New York City Economic Development Corporation

West Harlem Waterfront Park
Reef Ball Monitoring

FINAL REPORT

October 2008

HDR | LMS

West Harlem Waterfront Park

Reef Ball Monitoring

Manhattan, NY

- Final Report -

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EXECUTIVE SUMMARY

The rehabilitation of the shoreline through re-development projects like New York City Economic Development Corporation's (NYCEDC) West Harlem Waterfront Park (St. Clair Place to West 135th Street) in Manhattan provides an opportunity for aquatic habitat enhancement. For this project, reef balls were installed in June 2006 just off of the West Harlem Waterfront Park (approximately W 125th Street) to enhance nearshore aquatic habitat values. The installation of reef balls attempted to re-create the ecosystem and habitat provided by natural submerged structures that were once common along the shorelines of the lower Hudson River.

Aquatic biological and physical surveys were conducted in association with the West Harlem Waterfront Project's reef ball habitat enhancement to document conditions before and up to 18 months after the installation of reef balls. These surveys investigated the benthic invertebrate community, the epibenthic community, fish species use, sediment and hydrodynamic conditions on the near shore zone prior to habitat enhancement and within the reef ball field after the enhancement. The surveys demonstrated that submerged artificial structures can mimic natural, hard-substrate habitats by providing substrate to establish communities of epibenthic organisms as well as attracting important transient and migratory fish for feeding and refuge.

In general, benthic and epibenthic community development varied depending on monitoring period throughout the 18 month sampling period with an overall increase in benthic and epibenthic density, taxa richness, and diversity. Species evenness also improved among epibenthic taxa over the course of the 18 month survey. The increase in benthic and epibenthic species density, diversity and the presence of mollusks and chordates living on and around the reef balls indicates the beginning of a complex community structure.

The diver surveys revealed usage of the reef ball habitat by a diverse group of fish and invertebrate species. During the fish survey, spotted hake was first found to be present at the study site, followed by American eel, blue crab, striped bass and tautog by the end of the survey. This suggests a transition from use of habitat by transient fish species to more permanent residents that could utilize the habitat as grounds for spawning, feeding, and protection. The dive survey provided video documentation of habitat utilization by fish species like striped bass and tautog and invertebrates like blue crab and shrimp.

The pre- and post-installation surveys provided baseline information on the effectiveness of reef balls within the study area. These results outlined in this monitoring report demonstrate the successful use of reef balls in shoreline habitat enhancement. The increased epibenthic cover observed on reef balls in the study area should have a positive impact on the further development of benthic and fish populations, thereby leading to increased biomass and overall community structure.

1.0 INTRODUCTION

Shallow water areas and transition zones such as sandy beaches, rocky outcroppings, subtidal oyster reefs, and vegetated intertidal areas were historically found in the lower Hudson River. These structurally complex habitats supported resident fish and invertebrate populations as well as populations of migratory and transient fish species which use these areas for spawning and feeding (Levinton and Waldman 2006). However, intense coastal development and increasing urbanization and industrial use have modified the lower Hudson River, resulting in extensive losses of these complex habitats. Construction of bulkheads, revetments, and docks have hardened the shorelines and eliminated many natural sloping nearshore zones. The lack of aquatic habitat complexity decreases the value and function of these areas and has likely impacted invertebrate and fish populations in the Lower Hudson River.

The rehabilitation of the shoreline through re-development projects like New York City Economic Development Corporation's (NYCEDC) West Harlem Waterfront Park (St. Clair Place to West 135th Street) in Manhattan provides an opportunity for aquatic habitat enhancement. For this project, 50 dome-shaped reef balls were installed in June 2006 just off of the West Harlem Waterfront Park (approximately W 125th Street) to enhance nearshore aquatic habitat values. The installation of reef balls attempted to re-create the ecosystem and habitat provided by natural submerged structures that were once common along the shorelines of the lower Hudson River.

Reef balls are made of marine concrete and are designed to mimic the functions of a natural reef. They are hollow structures, which allows for water to flow through them. Due to the sediment type at the project location, reef balls were placed on the top of submerged piles and were chocked for stabilization and to prevent sinking. They were spaced about forty feet apart to minimize sedimentation and the filling-in of the reef ball.

The goal of aquatic habitat enhancement was to provide additional and/or alternative habitat that would benefit the resident and transient fish communities, as well as the invertebrate community found in the project area. Submerged artificial structures can imitate natural, hard-substrate habitats that attract and are important to many fish and invertebrate species. Clean, hard substrates can quickly become colonized by small stationary or mobile organisms (Meyer and Townsend 2000). Juvenile fish and crab species congregate in these areas, attracted by the structural refuge and foraging opportunities. The presence of this community can attract larger organisms seeking prey, including many important commercial and recreational species, such as striped bass, bluefish, winter flounder, and weakfish. In creating a network of structural habitat along the shoreline, artificial reefs support the movement and expand the distribution of shelter-seeking species or short-lived invertebrate species (Steimle and Zetlin 2000).

In response to Federal, U.S. Army Corp of Engineers (USACE) (Permit No. 2003-00103 Issued October 26, 2005) and state, New York State Department of Environmental Conservation (NYSDEC) (Permit NO. 2-6202-00179/00007 Issued August 15, 2005) permit conditions biological and physical pre-installation and post-installation surveys associated with the reef ball field were conducted from June 2006 through December 2007. This report summarizes the findings of these surveys.

2.0 METHODS

To assess the existing pre-installation conditions, a variety of biological and physical surveys were performed within and surrounding the permitted reef ball field in June of 2006. The reef ball field was installed later that month and is comprised of 50 reef balls spaced approximately 40 feet apart in the shoal habitat in the Hudson River near the West Harlem Waterfront Park along the west side of northern Manhattan (Figure 1). The first post-installation survey was conducted in November 2006 (6-month post-installation), the second post-installation survey was performed in June 2007 (12-month post-installation) and the final post-installation survey was conducted in December2007/January 2008 (18-month post-installation).

2.1 Benthic Invertebrate Survey

To assess the benthic community sediment grab samples were collected within and around the habitat enhancement area during the pre- and post-installation surveys (Figure 2). For each survey, a 0.05 m^2 standard Ponar grab was used to collect two benthic samples at 14 stations (i.e., 28 samples per survey). Each sample was then washed through a 500-µm mesh sieve. For each grab, the station location, survey time/date, weather/oceanographic conditions, water depth, sediment color/odor, grab volume, visual sediment texture and epibenthic fauna/flora were all recorded onsite. Organisms, sediment, and debris retained within the sieve were then placed into a labeled sample bottle and preserved with a 10% buffered formalin solution containing rose bengal stain for laboratory analysis.

In the laboratory, each sample was analyzed for species composition and abundance. Organisms were sorted from the remaining debris, identified by taxonomists and counted. Identifications were made to the lowest practical taxonomic level when not to the species level. Quality control (QC) procedures consisting of a Continuous Sampling Plan (CSP) to assure an Average Outgoing Quality Limit (AOQL) of ≤ 0.10 ($\geq$90%) were followed during sample sorting, enumeration and identification.

Benthic organisms were divided into three common groups: Annelids, Arthropods and Mollusks. All other organisms were grouped into the miscellaneous category which includes Chordates, Nemerteans, Sponges, etc.

2.1.1 Data Analysis - Benthic Invertebrate Survey

Benthic community biodiversity was assessed through calculation of taxa richness, Shannon-Wiener Index, and evenness (or equitability) from the benthic grab data. The index was calculated for each sample collected at each station.

Taxa richness is a measure of the total number of taxa collected in a sample. In counting the number of taxa present, general taxonomic designations at the generic, familial, and higher taxonomic levels were dropped if there was one valid lower-level designation for that group. For example, if *Leitoscoloplos* sp., *Leitoscoloplos fragilis*, and *Leitoscoloplos robustus* were all identified in one sample, then *Leitoscoloplos* sp. was skipped when counting the number of taxa. The number of taxa recorded in this example would be two.

The Shannon-Wiener Diversity Index (*H'*) is a widely used species diversity index. It provides more information about the benthic community structure than taxa richness because it takes into account the relative abundance of each taxa as well as taxa richness. The diversity index *H′* can range between values of 0 and 4. Low values of *H′* indicate low taxa richness and an uneven distribution of abundance among species while high values indicate high taxa richness and an even distribution of abundance among taxa. Typically, a healthy benthic macro-invertebrate community would have a high *H′* value. The index is computed as follows:

$$H' = -\sum_{i=1}^{s} (p_i)(Log_2 p_i)$$

where *S* is the total number of species per sample (i.e., taxa richness) and p_i is the proportion of total individuals in the i^{th} species. Mathematically, p_i is defined as n_i/N where n_i is the number of individuals of a taxa in a sample and *N* is the total number of individuals of all taxa in the sample.

The Evenness (E; or equitability) measures the distribution among species within the community by scaling one of the diversity measures relative to its maximal possible value. The evenness can range from 0 (uneven distribution) to 1 (even distribution). It is computed as follows:

$$E = \frac{H'}{H'_{\max}}$$

where *H'* is the observed diversity (as cited above) and H'_{max} is the logarithm of the total number of taxa (*S*) in the sample ($H'_{max} = Log_2 S$).

2.2 Epibenthic Survey

For the post-installation surveys, a sub-sample of 12 reef balls were sampled by divers (Figure 3). The reef balls were chosen to represent various water depth strata and spatial locations within the habitat enhancement area. The locations of the reef balls were recorded with a Trimble DGPS unit and marked with buoys so that divers could easily locate each reef ball during subsequent surveys.

Epibenthic samples were collected using a suction sampler (Figure 4). The suction sampler was used to collect organisms scraped off the reef ball by the diver into a 500µm nylon mesh net. In the suction sampler, a fast stream of water was driven through a wide pipe, which created a strong current of water through the mouth of the pipe. When the mouth of the pipe was placed near the reef ball during scraping, the particles that were scraped loose became entrained through the sampler and into an attached 500-µm mesh collection bag. Two scrapings were collected from each reef ball using a standard scraper; one (1) scraping was near the top of the reef ball and the other near the bottom. The two scrapings from each reef ball were combined into one sample. The scraping area was standardized to a 0.127-meter by 0.127-meter square area on top and bottom for a total scraping area of 0.032 m^2. All epibenthic densities were then standardized to a 1.0 m^2 area.

After each sample was collected, the suction sampler was brought to the surface. Samples were washed down into a labeled container and preserved with 10% Formalin solution containing rose bengal stain for later laboratory analysis. In the laboratory, each sample was analyzed for species composition and abundance in a technique identical to those described earlier for the benthic invertebrate survey.

Epibenthic organisms were divided into three common groups: Annelids, Arthropods and Mollusks. All other organisms were grouped into the Miscellaneous category which includes Chordates, Nemerteans, Sponges, etc.

2.3 Fisheries Survey

2.3.1 Fish Traps

To characterize the existing and post-installation juvenile and adult fish community, wire-mesh fish traps were set for a 24-hour period within the vicinity of the habitat enhancement area (Figure 5). Each rectangular trap measured 24-inches x 24-inches x 12-inches (height) and consisted of ¼-inch wire mesh. For the pre-installation survey, eight traps were set randomly at the study area. For the post-installation surveys, 14 traps of the same dimension were set during the 6-month and 12-month post-installation surveys, and 12 traps were set during the 18-month post-installation survey (Figure 5). Trap numbers varied as some traps were lost or damaged during the survey. For each survey, half the traps were baited and the other half were left unbaited. A DGPS location was recorded at each station and each trap was rigged with a float line and buoy.

At the end of the 24-hour sampling period, the traps were retrieved and the catch was sorted according to species. Each fish or blue crab was counted and measured for total length (TL) or carapace width (CW) to the nearest millimeter. If a species' catch was sub-sampled (i.e., random selection of 50 individuals for each species), then the volume of both the sub-sample and the full collection were recorded. Collections of small invertebrates, such as shrimp, mud crabs or tube worms were also noted.

2.3.2 Dive Survey & Video Analysis

Due to the transient nature of some species and the constraints imposed on the use of active fishing gear (trawls) by the presence of the reef balls, visual assessments (i.e. fish counts) were conducted using underwater video to document fish presence and absence within the project area. Dive surveys were conducted during the pre- and post-installation surveys (Figure 6).

For the pre-installation survey, transect lines were placed in designated areas within the reef ball field with a north/south orientation. A single video recording was made as the diver swam each transect. The weighted bottom transect line with flagging every 20 feet was used to standardize the distance covered. GPS coordinates were recorded for the start and end of each transect. These coordinates were used by the diver for the post-installation transects. The diver used a video camera to record wide angle and close up images of the habitat. Following each video transect survey; the diver conducted a visual census of the project site by swimming randomly and recording fish species. After each dive the recorded video was checked for quality to ensure that each dive was recorded correctly.

2.3.3 Local Fishermen Interviews

To supplement the fish trap and dive survey data and the observations during the pre- and post-installation surveys, a series of interviews with local fishermen, if present, were conducted at the project site.

2.4 Hydrodynamic & Sediment Survey

Current surveys were conducted during the pre-installation and first post-installation survey in order to characterize vertical profiles of tidal currents and velocities within the habitat enhancement area. Surveys were conducted at the four corners of the reef ball field using a vessel mounted Endeco 110 Current meter. The vertical profiles were conducted during various stages of an ebb or flood tide and were optimized to provide maximum resolution of tidal flow velocity and direction as well as maximize the coverage of the project area. Each vertical profile consisted of current velocity (knots) and directional (degrees) measurements at a surface depth three feet below the surface and three feet above the bottom. When possible, based on total water column depth, a mid-depth was recorded. To obtain accurate readings, the research vessel was anchored at each station from both the bow and the stern.

To assess sediment conditions within the habitat enhancement area, dive surveys were conducted. During the pre-installation survey, the diver noted and recorded with an underwater video typical bottom conditions, including evidence, if any, of sediment scouring and accumulation within the study area. During the post-installation surveys, transects were conducted and 12 reef balls were marked and surveyed for sediment scouring and deposition. These 12 reef balls were the same as those monitored during the epibenthos surveys.

3.0 BENTHIC INVERTEBRATE COMMUNITY

A total of 112 benthic macro-invertebrate samples were collected within and around the West Harlem Waterfront Park habitat enhancement area during the pre- and post- installation surveys (Figure 2). During each of these surveys, two benthic samples were collected from each of the 14 stations. Sediments collected during the sampling process typically were fine grain sediments, black and gray in color, and possessed a slight to pronounced odor of petroleum.

3.1 Pre-Installation Benthic Survey

Taxa Richness

Seventeen (17) true taxa were collected and identified within the study area during the June 2006 pre-installation survey. Taxa richness ranged between a low of five taxa at stations WHB-10 and WHB-12 to a high of 10 taxa at stations WHB-3 and WHB-9 (Table A-1). None of the 14 stations were determined to have true taxa richness values greater than 10.

Taxa consisted primarily of annelids (65%) as well as some arthropods (18%), one species of mollusk (*Mulinia lateralis*), and two miscellaneous species of Nemertea and Nematoda (Table A-1 & A-3). A total of 13 annelid taxa were identified, that included primarily *Streblospio benedicti*, Capitellidae, and *Leitoscoloplos fragilis*. The arthropods consisted of three taxa that included an amphipod, *Idotea* spp., and a decapod crab of the family Grapsidae (Table A-1).

Organism Density

Total benthic density averaged 900 organisms/m² across the 14 sampled locations during the June 2006 pre-installation survey (Table A-1, A-2). The highest densities were found at stations WHB-11 (1,948 organisms/m²) and WHB-3 (1,682 organisms/m²), while lowest densities were at WHB-6 (162 organisms/m²) and WHB-12 (228 organisms/m²).

The majority of organisms collected across all the stations were annelids (98%). *Streblospio benedicti* (38% of the total catch), Capitellidae (26%), *Leitoscoloplos fragilis* (12%), and *Scolecolepides viridis* (8%) were the dominant taxa. All four of these taxa were present at all the stations, except for *Leitoscoloplos fragilis* which was not found at station WHB-10. In addition, the common mud worm, *Polydora ligni*, (675 organsims/m²) and oligochaetes (133 organisms/m²) were abundant at several stations (Table A-1).

In general, total benthic density varied across all 14 stations, ranging from a low of 162 organisms/m² to a high of 1,948 organisms/m², although the taxa found within each station were similar (Table A-1).

Diversity (H') and Evenness (E)

Benthic diversity across all 14 stations sampled in the pre-installation survey averaged 1.99 and ranged from a low value of 1.27 at station WHB-10 to a high of 2.74 at WHB-6 (Table A-2). In the pre-installation survey, most of the stations (79%) fell within 0.5 on either side of the moderate value (2.0). The overall evenness value for the pre-installation survey was 0.69, which was influenced by two high values (0.91 at WHB-6 and 0.87 at WHB-5).

3.2 Post-Installation Benthic Surveys

3.2.1 6-Month Post-Installation Benthic Survey

Twenty-eight (28) true taxa were collected and identified within the study area during the 6-month post-installation survey, which took place on 14 and 15 November 2006. Taxa richness ranged between a low of five taxa at station WHB-1 to a high of 17 taxa at station WHB-9 (Table A-4). Nine of the 14 stations were determined to have true taxa richness values greater than 10.

Taxa Richness

Annelids were the dominant taxa (43%), followed by arthropods (32%; Table A-6). However, several additional bivalve species were collected, including *Teredo navalis*, *Mya arenaria*, *Geukensia demissa*, and *Tellina agilis*, although occurrences were limited to just a few stations (Table A-4). A Gastropod species, *Acteocina canaliculata*, was collected in low densities (10/m^2) at stations WHB-7, WHB-11, and WHB-13. Nine (9) new taxa of arthropods were collected during the six-month post-installation survey, including the crustaceans *Leucon americanus* and Gammaridae (Table A-4).

Organism Density

In the November 2006 post-installation survey, the total benthic density was 1,470 organisms/m^2 (Table A-4), of which annelids comprised 80% (1,175 individuals) of the total average benthic density (Table A-4). Density at each station ranged between 238 organisms/m^2 (WHB-1) and 3,582 organims/m^2 (WHB-9, Table A-4).

The percentage of Annelid density at each of the 14 stations in the six-month survey ranged from 48% (WHB-13) to 96% (WHB-10). The four most common taxa collected during the six-month post-installation survey were the annelids: Capitellidae (28% of the total catch), *Streblospio benedicti* (14%), *Polydora ligni* (12%), and *Nereis succinea* (12%). The fifth most common taxa collected was the cumacean, *Leucon americanus*, which represented 8% of the total catch (Table A-4). Although annelids still accounted for 80% of the organisms collected, more arthropod taxa were observed (Table A-6).

A total of 25 of the 37 taxa collected increased in average benthic density between the pre-installation and six-month post-installation surveys (Table A-4). This trend was prevalent among arthropods and mollusks in which 83% of the taxa increased in density. Approximately 53% of taxa within the Annelid phyla were found to have increased as well (Table A-4).

Diversity (H') and Evenness (E)

A total of nine stations, or 64%, had diversity greater than 2.50 during the six-month post-installation survey, including two stations (WHB-5 & WHB-12) with diversity above 3.0 indicative of a diverse benthic community (Table A-5). The increase in benthic evenness was more apparent, however, when comparing each grab individually as 79% of the stations had an evenness value at or above 0.70 during the six-month post-installation survey as compared to just 50% of the stations during the pre-installation survey (Table A-2 & A-5). The lowest evenness value (0.47 at WHB-2) was observed during the six-month post-installation survey.

3.2.2 12-Month Post-Installation Benthic Survey

Taxa Richness

Thirty (30) true taxa were collected and identified within the study area during the 12-month post-installation survey, which took place on 25 June 2007. Of the 30 true taxa collected, taxa richness ranged between a low of six taxa at station WHB-3 to a high of 19 taxa at station WHB-8 (Table A-7). Six of the 14 stations were determined to have true taxa richness values greater than 10. Benthic samples were comprised of annelids (45%), arthropods (35%), mollusks (13%) and two miscellaneous species of Nemertea (ribbon worm) and Nematoda (nematode worm), representing only 6% of total taxa present (Table A-9). Nine (9) new taxa were collected during the 12-month post-installation survey (Table A-7). Overall, these new taxa comprised 29% of the total taxa collected in June 2007. New annelid taxa were comprised of Hirudinea (leech), *Sabellaria vulgaris* (cement tube worm), and the family Paraonidae (Thread worm). In addition, new arthropod and gastropod taxa included amphipods (Aoridae family, Four-eyed amphipods) and decapods (Sevenspine bay shrimp, Atlantic mud crab, and Harris mud crab) and mollusks (blue mussel) (Table A-7).

Organism Density

Total benthic density averaged 819 organisms/m² across the 14 sampled locations during the 12-month post-installation survey (Table A-7). Abundance density at each station ranged from a low value of 105 organisms/m² (WHB-1) to a high value of 2,698 organisms/m² (WHB-8) (Table A-7 & A-8). Overall, 21 of the 44 taxa (48%) collected and identified between the six-month and 12-month post-installation surveys increased in average benthic density (Table A-7). Among the Annelids, 56 % of taxa increased in benthic density, while among the Arthropods 44% of species increased in benthic density. Only 38% of taxa increased within the phyla Mollusca between the six-month and 12-month post-installation surveys.

A total of 14 annelid taxa with an average density of 640 individuals/m^2 were collected and identified (Table A-9). Annelids caught in the 12-month post-installation survey were found to constitute 78% of the total benthic density (Table A-9). In this survey, the lowest percentage of annelids was found at station WHB-1 (27%), while the highest percentage was noted at station WHB-8 (94%). The most common taxa identified during the 12-month post-installation survey were the following species of polychaete worms: *Polydora ligni* (42% of total catch), Capitellidae (14%), *Leitoscoloplos fragilis* (11%), and *Nereis spp*. (5%) (Table A-7). Within the phyla, about half of the annelids caught belonged to the species *Polydora ligni* (54% of Annelid density). Other predominant benthic taxa were Capitellidae (18% of Annelid density), *Leitoscoloplos fragilis* (15%), and *Nereis spp*. (6%).

A total of 11 arthropod taxa (155 individuals/m^2) were caught in the 12-month survey, primarily composed of *Leucon americanus* (39% of arthropod density), *Crangon septemspinosa* (29%), and *Corophium spp.* (12%) (Table A-7). The decapod *Crangon septemspinosa* was not previously sampled in the either the pre-installation or the six-month post-installation assessment. The other three phyla sampled in the 12-month survey represented the minority of the total benthic density, with only four taxa of mollusks (11 organisms/m²), one taxa of Nemertea (11 organisms/m²) and one taxa of Nematoda (2 organisms/m²) identified (Table A-7).

