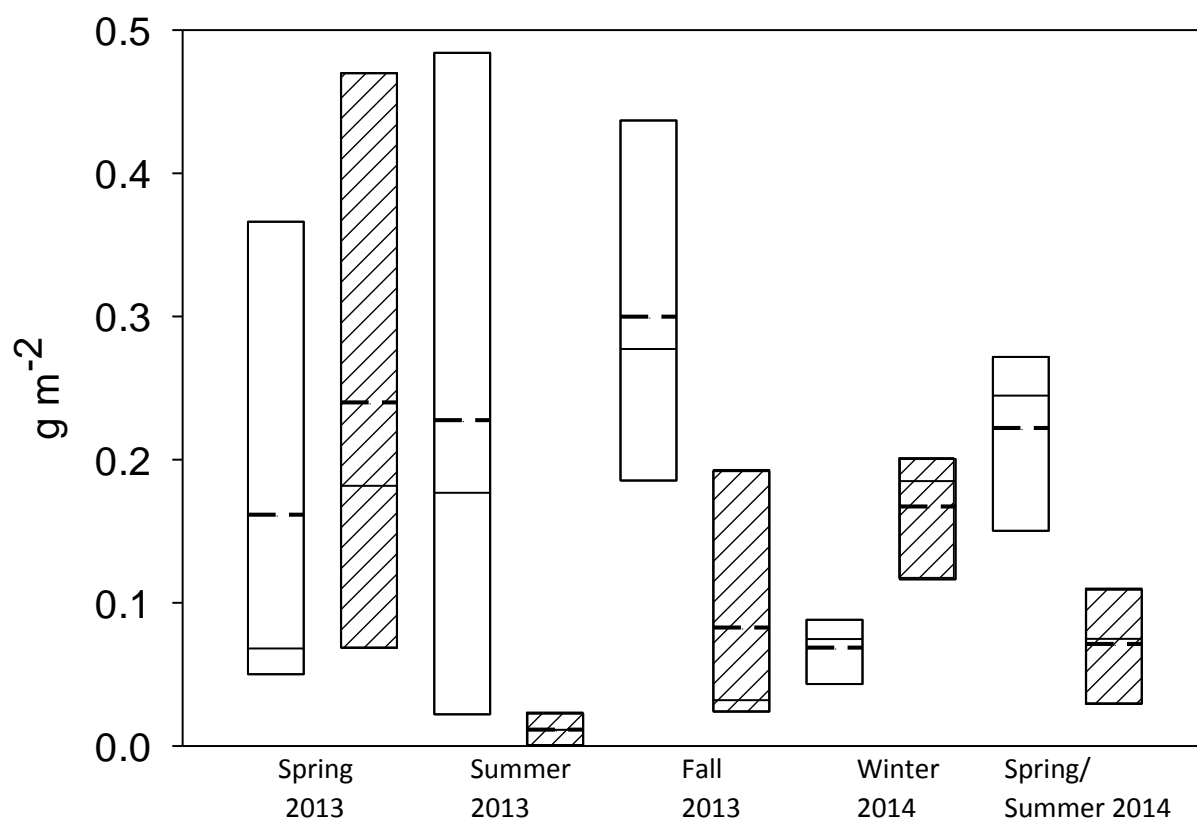


Figure 9. MLI nekton biomass for control (open) and restored (diagonal slash). Dashed line represents mean.

Table 4. Nekton species present at MLI monitoring sites. Bold species indicate unique presence at listed habitat type.

| | Control habitat site species | Biomass gAFDW | Number of individuals | Reef influenced habitat site species | Biomass (gAFDW) | Number of individuals |
|---------------|-------------------------------------|---------------|-----------------------|---|-----------------|-----------------------|
| Fish | Gobiesox strumosus | 0.0401 | 1 | Gobiesox strumosus | 0.0773 | 2 |
| | Cynoscion nebulosis | 1.7531 | 25 | Cynoscion nebulosis | 3.6163 | 43 |
| | Lagodon rhomboids | 0.2276 | 1 | Lagodon rhombiodes | 1.5021 | 1 |
| | Leiostomus xanthurus | 11.1348 | 271 | Leiostomus xanthurus | 22.1563 | 642 |
| | Ctenogobius boleosoma | 0.0221 | 3 | Ctenogobius boleosoma | 0.0543 | 3 |
| | Bagre marinus | 3.6695 | 1 | Bagre marinus | 3.5128 | 1 |
| | Cynoscion arenarius | 3.003 | 19 | Cynoscion arenarius | 0.2418 | 2 |
| | Micropogonius undulates | 41.8481 | 9 | Micropogonius undulatus | 16.4513 | 39 |
| | Menidia beryllina | 6.436 | 14 | Menidia beryllina | 4.5831 | 8 |
| | Brevoortia patronus | 63.306 | 820 | Brevoortia patronus | 33.0566 | 8 |
| | Anchoa mitchilli | 38.7591 | 1222 | Anchoa mitchilli | 18.128 | 376 |
| | Dasyatis Sabina | 29.96 | 1 | Dasyatis sabina | 35.2 | 1 |
| | Syngnathus louisianae | 0.0674 | 3 | Syngnathus louisianae | 0.1032 | 3 |
| | Sphoeroides nephalus | 0.0034 | 1 | Citharichthys spilopterus | 0.0086 | 1 |
| | Gobiosoma robustum | 0.0363 | 1 | Selene vomer | 0.3493 | 1 |
| | Mugil cephalus | 3.5258 | 6 | Dorosoma sp. | 0.2681 | 11 |
| | Scianops ocellatus | 11.669 | 2 | Alosa chrysochloris | 3.3297 | 1 |
| | Scianidae larva | 0.0346 | 4 | Strongylura marina | 0.0375 | 4 |
| | Synodus foetens | 0.0126 | 1 | | | |
| Shrimp | Paleomonetes pugio | 3.326 | 129 | Paleomonetes pugio | 3.4908 | 125 |
| | Litopenaeus setiferus | 72.8157 | 268 | Litopenaeus setiferus | 24.29638 | 119 |
| Crab | Calinectes sapidus | 0.3418 | 18 | Calinectes sapidus | 1.2505 | 25 |

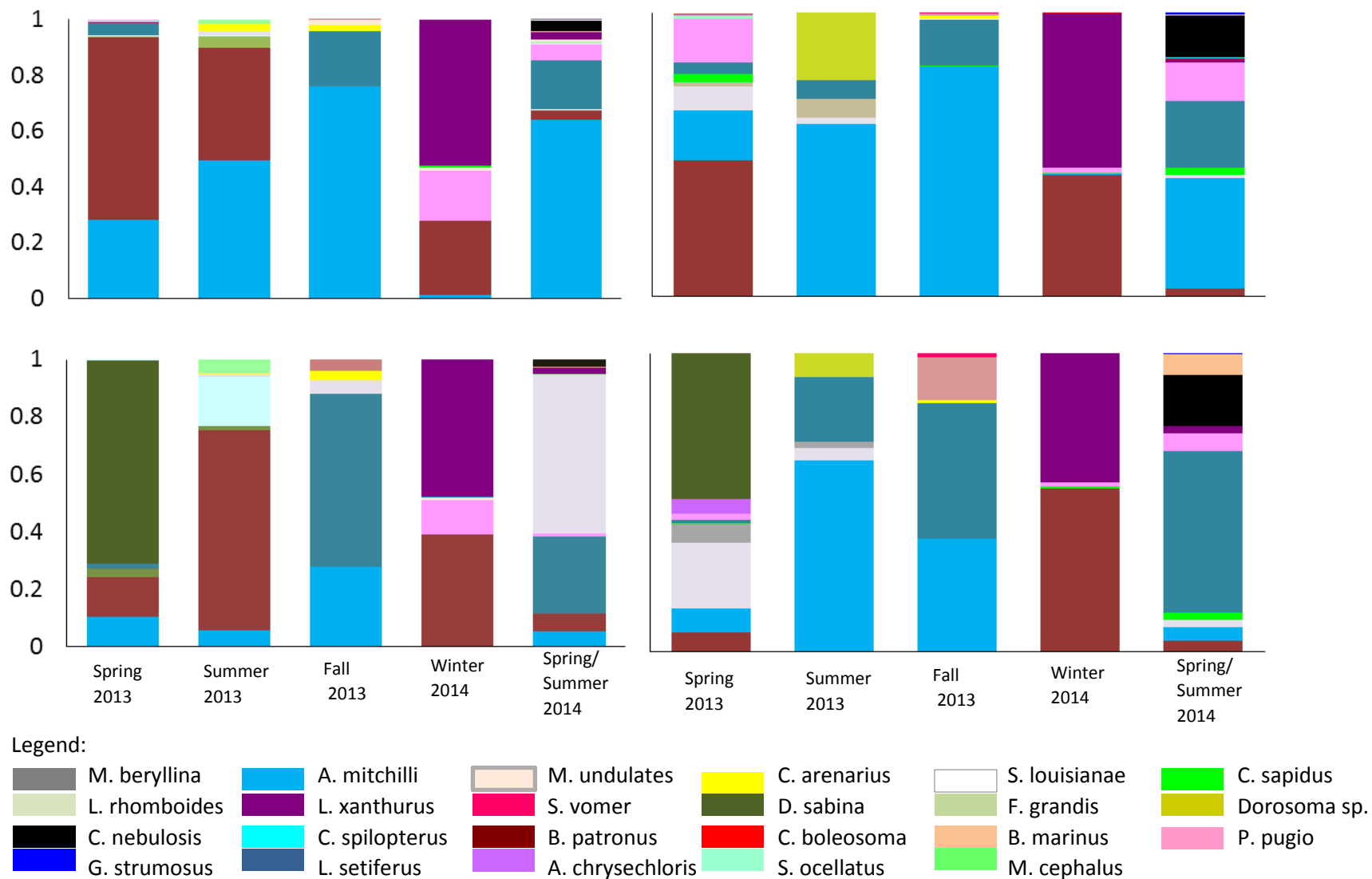


Figure 10. Nekton species % contribution to total number of individuals (top) and total biomass (bottom) for MLI control (left) and reefs (right).

Benthic environment monitoring-

Core samples were not taken during the fall 2013 sampling round due to adverse conditions. However, we found no evidence to suggest that benthic infauna biomass was distinct between the control and restored site ($p = 0.46$, Fig. 11) or among dates sampled ($p = 0.7$). There were five benthic groups found in the control cores and seven groups found in the reef influenced cores (Table 5). The low abundances of unique groups indicates that there is likely no variance in benthic infauna between the two sites. This indication is supported with minimal differences in measurements of changes in percent composition of infauna and epifauna biomass (Fig. 12). Organic matter content within sediment cores was also non-variable between sites ($p = 0.13$, Fig. 13) and among dates sampled ($p = 0.46$).

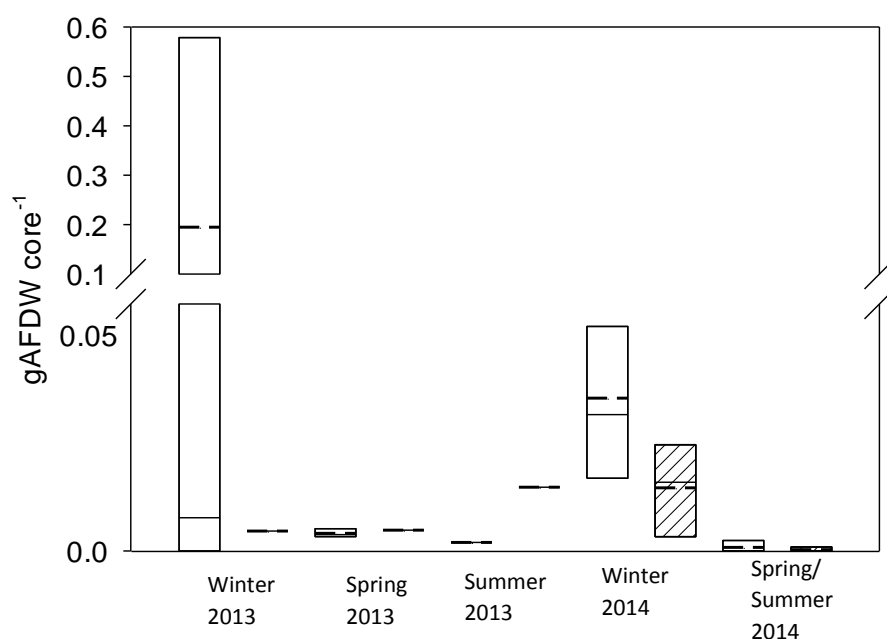


Figure 11. Infauna biomass of MLI sediment core sample (0.27m^3) for control transects (open) and reef transects (diagonal slash).

