2014 CAMINADA HEADLAND BEACH BENTHIC ORGANISM SURVEY: YEAR 2

by

Jerry A. McLelland, PhD

submitted to

Louisiana Universities Marine Consortium
for
LUMCON's Barataria-Terrebonne National Estuary Program

c/o

Richard DeMay,
Project manager

June 28, 2014

Contact information:
J. McLelland
Gulf Benthic Taxonomy Assessement
111 Cotton Creek Dr, Hattiesburg, MS 39402
Ph: 228-257-9207
email: mudcritters@gmail.com

2014 CAMINADA HEADLAND BEACH BENTHIC ORGANISM SURVEY: YEAR 2

Background

A pre-construction survey of the gulf shoreline benthic community from wet sand (intertidal) and wrack line habitats at four stations along the Caminada Headland Beach (Fourchon, Louisiana) was conducted April 1-2, 2013, as part of a beach and dune restoration project which requires monitoring of wintering piping plovers (*Charadrius melodus*) in that area (McLelland 2013). The 2013 survey showed that the intertidal macrobenthic population was dominated by the polychaete annelid, *Scolelepis squamata* and the amphipod crustacean, *Lepidactylus triarticulatus*. Although the latter was more numerous, the two populations were nearly equal in total biomass. The beach wrack-line invertebrate community at three of the four stations was dominated by large numbers and a rich variety of small insects, but was lower in total biomass than the corresponding intertidal zone fauna.

Year 2 of the survey was conducted April 16-17, 2014, and focused on three aspects: (1) revisiting the same four gulf-side stations to assess changes in the macroinvertebrate population structure resulting from beach renourishment and dune construction (post-construction); (2) survey an additional six gulf-side sites along the Caminada Headland Beach extending eastward from those surveyed in 2013 in order to provide a baseline for further restoration to commence as part of Phase II; and (3) survey the benthic community at three bay-side sites within the Caminada Headland Beach and Dune Restoration project footprint, areas known to provide forage for transient shorebirds. To allow comparison between sampling events, all year 2 samples were collected in the same manner as those of year 1. The locations of the 10 beach stations and 3 bayside stations appear on the map in Figure 1 (page 3).

Field Procedures.

Intertidal samples were collected at each station near mid-swash zone - that area halfway between the point at which waves break on the beach face and the upper extent of the moving water. A hand-held stainless steel box core, described by Saloman and Naughton (1977), was used for intertidal sampling (Fig. 2). The coring device, six inches (12.5cm) on a side and penetrating to a depth of 18-20cm, was used to collect three replicate quantitative samples at approximately 1 meter apart and representing 0.0156m^2 of substrate. Box Core samples were treated with a weak formalin solution to anesthetize motile organisms, then repeatedly elutriated through a 0.5mm mesh sieve. The elutriation technique served to float off soft-bodied infauna (e.g. polychaetes, amphipods) from the samples. The remaining sediment was screened through a 1.0mm sieve to remove possible heavier bodied organisms (e.g., mollusks). Samples

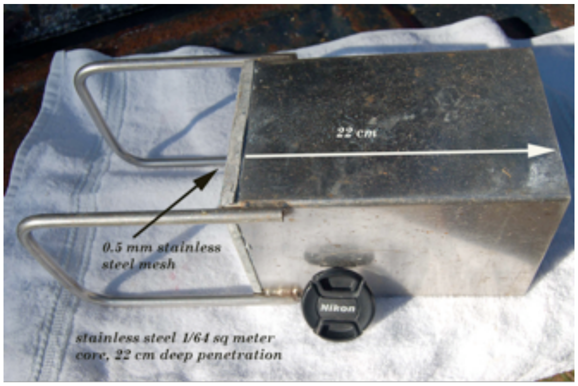

Figure 2. Box Core used in intertidal sampling. Photo by J.M. Foster.

Figure 1. Map showing locations of benthic stations at Caminada Headland Beach, Fourchon, Louisiana in Year 2 - 2014.

were preserved in the field with rose bengal-stained 5% formalin, labeled and returned to the laboratory for analysis. Rose bengal, a protein stain, facilitates the detection of benthic organisms among the sediment and detritus in the samples during the laboratory sorting process.

The wrack line community was sampled following National Water Quality Assessment (NAWQA) Program protocols (Moulton et al, 2002) for the collection of richest-targeted habitat (RTH) samples corresponding to approximately 0.25 square meters of wrack substrate (fine organics, shells, woody debris, drift vegetation, etc.) per sample. Three replicate samples were collected by scooping out about 5 cm of sediment inside a 0.25 square meter quadrant that was placed at about two meter intervals within a 10 meter section of the wrack line (Fig. 3). Large debris particles were removed from the samples by sifting through a coarse screen (4.0 mm) that was dipped in a water bucket to dislodge clinging organisms (spiders, insects, etc.). Samples were then processed and preserved in a similar manner to the box cores using elutriation and screening through a 1.0mm sieve.

Figure 3. 0.25 m quadrant used for sampling beach wrack fauna. Photo by J. McLelland.

One qualitative multi-habitat (QMH) wrack-line sample per station was collected to account for large and rare specimens (i.e. crabs, snails, etc.) occurring among the flotsam and jetsam within the same homogenous wrack-line section used for the collection of RTH sample. The purpose of this sample was to provide an indication of RTH sampling efficiency. QMH sampling, based on NAWQA protocols, was conducted by pushing a wide-mouth kicknet along the 10-meter wrack-line section with the ensuing sediment and debris (e.g., Sargassum weed) being washed by agitation in a sampling bucket. Organisms resulting from this action were placed in a jar, labeled and preserved.

Additional physical data included GPS coordinates, salinity, water and air temperatures, wind speed and direction, and sea state (Table 1). The three bay-side stations were sampled similarly to the beach station wrack-line habitats except that no QMH sample was collected (see Table 2 for station data).

Table 1. Caminada Headland Beach Gulf Side Benthic Field Data - April, 2014

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9	Station 10
Date sampled	4/17/14	4/17/14	4/17/14	4/17/14	4/17/14	4/16/14	4/16/14	4/16/14	4/17/14	4/16/14
Time on Site	0830 - 0930	0945 - 1045	1200 - 1315	1540 - 1645	1055 - 1152	1655 - 1815	1420 - 1530	0815 - 1005	1510 - 1600	1125 - 1240
Latitude	N 29.09067	N 29.11006	N 29.12492	N 29.13925	N 29.11792	N 29.13198	N 29.15350	N 29.16832	N 29.18192	N 29.18827
Longitude	W -90.21364	W -90.17769	W -90.15558	W -90.13197	W -90.16680	W -90.14399	W -90.10953	W -90.86990	W -90.06347	W -90.05154
Station ID no.	ID 334	ID 417	ID 406	ID 421	ID 411	ID 401	ID 526	ID 426	ID 493	ID 490
Intertidal length	7.1m	3.1m	5m	5.1m	4m	0	3.6m	3.5m	5m	3.3m
Wrack to water	1m	1m	3m	6m	3m	0	3m	3.5m	5m	3m
Sample types:										
box cores	3	3	3	3	3	3	3	3	3	3
wrack semi-quant	3	3	3	3	3	3	3	3	3	3
wrack qualitative	1	1	1	1	1	1	1	1	1	1
Physical data:										
salinity ppt	26	25	24	25	25	25	25	24	26	25.5
air temp °C	18.6	19.3	19.9	16.2	19.6	15	16.4	14.7	18.9	14.6
water temp °C	17.4	18	18	17.7	18	17.3	19.7	15.8	18.7	19
wind speed mph	15	10	5 - 10	5	10	<5	5 - 10	10 - 15	15	5
wind direction	ESE	E	E	E	E	E	E	E	E	E
% cloud cover	100	100	100	100	100	98	95	20	100	60
sea state ft	2	2	1	1-2	1.5	1	2	2	2 - 3	2

Table 2. Caminada Headland Beach Bay-Side Benthic Field Data – for April 2014

	BS 1	BS 2	BS 3
Date sampled	4/16/14	4/16/14	4/17/14
Time on Site	1009 - 1015	1300 - 1330	1320 - 1335
Latitude	N 29.17126	N 29.18443	N 29.11860
Longitude	W -90.08729	W -90.06441	W -90.16812
Station ID no.		ID 493	ID 711
Intertidal length	-	-	-
Wrack to water	-	-	-
Sample types:			
box cores	-	-	-
wrack semi-quant	3	3	3
wrack qualitative	-	-	-
Physical data:			
salinity ppt	24	20	23
air temp °C	15.3	13.7	19.1
water temp °C	16.1	21.9	19
wind speed mph	5 - 10	5	5 - 10
wind direction	E	E	E
% cloud cover	50	70	100
sea state ft	-	-	-

Laboratory Procedures.

Sorting was conducted under a stereoscopic dissecting microscope to remove all macrobenthic organisms and recognizable fragments. Specimens were counted and identified to the lowest possible taxonomic category with representative reference material being retained and transferred to 70% ethanol for storage. The remaining material was separated into major groups of prey items (e.g, annelids, arthropods, mollusks), preserved in ethanol and set aside for biomass measurement. A numerical database was constructed using Microsoft Access and data was further condensed and organized in spreadsheet format using Microsoft Excel. Numbers counted were converted to numbers per square meter using 64.103 per individual for box core data and 16 per individual for the 0.25 meter quadrant. Metrics of species diversity (H'), equitability (J') and dominance were calculated using formulae incorporated in the Excel spreadsheet.

Species diversity is the number of different species in a particular area (species richness) weighted by some measure of abundance such as number of individuals or biomass. The Shannon-Weiner Diversity Index (H') is the most popular mathematical expression of species richness and evenness in use in ecological investigation, including benthic monitoring studies. According to Pielou (1966), who studied the use of H' in detail, the index is appropriate to use when random samples are drawn from a large community in which the total numbers of species is known. H' is calculated as $-\sum \rho i \log n(\rho i)$, where ρi is the proportion of the total number of specimens *i* expressed as a proportion of the total number of species for all species in the ecosystem. The product of $\rho i \log n (\rho i)$ for each species in the ecosystem is summed and multiplied by −1 to give H'.

The species equitability index (J'), also known as Evenness, is another measure of how well the abundance of individuals is spread among the number of species. It is calculated as H'/H_{max}, where H_{max} is the maximum possible value of H', and equals the log of S, which is the number of species (species richness). The index of dominance, a measure of how a population is dominated by one or a few species, is calculated simply as 1-J'.

Total benthic biomass (by weight) of piping plover prey species was measured following methods described by Versar, Inc. (2002). Samples composed of prey specimen groups (see above), pooled from all replicates, were air dried to a constant weight at 60ºC in a drying oven and then baked for 4 hours at 500ºC in a muffle furnace to determine the ash-free dry weight. Samples were weighed before and after baking using an analytical balance accurate to 0.0001 g. Bivalves and barnacles in the samples were crushed prior to drying to eliminate water trapped in the shells.

Figure 4. Typical Gulf-side beach face.

