MACROBENTHIC COMMUNITY STRUCTURE OF SHALLOW WATER HABITATS Of THE FOUR MILE AND BLACK HALL RIVERS (OLD LYME, CT)

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I. Introduction

Benthic infaunal communities are comprised of a wide variety of small invertebrates including worms (polychaetes and oligochaetes); clams and snails (mollusks); and amphipods (crustaceans). Benthos are vital to ecosystem structure and function as a food resource for bottom feeding fish and as intermediate links between higher and lower trophic levels. They provide a significant transfer of carbon in the energy dynamics of estuaries like the Four Mile and Black Hall Rivers and act as agents of bioturbation and nutrient regeneration.

Macroinvertebrates provide environmental managers with the ideal measure of detecting environmental perturbations to coastal habitats. Benthoses are primarily sedentary and thus have limited escape mechanisms to avoid disturbances. Benthic invertebrates are relatively easy to monitor and tend to reflect the cumulative impacts of environmental perturbations. Benthic assemblages are usually comprised of a variety of species that represent a range of biotic responses to potential environmental stress. Increasing levels of environmental disturbances or pollution induced stress results in a decrease in overall benthic diversity; the elimination of pollution sensitive species, and ultimate community domination by pollution tolerant or opportunistic species. As conditions worsen, the affected area may become completely azoic.

II. Objectives

The major objective of this study is to document benthic community structure of shallow water habitats of the Four Mile (Figure1) and Black Hall (Figure 2) Rivers. This information will then be used to evaluate the possible impacts associated with a future potential dredging project.

III. Study Site

The following general description of study area is taken from the Town of Old Lyme Harbor Management Plan (2012). The Town of Old Lyme is situated on the east side of the Connecticut River where it meets Long Island Sound. Old Lyme's most outstanding natural feature is its estuarine environment with both the Four Mile and Black Hall rivers being major components.

Old Lyme is a recreation oriented, rural residential community. The predominant land use is single family residential, both year round and seasonal. Old Lyme's total land area amounts to 15,612 acres of which 40% lie within the coastal boundary.

The depth of water in Old Lyme at the mean low water mark ranges from 15 feet (within the federally maintained navigation channel of the Connecticut River) to exposed intertidal flats at varios locations. The normal tidal range is three feet and the average "spring" tidal range is five feet. The entire shoreline is within the coastal flood hazzard area and is subject to flooding and/or velocity waves during coastal storm events.

Because of its small population and lack of heavy industry, Old Lyme has not been faced with major sewage related pollution problems. Under the state's Clean Water Program, river basins are classified according to Water Quality standards. At the present time, Old Lyme river basins meet these standards. The Black Hall River is currently rated as Class A (Class SA) and the Four Mile River Basin as Class B (Class SB).

Old Lyme's location at the confluence of the Connecticut River and Long Island Sound has shaped its natural environment. The Old Lyme portion of the Connecticut River estuarine system include the Back and Black Hall estuaries. Within these embayments are large areas of tidal marsh and intertidal flats. The Four Mile River forms part of the boundary with the town of East Lyme. Hard and soft clams and the eastern oyster are found in the intertidal flats of both the Black Hall and Four Mile Rivers. The largest concentrations of breeding oysters are believed to be within the Back River and Black Hall River Estuary.

Coastline Consulting & Development, LLC conducted extensive hydrographic and topographic surveys of both the Four Mile asnd Black Hall Rivers (2013). They found the study area within the Black Hall River to comprise a section about 6,000 linear feet, beginning near the Route 156 bridge and extending south beyond the confluence with the Back River, into Long Island Sound. Water depths immediately south of the confluence of the Back River and Long Island Sound are as shallow as -2.0 feet MLW at low tide. Depths within the river proper are as shallow as -2.3 MLW at low tide. These shallow areas persist until the river reaches the Route 156 Bridge, where water deepens to -6.0 feet MLW and greater.

The study area in the Four Mile River extends about 4,000 linear feet, beginning near the head of the river and continuing south, under rthe railroad bridge into Long Island Sound. Water depths immediately south of the railroad bridge into Long Island Sound average around -2.5 feet MLW at low tide. These shallow areas persist until the river reaches the northern extent of the study area, where depths immediately adjacent to the Four Mile River Marina and the State of Connecticut Boat Launch are as shallow as -0.5 feet MLW.

In estuarine systems like the Four Mile River and Black Hall River study sites, there is a typical gradient in salinity which usually results in a longitudinal zonation of the biota. Estuaries can be conveniently divided into the following zones based on salinity values (Remane and Schliper, 1971):

Oligohaline	0-5 parts per thousand ("ppt")
Low Mesohaline	5-12 ppt
High Mesohaline	12-18 ppt
Polyhaline	18-25 ppt

Dauer (1993) emphasized the importance of salinity in determining the spatial distribution of estuarine faunas. The classic pattern is one of dominance of marine derived taxa at the seaward end, occurrence of largely freshwater taxa at the landward end and a depauparate group of brackish water adapted taxa in-between (Remane and Schliper, 1971).

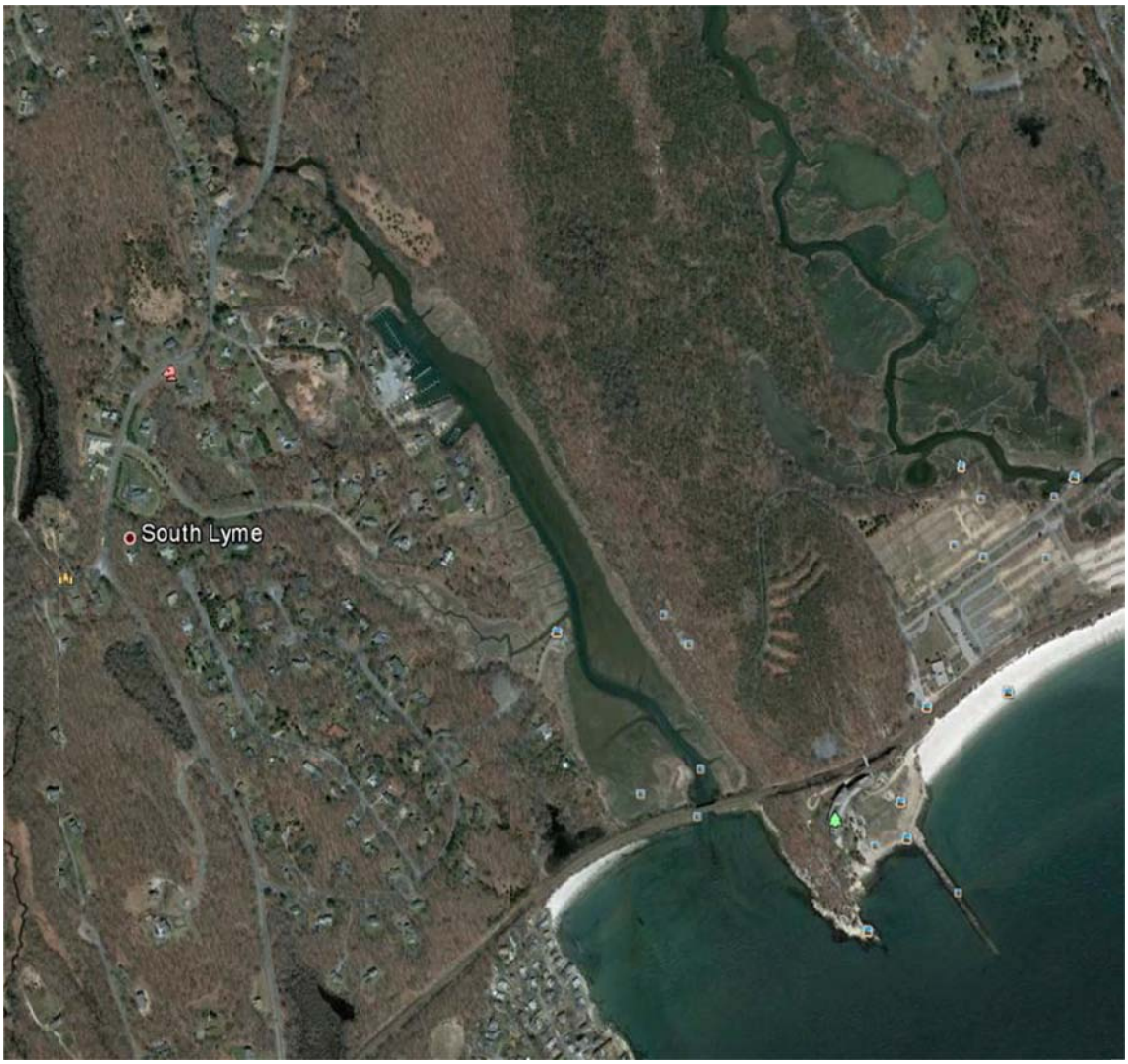

Figure 1. Aerial View of Four Mile River Study Area

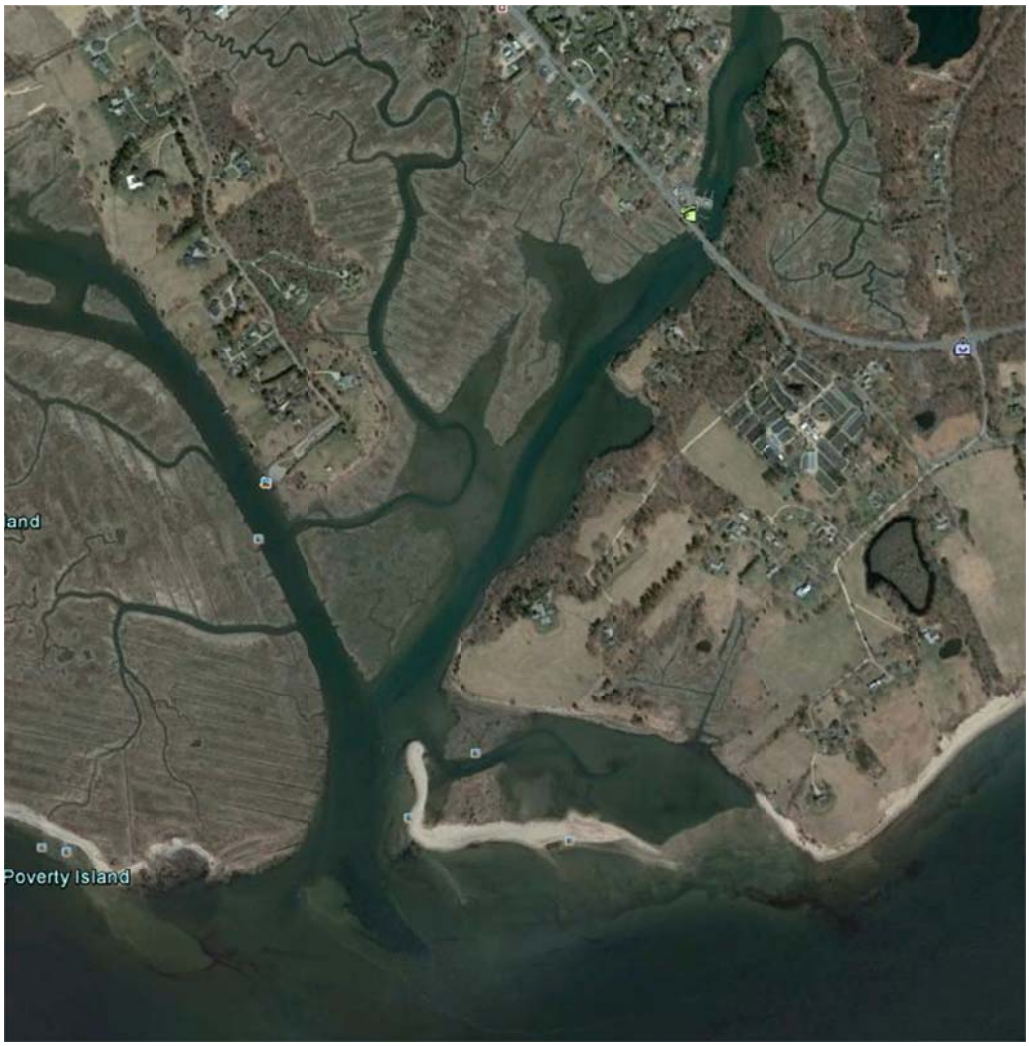

Figure 2. Aerial View of Black Hall River Study Area

IV. Methods

Each study site was divided into three general sampling regions (Figures 3 & 4) with a total of thirty-two sampling stations established in the Four Mile River and thirty in the Black Hall River (Figures 5 & 6). Benthic samples were taken using a standard 0.04m2 Van Veen grab with a single replicate taken at each station.\

Sediment samples were washed through a 0.5mm mesh screen, stained with rose bengal, and fixed in 10% buffered formalin. All organisms were identified to the lowest possible taxonomic category and counted. The following aspects of benthic community structure were examined: species richness, density, species diversity, dominance, biotic index and successional stage.

Station coordinates were determined with a Garmin GPS 76 marine navigator (Tables 12 & 13). The general substrate type was also determined for each station. Four Mile benthic samples were taken on Sepember 4 & 5 and Black Hall samples on Sepember 16 & 25, 2013.

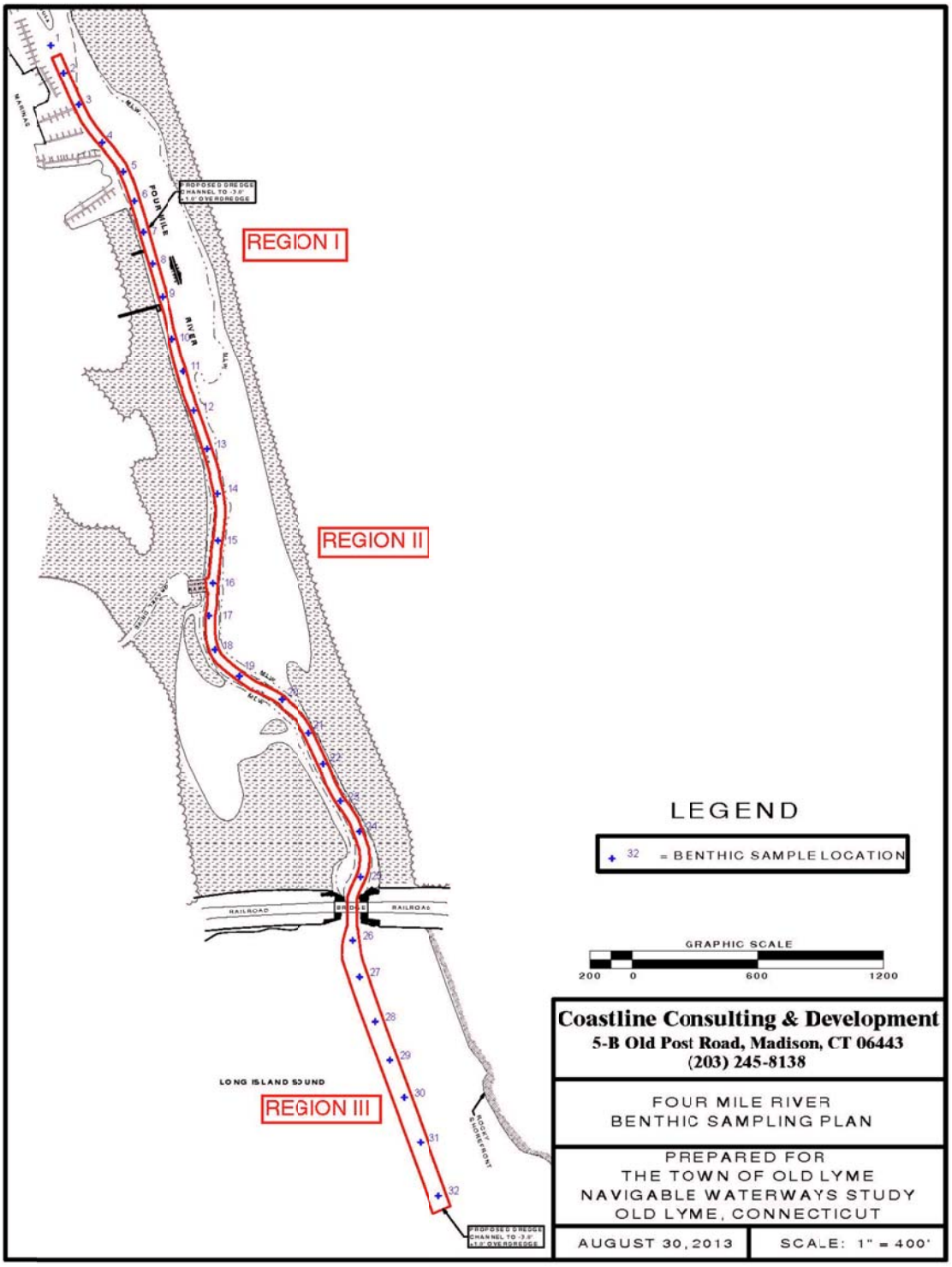

Figure 3. Four Mile River Sampling Regions & Stations

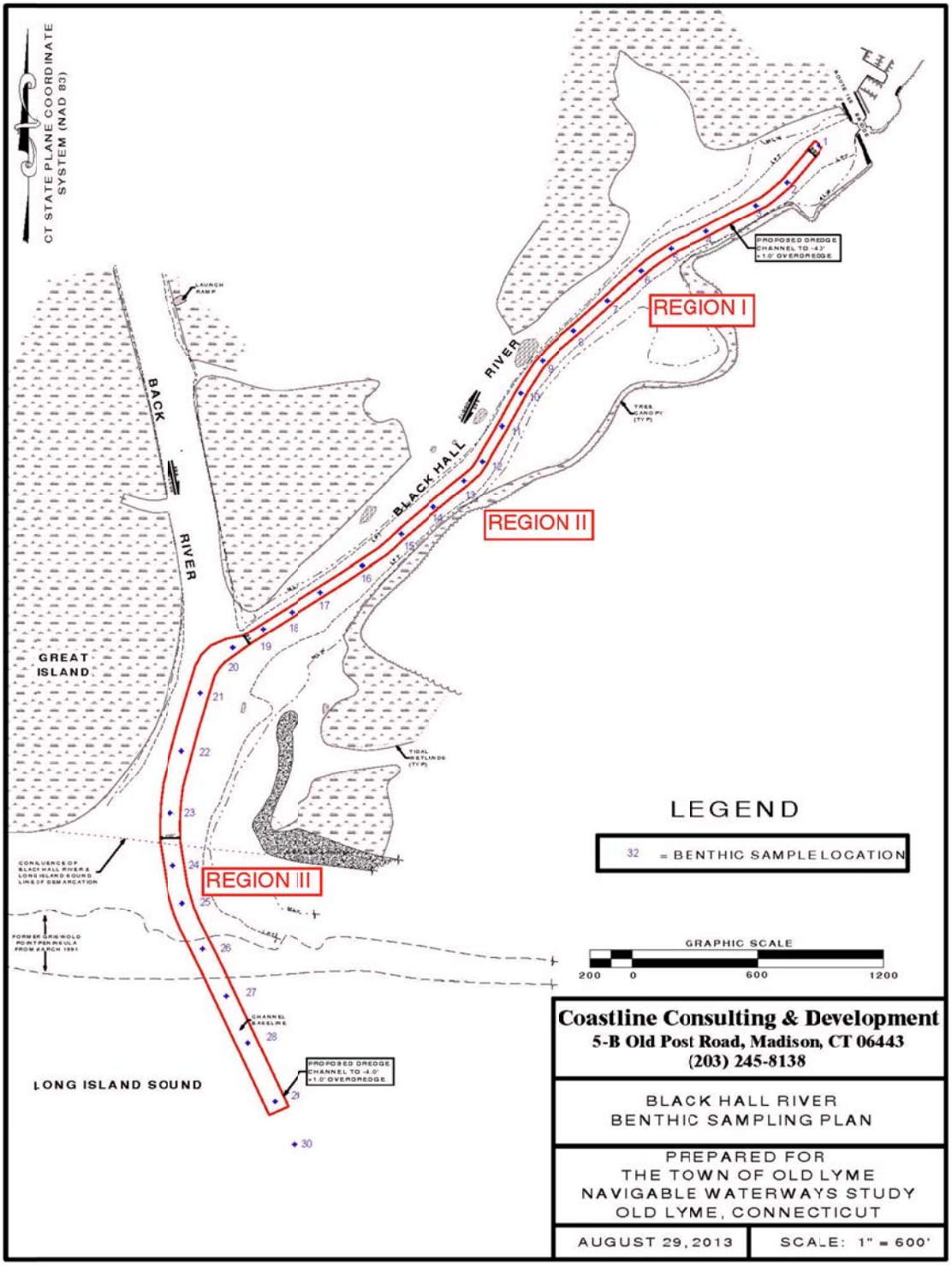

Figure 4. Black Hall River Sampling Regions & Stations

V. Results

FOUR MILE RIVER

A. General Community Composition

The entire study area was characterized by a moderately diverse assemblage of primarily mesohaline species with moderate to low species richness values. A total of 71 invertebrate species (Tables 1– 3) were recovered from the thirty-two sampling stations with varying richness values occurring throughout the study area. The number of species per $0.04m^2$ was highest at station #23 (30) and lowest at stations #2 and #28 (7) with the overall mean for the entire study area being 13.5. Region II reported the highest mean richness values per $0.04m^2$(16.9) and Region III the lowest (10.6). Polychaetes and amphipods were the dominant taxonomic groups accounting for 63.4% of all species collected.

The numerical abundance of individuals per $0.04m^2$ was highest at Station #15 (956) and lowest at Station #2 (56) with the overall mean for the study area being 224.1. Region II reported the highest mean density values (328.0) and Region III the lowest (67.0).

The numerical dominants of the entire study area were: the oligochaete, *Paraonais sp*; the polychaetes, *Leitoscoloplos robustus*, *Streblospio benedicti* and *Capitella capitata*; and the bivalve, *Gemma gemma*. Collectively these five species accounted for 77.3% of all individuals collected.

Region I (Inner Four Mile River Study Area)

A total of 36 invertebrate species were recovered from the twelve sampling stations: #1-12 (Figure 3) in Region I. Species richness values per $0.04m^2$ ranged from a high of 14 at stations #6 and 10 to a low of 7 at station #2 with the overall mean for the region being 11.4. The mean density value for Region I was 203.2 individuals per $0.04m^2$ with Station #4 reporting the highest (351) and Station #2 the lowest (56).