Diversity (H') and Evenness (E)

Benthic diversity (H') across all 14 stations sampled in the 12-month post-installation survey ranged from a low value of 0.82 at station WHB-6 to a high value of 2.95 at station WHB-5 (Table A-8). A value of 2.0 represents a benthic community with moderate diversity and half the stations (50%) fell within 0.5 on either side of this moderate value. In addition, 86% (12) of stations sampled in this survey were equal to or greater than 2.0. According to these data from the two post-installation assessments, WHB-5 had consistently greater numbers of macroinvertebrate fauna (Table A-8, Table A-5). Final benthic diversity grab average was determined to be 2.35 (Table A-8).

3.2.3 18-Month Post-Installation Benthic Survey

Taxa Richness

Thirty-seven (37) total taxa were collected and identified within the study location during the 18-month post-installation survey, 18 and 19 December 2007 (Table A-10). Benthic samples were comprised of annelids (38%), arthropods (27%), mollusks (30%), and two (5%) additional phyla, Nemertea and Chordata (Table A-12). Benthic taxa richness was found to range between a low of 10 taxa at station WHB-6 to a high of 19 taxa at stations WHB-1 and WHB-19 (Table A-11). A total of 16 (46% of total catch) new taxa were sampled in the 18-month post-installation survey (Table A-10). New annelid taxa were comprised of *Glycinde solitaria*, *Nephtys* sp., and individuals from the family Syllidae (Table A-10). Of the new arthropod taxa collected, two belonged to separate families of Amphipods (Gammaridae and Oedicerotidae), as well as one Decapod (*Rhithropanopeus harrisi*), one Isopod (*Edotea triloba*), and one from the order Thoracica (*Balanus* sp.). Eight new mollusk taxa, including a generic gastropod species, were caught and identified during the 18-month post-installation survey. Bivalve taxa included *Yoldia* sp. and *Tellina* sp. and gastropod species included individuals from the family Naticidae, *Haminoea solitaria*, *Retusa canaliculata*, *Retusa obtusa*, and *Ilyanassa obsoleta*. The species *Mogula manhattensis* (Phylum Chordata) was found only in the 18-month post-installation survey (Table A-10).

Organism Density

Total benthic density averaged 6,981 organisms/m^2 across the 14 stations sampled during the 18-month post-installation survey (Table A-10). The abundance values of species caught ranged from a low of 2,662 organisms/m^2 at station WHB-13 to a high of 13,263 organisms/m^2 present at station WHB-3.

The total number of Annelid taxa sampled in the 18-month post-installation survey was 14 (38% of total taxa, Table A-12). The total average benthos density for Annelids was 5,552 organisms/m^2, comprising approximately 80% of the total catch. The lowest percentage of annelids was found at station WHB-4 (39%) and the highest was observed at WHB-6 (70%). The taxa with the largest grab averages for benthic density were *Streblospio benedicti* and Capitellidae (2,588 and 1,560 organisms/m^2 respectively). These two taxa represented about 47% and 28%, respectively, of all Annelid taxa collected in the 18-month post-installation survey. Another species with a larger grab average in the 18-month survey was *Leitoscoloplos fragilis* (679 organisms/m^2, 12% of total Annelid catch).

A total of ten (27% of total taxa) arthropod taxa were sampled in the 18-month post-installation survey (Table A-12). The average benthic density for arthropods was determined to be 226 organisms/m^2, which comprised approximately 3% of the entire benthic catch. Arthropod species that increased in benthic density include taxa new to the survey, as well as those that have been sampled in previous surveys. *Leucon americanus* showed the greatest overall benthic density with a grab average of 121 organisms/m^2, which comprised roughly half (54%) of all of the arthropods sampled. Other arthropod taxa found to increase in benthic density include individuals of the family Aoridae (14% of arthropod density) and *Cyathura polita* (8% of arthropod density). The remaining arthropods were species that were new to the 18-month post-installation survey.

Most new taxa observed belonged to the phyla Mollusca (8 true species). The total benthic density of Mollusks sampled was 1137 organisms/m^2 (Table A-10). The species with the largest grab average was *Mulinia lateralis* (961 organisms/m^2), which constituted 85% of all Mollusks sampled and 14% of the entire benthic catch.

Miscellaneous species caught in the 18-month post-installation survey were from the phyla Chordata and Nemertea. The Chordate species sampled was *Mogula Manhattensis* and had an average grab density of 20 organisms/m^2 (Table A-10). Another species observed in the 18-month post-installation survey was from the phyla Nemertea, which had an average grab density of 45 organisms/m^2. No individuals from the phylum Nematoda were sampled in the 18-month post-installation survey.

Diversity (H') and Evenness (E)

Species diversity (H') across all 14 stations sampled in the 18-month post-installation survey ranged from a low of 1.19 at station WHB-9 to a greater diversity value of 3.11 at station WHB-4 (Table A-11). Species diversity values that exceed 2.0 are considered to be indicative of a moderately diverse community. Only 14% (2) of the stations sampled had diversity values that fell within 0.5 of 2.0. Approximately 79% of all stations had diversity values greater than the moderate diversity value. The final benthic diversity grab average for the 18-month post-installation survey was 2.49 (Table A-11).

3.3 Summary of Benthic Surveys

Taxa Richness

A grand total of 63 taxa were caught and identified throughout the pre-installation and post-installation surveys, and taxa richness increased during each post-installation survey. Seventeen taxa were collected during the pre-installation survey, as compared to 28, 31, and 37 taxa collected during the 6-month, 12-month, and 18-month post-installation surveys, respectively (Table 3). The average benthic taxa richness per station increased from 8 to 16 taxa over the 18-month study period (Table 1 & 2).

The total taxonomic occurrence in the Annelid, Arthropod, and Mollusk species increased throughout the monitoring period (Table 3). The total number of Annelid taxa increased from 11 to 14 taxa from the pre-installation survey to the 18-month post-installation survey (Table 3). Similarly, Arthropods increased from three to ten taxa. However, the most notable increase was in Mollusks, which increased from one species of bivalve to 11 taxa by the end of the surveys. Tunicates, of the phylum Chordata, were collected during the 18-month survey as well (Table 1).

Organism Density

Similar results were observed in total average benthic density, in which densities increased from the pre-installation and final post-installation surveys (Table 1 & 2). The benthic abundance of organisms collected during the June 2006 pre-installation survey was 902 organisms/m^2, where densities varied among stations, indicating a somewhat impacted benthic community. Average densities were slightly higher during the 6-month post-installation survey, in which 1,471 organisms/m^2 were collected. Average density of the 12-month post-installation survey was the lowest of the four surveys, with 819 organisms/m^2. The highest density was observed during the 18-month post-installation survey, with 6,981 organisms/m^2 collected. This represents an 87% increase in the benthic community density over the survey in the study area.

Annelids, Arthropods, Mollusks, and Miscellaneous (i.e. Chordata and Nemertea) taxa showed increases in average density from the pre-installation to the 18-month post-installation survey (Table 3). The majority of organisms collected during the pre-installation benthic survey were Annelids (primarily polychaetes), which accounted for 98% of the total benthic abundance, or 883 organisms/m^2 (Table 3). Similar to the pre-installation survey, the 6-month survey was comprised of mostly Annelids, 1,175 organisms/m^2 or 80% of the average density. However, Arthropod density also increased during the 6-month survey, from 3 organisms/m^2 during the pre-installation survey to 204 organisms/m^2. The 12-month survey was composed mostly of Annelids (640 organisms/m^2) and Arthropods (155 organisms/m^2). The increase in density during the 18-month survey was due to large increases in the densities of Annelids (5,552 organisms/m^2) and Mollusks (1,137 organisms/m^2).

Diversity (H') and Evenness (E)

Species diversity ranged from 1.99 to 2.50, being lowest during the pre-installation survey and highest during the 6- and 18-month post-installation surveys (H'=2.50, 2.49, respectively; Table 2). The benthic community evenness varied slightly throughout all sampling periods from an initial value of 0.69 to 0.72 during the 12-month post-installation survey, and declining slightly to 0.62 during the 18-month survey (Table 2).

Overall, the benthic community appears to be more complex than prior to reef ball installation, with higher species densities and differentiated species assemblage with substantial abundances of arthropods and mollusk species.

4.0 Epibenthic Community

4.1 Post-Installation Epibenthic Surveys

A total of 34 samples were collected within the project area during the post-installation surveys. Samples were collected at 12 reef balls during the 6-month and 12-month post-installation surveys (Figure 3). However, during the 18-month post-installation survey, only 10 epibenthic samples were collected from these reef balls. Reef balls WHE-10 and WHE-11 were broken and therefore were unable to be sampled. Scrapings were used to find average epibenthic density (organisms/m^2) per reef ball.

4.1.1 6-Month Post-Installation Epibenthic Survey Taxa Richness

In the six-month survey, conducted on 29 November 2006, a total of 24 taxa were identified, including 11 species of arthropods (48% of total taxa), four species of annelids (17%), one species of chordate (4%), and one species of mollusk (4%) (*Mytilus edulis*, Table 4 & 6). In addition, a variety of six additional species (26%) were collected including bryozoans (*Membranipora spp*. and *Bowerbankia spp*.) hydroids (Phylum: Cnidaria, *Campanularia spp*.), flatworm (Phylum: Platyhelminthes, *Stylochus spp*.), and sponge (Phylum: Porifera, *Halichondria spp*., Table 4). Taxa richness ranged from 6 to 15 species across all stations and 11 of those stations had true taxa richness of 10 or greater (Table B-1).

Organism Density

The average epibenthic density of the 12 sampled reef balls in the six-month post-installation survey was 1,781 organisms/m² with density values ranging widely between 250 organisms/m² (WHE-4) and 6,188 organisms/m² (WHE-6; Table B-1, Table B-2). Density values did not include colonizing organisms, like the barnacle *Semibalanus balanoides*, which represented 38% of the total catch, the hydroid *Campanularia* spp. (9% of the catch by volume) and the bryozoan *Membranipora* spp. (6% of the catch by volume; Table B-2). Seven stations had epibenthic densities exceeding 1,000 organisms/m^2 (Table B-2).

The percentage of arthropods collected in the six-month samples (total density) was found to be 62% (1,099 organisms/m^2, Table B-3). Arthropods dominated the six-month survey samples, and included the amphipods *Corophium* spp. (661/m^2) and Pluestidae (190/m^2). The flatworm *Stylochus* spp. (23% of the total catch) was also collected in significant quantities (Table B-1). Annelids represented only 7% of the total catch in the six-month assessment.

Diversity (H') and Evenness (E)

The species diversity (H') value of the 12 reef balls sampled in the six-month post-installation survey ranged between 1.66 and 2.60 with an average value of 2.22 indicating a moderately diverse epibenthic community (Table B-2). Four stations had H' values greater than 2.50 (WHE-6, WHE-8, WHE-11, and WHE-12), but all were less than 3.0. The evenness (E) value of the 12 sampled reef balls on average was 0.63 and ranged between 0.46 (WHE-10) and 0.70 (WHE-11 and WHE-12; Table B-2). In total, 10 of the sampled reef balls had an evenness value greater than or equal to 0.60, indicating moderately distributed species diversity (Table B-2).

4.1.2 12-Month Post-Installation Epibenthic Survey

A total of 12 epibenthic samples were collected during the second post-installation survey, on 25 and 26 July 2007 (Figure-3). Reef ball WHE-10 was found broken and valid sample was collected. However, the epibenthic density of scrapings from WHE-10 was calculated based on a sampling area of 0.016 m^2, the area of one scraping.

Taxa Richness

Taxa richness within these samples ranged between 7 and 18 species (Table B-4). Eleven (92%) of the twelve total stations had taxa richness values equal to or greater than 10. A total of 27 taxa were collected and identified, including 12 species of arthropods (44% of total taxa) and six species of annelids (22%; Table B-6). Additionally, tunicates (4%), and mollusks (7%), and six miscellaneous (gastropods, bryozoans and hydroids) taxa were observed (22%). The average taxa richness calculated for the 12-month post-installation survey was 14 (Table B-4). The new taxa included *Modiolus demissus* (Mollusca), *Euplana gracilis* (Platyhelminthes), Nematoda, Nemertea, *Leitoscolopios fragilis, Nereis spp*., *Streblospio benedicti*, and one from the family Capitellidae (Table B-4).

Organism Density

The average epibenthic density was 33,030 organisms/m^2 (Table B-4). Epibenthic densities varied across the stations from a low of 3,938 organisms/m^2 (WHE-13) to a high of 186,615 organisms/m^2 (WHE-2). Density values did not include colonizing organisms. For instance, the barnacle *Balanus* spp. ranged from 5% (WHE-3, WHE-1) to 65% (WHE-4) to the station catch and averaged 26% of the total catch. The hydroid *Campanularia* spp. comprised a substantial portion of the station catch, ranging from no catch at WHE-10 to a maximum of 75% at WHE-7 and WHE-11. *Campanularia* spp. averaged 47% of the total epibenthic grab and the bryozoan *Membranipora* spp. averaged 3% (Table B-4).

The most dominant phylum was arthropods, with an average station density of 23,254/m^2, followed by annelids (7,126/m^2) and tunicates (1,063/m^2; Table B-6). Arthropods comprised 70% of the density and annelids comprised 22%. Arthropods were dominated by amphipods (total density 16,581/m^2) and isopods (5,985/m^2), although many other taxa including cumaceans (small benthic crustaceans) and decapods (shrimps, crabs) were also collected. *Polydora ligni* (mud worm) dominated the annelids, averaging 6,433/m^2 (Table B-4).

During the 12-month post-installation survey, many more mussels, tunicates, and nematodes were collected (Table B-4).

Diversity (H') and Evenness (E)

In the 12-month post-installation survey, the species diversity (H') ranged from 1.41 to 3.11 with an average species diversity value of 2.34 (Table B-5). Five stations sampled (42%) had diversity values greater than 2.5, with three stations having diversity values greater than 3.0 (Table B-5). Evenness ranged from 0.47 to 0.78, averaging 0.62 for the 12 stations, which was similar to the results obtained for the 6-month post-installation survey (Table B-2 and B-5). Half of the stations had evenness values greater than 0.60, and three stations were greater than 0.70.

4.1.3 18-Month Post-Installation Epibenthic Survey

A total of ten epibenthic samples were collected from the reef ball site during the 18-month post-installation survey, conducted on 10 and 15 January 2008 (Table B-7). Normally, 12 epibenthic sites are sampled; however, WHE-10 and WHE-11 were found broken during the dive survey and no samples were collected from these sites.

Taxa Richness

In the 18-month post-installation survey, a total of 29 taxa were observed, including 12 species of Annelids (40 % of total taxa), 11 species of Arthropods (37 %), four species of Mollusks (13 %), one species of Chordate (3 %, Table B-9). Colonizing epibenthic species, such as *Balanus* sp. (56 %) and *Electra* sp. (1 %), were represented as percentages of the total catch. Taxa richness within these samples ranged from eight to 19 taxa and the average taxa richness across stations was 14 (Table B-8). Eleven new species were identified from the samples collected from the 18-month post-installation survey. These taxa included four species of Annelids (families Ampharetidae, Goniadidae, Phyllodocidae, and *Podarke* sp.), four species of Arthropods (*Balanus* sp., *Callinectes sapidus*, *Edotea* sp., *Idotea* sp., and *Palaemonetes vulgaris*), two species of Mollusks (*Mulinia lateralis* and *Retusa canaliculata*), and one species of Bryozoa (*Electra* sp.).

Organism Density

The total overall average for epibenthic density was determined to be 17, 784 organisms/m^2 (Table B-7). Epibenthic density values ranged from 8,125 organisms/m^2 at WHE-8 to 27,656 organisms/m^2 at WHE-12.

The Annelids had the greatest overall density with a total of 7,151 organisms/m^2 present across all reef balls sampled. Two species constituted most of this total; *Nereis* sp. (3,010 organisms/m^2, 42 % of Annelid density) and *Polydora ligni* (2,911 organisms/m^2, 41 %). One species of Arthropod, *Corophium* sp., was present in a density of 1,044 organisms/m^2, comprising 48 % of total Arthropod density. The family Aoridae had an average density of approximately half that value. The Mollusk *Mulinia lateralis* had the only substantial average of the four species sampled (813 organisms/m^2, 89 % of total Mollusk density). The chordate *Mogula Manhattensis* had the largest average of all taxa sampled in the 18-month post-installation survey (6,917 organisms/m^2, 39 % of total epibenthic catch). The only miscellaneous group species to have a density similar to any of those discussed above was *Stylochus* sp. (615 organisms/m^2, 3 % of total catch).

Diversity (H') and Evenness (E)

In the 18-month post-installation survey, the species diversity (H') ranged from a low value of

2.05 to a high value of 3.28 with an average species diversity of 2.57 (Table B-8). All values were found to be greater than the moderate diversity value of 2.0. Species diversity at stations WHE-2 and WHE-4 exceeded 3.0 during the current survey. Epibenthic community evenness ranged from 0.58 to 0.80 across all ten stations sampled and averaged at 0.69 (Table B-8). Nine of the 10 stations sampled had evenness values greater than 0.60. Four stations were greater than 0.70 indicating a well distributed species diversity throughout the reef ball field.

4.3 Summary of the Epibenthic Survey

Taxa Richness

The epibenthic community was surveyed approximately every six months after the installation of the reef ball field, twice during the early winter (November 2006, January 2008) and once during the early summer (July 2007). Total taxa richness, diversity (i.e., number of species/m^2), and evenness (i.e., the distribution of the community) increased throughout the survey period (Tables 4 -6). Twenty-two total taxa were collected during the 6-month post-installation survey, as compared to 27 taxa during the 12-month, and 29 taxa during the 18-month survey.

Organism Density

The total epibenthic abundance increased from the 6- to the 12-month post-installation survey from 1,781 organisms/m^2 to 33,030 organisms/m^2 (Table 4 & 5). From the 12- to the 18-month post-installation surveys, epibenthic density declined to 17,784 organisms/m^2. However, this represents an overall 89% increase in epibenthic community density when compared to the 6-month post-installation survey.

Diversity (H’) and Evenness (E)

Species diversity increased steadily over the sampling period from 2.22 to 2.57, (Table 5). Species evenness demonstrated roughly the same pattern with average evenness increasing from the 6- and 12-month post-installation (E=0.63, 0.62, respectively) to the 18-month post-installation period (E=0.69; Table 5).

The epibenthic community appears to have developed into a more complex community by the 18-month post-installation survey than that observed during the initial survey. The high abundance of chordates and annelids supports the notion of increasing epibenthic community complexity within the study area. Overall, more diverse epibenthic species were observed at higher densities and were distributed more evenly during the 18-month sampling period when compared to the initial survey.

5.0 FISH COMMUNITY

5.1 Pre-Installation Fish Survey

During the pre-installation survey, a total of three spotted hake (*Urophycis regia*) were collected within the eight fish traps (Table 7a, Figure 5). All of the spotted hake were found in the baited traps, and they ranged in total length size from 162 mm to 164 mm (Table 7b). In addition, the field crews noted the presence of shrimp, snails and blue crab found inside and on the outside of the traps. Similar organisms were observed inside and outside of the traps in the six-month and twelve-month post-installation surveys. In addition to species mentioned above, Jellyfish (Phylum Cnidaria) species were observed in and around traps set in the June 2006 sampling event.

Local Fisherman Surveys

Four local fisherman surveys were conducted in June 2006 as part of the pre-installation survey. Two surveys were conducted during the week and two were conducted on the weekend. On three occasions there were no fishermen present during a four hour period in the morning (June 7, 8 and 24). However, on June 28 there was a fisherman. The fisherman had not caught anything while being interviewed, but said in the past he has caught American eels and a striped bass at this location. He said that he occasionally sees other people fishing in the area. The fisherman said he is typically at this spot during the week and is looking forward to being able to have more access to the waterfront once construction is complete.

Dive Survey and Video Analysis

No fish species were identified during the dive survey. Water was turbid and the bottom contained few dead bivalve shells and fine grain sediments.

5.2 Post-Installation Fish Surveys

5.2.1 6-Month Post-Installation Fish Survey

Of the fourteen baited and unbaited fish traps set during the six-month post-installation survey, several shrimp, two blue crabs (*Callinectes sapidus*), one juvenile striped bass (*Morone saxatilis*), and three American eels (*Anguilla rostrata*) were caught in the traps (Table 7a). The striped bass (Trap 7; TL = 71 mm) and eels (Trap 10) were caught in baited traps, while the blue crabs (Traps 3, 13) were caught in both unbaited and baited traps (Table 7b). The American eels ranged in total length size from 350 mm to 400 mm. Except for one location, the traps that caught organisms were located inshore, on the eastern edge of the reef ball field (Figure 5).

Local Fisherman Surveys

Four local fisherman surveys were conducted in November 2006 as part of the post-installation survey. On all four occasions of the post-installation surveys (November 11, 14, 18, 29) there were no fishermen present during the four hour period. This may have been due to construction of the waterfront park.

Dive Survey and Video Analysis

The diver did not observe any fish or other marine life during the dive survey. This may have been due to poor visibility and strong bottom currents (Figure 7).

5.2.2 12-Month Post-Installation Fish Survey

Baited and unbaited fish traps were set during the twelve-month post installation survey (Figure 5). Of those fourteen traps, two traps were lost during sampling. One American eel was caught in a baited trap (TL=410) and was slightly longer than American eels caught previously (Table 7a & b). Between the six-month and twelve-month post-installation surveys, American eels comprised approximately 11% of the total catch.

Local Fisherman Surveys

On all four occasions of the 12 month post- installation survey (June 1, 9, 19 and 23) there were no fishermen present during each four hour period. This is most likely due to construction of the water front park.

Dive Survey and Video Analysis

A dive survey was conducted for the 12-month post-installation survey and footage was taken inside of the reef ball field. Several fish species were observed swimming in and around the reef ball field. For example, juvenile striped bass were observed feeding in and around several reef balls. Similarly, blue crab, shrimps, and tautog were observed feeding and seeking cover within the openings of the reef balls and among the hydroids. Video footage can be found in Attachment I.

5.2.3 18-Month Post-Installation Fish Survey

Twelve fish traps were fished for approximately 24 hours during the 18-month post-installation fish survey (December 2007). Ten juvenile striped bass (*Morone saxatilis*) were collected, and no invertebrates were observed (Table 7a). Total lengths of the striped bass ranged from 63 mm to 89 mm, with an average length of 82 mm (Table 7b).

Local Fisherman Surveys

On all four occasions of the 12 month post- installation survey (December 18, 19 and 31 and Jan. 3) there were no fishermen present during each four hour period. This is most likely due to construction of the water front park.

Dive Survey and Video Analysis

A final dive survey was carried out for the 18-month post-installation survey and video footage was taken inside the reef ball field. No fish or crustacean species were observed by the diver on either of the two survey dates (January 10 & 15, 2008). However, the diver did note the presence of barnacles and marine growth on the surface of most reef balls.