***Results*.**

General field observations. The typical beach face at most of the Gulf-side stations was flat with little contour (Fig. 4). The substrate consisted of very fine, firmly packed sediment overlaying sparse amounts of shell hash composed of fine flakes at some stations and coarse rubble at others, usually the most recently reconstructed. The sediment was light brown in color due likely to large amounts of fine silt originating from nearby rivers and bays. The newly constructed beach at stations 1 and 2 contained only a minimal amount of sand and much larger shell particles and rubble originating from dredge material taken from offshore. In time it is likely that a deeper layer of sand will accumulate at these constructed sites to allow the recruitment and colonization of more normal infaunal populations. As in 2013, many of the larger shell pieces at the non-constructed stations still showed evidence of oil contamination with encrusted sand and weathered tar residue. The wrack line at the most recent high-tide mark, similar at all stations, was typified by varying amounts of recently washed up gulfweed (*Sargassum natans*) that

Figure 5. Sargassum clumps in wrack line.

appeared to have been deposited within a few days prior to our visit (Fig. 5). Station 6 was an anomaly among the Gulf-side sites in that it showed evidence of recent beach erosion with remnants of an old peat bank from marshland instead of a sandy beach face (Figs. 6 and 7). At the time of sampling, this station featured exposed mud flats, tide pools and clumps of algae-covered marsh roots present between the open water and the wrack line on the beach face; all of which created a complex habitat structure of cryptic microhabitats for the infaunal and attached macroinvertebrate community. Sampling was conducted at low tide resulting in exposed mud flats and tide pools. The intertidal samples taken here were abnormal in that there was little or no wave action, very little intertidal sand, and much fine silt and mud clumps.

Figure 6. Caminada Headland Beach Station 6.

Figure 7. Sampling the intertidal zone at Station 6.

Figure 8. Typical Bay-side station behind Caminada Headland Beach.

The three Bay-side stations, open to the bay on the north side, were similar in that they were typical exposed mud/sand-flat areas with standing water replenished by tidal inundation, and with varying amounts of fringing vegetation (Fig. 8). The sediment was composed of mud and fine-grained sand topped by a thin algal mat. Quadrant sampling at these stations was conducted at the waterline in sediment either exposed or with about a centimeter of water coverage.

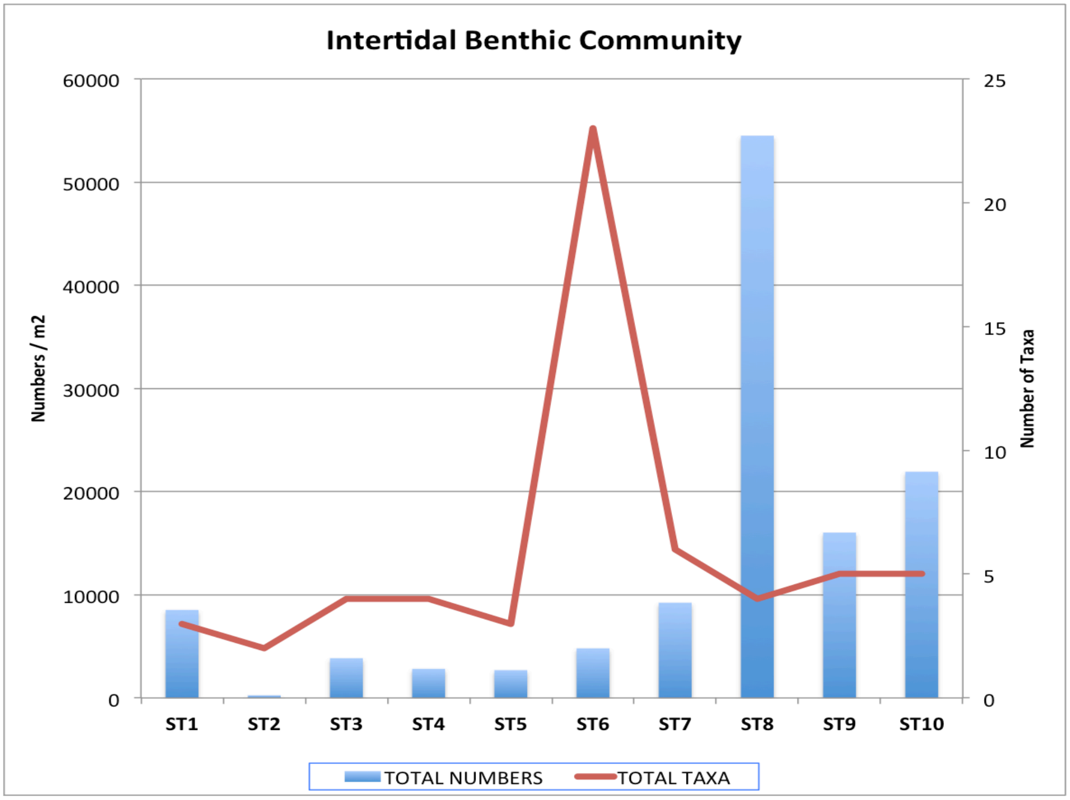

Figure 9. Intertidal total density vs. richness.

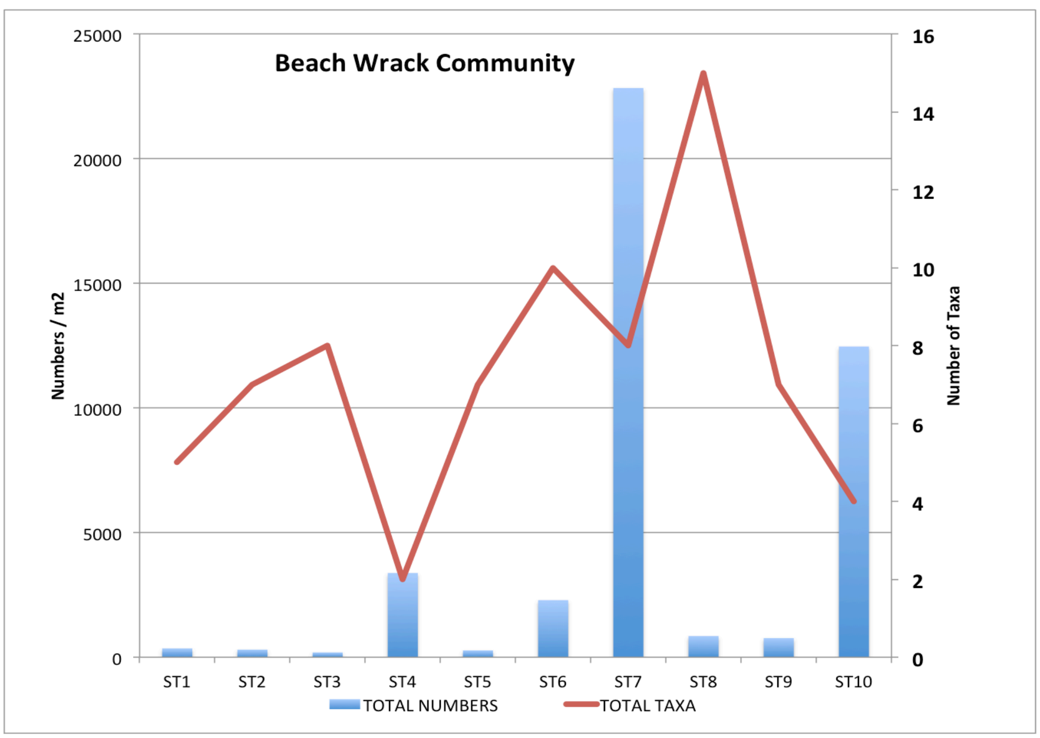

Figure 10. Wrack-line total density vs. richness.

Benthic fauna.

During the April 2014 sampling period, a total of 5,131 organisms were examined from Caminada Headland Beach samples (4675 from the 10 Gulf-side stations and 456 from the three Bay-side stations) representing 80 nominal taxa from six phyla. Numerical, biomass and diversity data are presented in Tables 3 and 4 for the intertidal and wrack line communities respectively and in Table 5 for the Bay-side benthic community. A complete phylogenetic listing of organisms encountered appears in Appendix I.

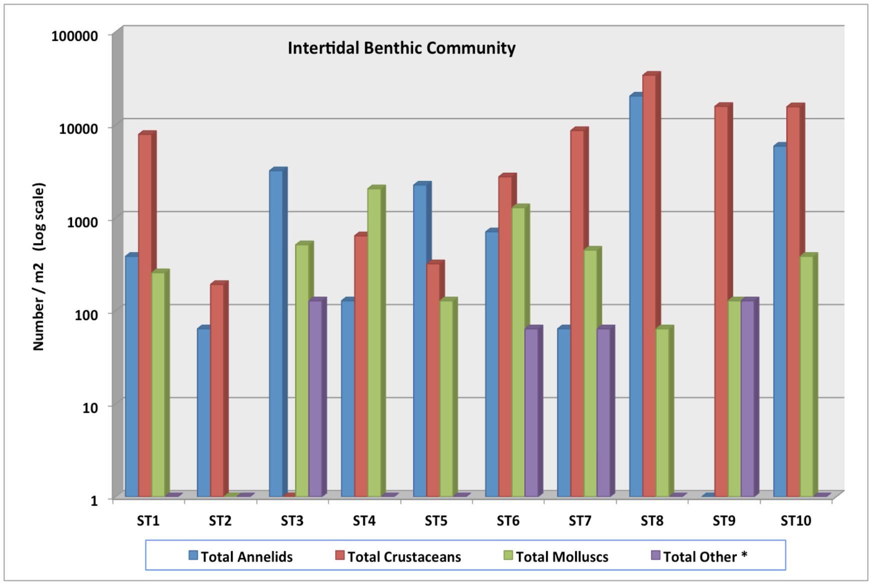

Figure 11. Gulf-side intertidal macrobenthic components.

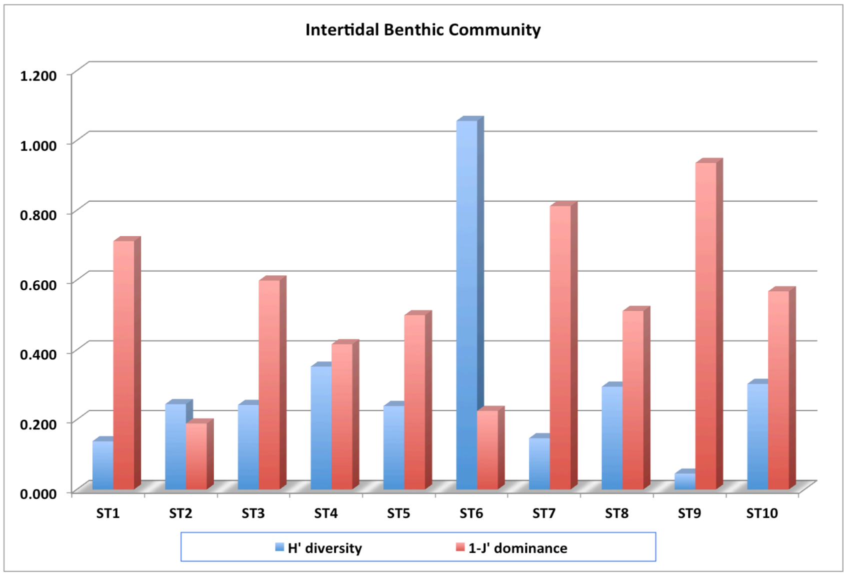

Figure 12. Gulf-side intertidal diversity indices.