Region I was characterized by a mix of predominately mesohaline invertebrate species with polychaetes and amphipods accounting for 69.4% of all species collected. The numerical dominants of Region I were the oligochaete, *Paranais* and the polychaetes, *Leitoscoloplos* and *Streblospio.* Collectively these three species accounted for 71.5% of all individuals collected.

Paranais, *Leitoscoloplos* and *Streblospio* were found at all twelve Region I sampling stations and achieved mean densities per $0.04m^2$ of 50.7, 48.6 and 46.2 respectively. Other species of importance in Region I were the polychaete, *Scoletoma tenuis* and the amphipod, *Ampelisca abdita*. These two species were reported from 83.3% of sampling stations and achieved mean densities per $0.04m^2$ of 11.8 and 12.3 respectively.

The substrate type in Region I was soft bottom characterized by silt to silty sand with abundant amounts of detritus. No live shellfish species were reported.

Station #1

A total of 9 species was reported from Station #1 with a density of 111 individuals per $0.04m^2$. The assemblage was dominated by two polychaetes *Mediomastus* and *Leitoscoloplos.* Collectively these two species accounted for 64.9% of all individuals collected. The substrate type was silt with abundant plant detritus. The depth at Station #1 was 4.0 feet.

Station #2

A total of 7 species was reported from Station #2 with a density of 56 individuals per $0.04m^2$. The assemblage was dominated by the polychaete *Leitoscoloplos* and the oligochaete *Paranais.* Collectively these two species accounted for 78.8% of all individuals collected. The substrate type was silt with detritus and the depth 6.5 feet.

Station #3

A total of 8 species was reported from Station #3 with a density of 138 individuals per $0.04m^2$. The assemblage was again dominated by the polychaete *Leitoscoloplos* and the oligochaete *Paranais.* Collectively these two species accounted for 80.4% of all individuals colleced. The substrate type was sandy-silty with plant detritus and the depth 5.0 feet.

Station #4

A total of 19 species was reported from station #4 with a density of 351 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Leitoscoloplos, Scoletoma* and *Streblospio* and the oligochaete, *Paranais*. Collectively these four species accounted for 76.1% of all individuals collected. Other species of importance were the polychaetes *Capitell*a and *Eteone* and the amphipods *Ampelisca* and *Listriella*. The substrate type was sand and the depth 5.0 feet.

Station #5

A total of 9 species was reported from station #5 with a density of 134 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Leitoscoloplos* and *Streblospio* and the oligochaete, *Paranais*. Collectively these three species accounted for 89.6% of all individuals collected. The substrate type was sandy-silt with detritus and the depth 5.0 feet.

Station #6

A total of 14 species was reported from station #6 with a density of 228 individuals per $0.04m^2$. The assemblage was again dominated by the polychaetes *Leitoscoloplos* and *Streblospio* and the oligochaete, *Paranais*. Collectively these three species accounted for 78.1% of all individuals collected. Other species of importance were the amphipods *Ampelisca* and *Microdeutopus* and the polychaete *Scoletoma*. The substrate type was sandy-silt with detritus and the depth 5.0 feet.

Station #7

A total of 10 species was reported from station #7 with a density of 194 individuals per $0.04m^2$. The assemblage was overwhelmingly dominated by the polychaete *Leitoscoloplos robustus* which by itself accounted for 66.0% of all individuals collected. Other species of

importance were the polychaetes *Streblospio* and *Tharyx* and the oligochaete *Paranais*. The substrate type was silt with detritus and the depth 5.0 feet.

Station #8

A total of 12 species was reported from station #8 with a density of 264 individuals per $0.04m^2$. The assemblage was again dominated by the polychaetes *Leitoscoloplos* and *Streblospio* and the oligochaete, *Paranais*. Collectively these three species accounted for 81.8% of all individuals collected. Other species of importance were the amphipod *Ampelisca* and the polychaetes *Eteone* and *Tharyx*. The substrate type was silt with detritus and the depth 5.0 feet.

Station #9

A total of 11 species was reported from station #9 with a density of 115 individuals per $0.04m^2$. The assemblage was again dominated by the polychaetes *Leitoscoloplos* and *Streblospio* and the oligochaete, *Paranais*. Collectively these three species accounted for 77.6% of all individuals collected. Other species of importance were the amphipod *Ampelisca* and the polychaetes *Scoletoma* and *Tharyx*. The substrate type was silt with detritus and the depth 5.0 feet.

Station #10

A total of 14 species was reported from station #10 with a density of 275 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Streblospio* and *Leitoscloplos;* the oligochaete, *Paranais* and the amphipod *Ampelisca*. Collectively these four species accounted for 86.2% of all individuals collected. Other species of importance were the amphipod *Microdeutopus;* the polychaete *Mediomastus* and the bivalve *Gemma*. The substrate type was sandy-silt with detritus and *Ampelisca* tubes. The depth was 5.0 feet.

Station #11

A total of 11 species was reported from station #11 with a density of 249 individuals per $0.04m^2$. The assemblage, like station #10, was dominated by the polychaetes *Streblospio* and *Leitoscloplos;* the oligochaete, *Paranais* and the amphipod *Ampelisca*. Collectively these four species accounted for 87.1% of all individuals collected. Other species of importance were the polychaete *Scoletoma* and the bivalve *Gemma*. The substrate type was sand with detritus and the depth 5.0 feet.

Station #12

A total of 13 species was reported from station #12 with a density of 323 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Streblospio* and *Mediomastus;* the oligochaete, *Paranais* and the bivalve *Gemma*. Collectively these four species accounted for 86.1% of all individuals collected. Other species of importance were the polychaete *Leitoscoloplos* and the amphipod *Ampelisca*. The substrate type was silt with detritus and the depth 5.0 feet.

REGION II (Middle Four Mile River Study Area)

A total of 57 invertebrate species were recovered from the thirteen sampling stations (#13-25) (Figure 3) in Region II. Species richness values per 0.04m2 ranged from a high of 30 at station #23 to a low of 11 at stations #13 and #21 with the overall mean for the region being 16.9. This is markedly higher than the 11.4 mean value reported from Region I. The mean density value for Region II was 328.0 individuals per $0.04m^2$ with Station #14 reporting the highest (956) and Station #25 the lowest (89).

Region II, like Region I, was characterized by a similar mix of predominately mesohaline invertebrate species with polychaetes and amphipods accounting for 64.9% of all species collected. The numerical dominants of Region II were the oligochaete, *Paranais* and the polychaetes, *Leitoscoloplos*. *Streblospio* and *Capitella.* Collectively these four species accounted for 75.9% of all individuals collected. *Paranais*, *Leitoscoloplos* and *Streblospio* were found at all thirteen Region I I sampling stations and achieved mean densities per $0.04m^2$ of 113.3, 42.7 and 63.2 respectively.*Capitella* was found at 92.3% of sampling stations and achieved a mean density 29.8 individuals per $0.04m^2$. Other species of importance in Region II were the polychaetes *Scoletoma*, *Mediomastus*, *Hediste* and *Tharyx;* the amphipod, *Ampelisca* and the bivalve *Gemma*.

The substrate type in Region II was of a soft bottom nature characterized mainly by sandy-silt to silty-sand with abundant amounts of plant detritus. No live shellfish species were reported.

Station #13

A total of 11 species was reported from Station #13 with a density of 90 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes, *Leitoscoloplos* and *Streblospio* and the oligochaete *Paranais*. Collectively these three species accounted for 71.1% of all individuals collected. The substrate type was silt with abundant plant detritus and the depth 5.0 feet.

Station #14

A total of 15 species was reported from Station #14 with a density of 956 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Mediomastus* and *Streblospio* and the oligochaete *Paranais*. Collectively these three species accounted for 86.4% of all individuals collected. Other species of importance were the polychaetes *Leitoscoloplos* and *Scoletoma* and the bivalve *Gemma*. The substrate type was silt with abundant plant detritus and the depth 5.0 feet.

Station #15

A total of 21 species was reported from Station #15 with a density of 809 individuals per $0.04m^2$. The assemblage was, like station #14, dominated by the polychaetes *Mediomastus* and *Streblospio* and the oligochaete *Paranais*. Collectively these three species accounted for 77.8% of all individuals collected. Other species of importance were the polychaetes *Leitoscoloplos*, *Capitella* and *Scoletoma* and the bivalve *Gemma*. The substrate type was silty-sand with abundant plant detritus and the depth 5.0 feet.

Station #16

A total of 14 species was reported from Station #16 with a density of 140 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Leitoscoloplos* and *Streblospio* and the oligochaete *Paranais.* Collectively these three species accounted for 72.9% of all individuals collected. Other species of importance were the polychaetes *Capitella*, *Scoletoma* and *Capitella.* The substrate type was silty-sand with plant detritus and the depth 5.0 feet.

Station #17

A total of 15 species was reported from Station #17 with a density of 347 individuals per $0.04m^2$. The assemblage was again dominated by the polychaetes *Leitoscoloplos* and *Streblospio* and the oligochaete *Paranais.* Collectively these three species accounted for 73.5% of all individuals collected. Other species of importance were the polychaetes *Mediomastus* and *Scoletoma;* the bivalve *Gemma* and the amphipod, *Ampelisca*. The substrate type was silty-sand with plant detritus and the depth 5.0 feet.

Station #18

A total of 13 species was reported from Station #18 with a density of 254 individuals per $0.04m^2$. The assemblage was dominated by the polychaete *Leitoscoloplos*, the oligochaete *Paranais* and the bivale *Gemma*. Collectively these three species accounted for 84.3% of all individuals collected. Other species of importance were the polychaetes *Mediomastus*, *Streblospio* and *Capitella* The substrate type was sandy-silt with plant detritus and the depth 5.5 feet.

Station #19

A total of 16 species was reported from Station #19 with a density of 195 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Leitoscoloplos*, *Streblospio* and *Capitell*a and the oligochaete *Paranais.* Collectively these four species accounted for 82.6% of all individuals collected. Other species of importance were the polychaetes *Pectinaria* and *Tharyx* and the bivalve *Gemma*. The substrate type was sandy-silt with plant detritus and the depth 5.0 feet.

Station #20

A total of 17 species was reported from Station #20 with a density of 374 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Leitoscoloplos*, *Streblospio* and *Capitell*a; the oligochaete *Paranais* and the amphipod *Ampelisca.* Collectively these five species accounted for 89.1% of all individuals collected. The substrate type was sandy-silt with *Ampelisca* tubes and the depth 5.0 feet.

Station #21

A total of 11 species was reported from Station #21 with a density of 166 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Leitoscoloplos*, *Capitell*a and *Streblospio*; the oligochaete *Paranais.* Collectively these four species accounted for 92.8% of all individuals collected. The substrate type was sandy-silt with plant detritus and the depth 5.5 feet.

Station #22

A total of 21 species was reported from Station #22 with a density of 145 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Leitoscoloplos* and *Streblospio;* the oligochaete *Paranais* and the bivalve *Gemma.* Collectively these four species accounted for 69.7% of all individuals collected. Other species of importance were the polychaetes *Pectinaria, Mediomastus* and *Glycera*. The substrate type was sandy-silt with plant detritus and shell hash. The depth was 5.0 feet.

Station #23

A total of 30 species was reported from Station #23 with a density of 230 individuals per $0.04m^2$. This station exhibited the highest species richness value of any throughout the Four Mile River study area. The assemblage at Station #23 did not exhibit the overwhelming dominance found at the other sampling stations. The dominant species were again the polychaetes *Leitoscoloplos* and *Streblospio;* the oligochaete *Paranais* and the bivalve *Gemma.* Collectively these four species accounted for only 54.3% of all individuals collected. Other species of importance were the polychaetes *Tharyx, Hediste, Scoletoma* and *Capitella* and the amphipods *Ampelisca* and *Microdeutopus*. The substrate type was sandy-silt with plant detritus and shell hash. The depth was 5.0 feet.

Station #24

A total of 18 species was reported from Station #24 with a density of 470 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Leitoscoloplos* and *Capitella;* the oligochaete *Paranais* and the bivalve *Gemma.* Collectively these four species accounted for 74.7% of all individuals collected. Other species of importance were the polychaetes *Pectinaria, Hediste* and *Streblospio* and the amphipods *Ampelisca* and *Microdeutopus.* The substrate type was silty-sand with plant detritus and the depth 5.0 feet.

Station #25

A total of 18 species was reported from Station #25 with a density of 248 individuals per $0.04\ m^2$. The assemblage was dominated by the polychaetes *Leitoscoloplos* and *Capitella* and the oligochaete *Paranais.* Collectively these three species accounted for 75.4% of all individuals collected. Other species of importance were the amphipod *Ampelisca* and the bivalve *Gemma.* The substrate type was silt with plant detritus and the depth 5.0 feet.

REGION III (Outer Four Mile River Study Area)

A total of 31 invertebrate species were recovered from the seven sampling stations: #26-#32 (Figure 3) in Region III. Species richness values per 0.04 m^2 ranged from a high of 18 (station #26) to a low of 7 (station #28) with the overall mean for the region being 10.6. Mean density was 67.0 individuals per 0.04 m^2 with Station #29 reporting the highest (141) and Station #31 the lowest (34). Polychaetes and amphipods were again the dominant taxonomic groups accounting for 64.5% of all species collected.

Region III was characterized by a similar mix of mainly mesohaline species with the numerical dominants being the polychaetes, *Leitoscoloplos, Magelona* and *Streblospio* and the oligochaete, *Paranais.* Collectively these four species accounted for 71.6% of all individuals collected. The substrate type was predominately sand to silty-sand with gravel at some stations. Region III was definitely a higher energy environment when compared to Regions I and II. Sampling was difficult because of both the bottom currents and the relatively hard bottom.

Station #26

A total of 18 species was reported from Station #26 with a density of 89 individuals per 0.04 m^2. There was no overwhelming dominant species at Station #26 with the polychaetes *Leitoscoloplos, Streblospio* and *Attlia* accounting for only 40.4% of all individuals collected. The substrate type was sand to silty-sand with some gravel and shell. The depth was 6.0 feet.

Station #27

A total of 10 species was reported from Station #27 with a density of 58 individuals per 0.04 m^2. Like Station #26, there was no overwhelming dominant species at Station #2 with the polychaete *Leitoscoloplos;* the oligochaete *Paranais* and the bivalve *Gemma* accounting for 58.6% of all individuals collected. The substrate type was gravelly sand and the depth was 5.5 feet.

Station #28

A total of only 7 species was reported from Station #28 with a density of 36 individuals per 0.04 m^2. The assemblage was dominated by the polychaete *Leitoscoloplos* which accounted for 50.0% of all individuals collected. The substrate type was sand and the depth 6.0 feet.

Station #29

A total of 13 species was reported from Station #29 with a density of 141 individuals per 0.04$m^{2.}$. The assemblage was dominated by the oligochaete, *Paraonis* and the polychaetes *Leitoscoloplos* and *Streblospio.* Collectively these three species accounted for 79.4% of all individuals collected. The substrate type was fine sand and the depth 4.5 feet.

Station #30

A total of 8 species was reported from station #30 with a density of 64 individuals per 0.04 m^2. The assemblage was dominated by a single species, the polychaete *Leitoscoloplos,* which accounted for 75.0% of all individuals collected. The substrate type was sand and the depth 5.0 feet.

Station #31

A total of 8 species was reported from station #31 with a density of 34 individuals per 0.04 m^2. The assemblage was again dominated by a single species, the polychaete *Leitoscoloplos*, which accounted for 50.0% of all individuals collected. The substrate type was sand and the depth 5.5 feet.

Station #32

A total of 9 species was reported from station #30 with a density of 47 individuals per 0.04 m^2. The assemblage was dominated by the polychaetes *Leitoscoloplos* and *Magelona* which collectively accounted for 59.6% of all individuals collected. The substrate type was silty-sand and the depth 7.0 feet.

B. SPECIES DIVERSITY

SHANNON-WIENER INDEX ("SHANNON INDEX") ANALYSIS

The Shannon Index (H') is the most widely used of all diversity indices and is relatively independent of sample size. This index incorporates both species richness (number of species present) and evenness (distribution of individuals among the species) into its equation:

$$H' = \frac{n \log n - \sum_{i=1}^{k} fi \log fi}{N}$$

High diversity values are usually indicative of low stressed environments while low diversity values indicate highly stressed conditions. H' values below 1.500 are generally considered to be indicative of stressed environments (Zettler, et al., 2007). H' values for the sampling stations can be found in Table 6.

Table 6 - Species Diversity (H') Values for Four Mile River Sampling Stations (September, 2013)

Station Number	Diversity (H') Value
1	1.599
2	1.356
3	1.293
4	2.083
5	1.422
6	1.784
7	1.194
8	1.642
9	1.831
10	1.742
11	1.736
12	1.769
13	1.836
14	1.516
15	1.750
16	1.969
17	1.926
18	1.463
19	1.781
20	1.930
21	1.615
22	2.298
23	2.724
24	2.042
25	1.782
26	2.524
27	1.967
28	1.414
29	1.794
30	0.978

Station Number	Diversity (H') Value
31	1.572
32	1.794
Mean Region I	1.621
Mean Region II	1.894
Mean Region III	1.720

Diversity values for the entire study area (Table 6) ranged from a high of 2.724 (Station #23) to a low of 0.978 (Station #30) with the overall mean being 1.979. The mean H' value for Region I was 1.621; Region II 1.894 and Region III 1.720. The lower reaches of Region II (Stations #20-#25) exhibited the highest H' values with the mean for those six stations being 2.065. Overall Diversity Values indicate the entire study area to be in a moderately stressed condition.

Zettler, et al. (2007) established the five following Ecological Quality ("EcoQ") classes based on the Shannon Index:

EcoQ Class	**H' Value**
High	> 4.0
Good	3.0 – 4.0
Moderate	2.0 – 3.0
Poor	1.0 – 2.0
Bad	< 1.0

Based on these criteria Region I fell into the Poor to moderate Ecological Quality Class. The upper portions of Region II (Stations #13-#19) fell into the poor to moderate class with the lower reaches (Stations #20-#25) falling into the moderate class. Region III was placed into the poor to moderate Ecological Quality Class.

C. BERGER-PARKER INDEX (d)

The Berger-Parker Index is a simple mathematical expression relating both species richness and abundance. It takes into account only the commonest species in the sample and is calculated as: **d= Nmax/N** where Nmax= the number of individuals in the most abundant species in the sample and N is the total number of individuals.

The index expresses the proportional importance of the most abundant species. Often in ecological studies the reciprocal **1/d** is used in data analysis. Increasing 1/d values indicates increasing diversity and reduction in the dominance of a single species. The Berger-Parker Index Values(1/d) for the Four Mile River Study area can be found in Table 7.

Berger-Parker values for the entire study area (Table 7) ranged from a high of 6.216 (Station #23) to a low of 1.333 (Station #30) with the overall mean being 3.467 Region II had the highest mean 1/d value (4.8160) which means that this area had the lowest dominance of any single species and the greatest diversity of any of the three sampling regions. The lower reaches of Region II (Stations #20-#25) exhibited the highest values with the mean for those six stations being 3.872. Overall the Berger-Parker results reflect the same pattern found with the Shannon Diversity Index.

Table 7 – Berger-Parker Values for Four Mile River Sampling Stations (September, 2013)

Station Number	Berger-Parker Index (1/d)
1	2.846
2	2.154
3	1.890
4	3.619
5	2.627
6	2.780
7	1.516
8	2.467
9	3.485
10	2.644
11	3.000
12	2.991
13	3.461
14	2.563
15	2.560
16	3.415
17	3.337
18	1.814
19	2.216
20	3.016
21	2.862
22	3.919
23	6.216
24	4.434
25	2.787
26	5.562
27	3.625
28	2.000
29	2.169

Station Number	Berger-Parker Index (1/d)
30	1.333
31	2.000
32	2.611
Mean Region I	2.669
Mean Region II	3.277
Mean Region III	2.329

D. SUCCESSIONAL STAGE ANALYSIS

Succession can be defined as the predictable appearance of macrobenthic invertebrate species belonging to specific functional types following disturbance. Three patterns of invertebrate colonization (successional stages) of shallow-water sediments can usually be recognized: Stage I, Stage II, and Stage III (Rhoads and Germano, 1986). Stage I species are early colonizers (pioneers) which arrive within days of a major bottom disturbance. These Stage I species, also called opportunists, experience high mortality and usually disappear as a result of competition and/or predation. Stage I species are considered to be r-strategists with short life cycles (<1 Year), small size, fast growth, and early sexual maturity. They are usually surface deposit feeders and are typified by Spionid (Streblospio benedicti) and Capetellid (Mediomastus ambiseta) polychaetes (Rhoads and Germano, 1986).

Stage I species are eventually replaced by a climax or equilibrium assemblage (Stage III) dominated by large, deep burrowing polychaetes and bivalves. These k-strategist species are characterized by long life cycles (>1 year), large body size, slow growth, and late sexual maturity. Typical Stage III species are the polychaetes *Leitoscoloplos robustus* (Orginiidae) and *Scoletoma tenuis* (Lumbrineridae) (Rhoads and Germano, 1986) and *Clymenella torquata* and the bivalve *Ensis directus*.

The successional process often involves a transitional state (Stage II) before the Stage III (equilibrium) community is established. The transitional phase usually involves the appearance of a diverse assemblage of tubiculous amphipods (*Ampelisca abdita*), mollusks, and polychaetes. This stage is also characterized by the presence of the declining remnants of Stage I species and the appearance of new Stage III species.

Mistri (2002) reported that shallow-water estuarine areas like the Four Mile and Black Hall Rivers are dynamic environments, whose main characteristic is the instability of chemical-physical properties with salinity often being highly variable. Disturbances can either be natural (storms, sediment resuspension, floods, etc.) or anthropogenic (dredging, trawling, etc.). Most natural disturbances are usually non-catastrophic in that some residents survive leading to reinvasion and recolonization.