Table 5. Benthic infauna and epifauna groups present at MLI. Bold groups indicate unique presence at listed habitat type

| Control benthic species | Number of individuals | Reef influenced benthic species | Number of individuals |
|-------------------------|-----------------------|---------------------------------|-----------------------|
| Isopod | 5 | Isopod | 12 |
| Amphipod | 65 | Amphipod | 29 |
| Polychaete | 117 | Polychaete | 91 |
| Eel | 1 | Bivalve | 1 |
| Crab | 2 | Gastropod | 1 |
| | | Shrimp | 1 |
| | | Worm | 1 |

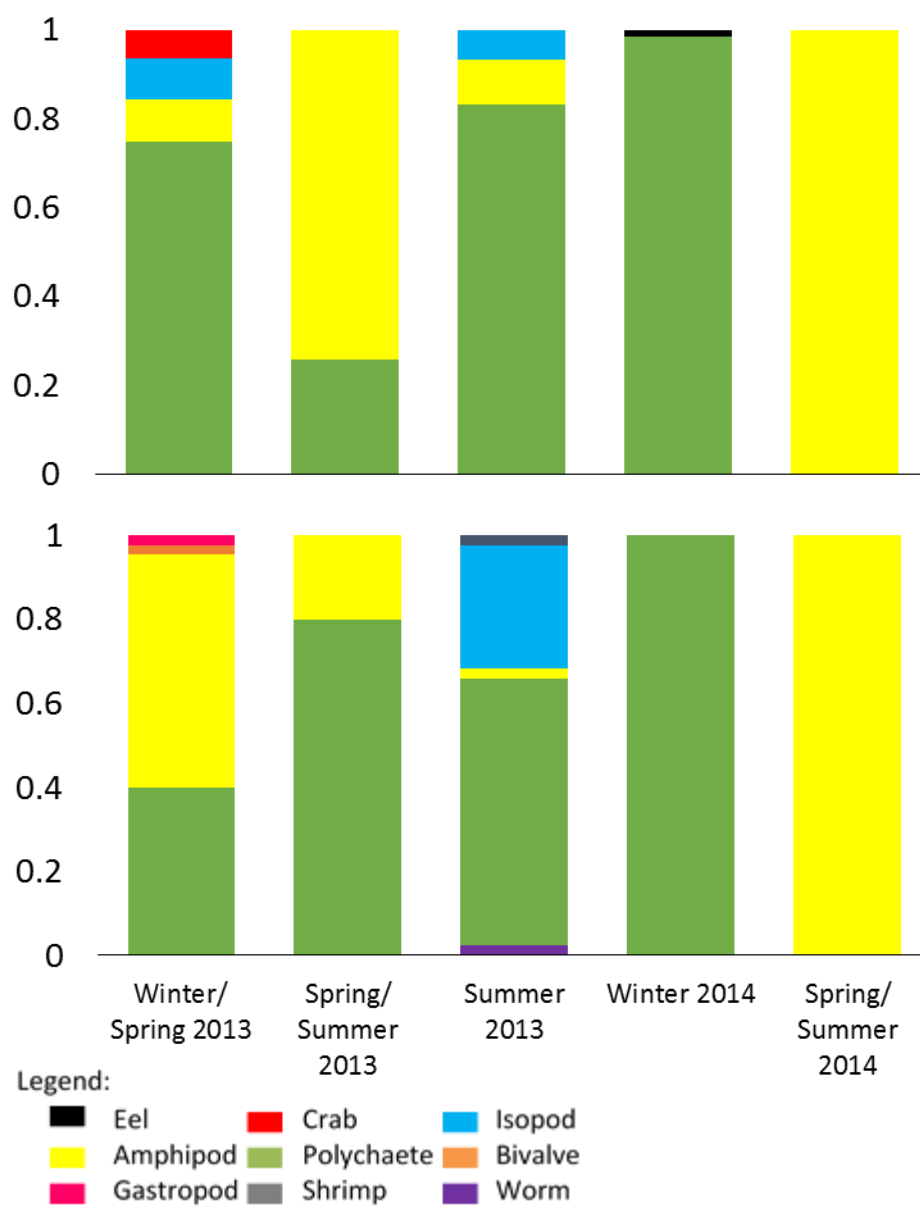


Figure 12. MLI sediment core % composition of number of individuals within benthic groups for control transects (top) and reef influenced transects (bottom).

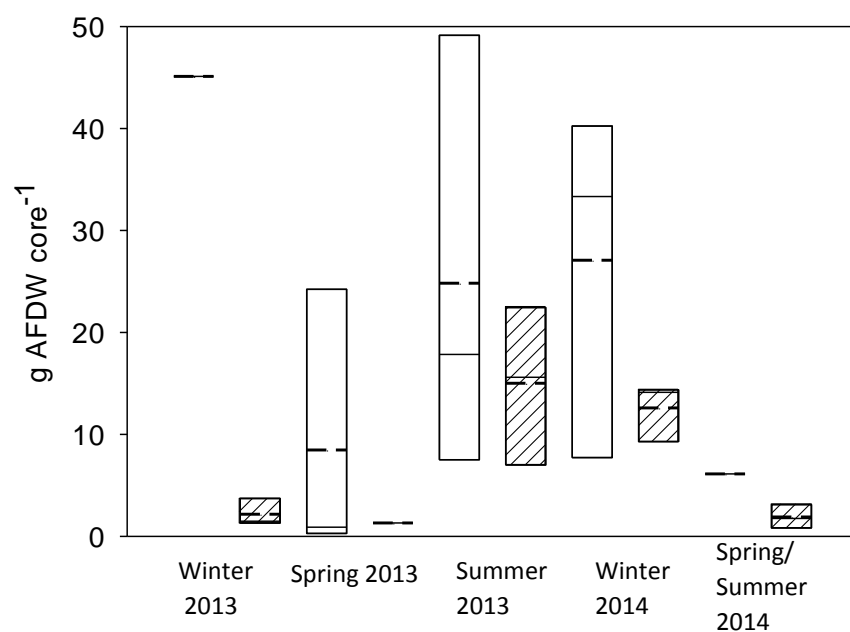


Figure 13. Organic matter content of MLI sediment core sample (0.27m^3) for control transects (open) and reef transects (diagonal slash).

Water column monitoring-

1.) Water column chlorophyll a content was also only variable among dates sampled ($p < 0.01$, Fig. 14), with the highest chlorophyll values measured in winter 2013 and the lowest in summer 2013. There was also no evidence of differences between control and reef water samples ($p = 0.25$).

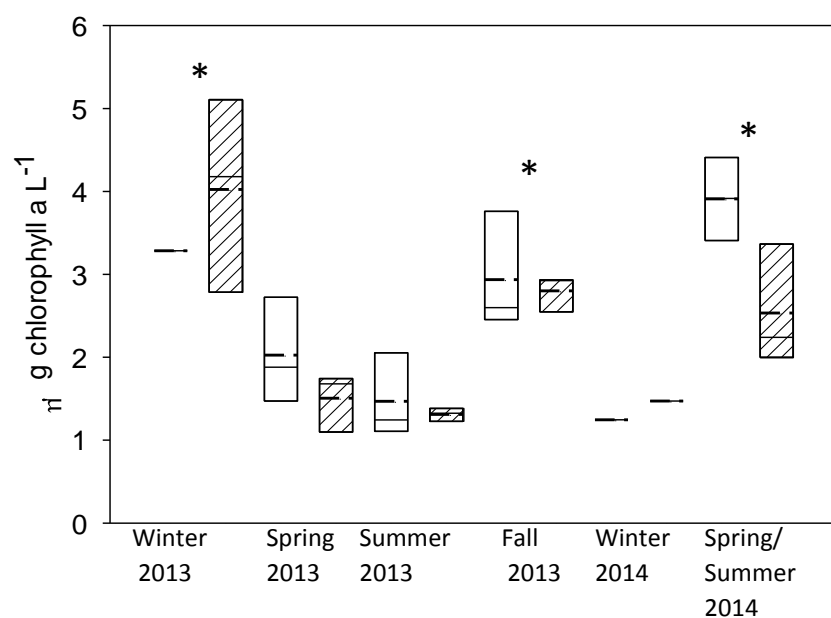


Figure 14. Chlorophyll a concentrations of water samples from MLI control (open) and reef transects (diagonal slash). Dashed lines represent the mean and symbols indicate significantly distinct dates.

2.) TSS- There was no evidence of different total suspended solids between the control and reef sites ($p=0.6$; Fig. 15), however there were differences among dates sampled ($p<0.01$). Water samples collected in October 2013 and May 2014 had higher suspended solids than all other dates sampled.

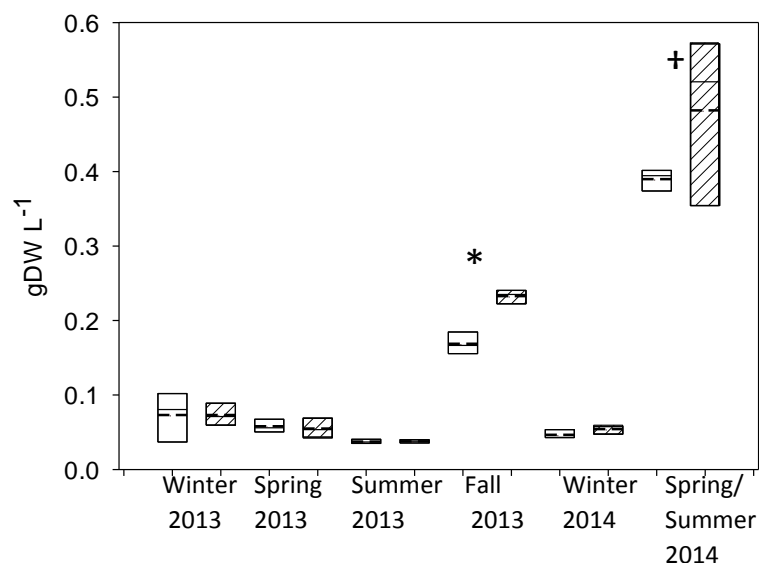


Figure 15. TSS of water samples from MLI control (open) and reef transects (diagonal slash). Dashed lines represent the mean and symbols indicate significantly distinct dates.

3.) DIN- Dissolved inorganic nitrogen concentrations showed a significant interaction between site and date sampled ($p<0.01$; Figure 16).