Gulf-side Stations

Among the ten Gulf-facing stations, station 8 had by far the largest number of intertidal individuals collected with over 50,000 organisms/m^2, largely due to high numbers of the haustoriid amphipod, *Lepidact ylus triarticulatus* and the spioninid polychaete, *Scolelepis squamata* (Figs. 9). The anomalous station 6 was characterized by the largest number of intertidal taxa present (23) among the ten stations, a feature which was reflected by its high H' diversity and low dominance index values (Fig. 12). This highly diverse station featured six species of annelids, 8 different crustaceans, and six different molluscs. The highest density of total organisms in the beach wrack-line community occurred at station 7 (22,832/m^2) with substantial numbers (12,464/m^2) also at station 10. High numbers of *Lepidactylus* accounted for the density at both of these stations and also at station 4 with 3,360 amphipods/m^2 (Figs. 10 and 14). Species diversity (H') values above 0.500 occurred at six of the 10 stations with the highest value (0.943) at station 8. Station 8, while having a moderate density compared to that of stations 7 and 10, had the highest number of taxa (15) featuring eight crustaceans and three different annelids (Fig. 10). An important potential food source for foraging shorebirds in the wrack environment was the fauna associated with the freshly washed-up Gulf weed. The gooseneck barnacle, *Lepas pectinata*, the Sargassum snail, *Litiopa melanostoma*, the caprellid amphipod, *Caprella equilibria*, and numerous unidentified pycnogonid crustaceans all were present at stations where *Sargassum* was abundant.

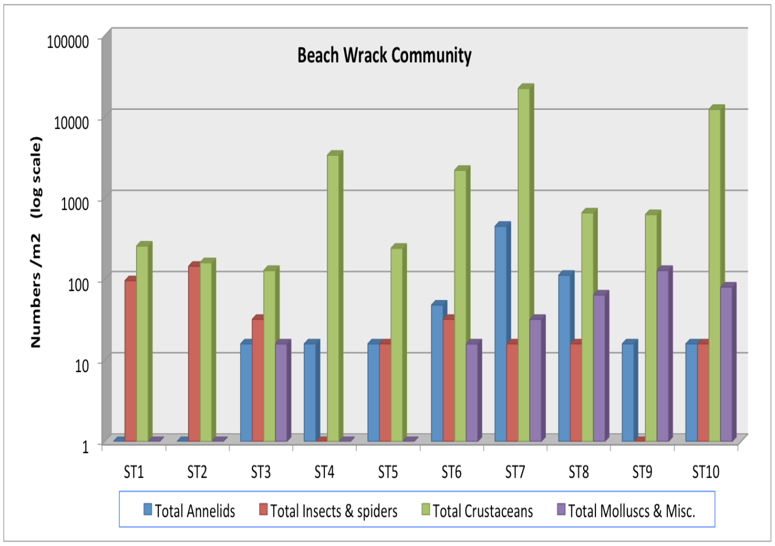

Figure 13. Gulf-side wrack-line macrobenthic components.

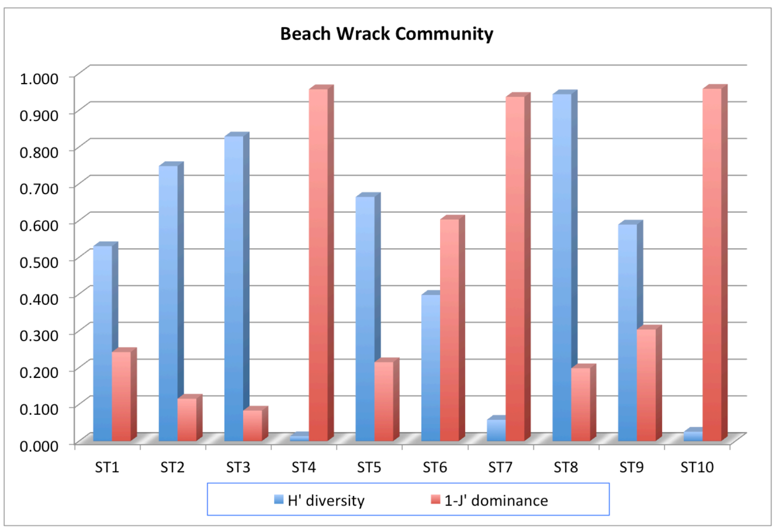

Figure 14. Gulf-side wrack-line diversity indices.

In terms of macrofaunal biomass, there was considerably more g /m^2 of available nutrition in the intertidal zone than in the wrack community (see the scales of Figs. 15 and 16) except for Station 2, a freshly reconstructed beach, which had exceptionally low intertidal values. Peaks of intertidal biomass at Stations 8 and 10 were due to large numbers of annelids, while at Stations 3 and 4 considerable numbers of bivalve molluscs (*Donax variabilis*) leant themselves to the available biomass (Figs. 11 and 17). In the wrack community, a relatively high peak (about 8 g/m2) occurred at Station 6; this value was a bit misleading as a single large anemone found attached to the rubble caused it. Other wrack biomass peaks occurred at stations 7 and 10 reflected large numbers of haustoriid amphipods (*Lepidactylus triariculatus*) embedded in the moist sand beneath the wrack line. In comparing the biomass totals of all stations (Figs. 19 and 20), annelids (44%), molluscs (31%) and crustaceans (22%) were well represented in the intertidal zone while in the wrack community, crustaceans (64%) comprised most of the volume. Again, the single occurrence of the large anemone at Station 6 skewed the percentage allotted to the "Molluscs & Misc" category.

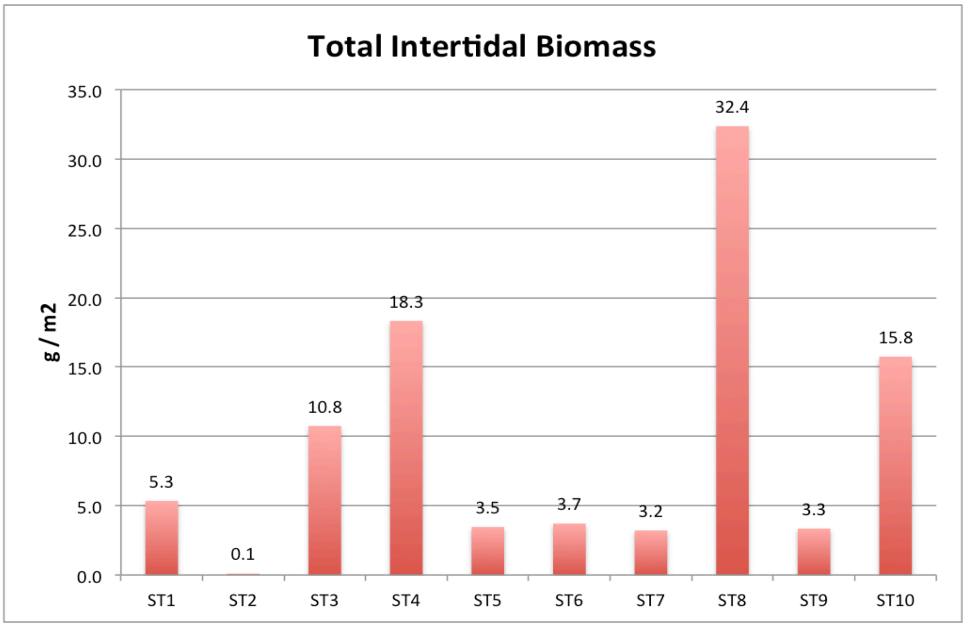

Figure 15. Gulf-side stations total intertidal biomass.

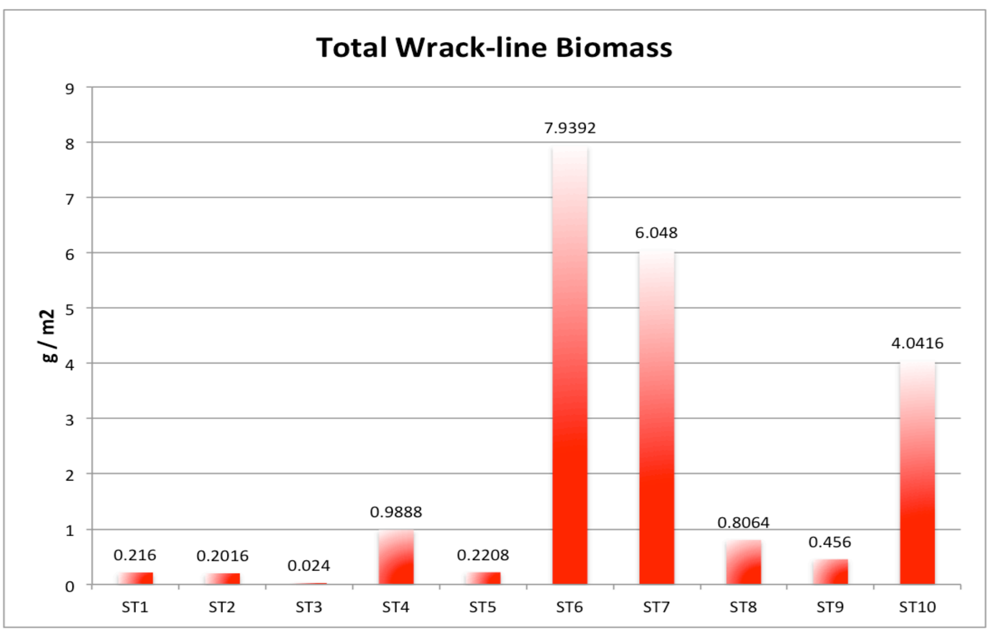

Figure 16. Gulf-side stations total wrack-line biomass.

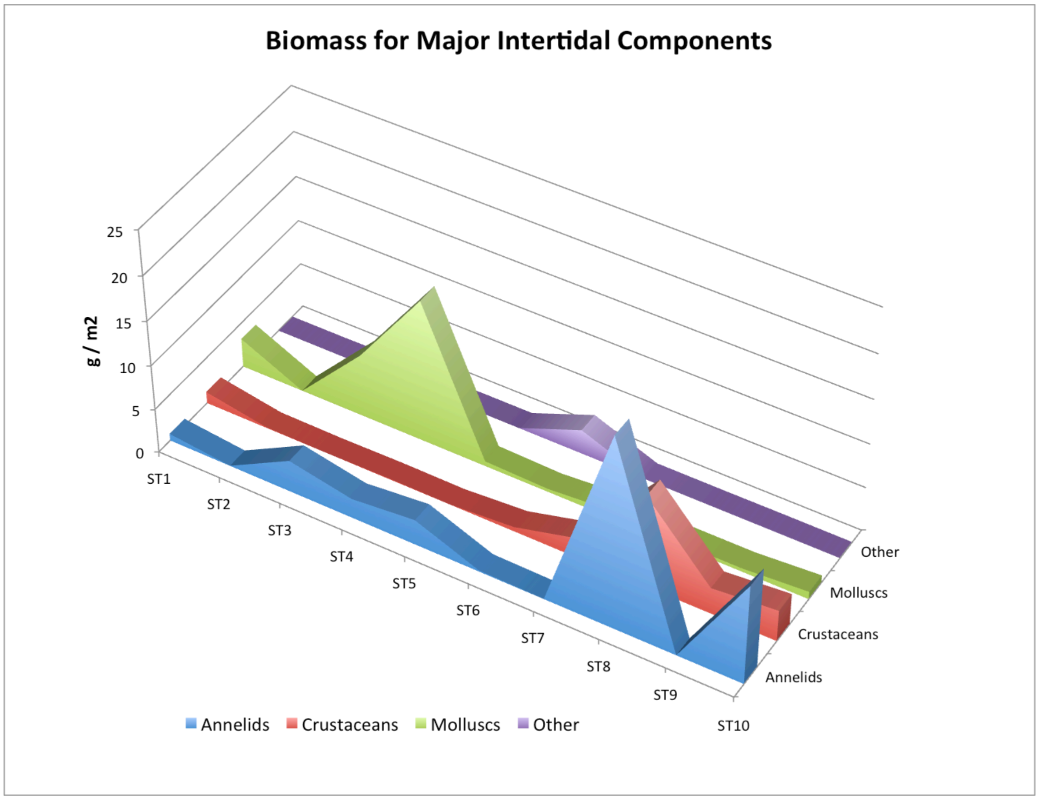

Figure 17 . Gulf-side stations intertidal biomass components.