Mistri (2002) also stated that physical disturbances (e.g., salinity changes) are common in estuarine habitats and that unstable communities are most resilient because they contain species adapted (r-selected) to variable environmental conditions. Pickett and White (1985) demonstrated that unstable communities are more likely than stable communities to return to their previous composition following disturbance.

Ritter et al. (2005) reported that in many estuaries the benthos is maintained in a constant state of early and intermediate succession because of frequent natural disturbances. Montagna et al. (1998) also found that benthic estuarine environments often tend to remain in a state of perpetual early succession by being in a state of constant disturbance.

Ysebaert, et al. (2003) reported that oligohaline-mesohaline estuarine zones are highly variable environments causing numerous, perhaps constant disturbances that probably result in communities that seldom progress beyond early benthic-community succession.

The Four Mile benthic assemblage was dominated by seven invertebrate species which collectively accounted for 85.9% of all individuals collected. Four of these were Stage I opportunistc species and included the polychaetes *Streblospio*, *Capitella* and *Mediomastus* and the oligochaete *Paranais*. These four opportunists acconted for 58.0% of all individuals

collected. The other three dominants were the Stage II species *Gemma* (bivalve) and *Ampelisca* (amphipod) and the Stage III species *Leitoscoloplos*.

Nilsson, et al. (2000) found the oligochaete genus *Paranais* to be typical of ephemeral and chronically disturbed habitats. Oligochaetes are generally considered to be one of the most common opportunists in low saline environments and are considered to be Stage I species. The polychaetes *Streblospio, Mediomastus, Capitella* and *Marenzelleria* have been documented by many authors to be typical Stage I species characteristic of chronically disturbed habitats

The results of this study indicate that the Four Mile River study site to be in a late Stage I to early Stage II successional state. Although Stage I opportunists are the numerical dominants there is also a mix of some Stage II (*Gemma, Ampelisca, Phyllodoce and Eteone)* and Stage III (*Leitoscoloplos Pectinaria* and *Scoletoma)* species. This is the general condition found throughout the study area..

E. K- Dominance Curve

The K-dominance curve first described by Lambshead et al. (1983) has been shown to be a useful tool in environmental impact studies in recent years (Newell et al. 1998). This statistic is a plot of the proportional contibution of each species in a community compared to the overall population density as a whole. Stage III communities characteristic of undisturbed environments have a high species diversity where each individual species makes a relatively small contibution to the overall population density. The K-dominance curve for these communities is typically Sigma-shaped and is depicted in Figure 5 .

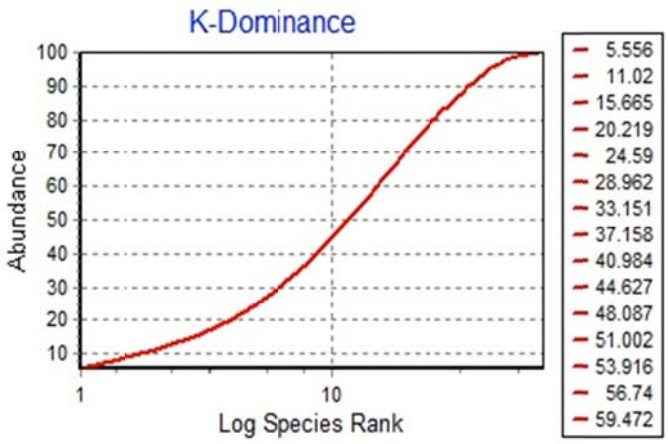

Figure 5 . Hypothetical K-Dominance Curve for Stage III Community

Early Stage I communities, however, have low species diversity which leads to as much as 80-90% of the population being dominated by only one or two r-selected opportunistic species. The K-dominance curve for these assemblages will have a steep slope and be highly elevated. This condition is depicted in Figure 6.

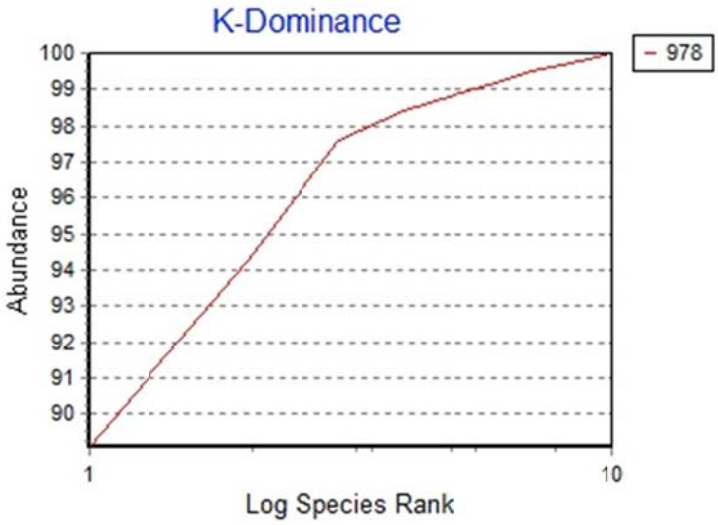

Figure 6. Hypothetical K-Dominance Curve for Early Stage I Community

The K-dominance curve for the Four Mile River study area is found in Figure 7. It clearly shows an intermediate condition between the two extremes previously described with the numerically dominant species accounting for 35% of the total community. This confirms the placement of the Four Mile River into the Late Stage I to Early Stage II successional state.

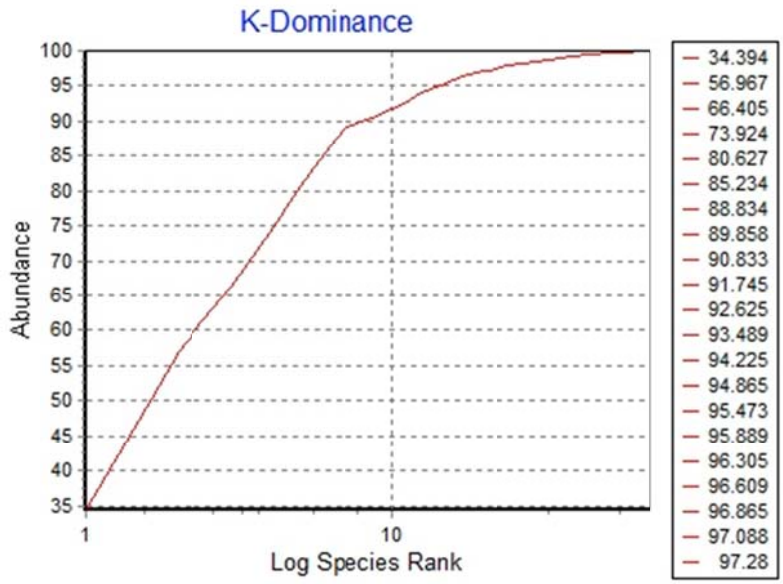

Figure 7. K-Dominance Curve for Four Mile River Study Area

F. AZTI MARINE BIOTIC INDEX (AMBI)

Recent interest on benthic indicators has increased dramatically, with a lot of new indicators proposed. One such indicator, the AMBI, was designed to establish the ecological quality of European coastal waters. The AMBI analyses the response of soft-bottom communities to natural and man-induced changes in water and sediment quality (Borja et al. 2000). The AZTI Biotic Index has been used in numerous studies to define the disturbance status of estuarine systems. Ramey et al. (2011) studied the use of AMBI in New Jersey coastal waters.

The AMBI offers a "pollution or disturbance classification" representing the benthic community "health". The AMBI has been verified successfully in relation to large set of environmental impact sources. The AMBI obtains a continuous value of an index representing the quality of the bottom conditions in a discreet range from 0 (Unpolluted) to 7 (Extremely Polluted). Benthic species are classified into five ecological groups according to their sensitivity/tolerance to increasing levels of environmental stress and five categories that define benthic community health: "UNDISTURBED" (<1.2), "SLIGHTLY DISTURBED" (1.2-3.3), "MODERATELY DISTURBED" (3.3-5.0), "HEAVILY DISTURBED" (5.0-6.0) and "EXTREMELY DISTURBED" (>6.0).

Table 8 - AMBI Biotic Index Values (BI) for Four Mile River Stations

Station Number	AMBI Value	Biotic Index Value	Disturnance Category
1	3.661	3	Moderately Disturbed
2	4.661	4	Moderately Disturbed
3	4.861	4	Moderately Disturbed
4	3.438	3	Moderately Disturbed
5	4.254	3	Moderately Disturbed
6	4.217	3	Moderately Disturbed
7	4.352	4	Moderately Disturbed
8	3.924	3	Moderately Disturbed
9	3.679	3	Moderately Disturbed
10	3.813	3	Moderately Disturbed
11	3.012	2	Slightly Disturbed
12	3.620	3	Moderately Disturbed
13	3.550	3	Moderately Disturbed
14	4.153	3	Moderately Disturbed
15	4.418	4	Moderately Disturbed
16	4.125	3	Moderately Disturbed
17	3.865	3	Moderately Disturbed
18	4.536	4	Moderately Disturbed
19	4.785	4	Moderatelyto Disturbed
20	4.031	3	Moderately Disturbed
21	5.051	5	Heavily Disturbed
22	3.370	3	Moderately Disturbed
23	3.237	2	Slightly Disturbed
24	3.819	3	Moderately Disturbed
25	4.567	4	Moderately Disturbed
26	3.222	2	Slightly Disturbed
27	3.080	2	Slightly Disturbed
28	3.250	2	Slightly Disturbed
29	3.993	3	Moderately Disturbed
30	3.738	3	Moderately Disturbed
31	3.485	3	Moderately Disturbed
32	2.426	2	Slightly Disturbed

Mean Study Area	3.881	3	Moderately Disturbed
Mean Region I	3.958	3	Moderately Disturbed
Mean Region II	4.116	3	Moderately Disturbed
Mean Region III	3.313	2-3	Slightly-Moderately Disturbed

The AMBI Index values (Table 8) revealed that 78.1% of sampling stations fell into the Moderately Disturbed Category with 18.1% being Slightly Disturbed. One sampling station (#21) was found to be in the Heavily Disturbed Category. Mean AMBI Values for the entire Four Mile study site (Table 8) placed the area into the Moderately Disturbed Category. Mean AMBI Values also placed the Regions I & II into the Moderately Disturbed Category and Region III into the Slightly to Moderately Disturbed Category. The distribution of disturbance categories for individual stations can be found in Figure 8.

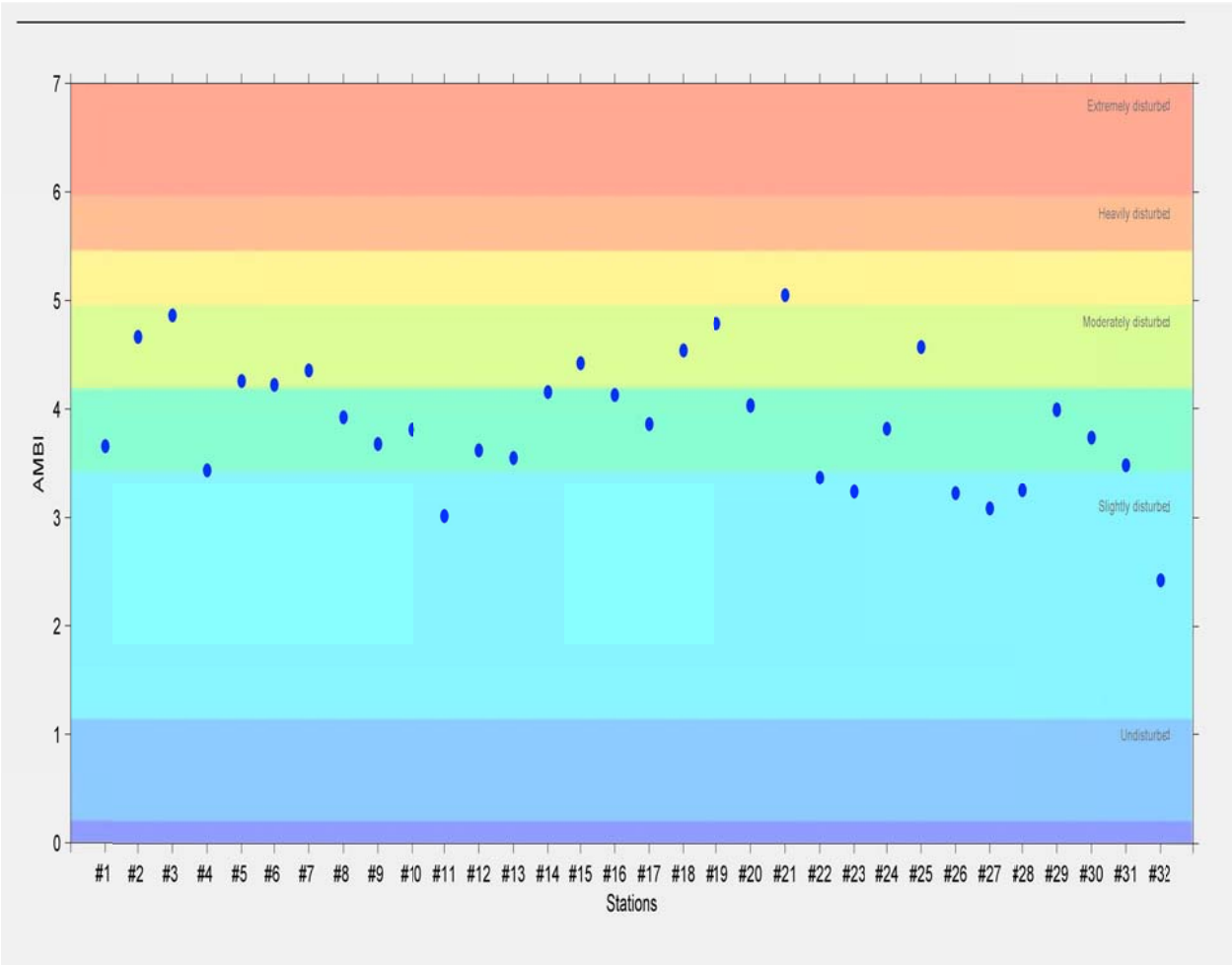

Figure 8. Scatter Diagram Showing Distribution of Disurbance Categories for Four Mile Sampling Stations

G. Cluster Analysis

Cluster analysis includes a broad suite of techniques designed to find groups of similar items within a data set. Hierarchial cluster methods produce a hierarchy of clusters from small clusters of very similar items to large clusters that include more dissimilar items. Hierarchial methods produce a graphical output known as a dendrogram or tree that shows this hierarchial clustering structure. The most commonly used method is agglomerative hierarchial clustering. This method finds clusters of most similar items and then progressively adds less similar items until all items have been included into a single large cluster.

The aim of clustering in benthic studies is to put sites which have similar species compositions into the same groups which are known as clusters. Cluster analysis provides a summary of the similarity in species composition of various sites (Stations). Stations that are grouped into the same cluster are more similar in species composition than stations grouped into different clusters. Hierarchical clustering methods do not only cluster sites, but also cluster the various clusters that were formed earlier in the clustering process.

Multivariate analyses were performed using the PAST Statistical Software Program (Hsmmer et al., 2001). Cluster analysis was performed by calculating the Bray-Curtis similarity coefficient for all pairs of sampling stations, after log (X+1) transformation of all species abundance values. Clusters were formed using the group-average linkage method between similarities. A non-metric multi-dimensional scaling (nMDS) was then performed on the similarity matrix generated by the cluster analysis. nMDS plots stations in a 2-dimensional space such that points close together in the plot represent stations that are very similar in species composition and points that are far apart represent very different assemblages.

The dendrogram created for the Four Mile River Sampling Stations can be found in Figure 9.

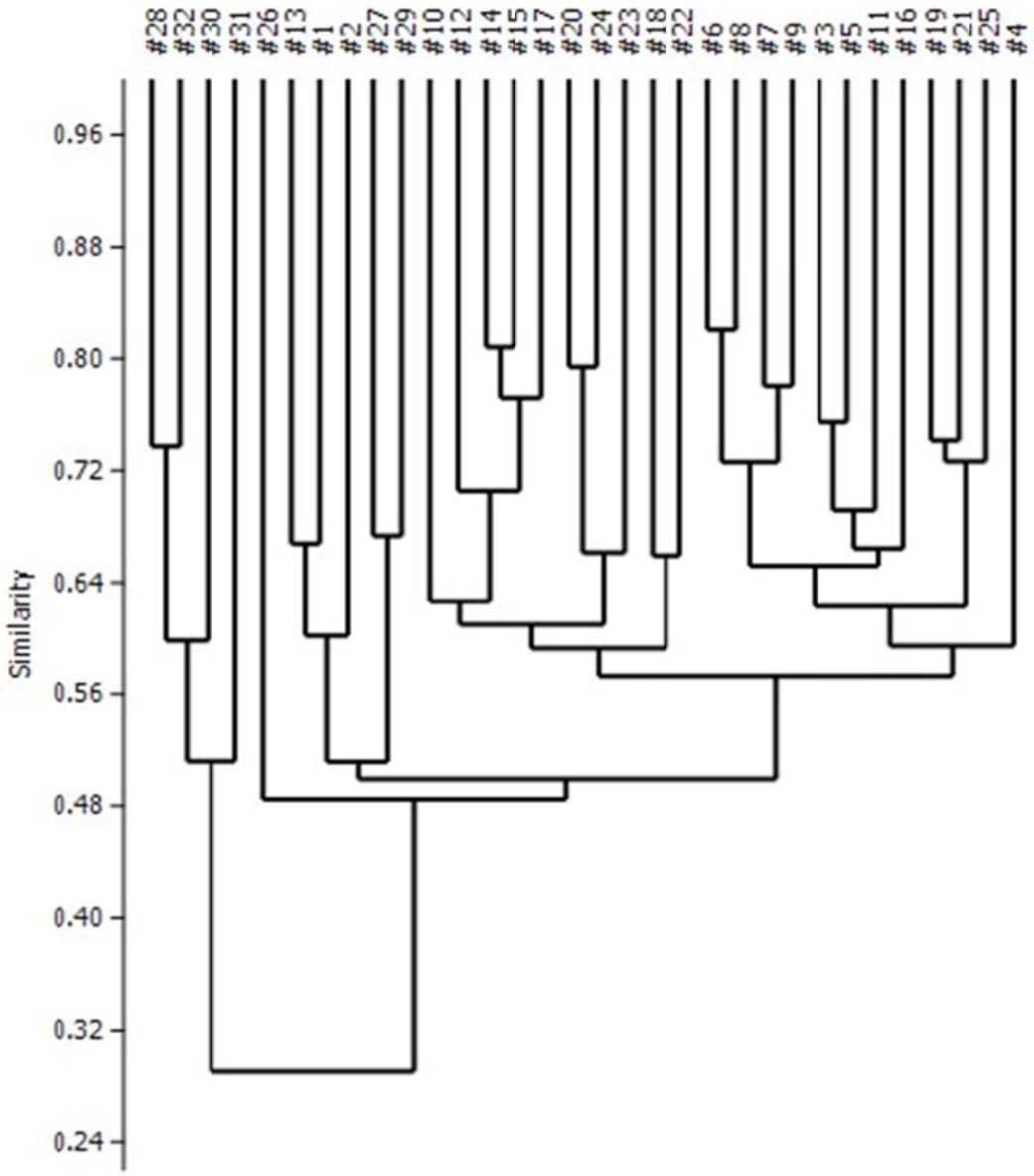

Figure 9. Dendrogram of Four Mile River Sampling Stations

The dendrogram (Figure 9) revealed two large and three small station clusters. Cluster A included the following 11 sampling stations: #3, #5 ,#6, #7, #8, #9, #11, #16, #19, #21 and #25. These 11 stations had very consistent species richness values ranging from 8-18/.04m2 and moderate numbers of *Leitoscoloplos* as well as low numbers of *Paranais* and *Streblospio.* Other species of importance in Cluster A were *Scoletoma, Gemma, Ampelisca* and *Tharyx.* Sixty-three percent of Stations in Cluster A are found in Region I with the remaining three found in Region II.

Cluster B included the following 10 sampling ststions: #10, #12, #14, #15, #17, #18, #20, #22, #23 and #24. This cluster exhibited consistent numbers of *Leitoscoloplos* and high numbers of *Paranais* and *Streblospio.* Other important species were *Mediomastus* and *Gemma*. The majority of stations in cluster B (80%) are found in Region II with the other two (#10 & #12) found in the lower reaches of Region I.

Cluster C included the following four sampling stations: #28, #30, #31 and #32. The stations in Cluster C were characterized by low species richness values and relatively low numbers of *Leitoscoloplos.* Other species of importance in this region were the polychaete, *Magelona* and the amphipods, *Trichophoxus* and *Paraphoxus.* All four statiopns in Cluster C are found in Region III.

Cluster D included the following three sampling stations: #1, #2 and #13. Cluster D was characterized by low species richness values and low numbers of *Paranais* and *Streblospio* and low to moderate numbers of *Leitoscloplos.* Other species of importance were *Mediomastus* and *Scoletoma*. Two of the three stations (#1 & #2) are found in the upper regions of Region I and station #13 in the lower reaches of Region II. Cluster E included only two sampling stations: #27 & #29. This small cluster was characterized by low numbers of *Paranais* and *Streblospio* and increasing importance of the polychaete, *Magelona.* These two stations are found in the lower reaches of Region III.

A non-metric multi-dimensional scaling (nMDS) was then performed on the similarity matrix generated by the cluster analysis (Figures 10 & 11). nMDS plots the Four Mile River stations in a 2-dimensional space such that points close together in the plot represent stations that are very similar in species composition and points that are far apart represent very different assemblages. Figure 10 shows Clusters B and C and Figure 11 Cluster A.