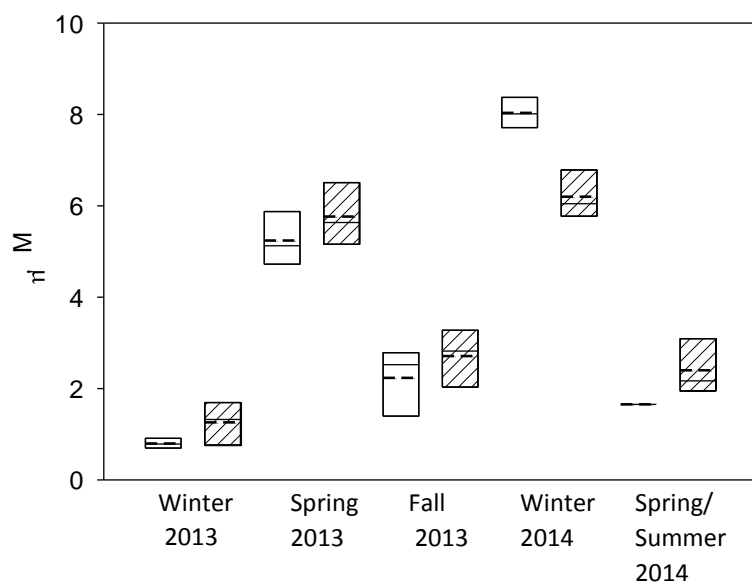


Figure 16. DIN of water samples from MLI control (open) and reef transects (diagonal slash). Dashed lines represent mean.

4.) PO_4^{3-} - There was no evidence for different orthophosphate concentrations either between sites or among dates.

Summary-

- There was no apparent difference in nekton biomass (overall average $0.16 \text{ gAFDW m}^{-2} \pm 0.03 \text{ SE}$) or number of nekton species between the control and reef influenced sites.
- There were differences in nekton species composition with several unique species sampled in each site, however the abundance of these species was low and indicates there is likely no difference between the sites.
- Neither benthic infaunal biomass (overall average $0.03 \text{ gAFDW} \pm 0.02 \text{ SE}$) nor community composition appeared to be distinct between the control and reef influenced sites.
- Organic matter content of sediments within both sites appears to be similar with an average of $14.6 \text{ gAFDW} (\pm 3.7 \text{ SE})$ per core.
- There did not appear to be an effect of the installed reefs on chlorophyll abundance, TSS, DIN, or orthophosphates in water samples during the monitored time period (overall average $2.4 \mu\text{g L}^{-1} \pm 0.2 \text{ SE}$)

Restoration monitoring project #3- Helen Wood Park marsh restoration:

Vegetation monitoring-

We found a large disparity between vegetation communities at the restored marsh compared with the nearby, unrestored shoreline. While the restored marsh exhibited an exceedingly complex and dense community of native marsh species (Table 6), the unrestored shoreline was mostly barren with low density patches of *Phragmites karka*. Vegetation dynamics of the restored marsh was a primary focus of this project and four transects of different lengths were established within the marsh. Each transect had four permanent stations set at equidistant lengths along each transect in order to capture natural variability of the marsh terrain (Fig. 17). One noticeable feature that became more apparent over time was the erosion of the 0m station in transect three, likely because of physical tidal forcing due to a gap in the breakwaters in front of the marsh (Fig. 17). A timeline of vegetation species percent composition of shoot counts for each transect can be found in Figures 18 and 19. We lost several stations (Transect 2, stations 2, 3, and 4; Transect 3, stations 2, 3, and 4) temporarily because of extensive *P. karka* overgrowth and inability to access the stations. We subsequently reestablished new stations outside of the *P. karka* overgrowth and monitored these stations for the remainder of the monitoring period. Transect 3, station 2 could not be replace due to an extensive tidal wrack that prevented vegetation growth for ten meters to either side of the station.

Within the restored marsh, community dynamics fluctuated greatly over time for many stations. This was most evident in stations closest to the disturbance prone edges of the marsh bordered by Dauphin Island Parkway (Fig. 18). City maintenance crews maintained regular roadside mowing along this border, leading to an increase in disturbance related vegetation. Alternatively, stations closer to the intertidal were more stable with lower diversity, with more resemblance to an undisturbed local marsh. One special interest of this restoration was to monitor the expansion of the disturbance prone reed species *P. karka*. Changes in abundance were tracked over time and indicate that this species is expanding within the HWP borders, while the prominent marsh species smooth cordgrass (*S. alterniflora*) and black needlerush (*J. roemerianus*) appeared to be on the decline (Fig. 20). However, it should be noted that this is only over a 1.5 year period and no long term conclusions can be drawn. It does appear, however, that the intertidal zone of the marsh is expanding seaward due to

increasing densities of *S. alterniflora* over time at the first stations of Transects 1 and 2, but densities are decreasing at the first station of Transect 3 (Fig. 21). In the backmarsh transect, sturdy bulrush (*S. robustus*) densities appear to have remained stable over time, with little expansion of *P. karka* in this area (Figures 19 and 22).

Seagrass was present in multiple locations within the restored marsh site. Widgeongrass (*R. maritima*) patches were ephemeral around the intertidal zone in the front marsh, and more constant in one of the rear-marsh tidal creeks. Sediment cores (200cm²) containing seagrass were taken to examine shoot densities, above/belowground biomass, and shoot morphologies. These results of these measurements extrapolated to m² for ease of comparison are located in Table 7, although it should be noted that these patches were < 1m² in size. When present, densities of the patches were variable and peaked in fall 2013. Leaf area per shoot was highest in the summer of 2014, lowest in winter 2014.

Table 6. Vegetation species present at HWP restored and control sites.

| HELEN WOOD PARK (HWP) | STABLE/NATIVE MARSH SPECIES | DISTURBANCE/ INVASIVE SPECIES | BOTH STABLE AND DISTURBANCE |
|-----------------------|---|---|---|
| RESTORED | <i>Spartina alterniflora</i> , <i>Spartina spartinae</i> , <i>Spartina patens</i> , <i>Juncus roemerianus</i> , <i>Cladium jamaicense</i> , <i>Schoenoplectus robustus</i> , <i>Sabatia brevifolia</i> , <i>Ruppia maritima</i> | <i>Typha latifolia</i> , <i>Mitreola petiolata</i> , <i>Ipomea lacunose</i> , <i>Phragmites karka</i> | <i>Sagittaria lancifolia</i> , <i>Distichlis spicata</i> |
| CONTROL | | <i>Phragmites karka</i> | |

Table 7. *R. maritima* morphological metrics.

| Metric (±SE) | Fall 2013* | Winter 2014 | Summer 2014 |
|--------------------------------------|------------------|-------------|-------------|
| Density (shoots m ⁻²) | 19,850 (±12,886) | 4,050 | 12,350 |
| Avg. # of leaves shoot ⁻¹ | 3 (± 0.04) | 3 (± 0.1) | 3 (± 0.1) |
| Avg. leaf area shoot ⁻¹ | 7.7 (± 0.6) | 4.8 (± 0.8) | 9.4 (± 1.8) |
| Aboveground biomass (gAFDW) | 0.77 (± 0.55) | 0.05 | 0.27 |
| Belowground biomass (gAFDW) | 0.46 (± 0.27) | 1.43 | 0.2 |

*Indicates measurements are the average of three core samples, while other dates only had one patch to sample.

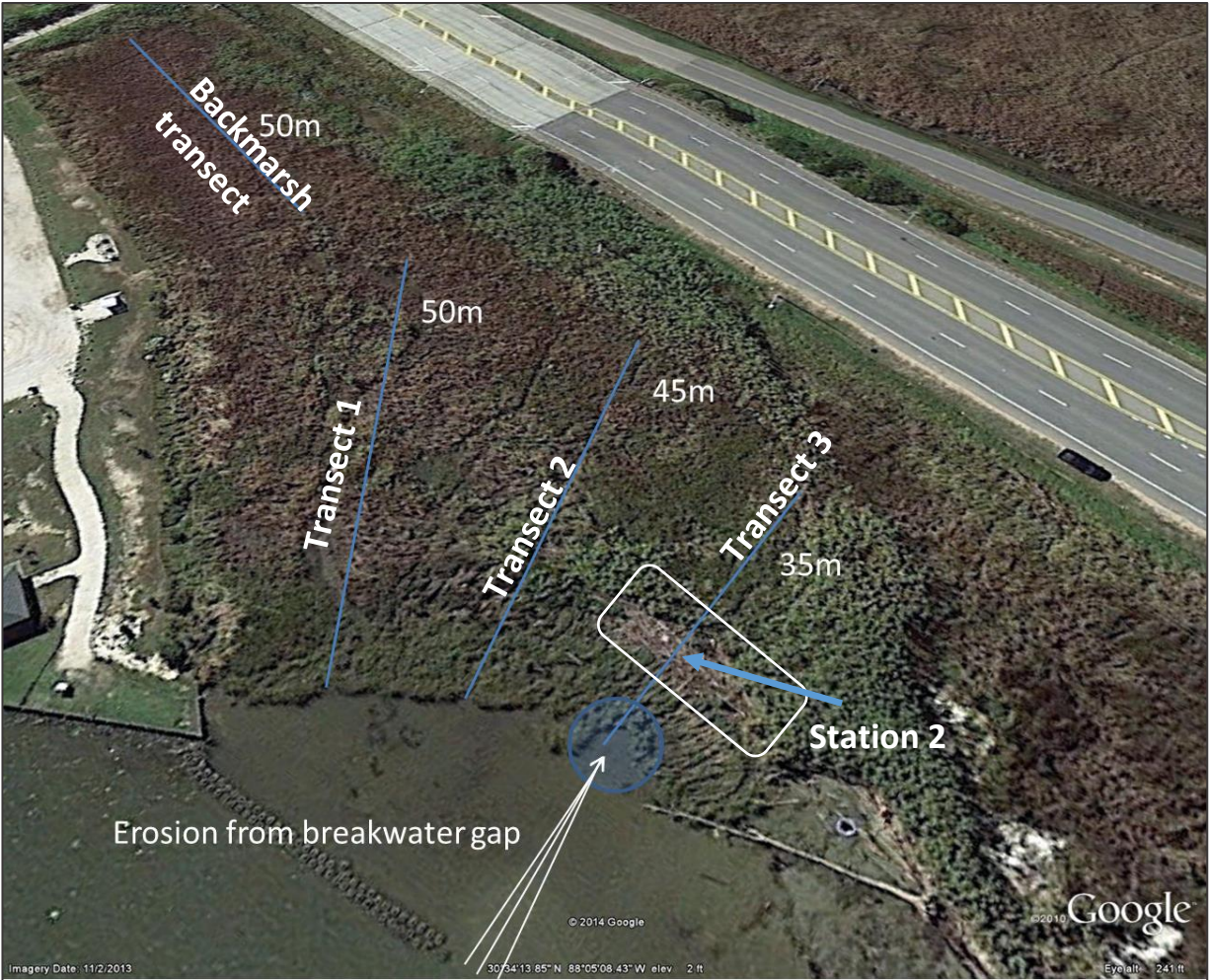


Figure 17. Map of permanent transects and each transect length within HWP restored marsh. Note the extensive wrack line that buried station two in Transect 3, as well as the erosion of the waterline at station 1