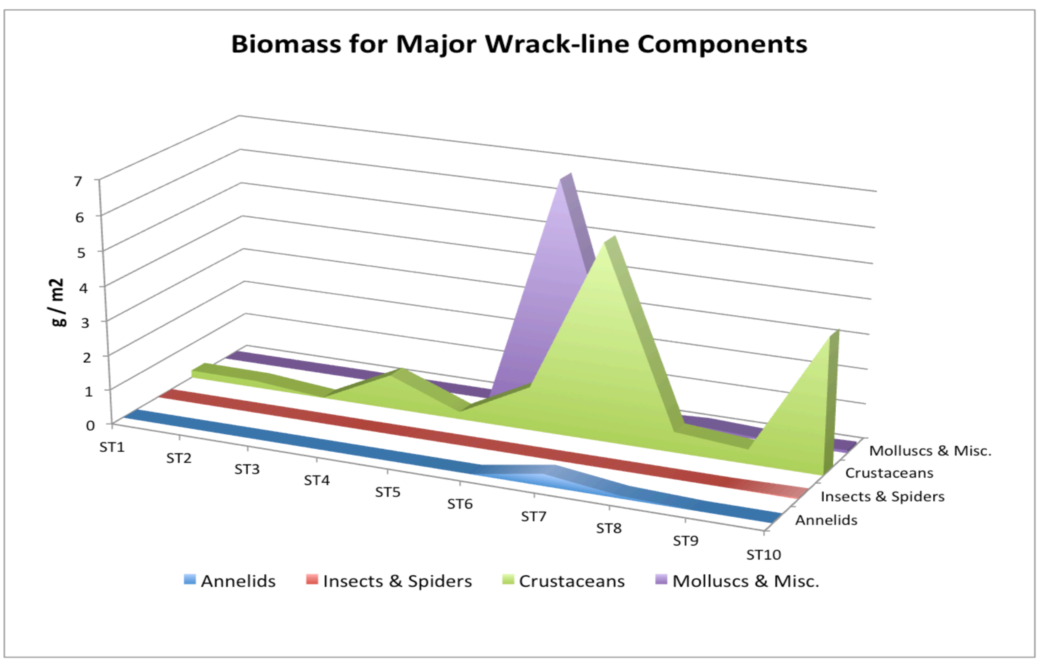

Figure 18. Gulf-side stations wrack-line biomass components.

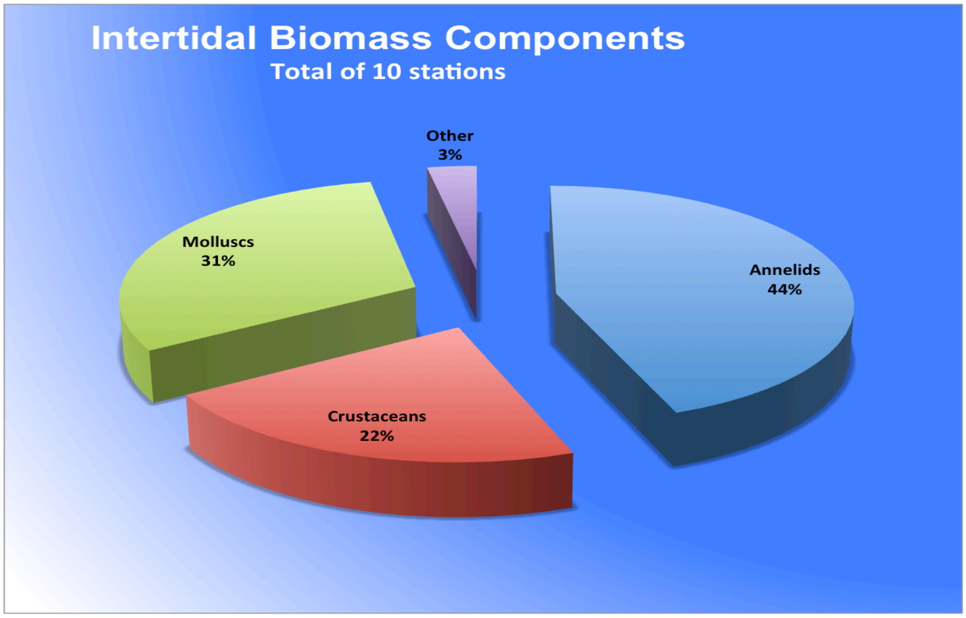

Figure 19. Gulf-side stations combined intertidal biomass components.

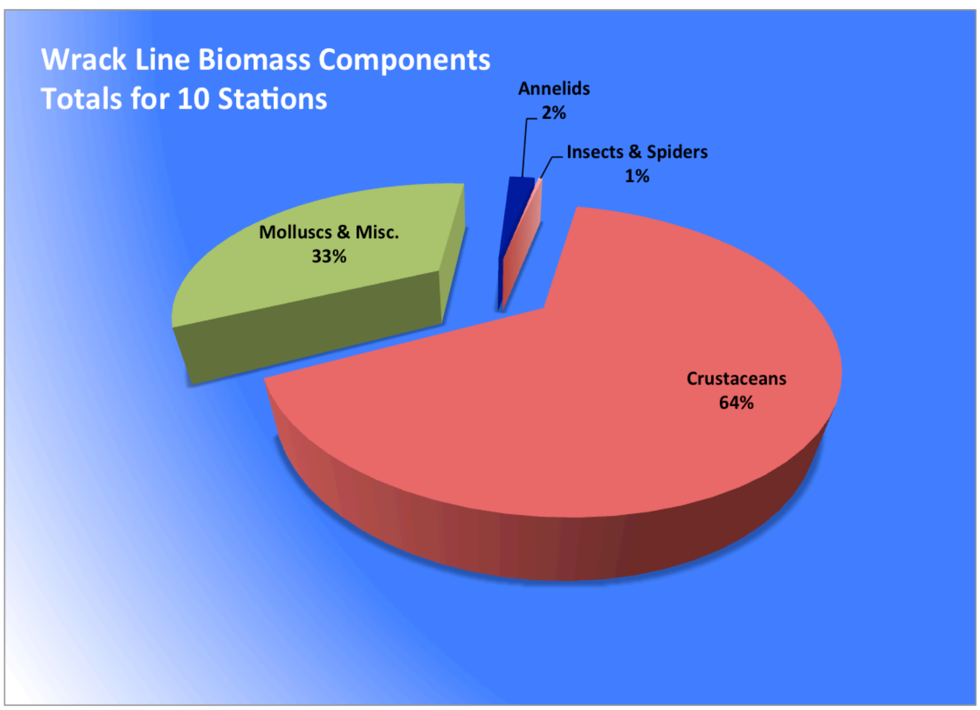

Figure 20. Gulf-side stations combined wrack-line biomass components.

Bay-side Stations

Of the three Bay-side sites, station BS1 had the highest density (5504 organisms/m2) and a larger number of taxa (Fig. 21). While H' diversity values were similar at all three stations (above 0.500), the dominance index was lowest at BS3 (Fig. 22). The fauna at the Bay-side stations was typical of that found in low energy, protected areas with higher amounts of settled silt and detritus. The deposit-feeding polychaetes, *Capitella capitata, Eteone heteropoda, Heteromastus filiformis*, and *Laeonereis culveri* were common at BS1 as well as large numbers of small podocopid ostracods. These two groups are depicted respectively by the annelid and crustacean peaks in Fig. 23. Salt-tolerant insects occurred at all three stations including several types of dipterans and staphylinid beetle larvae. Demersal fish eggs, possibly those of the sheepshead minnow, *Cyprinodon variegatus*, were present at stations BS1 and BS3.

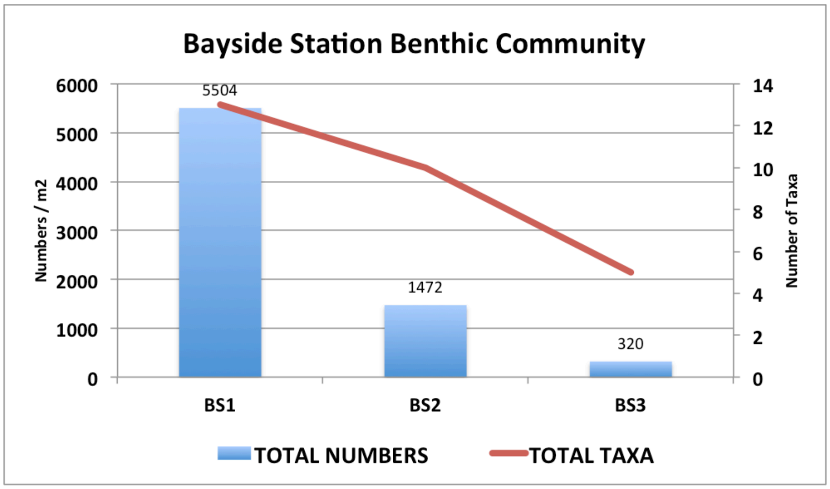

Figure 21. Bayside stations. Total macrobenthic density vs. richness.

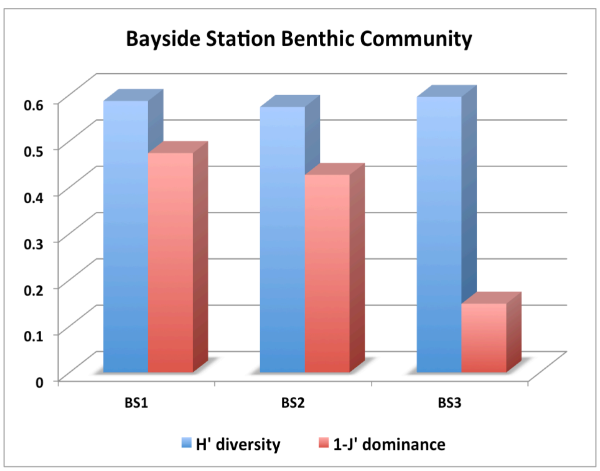

Figure 22. Bayside stations. Diversity indices.

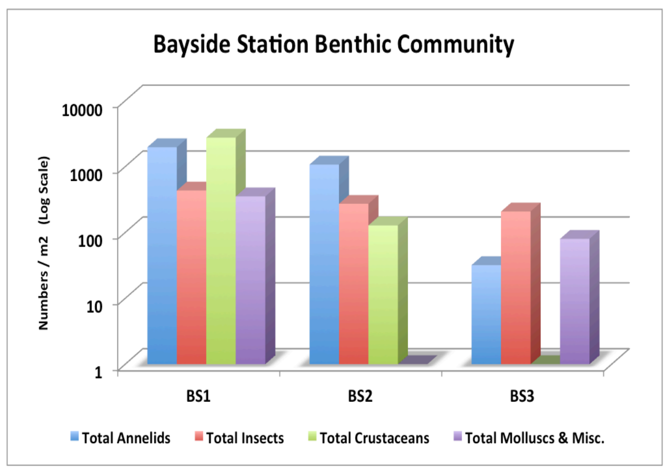

Figure 23. Bayside stations. Macrobenthic components.