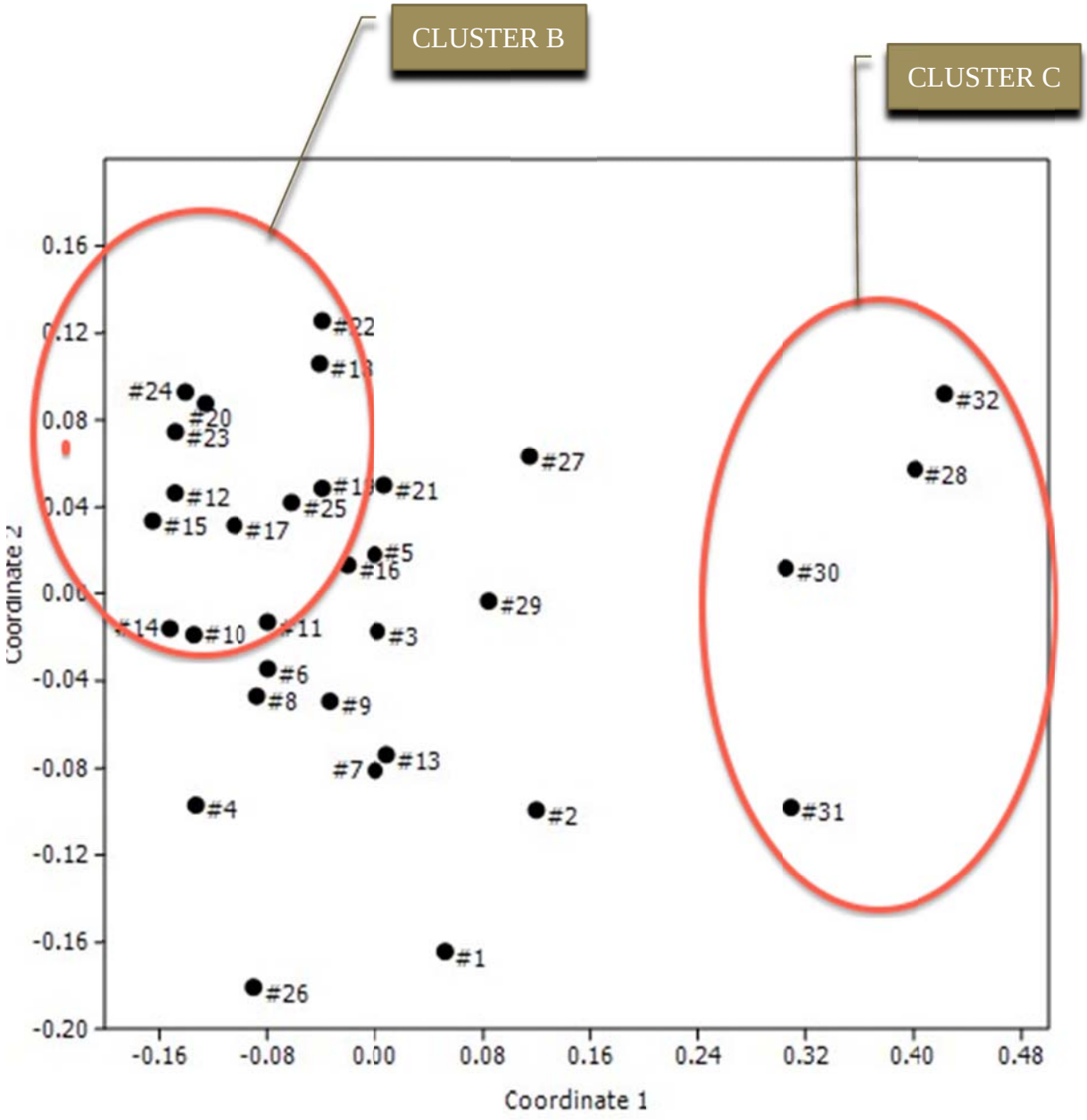

Figure 10. nMDS Plot Showing Cluster B & C

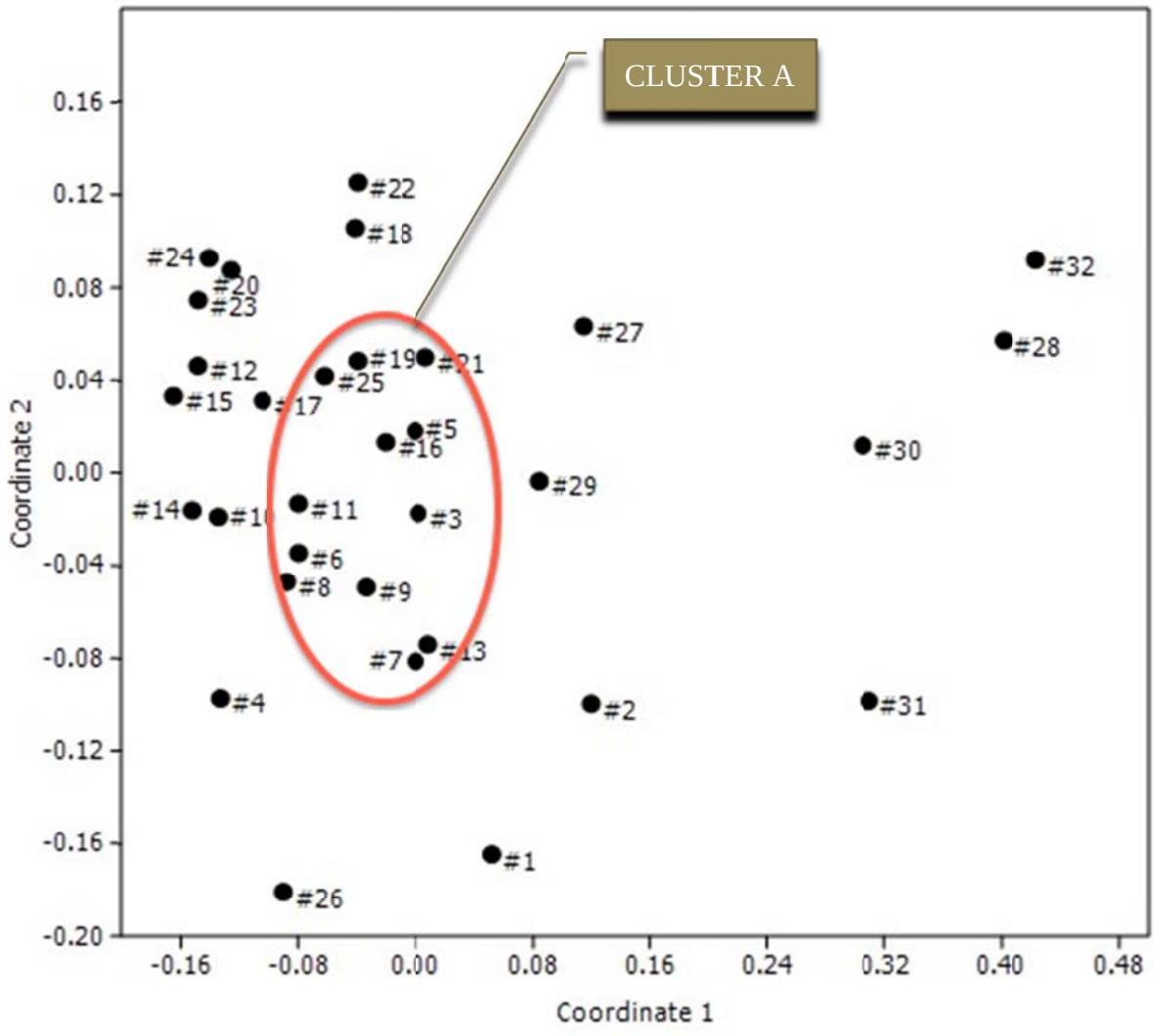

Figure 11. nMDS Plot Showing Cluster A

Black Hall River

A. General Community Composition

The entire study area, like that of the Four Mile River, was characterized by a moderately diverse assemblage of primarily mesohaline species with moderate to low species richness values. A total of 75 invertebrate species (Tables 4 & 5) were recovered from the thirty sampling stations with varying richness values occurring throughout the study area. The number of species per 0.04 m^2 was highest at station #23 (28) and lowest at station #29 (7) with the overall mean for the entire study area being 16.7. Regions I (18.1) and II (17.1) reported the highest mean richness values per 0.04m^2 and Region III the lowest (14.1). Polychaetes and amphipods were the dominant taxonomic groups accounting for 57.4% of all species collected.

The numerical abundance of individuals per 0.04 m^2 was highest at Station #3 (932) and lowest at Station #29 (31) with the overall mean for the study area being 357.3. Region I reported the highest mean density value (536.9) and Region III the lowest (163.2).

The numerical dominants of the entire study area were: the oligochaete, *Paraonais sp*; the polychaetes, *Leitoscoloplos robustus*, *Streblospio benedicti* and *Marenzelleria viridis* and the bivalve, *Gemma gemma*. Collectively these five species accounted for 74.7% of all individuals collected.

Region I (Inner Black Hall River Study Area)

A total of 39 invertebrate species were recovered from the ten sampling stations: #1-10 (Figure 4) in Region I. Species richness values per 0.04 m^2 ranged from a high of 24 at station #9 to a low of 13 at station #1 with the overall mean for the region being 18.8. The mean density value for Region I was 536.7 individuals per 0.04 m^2 with Station #43 reporting the highest (932) and Station #1 the lowest (587).

Region I was characterized by a mix of predominately mesohaline invertebrate species with polychaetes, amphipods and bivalves accounting for 71.7% of all species collected. The numerical dominants of Region I were the oligochaete, *Paranais* and the polychaetes, *Leitoscoloplos, Streblospio* and *Marenzelleria*. Collectively these four species accounted for 84.1% of all individuals collected. *Paranais, Leitoscoloplos* and *Streblospio* were found at all ten stations and achieved mean densities per 0.04m^2 of 89.6, 48.6 and 251 respectively. Other species of importance in Region I were the polychaetes *Mediomastus* and *Polydora* and the bivale, *Gemma.*

The substrate type in Region I was soft bottom characterized by silt to silty sand with abundant amounts of detritus .

Station #1

A total of 13 species was reported from Station #1 with a density of 87 individuals per 0.04 m^2. The assemblage was dominated by two polychaetes *Polydora* and *Streblospio.* Collectively these two species accounted for 70.1% of all individuals collected. The substrate type was silt with plant detritus and some gravel.

Station #2

A total of 20 species was reported from Station #2 with a density of 501 individuals per 0.04 m^2. The assemblage was dominated by a single polychaete, *Streblospio* which accounted for 56.1% of all individuals collected. Other species of importance were the polychaetes *Polydora,,Marenzelleria* and *Leitoscoloplos;* the bivalve, *Gemma* and the oligochaete *Paranais*. The substrate type was sandy-silt with detrius and some gravel.

Station #3

A total of 16 species was reported from Station #3 with a density of 932 individuals per 0.04 m2. The assemblage was again dominated by the polychaetes *Streblosio* and *Marenzelleria* and the oligochaete *Paranais.* Collectively these three species accounted for 80.3% of all individuals colleced. Other species of importance were the bivalve *Gemma*, the isopod *Cyathura* and the polychaete *Leitoscoloplo*s. The substrate type was sand with plant detritus.

Station #4.

A total of 18 species was reported from station #4 with a density of 507 individuals per 0.04m^2. The assemblage was dominated by the polychaetes *Marenzelleria* and *Streblospio* and the oligochaete, *Paranais*. Collectively these four species accounted for 76.1% of all individuals collected. Other species of importance were the polychaetes *Leitoscoloplos* and *Mediomastus* and the bivalve *Gemma.* The substrate type was sand with plant detritus.

Station #5

A total of 17 species was reported from station #5 with a density of 477 individuals per 0.04m^2. The assemblage was again dominated by the polychaetes *Marenzelleria* and *Streblospio* and the oligochaete, *Paranais*. Collectively these three species accounted for 79.7% of all individuals collected. Other species of importance were the polychaetes *Leitoscoloplos*, *Capitella* and *Mediomastus.* The substrate was silt with detritus.

Station #6

A total of 19 species was reported from station #6 with a density of 503 individuals per 0.04m^2. The assemblage was again dominated by the polychaetes *Marenzelleria* and *Streblospio* and the oligochaete, *Paranais*. Collectively these three species accounted for 83.9% of all individuals collected. Other species of importance were the polychaete *Leitosoloplos* and the bivale *Tellina.* The substrate type was silt with detritus.

Station #7

A total of 22 species was reported from station #7 with a density of 582 individuals per 0.04m^2. The assemblage was dominated by the polychaetes *Marenzelleria*, *Streblospio* and *Leitoscoloplos* and the oligochaete *Paranais.* Collectively these four species accounted for 76.9% of all individuals collected. Other species of importance were the polychaete *Mediomastus* and the bivalve *Gemma*. The substrate type was silt with detritus.

Station #8

A total of 20 species was reported from station #8 with a density of 264 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Streblospio, Leitoscoloplos* and *Mediomastus* and the oligochaete, *Paranais*. Collectively these four species accounted for 88.7% of all individuals collected. Other species of importance were the amphipod *Ampelisca* the polychaete *Marenzelleria* and the bivalve *Gemma*. The substrate type was silt with detritus.

Station #9

A total of 24 species was reported from station #9 with a density of 810 individuals per $0.04m^2$. The assemblage was overwhwlmingly dominated by the polychaetes *Leitoscoloplos* and *Streblospio* and the oligochaete, *Paranais*. Collectively these three species accounted for 90.9% of all individuals collected. Other species of importance were the bivalve *Gemma* and the polychaetes *Mediomastus* and *Polydora.* The substrate type was silt with detritus.

Station #10

A total of 19 species was reported from station #10 with a density of 557 individuals per $0.04m^2$. The assemblage was again dominated by the polychaetes *Streblospio* and *Leitoscloplos* and the oligochaete, *Paranais*. Collectively these three species accounted for 85.5% of all individuals collected. Other species of importance were the amphipod *Microdeutopus;* and the polychaetes *Mediomastus Capitella.* The substrate type was silt with detritus.

REGION II (Middle Black Hall River Study Area)

A total of 44 invertebrate species were recovered from the ten sampling stations (#11-20) (Figure 4) in Region II. Species richness values per $0.04m^2$ ranged from a high of 27 at stations #18 and #19 to a low of 11 at station #14 with the overall mean for the region being 17.1. This is almost identical to that reported from Region I. The mean density value for Region II was 392.7 individuals per 0.04 m2 with Station #18 reporting the highest (810) and Station #16 the lowest (194).

Region II, like Region I, was characterized by a similar mix of predominately mesohaline invertebrate species with polychaetes and gastropods accounting for 69.8% of all species collected. The numerical dominants of Region II were the oligochaete, *Paranais*; the polychaetes, *Leitoscoloplos*, *Streblospio* and *Marenzelleria* and the bivalve *Gemma.* Collectively these five species accounted for 53.7% of all individuals collected. Other species of importance in Region II were the polychaetes *Capitella*, *Mediomastus* and *Tharyx* and the amphipod, *Ampelisca.*

The substrate type in Region II was predominately silty-sandy-shell. This indicates a higher energy environment than that found in Region I. No live shellfish species were reported.

Station #11

A total of 12 species was reported from station #11 with a density of 208 individuals per $0.04m^2$. The assemblage was dominated by the polychaete *Streblospio;* the oligochaete, *Paranais* and the bivalve *Gemma*. Collectively these three species accounted for 80.8% of all individuals collected. Other species of importance were the polychaete *Leitoscoloplos* and the amphipod *Lembos.* The substrate type was silt with detritus.

Station #12

A total of 20 species was reported from station #12 with a density of 370 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Streblospio* and *Leitoscoloplos* and the oligochaete, *Paranais*. Collectively these three species accounted for 84.1% of all individuals collected. Other species of importance were the polychaetes *Marenzelleria* and *Mediomastus*. The substrate type was silt with detritus.

Station #13

A total of 24 species was reported from Station #13 with a density of 743 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes, *Streblospio* and *Mediomastus;* the oligochaete *Paranais* and the bivalve *Gemma.* Collectively these four species accounted for 78.9% of all individuals collected. Other species of importance were the polychaetes *Leitoscoloplos* and *Marenzelleria* and the amphipod *Microdeutopus.* The substrate type was silt with plant detritus.

Station #14

A total of 11 species was reported from Station #14 with a density of 238 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Streblospio* and *Marenzelleria*; the bivalve *Gemma* and the oligochaete *Paranais.* Other species of importance were the polychaetes *Leitoscoloplos* and *Polydora*. The substrate type was sandy-gravel.

Station #15

A total of 21 species was reported from Station #15 with a density of 809 individuals per $0.04m^2$. The assemblage was, like station #14, dominated by the polychaetes *Mediomastus* and *Streblospio* and the oligochaete *Paranais*. Collectively these three species accounted for 77.8% of all individuals collected. Other species of importance were the polychaetes *Leitoscoloplos*, *Capitella* and *Scoletoma* and the bivalve *Gemma*. The substrate type was silty-sand with abundant plant detritus and the depth 5.0 feet.

Station #16

A total of 13 species was reported from Station #16 with a density of 194 individuals per $0.04m^2$. The assemblage was again dominated by the polychaete *Streblospio;* the oligochaete *Paranais* and the bivalve *Gemma.* Collectively these three species accounted for 79.4% of all individuals collected. Other species of importance were the polychaete *Leitoscoloplos* and the amphipod *Ampelisca.* The substrate type was silt with some sand and plant detritus.

Station #17

A total of 13 species was reported from Station #17 with a density of 292 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Leitoscoloplos* and *Streblospio* and the oligochaete *Paranais.* Collectively these three species accounted for 80.7% of all individuals collected. Other species of importance were the gastropod *Retusa;* the bivalve *Gemma* and the amphipod *Ampelisca*. The substrate type was silt with plant detritus.

Station #18

A total of 27 species was reported from Station #18 with a density of 810 individuals per 0.04 m2. The assemblage was dominated by the polychaetes *Streblospio, Leitoscoloplos* and *Capitella* and the oligochaete *Paranais.* Collectively these four species accounted for 86.3% of all individuals collected. Other species of importance were the polychaetes *Mediomastus,* and *Tharyx* and the bivalve *Tellina.* The substrate type was silt with plant detritus.

Station #19

A total of 27 species was reported from Station #19 with a density of 578 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Leitoscoloplos*, *Streblospio* and *Mediomastus* and the oligochaete *Paranais.* Collectively these four species accounted for 77.3% of all individuals collected. Other species of importance were the bivalves *Gemma* and *Tellina* and the gastropods *Retusa* and *Acteon.* The substrate type was silt with plant detritus.

Station #20

A total of 12 species was reported from Station #20 with a density of 186 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Streblospio* and *Leitoscoloplos;* the oligochaete *Paranais* and the amphipod *Ampelisca.* Collectively these four species accounted for 88.2% of all individuals collected. Other species of importance were the polychaete *Mediomastus* and the bivalve *Tellina*. The substrate type was silt with plant detritus.

REGION III (Outer Black Hall River Study Area)

A total of 49 invertebrate species were recovered from the ten sampling stations: #21-30 (Figure 4) in Region III. Species richness values per $0.04m^2$ ranged from a high of 28 (station #23) to a low of 7 (station #29) with the overall mean for the region being 14.1. Mean density was 163.2 individuals per $0.04m^2$ with Station #21 reporting the highest (368) and Station #29 the lowest (31). Polychaetes and amphipods were the dominant taxonomic groups accounting for 63.3% of all species collected.

Region III was characterized by a similar mix of mainly mesohaline species with the numerical dominants being the polychaetes, *Marenzelleria, and Streblospio;* the oligochaete, *Paranais* and the bivalve *Gemma*. Collectively these four species accounted for % of all individuals collected. Other species of importance were the polychaetes *Leitoscoloplos* and *Autolytus*; the gastropod *Crepidula* and the amphipods *Lembos* and *Ampithoe*. The substrate type was predominately sand to silty-sandy-shell with gravel at some stations. Region III was definitely a higher energy environment when compared to Regions I and II. Sampling was difficult because of both the bottom currents and the relatively hard bottom. Live oysters were found in low numbers at Stations #24 & #25.

Station #21

A total of 16 species was reported from Station #21 with a density of 368 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Streblospio* and *Marenzelleria* the oligochaete *Paranais*. Collectively these three species accounted for 69.5.5% of all individuals collected. Other species of importance were the bivalve *Gemma* and the polychaetes *Leitoscoloplos* and *Capitella*. The substrate type was sandy-silt with plant detritus.

Station #22

A total of 17 species was reported from Station #22 with a density of 203 individuals per $0.04m^2$. The assemblage was dominated by the polychaete *Streblospio* and the oligochaete *Paranais*. Collectively these two species accounted for 64.1% of all individuals collected. Other species of importance were the polychaetes *Leitoscoloplos* and *Marenzelleria* and the amphipod *Lembos*. The substrate type was sandy-silt with shell hash.

Station #23

A total of 28 species was reported from Station #23 with a density of 352 individuals per $0.04m^2$. This station exhibited the highest species richness value of any throughout the Black Hall River study area. The dominant species were again the polychaetes *Leitoscoloplos* and *Streblospio* and the oligochaete *Paranais*. Collectively these three species accounted for 77.6% of all individuals collected. Other species of importance were the polychaetes *Attillia* and *Marenzelleeria* and the gastropod *Crepidula*. The substrate type was silty-sandy shell.

Station #24

A total of 25 species was reported from Station #24 with a density of 336 individuals per $0.04m^2$. The assemblage was dominated by the polychaetes *Streblospio* and *Autolytus;* the oligochaete *Paranais* and the amphipod *Lembos*. Collectively these four species accounted for 77.9% of all individuals collected. Other species of importance were the polychaetes *Atillia*, and

Tharyx and the amphipod *Elasmopus.* The substrate type was silty-sandy shell with some gravel and oyster shells.

Station #25

A total of 10 species was reported from Station #25 with a density of 37 individuals per $0.04m^2$. There were no overwhelming dominants at Station #25 but several species of importance were the gastropod *Crepidula*, the amphipod *Melita* and the polychaete *Autolytus*. The substrate type was shell with many small rocks. This hard bottom was difficult to sample and consequently only a small sample was obtained.

Station #26

A total of 9 species was reported from Station #26 with a density of 61 individuals per $0.04m^2$. There was no overwhelming dominant species at Station #26 with the amphipods *Elasmopus* and *Ampithoe* and the oligochaete *Paranais* accounting for 462.3% of all individuals collected. The substrate type was gravel with shell hash.

Station #27

A total of 8 species was reported from Station #27 with a density of 73 individuals per 0.04m2. The assemblage was dominated by the amphipods *Ampithoe* and *Elasmopus* and the gastropod *Crepidula* Collectively these three species accounted for 73.9% of all individuals collected. The substrate type was cobble and shell with *Ulva* growth.