5.3 Summary of Fish Surveys

Spotted hake was collected during the pre-installation survey (June 2006), whereas two fish species (American eel and striped bass) and blue crab were collected during the post-installation surveys (November 2006, June 2007, and December 2007; Table 7a & 7b). The largest catch was during the 18-month survey, when 10 striped bass were collected. The lowest catch was during the 12-month survey when one American eel was collected. In total, three fish were collected during the pre-installation survey and 17 fish/crabs were collected during the three post-installation surveys. The blue crab (CW = 27 mm) and striped bass (TL < 100 mm) collected during the post-installation surveys were likely juveniles, whereas the American eels were adults (TL ≥ 300 mm).

The fish and crabs collected during the post-installation surveys were caught in traps primarily located on the inshore perimeter of the reef ball field, possibly indicating a preference for conditions in that area, such as greater light penetration and lower currents. These conditions may allow for higher densities of epiphytic growth and associated benthic invertebrates, which can serve as an important prey base for juvenile fishes.

Local Fisherman Surveys

Fisherman surveys were conducted during each survey. However, due to construction at the site there were no fishermen present for the post-installation surveys. The one fisherman interviewed is looking forward to being able to have more access to the waterfront once construction is complete.

Dive Survey and Video Analysis

A dive survey was completed for each survey and video footage was taken inside and around reef balls sampled during each post-installation survey. No fish species were observed during the pre-installation, 6-, and 18-month post-installation surveys. However, the epibenthic community for each reef ball was documented. Fish species (i.e. striped bass and tautog) were observed during the 12-month post-installation survey, along with blue crab, shrimp, and hydroids.

6.0 HYDRODYNAMIC & SEDIMENT SURVEY RESULTS

6.1 Pre-Installation Hydrodynamic and Sediment Survey

The results of the current survey performed at the four corners of the proposed reef ball field are summarized in Figure 7. Bottom currents ranged between 0.4 knots and 1.0 knots. As expected, they were generally strongest in the deeper water closer to the channel and in particular at the northwest corner. Conversely, the weakest currents were observed nearshore at the northeast station.

The video taken by the diver showed bottom sediments that consisted primarily of a soft silty mud, which could be penetrated to a depth of 0.6 – 0.9 m (2-3 ft). The diver also observed the presence of scattered timber, debris and rocks.

6.2 Post-Installation Hydrodynamic and Sediment Surveys

6.2.1 6-Month Post-Installation Hydrodynamic and Sediment Survey

Current ranges were similar with peak currents occurring during the ebb tide and reaching 1.1 knots and 1.2 knots at the northwest and southwest corners, respectively (Figure 7). Ebb tide currents were higher at the surface than above the bottom, while during the flood tide, current increased as depth increased. Current profiles were more consistent from surface to just above the bottom at interior corners of the reef ball than the exterior, western corners. Note that this was the only post-installation hydrodynamic survey conducted.

To assess if sedimentation or scouring is occurring around the reef balls, the diver measured the distance from the bottom of the reef ball to the sediment surface for 12 reef balls (Table C-1). These reef balls were the same as those sampled during the epibenthic surveys. No sediment accumulation appeared to have occurred at the twelve reef balls since their installation.

6.2.2 12-Month Post-Installation Sediment Survey

During the 12-month post-installation survey, sediments were observed on the inside of six (6) of the 12 reef balls, while two (2) reef balls were observed to not have any sediment accumulation (WHE-2 and WHE-11, Table C-2). Measurements were taken at the western, northern, eastern, and southern edges of the reef ball from the bottom of the reef ball to the sediment surface. The reef ball located at station WHE-10 was found broken in three pieces, consequently data regarding sediment accumulation or scouring could not be determined by the diver (Table 8). The average distance from the bottom of the reef ball to the sediment at each station ranged from 0.20 m (WHE-11) to 0.88 m; WHE-12; Table 8).

6.2.3 18-Month Post-Installation Sediment Survey

During the 18-month post-installation survey, the reef balls surveyed were between 0.20 m and 0.69 m from the sediment (Table C-3). Stations WHE-1, WHE-7, and WHE-12 had the least distance between the bottom of the reef ball and the sediment, averaging approximately 0.35 m each (0.20-0.48 m). Stations WHE-3 had the greatest distances between the corner of the reef balls and the sediment, averaging 0.66 m (0.58-0.69 m). Additionally, the diver noted that WHE-3 had hard-packed sediment beneath the reef ball, possibly indicating some scouring had occurred. Stations WHE-4 was between 0.56-0.66 m from the sediment, also representing a relatively large distance from the sediment.

6.3 Summary of Hydrodynamic and Sediment Surveys

Hydrodynamic surveys were conducted in June 2006 and November 2007 for the pre-installation and 6-month post-installation surveys, respectively. Few differences in water currents at the study area were observed between these surveys, and generally were swifter in the deeper waters near the channel of the Hudson River than in the shallower water near shore.

The reef ball field was placed on a soft-bottom, silty shoal, with each reef ball installed on a pedestal either 1m from the seabed in deeper stations or right above the seabed at the nearshore stations. Twelve reef balls were randomly chosen for the sediment and epibenthic surveys, and sampled during the 6-month (November 2006), 12-month (June 2007), and 18-month (January 2008) post-installation surveys. During the year since the reef ball field was first monitored, the distance of most of the reef balls from the sediment has been decreasing, an indication of sediment accumulation (Table 8). Generally, sediment accumulation occurred at reef balls near the upper and lower perimeters of the reef ball field (e.g., WHE-1, 4, 6, 8, 9, and 11; Figure 3). The most substantial sediment accumulation was observed at WHE-5 and WHE-6, where the average distance to the sediment decreased from almost one meter during the 6-month survey to less than half a meter during the 18-month survey. Although some scouring within the reef ball field was observed by the diver during the 18-month post-installation survey at WHE-3 all reef balls experienced a net decrease in the distance to the sediment (Table 8).

For three reef balls, the distance from the sediment fluctuated during each post-installation survey. Reef balls WHE-3 and WHE-12, at the lower portion of the reef ball field, increased in depth from the 6-month to the 12-month surveys, but by the 18-month survey, sediment had accumulated. In contrast, depths from WHE-7 to the sediment increased during the 12-month survey then decreased slightly during the 18-month survey, but still resulted in a net accumulation of sediment.

7.0 DISCUSSION

The installation of a reef ball field in the nearshore area at West Harlem was successful in enhancing the habitat from existing conditions. For the pre- and post-installation surveys each component of the aquatic community was evaluated to see how it responded to the change in aquatic habitat created by the reef balls. The following discussion addresses the benthos, epibenthos and fish separately and then summarizes the overall aquatic life community with and without reef balls.

The benthic survey showed an overall increase in benthic density from 902 organisms/m^2 during the pre-installation survey to 6,981 organisms/m^2 at the end of the 18-month post-installation survey (Table 1). Seasonal fluctuations were evident throughout the survey with lower abundances recorded for summer surveys (pre-installation and 12-month post-installation) and higher abundances for fall/winter surveys (6-month and 18-month post-installation). Comparable fluctuation patterns were observed in taxa richness and diversity of species in the benthic community (Table 2). The evenness of benthic species started out low and increased during the 6- and 12-month post-installation surveys,(E=0.62, Table 2), however the changes were small from one time period to the next.

The lower Hudson River has distinct seasonal variations in the tidal exchange of salt and fresh water. During summer, when the reef balls were installed, freshwater outflow in the river was expected to be low and salinity, especially along the bottom, was expected to be high. The combination of these factors creates a stratified vertical profile in the water column known as the salt wedge, which migrates up the river and may be important in the dispersal of invertebrate larvae (Levinton & Waldman 2006). Benthic abundance was highest during the fall/winter sampling periods and lowest during the summer periods. Stratified vertical profiles may be important in the dispersal of invertebrate larvae, but it appears another factor is responsible for the increased benthic density observed in the 6- and 18 month surveys. Overall, the high benthic abundance observed during the post-installation 18 month survey shows a dynamic community that may be developing within the reef ball field.

Reef balls may be directly or indirectly enhancing benthic fauna. Reef balls may directly influence benthic abundance by attracting epibenthic species which create a food source for benthic species in the feces and pseudo-feces they produce. In addition, reef balls may be indirectly influencing benthic abundance by altering local hydrodynamic forces within the study area and producing changes in substrate conditions.

In 2004, a benthic study was conducted at the West 135th Street Marine Transfer Station (MTS) which is just North of the West Harlem reef ball field. Benthic samples included Oligochaetes, Polychaetes, mudsnails and some bivalves (EEA, Inc. 2004). For the West Harlem reef ball project similar species were caught with similar abundances however the distribution of organism varied. In general, more than 300 benthic invertebrate species have been identified in the lower Hudson River Estuary (Levinton & Waldman 2006). Previous studies showed that these species vary considerably in occurrence and abundance both seasonally and spatially (Iocco et al. 2000, Gandarillas and Brinkhuis 1981, Cerrato et al. 1989, Dean 1975, BVA 1998).

Moreover, the density and diversity of benthic organisms in New York Harbor have been negatively correlated with pollution and sediment contamination (Stainken 1984, Cerrato 1986). Sediment contamination, including synthetic compounds used in herbicide and pesticide production (Bopp et al. 1991), metals, and petroleum hydrocarbons (Conner et al. 1979), has resulted from combined sewer discharges, urban runoff, stormwater runoff, industrial discharges, and maritime and industrial accidents (Long et al. 1995, HEP 1996). The spatial distribution of these contaminants varies, but their presence and concentrations could influence benthic community composition, species distributions, and species abundance (Stainken 1984, Cristini 1991, Long et al. 1995).

The importance of the benthic community, especially amphipods, as primary forage for fish has been well documented for the Hudson River (Levinton & Waldman 2006). Moreover, benthic organisms serve as a primary suspension-filter in the estuary by feeding on phytoplankton and other suspended materials in the water column (Levinton & Waldman 2006). The feeding and burrowing activities of benthic animals, such as oligochaetes and amphipods, serve to mix the river's sediments, creating an exchange between the sediment and the overlying water (Levinton & Waldman 2006). Although the extent and importance of benthic sediment mixing and exchange has not been fully investigated, it is clear that the benthic community as a whole plays a critical role in the overall health of the Hudson River ecosystem.

While most aquatic habitat enhancement projects tend to focus primarily on the direct benefits to fish and/or shellfish, the magnitude and diversity of the epifaunal invertebrate community which comes to inhabit an artificial structure may ultimately define the success or failure of an enhancement project. Often, it is the epifaunal community that provides the basis of the food chain supporting the desired and harvestable resources (Figley 2003).

Many factors can potentially interact to influence epibenthic colonization of hard substrata in estuarine ecosystems. Physical factors such as water depth, flow patterns, salinity, temperature, turbidity and available light as well as the seasonal timing of when the structure is placed may shape an epibenthic community (HRF 2006). In general, colonization will also be governed by the type of substrate used as well as its structural complexity (Figley 2003, HRF 2006). The reef balls used in this study, were manufactured with marine-friendly concrete and were designed to mimic natural reef systems. This concrete has a lower pH than conventional concrete, making it similar to the pH of the ocean and estuary bodies. The surface of the reef balls were texturized with small pits, encouraging the settlement and growth of many epifaunal species.

A seasonal fluctuation was evident in epibenthic density, however, the pattern was opposite of that seen in the benthic community. The epibenthic density was at its lowest during the 6-month post-installation survey (Table 4). This was an expected outcome because the community was only beginning to develop at that point. The density then increased rapidly to 33,030 organisms/m^2 during the 12-month post-installation survey, only to decrease to 17,784 organisms/m^2 by the 18-month post-installation survey (Table 4). These seasonal fluctuations exemplify the fact that colonization takes time and follows an anticipated path of succession. Overall, the survey shows snapshots at particular time periods that show the progression of the epibenthic community.

In general, fast-growing and short-lived species are the first organisms to colonize reef balls. In the temperate ocean waters off of New Jersey, for example, hydroids, bryozoans, barnacles and blue mussels (*Mytilus edulis*) were the first visible organisms to appear on reef substrates, followed by anemones, stony coral and sponges (Figley 2003). A similar initial pattern of development was observed between the 6- and 12-month post-installation surveys, when species use of reef balls increased rapidly. By the 12-month post-installation survey, it appeared as though the community was still developing and adjusting to the reef ball structures. The diversity and richness maintained by the 18-month survey suggest that the community is starting to show stability.

Overall, the increase in epibenthic density, taxa richness, diversity, and evenness over the course of the survey is an indicator of the suitability of these structures in providing adequate habitat for a wealth of marine species. It is crucial to have a thriving epibenthic community because these species provide an essential link in the food web between species present in the water column to those in the benthos. The results provide evidence that suggest a pattern toward complex community structure within the reef ball field.

During the pre-installation survey, fish species use of the West Harlem study site was limited to transient taxa such as spotted hake (*Urophycis regia*, three individuals caught, Table 7a.). Spotted hake was the only fish species captured within the eight fish traps, which is not surprising as spotted hake are somewhat common residents of the estuary (Able & Fahay 1998). By the 6-month post-installation survey, three American eel and one striped bass were caught along with some macroinvertebrates (two blue crab). No striped bass were caught in fish traps during the 12-month post-installation survey, however, American eel were caught during this sampling period.

The fish survey conducted during the 18-month post-installation survey revealed habitat usage by young of the year striped bass (ten caught, Table 7a.). These results were expected because of the increasing epibenthic density and diversity provides both food and shelter for fish species in the reef ball study area. The results provide evidence to suggest that the epibenthic colonization on reef balls is sufficient to support the habitat requirements of striped bass and the overall progression towards community complexity.

Another species observed during the video analysis, include tautog. Tautog utilize rocks and boulders in bays and sounds as primary habitat (Weiss, H.M. 1995). Tautog feed on barnacles off of piers and pilings and they are also known to inhabit ship wrecks and reefs in offshore areas (Bigelow & Schroeder 2002). The observation of tautog using reef ball habitat suggest that these structures adequately mimic natural reefs.

Fish traps are probably not representative of the abundance and diversity of fish in the reef ball field however; traps were chosen in order to have comparable survey methods for pre- and post-installation surveys. In addition, video analysis showed several fish species (i.e. striped bass and tautog) using the reef ball field sampling periods when they were not observed in fish traps.

Certain fish species might prefer reef balls over fish traps due to the protection the former offers from the fast currents of the Hudson River.

Hydrodynamic forces are among the most important factors affecting artificial reef stability and performance. Currents within a reef field can cause units to shift, scour or deposit sediments, and reduce the weight-bearing capacity of the bottom (Seaman 2000). Initial measurements of both the hydrodynamic processes and sediment characteristics within the reef ball field indicate that the area should be conducive to habitat enhancement. During the post-installation surveys, scouring has not occurred within the reef ball field. However, there has been some sedimentation around the base of the reef balls. Due to the hydrodynamics in the area some sedimentation was expected within the first year after reef ball installation. It is expected that the area will reach equilibrium within the reef ball itself.

The project was successful in enhancing the nearshore area off of West Harlem by providing complex structure to a generally featureless shoal. The results clearly show the enhancement of benthic, epibenthic, and fish community structure in the study area. The increased epibenthic cover observed on reef balls in the study area should have a positive impact on the further development of benthic and fish populations, thereby leading to increased biomass and overall community structure.

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Table 1. Benthos Density (organisms/m² ± SE) collected at West Harlem Waterfront Project (18-Month Post-Installation).

Phylum	Class	Order	Family	Genus Species	Grab Average Pre-Install	Grab Average 6-Month Post	Grab Average 12-Month Post	Grab Average 18-Month Post
Nemertea	---	---	---	---	6 (± 2.36)	43 (± 9.49)	11 (± 2.61)	45 (± 14.3)
Nematoda	---	---	---	---	3 (± 2.14)	0 (± 0.00)	2 (± 2.04)	0 (± 0.00)
Annelida	Hirudinea	---	---	---	0 (± 0.00)	0 (± 0.00)	7 (± 4.16)	0 (± 0.00)
	Oligochaeta	---	---	---	22 (± 9.53)	79 (± 23.3)	3 (± 1.19)	205 (± 58.01)
	Polychaeta	---	---	---	2 (± 1.47)	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)
		Ampharetida	Ampharetidae	---	0 (± 0.00)	1 (± 0.68)	1 (± 0.92)	14 (± 6.34)
		Ariciida	Orbiniidae	Leitoscoloplos fragilis	111 (± 28.4)	72 (± 15.03)	94 (± 24.35)	679 (± 95.96)
		Canalipalpata	Sabellariidae	Sabellaria vulgaris	0 (± 0.00)	0 (± 0.00)	1 (± 0.68)	0 (± 0.00)
		Capitellida	Capitellidae	---	232 (± 53.56)	409 (± 99.15)	115 (± 22.94)	1560 (± 303.59)
		Phyllodocida	Goniadidae	---	0 (± 0.00)	8 (± 2.04)	0 (± 0.00)	92 (± 15.49)
				Glycinde solitaria	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)	3 (± 3.39)
			Glyceridae	Glycera sp.	1 (± 0.68)	0 (± 0.00)	1 (± 0.92)	18 (± 11.65)
			Nephtyidae	Nephtys sp.	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)	1 (± 0.92)
			Nereidae	Nereis sp.	8 (± 6.07)	0 (± 0.00)	38 (± 18.52)	61 (± 32.33)
				Nereis succinea	0 (± 0.00)	170 (± 58.23)	0 (± 0.00)	0 (± 0.00)
				Nereis virens	0 (± 0.00)	1 (± 0.68)	0 (± 0.00)	0 (± 0.00)
			Phyllodocidae	---	1 (± 0.68)	0 (± 0.00)	1 (± 0.68)	181 (± 23.87)
				Eteone sp.	28 (± 7.74)	46 (± 10.02)	0 (± 0.00)	0 (± 0.00)
			Spionidae	---	2 (± 1.08)	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)
				Polydora ligni	65 (± 47.52)	178 (± 124.23)	343 (± 197.63)	80 (± 53.05)
				Streblospio benedicti	341 (± 86.05)	206 (± 71.26)	18 (± 14.14)	2588 (± 786.34)
				Scolecolepides viridis	68 (± 20.58)	1 (± 0.92)	17 (± 3.62)	0 (± 0.00)
			Syllidae	---	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)	2 (± 2.04)
		Spionida	Paraonidae	---	0 (± 0.00)	0 (± 0.00)	1 (± 1.36)	0 (± 0.00)
		Terebellida	Pectinariidae	Pectinaria gouldii	2 (± 1.08)	5 (± 3.55)	1 (± 0.68)	69 (± 22.63)
Arthropoda	Crustacea	Amphipoda	---	---	1 (± 1.36)	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)
			Ampeliscidae	Ampelisca spp.	1 (± 0.00)	0 (± 0.00)	1 (± 0.68)	0 (± 0.00)
				Ampelisca abdita	0 (± 0.00)	0 (± 0.00)	8 (± 1.96)	8 (± 3.86)
			Aoridae	---	0 (± 0.00)	0 (± 0.00)	1 (± 0.68)	32 (± 11.49)
			Corophiidae	Corophium spp.	0 (± 0.00)	3 (± 2.14)	19 (± 13.47)	5 (± 2.5)
			Gammaridae	---	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)	22 (± 20.26)
				Gammarus sp.	0 (± 0.00)	27 (± 5.99)	7 (± 2.89)	0 (± 0.00)
			Melitidae	---	0 (± 0.00)	1 (± 1.36)	0 (± 0.00)	0 (± 0.00)
			Oedicerotidae	---	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)	14 (± 5.07)
			Pluestidae	---	0 (± 0.00)	16 (± 13.49)	0 (± 0.00)	0 (± 0.00)
		Cumacea	Leuconidae	Leucon americanus	0 (± 0.00)	117 (± 31.11)	61 (± 19.23)	121 (± 25.9)
		Decapoda	Crangonidae	Crangon septemspinosa	0 (± 0.00)	0 (± 0.00)	45 (± 9.78)	0 (± 0.00)
			Grapsidae	---	1 (± 0.68)	1 (± 0.68)	0 (± 0.00)	0 (± 0.00)
				Hemigrapsus sanguineus	0 (± 0.00)	1 (± 0.92)	0 (± 0.00)	0 (± 0.00)
			Portunidae	Callinectes sapidus	0 (± 0.00)	1 (± 0.68)	0 (± 0.00)	0 (± 0.00)
			Panopeidae	Panopeus herbstii	0 (± 0.00)	0 (± 0.00)	1 (± 0.68)	0 (± 0.00)
			Xanthidae	Rhithropanopeus spp.	0 (± 0.00)	0 (± 0.00)	1 (± 1.36)	0 (± 0.00)
				Rhithropanopeus harrisii	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)	2 (± 2.04)
		Isopoda	Anthuridae	Cyathura polita	0 (± 0.00)	22 (± 7.81)	7 (± 2.67)	18 (± 7.19)
			Idoteidae	Edotea sp.	0 (± 0.00)	15 (± 5.78)	5 (± 3.41)	0 (± 0.00)
				Edotea triloba	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)	2 (± 2.26)
				Idotea sp.	1 (± 0.68)	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)
		Thoracica	Balanidae	Balanus sp.	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)	2 (± 1.56)
Mollusca	Bivalvia	---	---	---	0 (± 0.00)	0 (± 0.00)	1 (± 0.68)	12 (± 12.23)
	Bivalvia	Eulamellibranchia	Teredinidae	Teredo navalis	0 (± 0.00)	24 (± 23.75)	0 (± 0.00)	0 (± 0.00)
		Myoida	Myidae	Mya arenaria	0 (± 0.00)	1 (± 0.68)	1 (± 0.68)	1 (± 0.68)
		Mytiloida	Mytilidae	Geukensia demissa	0 (± 0.00)	1 (± 0.68)	0 (± 0.00)	0 (± 0.00)
				Mytilus edulis	0 (± 0.00)	0 (± 0.00)	1 (± 0.92)	0 (± 0.00)
		Nuculoida	Nuculanidae	Yoldia sp.	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)	4 (± 4.07)
		Veneroida	Mactridae	Mulinia lateralis	5 (± 4.07)	20 (± 12.75)	0 (± 0.00)	961 (± 189.92)
			Tellinidae	Tellina sp.	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)	3 (± 1.63)
				Tellina agilis	0 (± 0.00)	2 (± 1.47)	8 (± 2.41)	0 (± 0.00)
	Gastropoda	---	---	---	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)	2 (± 2.26)
		Archeogastropoda	Naticidae	---	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)	1 (± 0.68)
		Cephalaspidea	Atyidae	Haminoea solitaria	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)	95 (± 37.58)
			Retusidae	Retusa canaliculata	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)	45 (± 15.85)
				Retusa obtusa	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)	9 (± 8.12)
			Scaphandridae	Acteocina canaliculata	0 (± 0.00)	2 (± 1.08)	0 (± 0.00)	0 (± 0.00)
		Neogastropoda	Nassariidae	Ilyanassa obsoleta	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)	5 (± 1.92)
Chordata	Ascidacea	Pleurogona	Molgulidae	Mogula manhattensis	0 (± 0.00)	0 (± 0.00)	0 (± 0.00)	20 (± 20.36)
Average Taxa Richness					**8**	**12**	**10**	**16**
Total Average Benthos Density (organisms/m²)					**902**	**1,471**	**819**	**6,981**

Table 2. Benthic community true taxa richness, density (organisms/m^2), Diversity (H'), and Evenness (E) collected at West Harlem Waterfront Project (18-Month Post-Installation).