Macrobenthic biomass values at the Bayside stations mirrored the trends seen in the density and richness categories at the corresponding stations. The biomass at Station BS1 nearly doubled that of BS2, which, in turn, was over 15 times that of BS3 (Fig. 24). Only a few small insects and fish eggs populated the latter station whereas in BS1 and BS2 larger organisms such as capitellid polychaetes and large dipteral larvae (e.g., Dolichopodidae) were present. Over all three bayside stations, annelids accounted for 61% of the biomass while insects were second at 30% (Fig. 26).

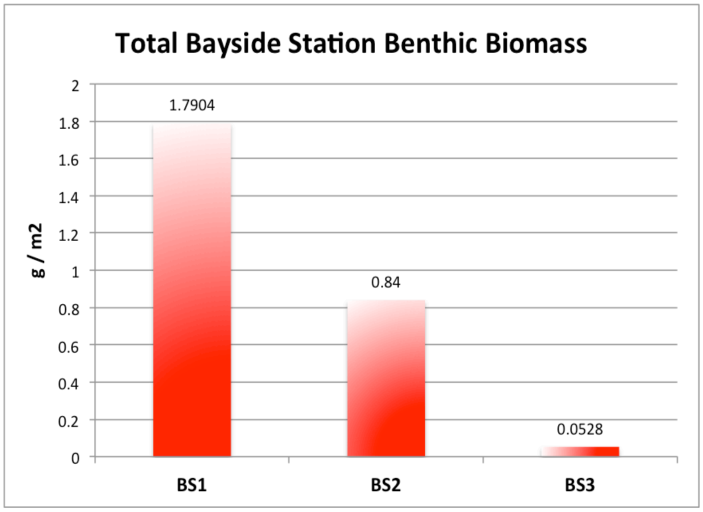

Figure 24. Bayside stations. Total macrobenthic biomass.

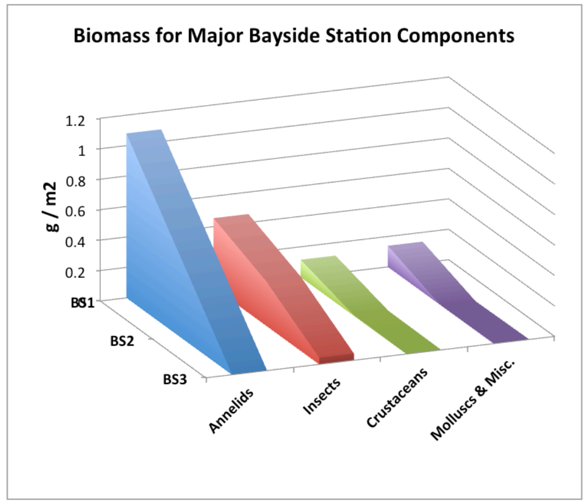

Figure 25. Bayside stations. Macrobenthic biomass components.

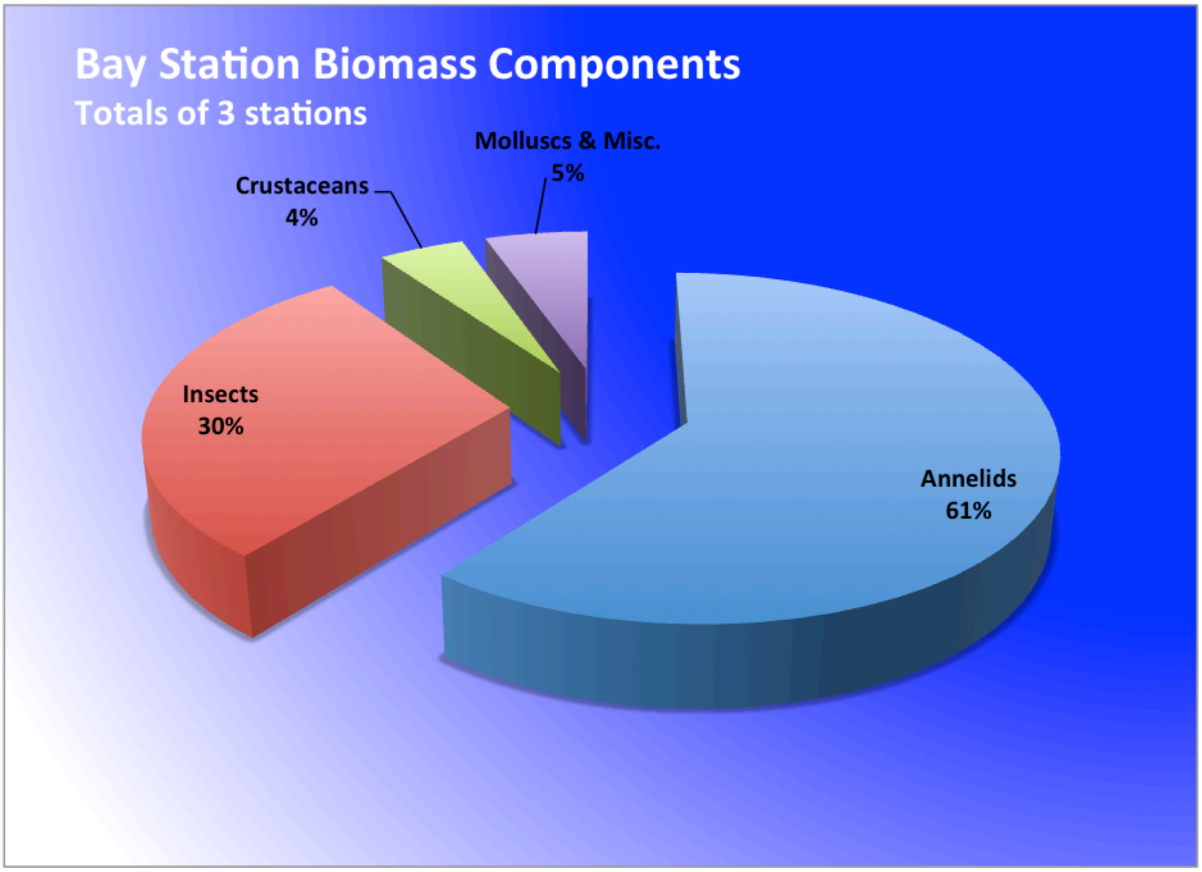

Figure 26. Bayside stations. Combined macrobenthic biomass components.

Comparison with 2013 data.

The faunal and physical data at stations 1 through 4 provided the only direct comparison between the 2013 and 2014 sampling events, with the caveat that beach reconstruction occurred at stations 1 and 2 in the interim between sampling events while the collections from stations 3 and 4 represented only pre-construction data. The six remaining beach sites were pre-construction from 2014.

Intertidal zone. H' species diversity was higher at stations 3 and 4 in comparison to stations 1 and 2 for both sampling periods, although only slightly so in 2014 (Fig. 27).

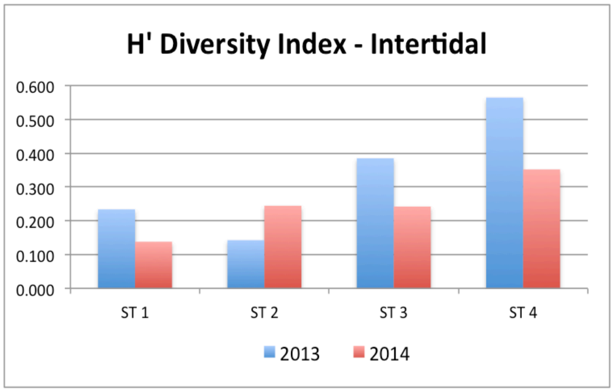

Figure 27. Intertidal H' diversity. 2013 vs. 2014.

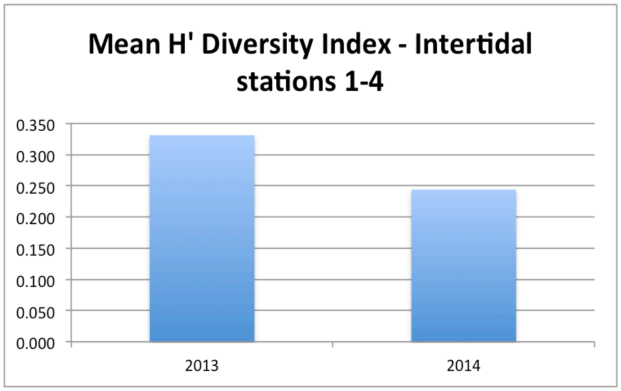

Figure 28. Intertidal mean H' diversity. 2013 vs 2014.

However, in comparing the mean diversity over all four stations, the 2013 values appeared substantially higher (Fig. 28). From a numeric standpoint, the 2013 total macrobenthic density was higher among three of the four stations with the exception being station 3 which had extreme numbers of annelids (Figs 29 and 30). Stations 1 and 2 were exceptionally high in crustaceans in 2013 with values peaking at 17,180 per m2 at station 2

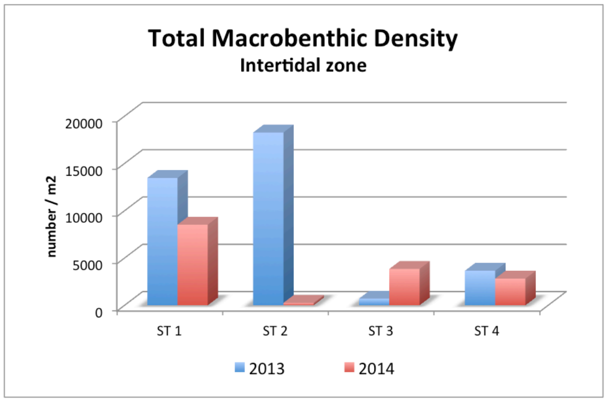

Figure 29. Total intertidal density. 2013 vs 2914

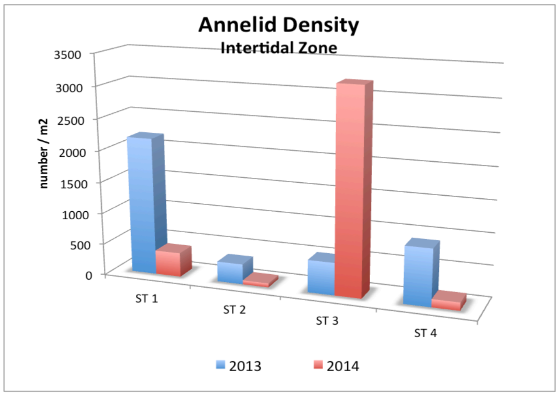

Figure 30. Intertidal annelid density. 2013 vs 2014

(Fig. 31). The 2014 mollusc density at stations 3 and 4 exceeded values of stations 1 and 2 and were also higher than any of the four stations during 2013 (Fig. 32). The higher density of this larger-bodied taxa, combined with the numerical abundance of annelids at

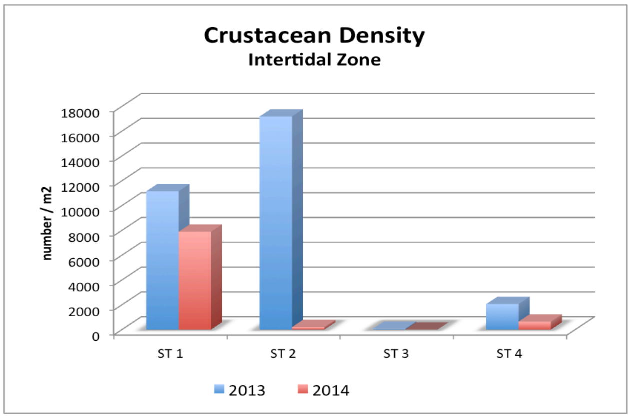

Figure 31. Intertidal crustacean density. 2013 vs 2014.