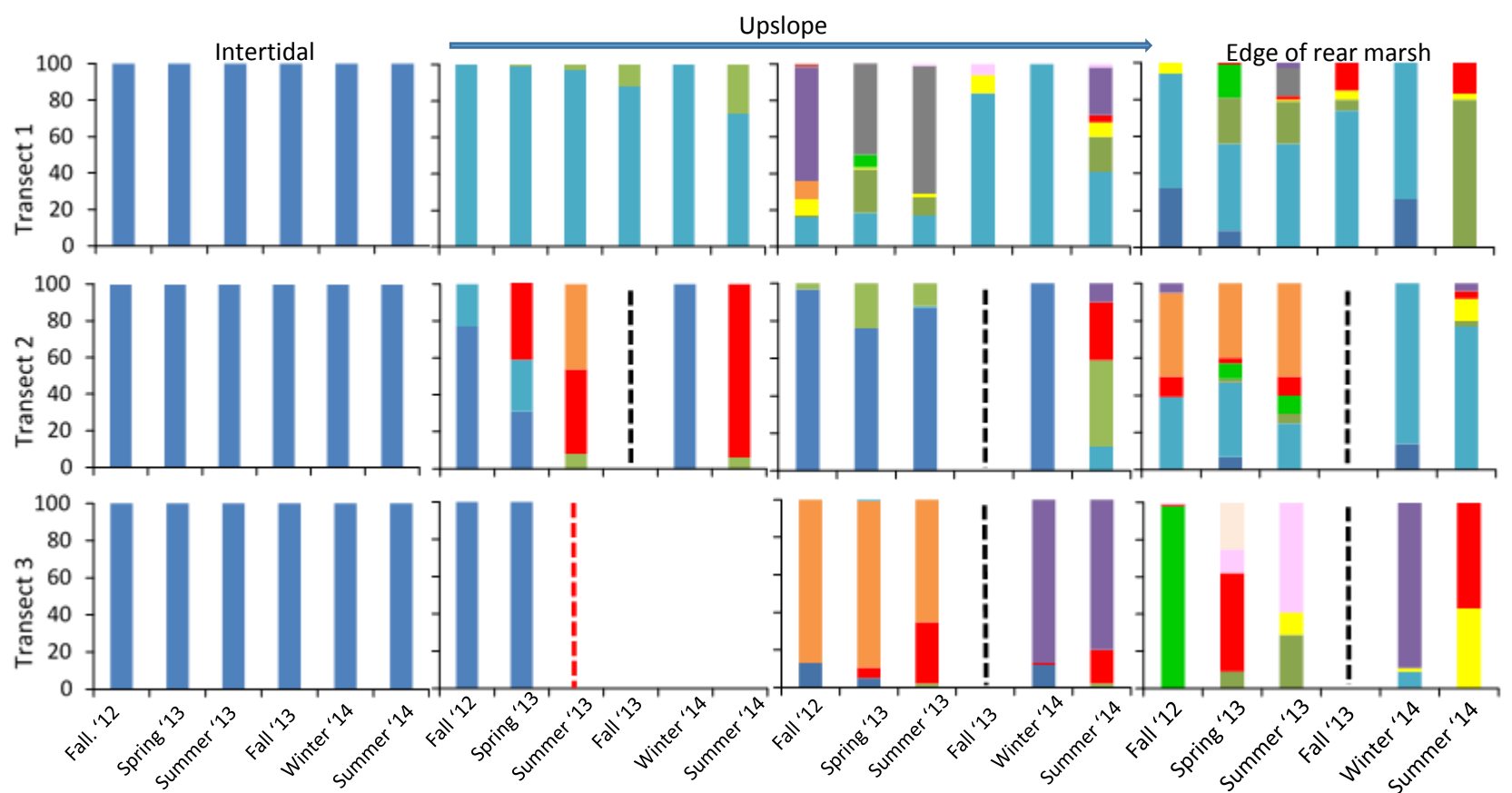


Figure 18: Marsh vegetation percent community composition of shoot counts (per m²) at Helen Wood Park (left to right: stations 1, 2, 3, and 4 along each transect). Station loss events were contributed to *P. karka* overgrowth at Transect 2, stations 2,3, 4 and Transect 3, stations 2,3,4 and extensive wrack deposition at Transect 3, station 2.

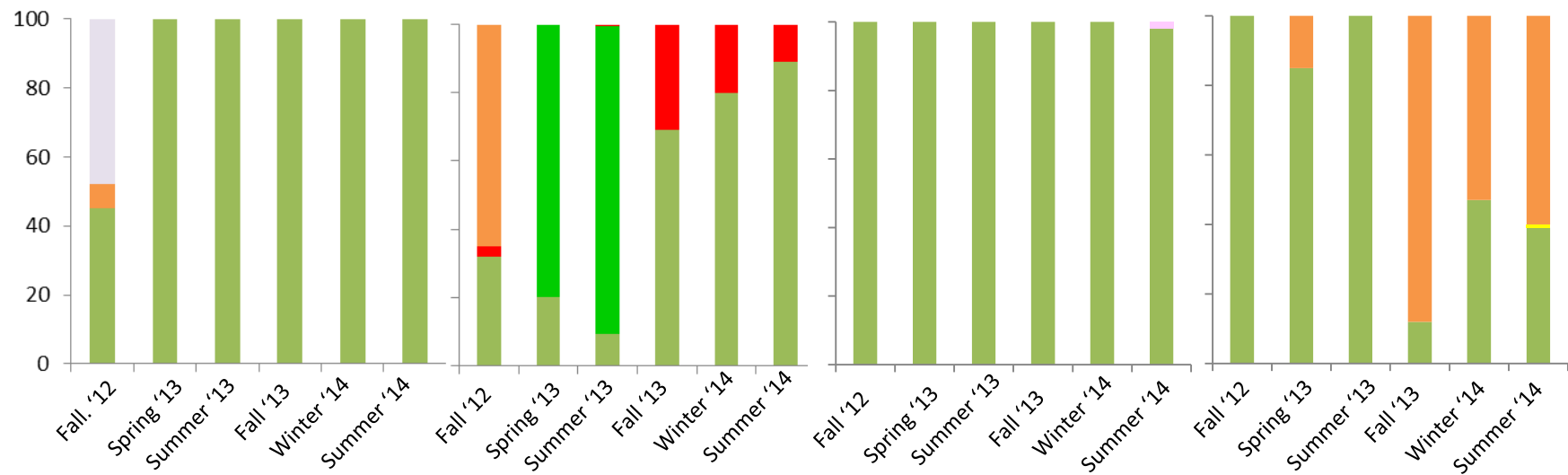


Figure 19. Percent community composition of shoot counts (per m²) of the backmarsh transect at Helen Wood Park (left to right: stations 1, 2, 3, 4).

Legend:

Stable species:

S. patens

S. robustus

S. tabernaemontani

Disturbance species:

T. latifolia

P. karka

Both:

S. latifolia

D. spicata

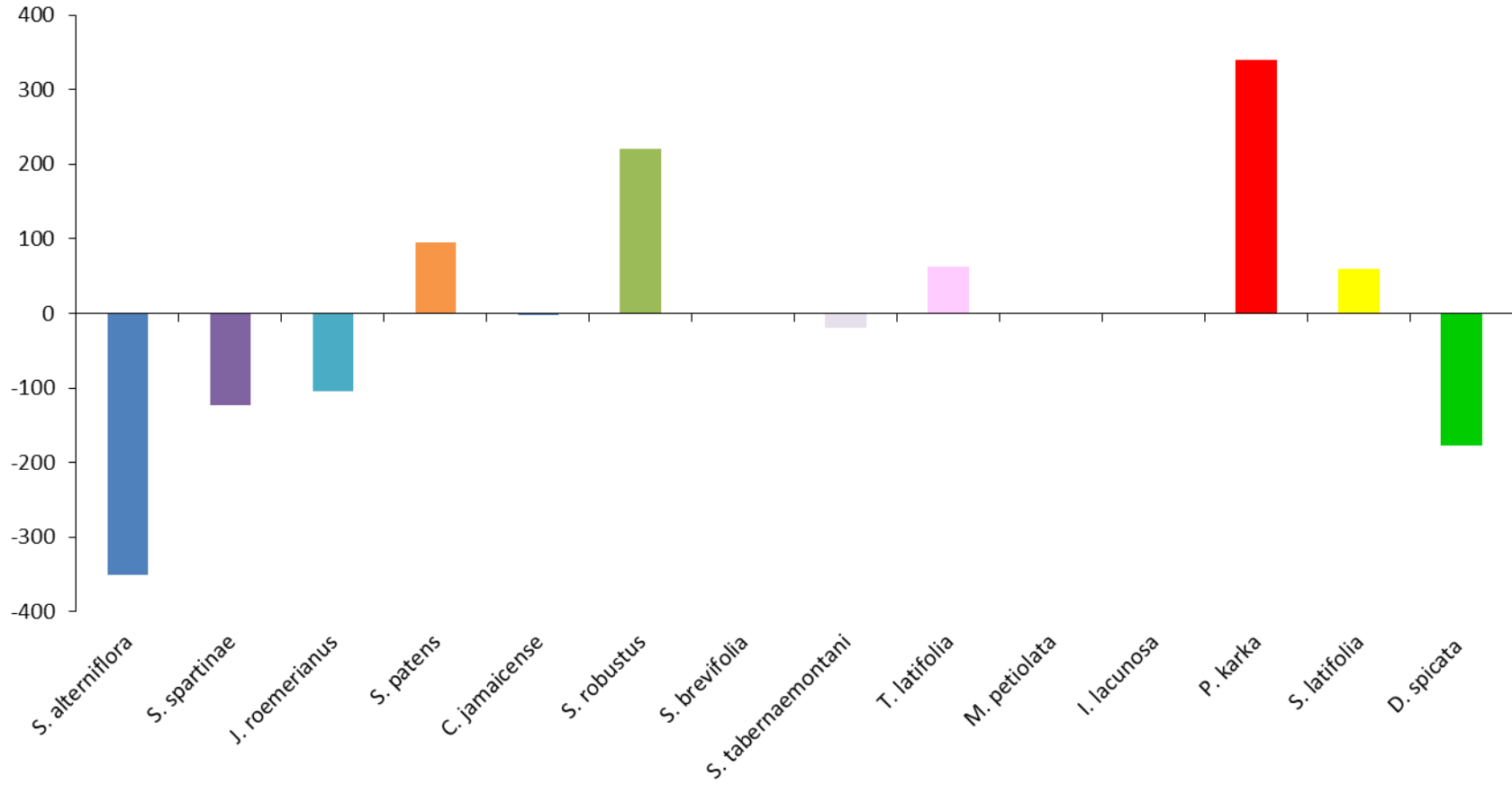


Figure 20. Cumulative percent change in contribution of marsh vegetation (percent of shoots m^{-2}) of all sampling stations over sampling period (9/2012- 5/2014).