Survey	Taxa Richness	Density (organisms/m^2)	Diversity (H')	Evenness (E)
Grab Average (18-Month Post)	16	6,981	2.49	0.62
Grab Average (12-Month Post)	10	819	2.35	0.72
Grab Average (6-Month Post)	12	1,470	2.50	0.71
Grab Average (Pre-Install)	8	900	1.99	0.69

Table 3. Benthic community taxa occurrence and total density (organisms/m^2) occurrence at West Harlem Waterfront Project (18-Month Post-Installation).																
Station	Taxa Occurrence								Total Density (organisms/m^2) Occurrence							
	Annelida		Arthropoda		Mollusca		Miscellaneous		Annelida		Arthropoda		Mollusca		Miscellaneous	
	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
Total 18-Month Post	14	38%	10	27%	11	30%	2	5%	5,552	80%	226	3%	1,137	16%	66	1%
Total 12-Month Post	14	45%	11	35%	4	13%	2	6%	640	78%	155	19%	11	1%	13	2%
Total 6-Month Post	12	43%	9	32%	6	21%	1	4%	1,175	80%	204	14%	50	3%	43	3%
Total Pre-Install	11	65%	3	18%	1	6%	2	12%	883	98%	3	0%	5	1%	10	1%

Table 4. Epibenthic Density (organisms/m^2, scrapings per reef ball) collected at West Harlem Waterfront Project (18-Month Post-Installation). Stations WHE-10 and WHE-11 were damaged and no samples were taken during the 18-month survey.

Phylum	Class	Order	Family	Genus Species	Average 6-Month	Average 12-Month	Average 18-Month
Bryozoa*	---	---	---	---	0	3%	0%
	Gymnolaemata	Cheilostomata	Electridae	*Electra* sp.	0%	0%	1%
			Membraniporidae	*Membranipora* sp.	6%	0%	0%
				Membranipora tenuis	0%	0%	0%
		Ctenostomata	Vesicularidae	*Bowerbankia* sp.	2%	0%	0%
Cnidaria*	Hydrozoa	Thecata	Campanularidae	---	9%	47%	0
Nematoda	---	---	---	---	0	41	0
Nemertea	---	---	---	---	0	13	0
Platyhelminthes	Turbellaria	Polycladida	Leptoplanidae	*Euplana gracilis*	0	3	0
			Stylochidae	*Stylochus* sp.	414	747	615
Porifera	Desmospongiae	Halichondrida	Halichondridae	*Halichondria* sp.	89	0	0
Annelida	Oligochaeta	---	---	---	0	27	29
	Polychaeta	Aciculata	Hesionidae	*Podarke* sp.	0	0	42
		Ariciida	Orbiniidae	*Leitoscoloplos fragilis*	0	33	161
		Canalipalpata	Ampharetidae	---	0	0	16
			Pectinariidae	*Pectinaria gouldii*	5	0	5
			Sabellariidae	*Sabellaria vulgaris*	36	0	458
			Spionidae	*Polydora ligni*	21	6,433	2,911
				Streblospio benedicti	0	326	328
		Capitellida	Capitellidae	---	0	25	57
		Phyllodocida	Nereidae	*Nereis* sp.	65	282	3,010
			Nereidae	*Nereis succinea*	0	0	0
			Phyllodocidae	---	0	0	120
			Goniadidae	---	0	0	13
Arthropoda	Crustacea	Amphipoda	Ampeliscidae	*Ampelisca abdita*	0	13	0
			Aoridae	---	0	348	518
			Corophiidae	*Corophium* sp.	661	13,566	1,044
			Gammaridae	*Gammarus* sp.	3	0	10
			Hyperiidea	---	3	0	0
			Melitidae	*Melita* sp.	3	18	0
				Melita dentata	5	0	0
				Melita netida	3	0	415
			Photidae	---	23	0	0
			Pleustidae	---	190	2,635	0
		Cumacea	Diastylidae	*Diastylis* sp.	0	13	0
			Leuconidae	*Leucon americanus*	0	150	128
		Decapoda	Crangonidae	*Crangon septemspinos*	0	9	0
			Palaemonidae	*Palaemonetes* spp.	0	452	0
				Palaemonetes vulgaris	0	0	5
			Portunidae	*Callinectes sapidus*	0	0	5
			Xanthidae	---	0	64	0
		Cirripedia* (Sub-Class)	---	---	5%	0%	0%
			Archaeobalanidae	*Semibalanus balanoides*	38%	0%	0%
			Balanidae	*Balanus spp.*	0%	26%	56%
		Copepoda	---	---	13	0	0

Table 4. Epibenthic Density (organisms/m^2, scrapings per reef ball) collected at West Harlem Waterfront Project (18-Month Post-Installation). Stations WHE-10 and WHE-11 were damaged and no samples were taken during the 18-month survey.

Phylum	Class	Order	Family	Genus Species	Average 6-Month	Average 12-Month	Average 18-Month
Arthropoda	Crustacea	Isopoda	Idoteidae	*Chiridotea* sp.	3	0	0
				Edotea sp.	0	0	8
				Idotea sp.	193	0	10
				Idotea baltica	0	0	44
				Idotea metallica	0	5,985	0
Mollusca	Bivalvia	Mytioida	Mytilidae	*Modiolus demissus*	0	16	42
				Mytilus edulis	10	767	39
		Veneroida	Mactridae	*Mulinia lateralis*	0	0	813
	Gastropoda	Cephalaspidea	Retusidae	*Retusa canaliculata*	0	0	21
Chordata	Ascidacea	Pleurogona	Molgulidae	*Molgula manhattensis*	42	1,063	6,917
True Taxa Richness					22	27	29
Total Epibenthic Density (organisms/m^2)					1,781	33,030	17,784

*Bryozoa, Cnidaria, and Cirripedia (Sub-Class) taxa are colonizing species in which individual counts were not possible. Instead, these taxa are represented as a percentage of the overall sample volume. These taxa were included in the taxa richness calculations and excluded from the density calculations. NS=No sample taken due to broken reef ball.

Table 5. Epibenthic community taxa richness, density (organisms/m^2, scrapings per reef ball), Diversity (H'), and Evenness (E) collected at West Harlem Waterfront Project (18-Month Post-Installation).

Station	Taxa Richness*	Density (organisms/m^2)	Diversity (H')	Evenness (E)
Average (6-Month)	12	1,781	2.22	0.63
Average (12-Month)	14	32,528	2.34	0.62
Average (18-Month)	14	17,784	2.57	0.69

*Bryozoa, Cnidaria, and Cirripedia (sub-Class) taxa were included in the taxa richness calculations and excluded from the density, diversity, and evenness calculations. WHE-10 and WHE-11 were found broken during the 18-month survey, therefore no samples were collected from these stations.

Table 6. Epibenthic community true taxa occurrence and total density (organisms/m^2, scrapings per reef ball) occurrence at West Harlem Waterfront Project (18-Month Post-Installation).

Station	Taxa Occurrence*										Total Density (organisms/m^2) Occurrence									
	Annelida		Arthropoda		Mollusca		Chordata		Miscellaneous		Annelida		Arthropoda		Mollusca		Chordata		Miscellaneous	
	NO.	%	NO.	%	NO.	%	No.	%	NO.	%	NO.	%	NO.	%	NO.	%	No.	%	NO.	%
Total (6-Month)	4	17%	11	48%	1	4%	1	4%	6	26%	128	7%	1,099	62%	10	1%	42	2%	503	28%
Total (12-Month)	6	22%	12	44%	2	7%	1	4%	6	22%	6,831	21%	23,068	71%	777	2%	1055	3%	797	2%
Total (18-Month)	12	40%	11	37%	4	13%	1	3%	2	7%	7,151	40%	2,188	12%	914	5%	6917	39%	615	3%

*Bryozoa and Cnidaria taxa were included in the taxa richness calculations under Miscellaneous and excluded from the density calculations. Cirripedia (sub-Class) taxa were included in the taxa richness calculations under Arthropods and were excluded from the density calculations. WHE-10 and WHE-11 were found broken during the 18-month survey, therefore no samples were collected from these stations.

Table 7a: Numbers represent the total catch for each of the pre-installation, 6-Month, 12-Month, and 18-Month post-installation surveys.

Common Name	Scientific Name	Pre-Installation	6-Month	12-Month	18-Month
American eel	*Anguilla rostrata*		3	1	
Blue crab	*Callinectes sapidus*		2		
Spotted hake	*Urophycis regia*	3			
Striped bass	*Morone saxatilis*		1		10

Table 7b: Total lengths (TL) and carapace widths (CW) of fish and blue crab species collected during the pre-installation, 6-Month, 12-Month, and 18-Month post-installation surveys.

Survey	Date	Station	Species	TL/CW (mm)
Pre-Installation	6/8/06	WHFT-5	Spotted hake	164
		WHFT-8	Spotted hake	163
		WHFT-8	Spotted hake	162
6-Month Post-Installation	11/14/06	WHFT-3	Blue crab	27
		WHFT-7	Striped bass	71
		WHFT-10	American eel	300
		WHFT-10	American eel	350
		WHFT-10	American eel	400
		WHFT-13	Blue crab	No length taken
12-Month Post-Installation	6/25/07	WHFT-9	American eel	410
18-Month Post-Installation	12/18/07	WHFT-3	Striped bass	87
		WHFT-3	Striped bass	89
		WHFT-7	Striped bass	87
		WHFT-7	Striped bass	79
		WHFT-7	Striped bass	86
		WHFT-7	Striped bass	79
		WHFT-8	Striped bass	63
		WHFT-9	Striped bass	89
		WHFT-9	Striped bass	88
		WHFT-9	Striped bass	71

Table-8: Sediment survey conducted at West Harlem Waterfront Park (18-Month Post-Installation).

Station	Coordinates		Average Distance (± SE) to Sediment (m) at Reef Ball Corners		
	N	W	6-mo post-install*	12-mo post-install	18-mo post-install
WHE-1	40 49.210	73 57.664	0.61	0.29 (± 0.06)	0.34 (± 0.02)
WHE-2	40 49.247	73 57.667	0.61	0.61 (± 0)	0.46 (± 0.03)
WHE-3	40 49.213	73 57.672	0.76	0.84 (± 0.05)	0.66 (± 0.03)
WHE-4	40 49.207	73 57.675	0.76	0.69 (± 0.04)	0.60 (± 0.02)
WHE-5	40 49.225	73 57.664	0.91	0.76 (± 0.11)	0.45 (± 0.02)
WHE-6	40 49.210	73 57.691	0.91	0.84 (± 0.08)	0.44 (± 0.03)
WHE-7	40 49.243	73 57.642	0.46	0.21 (± 0.05)	0.35 (± 0.03)
WHE-8	40 49.256	73 57.634	0.76	0.61 (± 0.06)	0.56 (± 0)
WHE-9	40 49.254	73 57.646	0.76	0.76 (± 0.09)	0.52 (± 0.01)
WHE-10	40 49.269	73 57.663	0.76	NS	NS
WHE-11*	40 49.259	73 57.661	0.76	0.20 (± 0.04)	NS
WHE-12	40 49.234	73 57.685	0.46	0.88 (± 0.07)	0.35 (± 0.07)

*Distance was taken at one point on the reef ball
NS = No sample taken due to broken reef ball

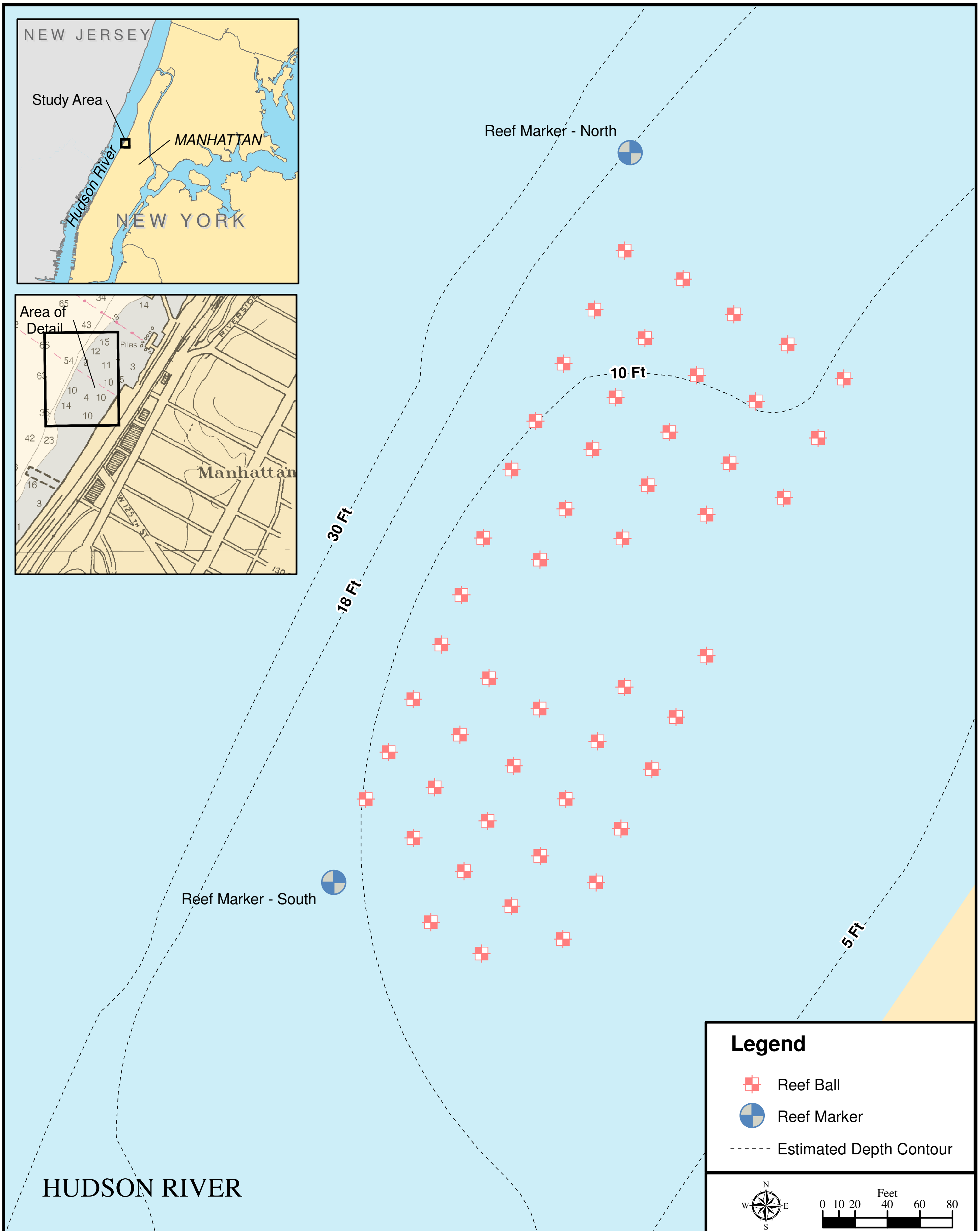
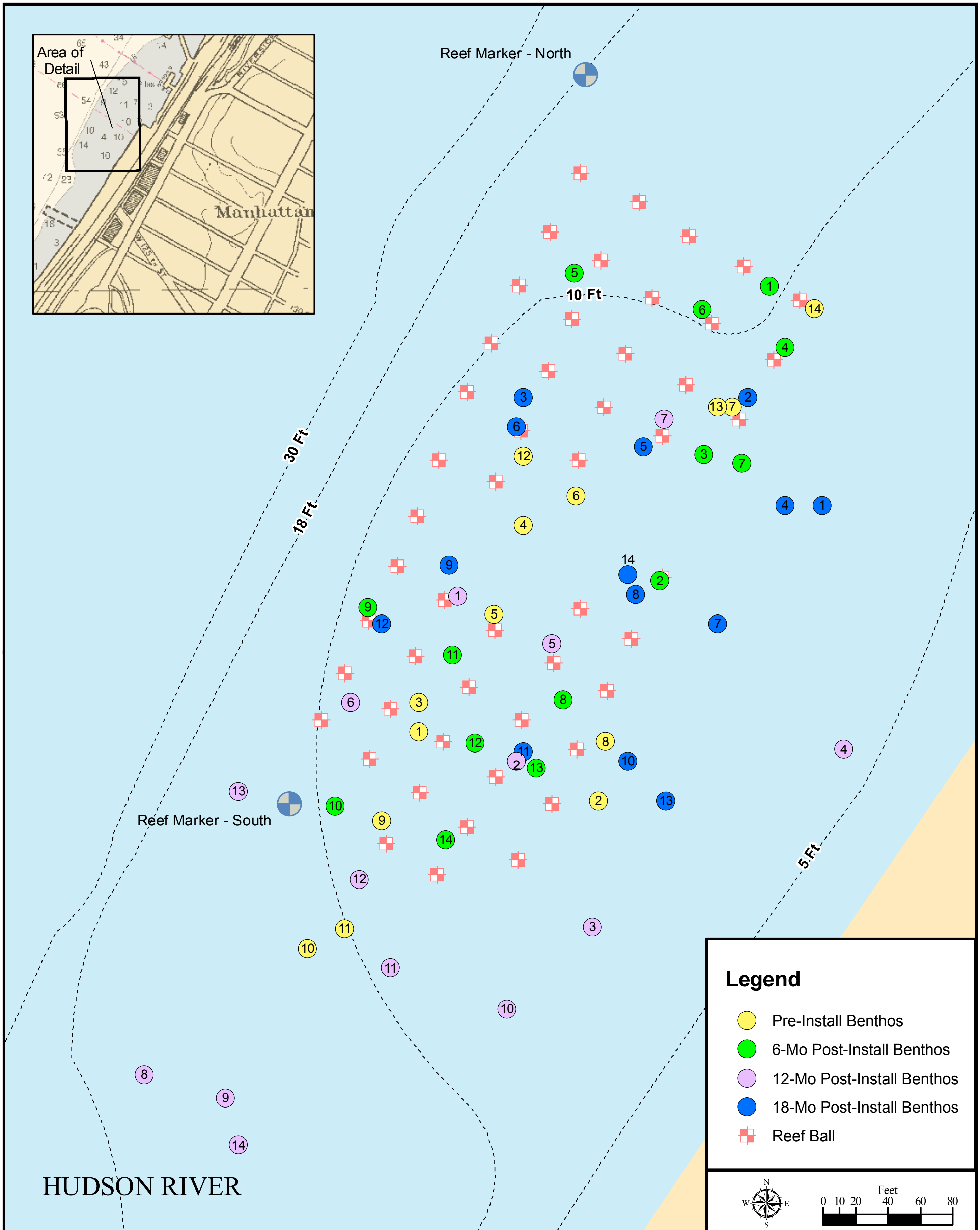
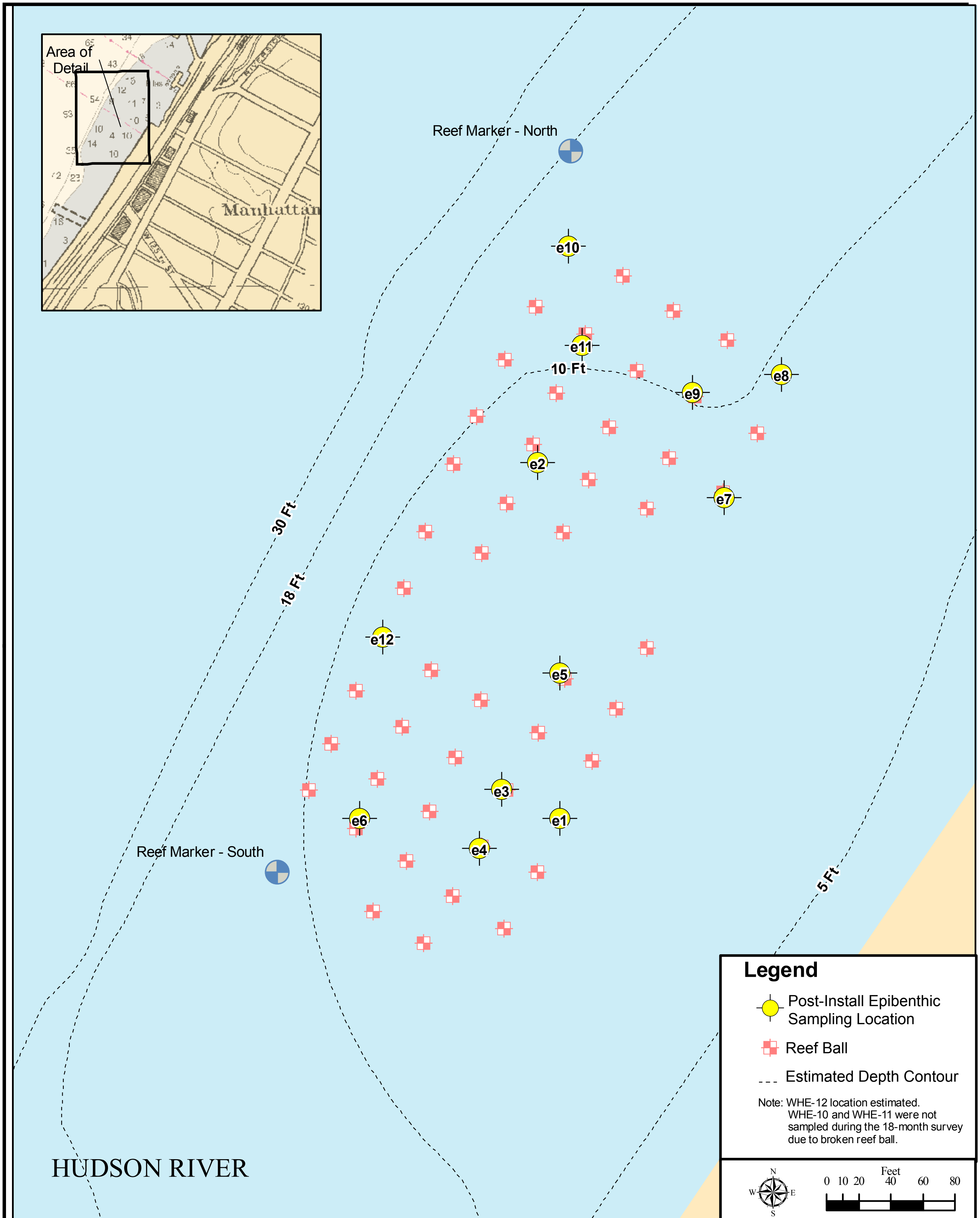