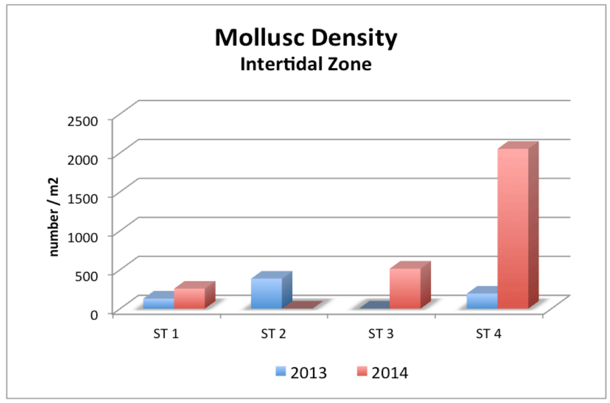

Figure 32. Intertidal mollusc density. 2013 vs 2014.

station 3 during 2014, attributed to a higher g/m^2 macrobenthic biomass at these two stations in 2014 (Fig. 34). In comparing intertidal biomass components combined over the four stations, molluscs comprised a much larger percentage (76%) in 2014 whereas crustaceans and annelids were nearly equally important (41-42%) in 2013 (Figs. 33 and 34).

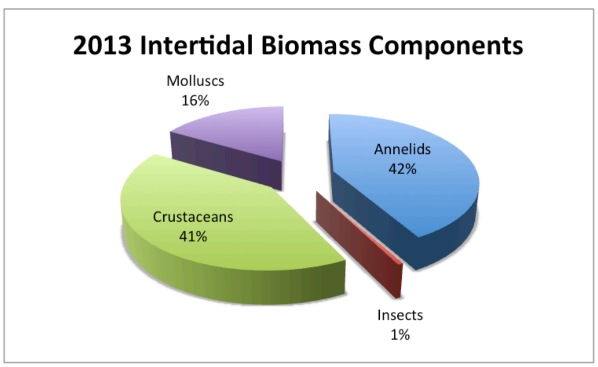

Figure 33. 2013 combined intertidal biomass components

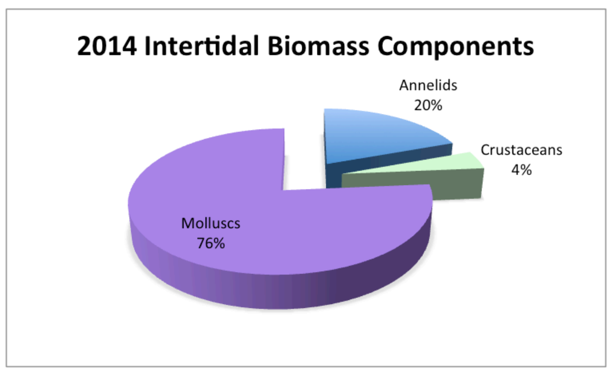

Figure 34. 2014 combined intertidal biomass components.

Wrack-line community. In general, the wrack community in 2014 was much less complex in terms of density and species richness than in 2013. There were far fewer numbers and types of insects present in 2014 (Fig. 37) but this was partially compensated by an increased density of fresh Sargassum weed with its associated barnacles, amphipods and snails. Similar to the intertidal zone, the mean H' species diversity for 2014 in the wrack community among the four stations was considerably lower, reflecting a drastically depressed value at station 4 (Fig. 35), a result of a large number of haustoriid amphipods (*Lepidactylus triarticulatus*) at this station (Fig. 38). Largely because of the absence of insects, in 2014 the wrack community biomass was comprised mostly of crustaceans (98%) at stations 1-4 (Figs. 39 and 40).

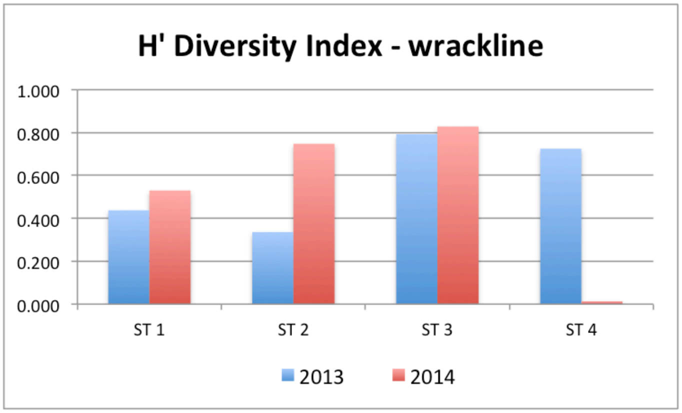

Figure 35. Wrack-line H' diversity. 2013 vs 2014.

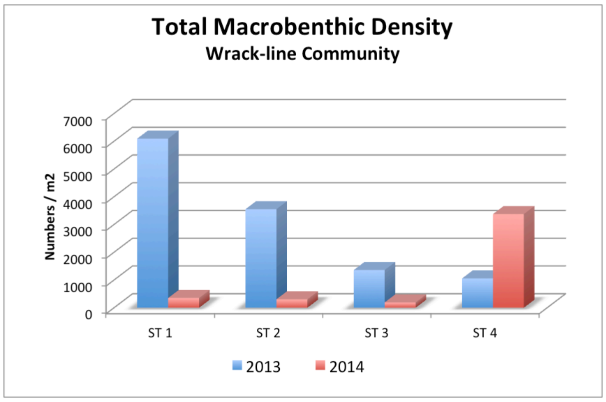

Figure 36. Wrack-line total density. 2013 vs 2014.

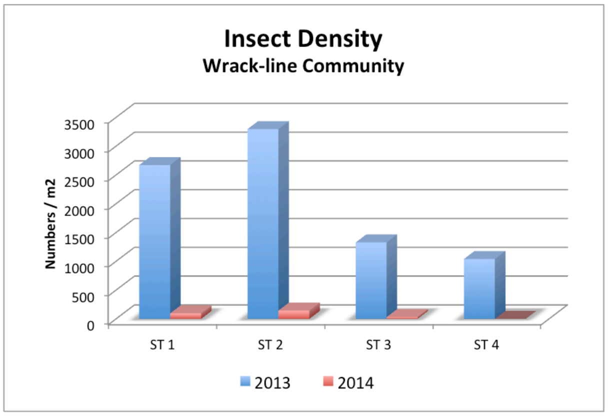

Figure 37. Wrack-line insect density. 2013 vs 2014.

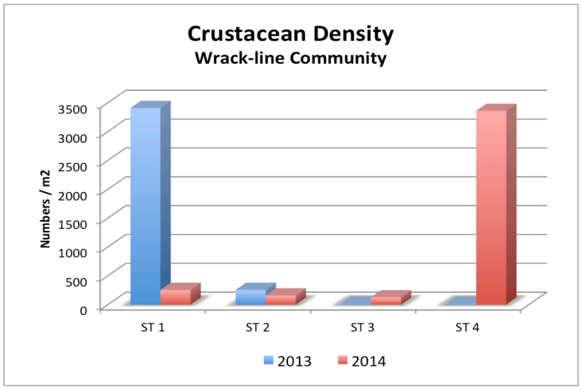

Figure 38. Wrack-line crustacean density. 2013 vs 2014.

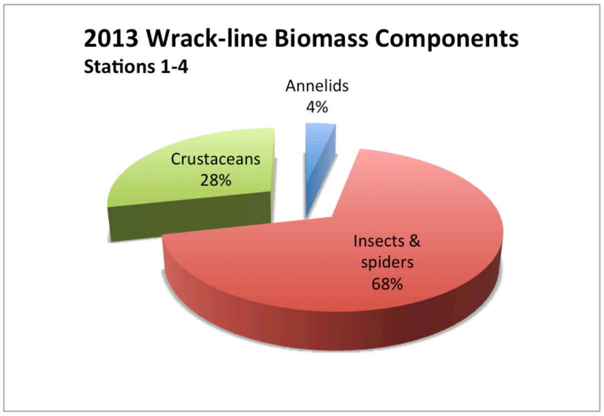

Figure 39. 2013 combined wrack-line biomass components.

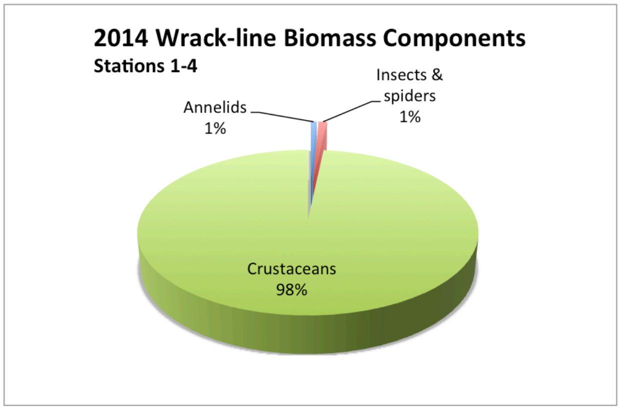

Figure 40. 2014 combined wrack-line biomass components.

Post construction vs. Pre construction stations comparisons.

In comparing the station 1 and 2 datasets from 2013 (pre-construction) to 2014 (post-construction), it can be shown that in both the intertidal and wrack-line communities, the total density, species richness, and biomass of benthic macroinvertebrates are greater in the pre-existing condition (see the station 1 and 2 profiles in Figures 29 and 36). All of the major taxonomic groups showed a decrease in the 2014 samples except for the molluscs at station 1 which had slightly higher numbers in the newly constructed beach. This could perhaps be because the benthic populations that were greatly reduced during reconstruction haven't yet become re-established or because the drastically altered sediment profile has yet to become stable.

Summary and Conclusions

The key components in the Macrobenthic community from the 2013 study were again present along the Caminada Headland Beach in 2014. The polychaete, *Scolelepis squamata*, the amphipod, *Lepidactylus triarticulatus* and the bivalve mollusc, *Donax variablilis* accounted for most of the Macrobenthic density and biomass in the intertidal zone at the ten beach stations, while cryptic organisms associated with the freshly deposited clumps of gulfweed (*Sargassum natans*) added to the nutritional value and potential shore-bird forage in the wrack-line community at most of the stations. The above-mentioned intertidal species are commonly occurring inhabitants of intertidal and near-shore benthic habitats from the barrier island and mainland beaches from the Florida panhandle area to Texas (Rakocinski et al. 1991, 1993; McLelland and Heard 1991; Mikkelsen and Bieler 2008; Tunnel et al. 2010).