Station #28

A total of 8 species was reported from Station #28 with a density of 74 individuals per $0.04m^2$. The assemblage was dominated by the polychaete *Paraonis;* the *oligochaete Paranais* and the bivalve *Gemma.* These three species accounted for 81.1% of all individuals collected. The substrate type was sand.

Station #29

A total of 7 species was reported from Station #29 with a density of 31 individuals per $0.04m^{2.}$. The assemblage was dominated by the oligochaete, *Paraonis* and the bivalve *Gemma*. Collectively these two species accounted for 64.5% of all individuals collected. The substrate type was sand.

Station #30

A total of 13 species was reported from station #30 with a density of 97 individuals per $0.04m^2$. The assemblage was dominated by the oligochaete *Paranais* and the gastropod *Crepidula.* Which collectively accounted for 75.3% of all individuals collected. The substrate type was sandy-shell.

B. SPECIES DIVERSITY

SHANNON-WIENER INDEX ("SHANNON INDEX") ANALYSIS

The Shannon Index (H') is the most widely used of all diversity indices and is relatively independent of sample size. This index incorporates both species richness (number of species present) and evenness (distribution of individuals among the species) into its equation:

$$H' = \frac{n \log n - \sum_{i=1}^{k} fi \log fi}{N}$$

High diversity values are usually indicative of low stressed environments while low diversity values indicate highly stressed conditions. H' values below 1.500 are generally considered to be indicative of stressed environments (Zettler, et al., 2007). H' values for the sampling stations can be found in Table 9.

Table 9 - Species Diversity (H') Values for Black Hall River Sampling Stations (September, 2013)

Station Number	Diversity (H') Value
1	1.728
2	1.633
3	1.652
4	1.743
5	1.585
6	1.580
7	1.991
8	1.539
9	1.592
10	1.573
11	1.503
12	1.648
13	1.762
14	1.835
15	1.746
16	1.555
17	1.300
18	1.643
19	2.076
20	1.597
21	1.645
22	1.937
23	1.819
24	1.712
25	1.896
26	1.916
27	1.707
28	1.564
29	1.579
30	1.568

Mean Region I	1.662
Mean Region II	1.667
Mean Region III	1.734

Diversity values for the entire study area (Tables 4-5a.) ranged from a high of 2.076 (Station #19 to a low of 1.300 (Station #17) with the overall mean being 1.687. The mean H' value for Region I was 1.662; Region II 1.667 and Region III 1.734. Species diversity values were fairly consistent throughout the entire Black Hall River study area. Overall Diversity Values indicate the entire study area to be in a moderately stressed condition.

Zettler, et al. (2007) established the five following Ecological Quality ("EcoQ") classes based on the Shannon Index:

EcoQ Class	**H' Value**
High	> 4.0
Good	3.0 – 4.0
Moderate	2.0 – 3.0
Poor	1.0 – 2.0
Bad	< 1.0

Based on these criteria the entire Black Hall study area would fall into the poor to moderate Ecological Quality Class.

C. BERGER-PARKER INDEX (d)

The Berger-Parker Index is a simple mathematical expression relating both species richness and abundance. It takes into account only the commonest species in the sample and is calculated as: **d= Nmax/N** where Nmax = the number of individuals in the most abundant species in the sample and N is the total number of individuals.

The index expresses the proportional importance of the most abundant species. Often in ecological studies the reciprocal **1/d** is used in data analysis. Increasing 1/d values indicates increasing diversity and reduction in the dominance of a single species. The Berger-Parker Index Values(1/d) for the Black Hall River study area can be found in Table 3.

Berger-Parker values for the entire study area (Table 10) ranged from a high of 3.389 (Station #26) to a low of 1.631 (Station #17) with the overall mean being 2.217. The Berger-Parker Index values were fairly consistent throughout the study area. The values were lower than those reported from the Four Mile River indicating strong species dominance throughout the study area. Overall the Berger-Parker results reflect the same pattern of lower species diversity values found with the Shannon Diversity Index.

Table 10. Berger- Parker(1/d) Index Values for Black Hall River Sampling Stations (September, 2013)

Station Number	Berger-Parker Index (1/d)
1	2.636
2	1.783
3	2.188
4	3.209
5	1.963
6	2.276
7	3.304
8	1.785
9	2.037
10	1.989
11	1.809
12	2.189
13	1.920
14	2.833
15	3.111
16	1.902
17	1.631
18	2.120
19	2.491
20	2.188
21	2.152
22	2.570
23	2.058
24	1.663
25	2.643
26	3.389
27	3.042
28	2.846
29	2.818
30	2.021
Mean Region I	2.344
Mean Region II	2.219
Mean Region III	2.089

D. SUCCESSIONAL STAGE ANALYSIS

Succession can be defined as the predictable appearance of macrobenthic invertebrate species belonging to specific functional types following disturbance. Three patterns of invertebrate colonization (successional stages) of shallow-water sediments can usually be recognized: Stage I, Stage II, and Stage III (Rhoads and Germano, 1986). Stage I species are early colonizers (pioneers) which arrive within days of a major bottom disturbance. These Stage I species, also called opportunists, experience high mortality and usually disappear as a result of competition and/or predation. Stage I species are considered to be r-strategists with short life cycles (<1 Year), small size, fast growth, and early sexual maturity. They are usually surface deposit feeders and are typified by Spionid (*Streblospio benedicti*) and Capetellid (*Mediomastus ambiseta*) polychaetes (Rhoads and Germano, 1986).

Stage I species are eventually replaced by a climax or equilibrium assemblage (Stage III) dominated by large, deep burrowing polychaetes and bivalves. These k-strategist species are characterized by long life cycles (>1 year), large body size, slow growth, and late sexual maturity. Typical Stage III species are the polychaetes *Leitoscoloplos robustus* (Orginiidae) and *Scoletoma tenuis* (Lumbrineridae) (Rhoads and Germano, 1986) and *Clymenella torquata* and the bivalve *Ensis directus*.

The successional process often involves a transitional state (Stage II) before the Stage III (equilibrium) community is established. The transitional phase usually involves the appearance of a diverse assemblage of tubiculous amphipods (*Ampelisca abdita*), mollusks, and polychaetes. This stage is also characterized by the presence of the declining remnants of Stage I species and the appearance of new Stage III species.

Mistri (2002) reported that shallow-water estuarine areas like the Black Hall & Four Mile Rivers are dynamic environments, whose main characteristic is the instability of chemical-physical properties with salinity often being highly variable. Disturbances can either be natural (storms, sediment resuspension, floods, etc.) or anthropogenic (dredging, trawling, etc.). Most natural disturbances are usually non-catastrophic in that some residents survive leading to reinvasion and recolonization.

Mistri (2002) also stated that physical disturbances (e.g., salinity changes) are common in estuarine habitats and that unstable communities are most resilient because they contain species adapted (r-selected) to variable environmental conditions. Pickett and White (1985) demonstrated that unstable communities are more likely than stable communities to return to their previous composition following disturbance.

Ritter et al. (2005) reported that in many estuaries the benthos is maintained in a constant state of early and intermediate succession because of frequent natural disturbances. Montagna et al. (1998) also found that benthic estuarine environments often tend to remain in a state of perpetual early succession by being in a state of constant disturbance.

Ysebaert, et al. (2003) reported that oligohaline-mesohaline estuarine zones are highly variable environments causing numerous, perhaps constant disturbances that probably result in communities that seldom progress beyond early benthic-community succession.

Nilsson, et al. (2000) found the oligochaete genus *Paranais* to be typical of ephemeral and chronically disturbed habitats. Oligochaetes are generally considered to be one of the most common opportunists in low saline environments and are considered to be Stage I species. The

polychaetes *Streblospio, Mediomastus* and *Capitella* have been documented by many authors to be typical of chronically disturbed habitats

The Black Hall benthic assemblage was dominated by the following five species: *Paranais, Streblospio, Marenzelleria, Leitoscoloplos* and Gemma. Collectively these five species accounted for 74.7% of all individuals collected. Three of these were Stage I opportunistic species and included the polychaetes *Streblospio* and *Marenzelleria* and the oligochaete *Paranais*. These three opportunists accounted for 61.9% of all individuals collected. The other two dominants were the Stage II species *Gemma* and the Stage III *Leitoscoloplos*.

The results of this study indicate that the Black Hall River study site, like the Four Mile, is in a late Stage I to early Stage II suceesional state. Although Stage I opportunists are the numerical dominants there is also a mix of some Stage II (*Gemma, Ampelisca, Phyllodoce and Eteone)* and Stage III (*Leitoscoloplos Pectinaria* and *Scoletoma*) species. This is the general condition found throughout the study area..

E. K-DOMINANCE CURVE

The K-dominance curve first described by Lambshead et al.(1983) has been shown to be a useful tool in environmental impact studies in recent years (Newell et al. 1998). This statistic is a plot of the proportional contibution of each species in a community compared to the overall population density as a whole. Stage III communities characteristic of undisturbed environments have a high species diversity where each individual species makes a relatively small contibution to the overall population density. The K-dominance curve for these communities is typically Sigma-shaped and is depicted in Figure 11.

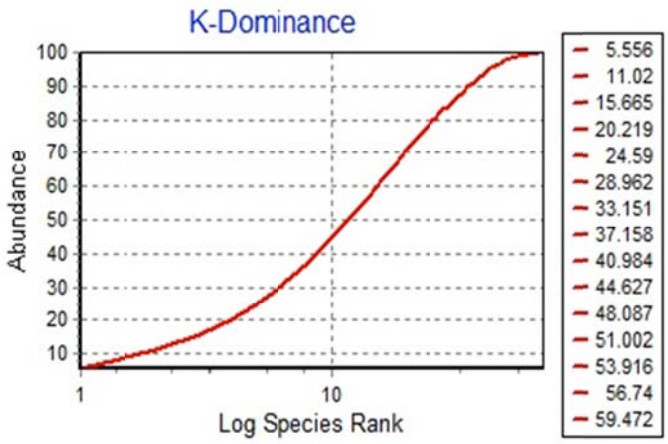

Figure 11. Hypothetical K-Dominance Curve for Stage III Community

Early Stage I communities, however, have low species diversity which leads to as much as 80-90% of the population being dominated by only one or two r-selected opportunistic species. The K-dominance curve for these assemblages will have a steep slope and be highly elevated. This condition is depicted in Figure 12.

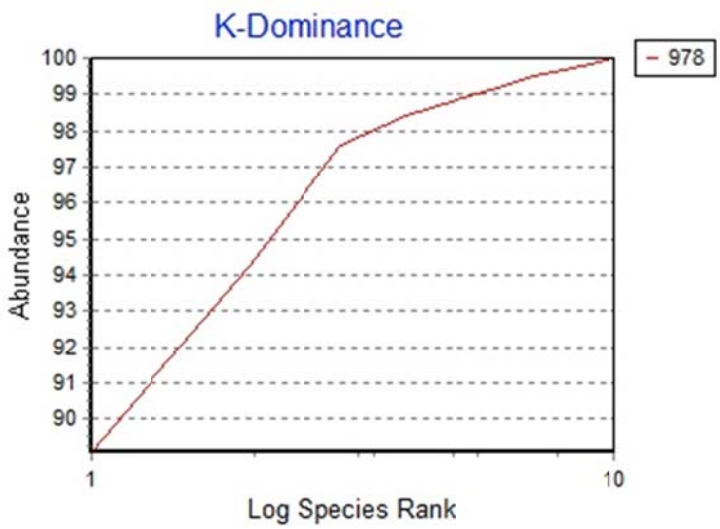

Figure 12. Hypothetical K-Dominance Curve for Early Stage I Community

The K-dominance curve for the Black Hall River study area is found in Figure 13. It clearly shows, like that found in the Four Mile River, an intermediate codition between the two extremes previously described with the numerically dominant species accounting for 40% of the total community. This confirms the placement of the Black Hall River into the Late Stage I to Early Stage II successional state.

Figure 13. K-Dominance Curve for Black Hall River Study Area

F. AZTI MARINE BIOTIC INDEX (AMBI)

Recent interest on benthic indicators has increased dramatically, with a lot of new indicators proposed. One such indicator, the AMBI, was designed to establish the ecological quality of European coastal waters. The AMBI analyses the response of soft-bottom communities to natural and man-induced changes in water and sediment quality (Borja et al. 2000). The AZTI Biotic Index has been used in numerous studies to define the disturbance status of estuarine systems. Ramey et al. (2011) studied the use of AMBI in New Jersey coastal waters.

The AMBI offers a "pollution or disturbance classification" representing the benthic community "health". The AMBI has been verified successfully in relation to large set of environmental impact sources. The AMBI obtains a continuous value of an index representing the quality of the bottom conditions in a discreet range from 0 (Unpolluted) to 7 (Extremely Polluted). Benthic species are classified into five ecological groups according to their sensitivity/tolerance to increasing levels of environmental stress and five categories that define benthic community health: "UNDISTURBED" (<1.2), "SLIGHTLY DISTURBED" (1.2-3.3), "MODERATELY DISTURBED" (3.3-5.0), "HEAVILY DISTURBED" (5.0-6.0) and "EXTREMELY DISTURBED" (>6.0).

Table 11 - AMBI Biotic Index Values (BI) for Black Hall River Stations

Station Number	AMBI Value	Biotic Index Value	Disturnance Category
1	3.940	3	Moderately Disturbed
2	3.342	3	Moderately Disturbed
3	3.280	2	Slightly Disturbed
4	3.246	2	Slightly Disturbed
5	3.409	3	Moderately Disturbed
6	3.304	3	Moderately Disturbed
7	2.871	2	Slightly Disturbed
8	3.397	3	Moderately Disturbed
9	3.620	3	Moderately to Disturbed
10	3.899	3	Moderately Disturbed
11	3.168	2	Slightly Disturbed
12	3.833	3	Moderately Disturbed
13	3.095	2	Slightly Disturbed
14	3.012	2	Slightly Disturbed
15	2.757	2	Moderately Disturbed
16	3.140	2	Slightly Disturbed
17	3.580	3	Moderately Disturbed
18	4.012	3	Moderately Disturbed
19	4.503	4	Moderately Disturbed
20	3.895	3	Moderately Disturbed
21	4.144	3	Moderately Disturbed
22	4.151	3	Moderately Disturbed
23	4.329	4	Moderately Disturbed
24	4.560	4	Moderately Disturbed
25	2.635	2	Slightly Disturbed
26	3.356	3	Moderately Disturbed
27	2.261	2	Slightly Disturbed
28	3.628	3	Moderately Disturbed
29	3.339	3	Moderately Disturbed
30	4.439	4	SModerately Disturbed

Mean Study Area	3.57	3	Moderately Disturbed
Mean Region I	3.429	3	Moderately Disturbed
Mean Region II	3.498	3	Moderately Disturbed
Mean Region III	3.685	3	Moderately Disturbed

The AMBI Index values (Table 11) revealed that 66.7% of sampling stations fell into the Moderately to Disturbed Category with 33.3% being Slightly Disturbed. No sampling stations were found to be in the two worst disturbance categories: Heavily Disturbed and Extremely Disturbed. Mean AMBI Values for the entire Black Hall study site (Table 11) placed the area into the Moderately Disturbed Category. Mean AMBI Values also placed the individual sampling regions into the Moderately Disturbed Category. The distribution of disturbance categories for individual stations can be found in Figure 14.

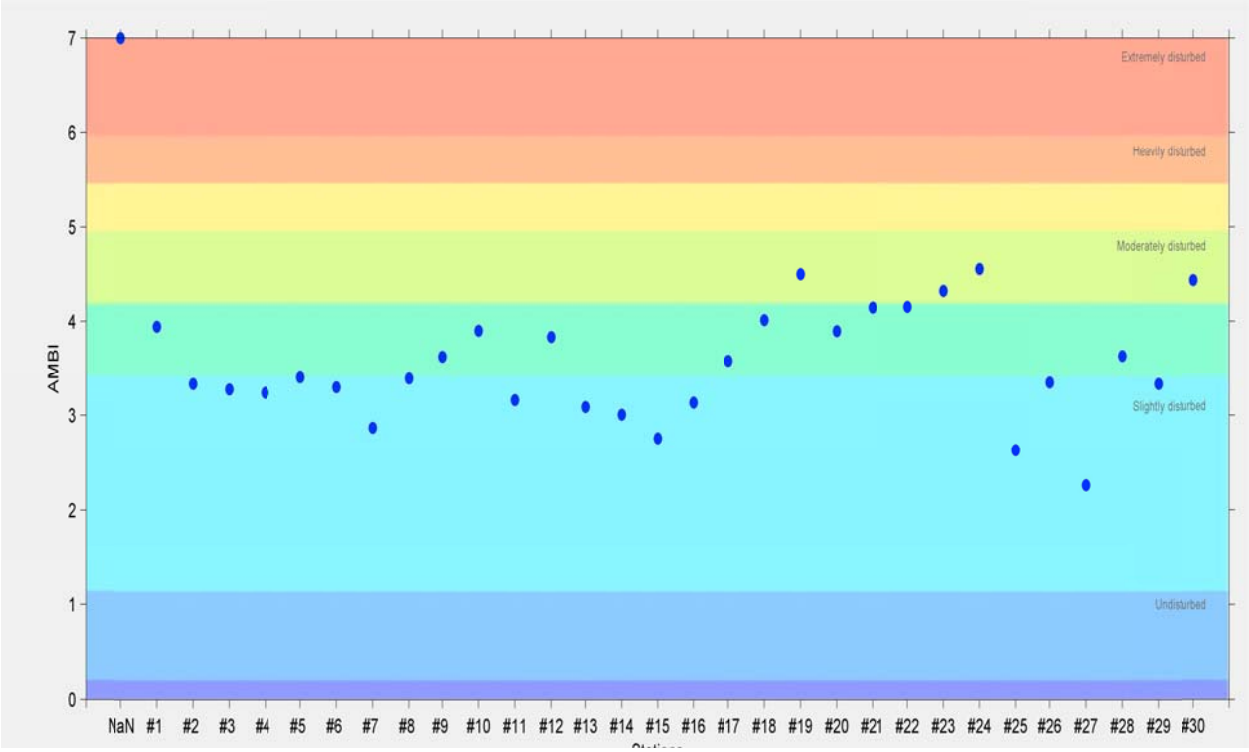

Figure 14. Scatter Diagram Showing Distribution of Distrubance Categories for Black Hall Sampling Stations

G. CLUSTER ANALYSIS

Cluster analysis includes a broad suite of techniques designed to find groups of similar items within a data set. Hierarchial cluster methods produce a hierarchy of clusters from small clusters of very similar items to large clusters that include more dissimilar items. Hierarchial methods produce a graphical output known as a dendrogram or tree that shows this hierarchial clustering structure. The most commonly used method is agglomerative hierarchial clustering. This method finds clusters of most similar items and then progressively adds less similar items until all items have been included into a single large cluster.

The aim of clustering in benthic studies is to put sites which have similar species compositions into the same groups which are known as clusters. Cluster analysis provides a summary of the similarity in species composition of various sites (Stations). Stations that are grouped into the same cluster are more similar in species composition than stations grouped into different clusters. Hierarchical clustering methods do not only cluster sites, but also cluster the various clusters that were formed earlier in the clustering process.

Multivariate analyses were performed using the PAST Statistical Software Program (Hsmmer et al., 2001). Cluster analysis was performed by calculating the Bray-Curtis similarity coefficient for all pairs of sampling stations, after log (X+1) transformation of all species abundance values. Clusters were formed using the group-average linkage method between similarities. A non-metric multi-dimensional scaling (nMDS) was then performed on the similarity matrix generated by the cluster analysis. nMDS plots stations in a 2-dimensional space such that points close together in the plot represent stations that are very similar in species composition and points that are far apart represent very different assemblages.

The dendrogram created for the Black Hall River Sampling Stations can be found in Figure 15.

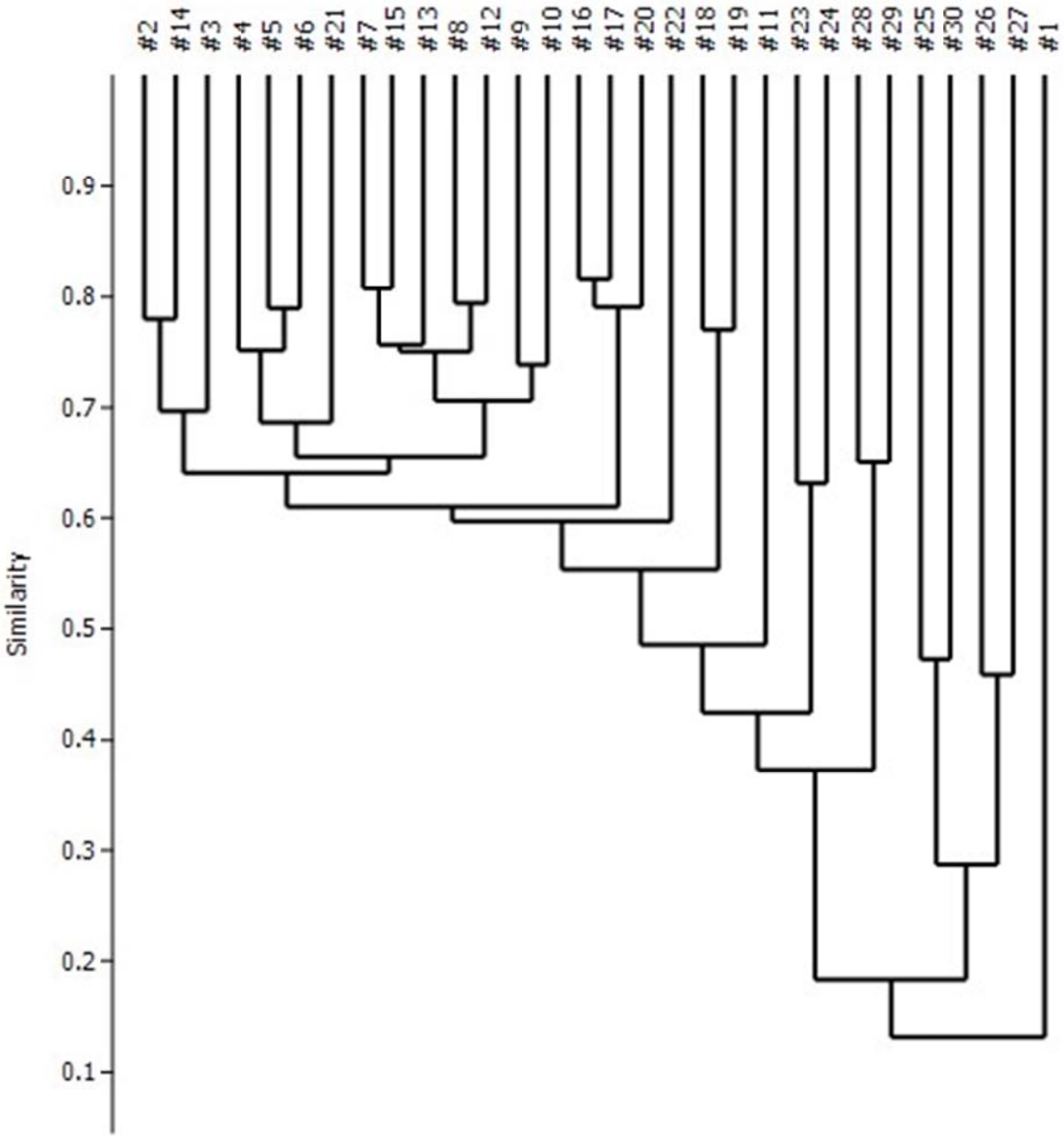

Figure 15. Dendrogram of Black Hall River Sampling Stations

The dendrogram (Figure 15) of the Black Hall stations did not reveal the distinct cluster formations that characterized the Four Mile River. The Black Hall dendrogram revealed one lage general cluster consisting of thirteen stations and one small cluster of three to four stations. Eight of the thirteen stations of the large cluster were located in Region I and the rest in Region II indicating a strong benthic similarity between them. The small cluster consisted of the following stations: #14, #16, #17 & #20. These stations had almost identical species richness values (11-13 species/.04m^2) and showed similar density values for *Leitoscoloplos, Ampelisca* and *Streblospio.* They were also characterized by very low numbers of the oligochaete *Paraanis.*

The non-metric multi-dimensional scaling (nMDS) analysis was also performed on the similarity matrix generated by the cluster analysis (Figure 16). The two clusters previously described can be more easily visualized in this nMDS Plot.