FIGURE 1:STUDY AREA WITH REEF BALL LOCATIONS



HDR | LMS

FIGURE 2: BENTHIC SAMPLING LOCATIONS: PRE- AND POST-INSTALLATION SURVEYS



HDR | LMS

FIGURE 3: EPIBENTHIC SAMPLING LOCATIONS DURING POST-INSTALLATION SURVEYS

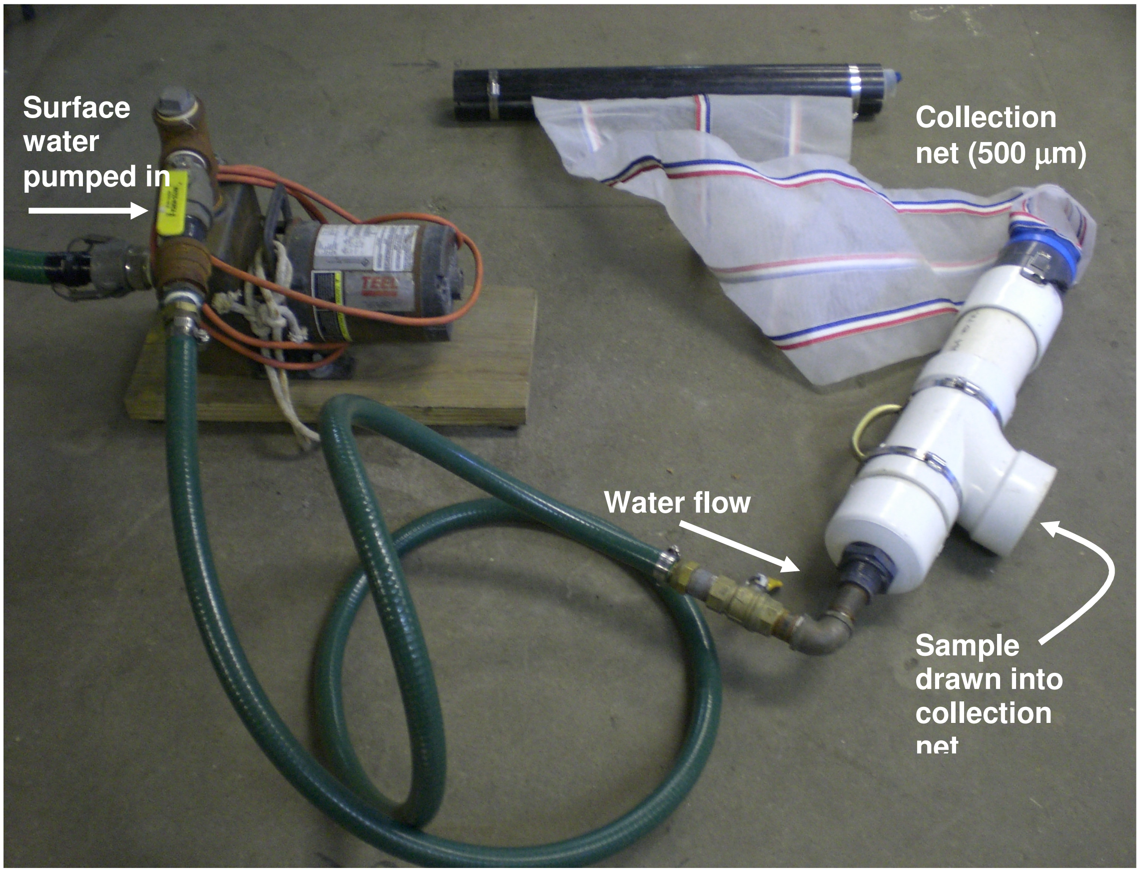
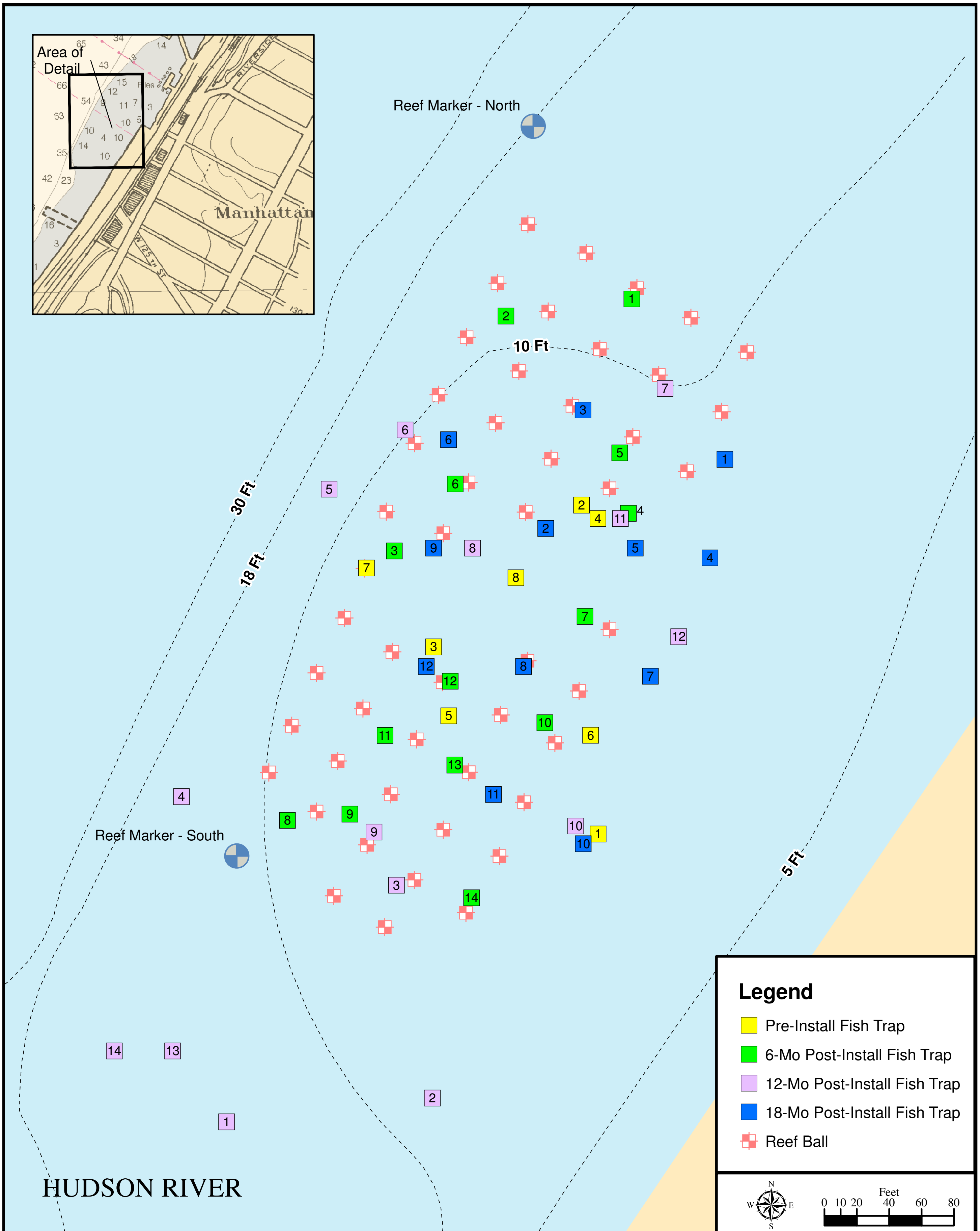


Figure 4. Suction sampler used in post-installation epibenthic sampling.



HDR | LMS

FIGURE 5: PRE- AND POST-INTALLATION FISH TRAP SAMPLING LOCATIONS

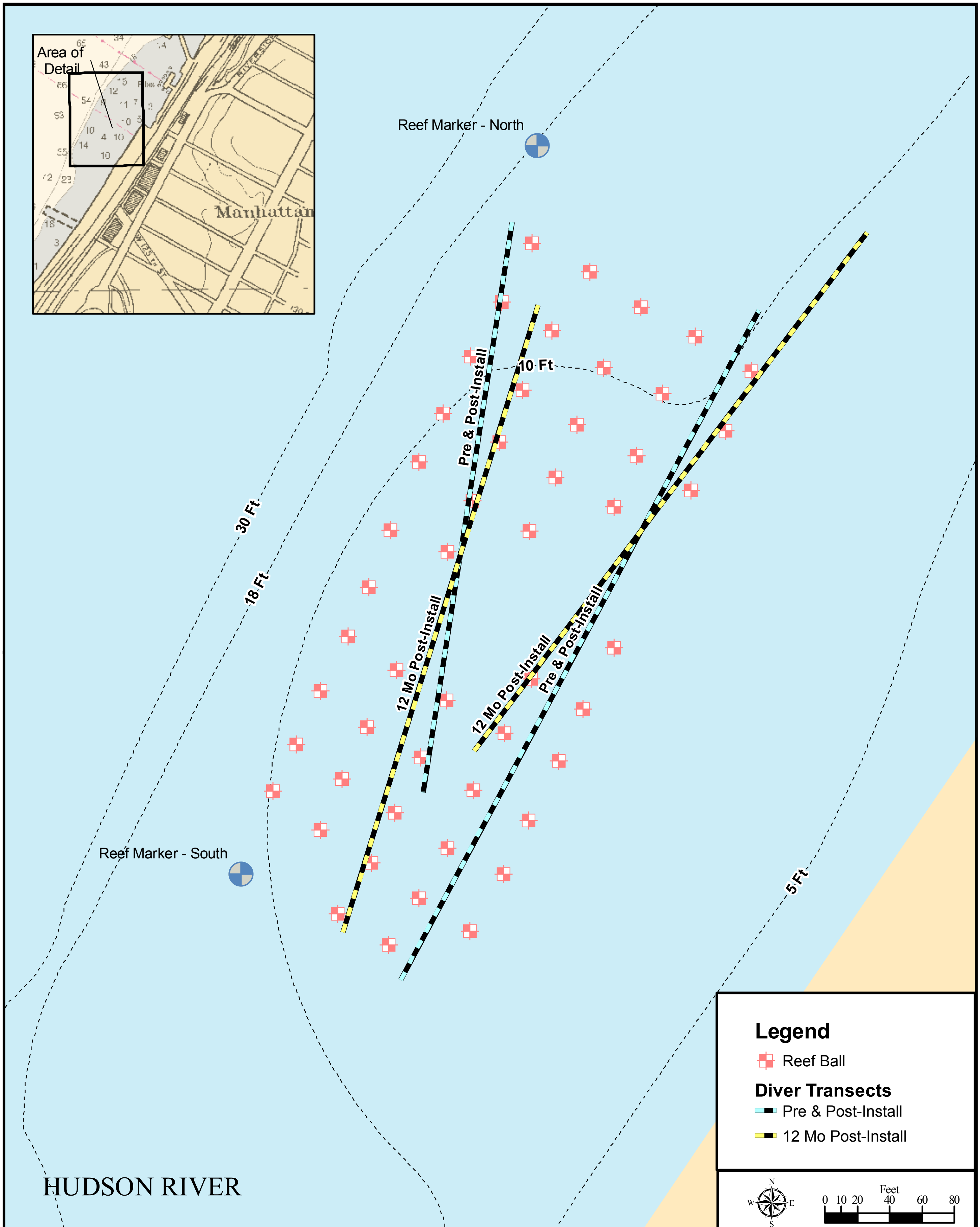


FIGURE 6: POST-INSTALLATATION SURVEY DIVER TRANSECTS

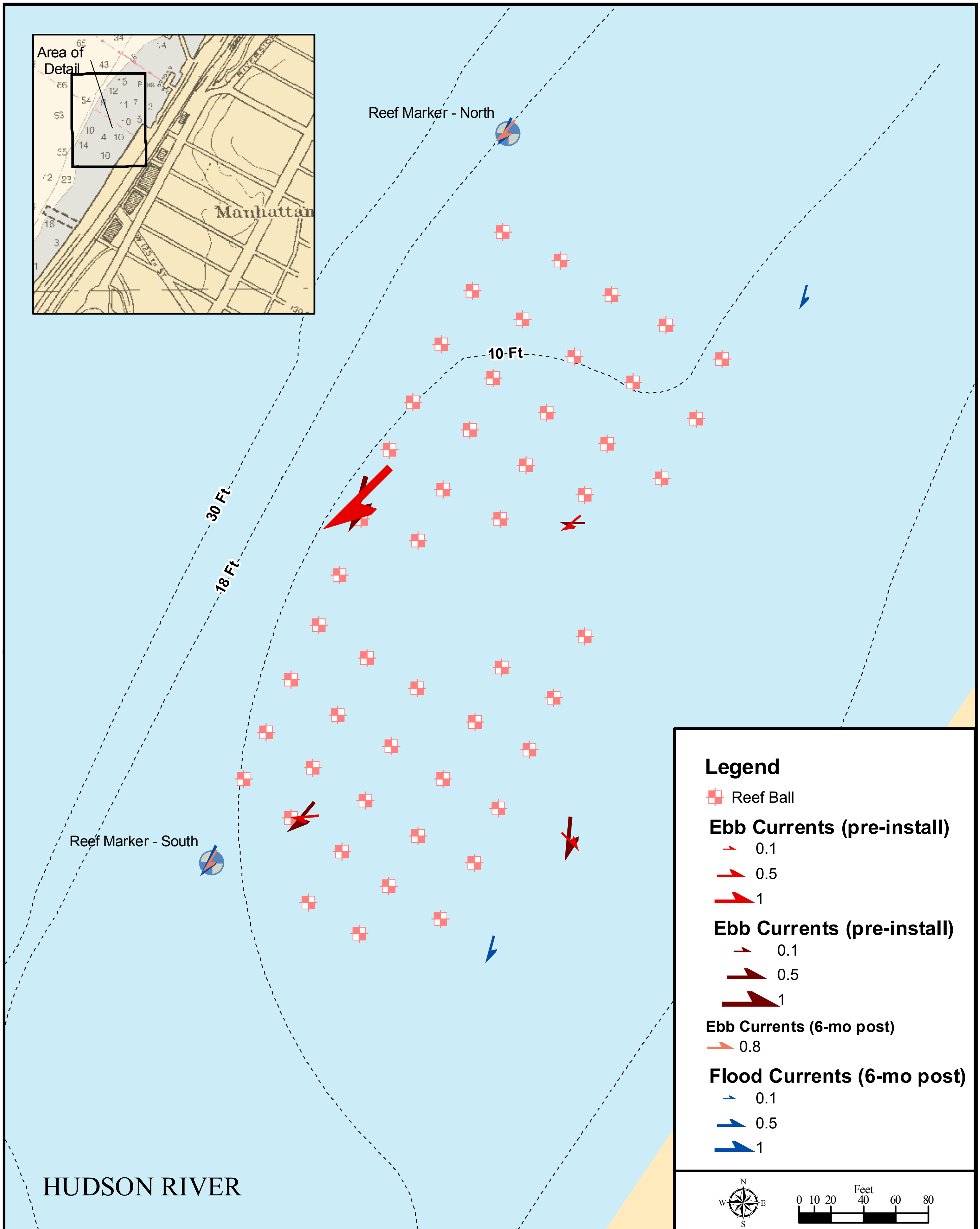


FIGURE 7: PRE- AND POST-INSTALLATATION HYDRODYNAMIC SURVEYS

APPENDIX A

Benthos density (organisms/m^2) collected at the West Harlem Waterfront Project.

Table A-1. Benthos Density (Organisms/m^2) collected at West Harlem Waterfront Project (Pre-Installation).

Phylum	Class	Order	Family	Genus Species	WHB-1	WHB-2	WHB-3	WHB-4	WHB-5	WHB-6	WHB-7	WHB-8	WHB-9	WHB-10	WHB-11	WHB-12	WHB-13	WHB-14
Nemertea	---	---	---	---	0	0	0	0	0	10	10	0	10	0	19	0	29	10
Nematoda	---	---	---	---	0	10	10	0	0	0	29	0	0	0	0	0	0	0
Annelida	Oligochaeta	---	---	---	48	133	0	0	19	10	10	10	19	19	48	0	0	0
	Polychaeta	---	---	---	0	0	10	0	19	0	0	0	0	0	0	0	0	0
		Ariciida	Orbiniidae	Leitoscoloplos fragilis	10	76	10	171	95	29	323	152	67	0	105	10	238	276
		Capitellida	Capitellidae	---	86	513	86	38	143	38	494	266	190	19	361	48	589	380
		Phyllodocida	Glyceridae	Glycera sp.	10	0	0	0	0	0	0	0	0	0	0	0	0	0
			Nereidae	Nereis sp.	0	0	86	0	10	0	0	0	10	0	0	0	0	0
			Phyllodocidae	---	10	0	0	0	0	0	0	0	0	0	0	0	0	0
				Eteone sp.	0	0	29	19	19	10	38	76	86	0	29	0	67	19
			Spionidae	---	10	10	0	10	0	0	0	0	0	0	0	0	0	0
			Spionidae	Polydora ligni	29	0	675	0	48	10	0	0	95	57	0	0	0	0
				Streblospio benedicti	627	38	722	228	76	38	247	627	485	371	1074	133	76	38
				Scolecolepides viridis	48	57	38	38	10	19	29	105	114	29	314	29	48	76
			Pectinariidae	Pectinaria gouldii	10	0	10	0	0	0	0	0	10	0	0	0	0	0
Arthropoda	Crustacea	Amphipoda	---	---	0	0	0	0	0	0	0	0	0	0	0	0	19	0
		Decapoda	Grapsidae	---	0	0	10	0	0	0	0	0	0	0	0	0	0	0
		Isopoda	Idoteidae	Idotea sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Mollusca	Bivalvia	Veneroida	Mactridae	Mulinia lateralis	0	57	0	0	0	0	0	0	0	0	0	10	0	10
True Taxa Richness					**9**	**8**	**10**	**6**	**8**	**8**	**8**	**6**	**10**	**5**	**7**	**5**	**7**	**8**
Total Benthos Density (organisms/m2)					**884**	**893**	**1682**	**504**	**437**	**162**	**1178**	**1235**	**1083**	**494**	**1948**	**228**	**1064**	**817**

Table A-2. Benthic community true taxa richness, density (organisms/m^2), Diversity (H'), and Evenness (E) collected at West Harlem Waterfront Project. (Pre-Installation)

Station	Taxa Richness	Density (organisms/m2)	Diversity (H')	Evenness (E)
WHB-1	9	884	1.64	0.52
WHB-2	8	893	2.01	0.67
WHB-3	10	1,682	1.92	0.58
WHB-4	6	504	1.9	0.73
WHB-5	8	437	2.62	0.87
WHB-6	8	162	2.74	0.91
WHB-7	8	1,178	2.04	0.68
WHB-8	6	1,235	1.95	0.75
WHB-9	10	1,083	2.43	0.73
WHB-10	5	494	1.27	0.55
WHB-11	7	1,948	1.86	0.66
WHB-12	5	228	1.68	0.72
WHB-13	7	1,064	1.92	0.68
WHB-14	8	817	1.92	0.64

Table A-3. Taxa occurrence and total density (organisms/m2) occurrence at West Harlem Waterfront Project. (Pre-Installation)																
Station	**Taxa Occurrence**								**Total Density (organisms/m²) Occurrence**							
	Annelida		**Arthropoda**		**Mollusca**		**Miscellaneous**		**Annelida**		**Arthropoda**		**Mollusca**		**Miscellaneous**	
	NO.	**%**	**NO.**	**%**	**NO.**	**%**	**NO.**	**%**	**NO.**	**%**	**NO.**	**%**	**NO.**	**%**	**NO.**	**%**
WHB-1	9	100%	0	0%	0	0%	0	0%	884	100%	0	0%	0	0%	0	0%
WHB-2	6	75%	0	0%	1	13%	1	13%	827	93%	0	0%	57	6%	10	1%
WHB-3	8	80%	1	10%	0	0%	1	10%	1663	98%	10	1%	0	0%	10	1%
WHB-4	6	100%	0	0%	0	0%	0	0%	504	100%	0	0%	0	0%	0	0%
WHB-5	8	100%	0	0%	0	0%	0	0%	437	100%	0	0%	0	0%	0	0%
WHB-6	7	88%	0	0%	0	0%	1	12%	152	94%	0	0%	0	0%	10	6%
WHB-7	6	75%	0	0%	0	0%	2	25%	1140	97%	0	0%	0	0%	38	3%
WHB-8	6	100%	0	0%	0	0%	0	0%	1235	100%	0	0%	0	0%	0	0%
WHB-9	9	90%	0	0%	0	0%	1	10%	1074	99%	0	0%	0	0%	10	1%
WHB-10	5	100%	0	0%	0	0%	0	0%	494	100%	0	0%	0	0%	0	0%
WHB-11	6	86%	0	0%	0	0%	1	14%	1929	99%	0	0%	0	0%	19	1%
WHB-12	4	80%	0	0%	1	20%	0	0%	219	96%	0	0%	10	4%	0	0%
WHB-13	5	72%	1	14%	0	0%	1	14%	1017	95%	19	2%	0	0%	29	3%
WHB-14	5	63%	1	12%	1	12%	1	12%	788.5	97%	9.5	1%	9.5	1%	9.5	1%
Total	**11**	**65%**	**3**	**18%**	**1**	**6%**	**2**	**12%**	**883**	**98%**	**3**	**0%**	**5**	**1%**	**10**	**1%**

Table A-4. Benthos Density (organisms/m^2) collected at West Harlem Waterfront Project (Six-Month Post-Installation).