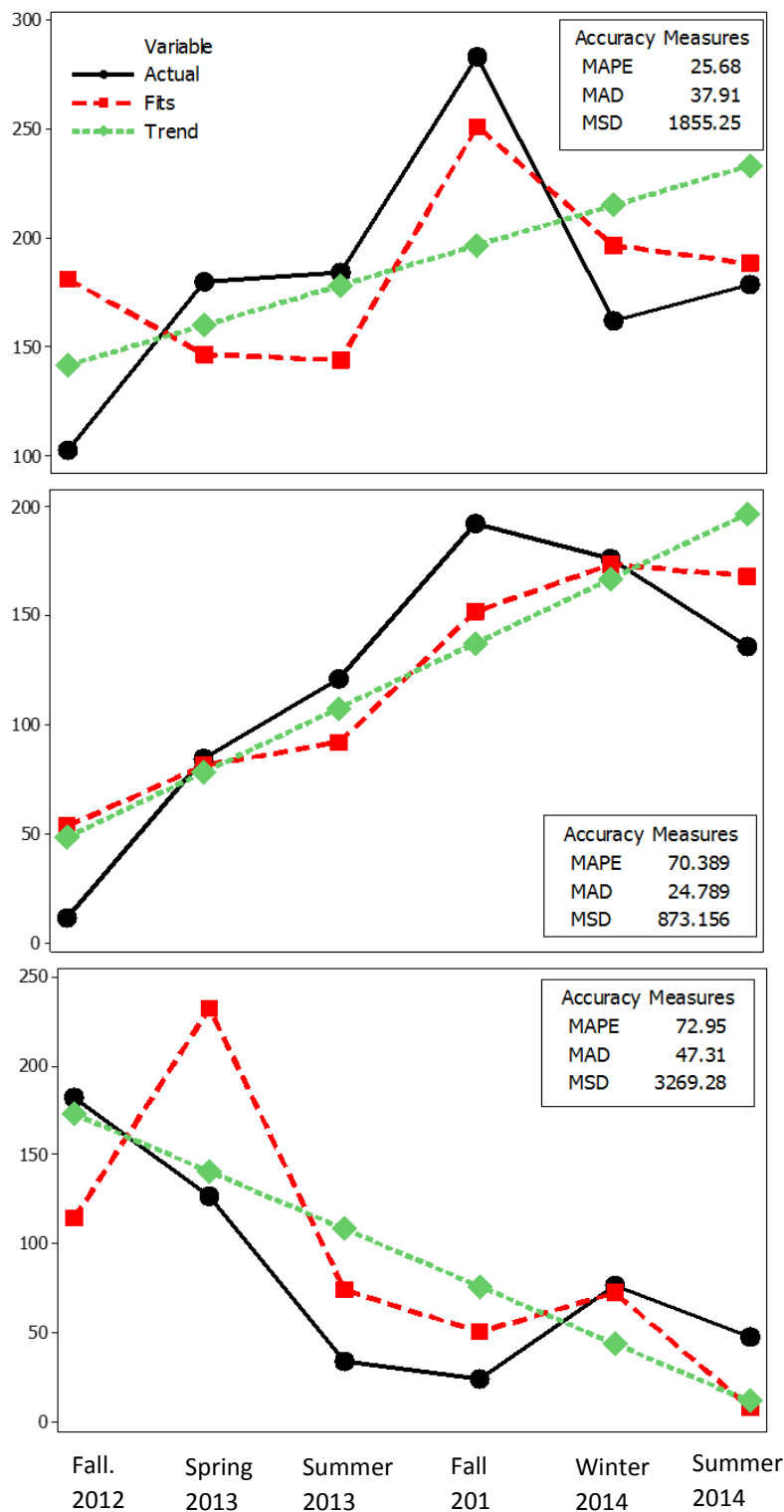


Figure 21. Time decomposition graphs depicting *S. alterniflora* density measurements at waterline over monitoring period (Top to bottom: Transects 1, 2, and 3).

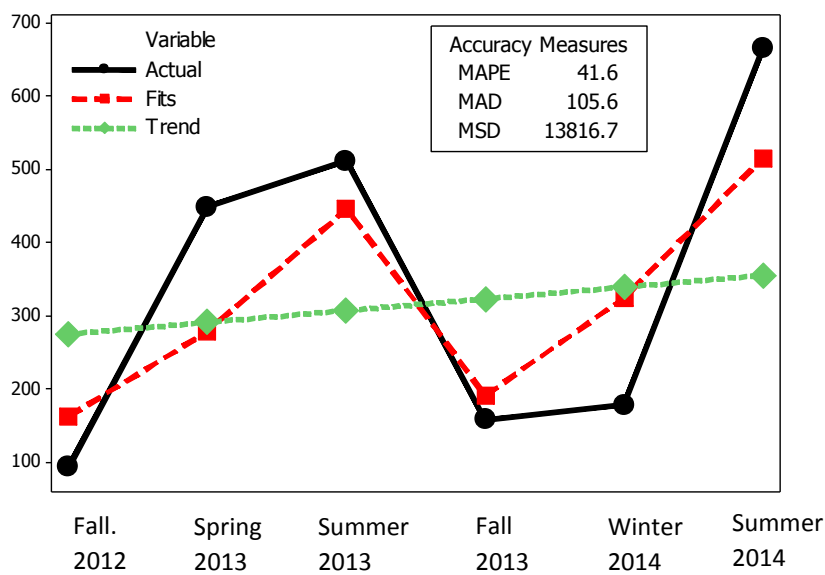


Figure 22. Time decomposition graph depicting *S. robustus* density measurements within the Backmarsh transect over monitoring period.

Nekton monitoring-

Average nekton biomass sampled at the restoration site was higher than the biomass sampled at the control site (34.6 ± 16 and 9.02 ± 3.7 gAFDW, respectively; Fig. 23), as confirmed by a non-parametric analysis ($p = 0.017$). A non-parametric test similarly suggested that nekton biomass was also seasonally variable ($p < 0.01$). Nekton species diversity was also distinct between the control and restored marsh sites. The control site had five unique species out of 21 species total, with only one specimen each, while the restored marsh site had multiple specimens from nearly all eleven unique species out of 29 total species collected. Most of the unique species identified at the restored marsh site were species that preferred structured or vegetated habitat (i.e. *F. majalis*, *C. boleosoma*, *A. rostrata*, *H. jaguana*, and *U. longisignalis*). The largest contributor to the control site's nekton biomass was from Atlantic croaker (*M. undulatus*; Table 8), and the largest number of individuals collected was approximately 1,750 inland silversides (*M. beryllina*). Within the restored marsh site, the largest contributor to biomass was spot croaker (*L. xanthurus*) and the largest number of individuals collected was approximately 2,900 grass shrimp (*P. pugio*). Differences between sites can also be seen in the nekton biomass percent composition attributed to each species and how this composition changes over time (Fig. 24). The two sites differ in greatest contributing nekton species and how those species' abundances change throughout the sampling period.

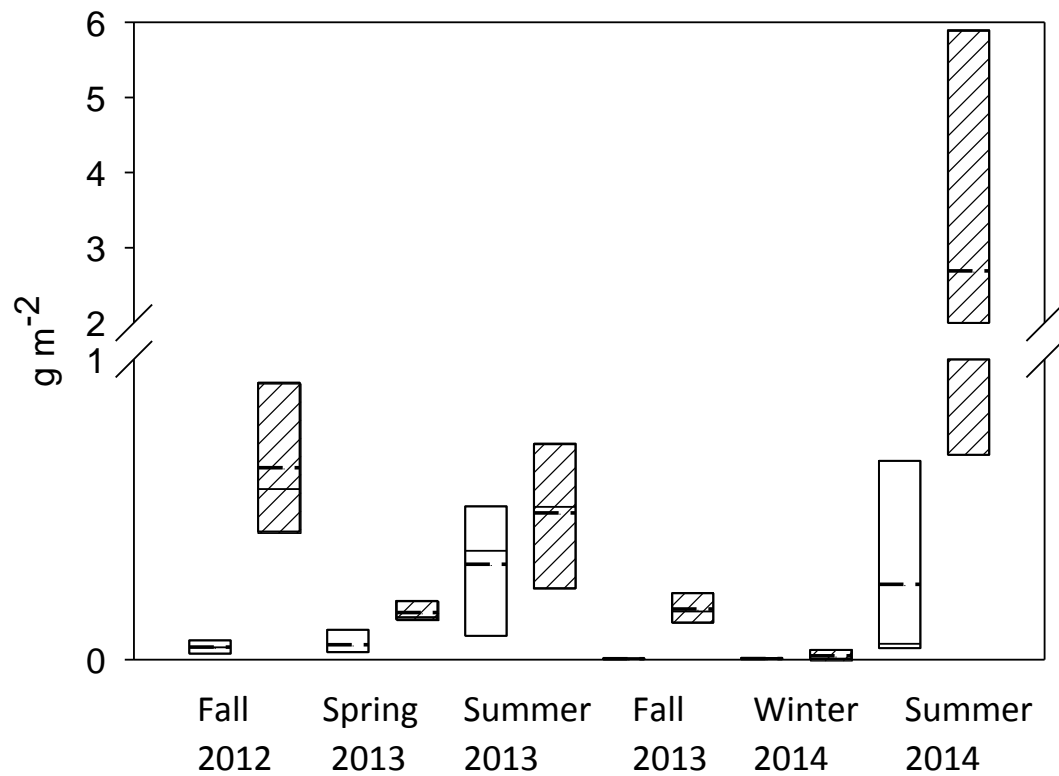


Figure 23. HWP nekton biomass for control (open) and restored (diagonal slash). Dashed line represents mean.

Table 8. Nekton species present at HWP restoration monitoring sites. Bold species indicate unique presence at listed habitat type.

| | Control habitat site species | Biomass gAFDW | Number of individuals | Reef influenced habitat site species | Biomass (gAFDW) | Number of individuals |
|---------------|-------------------------------------|-----------------------|-----------------------|---|-----------------|-----------------------|
| Fish | Anchoa mitchilli | 2.21 | 48 | Anchoa mitchilli | 7.08 | 102 |
| | Micropogonius undulates | 32.0 | 63 | Micropogonius undulates | 5.07 | 35 |
| | Arius felis | 17.7 | 6 | Arius felis | 0.48 | 1 |
| | Syngnathus louisianae | 4.5*10 ⁻³ | 1 | Syngnathus louisianae | 0.10 | 3 |
| | Prionotus tribulus | 9.7*10 ⁻³ | 1 | Prionotus tribulus | 0.05 | 5 |
| | Cynoscion nebulosis | 0.63 | 10 | Cynoscion nebulosis | 1.82 | 18 |
| | Menidia beryllina | 4.58 | 1743 | Menidia beryllina | 2.06 | 510 |
| | Mugil cephalus | 4.50 | 10 | Mugil cephalus | 14.9 | 21 |
| | Fundulus grandis | 0.86 | 3 | Fundulus grandis | 11.68 | 30 |
| | Leiostomus xanthurus | 3.29 | 11 | Leiostomus xanthurus | 396.7 | 1,621 |
| | Lutjanus griseus | 4.85*10 ⁻³ | 1 | Lutjanus griseus | 0.83 | 22 |
| | Lagodon rhomboides | 0.57 | 2 | Lagodon rhomboides | 3.89 | 7 |
| | Cynoscion arenarius | 0.11 | 1 | Fundulus majalis | 0.17 | 1 |
| | Heterandria formosa | 0.013 | 1 | Bollmania communis | 1.05 | 41 |
| | Strongylura marina | 0.024 | 1 | Ctenogobius boleosoma | 1.32 | 75 |
| | Menidia peninsulae | 0.31 | 1 | Symphurus plagiusa | 0.05 | 3 |
| | Leptocephalus | 4.8*10 ⁻³ | 1 | Anguilla rostrata | 0.01 | 1 |
| | | | | Pogonius chromis | 0.03 | 2 |
| | | | | Farfantepenaeus aztecus | 0.74 | 18 |
| | | | | Harengula jaguana | 0.07 | 1 |
| | | | | Brevoortia patronus | 5.23 | 56 |
| | | | | Citharichthys spilopterus | 0.02 | 1 |
| Shrimp | Litopenaeus setiferus | 10.7 | 115 | Litopenaeus setiferus | 33.1 | 351 |
| | Palaemonetes pugio | 1.69 | 48 | Palaemonetes pugio | 70.9 | 2,873 |
| Crab | Callinectes sapidus | 20.6 | 84 | Callinectes sapidus | 19.1 | 322 |
| | | | | Uca longisignalis | 0.04 | 1 |