The three bayside stations on the backside of Caminada Headland Beach varied from very little biomass to a healthy population of annelids and larval insects. In terms of density and biomass, the key players in these calmer waters were the polychaetes, *Capitella sp*. and *Laenonereis culveri* and several species of salt-tolerant insects, with the relatively large larvae of the long-legged fly (Dolichopodidae) occurring in abundance. These mesohaline organisms are common along bays and estuaries of the northern Gulf of Mexico (Heard 1982; LaSalle and Bishop 1987).

The findings of Year 2 of the Caminada Headland Beach benthic survey are summarized thus:

1. 80 nominal taxa from 6 different phyla were represented from the total of 5, 131 organism examined. The intertidal organism *Scolelepis squamata, Lepidactylus triarticulatus* and *Donax variabilis* accounted for most of the numeric density and biomass (g/m2) at the 10 beach stations while the polychaetes, *Capitella sp*. and *Laeonereis culveri*, and several species of salt-tolerant dipteran insects were important food resources at the three calm-water bayside stations.

2. Among the beach stations, Station 8 had the highest numerical density of organisms and biomass in the intertidal zone owing to the large numbers of annelids and amphipods (greater than 50,000 / m2) present there. Station 7 featured the highest density of wrack-line organisms (over 20,000 / m2), again due to a healthy population embedded *L. triarticulatus*, while station 8 had the larger number of taxa (15) among wrack environments sampled.

3. Station 6 was anomalous among beach stations by displaying characteristics of an old peat bank from an eroded marsh. The highest intertidal H' diversity value (> 1.0) among the beach stations occurred at station 6, demonstrated by the fact that of the 23 intertidal taxa, 16 were unique to that station.

4. In the wrack community, H' diversity values greater than 0.500 were seen at six of the Gulf-side stations with the maximum (0.943) occurring at station 8 (15 total taxa).

5. Intertidal macrobenthic biomass at the Gulf-side stations was overall greater than at corresponding wrack-line communities. Intertidal biomass peaks occurred at stations 8 and 10, with 32.4 and 15.8 g/m2 respectively, due to large numbers of annelids present.

6. Although H' diversity values were similar at the bay-side stations, BS1 had the highest density (5504/m2) and species richness (13) of the three stations followed by BS2 and BS1. Macrobenthic biomass values mirrored the trends seen in the density and richness profiles with the value of BS1 nearly doubling that of BS2, which, in turn, was over 15 times that of BS3.

7. Data from Gulf-side stations 1-4 collected in 2013 and 2014 were compared. In the intertidal zone, H' diversity values were higher in 2013 at stations 1, 3 and 4 with the mean diversity of all four stations higher in 2013. Total macrobenthic density was also higher at these same stations in 2013, mostly skewed by large numbers of crustaceans at stations 1 and 2; however the mollusc populations was larger at station 4 and annelid numbers were higher at station 3 in 2014. The intertidal biomass at stations 1-4 was predominantly molluscs (76%) whereas in 2013, the biomass was evenly split between annelids (42%) and crustaceans (41%). The wrack-line community in 2014 was much less complex than in 2013 largely because of the absence of the rich insect fauna present in the latter year. For example, the combined wrack biomass from 2014 was mostly crustaceans (98%) whereas in 2013, insects and spiders comprised 68 percent of the biomass.

7. Data from Gulf-side stations 1 and 2 collected in 2013 (pre-construction) were compared to the same for those collected in 2014 not long after beach reconstruction. In both, the intertidal and wrack-line communities at these two stations, values for total density, species richness and biomass were greater prior to reconstruction. All of the major taxonomic groups showed a decrease in the 2014 samples except for the molluscs at station 1 which had slightly higher numbers in the newly constructed beach.

Table 3. Summary of Intertidal Box Core Data – condensed by station.
Values in numbers/ m^2

TAXA	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10
ANNELIDA										
Polychaeta										
Family Capitellidae										
Capitella capitata complex							64			
Mediomastus sp.						192				
Family Lumbrineridae										
Scoletoma sp.				128		64				
Family Nereididae										
Unid. Nereididae						256				
Family Phyllodocidae										
Unid. Phyllodocidae						64				
Family Spionidae										
Polydora sp.						64				
Scolelepis squamata	385	64	3205		2244			20321		5897
Unid. Spionidae						64				
ARTHROPODA										
Arachnida										
Order Araneae										
Unid. Araneae									64	
Insecta										
Unid. Insecta									64	
Order Collembola										
Unid. Collembola							64			
Order Hymenoptera										
Family Formicidae										
Unid. Formicidae			64							
Order Lepidoptera										
Unid. Lepidoptera			64							
Malacostraca										
Order Amphipoda										
Family Caprellidae										
Caprella equilibra						64				
Family Gammaridae										
Gammarus mucronatus						64				
Family Haustoriidae										
Lepidactylus triarticulatus	7885	192		641	321	1667	8590	34039	15769	15577
Family Isaeidae										
Microprotopus sp.						321				

TAXA	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10
Family Liljeborgiidae										
Listriella barnardi						192				
Family Melitidae										
Melita sp.						64				
Family Oedicerotidae										
Ameroculodes miltoni						64				
Order Cumacea										
Family Bodotriidae										
Cyclaspis varians						64				
Order Decapoda										
Family Hippidae										
Emerita talpoida								64		
Family Penaeidae										
Penaeidae zoea										64
Order Isopoda										
Family Idoteidae										
Erichsonella sp.						64				
Family Sphaeromatidae										
Ancinus depressus						192	64			
MOLLUSCA										
Bivalvia										
Order Veneroida										
Family Donacidae										
Donax variabilis	256		513	1987	128	128	385	64	64	192
Family Mactridae										
Mulinia lateralis						64				
Family Montacutidae										
Mysella planulata				64		705				
Family Tellinidae										
Unid. Tellinidae						256				192
Family Veneridae										
Petricolaria pholadiformis						64				
Gastropoda										
Order Littorinimorpha										
Family Tornidae										
Unid. Tornidae						64	64		64	
MISC TAXA										
Cnidaria										

TAXA	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10
Unid. Anthozoa						64				
TOTAL NUMBERS	8526	256	3846	2821	2692	4808	9231	54488	16026	21923
TOTAL TAXA	3	2	4	4	3	23	6	4	5	5
diversity indices										
Hmax'	0.477	0.301	0.602	0.602	0.477	1.362	0.778	0.602	0.699	0.699
H' diversity	0.138	0.244	0.242	0.352	0.239	1.056	0.147	0.294	0.045	0.302
J' evenness (equitability)	0.289	0.811	0.402	0.584	0.501	0.775	0.188	0.489	0.065	0.433
1-J' dominance	0.711	0.189	0.598	0.416	0.499	0.225	0.812	0.511	0.935	0.567
						numbers/m2				
Total Annelids	385	64	3205	128	2244	705	64	20321	0	5897
Total Crustaceans	7885	192	0	641	321	2756	8654	34103	15769	15641
Total Molluscs	256	0	513	2051	128	1282	449	64	128	385
Total Other	0	0	128	0	0	64	64	0	128	0
						AFD biomass - g/m2				
Total Annelids	0.79	0.02	3.63	2.23	2.88	0.13	0.02	21.62	0.00	11.33
Total Crustaceans	1.31	0.08	0.00	0.08	0.02	0.50	2.31	10.37	2.94	3.56
Total Molluscs	3.25	0.00	7.02	16.02	0.56	0.35	0.87	0.38	0.38	0.87
Total Other	0.00	0.00	0.10	0.00	0.00	2.73	0.02	0.00	0.02	0.00

Table 4. Summary of Wrackline Quantitative Data – condensed by station.
Values in numbers/m^2

TAXA	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10
ANNELIDA										
Polychaeta										
Unid. Polychaeta			16							
Family Capitellidae										
Capitella capitata complex										16
Family Nereididae										
Unid. Nereididae						16		32	16	
Family Phyllodocidae										
Unid. Phyllodocidae							16			
Family Spionidae										
Polydora cornuta						32		32		
Scolelepis squamata				16	16		432	48		
ARTHROPODA										
Chelicerata										
Order Trombidiformes										
Unid. Hydrachnidia	16									
Insecta										
Order Coleoptera										
Unid. Coleoptera		32								
Family Chrysomelidae										
Unid. Chrysomelidae		16								
Family Staphylinidae										
Unid. Staphylinidae	80	64	16							
Order Collembola										
Unid. Collembola						32				
Order Diptera										
Unid. Diptera			16					16		16
Family Sciaridae										
Unid. Sciaridae		16			16					
Order Hymenoptera										
Unid. Hymenoptera		16								
FamilyFormicidae										
Unid. Formicidae							16			
Malacostraca										
Order Amphipoda										
Family Ampithoidae										
Unid. Ampithoidae	16									

TAXA	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10
Family Aoridae										
Grandidierella bonnieroides								16		
Family Caprellidae										
Caprella equilibra			16			16	32	16	32	
Family Corophiidae										
Unid. Corophiidae					16			16		
Monocorophium ascherusicum					16			48		
Family Gammaridae										
Gammarus mucronatus					16	16		16		
Family Haustoriidae										
Lepidactylus triarticulatus	192		16	3360		1712	22288	272	416	12352
Family Isaeidae										
Microprotopus sp.						80				
Family Stenothoidae										
Stenothoe minuta						16				
Order Isopoda										
Family Idoteidae										
Synidotea fosteri							16			
Family Janiridae										
Carpias minutus			64		64				16	
Maxillopoda										
Order Lepadiformes										
Family Lepadidae										
Lepas pectinata		96			128			144	128	
Order Sessilia										
Family Balanidae										
Unid. Balanidae						352		128		
Pycnogonida										
Unid. Pycnogonida	48	64	32						32	
MOLLUSCA										
Bivalvia										
Order Veneroida										
Family Veneridae										
Petricolaria pholadiformis							16	16		
Gastropoda										
Order Caenogastropoda										
Family Litiopidae										
Litiopa melanostoma			16					32	128	
Order Neotaenioglossa										

TAXA	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	ST9	ST10
Family Hydrobiidae										
Unid. Hydrobiidae										80
Order Nudibranchia										
Unid. Nudibranchia							16			
MISC TAXA										
Cnidaria										
Unid. Anthozoa						16				
Echinodermata										
Unid. Ophiurida								16		
TOTAL NUMBERS	352	304	192	3376	272	2288	22832	848	768	12464
TOTAL TAXA	5	7	8	2	7	10	8	15	7	4

diversity indices										
Hmax'	0.699	0.845	0.903	0.301	0.845	1.000	0.903	1.176	0.845	0.602
H' diversity	0.530	0.748	0.828	0.013	0.664	0.397	0.058	0.943	0.589	0.025
J' evenness (equitability)	0.758	0.885	0.917	0.043	0.785	0.397	0.064	0.802	0.697	0.042
1-J' dominance	0.242	0.115	0.083	0.957	0.215	0.603	0.936	0.198	0.303	0.958

					numbers/m2					
Total Annelids	0	0	16	16	16	48	448	112	16	16
Total Insects & spiders	96	144	32	0	16	32	16	16	0	16
Total Crustaceans	256	160	128	3360	240	2192	22336	656	624	12352
Total Molluscs & Misc.	0	0	16	0	0	16	32	64	128	80

					AFD biomass - g/m2					
Total Annelids	0.000	0.000	0.005	0.005	0.005	0.005	0.346	0.082	0.005	0.005
Total Insects & spiders	0.005	0.005	0.005	0.000	0.005	0.005	0.005	0.005	0.000	0.038
Total Crustaceans	0.211	0.197	0.010	0.984	0.211	1.253	5.664	0.595	0.418	3.912
Total Molluscs & Misc.	0.000	0.000	0.005	0.000	0.000	6.677	0.034	0.125	0.034	0.086