Phylum	Class	Order	Family	GenusSpecies	WHB-1	WHB-2	WHB-3	WHB-4	WHB-5	WHB-6	WHB-7	WHB-8	WHB-9	WHB-10	WHB-11	WHB-12	WHB-13	WHB-14	Grab Average 6-Month Post*	Grab Average Pre-Install
Nemertea	---	---	---	---	0	10	0	67	10	86	67	105	38	10	57	19	86	48	**43**	**6**
Nematoda	---	---	---	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Annelida	Oligochaeta	---	---	---	0	10	48	76	200	57	124	57	314	19	19	29	29	124	**79**	**22**
	Polychaeta	---	---	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
		Ampharetida	Ampharetidae	---	0	0	0	10	0	0	0	0	0	0	0	0	0	0	**1**	**0**
		Ariciida	Orbiniidae	Leitoscoloplos fragilis	0	95	57	95	86	171	162	124	95	0	0	48	29	48	72	**111**
		Capitellida	Capitellidae	---	143	1036	276	190	228	1150	361	475	988	38	171	219	371	86	**409**	**232**
		Phyllodocida	Goniadidae	---	10	0	10	19	10	10	0	19	0	0	0	0	10	19	**7**	**0**
			Glyceridae	Glycera sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
			Nereidae	Nereis spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**8**
				Nereis succinea	0	0	0	19	200	10	0	29	485	437	618	266	0	323	**170**	**0**
				Nereis virens	0	0	10	0	0	0	0	0	0	0	0	0	0	0	**1**	**0**
			Phyllodocidae	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
				Eteone sp.	29	67	48	48	133	95	67	48	48	19	0	0	38	0	**45**	**28**
			Spionidae	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
				Polydora ligni	0	0	0	0	10	0	0	0	542	1710	181	10	0	38	**178**	**65**
				Streblospio benedicti	0	38	57	10	105	29	38	76	836	599	475	124	57	437	206	**341**
				Scolecolepides viridis	0	10	0	0	0	0	10	0	0	0	0	0	0	0	1	**68**
			Pectinariidae	Pectinaria gouldii	0	0	0	0	10	0	0	0	19	0	48	0	0	0	**5**	**2**
Arthropoda	Crustacea	Amphipoda	---	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
			Corophiidae	Corophium spp.	0	0	0	0	0	0	0	0	29	10	0	10	0	0	**3**	**0**
			Gammaridae	Gammarus sp.	0	19	29	10	38	19	19	10	19	0	67	38	76	29	**26**	**0**
			Melitidae	---	0	0	0	0	0	0	0	0	0	0	0	19	0	0	**1**	**0**
			Pluestidae	---	0	0	0	0	0	0	0	0	19	0	10	190	0	0	**16**	**0**
		Cumacea	Leuconidae	Leucon americanus	48	133	209	143	323	276	38	76	0	0	0	0	295	105	**117**	**0**
		Decapoda	Grapsidae	---	0	0	0	0	0	0	0	0	0	0	0	10	0	0	1	**1**
				Hemigrapsus sanguineus	0	0	0	0	0	0	0	0	10	0	0	10	0	0	**1**	**0**
			Portunidae	Callinectes sapidus	0	0	0	0	0	0	0	0	10	0	0	0	0	0	**1**	**0**
		Isopoda	Anthuridae	Cyathura polita	10	0	0	0	19	0	0	10	67	67	86	29	10	10	**22**	**0**
			Idoteidae	Edotea sp.	0	0	0	0	29	0	0	0	57	38	48	38	0	0	**15**	**0**
				Idotea spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Mollusca	Bivalvia	Eulamellibranchia	Teredinidae	Teredo navalis	0	0	0	0	0	0	0	0	0	0	0	333	0	0	**24**	**0**
		Myoida	Myidae	Mya arenaria	0	0	0	0	0	0	0	10	0	0	0	0	0	0	**1**	**0**
		Mytiloida	Mytilidae	Geukensia demissa	0	0	0	0	10	0	0	0	0	0	0	0	0	0	**1**	**0**
		Veneroida	Mactridae	Mulinia lateralis	0	0	0	0	0	0	162	10	0	0	10	0	95	10	**20**	**5**
			Tellinidae	Tellina agilis	0	0	0	0	0	0	0	0	10	0	19	0	0	0	**2**	**0**
	Gastropoda	Cephalaspidea	Scaphandridae	Acteocina canaliculata	0	0	0	0	0	0	10	0	0	0	10	0	10	0	**2**	**0**
True Taxa Richness					**5**	**9**	**9**	**11**	**15**	**10**	**11**	**13**	**17**	**10**	**14**	**15**	**12**	**12**	**12**	**8**
Total Benthos Density (organisms/m^2)					**238**	**1,416**	**741**	**684**	**1,406**	**1,900**	**1,055**	**1,045**	**3,582**	**2,945**	**1,815**	**1,387**	**1,102**	**1,273**	**1,470**	**900**

* 6-month grab averages in **bold** = an increase over the pre-installation grab average.

Table A-5. Benthic community true taxa richness, density (organisms/m^2), Diversity (H'), and Evenness (E) collected at West Harlem Waterfront Project (Six-Month Post-Installation).

Station	Taxa Richness	Density (organisms/m^2)	Diversity (H')	Evenness (E)
WHB-1	5	238	1.65	0.71
WHB-2	9	1,416	1.49	0.47
WHB-3	9	741	2.47	0.78
WHB-4	11	684	2.87	0.83
WHB-5	15	1,406	3.14	0.80
WHB-6	10	1,900	1.96	0.59
WHB-7	11	1,055	2.80	0.81
WHB-8	13	1,045	2.69	0.73
WHB-9	17	3,582	2.85	0.70
WHB-10	10	2,945	1.76	0.53
WHB-11	14	1,815	2.76	0.72
WHB-12	15	1,387	3.12	0.80
WHB-13	12	1,102	2.73	0.76
WHB-14	12	1,273	2.74	0.76
Grab Average (6-Month Post)	**12**	**1470**	**2.50**	**0.71**
Grab Average (Pre-Install)	**8**	**900**	**1.99**	**0.69**

Table A-6. Benthic community taxa occurrence and total density (organisms/m^2) occurrence at West Harlem Waterfront Project (Six-Month Post-Installation).

Station	Taxa Occurrence								Total Density (organisms/m^2) Occurrence							
	Annelida		Arthropoda		Mollusca		Miscellaneous		Annelida		Arthropoda		Mollusca		Miscellaneous	
	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
WHB-1	3	60%	2	40%	0	0%	0	0%	181	76%	57	24%	0	0%	0	0%
WHB-2	6	67%	2	22%	0	0%	1	11%	1,254	89%	152	11%	0	0%	10	1%
WHB-3	7	78%	2	22%	0	0%	0	0%	504	68%	238	32%	0	0%	0	0%
WHB-4	8	73%	2	18%	0	0%	1	9%	466	68%	152	22%	0	0%	67	10%
WHB-5	9	60%	4	27%	1	7%	1	7%	979	70%	409	29%	10	1%	10	1%
WHB-6	7	70%	2	20%	0	0%	1	10%	1,520	80%	295	16%	0	0%	86	5%
WHB-7	6	55%	2	18%	2	18%	1	9%	760	72%	57	5%	171	16%	67	6%
WHB-8	7	54%	3	23%	2	15%	1	8%	827	79%	95	9%	19	2%	105	10%
WHB-9	8	47%	7	41%	1	6%	1	6%	3,325	93%	209	6%	10	0%	38	1%
WHB-10	6	60%	3	30%	0	0%	1	10%	2,822	96%	114	4%	0	0%	10	0%
WHB-11	6	43%	4	29%	3	21%	1	7%	1,511	83%	209	12%	38	2%	57	3%
WHB-12	6	40%	7	47%	1	7%	1	7%	694	50%	342	25%	333	24%	19	1%
WHB-13	6	50%	3	25%	2	17%	1	8%	532	48%	380	34%	105	9%	86	8%
WHB-14	7	58%	3	25%	1	8%	1	8%	1,074	84%	143	11%	10	1%	48	4%
Total 6-Month Post	**12**	**43%**	**9**	**32%**	**6**	**21%**	**1**	**4%**	**1,175**	**80%**	**204**	**14%**	**50**	**3%**	**43**	**3%**
Total Pre-Install	**11**	**65%**	**3**	**18%**	**1**	**6%**	**2**	**12%**	**883**	**98%**	**3**	**0%**	**5**	**1%**	**10**	**1%**

Table A-7. Benthos Density (organisms/m^2) collected at West Harlem Waterfront Project (12-Month Post-Installation).

Phylum	Class	Order	Family	GenusSpecies	WHB-1	WHB-2	WHB-3	WHB-4	WHB-5	WHB-6	WHB-7	WHB-8	WHB-9	WHB-10	WHB-11	WHB-12	WHB-13	WHB-14	Grab Average 12-Month Post*	Grab Average 6-Month Post*	Grab Average Pre-Install
Nemertea	---	---	---	---	0	0	0	19	10	0	19	10	10	29	19	19	0	19	**11**	**43**	**6**
Nematoda	---	---	---	---	0	0	0	0	0	0	0	29	0	0	0	0	0	0	2	0	**3**
Annelida	Hirudinea	---	---	---	0	0	0	0	0	38	0	48	0	0	0	0	10	0	7	**0**	**0**
	Oligochaeta	---	---	---	0	0	0	0	0	0	10	10	10	0	0	0	0	10	**3**	**79**	**22**
	Polychaeta	---	---	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
		Ampharetida	Ampharetidae	---	0	10	0	0	0	0	0	0	0	0	0	0	0	10	**1**	**1**	**0**
		Ariciida	Orbiniidae	*Leitoscoloplos fragilis*	10	276	29	0	114	0	276	114	95	86	143	67	0	105	94	72	**111**
		Canalipalpata	Sabellariidae	*Sabellaria vulgaris*	0	0	0	0	0	0	0	10	0	0	0	0	0	0	**1**	**0**	**0**
		Capitellida	Capitellidae	---	10	257	114	143	95	0	143	67	76	266	162	67	10	200	**115**	**409**	**232**
		Phyllodocida	Goniadidae	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**8**	**0**
			Glyceridae	*Glycera* sp.	0	0	0	0	0	0	10	0	0	0	10	0	0	0	**1**	0	**1**
			Nereidae	*Nereis* sp.	0	0	0	29	0	67	0	247	95	10	0	0	86	0	**38**	0	**8**
				Nereis succinea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**170**	**0**
				Nereis virens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**1**	**0**
			Phyllodocidae	---	0	0	0	0	0	0	0	10	0	0	0	0	0	0	**1**	0	**1**
				Eteone sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**46**	**28**
			Spionidae	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
				Polydora ligni	0	0	0	0	0	2309	0	1796	295	0	0	29	333	38	**343**	**178**	**65**
				Streblospio benedicti	0	0	0	0	0	0	19	200	0	10	0	0	29	0	18	206	**341**
				Scolecolepides viridis	10	10	48	29	19	0	19	19	10	38	10	10	0	19	17	1	**68**
		Spionida	Paraonidae	---	0	0	0	0	19	0	0	0	0	0	0	0	0	0	**1**	0	**0**
		Terebellida	Pectinariidae	*Pectinaria gouldii*	0	0	0	0	0	0	0	10	0	0	0	0	0	0	1	**5**	**2**
Arthropoda	Crustacea	Amphipoda	Ampeliscidae	*Ampelisca spp.*	10	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	**1**
				Ampelisca abdita	0	10	0	0	19	0	19	0	10	19	10	10	10	10	**8**	**0**	**0**
			Aoridae	---	0	0	0	0	0	0	0	0	0	0	0	0	0	10	**1**	**0**	**0**
			Corophiidae	*Corophium* sp.	0	0	0	0	0	190	19	38	10	10	0	0	0	0	**19**	**3**	**0**
			Gammaridae	*Gammarus* sp.	38	0	10	0	19	0	0	10	0	0	10	10	0	0	**7**	**27**	**0**
			Melitidae	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**1**	**0**
			Pluestidae	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**16**	**0**
		Cumacea	Leuconidae	*Leucon americanus*	0	38	29	10	29	0	152	19	95	38	257	57	19	114	**61**	**117**	**0**
		Decapoda	Crangonidae	*Crangon*	10	0	0	95	57	38	86	0	29	86	48	105	29	48	**45**	**0**	**0**
			Grapsidae	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**1**
				Hemigrapsus sanguineus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**1**	**0**
			Portunidae	*Callinectes sapidus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**1**	**0**
			Panopeidae	*Panopeus herbstii*	0	0	0	0	0	0	0	10	0	0	0	0	0	0	**1**	**0**	**0**
				Rhithropanopeus	0	0	0	0	0	0	0	0	0	0	0	0	19	0	**1**	**0**	**0**
		Isopoda	Anthuridae	*Cyathura polita*	0	0	0	19	0	0	19	10	0	0	10	19	29	0	**7**	**22**	**0**
			Idoteidae	*Edotea* sp.	0	0	0	0	0	10	10	48	0	0	0	0	0	0	**5**	**15**	**0**
				Idotea sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Mollusca	Bivalvia	---	---	---	10	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**0**	**0**
		Eulamellibranchia	Teredinidae	*Teredo navalis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**24**	**0**
		Myoida	Myidae	*Mya arenaria*	0	0	0	0	0	0	0	0	10	0	0	0	0	0	**1**	**1**	**0**
		Mytiloida	Mytilidae	*Geukensia demissa*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**1**	**0**
				Mytilus edulis	0	0	0	0	10	10	0	0	0	0	0	0	0	0	**1**	**0**	**0**
		Veneroida	Mactridae	*Mulinia lateralis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**20**	**5**
			Tellinidae	*Tellina agilis*	10	10	10	19	19	0	29	0	0	0	10	0	0	10	**8**	**2**	**0**
	Gastropoda	Cephalaspidea	Scaphandridae	*Acteocina canaliculata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**2**	**0**
True Taxa Richness					**7**	**7**	**6**	**8**	**11**	**7**	**14**	**19**	**12**	**10**	**11**	**10**	**10**	**12**	**10**	**12**	**8**
Total Benthos Density (organisms/m^2)					**105**	**608**	**238**	**361**	**409**	**2,660**	**827**	**2,698**	**741**	**589**	**684**	**390**	**570**	**589**	**819**	**1,470**	**900**

* 6-month & 12-month grab averages in **bold** = an increase over the pre-installation grab average.

Table A-8. Benthic community true taxa richness, density (organisms/m^2), Diversity (H'), and Evenness (E) collected at West Harlem Waterfront Project (12-Month Post-Installation).

Station	Taxa Richness	Density (organisms/m^2)	Diversity (H')	Evenness (E)
WHB-1	7	105	2.73	0.97
WHB-2	7	608	1.67	0.59
WHB-3	6	238	2.08	0.80
WHB-4	8	361	2.42	0.81
WHB-5	11	409	2.95	0.85
WHB-6	7	2,660	0.82	0.29
WHB-7	14	827	2.89	0.76
WHB-8	19	2,698	2.00	0.47
WHB-9	12	741	2.67	0.74
WHB-10	10	589	2.50	0.75
WHB-11	11	684	2.42	0.70
WHB-12	10	390	2.88	0.87
WHB-13	10	570	2.13	0.64
WHB-14	12	589	2.78	0.77
Grab Average (12-Month Post)	**10**	**819**	**2.35**	**0.72**
Grab Average (6-Month Post)	**12**	**1470**	**2.50**	**0.71**
Grab Average (Pre-Install)	**8**	**900**	**1.99**	**0.69**

Table A-9. Benthic community taxa occurrence and total density (organisms/m²) occurrence at West Harlem Waterfront Project (12-Month Post-Installation).

Station	Taxa Occurrence								Total Density (organisms/m²) Occurrence							
	Annelida		Arthropoda		Mollusca		Miscellaneous		Annelida		Arthropoda		Mollusca		Miscellaneous	
	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
WHB-1	3	38%	3	38%	2	25%	0	0%	29	27%	57	55%	19	18%	0	0%
WHB-2	4	57%	2	29%	1	14%	0	0%	551	91%	48	8%	10	2%	0	0%
WHB-3	3	50%	2	33%	1	17%	0	0%	190	80%	38	16%	10	4%	0	0%
WHB-4	3	38%	3	38%	1	13%	1	13%	200	55%	124	34%	19	5%	19	5%
WHB-5	4	36%	4	36%	2	18%	1	9%	247	60%	124	30%	29	7%	10	2%
WHB-6	3	43%	3	43%	1	14%	0	0%	2,413	91%	238	9%	10	0%	0	0%
WHB-7	6	43%	6	43%	1	7%	1	7%	475	57%	304	37%	29	3%	19	2%
WHB-8	11	58%	6	32%	0	0%	2	11%	2,527	94%	133	5%	0	0%	38	1%
WHB-9	6	50%	4	33%	1	8%	1	8%	580	78%	143	19%	10	1%	10	1%
WHB-10	5	50%	4	40%	0	0%	1	10%	409	69%	152	26%	0	0%	29	5%
WHB-11	4	36%	5	45%	1	9%	1	9%	323	47%	333	49%	10	1%	19	3%
WHB-12	4	40%	5	50%	0	0%	1	10%	171	44%	200	51%	0	0%	19	5%
WHB-13	5	50%	5	50%	0	0%	0	0%	466	82%	105	18%	0	0%	0	0%
WHB-14	6	50%	4	33%	1	8%	1	8%	380	65%	181	31%	10	2%	19	3%
Total 12-Month Post	**14**	**45%**	**11**	**35%**	**4**	**13%**	**2**	**6%**	**640**	**78%**	**155**	**19%**	**11**	**1%**	**13**	**2%**
Total 6-Month Post	**12**	**43%**	**9**	**32%**	**6**	**21%**	**1**	**4%**	**1,175**	**80%**	**204**	**14%**	**50**	**3%**	**43**	**3%**
Total Pre-Install	**11**	**65%**	**3**	**18%**	**1**	**6%**	**2**	**12%**	**883**	**98%**	**3**	**0%**	**5**	**1%**	**10**	**1%**

Table A-10. Benthos Density (organisms/m^2) collected at West Harlem Waterfront Project (18-Month Post-Installation).

Phylum	Class	Order	Family	Genus Species	WHB-1	WHB-2	WHB-3	WHB-4	WHB-5	WHB-6	WHB-7	WHB-8	WHB-9	WHB-10	WHB-11	WHB-12	WHB-13	WHB-14	Grab Average 18-Month Post*	Grab Average 12-Month Post*	Grab Average 6-Month Post*	Grab Average Pre-Install
Nemertea	---	---	---	---	0	10	0	152	10	0	147	29	29	69	48	16	109	19	**45**	**11**	**43**	6
Nematoda	---	---	---	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	3
Annelida	Hirudinea	---	---	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**7**	0	0
	Oligochaeta	---	---	---	48	19	485	238	713	539	159	171	143	19	76	79	43	143	**205**	3	**79**	22
	Polychaeta	---	---	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
		Ampharetida	Ampharetidae	---	0	0	0	0	0	0	0	29	86	31	0	16	24	10	**14**	**1**	**1**	0
		Ariciida	Orbiniidae	Leitoscoloplos fragilis	627	836	447	979	1235	267	762	827	29	567	1055	158	651	1064	**679**	94	72	111
		Canalipalpata	Sabellariidae	Sabellaria vulgaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0
		Capitellida	Capitellidae	---	1482	722	3582	1121	3506	2568	1492	1883	171	560	2613	174	627	1340	**1560**	115	**409**	232
		Phyllodocida	Goniadidae	---	0	76	76	190	152	114	159	57	0	91	76	79	52	162	**92**	0	**8**	0
				Glycinde solitaria	0	48	0	0	0	0	0	0	0	0	0	0	0	0	**3**	0	0	0
			Glyceridae	Glycera sp.	48	19	162	0	0	0	0	0	0	0	19	0	0	0	**18**	**1**	0	1
			Nephtyidae	Nephtys sp.	10	0	0	0	0	0	0	0	0	0	0	0	0	10	**1**	0	0	0
			Nereidae	Nereis sp.	67	10	437	10	0	0	20	29	200	10	0	79	0	0	**61**	**38**	0	8
				Nereis succinea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**170**	0
				Nereis virens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0
			Phyllodocidae	---	124	124	95	266	323	57	196	200	171	142	105	285	109	333	**181**	1	0	1
				Eteone sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**46**	28
			Spionidae	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
				Polydora ligni	0	0	713	0	0	0	0	0	285	0	10	111	0	0	**80**	**343**	**178**	65
				Streblospio benedicti	76	656	6213	817	2375	4611	558	1455	8787	348	1710	7489	209	922	**2588**	18	206	341
				Scolecolepides viridis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	1	68
			Syllidae	---	0	0	0	0	0	0	0	29	0	0	0	0	0	0	**2**	0	0	0
		Spionida	Paraonidae	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0
		Terebellida	Pectinariidae	Pectinaria gouldii	0	0	162	0	86	32	0	57	228	10	105	238	0	48	**69**	1	**5**	2
Arthropoda	Crustacea	Amphipoda	Ampeliscidae	Ampelisca spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
				Ampelisca abdita	10	0	0	0	0	0	20	0	29	48	10	0	0	0	**8**	**8**	0	0
			Aoridae	---	19	19	152	67	10	0	0	86	0	22	29	32	0	10	**32**	**1**	0	0
			Corophiidae	Corophium spp.	19	0	0	0	0	0	0	29	0	0	0	16	0	0	**5**	**19**	**3**	0
			Gammaridae	---	19	10	285	0	0	0	0	0	0	0	0	0	0	0	**22**	0	0	0
				Gammarus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**7**	**27**	0
			Melitidae	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0
			Oedicerotidae	---	10	57	19	10	48	0	0	29	0	22	0	0	0	0	**14**	0	0	0
			Pluestidae	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**16**	0
		Cumacea	Leuconidae	Leucon americanus	19	181	76	57	304	127	61	86	171	57	200	32	24	304	**121**	**61**	**117**	0
		Decapoda	Crangonidae	Crangon septemspinosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**45**	0	0
			Grapsidae	---	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
				Hemigrapsus sanguineus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0
			Portunidae	Callinectes sapidus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0
			Panopeidae	Panopeus herbstii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0
			Xanthidae	Rhithropanopeus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0
				Rhithropanopeus harrisii	0	0	0	0	0	0	0	0	29	0	0	0	0	0	**2**	0	0	0
		Isopoda	Anthuridae	Cyathura polita	67	0	0	10	0	0	20	29	86	22	0	0	14	0	**18**	**7**	**22**	0
			Idoteidae	Edotea sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**5**	**15**	0
				Edotea triloba	0	0	0	0	0	0	0	0	0	0	0	32	0	0	**2**	0	0	0
				Idotea sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		Thoracica	Balanidae	Balanus sp.	0	0	0	10	0	0	20	0	0	0	0	0	0	0	**2**	0	0	0
Mollusca	Bivalvia	---	---	---	0	0	0	0	0	0	0	171	0	0	0	0	0	0	**12**	**1**	0	0
		Eulamellibranchia	Teredinidae	Teredo navalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**24**	0
		Myoida	Myidae	Mya arenaria	0	0	0	0	0	0	0	0	0	0	0	0	0	10	**1**	**1**	**1**	0
		Mytiloida	Mytilidae	Geukensia demissa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0
				Mytilus edulis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0
		Nuculoida	Nuculanidae	Yoldia sp.	57	0	0	0	0	0	0	0	0	0	0	0	0	0	**4**	0	0	0
		Veneroida	Mactridae	Mulinia lateralis	760	1549	67	504	2242	839	872	2282	29	1285	817	253	613	1340	**961**	0	**20**	5
			Tellinidae	Tellina sp.	0	10	0	10	0	0	20	0	0	0	0	0	0	0	**3**	0	0	0
				Tellina agilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**8**	**2**	0
	Gastropoda	---	---	---	0	0	0	0	0	32	0	0	0	0	0	0	0	0	**2**	0	0	0
		Archeogastropoda	Naticidae	---	0	0	0	0	0	0	0	0	0	0	10	0	0	0	**1**	0	0	0
		Cephalaspidea	Atyidae	Haminoea solitaria	105	48	0	456	10	0	289	29	0	207	0	0	185	0	**95**	0	0	0
			Retusidae	Retusa canaliculata	0	0	0	29	133	0	29	171	0	53	95	0	0	114	**45**	0	0	0
				Retusa obtusa	0	114	0	10	0	0	0	0	0	0	0	0	0	0	**9**	0	0	0
			Scaphandridae	Acteocina canaliculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**	0
		Neogastropoda	Nassariidae	Ilyanassa obsoleta	19	10	10	0	10	0	0	0	0	0	10	0	0	19	**5**	0	0	0
Chordata	Ascidacea	Pleurogona	Molgulidae	Mogula manhattensis	0	0	285	0	0	0	0	0	0	0	0	0	0	0	**20**	0	0	0
True Taxa Richness					**19**	**18**	**17**	**18**	**15**	**10**	**16**	**19**	**15**	**18**	**17**	**16**	**12**	**16**	**16**	**10**	**12**	8
Total Benthos Density (organisms/m^2)					**3,582**	**4,513**	**13,263**	**4,931**	**11,153**	**9,186**	**4,827**	**7,674**	**10,470**	**3,562**	**6,983**	**9,088**	**2,662**	**5,843**	**6981**	819	**1470**	900

* 6-month, 12-month, & 18-month grab averages in **bold** = an increase over the pre-installation grab average.