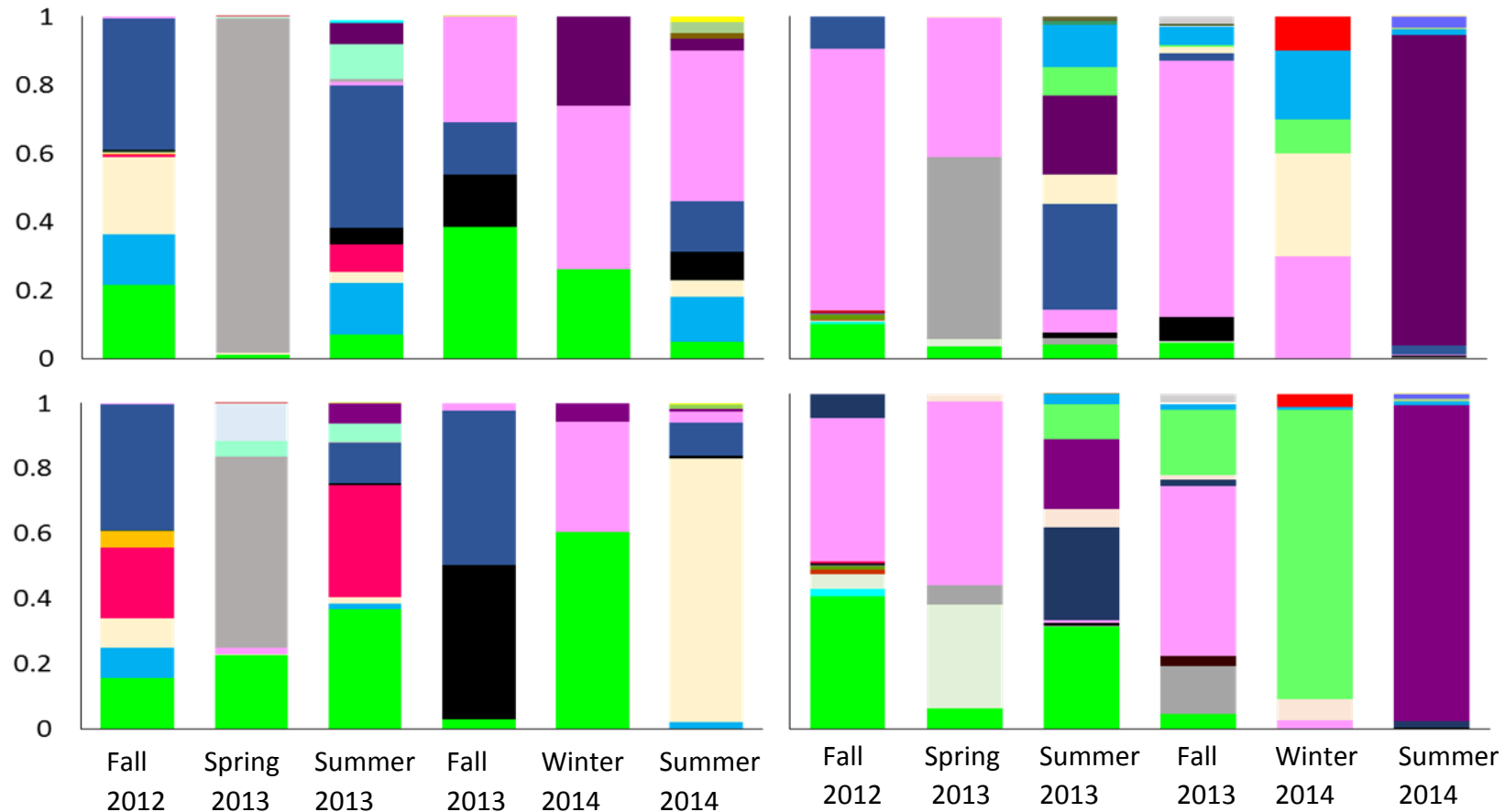


Figure 24. Nekton species % contribution to total number of individuals (top) and total biomass (bottom) for HWP control (left) and restored marsh (right).

Benthic environment monitoring-

A non-parametric analysis indicates there is no distinction in benthic infauna biomass between the control and restored marsh sites. However, this relationship was largely driven by a single collection of a giant hermit crab (*Petrochirus diogenes*) from the control site during the fall 2012 sampling (Fig. 25). This data point was removed and the dataset was rerun with a non-parametric test that indicates unique infauna biomasses between the two sites ($p=0.04$), upon removal of the single hermit crab biomass (Fig. 26). These differences are supported by the larger number of individuals sampled from each major benthic group at the restored site versus the control site (Table 9.). The restored marsh site had several unique benthic groups collected, most of which are indicative of benthic environments with detrital material and/or structure, e.g. marshes and seagrass beds. This larger diversity in the restored marsh site also fluctuated seasonally (Fig. 27). We found a significant interaction between site and date sampled ($p=0.014$) for organic material composition of the sediments cored (gAFDW 0.27m^{-3} ; Fig. 28). Personal observations provide evidence that the control site receives large depositions of organic detritus from the Mobile Bay Delta region, particularly after large storms, which could influence the organic material sampled at this site. Allochthonous material was generally not influential in the intertidal cores of the restored marsh site, due to deposition of most of this Delta material within the marsh itself (e.g. large wrack deposit within transects).

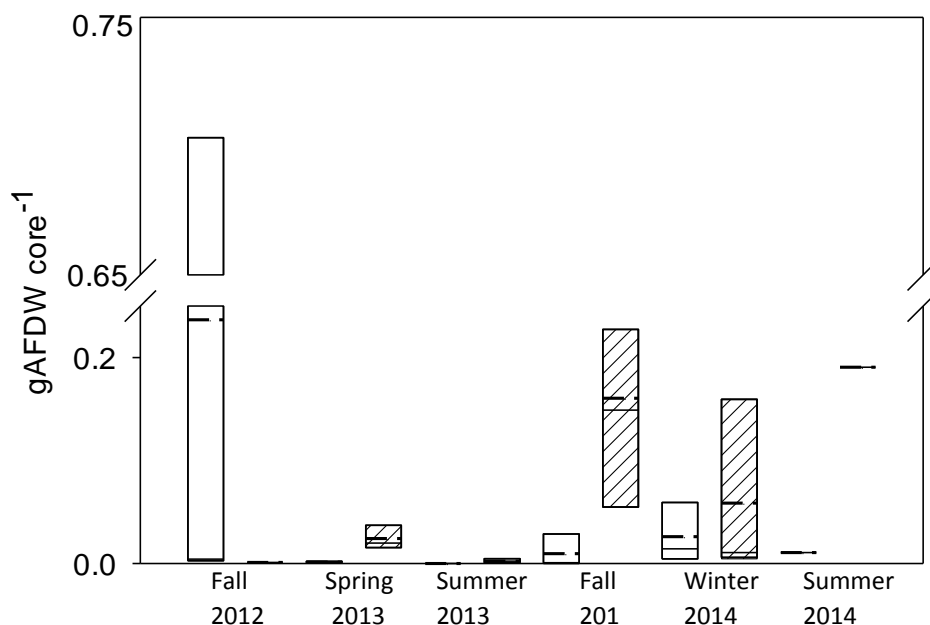


Figure 25. Infauna biomass of HWP sediment core sample (0.27m^3) for control transects (open) and restored marsh transects (diagonal slash), including *P. diogenes* biomass for control site in fall 2012.

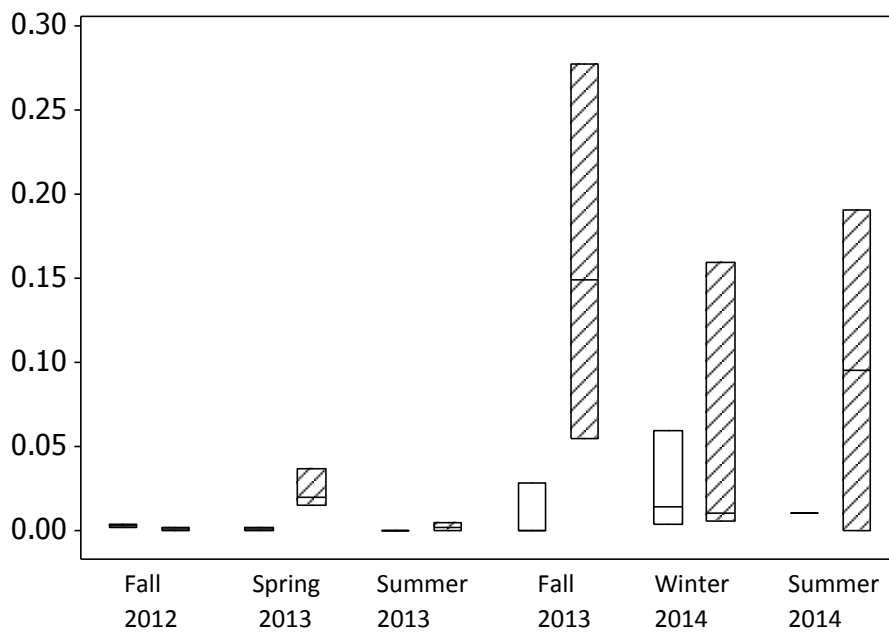
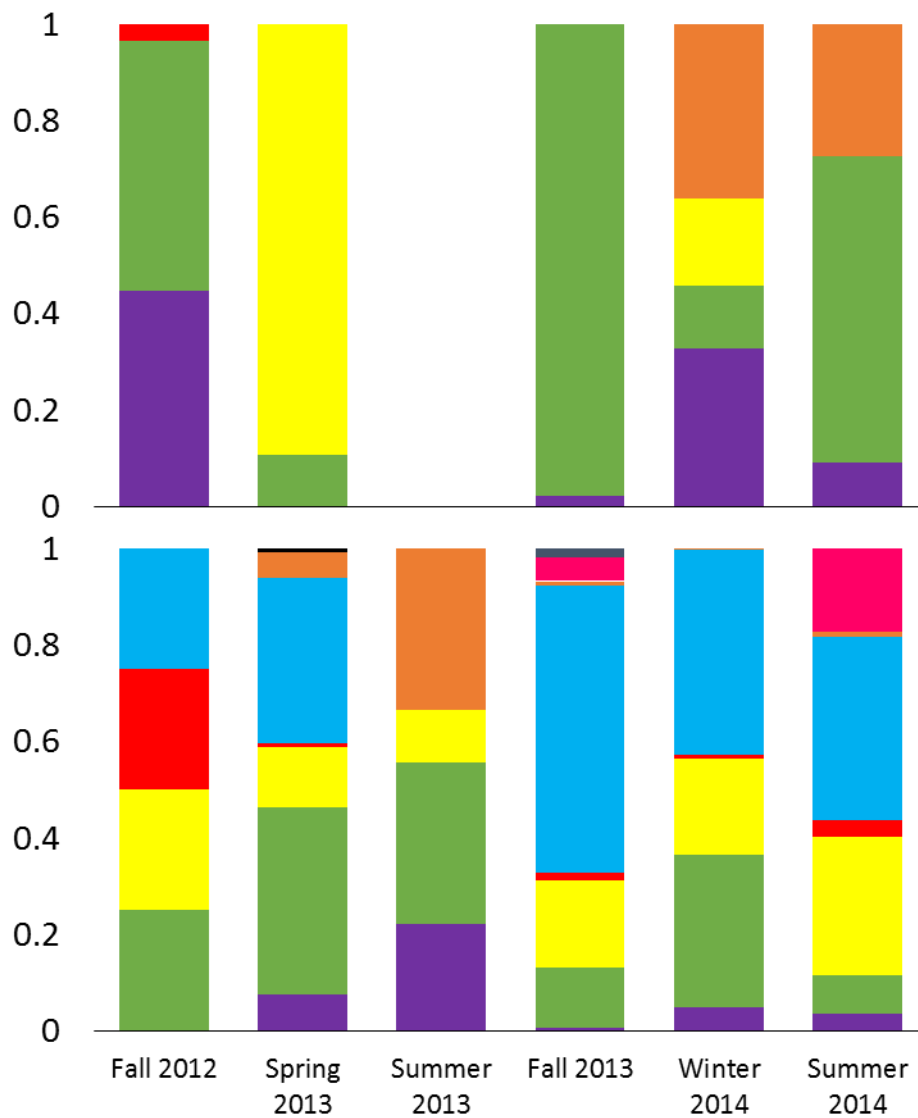


Figure 26. Infauna biomass of HWP sediment core sample (0.27m³) for control transects (open) and restored marsh transects (diagonal slash), with *P. diogenes* biomass removed.