Table 5. Summary of Bay-side Quantitative Data – condensed by station.
Values in numbers/m^2

TAXA	BS1	BS2	BS3
ANNELIDA			
Clitellata			
Family Enchytraeidae			
Unid. Enchytraeidae			32
Polychaeta			
Family Nereididae			
Laeonereis culveri	128	96	
Neanthes succinea		16	
Family Phyllodocidae			
Eteone heteropoda	16	16	
Family Capitellidae			
Capitella capitata complex	1744	944	
Heteromastus filiformis	80		
ARTHROPODA			
Insecta			
Order Coleoptera			
Family Staphylinidae			
Unid. Staphylinidae		16	144
Order Diptera			
Unid. Diptera	32	160	48
Family Ceratopogonidae			
Unid. Ceratopogonidae	16		16
Family Dolichopodidae			
Unid. Dolichopodidae	368	96	
Order Hymenoptera			
Family Formicidae			
Unid. Formicidae	16		
Malacostraca			
Order Amphipoda			
Family Haustoriidae			
Lepidactylus triarticulatus		80	
Family Melitidae			
Melita sp.		32	
Order Isopoda			
Family Idoteidae			
Edotea triloba		16	
Ostracoda			
Order Podocopida			

TAXA	BS1	BS2	BS3
Unid. Podocopida	2752		
MOLLUSCA			
Bivalvia			
Order Veneroida			
Family Donacidae			
Donax variabilis	16		
Family Mesodesmatidae			
Ervilia concentrica	16		
Gastropoda			
Order Neotaenioglossa			
Family Hydrobiidae			
Unid. Hydrobiidae	64		
MISC TAXA			
Chordata			
Demersal fish eggs	256		80
TOTAL NUMBERS	5504	1472	320
TOTAL TAXA	13	10	5

diversity indices			
Hmax'	1.113943352	1	0.698970004
H' diversity	0.586250562	0.573407461	0.595207178
J' evenness (equitability)	0.526283999	0.573407461	0.851548956
1-J' dominance	0.473716001	0.426592539	0.148451044

		numbers/m2	
Total Annelids	1968	1072	32
Total Insects	432	272	208
Total Crustaceans	2752	128	0
Total Molluscs & Misc.	352	0	80

		AFD biomass - g/m2	
Total Annelids	1.080	0.542	0.005
Total Insects	0.456	0.293	0.043
Total Crustaceans	0.115	0.005	0.000
Total Molluscs & Misc.	0.139	0.000	0.005

Literature Cited.

Heard, R.W. 1982. Guide to common tidal marsh invertebrates of the Northeastern Gulf of Mexico. Mississippi-Alabama Sea Grant Consortium. MASGP-79-004, 88p.

LaSalle, M.W. and T.D. Bishop. 1987. Seasonal abundance of aquatic Diptera in two oligohaline tidal marshes in Missssissippi. Estuaries 10(4): 303-315.

McLelland, J.A. 2013. Caminada headland beach and dune restoration project (BA-45) – pre-construction benthic organism survey. Final report to LUMCON/B-TNEP, June 28, 2013. 16p.

McLelland, J.A. and R. W. Heard. 1991. Effects of an oil spill on the sand beach and near shore macroinfauna populations of Horn Island, Mississippi. Final report to U.S. National Park Service, Dept. of the Interior. 180p, unpubl.

Mikkelsen, P.M and R. Bieler. 2008. Seashells of Southern Florida. Living Marine Mollusks of the Florida Keys and Adjacent Regions. Bivalves. Princeton University Press, Princeton, NJ. 503p.

Moulton, SR, Kennen, JG, Goldstein, RM, and Hambrook, JA. 2002. Revised Protocols for Sampling Algal, Invertebrates, and Fish as Part of the National Water Quality Assessment Program U.S. Geological Survey Open-File Report 02-150, 75p.

Pielou, E.C. 1966. Species-diversity and pattern-diversity in the study of ecological succession. Journal of Theoretical Biology 10: 370-383.

Rakocinski, C.F., R.W. Heard, T. Simons and D. Gledhill. 1991. Macroinvertebrate associations from beaches of selected barrier islands in the northern Gulf of Mexico. Bulletin of Marine Science 48(3): 689-701.

Rakocinski, C.F., R.W. Heard, S.E. LeCroy, J.A. McLelland and T. Simons. 1993. Seaward change and zonation of the sandy-shore macrofauna at Perdido Key, Florida, U.S.A. Estuarine, Coastal, and Shelf Science, 36, 81-104.

Saloman, C. H. and S. P. Naughton. 1977. Effect of hurricane Eloise on the benthic fauna of Panama City Beach, Florida, USA. Marine BioIogy 42: 357-363.

Tunnel, J.W., J. Andrews, N.C. Barrera, and F. Moretzsohn. 2010. Encyclopedia of Texas Seashells. Identification, Ecology, Distribution, and History. Texas A&M University Press, College Station, TX. 512p.

Versar, Inc. 2002. Methods for calculating the Chesapeake Bay Benthic Index of Biotic Integrity. http://www.baybenthos.versar.com. 27pp.

Acknowledgements.

The Louisiana Coastal Protection and Restoration Authority provided funding for the second year of this project through a contract with the Louisiana Marine Consortium (LUMCON) for the Barataria-Terrebonne National Estuary Program. I wish to thank Richard DeMay for managing the project, for logistic support on Grand Isle, Louisiana, and for his help in field collections. Natalie Waters, Scott Walter, and Michael Massimi provided additional field help. I am grateful to Sara LeCroy (USM-GCRL) for aid in identifying amphipods.

***Appendices*.**

Appendix I. Phylogenetic listing of taxa.

Phylum	Class	Subclass	Order	Suborder	Family	Taxon	Authority
Annelida	Clitellata	Oligochaeta	Haplotaxida	Tubificina	Enchytraeidae	Unid. Enchytraeidae	
	Polychaeta	Aciculata	Eunicida		Lumbrineridae	Scoletoma sp.	
			Phyllodocida	Nereidiformia	Nereididae	Laeonereis culveri	(Webster, 1880)
						Neanthes succinea	(Frey & Leukart, 1847)
						Unid. Nereididae	
				Phyllodociformia	Phyllodocidae	Eteone heteropoda	Hartman, 1951
						Unid. Phyllodocidae	
		Canalipalpata	Sabellida		Serpulidae	Unid. Serpulidae	
			Spionida	Spioniformia	Spionidae	Polydora cornuta	Bosc, 1802
						Polydora sp.	
						Scolelepis squamata	(Muller, 1806)
						Unid. Spionidae	
		Scolecida			Capitellidae	Capitella capitata complex	(Fabricius, 1780)
						Heteromastus filiformis	(Claparede, 1864)
						Mediomastus sp.	
						Unid. Polychaeta	
Arthropoda	Arachnida		Araneae			Unid. Araneae	
	Chelicerata	Acari	Trombidiformes			Unid. Hydrachnidia	
	Insecta	Pterygota	Coleoptera	Polyphaga	Chrysomelidae	Unid. Chrysomelidae	
					Staphylinidae	Unid. Staphylinidae	
						Unid. Coleoptera	
			Diptera		Ceratopogonidae	Unid. Ceratopogonidae	
					Dolichopodidae	Unid. Dolichopodidae	
					Sciaridae	Unid. Sciaridae	
						Unid. Diptera	
			Hymenoptera		Formicidae	Unid. Formicidae	
						Unid. Hymenoptera	
			Collembola			Unid. Collembola	
			Lepidoptera			Unid. Lepidoptera	
						Unid. Insecta	
	Malacostraca	Eumalacostraca	Amphipoda	Caprellidea	Caprellidae	Caprella equilibra	Say, 1818

Phylum	Class	Subclass	Order	Suborder	Family	Taxon	Authority
				Gammaridea	Ampithoidae	Unid. Ampithoidae	
					Aoridae	Grandidierella bonnieroides	Stephensen, 1948
					Corophiidae	Apocorophium lacustre	(Vanhoffen, 1911)
						Monocorophium ascherusicum	(Costa, 1857)
						Unid. Corophiidae	
					Gammaridae	Gammarus mucronatus	Say, 1818
						Unid. Gammaridae	
					Haustoriidae	Lepidactylus triarticulatus	Robertson & Shelton, 1980
					Isaeidae	Microprotopus sp.	
					Ischyroceridae	Erichthonius brasiliensis	(Dana, 1853)
					Liljeborgiidae	Listriella barnardi	Wigley, 1966
					Melitidae	Melita sp.	
					Oedicerotidae	Ameroculodes miltoni	Foster & Heard, 2002
					Podoceridae	Podocerus brasiliensis	(Dana, 1853)
					Stenothoidae	Stenothoe minuta	Holmes, 1905
						Stenothoe sp.	
				Senticaudata	Hyalidae	Unid. Hyalidae	
			Cumacea		Bodotriidae	Cyclaspis varians	Calman, 1912
					Diastylidae	Oxyurostylis lecroyae	Roccatagliata & Heard, 1995
						Oxyurostylis sp.	
			Decapoda	Dendrobranchiata	Penaeidae	Penaeidae post larva	
						Penaeidae zoea	
				Pleocyemata	Hippidae	Emerita talpoida	(Say, 1817)
						Unid. Paguroidea	
			Isopoda	Asellota	Janiridae	Carpias minutus	(Richardson, 1902)
				Flabellifera	Sphaeromatidae	Ancinus depressus	(Say, 1818)
				Valvifera	Idoteidae	Edotea triloba	(Say, 1818)
						Erichsonella sp.	
						Synidotea fosteri	Schotte & Heard, 2004
	Maxillopoda	Thecostraca	Lepadiformes	Lepadomorpha	Lepadidae	Lepas pectinata	Spengler, 1793
			Sessilia	Balanomorpha	Balanidae	Unid. Balanidae	
	Ostracoda	Podocopa	Podocopida			Unid. Podocopida	
	Pycnogonida					Unid. Pycnogonida	
Chordata	Actinopterygii					Demersal fish eggs	

Phylum	Class	Subclass	Order	Suborder	Family	Taxon	Authority
Cnidaria	Anthozoa					Unid. Anthozoa	
Echinodermata	Ophiuroidea		Ophiurida			Unid. Ophiurida	
Mollusca	Bivalvia	Heterodonta	Myoida		Corbulidae	Unid. Corbulidae	
			Veneroida		Donacidae	Donax variabilis	Say, 1822
					Mactridae	Mulinia lateralis	(Say, 1822)
					Mesodesmatidae	Ervilia concentrica	(Holmes, 1860)
					Montacutidae	Mysella planulata	(Stimpson, 1857)
					Tellinidae	Unid. Tellinidae	
					Veneridae	Petricolaria pholadiformis	(Lamarck, 1818)
		Pteriomorphia	Arcoida		Arcidae	Anadara brasiliana	(Lamarck, 1819)
						Unid. Bivalvia	
	Gastropoda	Caenogastropoda	Littorinimorpha		Tornidae	Unid. Tornidae	
					Litiopidae	Litiopa melanostoma	Rang, 1829
		Opisthobranchia	Nudibranchia			Unid. Nudibranchia	
			Neotaenioglossa		Hydrobiidae	Unid. Hydrobiidae	