Table A-11. Benthic community true taxa richness, density (organisms/m^2), Diversity (H'), and Evenness (E) collected at West Harlem Waterfront Project (18-Month Post-Installation).

Station	Taxa Richness	Density (organisms/m^2)	Diversity (H')	Evenness (E)
WHB-1	19	3,582	2.62	0.62
WHB-2	18	4,513	2.78	0.67
WHB-3	17	13,263	2.41	0.59
WHB-4	18	4,931	3.11	0.75
WHB-5	15	11,153	2.64	0.68
WHB-6	10	9,186	1.98	0.60
WHB-7	16	4,827	2.95	0.74
WHB-8	19	7,674	2.81	0.66
WHB-9	15	10,470	1.19	0.30
WHB-10	18	3,562	2.92	0.70
WHB-11	17	6,983	2.51	0.61
WHB-12	16	9,088	1.27	0.32
WHB-13	12	2,662	2.78	0.78
WHB-14	16	5,843	2.85	0.71
Grab Average (18-Month Post)	**16**	**6,981**	**2.49**	**0.62**
Grab Average (12-Month Post)	**10**	**819**	**2.35**	**0.72**
Grab Average (6-Month Post)	**12**	**1,470**	**2.50**	**0.71**
Grab Average (Pre-Install)	**8**	**900**	**1.99**	**0.69**

Table A-12. Benthic community taxa occurrence and total density (organisms/m^2) occurrence at West Harlem Waterfront Project (18-Month Post-Installation).

Station	Taxa Occurrence								Total Density (organisms/m^2) Occurrence							
	Annelida		Arthropoda		Mollusca		Miscellaneous		Annelida		Arthropoda		Mollusca		Miscellaneous	
	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
WHB-1	8	42%	7	37%	4	21%	0	0%	2,480	69%	162	5%	941	26%	0	0%
WHB-2	9	47%	4	21%	5	26%	1	5%	2,508	56%	266	6%	1,729	38%	10	0%
WHB-3	10	59%	4	24%	2	12%	1	6%	12,370	93%	532	4%	76	1%	285	2%
WHB-4	7	39%	5	28%	5	28%	1	6%	3,620	73%	152	3%	1,007	20%	152	3%
WHB-5	7	47%	3	20%	4	27%	1	7%	8,389	75%	361	3%	2,394	21%	10	0%
WHB-6	7	70%	1	10%	2	20%	0	0%	8,188	89%	127	1%	871	9%	0	0%
WHB-7	7	44%	4	25%	4	25%	1	6%	3,347	69%	122	3%	1,211	25%	147	3%
WHB-8	10	50%	5	25%	4	20%	1	5%	4,736	62%	257	3%	2,653	35%	29	0%
WHB-9	9	60%	4	27%	1	7%	1	7%	10,099	96%	314	3%	29	0%	29	0%
WHB-10	9	50%	5	28%	3	17%	1	6%	1,777	50%	170	5%	1,545	43%	69	2%
WHB-11	9	53%	3	18%	4	24%	1	6%	5,767	83%	238	3%	931	13%	48	1%
WHB-12	10	63%	4	25%	1	6%	1	6%	8,708	96%	111	1%	253	3%	16	0%
WHB-13	7	58%	2	17%	2	17%	1	8%	1,716	64%	38	1%	799	30%	109	4%
WHB-14	9	56%	2	13%	4	25%	1	6%	4,028	69%	314	5%	1,482	25%	19	0%
Total 18-Month Post	**14**	**38%**	**10**	**27%**	**11**	**30%**	**2**	**5%**	**5,552**	**80%**	**226**	**3%**	**1,137**	**16%**	**66**	**1%**
Total 12-Month Post	**14**	**45%**	**11**	**35%**	**4**	**13%**	**2**	**6%**	**640**	**78%**	**155**	**19%**	**11**	**1%**	**13**	**2%**
Total 6-Month Post	**12**	**43%**	**9**	**32%**	**6**	**21%**	**1**	**4%**	**1,175**	**80%**	**204**	**14%**	**50**	**3%**	**43**	**3%**
Total Pre-Install	**11**	**65%**	**3**	**18%**	**1**	**6%**	**2**	**12%**	**883**	**98%**	**3**	**0%**	**5**	**1%**	**10**	**1%**

APPENDIX B

Epibenthic density (organisms/m^2) collected at the West Harlem Waterfront Project.

Table B-1. Epibenthic Density (organisms/m^2, scrapings per reef ball) collected at West Harlem Waterfront Project (Six-Month Post-Installation).

Phylum	Class	Order	Family	Genus Species	WHE-1	WHE-2	WHE-3	WHE-4	WHE-5	WHE-6	WHE-7	WHE-8	WHE-9	WHE-10	WHE-11	WHE-12	Average
Bryozoa*	Gymnolaemata	Cheilostomata	Membraniporidae	*Membranipora spp.*	4%	0%	14%	22%	3%	3%	16%	2%	2%	0%	10%	0%	**6%**
				Membranipora tenuis	0%	2%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	**0%**
		Ctenostomata	Vesiculariidae	*Bowerbankia spp.*	0%	4%	4%	2%	0%	4%	8%	1%	4%	1%	2%	1%	**2%**
Cnidaria*	Hydrozoa	Hydroida	Campanulariidae	*Campanularia spp.*	3%	6%	22%	54%	0%	7%	9%	3%	5%	1%	2%	1%	**9%**
Platyhelminthes	Turbellaria	Polycladida	Stylochidae	*Stylochus spp.*	281	500	188	125	156	813	281	313	1,250	281	156	625	**414**
Porifera	Demospongiae	Halichondra	Halichondriidae	*Halichondria spp.*	0	156	0	0	0	688	0	31	156	31	0	0	**89**
Annelida	Polychaeta	Canalipalpata	Pectinariidae	*Pectinaria gouldii*	0	31	0	0	0	0	0	0	0	31	0	0	**5**
			Sabellariidae	*Sabellaria vulgaris*	0	0	63	0	31	125	0	0	94	0	0	125	**36**
			Spionidae	*Polydora ligni*	0	31	0	0	0	94	0	63	31	0	31	0	**21**
		Phyllodocida	Nereidae	*Nereis succinea*	63	63	31	0	0	188	63	94	94	31	31	125	**65**
Arthropoda	Crustacea	Amphipoda	Corophiidae	*Corophium spp.*	63	1,469	313	31	63	2,688	63	94	625	1,469	156	906	**661**
			Gammaridae	*Gammarus spp.*	0	0	0	0	0	0	31	0	0	0	0	0	**3**
			Hyperiidea	---	0	0	0	0	0	0	0	0	0	31	0	0	**3**
			Melitidae	*Melita spp.*	0	0	0	0	0	0	0	0	0	31	0	0	**3**
				Melita dentata	0	0	0	0	0	0	0	0	0	0	0	63	**5**
				Melita netida	0	0	0	0	0	0	0	0	0	31	0	0	**3**
			Photidae	---	156	0	0	0	0	0	0	0	0	0	125	0	**23**
			Pluestidae	---	344	531	188	31	0	438	94	94	281	63	0	219	**190**
		Cirripedia (Sub-Class)*	---	---	3%	6%	1%	3%	0%	1%	3%	11%	10%	3%	13%	3%	**5%**
			Archaeobalanidae	*Semibalanus balanoides*	47%	27%	22%	8%	66%	12%	36%	73%	51%	48%	44%	20%	**38%**
		Copepoda (Sub-Class)	---	---	0	0	0	31	0	63	0	31	0	0	0	31	**13**
		Isopoda	Chiridotea	*Chiridotea spp.*	0	0	0	0	0	0	0	0	0	0	31	0	**3**
			Idoteidae	*Idotea sp.*	469	31	63	31	31	875	31	313	63	156	31	219	**193**
Mollusca	Bivalvia	Mytiloida	Mytilidae	*Mytilus edulis*	0	0	31	0	0	0	0	0	94	0	0	0	**10**
Chordata	Ascidiacea	Stolidobranchia	Molgulidae	*Molgula manhattensis*	0	0	0	0	0	219	0	0	0	31	31	219	**42**
True Taxa Richness					**10**	**13**	**12**	**10**	**6**	**15**	**11**	**13**	**14**	**15**	**13**	**13**	**12**
Total Epibenthic Density (organisms/m^2)					**1,375**	**2,813**	**875**	**250**	**281**	**6,188**	**563**	**1,031**	**2,688**	**2,188**	**594**	**2,531**	**1,781**

*Bryozoa, Cnidaria, and Cirripedia (sub-Class) taxa are colonizing species in which individual counts were not possible. Instead, these taxa are represented as a percentage of the overall sample volume. These taxa were included in the taxa richness calculations and excluded from the density calculations.

Table B-2. Epibenthic community true taxa richness, density (organisms/m^2, scrapings per reef ball), Diversity (H'), and Evenness (E) collected at West Harlem Waterfront Project (Six-Month Post-Installation).

Station	True Taxa Richness*	Density (organisms/m2)	Diversity (H')	Evenness (E)
WHE-1	10	1,375	2.26	0.68
WHE-2	13	2,813	1.96	0.53
WHE-3	12	875	2.37	0.66
WHE-4	10	250	2.00	0.60
WHE-5	6	281	1.66	0.64
WHE-6	15	6,188	2.52	0.65
WHE-7	11	563	2.10	0.61
WHE-8	13	1,031	2.54	0.69
WHE-9	14	2,688	2.29	0.60
WHE-10	15	2,188	1.80	0.46
WHE-11	13	594	2.60	0.70
WHE-12	13	2,531	2.58	0.70
Average	**12**	**1,781**	**2.22**	**0.63**

*Bryozoa, Cnidaria, and Cirripedia (sub-Class) taxa were included in the taxa richness calculations and excluded from the density, diversity, and evenness calculations.

Table B-3. Epibenthic community taxa occurrence and total density (organisms/m^2, scrapings per reef ball) occurrence at West Harlem Waterfront Project (Six-Month Post-Installation).

Station	Taxa Occurrence*										Total Density (organisms/m^2) Occurrence									
	Annelida		Arthropoda		Mollusca		Chordata		Miscellaneous		Annelida		Arthropoda		Mollusca		Chordata		Miscellaneous	
	NO.	%	NO.	%	NO.	%	No.	%	NO.	%	NO.	%	NO.	%	NO.	%	No.	%	NO.	%
WHE-1	1	13%	4	50%	0	0%	0	0%	3	38%	63	5%	1,031	75%	0	0%	0	0%	281	20%
WHE-2	3	27%	3	27%	0	0%	0	0%	5	45%	125	4%	2,031	72%	0	0%	0	0%	656	23%
WHE-3	2	20%	3	30%	1	10%	0	0%	4	40%	94	11%	563	64%	31	4%	0	0%	188	21%
WHE-4	0	0%	4	50%	0	0%	0	0%	4	50%	0	0%	125	50%	0	0%	0	0%	125	50%
WHE-5	1	20%	2	40%	0	0%	0	0%	2	40%	31	11%	94	33%	0	0%	0	0%	156	56%
WHE-6	3	23%	4	31%	0	0%	1	8%	5	38%	406	7%	4,063	66%	0	0%	219	4%	1,500	24%
WHE-7	1	11%	4	44%	0	0%	0	0%	4	44%	63	11%	219	39%	0	0%	0	0%	281	50%
WHE-8	2	18%	4	36%	0	0%	0	0%	5	45%	156	15%	531	52%	0	0%	0	0%	344	33%
WHE-9	3	25%	3	25%	1	8%	0	0%	5	42%	219	8%	969	36%	94	3%	0	0%	1,406	52%
WHE-10	2	14%	6	43%	0	0%	1	7%	5	36%	63	3%	1,781	81%	0	0%	31	1%	313	14%
WHE-11	2	18%	4	36%	0	0%	1	9%	4	36%	63	11%	344	58%	0	0%	31	5%	156	26%
WHE-12	2	18%	5	45%	0	0%	1	9%	3	27%	250	10%	1,438	57%	0	0%	219	9%	625	25%
Total	**4**	**17%**	**11**	**48%**	**1**	**4%**	**1**	**4%**	**6**	**26%**	**128**	**7%**	**1,099**	**62%**	**10**	**1%**	**42**	**2%**	**503**	**28%**

*Bryozoa and Cnidaria taxa were included in the taxa richness calculations under Miscellaneous and excluded from the density calculations. Cirripedia (sub-Class) taxa were included in the taxa richness calculations under Arthropods and were excluded from the density calculations

Table B-4. Epibenthic Density (organisms/m^2, scrapings per reef ball) collected at West Harlem Waterfront Project (12-Month Post-Installation).

Phylum	Class	Order	Family	Genus Species	WHE-1	WHE-2	WHE-3	WHE-4	WHE-5	WHE-6	WHE-7	WHE-8	WHE-9	WHE-10	WHE-11	WHE-12	Average 12-Month	Average 6-Month
Bryozoa*	---	---	---	---	10%	0%	0%	0%	0%	0%	3%	15%	5%	0%	0%	5%	3%	0%
	Gymnolaemata	Cheilostomata	Membraniporidae	*Membranipora spp.*	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	6%
				Membranipora tenuis	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Ctenostomata	Vesiculariidae	*Bowerbankia spp.*	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%
Cnidaria*	Hydrozoa	Hydroida	Campanulariidae	*Campanularia spp.*	50%	50%	70%	30%	40%	50%	75%	35%	50%	0%	75%	40%	47%	9%
Nematoda	---	---	---	---	0	208	31	0	0	0	63	0	156	0	31	0	41	0
Nemertea	---	---	---	---	0	0	0	0	156	0	0	0	0	0	0	0	13	0
Platyhelminthes	Turbellaria	Polycladida	*Leptoplanidae*	*Euplana gracilis*	0	0	31	0	0	0	0	0	0	0	0	0	3	0
			Stylochidae	*Stylochus spp.*	391	1,875	31	1,250	234	625	500	1,250	938	0	1,094	781	747	414
Porifera	Demospongiae	Halichondra	Halichondriidae	*Halichondria spp.*	0	0	0	0	0	0	0	0	0	0	0	0	0	89
Annelida	Oligochaeta	---	---	---	0	0	0	0	234	0	0	0	0	63	31	0	27	0
	Polychaeta	*Ariciida*	*Orbiniidae*	*Leitoscoloplos fragilis*	0	104	0	0	234	0	0	0	0	63	0	0	33	0
		Canalipalpata	Pectinariidae	*Pectinaria gouldii*	0	0	0	0	0	0	0	0	0	0	0	0	0	5
			Sabellariidae	*Sabellaria vulgaris*	0	0	0	0	0	0	0	0	0	0	0	0	0	36
			Spionidae	*Polydora ligni*	4,453	20,208	875	6,563	3,906	3,594	1,875	4,844	14,219	3,563	7,469	5,625	6,433	21
				Streblospio benedicti	0	208	0	0	1,953	0	63	0	0	1,625	63	0	326	0
		Capitellida	Capitellidae	---	0	0	0	0	234	0	0	0	0	63	0	0	25	0
		Phyllodocida	Nereidae	*Nereis spp.*	117	1,563	63	156	78	0	125	156	313	375	125	313	282	65
				Nereis succinea	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arthropoda	Crustacea	Amphipoda	Ampeliscidae	*Ampelisca abdita*	0	0	0	156	0	0	0	0	0	0	0	0	13	0
			Aoridae	---	195	0	313	313	234	0	1,250	1,250	625	0	0	0	348	0
			Corophiidae	*Corophium spp.*	1,680	92,500	188	2,813	1,797	8,594	1,000	2,188	5,313	0	29,688	17,031	13,566	661
			Gammaridae	*Gammarus spp.*	0	0	0	0	0	0	0	0	0	0	0	0	0	3
			Hyperiidea	---	0	0	0	0	0	0	0	0	0	0	0	0	0	3
			Melitidae	*Melita spp.*	0	0	63	156	0	0	0	0	0	0	0	0	18	3
				Melita dentata	0	0	0	0	0	0	0	0	0	0	0	0	0	5
				Melita netida	0	0	0	0	0	0	0	0	0	0	0	0	0	3
			Photidae	---	0	0	0	0	0	0	0	0	0	0	0	0	0	23
			Pluestidae	---	313	9,688	594	3,750	1,172	234	563	0	469	0	11,875	2,969	2,635	190
		Cumacea	Diastylidae	*Diastylis spp.*	0	0	0	0	0	0	0	0	156	0	0	0	13	0
			Leuconidae	*Leucon americanus*	0	313	0	0	547	0	250	156	469	0	63	0	150	0
		Decapoda	Crangonidae	*Crangon septemspinosa*	0	0	0	0	78	0	0	0	0	0	31	0	9	0
			Palaemonidae	*Palaemonetes*	234	1,250	250	156	156	313	250	625	1,563	0	625	0	452	0
			Xanthidae	---	0	208	63	156	0	0	63	0	156	0	125	0	64	0
		Cirripedia (Sub-Class)*	---	---	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%
			Archaeobalanidae	*Semibalanus balanoides*	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	38%
			Balanidae	*Balanus spp.*	5%	20%	5%	65%	55%	40%	20%	15%	20%	25%	15%	30%	26%	0%
		Copepoda (Sub-Class)	---	---	0	0	0	0	0	0	0	0	0	0	0	0	0	13
		Isopoda	Chiridotea	*Chiridotea spp.*	0	0	0	0	0	0	0	0	0	0	0	0	0	3
			Idoteidae	*Idotea sp.*	0	0	0	0	0	0	0	0	0	0	0	0	0	193
				Idotea metallica	508	49,531	625	3,281	469	2,813	1,313	4,375	3,750	0	2,188	2,969	5,985	0
Mollusca	Bivalvia	Mytiloida	Mytilidae	*Modiolus demissus*	0	0	31	156	0	0	0	0	0	0	0	0	16	0
				Mytilus edulis	0	8,333	0	0	0	313	0	0	0	0	94	469	767	10
Chordata	Ascidiacea	Stolidobranchia	Molgulidae	*Molgula manhattensis*	273	625	781	1,250	859	469	750	2,656	4,375	0	719	0	1,063	42
True Taxa Richness					12	16	16	15	18	10	16	12	16	7	17	10	14	12
Total Epibenthic Density (organisms/m^2)					8,164	186,615	3,938	20,156	12,344	16,953	8,063	17,500	32,500	5,750	54,219	30,156	33,030	1,781

*Bryozoa, Cnidaria, and Cirripedia (sub-Class) taxa are colonizing species in which individual counts were not possible. Instead, these taxa are represented as a percentage of the overall sample volume. These taxa were included in the taxa richness calculations and excluded from the density calculations.

Table B-5. Epibenthic community true taxa richness, density (organisms/m^2, scrapings per reef ball), Diversity (H'), and Evenness (E) collected at West Harlem Waterfront Project (12-Month Post-Installation).

Station	Taxa Richness	Density (organisms/m^2)	Diversity (H')	Evenness (E)
WHE-1	12	8,164	2.11	0.59
WHE-2	16	186,615	2.03	0.51
WHE-3	16	3,938	3.04	0.76
WHE-4	15	20,156	2.31	0.59
WHE-5	18	12,344	3.11	0.75
WHE-6	10	16,953	2.02	0.61
WHE-7	16	8,063	3.11	0.78
WHE-8	12	17,500	2.64	0.74
WHE-9	16	32,500	2.52	0.63
WHE-10	7	5,750	1.41	0.50
WHE-11	17	54,219	1.90	0.47
WHE-12	10	30,156	1.87	0.56
Average (12-Month)	**14**	**33,030**	**2.34**	**0.62**
Average (6-Month)	**12**	**1,781**	**2.22**	**0.63**

*Bryozoa, Cnidaria, and Cirripedia (sub-Class) taxa were included in the taxa richness calculations and excluded from the density, diversity, and evenness calculations.

Table B-6. Epibenthic community taxa occurrence and total density (organisms/m^2, scrapings per reef ball) occurrence at West Harlem Waterfront Project (12-Month Post-Installation).