Table 9. Number of individuals sampled from HWP control and restored marsh sites for each benthic habitat group over entirety of monitoring period.

| Control benthic species | Number of individuals | Reef influenced benthic species | Number of individuals |
|-------------------------|-----------------------|---------------------------------|-----------------------|
| Worm | 35 | Worm | 38 |
| Polychaete | 77 | Polychaete | 268 |
| Amphipod | 60 | Amphipod | 231 |
| Bivalve | 25 | Bivalve | 15 |
| crab | 1 | Crab | 17 |
| | | Isopod | 598 |
| | | Gastropod | 44 |
| | | Eel | 1 |
| | | Goby | 1 |
| | | Shrimp | 10 |



Legend:



Figure 27. HWP sediment core % composition of number of individuals within benthic groups collected for control transects (top) and restored transects (bottom).

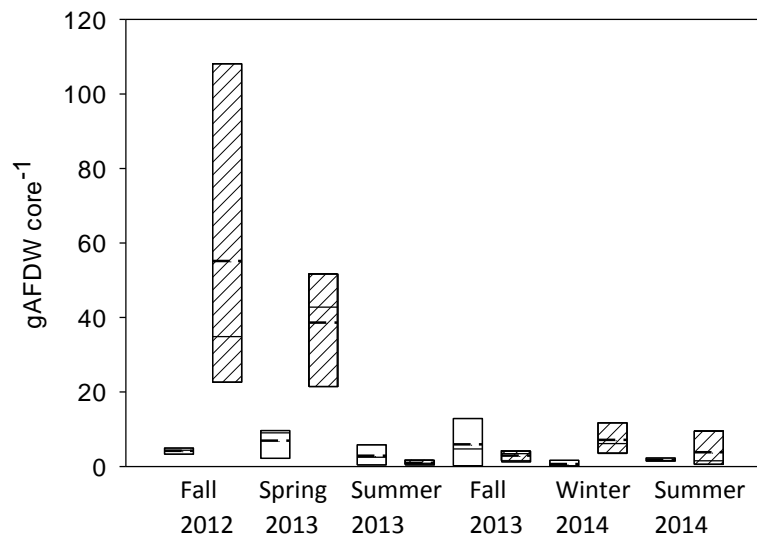


Figure 28. Organic matter content of HWP sediment core sample (0.27m³) for control transects (open) and restored marsh transects (diagonal slash).

Water quality monitoring:

- 1.) Chlorophyll- A two-way ANOVA indicates that there is a significant interaction of site and time sampled for water column chlorophyll a content ($p = 0.031$), as evidenced by Figure 29.
- 2.) TSS- Total suspended solids had a significant interaction between sites and dates sampled ($p < 0.01$; Fig. 30)
- 3.) DIN- Dissolved inorganic nitrogen concentrations were also had a significant interaction between sites and dates sampled ($p < 0.01$; Fig. 31)
- 4.) PO_4^{3-} -There was a significant distinction between sites for orthophosphate concentrations in water samples, with the restored site having higher concentrations on average ($p = 0.01$; Fig. 32).

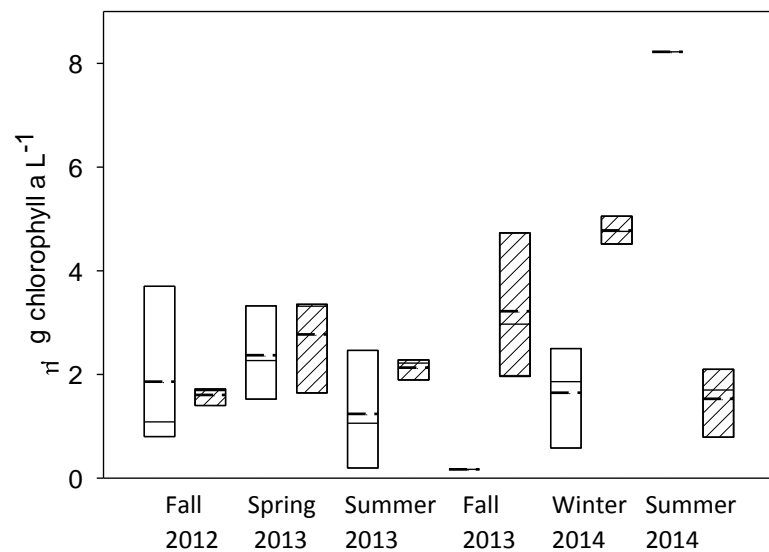


Figure 29. Chlorophyll a concentrations of water samples from HWP control (open) and restored transects (diagonal slash). Dashed lines represent mean of samples.

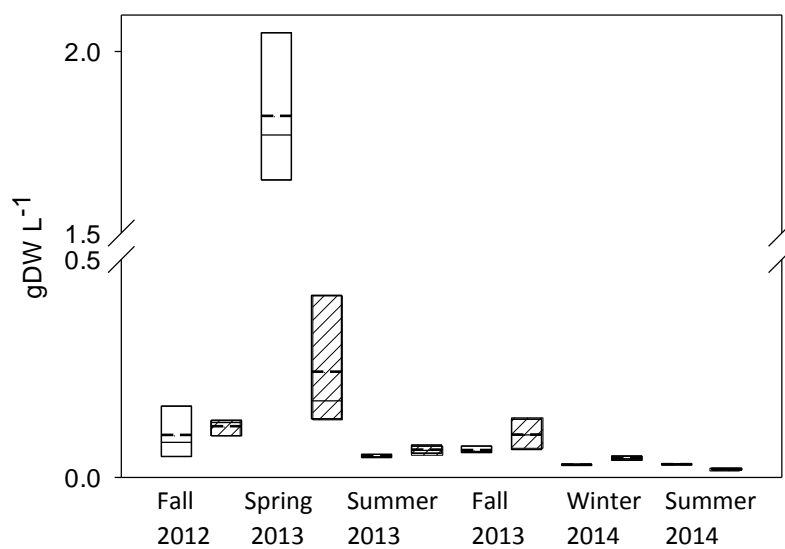


Figure 30. TSS of water samples from HWP control (open) and restored transects (diagonal slash). Dashed lines represent mean of samples.

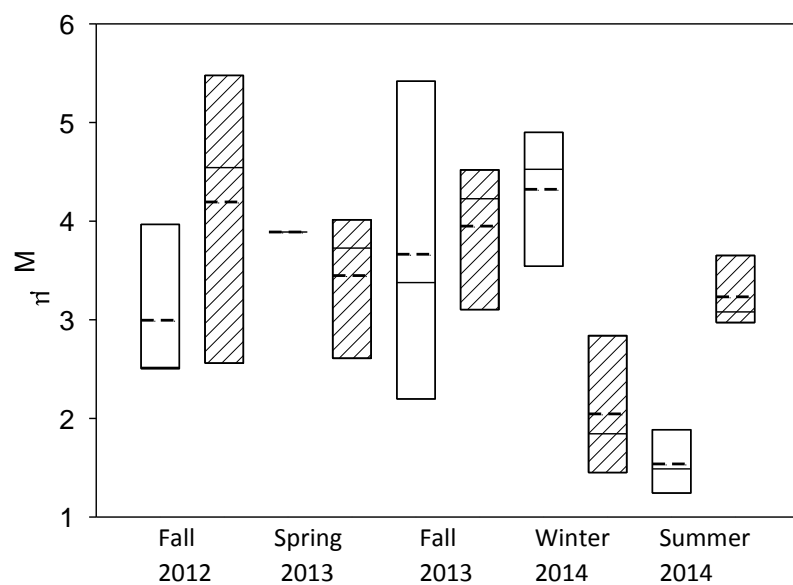


Figure 31. DIN of water samples from HWP control (open) and restored transects (diagonal slash). Dashed lines represent mean of samples.

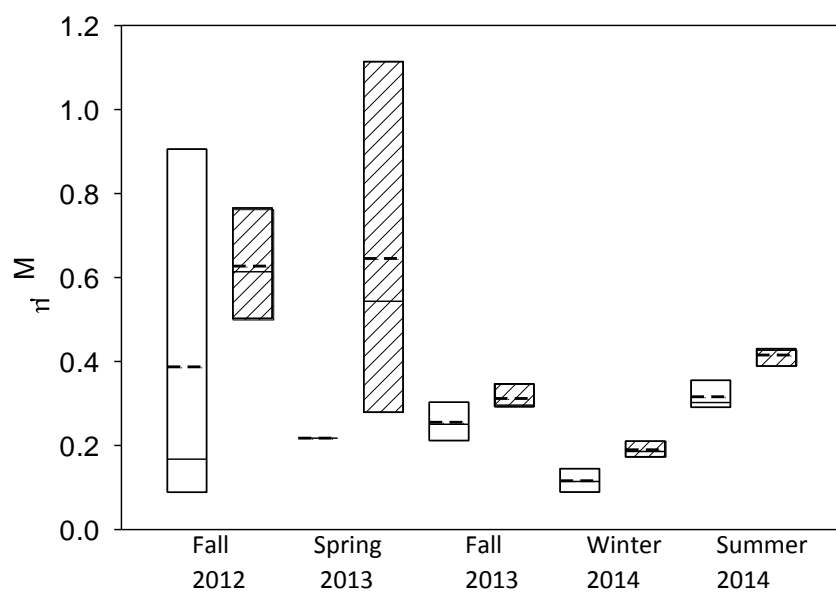


Figure 32. PO_4^{3-} concentration of water samples from HWP control (open) and restored transects (diagonal slash). Dashed lines represent mean of samples.

Station elevation profiles-

Elevation at each station was quantified using Real Time Kinetics point measurements compared with the NAVD1988 dataset. Control site station elevations had a greater slope starting from the vegetation line station down to the intertidal station (approximately 15m; Fig. 33). The restored marsh stations had a far gentler slope transitioning from the back of the marsh stations down to the intertidal stations (ranging from 35 to 50m in length; Fig. 33).

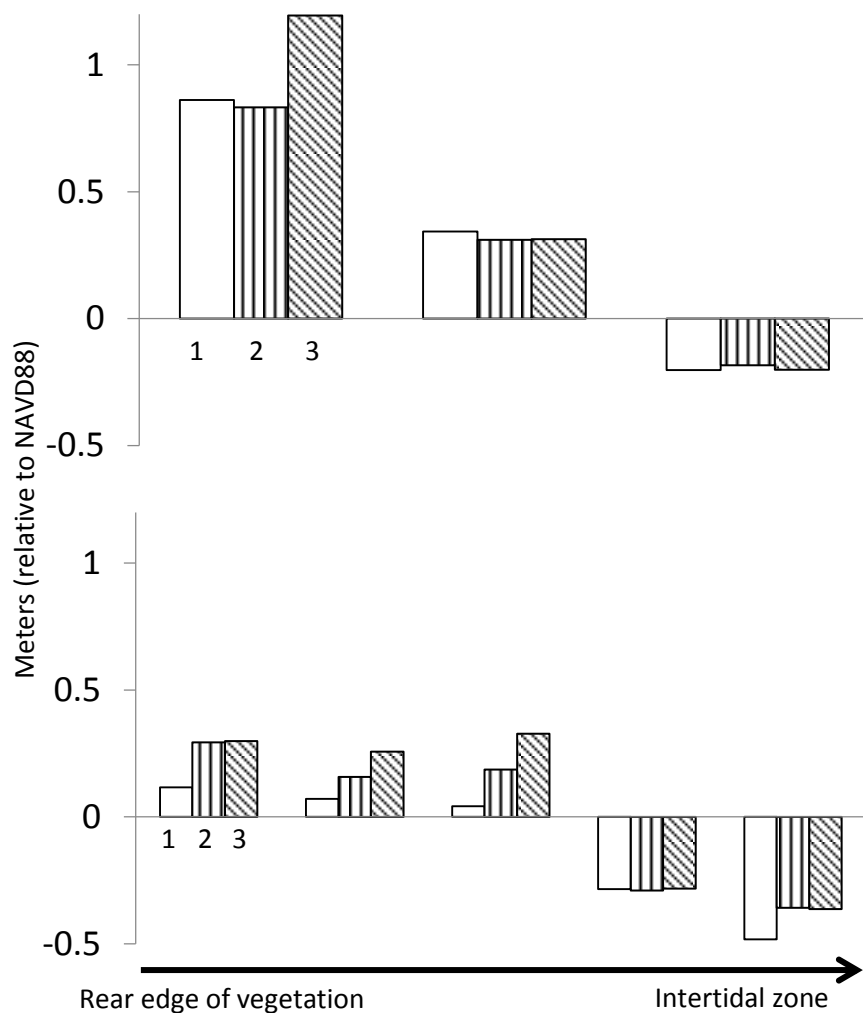


Figure 33. Elevation height measurements for control transects 1-3 (top) and restored vegetation transects 1-3 (bottom) for all monitored stations.