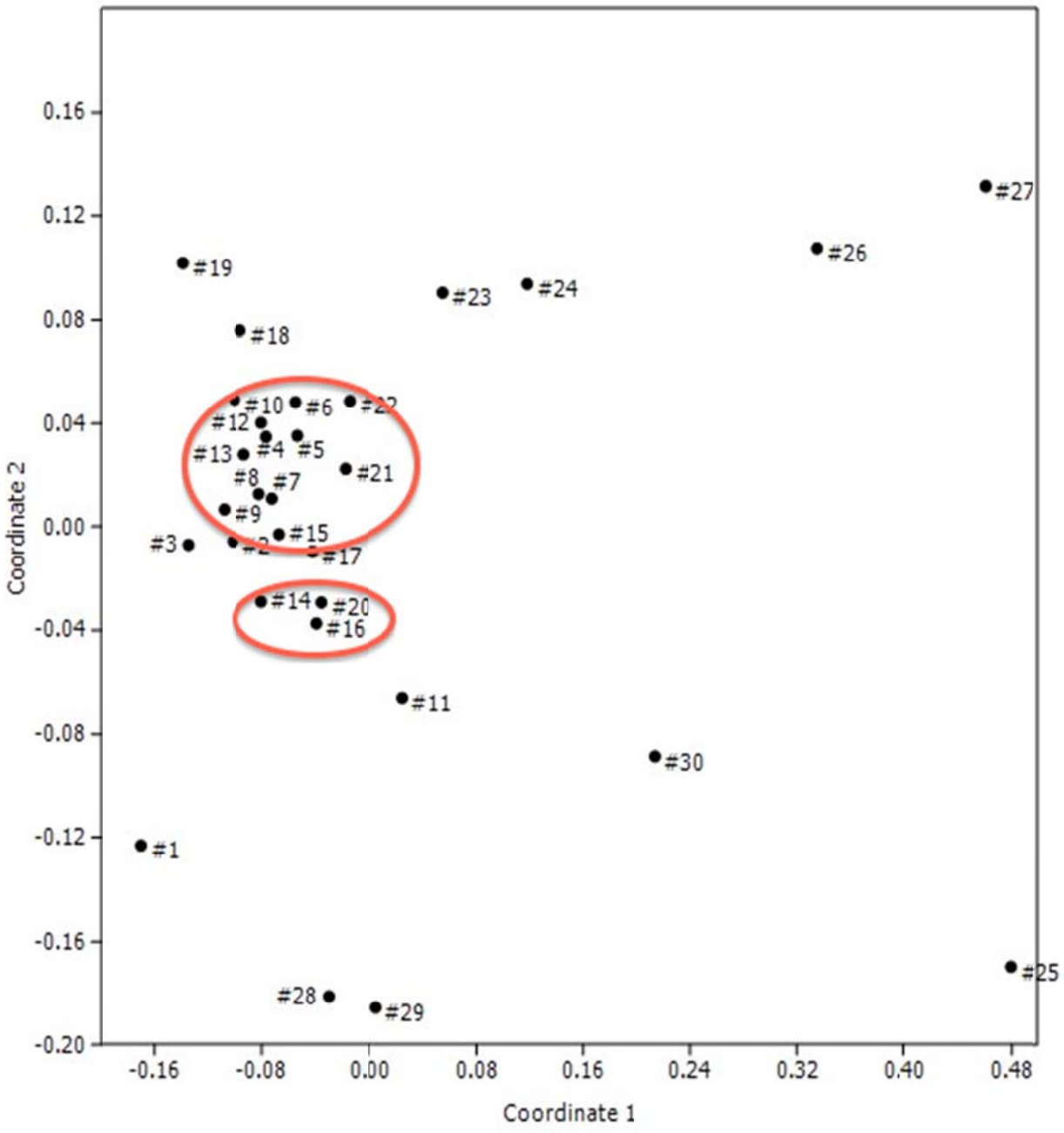

Figure 16. nMDS Plot for Black Hall River Stations

VI. Proposed Dredging Project

The propsed dredge channel footprint for the Black Hall River is approximately 6,000 feet in length, beginning near the Route 156 Bridge and extending south to Long Island Sound. The channel is proposed to a depth of -4.0 feet MLW (+ 1.0 foot overdredge). A total of 13,176 cubic yards of material will be dredged.

The proposed dredge channel footprint for the Four Mile River is approximately 4,000 linear feet, beginning at the head of the river near the Four Mile River Marina and terminating 1,000 feet south of the railroad bridge into Long Island Sound. The channel is proposed to a depth of -3.0 feet MLW (+1.0 foot overdredge). A total of 9,787 cubic yards of material is proposed to be dredged.

Dredging is a large scale anthropogenic disturbance whose major effects on the benthos are removal, smothering and turbidity related (Montagna et al. 1998). The general impacts of dredging have been reviewed by Shank and Cronin (1970), Windom (1970), Morton (1977), Guillory (1982), Allen and Hardy (1980), Newell et al. (1998), Hitchcock et al. (1999), and Newell et al. (2004).

Disturbance is one of the major factors changing and structuring biological communities and influencing variations in species diversity (Hall, 1994; Kroger, 2003). Disturbance can be defined as any relatively discrete event in time that disrupts ecosystem, community or population structure and changes resources, substrate availability or the physical environment (Kroger, 2003). Disturbances can either be natural or man-induced (anthropogenic).

Most studies show dredging itself is usually accompanied by a significant fall in species numbers, population density, and biomass of benthic organisms. Hitchcock et al. (1999) and Newell et al.(2004) have shown that dredging can result in a 30-70% reduction in benthic species richness and a 40-95% reduction in population density and biomass. They also found that there was little evidence that deposition of sediment from outwash during the dredging had any significant negative impact on benthos outside the immediate dredged area.

Hitchcock et al. (1999) reported that the rate of benthic recovery and recolonizaiton to be highly variable depending on the type of community which inhabits the deposits in dredged areas and surrounding deposits and the extent to which the community is naturally adapted to disturbance. They define the process of recovery following environmental disturbance as establishment of a successional community of species which progress towards a community which is similar in species composition, population density and biomass to that previously present. They felt, however, that a more practical approach to the question of recovery is the recognition of the establishment of a community which is capable of maintaining itself and in which 80% of the species diversity and biomass has been restored. This 80% level should result in substantial restoration of benthic carrying capacity even though the precise species composition may not be identical to that recorded in the pre-dredged system.

Hitchcock et al. (1999) is an extensive review of dredge impact studies world-wide found that the recolonization of fine muds which typically characterize estuarine habitats was extremely rapid. They found that in these Stage I environments complete benthic recovery typical occurs within several months. The natural communities of sands and gravels which are characterized by varying proportions of slow growing (k-selected) species were found to recolonize at a slower pace. They concluded that a benthic recovery time of 6-8 months is typical for many estuarine muds while sand and gravels may take from 2-3 years.

Newell, et al. (1998) and Newell, et al. (2004) reported that shallow benthic habitats like the Four Mile and Black Hall estuaries experience relatively frequent wave, wind and current induced disturbances and are thus typically inhabited by low diversity, r-selected opportunistic benthic assemblages. These communities are naturally held in early successional stages and are able to recover more rapidly than communities in stable environments. They characterized typical recovery times for these shallow estuarine systems to be typically at 6-8 months.

Garcia and Gomez (2006) report that processes of recolonization followed by successional dynamics can rapidly reestablish macrobenthic community structure following a dredging disturbance. Recolonization may occur through the water column (settlement of planktonic larvae) or through lateral movements of juveniles or adults (post-settlement movements). They found in their study of small scale dredging impacts that the recolonization process in experimental dredged areas began within fifteen days.

Wilber et al. (2007) in an extensive review of dredge studies concluded that the most consistent physical parameter influencing benthic recovery rates is the prior disturbance history of the habitat. Benthic recovery was found to occur most rapidly in shallow estuarine areas where the resident species assemblages are already adapted to chronically disturbed sediments.

VII. Conclusion

It is projected that the proposed dredging project will result in a significant but temporary reduction in benthic species richness, population density, and biomass within the dredged area footprint. It is also projected that there will be no significant negative impact on benthic species outside the immediate dredge area footprint. Dernie et al. (2003) reported that following a disturbance event such as dredging both the sediment habitat and the associated infaunal community are amenable to restoration over a period of time

Both project sites were found to support a typical assemblage of benthic species that is in late Stage I to early Stage II successional stage. It is likely that the study site is subjected to natural disturbances such as those related to storms and salinity fluctuations which prevents the development of a late Stage II condition and maintains the site in a continual late Stage I state.

The proposed dredging project will initially transform the dredge area from its present late Stage I condition to a early Stage I state dominated by opportunistic, r-selected species such as *Mediomastus, Streblospio, Paranais* and *Marenzelleria*. The areas adjacent to the proposed dredge site are assumed also in similar scuccessional states and harbor the same general mix of species found in the proposed dredge area. These adjacent areas are not expected to be adversely affected by the proposed dredging and therefore will act as benthic "refuges," providing a major source of recruits for the recolonization by the same mix of species currently inhabiting the proposed dredge site. This new early Stage I condition will gradually be transformed back to the current late Stage I to early Stage II condition.

Dernie et al. (2003) concluded that biological recovery rates following a disturbance are mediated by a combination of physical and biological factors that differ in their relative importance in different habitats. The benthic assemblages of the Four Mile and Black Hall Rivers were found to be dominated by a mix of opportunisic species (*Streblospio, Paranais, Marenzelleria, Mediomastus* and *Capitella*). These systems are typical of those described in the literature as being capable of rapid colonization after cessation of dredging. Numerous studies have documented that shallow estuarine systems like the Four Mile and Black Hall Rivers can achieve near complete benthic recovery within a matter of months of cessation of dredging.

The proposed dredge projects will therefore not result in any permanent loss of benthic productivity. It is projected that the recolonization of the Four Mile and Black Hall Rivers leading to nearly complete benthic recovery (80% level) should occur within 8-12 months of the cessation of dredging.

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TABLES

1-5a: MACROBENTHIC COMMUNITY STRUCTURE

11-12: GPS COORDINATES OF SAMPLE STATIONS

Table 1. Macrobenthic Community Structure of Shallow Water Habitats of Four Mile River (Old Lyme, CT) **REGION I** (Number/0.04m^2) (Stations 1-6)

TAXON	**STATION NUMBER**					
	#1	**#2**	**#3**	**#4**	**#5**	**#6**
Annelida						
Polychaeta						
Leitoscoloplos robustus	**39**	**26**	**38**	**97**	**21**	**82**
Mediomastus ambiseta	**33**	**-**	**-**	**-**	**-**	**-**
Streblospio benedicti	**4**	**3**	**8**	**51**	**51**	**29**
Heteromastus filiformis	**2**	**-**	**-**	**-**	**--**	**-**
Eteone longa	**-**	**--**	**-**	**12**	**-**	**9**
Scoletoma tenuis	**5**	**-**	**7**	**89**	**1**	**11**
Phyllodoce mucosa	**-**	**--**	**--**	**-**	**--**	**-**
Phyllodoce arenae	**-**	**--**	**--**	**1**	**-**	**-**
Cossura longocirrata	**-**	**5**	**-**	**--**	**-**	**--**
Polydora cornuta	**-**	**-**	**-**	**--**	**-**	**1**
Polydora ligni	**1**	**-**	**1**	**1**	**--**	**-**
Spio setosa	**-**	**-**	**-**	**1**	**-**	**-**
Harmothoe imbricata	**--**	**1**	**-**	**-**	**--**	**-**
Hediste diversicolor	**--**	**--**	**-**	**-**	**--**	**1**
Attlia succinea	**--**	**1**	**-**	**8**	**-**	**4**
Tharyx acutus	**--**	**--**	**1**	**6**	**-**	**3**
Pilargiidae	**-**	**-**	**-**	**-**	**-**	**-**
Acmira spp.	**-**	**-**	**-**	**-**	**-**	**-**
Magelona spp.	**-**	**-**	**-**	**-**	**-**	**-**
Nephtys incisa	**-**	**-**	**-**	**-**	**-**	**-**
Pectinaria gouldii	**-**	**-**	**-**	**1**	**-**	**1**
Glycera capitata	**-**	**-**	**-**	**-**	**-**	**-**
Spioniidae	**-**	**-**	**-**	**-**	**-**	**-**
Marenzelleria viridis	**-**	**-**	**-**	**-**	**-**	**-**
Autolytus spp.	**-**	**-**	**-**	**-**	**-**	**-**
Capitella capitata	**-**	**-**	**-**	**17**	**3**	**-**
Goniadella gracilis	**-**	**-**	**-**	**-**	**-**	**-**
Podarke obscura	**-**	**-**	**-**	**-**	**-**	**-**
Asabellides oculata	**-**	**-**	**-**	**-**	**-**	**-**
Drilonereis longa	**-**	**-**	**-**	**-**	**-**	**-**
Oligochaete sp.						**--**
Paranais sp.	**5**	**18**	**73**	**30**	**48**	**67**
	#1	#2	#3	#4	#5	#6
Rhynchocoela						
Nemertean spp.	**-**	**-**	**1**	**1**	**-**	**-**
Cerebratulus sp.	**-**	**-**	**-**	**-**	**-**	**-**
Mollusca						
Gastropoda						
Urosalpinx cinerea	**-**	**-**	**-**	**-**	**-**	**--**
Acteon punctostriatus	**-**	**-**	**-**	**--**	**-**	**-**

Mitrella lunata	-	--	-	-	-	-
Nassarius trivittatus	-	-	--	-	-	-
Retusa canaliculata	-	-	-	-	-	--
Crepidula fornicata	--	-	-	--	--	--
Crepidula plana	--	-	-	-	-	-
Nudibranchia	-	-	-	-	-	-
Bivalvia						--
Macoma baltica	-	-	-	-	-	-
Tellina agilis	-	-	-	**1**	-	-
Mulinia lateralis	-	-	-	-	-	-
Petricola pholadiformis	-	-	-	-	-	-
Gemma gemma	**1**	-	**9**	-	**6**	**5**
Lyonsia hyalina	-	-	-	-	-	-
Solemya velum	-	-	-	-	-	-
Anadara transversa	-	-	-	-	-	-
Arthropoda						
Amphipoda						
Ampelisca abdita	**2**	**2**	-	**15**	**1**	**8**
Ampelisca sp.	-	-	-	-	-	-
Listriella barnardi	-	-	-	**8**	-	-
Leptocheirus pinguis	-	-	-	-	**1**	-
Corophium tuberculatum	-	-	-	-	-	-
Microdeutopus anomalus	-	-	-	-	-	-
Microdeutopus gryllotalpa	-	-	-	**8**	-	**6**
Ericthonius brasiliensis	-	-	-	-	-	-
Caprella sp.	-	-	-	-	-	-
Elasmopus levis	-	-	-	-	-	-
Erichsonella filiformis	-	-	-	-	-	-
Trichophoxus epistomis	-	-	-	-	-	-
Microprotopus raneyi	-	-	-	-	-	-
Gammarus mucronatus	-	-	-	-	-	-
Paraphoxus spinosa	-		-	-	-	-
Decapoda						
Pagurus longicarpus	**1**	-	-	-	-	**1**
Dyspanopeus sayi	-	-	-	-	-	-
Crangon septemspinosa	-	-	-	-	-	-
Callianassa atlantica	-	-	-	**2**	-	-
Isopoda						
Edotea triloba	-	-	-	-	-	-
Cyathura polita	-	-	-	-	-	-
Cumacea						
Leucon americana	--	-	-	**1**	**2**	-
TOTALS	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**
Number of Species	**9**	**7**	**8**	**19**	**9**	**14**
Number of Individuals	**111**	**56**	**138**	**351**	**134**	**228**

Table 1a. Macrobenthic Community Structure of Shallow Water Habitats of Four Mile River (Old Lyme, CT) **REGION I** (Number/0.04m$^{2)}$) (Stations 7-12)

TAXON	**STATION NUMBER**					
	#7	**#8**	**#9**	**#10**	**#11**	**#12**
Annelida						
Polychaeta						
Leitoscoloplos robustus	**128**	**34**	**33**	**20**	**53**	**12**
Mediomastus ambiseta	**-**	**-**	**-**	**7**	**-**	**35**
Streblospio benedicti	**22**	**107**	**29**	**79**	**83**	**88**
Heteromastus filiformis	**-**	**-**	**-**	**-**	**--**	
Eteone longa	**-**	**13**	**1**	**5**	**1**	**-**
Scoletoma tenuis	**2**	**4**	**6**	**-**	**15**	**2**
Phyllodoce mucosa	**-**	**--**	**--**	**-**	**--**	**-**
Phyllodoce arenae	**-**	**--**	**--**	**-**	**-**	**-**
Cossura longocirrata	**-**	**--**	**-**	**--**	**-**	**--**
Polydora cornuta	**4**	**-**	**-**	**--**	**-**	**-**
Polydora ligni	**-**	**-**	**2**	**4**	**1**	**-**
Spio setosa	**-**	**-**	**-**	**-**	**-**	**-**
Harmothoe imbricata	**--**	**--**	**-**	**-**	**--**	**-**
Hediste diversicolor	**--**	**--**	**1**	**-**	**--**	**--**
Attlia succinea	**--**	**3**	**2**	**3**	**-**	**1**
Tharyx acutus	**8**	**11**	**6**	**1**	**-**	**-**
Pilargiidae	**1**	**-**	**-**	**-**	**-**	**-**
Acmira spp.	**-**	**-**	**-**	**-**	**-**	**-**
Magelona spp.	**-**	**-**	**-**	**-**	**-**	**-**
Nephtys incisa	**-**	**-**	**-**	**-**	**-**	**-**
Pectinaria gouldii	**-**	**-**	**-**	**1**	**3**	**4**
Glycera capitata	**-**	**-**	**-**	**-**	**-**	**-**
Spioniidae	**-**	**-**	**-**	**-**	**-**	**-**
Marenzelleria viridis	**-**	**-**	**-**	**-**	**-**	**-**
Autolytus spp.	**-**	**-**	**-**	**-**	**-**	**-**
Capitella capitata	**-**	**-**	**-**	**-**	**-**	**2**
Goniadella gracilis	**-**	**-**	**-**	**-**	**-**	**-**
Podarke obscura	**-**	**-**	**-**	**-**	**-**	**-**
Asabellides oculata	**-**	**-**	**-**	**-**	**-**	**-**
Drilonereis longa	**-**	**-**	**-**	**-**	**-**	**-**
	#7	**#8**	**#9**	**#10**	**#11**	**#12**
Oligochaete sp.						**--**
Paranais sp.	**23**	**75**	**22**	**104**	**35**	**108**
Rhynchocoela						
Nemertean spp.	**-**	**1**	**-**	**-**	**-**	**-**
Cerebratulus sp.	**1**	**-**	**-**	**-**	**1**	**-**
Mollusca						
Gastropoda						
Urosalpinx cinerea	**-**	**-**	**-**	**-**	**-**	**--**
Acteon punctostriatus	**-**	**-**	**-**	**--**	**-**	**-**
Mitrella lunata	**-**	**--**	**-**	**-**	**-**	**-**
Nassarius trivittatus	**-**	**-**	**--**	**-**	**-**	**-**
Retusa canaliculata	**-**	**-**	**-**	**-**	**-**	**--**