Station	Taxa Occurrence*										Total Density (organisms/m^2) Occurrence									
	Annelida		Arthropoda		Mollusca		Chordata		Miscellaneous		Annelida		Arthropoda		Mollusca		Chordata		Miscellaneous	
	NO.	%	NO.	%	NO.	%	No.	%	NO.	%	NO.	%	NO.	%	NO.	%	No.	%	NO.	%
WHE-1	2	17%	6	50%	0	0%	1	8%	3	25%	4,570	56%	2,930	36%	0	0%	273	3%	391	5%
WHE-2	4	25%	7	44%	1	6%	1	6%	3	19%	22,083	12%	153,490	82%	8,333	4%	625	0%	2,083	1%
WHE-3	2	13%	8	50%	1	6%	1	6%	4	25%	938	24%	2,094	53%	31	1%	781	20%	94	2%
WHE-4	2	13%	9	60%	1	7%	1	7%	2	13%	6,719	33%	10,781	53%	156	1%	1,250	6%	1,250	6%
WHE-5	6	33%	8	44%	0	0%	1	6%	3	17%	6,641	54%	4,453	36%	0	0%	859	7%	391	3%
WHE-6	1	10%	5	50%	1	10%	1	10%	2	20%	3,594	21%	11,953	71%	313	2%	469	3%	625	4%
WHE-7	3	19%	8	50%	0	0%	1	6%	4	25%	2,063	26%	4,688	58%	0	0%	750	9%	563	7%
WHE-8	2	17%	6	50%	0	0%	1	8%	3	25%	5,000	29%	8,594	49%	0	0%	2,656	15%	1,250	7%
WHE-9	2	13%	9	56%	0	0%	1	6%	4	25%	14,531	45%	12,500	38%	0	0%	4,375	13%	1,094	3%
WHE-10	6	86%	1	14%	0	0%	0	0%	0	0%	5,750	100%	0	0%	0	0%	0	0%	0	0%
WHE-11	4	24%	8	47%	1	6%	1	6%	3	18%	7,688	14%	44,594	82%	94	0%	719	1%	1,125	2%
WHE-12	2	20%	4	40%	1	10%	0	0%	3	30%	5,938	20%	22,969	76%	469	2%	0	0%	781	3%
Total (12-Month)	**6**	**22%**	**12**	**44%**	**2**	**7%**	**1**	**4%**	**6**	**22%**	**7,126**	**22%**	**23,254**	**70%**	**783**	**2%**	**1063**	**3%**	**804**	**2%**
Total (6-Month)	**4**	**17%**	**11**	**48%**	**1**	**4%**	**1**	**4%**	**6**	**26%**	**128**	**7%**	**1,099**	**62%**	**10**	**1%**	**42**	**2%**	**503**	**28%**

*Bryozoa and Cnidaria taxa were included in the taxa richness calculations under Miscellaneous and excluded from the density calculations. Cirripedia (sub-Class) taxa were included in the taxa richness calculations under Arthropods and were excluded from the density calculations

Table B-7. Epibenthic Density (organisms/m², scrapings per reef ball) collected at West Harlem Waterfront Project (18-Month Post-Installation). Stations WHE-10 and WHE-11 were damaged and no samples were taken.

Phylum	Class	Order	Family	Genus Species	WHE-1	WHE-2	WHE-3	WHE-4	WHE-5	WHE-6	WHE-7	WHE-8	WHE-9	WHE-10	WHE-11	WHE-12	Average 18-Month	Average 12-Month	Average 6-Month
Bryozoa*	---	---	---	---	0%	0%	0%	0%	0%	0%	0%	0%	0%	NS	NS	0%	0%	3%	0
	Gymnolaemata	Cheilostomata	Electridae	*Electra* sp.	1%	0%	1%	1%	0%	0%	1%	1%	1%	NS	NS	0%	1%	0%	0%
			Membraniporidae	*Membranipora* sp.	0%	0%	0%	0%	0%	0%	0%	0%	0%	NS	NS	0%	0%	0%	6%
				Membranipora tenuis	0%	0%	0%	0%	0%	0%	0%	0%	0%	NS	NS	0%	0%	0%	0%
		Ctenostomata	Vesicularidae	*Bowerbankia* sp.	0%	0%	0%	0%	0%	0%	0%	0%	0%	NS	NS	0%	0%	0%	2%
Cnidaria*	Hydrozoa	Thecata	Campanularidae	---	0	0	0	0	0	0	0	0	0	NS	NS	0	0	47%	9%
Nematoda	---	---	---	---	0	0	0	0	0	0	0	0	0	NS	NS	0	0	41	0
Nemertea	---	---	---	---	0	0	0	0	0	0	0	0	0	NS	NS	0	0	13	0
Platyhelminthes	Turbellaria	Polycladida	Leptoplanidae	*Euplana gracilis*	0	0	0	0	0	0	0	0	0	NS	NS	0	0	3	0
			Stylochidae	*Stylochus* sp.	521	78	703	208	1146	781	208	573	833	NS	NS	1094	615	747	414
Porifera	Desmospongiae	Halichondrida	Halichondridae	*Halichondria* sp.	0	0	0	0	0	0	0	0	0	NS	NS	0	0	0	89
Annelida	Oligochaeta	---	---	---	0	234	0	0	0	0	52	0	0	NS	NS	0	29	27	0
	Polychaeta	Aciculata	Hesionidae	*Podarke* sp.	104	0	0	313	0	0	0	0	0	NS	NS	0	42	0	0
		Ariciida	Orbiniidae	*Leitoscoloplos fragilis*	104	0	0	938	104	0	156	0	313	NS	NS	0	161	33	0
		Canalipalpata	Ampharetidae	---	0	156	0	0	0	0	0	0	0	NS	NS	0	16	0	0
			Pectinariidae	*Pectinaria gouldii*	0	0	0	0	0	0	52	0	0	NS	NS	0	5	0	5
			Sabellariidae	*Sabellaria vulgaris*	0	1406	0	208	208	1250	156	0	1042	NS	NS	313	458	0	36
			Spionidae	*Polydora ligni*	3750	4141	1797	1250	4063	3125	2240	1927	1979	NS	NS	4844	2,911	6,433	21
				Streblospio benedicti	104	2656	0	313	0	0	0	0	208	NS	NS	0	328	326	0
		Capitellida	Capitellidae	---	0	0	0	313	0	0	156	0	104	NS	NS	0	57	25	0
		Phyllodocida	Nereidae	*Nereis* sp.	3542	2891	2422	2292	1979	7969	1615	1771	2188	NS	NS	3438	3,010	282	65
			Nereidae	*Nereis succinea*	0	0	0	0	0	0	0	0	0	NS	NS	0	0	0	0
			Phyllodocidae	---	0	625	0	313	104	0	52	0	104	NS	NS	0	120	0	0
			Goniadidae	---	0	78	0	0	0	0	52	0	0	NS	NS	0	13	0	0
Arthropoda	Crustacea	Amphipoda	Ampeliscidae	*Ampelisca abdita*	0	0	0	0	0	0	0	0	0	NS	NS	0	0	13	0
			Aoridae	---	1042	313	547	938	208	625	313	677	521	NS	NS	0	518	348	0
			Corophiidae	*Corophium* sp.	833	859	938	0	313	3125	313	573	833	NS	NS	2656	1,044	13,566	661
			Gammaridae	*Gammarus* sp.	0	0	0	104	0	0	0	0	0	NS	NS	0	10	0	3
			Hyperiidea	---	0	0	0	0	0	0	0	0	0	NS	NS	0	0	0	3
			Melitidae	*Melita* sp.	0	0	0	0	0	0	0	0	0	NS	NS	0	0	18	3
				Melita dentata	0	0	0	0	0	0	0	0	0	NS	NS	0	0	0	5
				Melita netida	188	547	1016	313	208	313	104	208	313	NS	NS	938	415	0	3
			Photidae	---	0	0	0	0	0	0	0	0	0	NS	NS	0	0	0	23
			Pleustidae	---	0	0	0	0	0	0	0	0	0	NS	NS	0	0	2,635	190
		Cumacea	Diastylidae	*Diastylis* sp.	0	0	0	0	0	0	0	0	0	NS	NS	0	0	13	0
			Leuconidae	*Leucon americanus*	0	859	0	313	0	0	0	0	104	NS	NS	0	128	150	0
		Decapoda	Crangonidae	*Crangon septemspinos*	0	0	0	0	0	0	0	0	0	NS	NS	0	0	9	0
			Palaemonidae	*Palaemonetes* spp.	0	0	0	0	0	0	0	0	0	NS	NS	0	0	452	0
				Palaemonetes vulgaris	0	0	0	0	0	0	0	52	0	NS	NS	0	5	0	0
			Portunidae	*Callinectes sapidus*	0	0	0	0	0	0	52	0	0	NS	NS	0	5	0	0
			Xanthidae	---	0	0	0	0	0	0	0	0	0	NS	NS	0	0	64	0
		Cirripedia* (Sub-Class)	---	---	0%	0%	0%	0%	0%	0%	0%	0%	0%	NS	NS	0%	0%	0%	5%
			Archaeobalanidae	*Semibalanus balanoides*	0%	0%	0%	0%	0%	0%	0%	0%	0%	NS	NS	0%	0%	0%	38%
			Balanidae	*Balanus spp.*	60%	0%	50%	60%	65%	75%	50%	60%	60%	NS	NS	75%	56%	26%	0%
		Copepoda	---	---	0	0	0	0	0	0	0	0	0	NS	NS	0	0	0	13
		Isopoda	Idoteidae	*Chiridotea* sp.	0	0	0	0	0	0	0	0	0	NS	NS	0	0	0	3
				Edotea sp.	0	78	0	0	0	0	0	0	0	NS	NS	0	8	0	0
				Idotea sp.	104	0	0	0	0	0	0	0	0	NS	NS	0	10	0	193
				Idotea baltica	0	0	234	0	0	0	0	0	208	NS	NS	0	44	0	0
				Idotea metallica	0	0	0	0	0	0	0	0	0	NS	NS	0	0	5,985	0
Mollusca	Bivalvia	Mytioida	Mytilidae	*Modiolus demissus*	0	0	0	208	0	0	0	0	208	NS	NS	0	42	16	0
				Mytilus edulis	0	78	0	0	104	0	0	0	208	NS	NS	0	39	767	10
		Veneroida	Mactridae	*Mulinia lateralis*	0	1016	78	4271	104	0	1094	0	1563	NS	NS	0	813	0	0
	Gastropoda	Cephalaspidea	Retusidae	*Retusa canaliculata*	0	0	0	208	0	0	0	0	0	NS	NS	0	21	0	0
Chordata	Ascidacea	Pleurogona	Molgulidae	*Molgula manhattensis*	6875	3281	8281	5938	8333	8906	2708	2344	8125	NS	NS	14375	6,917	1,063	42
True Taxa Richness					13	17	11	19	13	9	18	10	19	NS	NS	8	14	14	12
Total Epibenthic Density (organisms/m²)					17,167	19,297	16,016	18,438	16,875	26,094	9,323	8,125	18,854	NS	NS	27,656	17,784	33,030	1,781

*Bryozoa, Cnidaria, and Cirripedia (Sub-Class) taxa are colonizing species in which individual counts were not possible. Instead, these taxa are represented as a percentage of the overall sample volume. These taxa were included in the taxa richness calculations and excluded from the density calculations. NS=No sample taken due to broken reef ball.

Table B-8. Epibenthic community taxa richness, density (organisms/m^2, scrapings per reef ball), Diversity (H'), and Evenness (E) collected at West Harlem Waterfront Project (18-Month Post-Installation).

Station	Taxa Richness*	Density (organisms/m^2)	Diversity (H')	Evenness (E)
WHE-1	13	17,167	2.34	0.63
WHE-2	17	19,297	3.28	0.80
WHE-3	11	16,016	2.24	0.65
WHE-4	19	18,438	3.01	0.71
WHE-5	13	16,875	2.15	0.58
WHE-6	9	26,094	2.35	0.74
WHE-7	18	9,323	2.84	0.68
WHE-8	10	8,125	2.51	0.76
WHE-9	19	18,854	2.90	0.68
WHE-10	**Reef Ball Found Broken - No Sample Taken**			
WHE-11				
WHE-12	8	27,656	2.05	0.68
Average (18-Month)	**14**	**17,784**	**2.57**	**0.69**
Average (12-Month)	**14**	**33,030**	**2.34**	**0.62**
Average (6-Month)	**12**	**1,781**	**2.22**	**0.63**

*Bryozoa, Cnidaria, and Cirripedia (sub-Class) taxa were included in the taxa richness calculations and excluded from the density, diversity, and evenness calculations. WHE-10 and WHE-11 were found broken, therefore no samples were collected from these stations.

Table B-9. Epibenthic community true taxa occurrence and total density (organisms/m², scrapings per reef ball) occurrence at West Harlem Waterfront Project (18-Month Post-Installation).

Station	Taxa Occurrence*										Total Density (organisms/m²) Occurrence									
	Annelida		Arthropoda		Mollusca		Chordata		Miscellaneous		Annelida		Arthropoda		Mollusca		Chordata		Miscellaneous	
	NO.	%	NO.	%	NO.	%	No.	%	NO.	%	NO.	%	NO.	%	NO.	%	No.	%	NO.	%
WHE-1	5	38%	5	38%	0	0%	1	8%	2	15%	7,604	44%	2,167	13%	0	0%	6,875	40%	521	3%
WHE-2	8	47%	5	29%	2	12%	1	6%	1	6%	12,188	63%	2,656	14%	1,094	6%	3,281	17%	78	0%
WHE-3	2	18%	5	45%	1	9%	1	9%	2	18%	4,219	26%	2,734	17%	78	0%	8,281	52%	703	4%
WHE-4	8	42%	5	26%	3	16%	1	5%	2	11%	5,938	32%	1,667	9%	4,688	25%	5,938	32%	208	1%
WHE-5	5	38%	4	31%	2	15%	1	8%	1	8%	6,458	38%	729	4%	208	1%	8,333	49%	1,146	7%
WHE-6	3	33%	4	44%	0	0%	1	11%	1	11%	12,344	47%	4,063	16%	0	0%	8,906	34%	781	3%
WHE-7	9	50%	5	28%	1	6%	1	6%	2	11%	4,531	49%	781	8%	1,094	12%	2,708	29%	208	2%
WHE-8	2	20%	5	50%	0	0%	1	10%	2	20%	3,698	46%	1,510	19%	0	0%	2,344	29%	573	7%
WHE-9	7	37%	6	32%	3	16%	1	5%	2	11%	5,938	31%	1,979	10%	1,979	10%	8,125	43%	833	4%
WHE-10	Reef Ball Found Broken - No Sample Taken																			
WHE-11																				
WHE-12	3	38%	3	38%	0	0%	1	13%	1	13%	8,594	31%	3,594	13%	0	0%	14,375	52%	1,094	4%
Total (18-Month)	**12**	**40%**	**11**	**37%**	**4**	**13%**	**1**	**3%**	**2**	**7%**	**7,151**	**40%**	**2,188**	**12%**	**914**	**5%**	**6917**	**39%**	**615**	**3%**
Total (12-Month)	**6**	**22%**	**12**	**44%**	**2**	**7%**	**1**	**4%**	**6**	**22%**	**6,831**	**21%**	**23,068**	**71%**	**777**	**2%**	**1055**	**3%**	**797**	**2%**
Total (6-Month)	**4**	**17%**	**11**	**48%**	**1**	**4%**	**1**	**4%**	**6**	**26%**	**128**	**7%**	**1,099**	**62%**	**10**	**1%**	**42**	**2%**	**503**	**28%**

*Bryozoa and Cnidaria taxa were included in the taxa richness calculations under Miscellaneous and excluded from the density calculations. Cirripedia (sub-Class) taxa were included in the taxa richness calculations under Arthropods and were excluded from the density calculations. WHE-10 and WHE-11 were found broken, therefore no samples were collected from these stations.

APPENDIX C

Sediment survey data collected at the West Harlem Waterfront Project.

Table C-1: Sediment survey conducted at West Harlem Waterfront Park (6-Month Post-Installation).

Station	Coordinates		Date	Time	Distance to Sediment (m)*	Comments
	N	W				
WHE-1	40 49.210	73 57.664	11/28/2006	12:03	0.61	No marine life or sediment inside, growth present.
WHE-2	40 49.247	73 57.667	11/28/2006	12:07	0.61	No marine life, covered with growth.
WHE-3	40 49.213	73 57.672	11/28/2006	12:15	0.76	No fish or silt observed in reef ball, growth present.
WHE-4	40 49.207	73 57.675	11/28/2006	12:23	0.76	No fish, shrimp and growth present.
WHE-5	40 49.225	73 57.664	11/28/2006	12:55	0.91	Marine growth, fish present.
WHE-6	40 49.210	73 57.691	11/28/2006	13:15	0.91	Minimal marine growth, no fish/marine life present.
WHE-7	40 49.243	73 57.642	11/28/2006	13:44	0.46	Light marine growth, no fish.
WHE-8	40 49.256	73 57.634	11/28/2006	13:48	0.76	No fish, some marine growth.
WHE-9	40 49.254	73 57.646	11/28/2006	13:58	0.76	No fish, typical marine growth.
WHE-10	40 49.269	73 57.663	11/29/2006	12:25	0.76	No marine life, marine growth present, solf/silty mud present.
WHE-11	40 49.259	73 57.661	11/29/2006	12:10	0.76	No marine life, marine growth present, solf/sandy/silty mud present.
WHE-12	40 49.234	73 57.685	11/29/2006	12:52	0.46	No marine life, marine growth present, solf/sandy/silty mud present.

*Distance was taken at one point on the reef ball

Table C-2: Sediment survey conducted at West Harlem Waterfront Park (12-Month Post-Installation).

Station	Coordinates		Date	Time	Distance to Sediment (m) at Reef Ball Corners				Comments
	N	W			NE	NW	SE	SW	
WHE-1	40 49.210	73 57.664	7/26/2007	10:51	0.30	0.18	0.46	0.21	0.013-0.025 m of silt recorded inside.
WHE-2	40 49.247	73 57.667	7/25/2007	13:06	0.61	0.61	0.61	0.8-0.9	No sediments found inside reef ball, far off bottom.
WHE-3	40 49.213	73 57.672	7/26/2007	10:15	0.76	0.91	0.8-0.9	0.6-0.8	0.013 m of sediment inside reef ball, typical marine growth observed.
WHE-4	40 49.207	73 57.675	7/26/2007	9:50	0.76	0.76	0.61	0.61	0.013-0.025 m of sediment noted inside.
WHE-5	40 49.225	73 57.664	7/26/2007	11:40	0.46	0.91	0.76	0.91	0.013 m of sediment inside with a lot of vegetation.
WHE-6	40 49.210	73 57.691	7/26/2007	9:35	0.61	0.91	0.91	0.91	0.013-0.025 m of sediment recorded inside.
WHE-7	40 49.243	73 57.642	7/25/2007	13:55	0.27	0.30	0.15	0.09	Less growth was observed on the reef ball when compared to the others.
WHE-8	40 49.256	73 57.634	7/25/2007	14:10	0.46	0.61	0.61	0.76	Ample vegetation, barnacle species found, no fish or crab species observed.
WHE-9	40 49.254	73 57.646	7/25/2007	14:50	0.91	0.91	0.61	0.61	0.025 m of sediment observed inside reef ball, plenty of vegetation, fish and crab
WHE-10	40 49.269	73 57.663	7/25/2007	10:05	NS	NS	NS	NS	Reef ball found broken in three pieces, not on the pedestal, and resting on the river
WHE-11*	40 49.259	73 57.661	7/25/2007	10:18	0.23	0.28	0.18	0.10	No sediments found inside reef ball.
WHE-12	40 49.234	73 57.685	7/26/2007	13:05	0.76	1.07	0.91	0.76	0.013 m of sediment recorded on inside of reef ball.

***** Northwestern, Northeastern, Southeastern, Southwestern measurements taken at Western, Northern, Eastern, and Southern edges respectively.
NS = No sample taken due to broken reef ball.

Table C-3: Sediment survey conducted at West Harlem Waterfront Park (18-Month Post-Installation).

Station	Coordinates		Date	Time	Distance to Sediment (m) at Reef Ball Corners				Comments
	N	W			NE	NW	SE	SW	
WHE-1	40 49.210	73 57.664	1/10/2008	11:30	0.38	0.30	0.30	0.36	Marine growth evident.
WHE-2	40 49.247	73 57.667	1/15/2008	12:40	0.51	0.51	0.41	0.41	Scour hole on Northside was 0.22 m deep.
WHE-3	40 49.213	73 57.672	1/10/2008	13:05	0.58	0.69	0.69	0.69	No fish, hard-packed mud material beneath reef ball.
WHE-4	40 49.207	73 57.675	1/10/2008	12:25	0.61	0.56	0.66	0.58	No comments
WHE-5	40 49.225	73 57.664	1/15/2008	10:40	0.43	0.43	0.43	0.51	Light scarring on reef ball.
WHE-6	40 49.210	73 57.691	1/15/2008	14:30	0.51	0.46	0.43	0.36	No comments
WHE-7	40 49.243	73 57.642	1/10/2008	15:50	0.28	0.36	0.36	0.41	No comments
WHE-8	40 49.256	73 57.634	1/10/2008	14:55	0.56	0.56	0.56	0.56	No comments
WHE-9	40 49.254	73 57.646	1/10/2008	15:10	0.51	0.53	0.51	0.53	No comments
WHE-10	40 49.269	73 57.663	1/10/2008	NS	NS	NS	NS	NS	Reef ball broken, no sampled was collected.
WHE-11	40 49.259	73 57.661	1/10/2008	NS	NS	NS	NS	NS	Reef ball broken, no sampled was collected.
WHE-12	40 49.234	73 57.685	1/15/2008	11:10	0.46	0.48	0.20	0.25	No comments

NS = No sample due to broken reef ball

APPENDIX D

PHOTO INDEX

D-1: Reef ball on pedestal

D-2: Reef balls on site prior to installation

D-3: Reef ball mounted on pedestal and pile ready for installation

D-4: Installation of reef balls. The white buoys in the water indicate reef ball locations

D- 5: Diver preparing to swim transects of the reef ball field

D-6: Diver swimming to a reef ball to collect an epibenthic sample

D-7: Benthic sampling was conducted using a standard Ponar Grab

D-8:   Sediments at the project site were typically fine grain and were black and gray in color. This is an example of a benthic sample.

D-9: Reef ball # 9 is located in the northeast corner of the reef ball field near the shore. This picture was taken during the 12 month Post-Installation Survey. Hydroids and tunicates are colonizing the reef ball.

D-10: Reef ball # 11 is located in the northwest corner of the reef ball field near the channel. This picture was taken during the 12 month Post-Installation Survey. A blue crab is sitting in the reef ball. Blue crabs were also found in several other reef balls.

D-11: Reef ball # 5 is located in the center of the reef ball field. This picture was taken during the 12 month Post-Installation Survey. The reef ball is densely colonized by hydroids and tunicates which provide habitat for annelids and arthropods.

D-12: Reef Ball #1 is located at the southern nearshore edge of the reef ball field. This picture was taken during the 12 month Post-Installation Survey. There is a small fish located above the rope.

D-13: Reef Ball #6 is located at the southwest edge of the reef ball field. This picture was taken during the 12 month Post-Installation Survey. This reef ball shows the early development of the epibenthic community. The development of the epibenthic community varied for each reef ball depending on its location within the reef ball field. On the left hand side of the picture you can see the pedestal that the reef ball sits on.

D-14: Reef Ball #4 is located at the southeast portion of the reef ball field closer to the shore. This picture was taken during the 12 month Post-Installation Survey. There is a small fish located at the top of the reef ball.

D-15: Reef Ball #2 is located in the center of the reef ball field. This picture was taken during the 12 month Post-Installation Survey. The reef ball is densely covered with hydroids and tunicates and is exhibiting an established epibenthic community.

D-16: Reef ball # 3 is located near the center of the reef ball field. This picture was taken during the 12 month Post-Installation Survey. The reef ball is densely covered with hydroids and tunicates and is exhibiting an established epibenthic community.

D-17: Reef Ball #6. Tunicates colonizing the reef ball