Summary:

- Vegetation communities were distinct for the *P. karka* monoculture control site versus the highly diverse restored marsh site.
- However, short term monitoring found *P. karka* increasing within the restored marsh site and stable marsh species *S. alterniflora* and *J. roemerianus* declining.
- The stations with highest floral species diversity were located near the area of the marsh bordered by Dauphin Island Parkway, with many of the species disturbance related.
- Restored marsh habitat appears to be expanding seaward, with *S. alterniflora* densities increasing over time for two of the three transects.
- The third transect is losing marsh habitat landward, likely due to high physical disturbance caused by a gap in submerged breakwaters located directly in front of the restored marsh.
- *R. maritima* was sporadically present in the intertidal zone in front of the restored marsh and more permanently present in a shallow back marsh tidal creek.
- The intertidal *R. maritima* sampled exhibited the highest densities in fall of 2013 and largest leaf area per shoot in the summer of 2014.
- Seagrass presence was variable between sampling dates and is likely an ephemeral patch. This patch may or may not be influenced by the restored marsh, the protective breakwaters, or a combination of both, however there is no pre-restoration sampling that could substantiate either scenario.
- Nekton biomass was higher at the restored marsh site and seasonally variable at both sites.
- Species diversity was different between the control and restored site, with the restored marsh seining capturing a greater abundance of species that generally prefer or require structure and vegetation in at least part of their life cycle.
- With the outlier removed (see benthic environment monitoring, above), we found larger biomasses of sediment infauna in the restored marsh intertidal zone than within the control sediment.
- Diversity and number of individuals in the benthic groups collected at the restored site was greater than the control site.
- Chlorophyll a, TSS, and DIN variability were dependent on both site and time of year sampled.
- Orthophosphate concentrations were higher in the restored marsh site, compared with control transects.
- The restored marsh exhibited a much gentler sloping to the intertidal zone than the nearby unrestored control site.

Final Report Part 2: Historical data compilation for Mobile Bay trends in biological stressors and responses

As a complement to the field project, we also surveyed the literature to reconstruct historic changes in environmental quality in Mobile Bay (i.e. water clarity, chlorophyll concentration) and examine whether relationships exist with the historical increase of human occupation and exploitation of the Mobile Bay area. This information was intended to offer a robust analysis of what environmental quality metrics have changed, and which ones have not, over the last century as a result of human occupation of the Bay. The information will help managers devise policies of environmentally and economically sustainable growth as well as prioritize strategies for restoration and conservation in the Mobile Bay area.

The search for any and all historical datasets available for the Mobile Bay region led to an immediate discovery of the large paucity of long term biological monitoring. Many sampling events only took place once a year, in separate regions of the Bay, or were only conducted as single events. In addition, there are multiple compatibility issues with types of equipment and methods used to obtain data for sampling chlorophyll, light availability, dissolved oxygen, etc. Also, the sites sampled were different depending on which agency or individual collected the data. Because of this, only a very limited amount of data was determined to be comparable over time. The datasets found to be used in the long term trend analysis are listed in Table 1. Note: not all data from each dataset was used in the analysis, only portions of data from within the area of interest and excluding the shipping channel (Fig. 1). The area of the Bay used for the analysis is the northern portion, above Fairhope point up to Interstate 10. This portion was chosen because it is most likely to have the greatest amount of influence from riverine sources, yet also experiences salt wedge influence. This area is most likely to show any potential biological and/or physical responses to changes in upland habitat and/or water quality.

All measurements used for the trend analyses were averaged over the most active chlorophyll seasons only (spring, summer, fall) in order to overcome any seasonal fluctuations, and only those datasets that sampled during the entire active seasons were included. These measurements also averaged both surface and bottom measurements to overcome salinity influences. We only included years that had a spatially redundant sampling strategy within the area of interest, in order to avoid any site specific bias. Upon examination of long term trends in chlorophyll a abundance in the water column ($\mu\text{g L}^{-1}$), we found an increasing trend in chlorophyll a content over time ($R^2 = 0.53$; Fig. 2) that places the average well into the EPA's definition of fair water quality standard ($5\text{--}20 \mu\text{g L}^{-1}$). However several caveats must be included with this analysis: firstly, this analysis only includes the years 1990 until 1999 and is missing data for 1996 and 1997; secondly, without older data it cannot be determined whether earliest sampled years were unusually low for this region; thirdly, the current state of conditions cannot be determined and therefore the analysis is simply a snapshot of past water quality. These same issues are encountered when analyzing the DO datasets, which found a slight decrease in average DO (mg L^{-1}) content ($R^2 = 0.24$; Fig. 3). In order to confirm the temporal trends found in these analyses, current sampling regimes should be conducted and long term monitoring plans set in place to track any changes in these water quality parameters.



Figure 1. Mobile Bay with area of interest encircled and showing exclusion of any shipping channel measurements.

Table 1. List of datasets used in long term trend analysis.

| Dataset | Years encompassed | Parameters | Sampling schedule |
|-----------------------------------|--------------------------|------------------------------|--------------------------|
| Pennock et al. | 1989-1999 | DO, chl a, light attenuation | Random |
| Alabama Coastal Foundation | 1991-2005 | DO, secchi depth | Weekly |

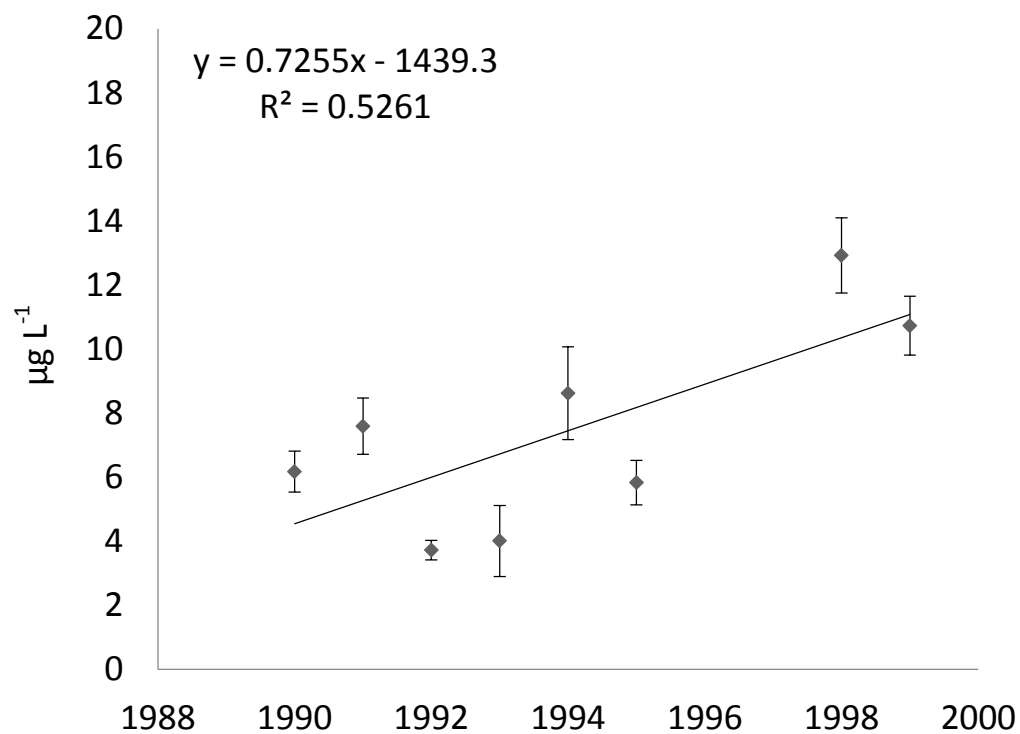


Figure 2. Chlorophyll a content ($\pm\text{SE}$) for area of interest within Mobile Bay.

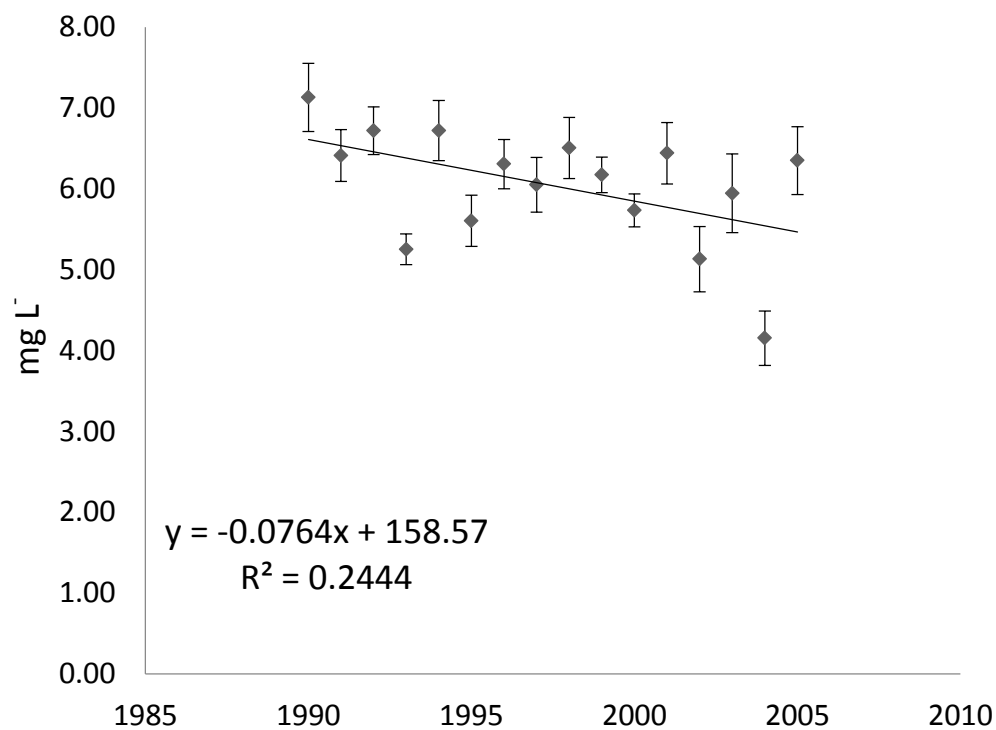


Figure 3. DO content ($\pm\text{SE}$) for area of interest within Mobile Bay.

Summary:

- Dataset compilations of water quality for Mobile Bay are severely lacking, with few long term datasets available.
- Incompatibility between techniques and methods led to further restrictions in analysis of datasets.
- Many sampling regimes were incomplete, i.e. only conducted once to three times per year and not seasonally, only single replicate samples leading to lack of confidence in dataset, or a lack of spatial replication that leads to high sample site bias.
- Datasets from different agencies focused on particular portions of the Bay, and therefore could not be compared with other agencies' datasets over time.
- Only inferences can be drawn from the analyses utilizing known Mobile Bay water quality datasets, and these inferences have multiple caveats. It is imperative to continue water column sampling within the area of interest and to maintain a sampling regime for at least three years for a more educated conclusion as to the state of Mobile Bay water quality.