Crepidula fornicata	--	-	-	--	-	--
Crepidula plana	--	-	-	-	-	-
Nudibranchia	**1**	-	-	-	-	-
Bivalvia						
Macoma baltica	-		-	-	**1**	
Tellina agilis	-	**1**	-	-	-	-
Mulinia lateralis	-	-	-	-	-	-
Petricola pholadiformis	-	-	-	-	-	-
Gemma gemma	-	**3**	**2**	**6**	**8**	**47**
Lyonsia hyalina	-	-	-	-	-	-
Solemya velum	-	-	-	-	-	-
Anadara transversa	-	-	-	-	-	-
Arthropoda						
Amphipoda						
Ampelisca abdita	**4**	**9**	**12**	**34**	**46**	**15**
Ampelisca sp.	-	**3**	-	-	-	-
Listriella barnardi	-	-	-	-	-	-
Leptocheirus pinguis	-	-	-	**1**	-	-
Corophium tuberculatum	-	-	-	-	**3**	-
Microdeutopus anomalus	-	-	-	**4**	-	-
Microdeutopus gryllotalpa	-	-	**1**	**6**	-	-
Ericthonius brasiliensis	-	-	-	-	-	-
Caprella sp.	-	-	-	-	-	-
Elasmopus levis	-	-	-	-	-	-
Erichsonella filiformis	-	-	-	-	-	-
Trichophoxus epistomis	-	-	-	-	-	-
Microprotopus raneyi	-	-	-	-	-	-
Gammarus mucronatus	-	-	-	-	-	-
Paraphoxus spinosa	-	-	-	-	-	-
						-
Decapoda						
Pagurus longicarpus	-	-	-	-	-	**4**
Dyspanopeus sayi	-	-	-	-	-	-
Crangon septemspinosa	-	-	-	-	-	**4**
Callianassa atlantica	-	-	-	-	-	-
Isopoda						
Edotea triloba	-	-	-	-	-	-
Cyathura polita	-	-	-	-	-	-
Cumacea						
Leucon americana	--	-	-	--	1	-
TOTALS	**#7**	**#8**	**#9**	**#10**	**#11**	**#12**
Number of Species	**10**	**12**	**11**	**14**	**11**	**13**
Number of Individuals	**194**	**264**	**115**	**275**	**249**	**323**

Table 2. Macrobenthic Community Structure of Shallow Water Habitats of Four Mile River (Old Lyme,CT) **REGION II** (Number/0.04m^2) (Stations 13-18)

TAXON	STATION NUMBER					
	#13	#14	#15	#16	#17	#18
Annelida						
Polychaeta						
Leitoscoloplos robustus	22	59	51	32	72	24
Mediomastus ambiseta	3	168	124	-	17	12
Streblospio benedicti	26	285	189	29	79	7
Heteromastus filiformis	-	-	-		--	-
Eteone longa	-	1	2	3	-	-
Scoletoma tenuis	13	37	15	9	18	-
Phyllodoce mucosa	-	--	--	-	4	-
Phyllodoce arenae	-	1	1	-	-	-
Cossura longocirrata	-	--	-	--	-	--
Polydora cornuta	-	1	-	--	-	-
Polydora ligni	-		-	1	--	-
Spio setosa	-	-	-	-	-	-
Harmothoe imbricata	--	--	-	-	--	-
Hediste diversicolor	1	--	-	5	2	3
Attlia succinea	2	2	3	-	2	-
Tharyx acutus	--	--	3	2	-	1
Pilargiidae	-	-	-	-	-	-
Acmira spp.	3	-	-		-	-
Magelona spp.	-	-	-	-	-	-
Nephtys incisa	-	-	-	-	-	-
Pectinaria gouldii	-	-	5	1	3	2
Glycera capitata	-	-	-	-	-	-
Spioniidae	-	-	-	-	-	-
Marenzelleria viridis	-	-	-	-	-	-
Autolytus spp.	-	-	-	-	-	-
Capitella capitata	-	3	68	6	5	9
Goniadella gracilis	-	-	-	-	-	-
Podarke obscura	-	-	-	-	-	-
Asabellides oculata	-	-	-	-	-	-
Drilonereis longa	-	-	-	-	-	-
Oligochaete sp.						
Paranais sp.	16	373	316	41	104	140
Rhynchocoela						
Nemertean spp.	-	-	1	-	-	1
Cerebratulus sp.	-	1	-	-	-	-
Mollusca						
Gastropoda						
Urosalpinx cinerea	-	-	1	-	-	-
Acteon punctostriatus	-	-	-	--	-	1
Mitrella lunata	-	--	-	-	-	-
Nassarius trivittatus	-	-	1	-	-	-
Retusa canaliculata	-	-	-	-	-	-

Crepidula fornicata	--	-	-	--	-	-
Crepidula plana	--	-	-	-	-	-
Nudibranchia	-	-	-	-	-	-
Bivalvia						
Macoma baltica	-	-	-	-	-	-
Tellina agilis	-	-	-	**4**	**2**	**3**
Mulinia lateralis	-	-	-	-	-	-
Petricola pholadiformis	-	-	-		-	-
Gemma gemma	-	**11**	**13**	**3**	**14**	**50**
Lyonsia hyalina	-	-	-	-	-	-
Solemya velum	-	-	-	-	-	-
Anadara transversa	-	-	-	-	-	-
Arthropoda						
Amphipoda						
Ampelisca abdita	**2**	**4**	**3**	-	**21**	**1**
Ampelisca sp.	-	**1**	-	-	-	-
Listriella barnardi	-	**9**	**3**	-	**3**	-
Leptocheirus pinguis	-	-	-	-	-	-
Corophium tuberculatum	-	-	-	-	-	-
Microdeutopus anomalus	-	-	-	-	-	-
Microdeutopus gryllotalpa	-	-	-	-	**1**	-
Ericthonius brasiliensis	-	-	-	-	-	-
Caprella sp.	-	-	-	-	-	-
Elasmopus levis	-	-	-	-	-	-
Erichsonella filiformis	**1**	-	-	-	-	-
Trichophoxus epistomis	**1**	-	**1**	-	-	-
Microprotopus raneyi	-	-	**3**	-	-	-
Gammarus mucronatus	-	-	-	**1**	-	-
Paraphoxus spinosa	-	-	-	-	-	-
Decapoda						
Pagurus longicarpus	-	-	**3**	-	-	-
Dyspanopeus sayi	-	-	**3**	-	-	-
Crangon septemspinosa	-	-	-	-	-	-
Callianassa atlantica	-	-	-	**3**	-	-
Isopoda						
Edotea triloba	-	-	-	-	-	-
Cyathura polita	-	-	-	-	-	-
Cumacea						
Leucon americana	--	-	-	--	-	-
TOTALS	**#13**	**#14**	**#15**	**#16**	**#17**	**#18**
Number of Species	**11**	**15**	**21**	**14**	**15**	**13**
Number of Individuals	**90**	**956**	**809**	**140**	**347**	**254**

Table 2a. Macrobenthic Community Structure of Shallow Water Habitats of Four Mile River (Old Lyme, CT) **REGION II** (Number/0.04m^2) (Stations 19-25)

TAXON	STATION NUMBER						
	#19	#20	#21	#22	#23	#24	#25
Annelida							
Polychaeta							
Leitoscoloplos robustus	43	36	34	12	34	47	89
Mediomastus ambiseta	-	-	-	11	12	-	-
Streblospio benedicti	13	58	19	31	23	32	31
Heteromastus filiformis	-	-	-	-	--	-	-
Eteone longa	-	7	-	-	2	6	1
Scoletoma tenuis	2	-	-	2	9	1	-
Phyllodoce mucosa	-	--	--	-	--	-	-
Phyllodoce arenae	-	--	--	-	-	-	1
Cossura longocirrata	-		-	--	-	--	-
Polydora cornuta	-	-	-	--	-	-	-
Polydora ligni	-	-	-	-	--	-	-
Spio setosa	-	-	-	-	-	-	-
Harmothoe imbricata	--	-	-	-	--	-	-
Hediste diversicolor	1	3	2	1	10	9	1
Attlia succinea	2	-	3	2	-	-	3
Tharyx acutus	6	--	-	2	10	-	-
Pilargiidae	-	-	-	-	-	-	-
Acmira spp.	-	-	-	-	-	-	-
Magelona spp.	1	-	-	-	-	-	-
Nephtys incisa	-	-	-	-	-	-	3
Pectinaria gouldii	4	9	1	4	5	9	3
Glycera capitata	-	1	-	4	3	1	-
Spioniidae	-	-	-	1	-	-	-
Marenzelleria viridis	-	-	-	12	-	-	-
Autolytus spp.	-	-	-	1	1	-	-
Capitella capitata	17	62	43	1	13	101	59
Goniadella gracilis	-	-	-	-	1	-	-
Podarke obscura	-	-	-	-	1	-	-
Asabellides oculata	-	-	-	-	-	1	-
Drilonereis longa	-	-	-	-	-	-	-
Oligochaete sp.						--	
Paranais sp.	88	124	58	37	31	106	39
Rhynchocoela							
Nemertean spp.	-	-	1	-	1	1	2
Cerebratulus sp.	-	-	-	2	1	-	-
Mollusca							
Gastropoda							
Urosalpinx cinerea	-	-	-	-	-	--	-

Acteon punctostriatus	-	-	-	--	-	1	--
Mitrella lunata	-	--	-	-	-	-	-
Nassarius trivittatus	-	-	--	-	-	-	-
Retusa canaliculata	-	1	-	-	-	--	--
Crepidula fornicata	--	-	-	--	--	--	-
Crepidula plana	--	-	-	-	5	-	-
Nudibranchia	-	-	-	-	-	-	-
Bivalvia						--	
Macoma baltica	-	-	-	-	-	-	-
Tellina agilis	3	-	2	3	1	1	-
Mulinia lateralis	1	-	-	1	-	-	-
Petricola pholadiformis	-	1	-	-	-	-	-
Gemma gemma	8	4	1	21	37	97	8
Lyonsia hyalina	-	-	-	-	1	-	-
Solemya velum	-	-	-	-	1	-	-
Anadara transversa	-	-	-	-	-	-	-
Arthropoda							
Amphipoda							
Ampelisca abdita	-	53	-	-	9	41	5
Ampelisca sp.	-	-	-	-	-	-	-
Listriella barnardi	-	-	-		-	-	-
Leptocheirus pinguis	-	3	-	-		-	-
Corophium tuberculatum	-	-	-	1	-	-	-
Microdeutopus anomalus	-	-	-	-	-	-	-
Microdeutopus gryllotalpa	3	1	2	2	8	9	1
Ericthonius brasiliensis	-	-	-	-	-	-	-
Caprella sp.	-	-	-	-	-	-	-
Elasmopus levis	2	-	-	-	1	-	-
Erichsonella filiformis	-	-	-	-	1	-	1
Trichophoxus epistomis	-	-	-	-	-	-	-
Microprotopus raneyi	-	9	-	-	2	-	-
Gammarus mucronatus	-	-	1	-	2	-	-
Paraphoxus spinosa	-	-	-	-	-	-	-
Decapoda							
Pagurus longicarpus	-	-	-	-	1	2	-
Dyspanopeus sayi	-	-	-	-	1	-	-
Crangon septemspinosa	1	-	-	-	-	-	-
Callianassa atlantica	-	-	-	-	3	3	1
Isopoda							
Edotea triloba	-	1	-	-	-	-	-
Cyathura polita	-	1	-	-	-	-	-
Cumacea							
Leucon americana	--	-	-	-	-	-	-
TOTALS	**#19**	**#20**	**#21**	**#22**	**#23**	**#24**	**#25**
Number of Species	**16**	**17**	**11**	**21**	**30**	**18**	**18**
Number of Individuals	**195**	**374**	**166**	**145**	**230**	**470**	**248**

Table 3. Macrobenthic Community Structure of Shallow Water Habitats of Four Mile River (Old Lyme, CT) **REGION III** (Number/0.04m^2) (Stations 26-32)

TAXON	**STATION NUMBER**						
	#26	**#27**	**#28**	**#29**	**#30**	**#31**	**#32**
Annelida							
Polychaeta							
Leitoscoloplos robustus	**16**	**5**	**18**	**65**	**48**	**17**	**18**
Mediomastus ambiseta	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Streblospio benedicti	**11**	**10**	**-**	**14**	**-**	**-**	**-**
Heteromastus filiformis	**-**	**-**	**-**	**-**	**--**	**-**	**-**
Eteone longa	**-**	**--**	**-**	**1**	**-**	**-**	**-**
Scoletoma tenuis	**4**	**-**	**-**	**2**	**-**	**-**	**-**
Phyllodoce mucosa	**-**	**--**	**--**	**-**	**--**	**-**	**-**
Phyllodoce arenae	**-**	**--**	**--**	**-**	**-**	**-**	**-**
Cossura longocirrata	**-**	**-**	**-**	**--**	**-**	**--**	**-**
Polydora cornuta	**-**	**-**	**-**	**--**	**-**	**-**	**-**
Polydora ligni	**-**	**-**	**-**	**-**	**--**	**-**	**-**
Spio setosa	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Harmothoe imbricata	**--**	**-**	**-**	**-**	**--**	**1**	**-**
Hediste diversicolor	**--**	**--**	**-**	**-**	**--**	**-**	**-**
Attlia succinea	**9**	**2**	**-**	**1**	**-**	**1**	**-**
Tharyx acutus	**--**	**1**	**-**	**-**	**-**	**-**	**-**
Pilargiidae	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Acmira spp.	**-**	**-**	**2**	**4**	**1**	**-**	**4**
Magelona spp.	**-**	**6**	**8**	**12**	**7**	**2**	**10**
Nephtys incisa	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Pectinaria gouldii	**-**	**-**	**-**	**-**	**1**	**-**	**-**
Glycera capitata	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Spioniidae	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Marenzelleria viridis	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Autolytus spp.	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Capitella capitata	**2**	**-**	**5**	**-**	**-**	**-**	**3**
Goniadella gracilis	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Podarke obscura	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Asabellides oculata	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Drilonereis longa	**-**	**-**	**-**	**1**	**-**	**-**	**-**
Oligochaete sp.						**--**	
Paranais sp.	**13**	**16**	**-**	**33**	**2**	**5**	**-**
Rhynchocoela							
Nemertean spp.	**1**	**-**	**-**	**-**	**-**	**-**	**-**
Cerebratulus sp.	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Mollusca							
Gastropoda							
Urosalpinx cinerea	**-**	**-**	**-**	**-**	**-**	**--**	**-**
Acteon punctostriatus	**-**	**-**	**-**	**--**	**-**	**-**	**-**

Mitrella lunata	-	--	-	-	-	-	1
Nassarius trivittatus	-	1	--	-	1	-	2
Retusa canaliculata	-	-	-	-	-	--	-
Crepidula fornicata	6	-	-	--	--	--	-
Crepidula plana	--	-	-	-	-	-	-
Nudibranchia	-	-	-	-	-	-	-
Bivalvia						--	
Macoma baltica	-	-	-	-	-	-	-
Tellina agilis	1	6	-	2	-	3	5
Mulinia lateralis	-	-	-	-	-	-	-
Petricola pholadiformis	-	-	-	-	-	-	-
Gemma gemma	3	8	1	2	2	-	-
Lyonsia hyalina	-	-	-	-	-	-	-
Solemya velum	-	1	-	-	-	-	-
Anadara transversa	1	-	-	-	-	-	-
Arthropoda							
Amphipoda							
Ampelisca abdita	-	-	1	-	-	-	-
Ampelisca sp.	-	-	-	-	-	-	-
Listriella barnardi	-	-	-	-	-	-	-
Leptocheirus pinguis	-	-	-	-	-	-	-
Corophium tuberculatum	-	-	-	-	-	-	-
Microdeutopus anomalus	4	-	-	-	-	-	-
Microdeutopus gryllotalpa	7	-	-	-	-	-	-
Ericthonius brasiliensis	1	-	-	-	-	-	-
Caprella sp.	2	-	-	-	-	-	-
Elasmopus levis	-	-	-	-	-	-	-
Erichsonella filiformis	-	-	-	-	-	-	-
Trichophoxus epistomis	-	-	-	-	1	1	3
Microprotopus raneyi	5	-	-	-	-	-	-
Gammarus mucronatus	-	-	-	-	-	-	-
Paraphoxus spinosa	-		-	-	-	4	1
Decapoda							
Pagurus longicarpus	2	-	1	1	-	-	-
Dyspanopeus sayi	-	-	-	-	-	-	-
Crangon septemspinosa	-	-	-	-	-	-	-
Callianassa atlantica	-	-	-	-	-	-	-
Isopoda							
Edotea triloba	-	-	-	-	-	-	-
Cyathura polita	-	-	-	-	-	-	-
Cumacea							
Leucon americana	1	-	-	1	-	-	-
TOTALS	**#26**	**#27**	**#28**	**#29**	**#30**	**#31**	**#32**
Number of Species	**18**	**10**	**7**	**13**	**8**	**8**	**9**
Number of Individuals	**89**	**58**	**36**	**141**	**64**	**34**	**47**

Table 4. Macrobenthic Community Structure of Shallow Water Habitats of the Black Hall River (Old Lyme, CT) **REGION I** & **II** (Number/0.04m^2) (Stations 1-6)

TAXON	**STATION NUMBER**					
	#1	**#2**	**#3**	**#4**	**#5**	**#6**
Annelida						
Polychaeta						
Leitoscoloplos robustus	6	20	26	39	46	45
Mediomastus ambiseta	-	4	-	21	-	-
Streblospio benedicti	28	281	426	148	243	221
Heteromastus filiformis	1	2	5	2	--	-
Eteone longa	-	3	2	3	2	2
Scoletoma tenuis	-	-	-	-	-	-
Phyllodoce mucosa	-	--	--	1	--	-
Phyllodoce arenae	-	--	--	-	-	-
Cossura longocirrata	-	--	-	--	-	--
Polydora cornuta	33	29	4	2	-	-
Polydora ligni	-	-	-	-	--	3
Spio setosa	-	-	-	-	-	-
Harmothoe imbricata	--	--	-	-	--	-
Hediste diversicolor	2	4	5	2	1	2
Attlia succinea	1	13	-	-	-	-
Tharyx acutus	3	4	-	--	-	1
Ampharete americana	1	-	-	-	-	-
Acmira spp.	-	-	-	-	-	-
Pygospio elegan	-	-	16	-	3	-
Nephtys incisa	-	-	-	-	-	-
Pectinaria gouldii	-	-	-	-	1	1
Glycera capitata	-	-	-	1	1	-
Glycera americana	-	-	-	-	-	1
Paraonis fulgens	-	-	-	-	-	-
Marenzelleria viridis	-	22	141	158	68	-108
Autolytus spp.	-	-	-	-	-	-
Capitella capitata	-	-	-	8	16	2
Clymenella sp.	-	-	-	1	-	-
Clymenella mucosa	-	-	-	-	-	4
Spiochaetopterus oculatus	-	-	-	-	2	-
Sabella micropthalma	-	-	-	-	-	-
Sabellaria vulgaris	-	-	-	-	-	-
Diopatra cuprea	-	-	-	-	-	-
Oligochaete sp.						--
Paranais sp.	6	64	-181	102	69	93
Oligochaete B	**1**	-	-	-	-	-
Phoronida						
Phoronis sp.	-	1	-	-	-	-
Rhynchocoela						
Nemertean spp.	1	-	1	-	-	1
Cerebratulus sp.	-	-	1	1	1	1
Mollusca						
Gastropoda						
Urosalpinx cinerea	-	-	-	-	-	-
Acteon punctostriatus	-	1	-	--	-	-
Mitrella lunata	-	--	-	-	-	-
Nassarius trivittatus	-	-	--	-	-	-

Retusa canaliculata	-	-	-	-	-	--
Crepidula fornicata	--	-	-	--	--	--
Crepidula plana	--	-	-	-	-	-
Cylichna sp.	-	-	-	-	-	-
Odostomia seminude	-	-	-	-	-	-
Nudibranchia	-	-	-	-	-	-
Acanthodoris pilosa	-	-	-	-	-	-
Bivalvia						
Tellina agilis	-	-	-	4	4	10
Tellina truncata	-	-	-	-	-	-
Mulinia lateralis	-	-	-	-	-	1
Gemma gemma	1	42	59	10	7	3
Lyonsia hyalina	-	-	-	-	-	-
Crassostrea virginica	--	1	-	-	-	-
Siliqua costata	-	-	-	-	-	-
Mya arenaia	-	-	-	-	-	-
Ensis directus	-	-	-	-	-	-
Arthropoda						
Amphipoda						
Ampelisca abdita	--	3	6	-	-	1
Ampelisca vadorum	-	-	-	-	-	-
Corophium ascheriscum	1	-	-	-	-	-
Microdeutopus anomalus	-	-	-	-	-	-
Microdeutopus gryllotalpa	-	-	-	-	-	3
Micropthalmus sczelkowii	-	-	-	-	-	-
Lembos smthi	-	1	3	-	-	-
Elasmopus levis	-	-	-	-	-	-
Melita dentata	-	-	-	-	-	-
Unciola irrorata	-	-	-	-	-	-
Ampithoe longimana	-	-	-	-	-	-
Decapoda						
Pagurus longicarpus	-	-	-	-	-	-
Dyspanopeus sayi	-	-	-	-	-	-
Pinnixa sp.	-	-	-	-	-	-
Isopoda						
Edotea triloba	-	-	**5**	-	-	-
Cyathura polita	-	4	51	3	-	-
Cumacea						
Leucon americana	--	1	-	--	-	-
Dyastilis sculpta	-	1	-	1	1	-
Oxyurostylus smithi	-	-	-	-	1	-
TOTALS	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**
Number of Species	**13**	**20**	**16**	**18**	**17**	**19**
Number of Individuals	**87**	**501**	**932**	**507**	**477**	**503**

Table 4a. Macrobenthic Community Structure of Shallow Water Habitats of the Black Hall River (Old Lyme, CT) **REGION I & II** (Number/0.04m^2) (Stations 7-12)

TAXON	**STATION NUMBER**					
	#7	**#8**	**#9**	**#10**	**#11**	**#12**
Annelida						
Polychaeta						
Leitoscoloplos robustus	39	87	108	70	14	46
Mediomastus ambiseta	28	40	47	17	115	11
Streblospio benedicti	125	326	432	280	-	169
Heteromastus filiformis	-	-	-	-	--	-
Eteone longa	-	3	4	2	-	3
Scoletoma tenuis	-	-	-	-	-	-
Phyllodoce mucosa	-	--	--	-	--	-
Phyllodoce arenae	-	1	--	3	-	-
Polydora cornuta	3	2	17	9	-	2
Polydora ligni	-	-	-	-	--	-
Spio setosa	-	-	-	-	-	-
Harmothoe imbricata	--	--	-	-	--	-
Hediste diversicolor	-	1	5	2	-	-
Attlia succinea	2	-	-	-	-	-
Tharyx acutus	4	3	4	5	-	2
Ampharete americana	-	-	-	-	-	-
Acmira spp.	-	-	-	-	-	-
Pygospio elegan	-	-	-	-	-	1
Nephtys incisa	2	1	-	1	1	1
Pectinaria gouldii	-	1	-	1	-	-
Glycera capitata	-	1	-	-	-	-
Glycera americana	2	-	-	-	-	-
Paraonis fulgens.	-	5	-	-	-	-
Marenzelleria viridis	108	17	1	3	4	13
Autolytus spp.	-	-	-	-	-	-
Capitella capitata	-	-	-	12	-	5
Clymenella sp.	1	-	-		-	-
Clymenella mucosa	2	-	1	3	-	-
Spiochaetopterus oculatus	-	-	-	-	-	--1
Sabella micropthalma	-	-	-	-	-	-
Sabellaria vulgaris	-	-	-	-	-	-
Diopatra cuprea	-	-	-	-	-	-
Oligochaete sp.						--
Paranais sp.	46	63	146	126	34	96
Oligochaete B	-	-	-	-	-	-
Phoronida						
Phoronis sp.	-	-	-	-	-	-
Rhynchocoela						
Nemertean spp.	-	3	-	1	-	7
Cerebratulus sp.	1	-	1	-	-	-
Mollusca						
Gastropoda						
Urosalpinx cinerea	-	-	-	-	-	-
Acteon punctostriatus	-	-	-	--	1	-
Odostomia seminude	-	--	-	-	-	-
Nassarius trivittatus	-	-	--	-	-	-
Retusa canaliculata	1	-	1	-	3	--
Crepidula fornicata	--	-	-	--	--	--
Crepidula plana	--	-	-	-	-	-

Cylichna sp.	-	-	1	-	-	-
Crepidula convexa	-	-	-	-	-	-
Nudibranchia	-	-	-	-	-	-
Acanthodoris pilosa	-	-	-	-	-	1
Bivalvia						
Tellina agilis	6	4	2	2	1	2
Tellina truncata	1	-	-	-	-	-
Mulinia lateralis	-	-	-	-	-	-
Gemma gemma	31	13	29	8	17	2
Lyonsia hyalina	-	-	-	-	-	-
Crassostrea virginica	--			-	-	-
Siliqua costata	1	-	-	-	-	-
Ensis directus	-	-	1	-	-	-
Mya arenaria	-	1	-	-	-	-
Arthropoda						
Amphipoda						
Ampelisca abdita	4	9	16	2	7	3
Ampelisca vadorum	-	-	3	-	-	-
Corophium ascheriscum	-	-	-	-	-	-
Microdeutopus anomalus	-	-	1	-	-	-
Microdeutopus gryllotalpa	-	-	1	10	-	3
Microphalmus sczelkowii	-	-	1	-	-	
Lembos smthi	1	-	-	-	8	-
Elasmopus levis	-	-	-	-	-	-
Melita dentata	-	1	-	-	-	1
Unciola irrorata	-	-	-	-	-	-
Ampithoe longimana	-	-	-	-	-	-
Decapoda						
Pagurus longicarpus	-	-	-	-	-	-
Dyspanopeus sayi	-	-	-	-	-	-
Pinnixia sp.	-	-	-	-	-	-
Isopoda						
Edotea triloba	**1**	**-**	**1**	**-**	**-**	**1**
Cyathura polita	-	-	-		-	-
Cumacea						
Leucon americana	1	-	-	--	-	-
Dyastilis sculpta	-	-	4	-	1	-
Oxyurostylus smithi	-	-	-	-	-	-
TOTALS	**#7**	**#8**	**#9**	**#10**	**#11**	**#12**
Number of Species	**22**	**20**	**24**	**19**	**12**	**20**
Number of Individuals	**413**	**582**	**810**	**557**	**208**	**370**

Table 4b. Macrobenthic Community Structure of Shallow Water Habitats of the Black Hall River (Old Lyme, CT) **REGION I & II** (Number/0.04m^2) (Stations 13-20)

TAXON	**STATION NUMBER**							
	#13	**#14**	**#15**	**#16**	**#17**	**#18**	**#19**	**#20**
Annelida								
Polychaeta								
Leitoscoloplos robustus	48	14	25	12	24	58	65	14
Mediomastus ambiseta	62		13	-	-	41	57	5
Streblospio benedicti	387	84	99	102	177	382	93	48
Heteromastus filiformis	-	-	-	-	--	-	-	-
Eteone longa	4	-	2	-	-	1	4	-
Scoletoma tenuis	-	-	-	-	-	3	2	-
Phyllodoce mucosa	-	--	--	-	--	3	7	-
Phyllodoce arenae	-	--	--	-	-	-	-	-
Polydora cornuta	9	20	1	-	-	1	1	-
Polydora ligni	-	-	-	1	--	-	-	-
Spio setosa	-	-	-	-	-	-	-	-
Harmothoe imbricata	--	--	-	-	--	-	-	-
Hediste diversicolor		2		1	1	-	1	-
Attlia succinea	3	3	-	1	2	1	-	-
Tharyx acutus	2	-	-	-	2	13	6	-
Ampharete americana	-	-	-	-	-	-	-	-
Acmira spp.	-	-	-	-	-	2	2	-
Pygospio elegans	1	2	-	-	-	1	2	-
Nephtys incisa	1	-	-	-	-	1	-	-
Pectinaria gouldii	-	-	-	-	1	1	3	2
Glycera capitata	1	-	-	-	-	2	3	-
Glycera americana	-	-	-	-	-	-	-	-
Paraonis fulgens	-	-	-	-	-	-	-	-
Marenzelleria viridis	43	39	38	-	-	4	1	-
Autolytus spp.	-	-	-	-	-	-	-	-
Capitella capitata	3	-	-	-	2	52	21	-
Clymenella sp.	-	-	-	-	-	1	-	-
Clymenella mucosa	-	-	-	-	1	-	-	-
Spiochaetopterus oculatus	-	-	-	-	-	-	-	-
Sabella micropthalma	-	-	-	-	-	-	-	-
Sabellaria vulgaris	-	-	-	-	-	-	-	-
Diopatra cuprea	-	-	-	-	-	-	-	-
Oligochaete sp.								
Paranais sp.	69	31	32	34	56	211	232	85
Oligochaete B	-	-	-	-	-	-	-	-
Phoronida								
Phoronis sp.	-		-	2	-	-	-	4
Rhynchocoela								
Nemertean spp.	1	-	-	-	-	-	2	1
Cerebratulus sp.	1	-	-	1	-	1	2	-
Mollusca								
Gastropoda								
Urosalpinx cinerea	-	-	-	-	-	-		

Acteon punctostriatus	-		-	--		-	1	-
Mitrella lunata	-	--	-	-	-	-	-	-
Nassarius trivittatus	-	-	--	-	-	-	-	-
Retusa canaliculata	3	-	1	-	-	2	14	-
Crepidula fornicata	--	-	-	--	--	- -	-	-
Crepidula plana	--	-	-	-	-	-	-	-
Cylichna sp.	1	-	-	-	-	-	-	-
Odostomia seminude	-	-	-	-	-	-	1	-
Crepidula convexa	-	-	-	-	-	-	-	-
Nudibranchia	-	-	-	-	-	-	-	-
Acanthodoris pilosa	-	-	-	-	-	-	-	-
Bivalvia								
Tellina agilis	8	-	2	6	8	11	-	5
Tellina truncata	-	-	-	-	-	-	-	-
Mulinia lateralis	2	-	-	-	-	-	-	-
Gemma gemma	68	36	89	18	5	4	-	3
Lyonsia hyalina	-	-	-	-	-	-	1	-
Crassostrea virginica	--	-	-	-	-	-	-	-
Siliqua costata	-	-	-	-	-	-	-	-
Ensis directus	-	-	-	-	-	1	-	-
Mya arenaria	1	-	-	-	-	-	-	-
Arthropoda								
Amphipoda								
Ampelisca abdita	11	7	4	13	5	3	4	17
Ampelisca vadorum	-	-	-	-	-	-	-	-
Ampithoe longimana	-	-	-	-	-	-	-	-
Corophium ascheriscum	-	-	-	-	-	-	-	-
Microdeutopus anomalus	-	-	-	-	-	-	-	-
Microdeutopus gryllotalpa	13	-	-		-	7	10	-
Microphalmus sczelkowii	-	-	-	-	-	-	-	-
Lembos smthi	-	1	-	2			-	1

					-	-		
Unciola irrorata	-	-	-	-	-	-	-	-
Elasmopus levis	-	-	-	-	-	-	-	-
Melita dentata	-	-	-	-	-	-	-	-
Decapoda								
Pagurus longicarpus	-	-	-	-	-	-	-	-
Dyspanopeus sayi	-	-	-	-	-	-	-	-
Crangon septemspinosa	-	-	-	-	-	-	-	-
Callianassa atlantica	-	-	-	-	-	-	-	-
Pinnixa sp.	-	-	-	-	-	1	-	-
Isopoda								
Edotea triloba	**-**	**-**	**-**	**-**	**-**	**1**	**1**	**1**
Cyathura polita	-		-	-	-	-	-	-
Cumacea								
Leucon americana	-	1	-	--	-	-	-	-
Dyastilis sculpta	1	-		1	-	-	-	-
Oxyurostylus smithi	-	-	-	-	-	-	-	-
TOTALS	**#13**	**#14**	**#15**	**#16**	**#17**	**#18**	**#19**	**#20**
Number of Species	**24**	**11**	**12**	**13**	**13**	**27**	**27**	**12**
Number of Individuals	**743**	**238**	**308**	**194**	**292**	**810**	**578**	**186**

Table 5. Macrobenthic Community Structure of Shallow Water Habitats of the Black Hall River (Old Lyme, CT) **REGION III** (Number/0.04m^2) (Stations 21-26)

TAXON	**STATION NUMBER**					
	#21	**#22**	**#23**	**#24**	**#25**	**#26**
Annelida						
Polychaeta						
Leitoscoloplos robustus	8	11	16	-	-	-
Mediomastus ambiseta	-	-	-	-	-	-
Streblospio benedicti	73	51	86	27	--	8
Heteromastus filiformis	-	-	-	-	--	-
Eteone longa	1	1	2	1	-	-
Scoletoma tenuis	-	-	-	-	-	-
Phyllodoce mucosa	-	--	--	-	--	-
Phyllodoce arenae	-	--	--	-	-	-
Polydora cornuta	-	4	-	-	-	-
Polydora ligni	-	-	2	-	--	1
Spio setosa	-	-	-	1	-	-
Harmothoe imbricata	--	--	-	-	--	-
Hediste diversicolor	1	-		-	-	
Attlia succinea	-	2	9	12	-	2
Tharyx acutus	-	-	1	6	-	-
Ampharete americana	-	-	-	-	-	-
Acmira spp.	-	-	-	-	-	-
Pygospio elegan	-	-	-	-	-	-
Nephtys incisa	-	-	-	-	-	-
Pectinaria gouldii	1	-	-	1	-	-
Glycera capitata	-	-	-	-	-	-
Glycera americana	-	-	1	1	-	-
Paraonis fulgens	-	-	-	-	-	-
Marenzelleria viridis	45	11	4	3	-	-
Autolytus spp.	-	1	2	19	4	-
Capitella capitata	7	-	-	-	1	-
Clymenella sp.	-	-	-	-	-	-
Clymenella mucosa	-	-		-	-	-
Spiochaetopterus oculatus	-	-	-	-	-	-
Sabella micropthalma	-	-	-	1	-	-
Sabellaria vulgaris	-	-	2	-	-	-
Diopatra cuprea	-	-	-	-	-	-
Oligochaete sp.						--
Paranais sp.	171	79	173	202	3	18
Oligochaete B	-	-	-	-	-	-
Phoronida						
Phoronis sp.	-	-	-	-	-	-
Rhynchocoela						
Nemertean spp.	-	-	-	1	-	-
Cerebratulus sp.	-	-	-	-	-	-
Mollusca						
Gastropoda						
Urosalpinx cinerea	-	-	-	1	-	-
Acteon punctostriatus	-		-	--		-
Mitrella lunata	-	--	-	-	-	-
Nassarius trivittatus	-	-	1	1	-	-

Retusa canaliculata	2	-	-	-		--
Crepidula fornicata	--	-	1	--	4	4
Crepidula plana	--	5	12	11	14	-
Crepidula convexa	-	-	-	2	-	-
Cylichna sp.	-	-	-	-	-	-
Odostomia seminude	-	-	-	-	-	-
Nudibranchia	-	-	-	-	-	-
Acanthodoris pilosa	-	-	-	-	-	-
Bivalvia						
Tellina agilis	2	13	3	3	-	-
Tellina truncata	-	-	-	-	-	-
Mulinia lateralis	-	-	-	-	-	-
Mya arenaria	-	-	-	-	-	-
Gemma gemma	40	7	1	4	1	2
Lyonsia hyalina	-	-	-	-	-	-
Crassostrea virginica	--	-	-	2	1	-
Siliqua costata		-	-	-	-	-
Ensis directus	-	-		-	-	
Arthropoda						
Amphipoda						
Ampelisca abdita	-	-	-	-	-	-
Ampelisca vadorum	6	-	-	-	-	-
Corophium ascheriscum	1	1	4	4	2	-
Microdeutopus anomalus	-	-	4	-	-	-
Microdeutopus gryllotalpa	1	5	2	-	-	-
Microphalmus sczelkowii	-	-		-	-	-
Lembos smthi	-	7	9	14	-	6
Elasmopus levis	-	-	2	12	-	11
Melita dentata	-	-	-	-	6	-
Unciola irrorata	-	-	-	-	-	-
Ampithoe longimana	-	1	5	-	-	9
Decapoda						
Pagurus longicarpus	1	-	1	5	-	-
Dyspanopeus sayi	-	-	3	1	1	-
Pinnixia sp.	-	-	-	-	-	-
Isopoda						
Edotea triloba	-	-	**1**	-	-	-
Cyathura polita	-	3	2	-	-	-
Cumacea						
Leucon americana	4	-	1	1	-	-
Dyastilis sculpta	-	1	2	-	-	-
Oxyurostylis smithi	-	-	-	-	-	-
TOTALS	**#21**	**#22**	**#23**	**#24**	**#25**	**#26**
Number of Species	**16**	**17**	**28**	**25**	**10**	**9**
Number of Individuals	**368**	**203**	**352**	**336**	**37**	**61**

Table 5a. Macrobenthic Community Structure of Shallow Water Habitats of the Black Hall River (Old Lyme, CT) **REGION III** (Number/0.04m^2) (Stations 27-30)

TAXON	**STATION NUMBER**					
	#27	**#28**	**#29**	**#30**	**-----**	**--------**
Annelida						
Polychaeta						
Leitoscoloplos robustus	-	1	3	3	-	-
Mediomastus ambiseta	-	-	-	-	-	-
Streblospio benedicti	-	9	5	-	-	-
Heteromastus filiformis	-	-	-	-	--	-
Eteone longa	-	2	-	-	-	-
Scoletoma tenuis	-	-	-	1	-	-
Phyllodoce mucosa	-	--	--	-	--	-
Phyllodoce arenae	-	--	--	-	-	-
Polydora cornuta	-	-	-	-	-	-
Polydora ligni	-	-	-	-	--	-
Spio setosa	-	-	-	-	-	-
Harmothoe imbricata	--	--	-	-	--	-
Hediste diversicolor	-	-	-	-	-	-
Attlia succinea	-	-	-	-	-	-
Tharyx acutus	-	-	-	5	-	-
Diopatra cuprea	-	-	-	1	-	-
Acmira spp.	-	-	-	-	-	-
Pygospio elegan	-	-	-	-	-	-
Nephtys incisa	-	-	-	-		-
Pectinaria gouldii	-	-	-	-	-	
Glycera capitata	-	-	-	-	-	-
Glycera americana	-	-	-	-	-	
Paraonis fulgens	-	14	-	-	-	-
Marenzelleria viridis	-	-	-	-	-	-
Autolytus spp.	-	-	-	-	-	-
Capitella capitata	-	-	-	-	-	
Clymenella sp.	-	-	-	-	-	-
Clymenella mucosa	-	-	-	-	-	-
Spiochaetopterus oculatus	-	-	-	-	-	-
Sabella micropthalma	-	-	-	-	-	-
Sabellaria vulgaris	2	-	-	-	-	-
Oligochaetes.						
Paranais sp.	-	26	9	48	-	-
Oligochaete B	-	-	-	-	-	-
Phoronida						
Phoronis sp.	-	-	-	-	-	-
Rhynchocoela						
Nemertean spp.	-	-	-	-	-	-
Cerebratulus sp.	-	1	-	-	-	-
Mollusca						
Gastropoda						
Urosalpinx cinerea	-	-	-	-	-	-
Acteon punctostriatus	-	-	-	--	-	-
Mitrella lunata	-	--	-	-	-	-

Nassarius trivittatus	-	-	1	-	-	-
Retusa canaliculata	-	-	-	-	-	--
Crepidula fornicata	9	-	-	6	--	-
Crepidula plana	11	-	-	25	-	-
Crepidula convexa	-	-	-	-	-	-
Cylichna sp.	-	-	-	-	-	-
Odostomia seminude	-	-	-	-	-	-
Nudibranchia	-	-	-	-	-	-
Acanthodoris pilosa	-	-	-	-	-	-
Bivalvia						
Tellina agilis	-	-	-	1	-	-
Tellina truncata	-	-	-	-	-	-
Mulinia lateralis	-	-	-	-	-	-
Gemma gemma	4	20	11	-	-	-
Lyonsia hyalina	-	-	-	-	-	-
Crassostrea virginica	--	-	-	-	-	-
Siliqua costata		-	-	-	-	-
Ensis directus	-	-	-	-	-	-
Mya arenaria	-	-	-	-	-	-
Arthropoda						
Amphipoda						
Ampelisca abdita	-	-	-	3	-	-
Ampelisca vadorum	-	-	-	1	-	-
Corophium ascheriscum	-	-	-	-	-	-
Microdeutopus anomalus	-	-	-	-	-	-
Microdeutopus gryllotalpa	-	-	-	-	-	-
Microphalmus sczelkowii	-	-	-	1	-	-
Lembos smthi	1	1	-	-		-
Elasmopus levis	19	-	-	1	-	-
Melita dentata	-	-	-	-	-	-
Unciola irrorata	-	-	-	1	-	-
Ampithoe longimana	24	-	-	-	-	-
Decapoda						
Pagurus longicarpus	-	-	-	-	-	-
Dyspanopeus sayi	3	-	-	-	-	-
Pinnixia sp.	-	-	-	-	-	-
Isopoda						
Edotea triloba	-	-	**1**	-	-	-
Cyathura polita	-	-	-	-	-	-
Cumacea						
Leucon americana	-	-	-	-	-	-
Dyastilis sculpta	-	-	1	-		-
Oxyurostylus smithi	-	-	-	-	-	-
TOTALS	**#27**	**#28**	**#29**	**#30**	-	-
Number of Species	**8**	**8**	**7**	**13**	-	-
Number of Individuals	**73**	**74**	**31**	**97**	-	-

Table 12 – GPS Coordinates for Four Mile River Stations

Station Number	Latitude	Longitude
1	41 18 25.577	72 15 07.918
2	41 18 24.750	72 15 07.404
3	41 18 23.714	72 15 06.810
4	41 18 22.504	72 15 05.775
5	41 18 21.684	72 15 04.978
6	41 18 20.809	72 15 04.544
7	41 18 19.619	72 15 04.124
8	41 18 18.737	72 15 03.796
9	41 18 17.679	72 15 03.390
10	41 18 16.307	72 15 02.930
11	41 18 15.360	72 15 02.582
12	41 18 14.073	72 15 02.076
13	41 18 12.894	72 15 01.550
14	41 18 11.527	72 15 01.063
15	41 18 09.976	72 15 01.134
16	41 18 08.662	72 15 01.327
17	41 18 07.636	72 15 01.441
18	41 18 06.520	72 15 01.329
19	41 18 05.666	72 15 00.190
20	41 18 04.888	72 15 58.470
21	41 18 04.036	72 15 57.423
22	41 18 03.016	72 15 56.784
23	41 18 01.673	72 15 55.933
24	41 18 00.794	72 15 55.276
25	41 17 59.417	7 2 14 55.216
26	41 17 57.474	72 14 55.371
27	41 17 56.294	72 14 55.371
28	41 17 56.294	72 14 55.371
29	41 17 53.544	72 14 54.094
30	41 17 52.441	72 14 53.533
31	41 17 50.992	72 14 52.913
32	41 17 49.349	72 14 52.082

Table 13 – GPS Coordinates for Black Hall River Stations

Station Number	Latitude	Longitude
1	41 17 21.600	72 18 46.702
2	41 17 19.898	72 18 48.718
3	41 17 18.808	72 18 50.673
4	41 17 17.598	72 18 53.766
5	41 17 16.779	72 18 56.009
6	41 17 15.727	72 18 57.869
7	41 17 14.340	72 18 59.964
8	41 17 12.929	72 19 02.047
9	41 17 11.499	72 19 04.060
10	41 17 09.974	72 19 05.437
11	41 17 08.432	72 19 06.607
12	41 17 06.789	72 19 07.817
13	41 17 05.890	72 19 08.977
14	41 17 04.657	72 19 10.894
15	41 17 03.375	72 19 12.967
16	41 17 01.896	72 19 15.374
17	41 17 00.637	72 19 17.971
18	41 16 59.706	72 19 19.850
19	41 16 58.903	72 19 21.645
20	41 16 58.043	72 19 23.523
21	41 16 55.905	72 19 25.544
22	41 16 53.204	72 19 26.730
23	41 16 50.267	72 19 27.447
24	41 16 47.822	72 19 27.299
25	41 16 46.037	7 2 19 26.728
26	41 16 43.855	72 19 25.480
27	41 16 41.644	72 19 24.039
28	41 16 39.413	72 19 22.727
29	41 16 36.628	72 19 21.057
30	41 16 34.629	72 19 19.880